Chapter 2: Geologic realities for the New Kingdom town of Sai Island

2.1 Landscape and geology

by Julia Budka

Sai Island is a *c.* 32km² large Nile island in northern Sudan (see Chapter 1, Pl. 1 for its location). Geologically, Sai Island is situated between the Second and Third Nile Cataracts, the results of a large scale east-west trending tectonic uplift zone, which forced the Nile to incise into uplifted Neoproterozoic crystalline basement and its sedimentary cover.[128] As one of the largest Nile islands, Sai lies just south of the Batn el-Haggar and the granite outcrops of the Dal Cataract.[129]

Abundant archaeological remains from many periods start on the island as early as the late Early Palaeolithic,[130] covering several millennia until Christian[131] and Ottoman times (see Chapter 1.1).[132] These rich findings underline the prominence of this area for human history in Northeast Africa and especially for the contacts between various Nubian cultures and the Egyptian empire, combining abundant natural resources with the north-south communication path of the Nile.[133]

The geology of Sai comprises several types of metamorphic Precambrian rocks and Nubian sandstone, largely covered by thin layers of comparably much younger Nile sediments.[134] Flat terraced surfaces dominate the entire island and only the Nubian sandstone of Gebel Adou rises as an "Inselberg" in the centre of the island (see Fig. 1).[135] Gebel Adou is mainly comprised of different grades of Nubian sandstone on the outer surface (see Chapter 2.3). Dry *wadis* of various sizes run towards the eastern and western banks of the island.

One has to stress that the present shape and size of Sai Island contrasts with the conditions in ancient times. It is striking that the northernmost tip of the island comprises mostly Christian sites[136] – no Pharaonic remains are known north of SAC4 and SAV2 (see Chapter 1.2). One can conclude that what is presently a small channel/depression was originally a water-bearing palaeochannel which represented the northern shoreline of the island during the New Kingdom (see Chapter 2.2.2). Similar to the neighbouring site of Amara West, this palaeochannel dried out at some point, most likely in Post-Pharaonic times.[137] The part of Sai Island from this dried up palaeochannel up to the modern village Sai Sab only became a portion of the island after the New Kingdom, presumably during the Post-Meroitic period since it is so rich in remains

128 Thurmond et al. 2004; Anonymous 2005.

129 Vercoutter 1958, 144, fig. 1.

130 See especially new evidence from site B-8-11 which was occupied from the Acheulian to the Middle Palaeolithic: van Peer et al. 2003; van Peer 2004; Garcea 2004, 20–21; van Peer and Herman 2006; cf. also Garcea 2007 for other early evidence.

131 Tsakos 2012; Tsakos and Hafsaas-Tsakos 2014; Tsakos and Hafsaas-Tsakos 2016.

132 Cf. Vercoutter 1986, 15–16; Alexander 1997. See also the summary by Geus 1994a.

133 Sai was also connected to routes towards the desert, especially to Selima Oasis, an important waypoint of the Darb el-Arba'in; see Jesse et al. 2015, 162, pl. 3; for the importance of the hinterland in the general area of Sai and Amara West, see also Stevens and Garnett 2017.

134 See Geus 1996, 1170–1171, fig. 5; Draganits 2014, 20; Budka 2015a, 41.

135 See Geus 1996, 1170; van Peer et al. 2003, 187–193; Draganits 2014, 20–21. See also below, Chapter 2.2.

136 See Tsakos and Hafsaas-Tsakos 2014, 986, fig. 1.

137 For the situation of a 'dynamic riverine environment' at Amara West, see Woodward et al. 2017.

of medieval date.[138] That Sai Island was considerably smaller in antiquity, namely until the 1st Millennium BCE, is also supported by the distribution of the Holocene sites at Sai Island.[139] The line of sites towards the east, to the west and in the north corresponds exactly to the line visible on the flood inundation modelling of the area carried out by Jamie Woodward et al.[140] Taking into account this reconstruction of a much smaller size of Sai Island during the New Kingdom, the prominent position of the Egyptian town becomes especially obvious. This part of the eastern side of the island was never concerned with flooding, was always overlooking the main branch of the Nile in both directions and did not see the risk of a changing shore-line due to climate change or dry seasons (see also below, Chapter 2.6).

It is very likely that the Nile and smaller islands around Sai Island changed quite considerably throughout the ages. This becomes evident from the small sandy island which is presently located just opposite of the New Kingdom town. On the aerial photos from the 1950s this island was not yet visible.[141] All in all, the river and its course around Sai Island were subject to a number of modifications since the Holocene and differing water levels have to be expected throughout the ages.[142]

The earliest description about the situation of the river at Sai Island comes from the 17th century CE – in the travel account by Evilya Çelebi a "lake-like" appearance[143] is mentioned. Early travellers of the 19th century CE (see Chapter 1.2 and Table 1) also commented on the environment of the island. One especially interesting version is given by George Alexander Hoskins for the year 1835, referring to a very low water table during the dry season:[144] "June 9. At Gobetziteen the Island of Sais [sic] commences, and extends for six hours towards the north. At this season of the year no boat is necessary to visit this island, the water which separates it from the main land being only deep enough to reach the knees of the camels."[145] "Main land" refers here most probably not to the eastern bank, but to the western bank of the Nile with sandy dunes. This western bank is also marked on some maps of the 19th century CE with fuzzy boundaries towards the island.[146] Furthermore, Hoskins continues with a description of the island: "It contains no remains of Egyptian antiquities. The peasants spoke of ruins; but they proved to be some grey granite columns belonging to a Christian edifice. They are in the centre of the island, nearly half an hour from the river. Each column consists of one piece of granite, with a Greek cross on their capitals. They are not very unlike the Christian monolithic pillars in the centre of the splendid portico of Medenet Abou. There are a great many wells in this island, with waterwheels, by means of which a considerable part of the interior is irrigated. I had a drawing of these Christian ruins token by Mr. B.; but, not setting much value on it, I have mislaid it. From the number of houses the island appears to be populous."[147] That the interior of the island was irrigated by means of waterwheels and that Sai was densely populated contrasts with the current status, where waterwheels have been replaced by water pumps and the fields are clearly restricted to the shorelines.[148] Also nowadays, the water level within the Nile arm to the west of the island is very low and the floodplain in this part (e.g. around the village Mokrat) is very wide.

The changing water table according to seasons was also mentioned by Ernest A. Wallis Budge who likewise referred to earlier researchers: "Sâî is a difficult place to reach, unless the traveller has his own boat with him. On January 2nd, 1821, Cailliaud crossed the river on a raft made of reeds and pieces of

138 See Tsakos and Hafsaas-Tsakos 2010; Tsakos and Hafsaas-Tsakos 2012; Tsakos and Hafsaas-Tsakos 2016.

139 Garcea 2007, 109, fig. 1.

140 Woodward et al. 2017, 232, fig. 6.

141 Vercoutter 1958, pl. XL. Neither an island in front of the New Kingdom town nor a clear river course along the western shore was noted on the map by John Charles Ardagh from 1886, see Woodward et al. 2017, 229, fig. 1.

142 Woodward et al. 2017. Also today, the sandy islands within the western branch of the Nile around Sai change considerably in size during low/high water levels (personal observation between January and March 2011–2017). For a clear difference between the western and eastern sides of Sai Island already during the Holocene see Florenzano et al. 2019, 30.

143 In the translation by Prokosch 1994, 115: "Der segensbringende Nil breitet sich an dieser Stelle wie ein See aus."

144 That the Nile can be trespassed by camel during low water is also mentioned by Çelebi; Prokosch 1994, 117.

145 Hoskins 1835, 257.

146 Very clear on the map by John Charles Ardagh from 1886, see Woodward et al. 2017, 229, fig. 1.

147 Hoskins 1835, 257. For the mentioned columns of the Christian church/cathedral, see most recently Tsakos and Hafsaas-Tsakos 2016.

148 Water wheels were visible "everywhere" on the island until the 1950s, see Alexander 1997, 19.

palm trunk; Hoskins in June, 1832, needed no raft, for the water in the Western channel only came up to the camel's knees, and he passed over to the island from the mainland without difficulty; Burckhardt, who must have been there in the winter, could obtain the use of neither ferry nor raft, and was therefore obliged to abandon his projected visit."[149]

Until the 1990s Sai was only reachable by boat (preferably sailing boat),[150] providing also certain challenges for the French mission. At present, the island is still not connected with either the west or the east bank, but motorboats and especially the ferry boat crossing from the road to Abri to the eastern shore close to the Christian church have reduced the difficulties of reaching Sai to a minimum.

2.2 Georchaeological research on Sai

by Julia Budka

Within the AcrossBorders project, the geoarchaeological approach as a very powerful tool for understanding landscape change and associated human adaptation has been adopted.[151] This method is a well-established means of interpreting environmental and cultural signatures that are more often than not concealed within the landscape itself.[152] Environmental and climatic settings and changes of Sai Island were investigated by the AcrossBorders project applying geoarchaeological methods including surveying, aerial photos, drilling and test pits (see Chapter 1.3). The aim was to estimate the human interaction with the landscape, in particular during the 2nd Millennium BCE. For the town area and its hinterland a diachronic study of the local landscape, with special references to the location of settlement areas and cemeteries, was conducted, starting from the Late Prehistory.[153] Specific geoarchaeological research on Sai was carried out by Erich Draganits in 2014,[154] Sayantani Neogi in 2015[155] and Sayantani Neogi and Sean Taylor in 2016.[156] Their observations are presented here in chronological order.

2.2.1 Geoarchaeological survey in 2014[157]

In the context of the AcrossBorders project the geoarchaeological research on Sai Island, conducted from 4th to 17th January 2014 by Draganits, focused on the following main scientific questions:

A General geological situation and resources

B Rock types occurring in the New Kingdom town

C Provenance of stones from the New Kingdom town and potential quarry locations

D Landscape evolution and environmental change: possible erosion of the eastern part of the Pharaonic town and possible existence of an eastern fortification wall

E Cooperation with the zooarchaeological research concerning environment and landscape

F Cooperation with the archaeometric analysis of ceramics concerning possible clay resources

G Location of a harbour

149 Budge 1907, 463.
150 Alexander 1997, 19.
151 French 2015.
152 French 2003.
153 This can be built upon the work by van Peer 2003; van Peer and Herman 2006 and Garcea 2007.
154 Draganits 2014.
155 Neogi 2015.
156 Neogi and Taylor 2016a.
157 Based on the report by Erich Draganits; see Draganits 2014.

Sample	Sample ID	Date	Easting (UTM 36N)	Northing (UTM 36N)	Altitude (m)	Material	Amount
1	ED14/SAI/1	05.01.2014	222210,454	2295566,552	193,83	Sand	1 bag
2	ED14/SAI/2	05.01.2014	222210,454	2295566,552	193,83	Sand	1 bag
3	ED14/SAI/3	05.01.2014	221430,800	2294935,452	206,087	Caliche	1 piece
4	ED14/SAI/5	06.01.2014	222194,856	2294729,565	216,661	Sandstone	1 piece
5	ED14/SAI/6	06.01.2014	222097,422	2293819,749	220,026	Silicified wood	2 pieces
6	ED14/SAI/7	08.01.2014	222181,386	2295516,588	198,156	Sandstone	1 piece
7	ED14/SAI/8	09.01.2014	219901,735	2295183,418	201,28	Amphibolite	1 piece
8	ED14/SAI/9	09.01.2014	222284,823	2295256,513	204,543	Gravel	1 bag
9	ED14/SAI/10	12.01.2014	222190,018	2295509,193	197,195	Sand	1 bag
10	ED14/SAI/11	12.01.2014	222180,453	2295478,53	197,916	Silty clay	1 bag
11	ED14/SAI/12	12.01.2014	221956,527	2295379,612	207,048	Soil	1 bag
12	ED14/SAI/13	12.01.2014	220723,862	2293206,209	219,305	Marble	1 piece
13	ED14/SAI/14	14.01.2014	220645,99	2293118,303	203,924	Amphibolite	1 piece
14	ED14/SAI/15	14.01.2014	220801,34	2292157,143	208,25	Quartzite	1 piece
15	ED14/SAI/16	15.01.2014	222544,866	2291069,411	204,885	Quartzite	1 piece
16	ED14/SAI/17	16.01.2014	222615,989	2292257,206	193,59	Calcphyllite	1 piece
17	ED14/SAI/18	16.01.2014	221528,352	2290205,072	220,026	Amphibolite	1 piece

Tab. 3 Geoarchaeological samples from Sai 2014

The scarcity of vegetation, the presence of riverfront exposures as well as excellent outcrops provided by already excavated graves offered great geoarchaeological working conditions. The regional focus of the geoarchaeological fieldwork was the area of the New Kingdom town and its hinterland. In total, 1368 GPS waypoints were taken for locating geological samples, lithological boundaries and different kinds of observations. 17 reference samples of rocks and sediments were collected (Tab. 3).

A General geological situation and resources

Sai Island comprises medium-grade metamorphic Precambrian rocks: amphibolite (ED14/SAI/8, ED14/SAI/14, ED14/SAI/18), dolomite, quartzite (ED14/SAI/15–16), biotite gneiss, calcite marble (ED14/SAI/13)] in the west and southeast, dipping around 30° towards the northwest. These rocks are commonly cross-cut by large quartz-veins. In the central and northern part of the island these metavolcano-sedimentary rocks are overlain by subhorizontal Nubian sandstone (ED14/SAI/5, ED14/SAI/7), mainly consisting of medium- to coarse-grained fluvial quartz sandstone, conglomerate, rare siltstone and occasional silicified wood (ED14/SAI/6).

Except for the Nubian sandstone of the "Inselberg" Gebel Adou, almost all of these rocks are covered by thin layers of comparably much younger Nile sediments (in some places with Palaeolithic artefacts).[158] The Pre-Holocene Nile sediments mainly comprise gravely channel deposits and fine-grained floodplain sediments. The sub-rounded to rounded gravel (ED14/SAI/9) of the Pre-Holocene Nile terraces are strongly dominated by quartz clasts, followed by chert and beautiful agate. They are virtually free of carbonate clasts, while the fine-grained floodplain sediments commonly show soil formation processes (ED14/SAI/3, ED14/SAI/12) and related calcrete.[159] Holocene Nile sediments were found around the margin of Sai Island up to *c.* 7m above the Nile level during geoarchaeological fieldwork in the first half

[158] van Peer et al. 2003, Anonymous 2005; van Peer and Herman 2006, especially 42–44, fig. 1; Draganits 2014.
[159] See Lewis et al. 2011.

of January 2014. These sediments comprise of sand (ED14/SAI/1, ED14/SAI/2, ED14/SAI/10), silt and clay sized deposits (ED14/SAI/11).

B Rock types occurring in the New Kingdom town

In general, the rock types occurring at the site of the Egyptian town of Sai reflect the geological reality of the island and most of them are locally available. By far the most common rock types are quartz sandstone and amphibolite (or schist, see Chapter 3.2), while vein quartz, calcrete, biotite gneiss and calcite marble are comparably rare. Rock types which probably have been brought to the island include granite,[160] diorite,[161] gabbro[162] and gypsum.[163]

C Provenance of stones from the New Kingdom town and potential quarry locations

Concerning the provenance of these rocks, quartz sandstone ("Nubian sandstone") is very common in northern and central Sudan[164] as well as on Sai, directly in the area of the New Kingdom town at the eastern side of the island and around Gebel Adou (see Chapter 2.3). The dark amphibolite used for schist pavements within the town area, especially for the large administrative storage magazines, can be found in the western part of the island and in its southeast. No clear quarry sites for amphibolite were, however, noted.

Several quartz sandstone outcrops show traces of working by stonemason tools, for example directly east of the French excavation house and next to the houses south of the Ottoman fortress in the village of Adou.[165] However, these quarries are of very small scale and could presumably provide only minor quantities of dressed stones. Some of the working marks may also be related to grave shafts. Additionally, the coarse grained and friable sandstone in this area is of quite miserable quality for dressed stones. Consequently, the search for the provenance of the quartz sandstone as well as the amphibolite should not neglect areas just across both Nile branches opposite of Sai Island, in particular of the eastern riverside around the large "Inselberg" Gebel Abri.

D Landscape evolution and environmental change: possible erosion of the eastern part of the Pharaonic town and possible existence of an eastern fortification wall

The extent of Nile erosion in the area of the Pharaonic town is related to the question of the possible existence of an eastern fortification wall of the town, which was still in discussion in 2014, based on the reconstruction of a collapsed eastern side of the site by Azim (see Fig. 2).[166] There are indeed several examples of slope failure close to the Nile, probably caused by the undercutting of the slope toe and a raised groundwater table during flood periods.[167] To the east and northeast of the French excavation house some toppling failures of the Nubian sandstone can be observed (Pl. 3).

Despite of these toppling features, severe erosion in this part of the island is unlikely from the geoarchaeological point of view, mainly because of the surveillance of the low incision rate of the Nile.[168] Additional arguments against substantial erosion of the eastern sandstone cliff are the existence of a broad Nile terrace just east of the Pharaonic town and the presence of sandstone without indications for

[160] For various types of granite from the area of Aswan see Klemm and Klemm 2008, 233–267. Cf. also Aston et al. 2000, 35–37.

[161] Also from the area of Aswan, see Klemm and Klemm 2008, 21.

[162] See Klemm and Klemm 2008, 13. See also Aston et al. 2000, 32–34.

[163] See Klemm and Klemm 2008, 14–15. This sedimentary rock was used for producing plaster at Sai, see Chapter 4.6, as it was common within Pharaonic Egypt (Klemm and Klemm 2008, 15).

[164] Anonymous 2005.

[165] See already the comments by Vercoutter 1958, 147, note 24 (see Chapter 2.3).

[166] See Azim 1975, 94, pl. II; Geus 2004a, 115, fig. 89; Budka 2015a, 41; Adenstedt 2018. See also Chapter 3.5 in this volume.

[167] See also the observations by Budge 1907 (quoted in Chapter 1.2).

[168] van Peer et al. 2003; summarized by Budka 2015a, 41.

slope failure below the town.[169] Furthermore, in situ mud bricks documented about southeast of sector SAV1 East are exactly in line with a 67m long, straight linear structure in the geophysical survey visualized by means of a GIS project (Pl. 4).[170] The orientation of the mud bricks, measured with a geological compass, fits the orientation of the general town grid and possibly represent remains of an eastern fortification wall.[171]

E Cooperation with the zooarchaeological research concerning environment and landscape

The zooarchaeological investigation of the animal remains of sector SAV1 North in the Pharaonic town, conducted in 2014 by Konstantina Saliari, contributes substantially to the understanding of the economy, contacts, tradition and diet during this period (see also Chapter 5).[172] For the examination of the zooarchaeological data, the comparison with modern animals as well as the knowledge of the general environmental conditions is crucial. Therefore, three joint short excursions were carried out in the northern and central parts of the island, taking bones for a reference collection and documenting the geomorphological parameters as well as different environments.

F Cooperation with the archaeometric analysis of ceramics concerning possible clay resources

The study of ceramic fabric and composition of local Nile clays of both Nubian and Egyptian style by Giulia D'Ercole provides very important insights into economy, tradition and know-how during the investigated period.[173] Therefore, three short excursions were carried out together to study and sample potential clay sources as well as collecting dung from goat, sheep, donkey and cattle. Additionally, a pottery workshop in Abri[174] was visited to discuss local potter traditions and techniques.[175] Interestingly, the modern potters communicated that they partially differentiate their 'recipe' in terms of choice of clayey raw material and tempers, according to the specific function and the performance required by the vessel they manufacture. Generally, soil was and still is used for most ceramic vessels and mud bricks (cf. Chapter 5.1).

G Location of a harbour

No Pharaonic harbour or its remains have been located on Sai Island so far. This is not surprising, because during the Bronze Age simple landing sites, where ships were pulled onto sandy beaches are much more common than proper harbours or even ports.[176] In the vicinity of the New Kingdom town of Sai steep sandstone cliffs hinder easy landing, with the exception of the sandy areas directly north of the excavation house as well as directly east of the site and the large sandy area southeast of the Ottoman fortress.[177] All three sites offer landing possibilities and due to their position at the eroding bank the water depth is quite deep. The discovery of two stones which resemble Bronze Age stone anchors is quite remarkable.[178] One was found northeast of Temple A (Pl. 5), the other one south of the Ottoman fortress. They may support the assumption that both areas had been used as landing sites during that time (see Chapter 2.5).

[169] Identified as New Kingdom quarry 1 by the Klemms; see Chapter 2.3.
[170] Survey conducted by the Archaeological Prospection Services of University of Southampton and the British School at Rome in 2011; see above, Chapter 1.2.
[171] For an updated summary of the eastern town enclosure, see Adenstedt 2018.
[172] Cf. Saliari and Budka forthcoming.
[173] See D'Ercole et al. 2017; D'Ercole and Sterba 2018.
[174] See D'Ercole 2014a.
[175] The samples collected during these excursions and the knowledge gained from them were all used for experimental archaeology in 2014, see D'Ercole 2014b.
[176] It is striking that in Egypt several harbours have been located on the Red Sea and the Mediterranean coasts, but Nile harbours are hardly known; for this situation, see the discussion by Khalil 2015. See also below, Chapter 2.5.
[177] The latter was used as landing place by Budge in 1907; see Chapter 1.2.
[178] Wachsmann 1998.

2.2.2 Geoarchaeological survey of the hinterland of the New Kingdom town in 2015[179]

A geoarchaeological survey in the vicinity of the New Kingdom town site was undertaken by Sayantani Neogi from 18th January to 19th February 2015, assisted in the field by Miranda Semple, Martin Fera and Hassan Dawd. The objectives were specifically focused on the questions relating to the New Kingdom, especially the 18th Dynasty occupation of the island. These were to place the archaeological site in its environmental context, to understand the nature of any surface preparation prior to the establishment of the settlement, provenance of sandstones found within the New Kingdom town, potential sandstone quarry locations and to shed light on any possible harbour/landing ground on the island during the period concerned. Thus, the questions already investigated by Draganits received a follow-up investigation, partly introducing new lines of research and fresh sampling strategies.

This site margin survey work took the form of judgmentally placed test pits and hand auger profiles as well as opportunistic findings of exposed and available sections and quarry pits. At each profile *loci* the stratigraphy was located, recorded and photographed and old land surfaces sampled as appropriate. Three types of samples were taken: intact soil block samples for micromorphological analysis,[180] small bulk samples for physical characterisation (pH, particle size analysis, organic content using loss-on-ignition, multi-element analysis)[181] and sandstone blocks for petrographic analysis (see Chapter 2.3.3).[182]

A major component of geoarchaeological research in general is soil micromorphology. This technique, developed by the Austrian soil scientist Walter Kubiëna, examines soils and sediments in thin section with an optical microscope.[183] It allows very small components to be identified which otherwise would not be considered. At Sai, soil sampling was done by the removal of soil blocks using a knife. Once extracted, the samples were wrapped with cling-film, taped and sealed for laboratory processing. Following the method described by Chris Murphy,[184] they were manufactured at the McBurney Laboratory for Geoarchaeology, University of Cambridge. Thin sections were analysed under a Leica Wild M40 wide-view microscope.

Profiles and samples

In 2015, six profiles were recorded from the landscape survey and seven sets of soil block and bulk samples were collected. In addition, two soil block samples were collected from Profile 9 in SAV1 North, which represents soil from below the contact zone of the anthropogenic sediments and the natural soil. The descriptions and interpretation of the most relevant of these soil thin sections are given below.[185] Besides these, thirty-nine rock samples were collected for further scientific analysis from different sandstone outcrops of the island and from on-site debris (see Chapter 2.3.3).

Samples from the New Kingdom town, SAV1 North

The two block samples (9/4 and 9/5) from Square 180/2270 in SAV1 North were intended to reveal the Pre-Pharaonic soil type and environmental conditions on the island. They were taken from an archaeological section which had revealed the earliest levels of this sector of the town.[186] At SAV1 North, the walls were often set over an earlier layer of occupation, made of backfill pebble or earlier brick courses. In cases where no earlier remains were documented, the mud brick walls were set directly onto the natural gravel ground.[187] Samples 9/4 and 9/5 were taken to investigate the natural ground on which the

179 Based on the report by Sayantani Neogi; see Neogi 2015.
180 After Bullock 1985; Bullock et al. 1985; Murphy 1986; Courty et al. 1989; Stoops 2003; see Chapter 3.7.
181 After Milek and French 2007; Wilson et al. 2008.
182 Hutchinson 1974; Pettijohn et al. 1987.
183 Kubiëna 1970.
184 Murphy 1986.
185 Based on a report by Sayantani Neogi and Sean Taylor; Neogi and Taylor 2015.
186 See Budka and Doyen 2013, 171–172, fig. 1.
187 For details, see Doyen 2017.

18th Dynasty town was erected. The site SAV1 North is particularly representative to illustrate several aspects of the interrelationship between Pharaonic mud brick architecture and the local topography. The lowest occupation layers demonstrated that some works of levelling were carried out in the area by dumping pebbles as a backfill or by adjusting the irregular slope of the soil with a coating layer mixed with pebbles. However, it proved to be difficult to discern whether the pebble content of the ground is due to the process of intentional backfilling or the naturally gravelly geological environment.[188] Thus, micromorphology was used to provide further clues in this respect.

Sample 9/4 (~40–50cm)

Description

This soil thin section (Pls. 6, 7) has revealed the fabric to be made up of sandy silt loam (c/f_{50}µm ratio: 10:90) with high porosity (>60%). A wide range of minerals, especially including angular and sub-angular grains of quartz (100–200µm), mica (150–200µm) feldspar (<200µm), olivine (200µm), pyroxene (300–400µm) and other carbonate minerals were found embedded within the groundmass. These are observed as poorly sorted sand grains and rounded gravels and form the minority of the sediment which is otherwise dominant as very fine-grained sediment.

The organic content is relatively high (15–20%). This is characterised by humified organic punctuations (1–2µm), highly decomposed amorphous organic fine material (10–20µm) and some plant tissue remains. The sample exhibits an overall complex microstructure. Channel microstructure is dominant with spongy microstructure in discrete zones. Voids are channels (200–750µm), vughs (500–700µm) and fine planes. A faint horizontally bedded orientation of the channels is observed throughout.

Bioturbation and faunal activities are quite common as passage features with voids and channels filled with aggregates of groundmass material (50–200µm). Textural pedofeatures are otherwise very common with frequent birefringent clay in the fabric. Some redoximorphic features with moderately to highly impregnated typic orthic to dendritic nodules (250–370µm) are noticeable. Crystalline pedofeatures are few with some embedded nodules of secondary CaCO3 (<500µm) and micritic hypocoatings (130–430µm).

Interpretation

The sample was primarily expected to provide insight into the nature of the topography and existent environmental condition during the time of the Egyptian site establishment in the early New Kingdom. Interestingly, no significant micromorphological feature has been identified that would suggest thoughtful surface preparation before the establishment of the settlement at this particular area, such as truncations.[189] The faint horizontal distribution pattern of the channels with embedded rounded gravels suggests aggradation and can also indicate the weathering and rolling of these due to water action and subsequent deposition from somewhere else.[190] Certainly, the shape of the gravels indicates their fluvial origin.

Climatic conditions are perceived to be somewhat different to today. Humid conditions had favoured intermittent growth of vegetation across the site, and the channel microstructures are indicative of the extent to which the vegetation had established itself.[191] Likewise, the particular benign hydrological and biological conditions are seen to have been favourable for soil fauna to have been extremely active. The thin section shows abundant evidence for biological process associated with soil animals in the form of heavily bioturbated fabrics.[192] These are characterised by excremental fabric and 'bow like' passage features. Passage features with their characteristic crescent-like pattern mark the movement of these

188 For these difficulties, see Azim 1975, 95–99; Budka and Doyen 2013, 178 and Doyen 2017.
189 See already Doyen 2017 that foundation trenches are only attested for the enclosure wall at SAV1 North. Some New Kingdom storage pits were dug directly into the natural ground, see also evidence from SAV1 West and SAV1 East, Chapter 3.
190 Gé et al. 1993.
191 Kooistra and Pulleman 2010; Stoops et al. 2010.
192 Stolt and Lindbo 2010.

animals through the soil.[193] Therefore, the loose continuous and discontinuous infillings of groundmass material which fill many of the channels are indicative of the activities of soil animals.[194] Soil fauna are the prime movers in the breakdown of organic matter[195] and the amorphous, humified organic content of the sediment reflects this. The most likely time for the development of evidence for enhanced biological activity is during the early Holocene, when the climate was significantly moister and the region became a centre for important Neolithic cultures.[196]

The clay-rich birefringent fabric indicates soil formation processes were underway with the movement of clay down profile (illuviation) or the in situ weathering of primary minerals. There is certainly stability in the system.[197] The presence of redoximorphic pedofeatures indicates fluctuations of the ground water table and resultant wetting and drying conditions.[198] Rare crystalline pedofeatures are suggestive of reprecipitation of calcium carbonates,[199] which could have resulted from subsequent dry conditions.

Sample 9/5 (~55–65cm)

This sample derives from the same location at SAV1 North as Sample 9/4, but from a slightly lower position.

Description

Micromorphological analysis of this thin section (Pl. 8) showed again the predominance of very fine material, composed of clay loam (c/f_{50}µm ratio: 5:95) of a high porosity (>50%). Clay sized particles predominate with lesser silt and rarely sand. Embedded mineral grains consistently include angular to subangular quartz (100–250µm), mica (<250µm), feldspar (<150µm) and carbonate minerals. The organic content is moderate (10–15%) including dark organic punctuations (c.1–2µm), highly decomposed, humified, amorphous organic fine material mixed with the clay and humified plant tissues. The thin section exhibits a platy and vesicular microstructure thus creating an overall complex microstructure.

The thin section clearly showed a structure associated with processes of sedimentation. Allochthonous fragments of sedimentary crusts are observed within the groundmass. Otherwise, textural pedofeatures are observed as birefringent orientated clay within the fabric. Recrystallised nodules of calcium carbonate (>700µm) with superimposition of highly impregnated dendritic iron oxide nodules and very few typical orthic nodules of iron oxide (200–500µm) were also observed.

Interpretation

The presence of very few sand-sized particles along with abundant silt and clay-sized material, in sum giving a clay loam texture, is a reflection of the allochthonous mud being deposited on the Nile edge through overbank flooding in a low energy fluvial environment. This feature, to a lesser degree has been developed through pedogenic processes operating in the soil system. Clay had undoubtedly accumulated through in situ weathering; however, there is significant evidence for the illuviation of clay from former upper horizons by the presence of weakly birefringent fabric. This suggests a period of relative stability.[200]

Though there is lots of organic matter embedded in the groundmass, the absence of major bioturbational features suggests very little alteration after their deposition, hence suggesting a very rapid burial

193 Gerasimova and Lebedeva-Verba 2010.
194 Blanchart 1992; Kooistra and Pulleman 2010.
195 Darwin 1881.
196 See Garcea 2007.
197 Kühn et al. 2010.
198 Lindbo et al. 2010; see also Stoops 2003.
199 Durand et al. 2010.
200 Kühn et al. 2010.

of those sediments.[201] Alternating wetting and drying conditions through flooding had developed the superimposition of redoximorphic features on crystalline pedofeatures.[202]

Samples from outside the New Kingdom town – southern surrounding

Soil micromorphology from Profile 5

Profile 5 (20°43.564›N, 30°20.044’E) is located towards the south of the village Adou. The surface of the profile was characterised by a pebbly sandy surface (1–2cm) but when cleared, the section revealed calcite rich silt loam soil, much in contrast to the surface. Interpreted in the field as an old terrace of the Nile, two soil blocks for micromorphological analysis were collected from deep down the profile to yield information about the past environment. The descriptions and interpretations of these soil thin sections are given below.

Sample 5/1 (~85–95cm)

Description
Micromorphological observation of the fabric (Pl. 9) showed highly heterogeneous, poorly sorted material, with a texture of sandy silt loam (c/f_{50}µm ratio: 30:70). It has a very high porosity (>70%). The fabric is made up of very loosely packed sand-sized particles, silts, gravels and large rounded to sub-rounded aggregates (>1cm). Some of these aggregates appear to be fragments of fine grained, organic rich sedimentary crusts having vesicular microstructure. Otherwise, there are complex packing voids between mineral grains and aggregates, thereby making the overall microstructure complex. The coarse fraction of this heterogeneous fabric is made of fragments of carbonate gravels. Though the b-fabric is generally undifferentiated, the aggregates are weakly birefringent. Redoximorphic pedofeatures are abundant with highly impregnated, large dendritic nodules of iron oxide. A very high concentration of precipitated calcites was observed as well.

Interpretation
This sample clearly shows the processes of sedimentation of fine aggregates eroded, transported by water and deposited at this location. The aggregates were originally laid down in a low energy fluvial environment due to their small particle size. The weakly birefringent fabric observed in cross-polarised light indicates significant amounts of clay, although this is partly masked by the amorphous organic matter. The thin section is highly porous with sand grains and aggregates loosely packed. There has been very little bioturbation to disrupt the evidence for sedimentation, either because populations of soil fauna were low or sedimentation proceeded rapidly.

Sample 5/2 (~125–132cm)

Description
Microscopic observation has revealed that the whole fabric is apedal, well-sorted very fine silt loam (c/f_{50}µm ratio: 10:90) with moderate porosity (20–25%) and predominantly channel microstructure. Main voids are channels, vughs and some planes. Embedded in the groundmass are sand and silt-sized minerals including mica, feldspar, olivine and pyroxene and carbonate fragments. A few anthropogenic inclusions have also been observed in the form of fragments of bones (500µm–2mm, 1%, Pl. 10). The organic content is quite high in the whole thin section (<20%). Organic punctuations, highly decomposed amorphous organic fine material and humified plant tissues and some root fragments comprise the

201 Nichols 2009.
202 Fedoroff et al. 2010.

assemblage. Excremental pedofeatures are abundant in the form of infilled channels with aggregates of groundmass material. Redoximorphic pedofeatures are also noticeable in the form of iron oxide nodules.

Interpretation
Sample 5/2 contrasts strongly to 5/1. This horizon unequivocally represents the lower part of topsoil. The channel microstructure has developed by the rooting of plants growing at the ground surface and the burrowing action of soil fauna.[203] Humified and iron replaced fragments of plant tissues can be seen in channels.[204] The porosity (20–25%) reflects how biological processes have kept the soil profile well-aerated. It has received a lot of organic matter, although it is also full of different kinds of rocks of various lithologies. The fact that it has bones along with abundant rooting and organic matter suggests that it is the bottom of a buried 'A' horizon.

Samples from outside the New Kingdom town – northern part of the island

Sample Profile 1/1

Profile 1 (20°44'13.959495587478"N, 30°19'56.736878240482"E) was observed in the northern part of the island, 600m to the north off the town in a depression on the edge of a palaeochannel (see above, Chapter 2.1). Sample 1/1 was taken from a depth of 30-38cm of Profile 1. This sample was collected to improve the overall understanding of landscape evolution in Sai Island and as an appropriate control for determining whether the samples from the town represent the same geomorphological strata.

Description
Micromorphological analysis of this thin section (Pl. 11) reveals the presence of overwhelmingly fine clay sized sediment (c/f_{50}µm ratio: 5:95). The porous micromass (30–40%) is well-sorted and contains quartz, mica and mudstone. The overall microstructure is crack with angular planes, voids, channel and vesicles, often these voids are in a horizontal orientation. The micromass stained with organic pigments. The b-fabric is crystallitic with often weak birefringence. Pedofeatures comprise of abundant highly impregnated dendritic nodules of iron oxide. Reprecipitated calcium carbonate nodules and coatings have also been observed.

Interpretation
This fine sediment represents a sedimentary accumulation in a very low energy environment. It has a strongly developed subangular blocky microstructure consistent with fine material. The large well-developed peds are separated by interpedal accommodating planes and formed through shrink/swell processes of 2:1 clays. These clays have accumulated through deposition of fine sediment as a result of channel avulsion. To a much lesser extent, illuvial processes and also the in situ weathering of silicate minerals have contributed to the fine sediment. Illuviation of clay occurs when there is an excess of rainfall over evapotranspiration during the winter months or perhaps more relevantly in this case inundation by the river.[205] Organic matter is integral with this clay and also has a fluvial origin. The sample has a calcium carbonate content reflected by the calcitic crystallitic b-fabric observed in thin section. Calcification is the process leading to the accumulation of calcium carbonate in soils.[206] A number of other pedofeatures reflect the calcareous nature of the horizon has formed as calcium carbonate saturated soil water has precipitated calcite during periods of drying and are located in many voids. Superimposed to many of these, are dendritic nodules of Fe-hydroxide, developed because of

[203] Stoops et al. 2010.
[204] Fitzpatrick 1984.
[205] Fedoroff 1997.
[206] Gile et al. 1966; Machette 1985; Schaetzl et al. 1996.

a fluctuating water table. Abundant redoximorphic pedofeatures are evidence for alternating wet and dry conditions.[207]

Samples from outside the New Kingdom town – western part of the island

Sample Profile 2/1

Profile 2 (20°43'56.521174798028"N, 30°20'0.044419536243"E) was located towards the western bank of the island, within the current floodplain of the Nile. It was quite apparent that the Nile sediments here are recent (see above, Chapter 2.1 on the nature of the western shore of Sai Island). In order to understand the difference in soil property between the newer and the older Nilotic sediments, especially for a comparison of the soils/sediments between the eastern bank and the western bank of the island, Sample Profile 2/1 was collected.

Description
Micromorphological analysis (Pl. 12) has revealed extremely well-sorted sand and silt-sized material (c/f50µm ratio: 30:70) with complex packing voids and an enaulic related distribution pattern. The fine micromass is interbedded and cross-bedded with laminations. The organic matter, humified in nature, is also well-sorted and horizontally bedded.

Interpretation
Interbedded and cross bedded laminations suggesting even flow of water over time has deposited this sand. It is the result of an indeterminate number of fluvial events depositing well-sorted sand and fine organic matter. The sands have a parallel orientation which is stacked in multiple lenses. Excellent sorting and referred horizontal orientation are typical of those that have formed as overbank deposits in particular riverine environments.[208] The lack of pedofeatures indicates that there has been little pedogenic development suggesting a relatively recent emplacement of the sediment.[209] On the other hand, the sandy texture facilitates the free flow of water through the system making soil formation processes difficult to initiate unless there is sufficient stability through the influence of vegetation.

Overall interpretative discussion

The micromorphological observations of the soil blocks collected from different depths of the soil profiles have furnished a composite picture of landscape development around the New Kingdom town at Sai Island. At a depth of 85–95cm, at Profile 9/5 at SAV1 North, sedimentary aggradation occurred in a slightly less humid environment. The relative absence of soil fauna combined with low organic content suggests that this is correct.[210] At the depth of 55–65cm, an increase in the content of organic matter and the development of channel microstructure indicate changed hydrological conditions[211] suggesting an increase in moisture to the soil system. This interpretation receives additional weight from the almost absence of CaCO3 in the micromass, indicating that these soil horizons were not formed in an arid condition and the limited presence of CaCO3 represents re-deposition at significant depths in the subsoil.[212] The ubiquitous presence of iron hydroxide features is also closely linked to strong redox cycles due to alternating wetting

[207] Kovda and Mermut 2010.
[208] Mücher et al. 2010.
[209] Bolt et al. 1980.
[210] Phillips et al. 1999; Kooistra and Pulleman 2010; Stolt and Lindbo 2010.
[211] Gerasimova and Lebedeva-Verba 2010; Kooistra and Pulleman 2010; Kovda and Mermut 2010; Stolt and Lindbo 2010.
[212] Sehgal and Stoops 1972; Pal et al. 2000; Durand et al. 2010.

and drying through fluctuations in the water table in periods prior to the New Kingdom.[213] The presence of human occupation directly on this surface shows that such a location obviously had benefits for the New Kingdom occupants.

In the southern surroundings of the New Kingdom town, a buried 'A' horizon was discovered at the depth of 125–132cm in Profile 5, with an increase in the content of organic matter and crumb/aggregate microstructure.[214] The thickness, texture, structure and colour all suggest that this horizon is very well-developed. The crumb microstructure, with distinct peds and the presence of abundant channels are indicative of favourable conditions for the growth of vegetation. Crumb and granular microstructures can develop relatively quickly as part of grassland. These soils, when cultivated, are important to agriculture because they are very fertile, with thick, organic-rich 'A' horizons. Deep and readily tilled, they are important for cereal production.[215] Conditions change further up in the same profile (Sample 5/1) where a slope deposit is recorded with increasingly higher calcium carbonate deposition, marking a later change in the environmental condition due to climatic drying. At present, it remains tentative, but the New Kingdom cereal production was maybe located towards the south of the town (see Chapter 5).

Establishing the general size of the island during the New Kingdom was one of the main aims of AcrossBorders' geoarchaeological fieldwork. In this respect, Profile 1 in the presumed palaeochannel north of the Post-Meroitic cemetery was particularly relevant. Sample 1/1 marks the presence of extensive channel fill deposits which would have largely facilitated human activities from the New Kingdom until when the climate dried up.

Harbour

In order to understand whether there was a harbour or not during the New Kingdom occupation, a thorough coring in transect was undertaken in 2015 in the riverine alluvial platform adjacent to the town. This survey did not reveal the presence of any potential harbour. The nature of the soil and the adjacent cliff, however, suggest that this was perhaps a simple landing ground, sheltered by the steep sandstone cliff. Soil block samples were collected to provide further insight into this suggestion (see below, Chapter 2.5).

Conclusions

Landscape survey and profile observations showed that the underlying drift geology of the island is medium-grade metamorphic rocks (amphibolite, dolomite, quartzite, biotite gneiss, calcite marble), often overlain by medium to coarse-grained fluvial quartz sandstone, conglomerate, rare siltstone and occasional silicified wood.[216] Desert condition weathering often led to the disintegration and decay of these rocky outcrops, often in in situ conditions. The central plateau of the island is either a *serir* or pavement with a high amount of pebbles[217] or a characteristic *hamada* plain covered by angular gravels.[218]

The Pre-Holocene and Holocene Nile sediments on Sai mainly comprise channel deposits and fine-grained floodplain sediments and commonly show soil formation processes, mostly identified near the eastern, western and northern banks of the island. A thin layer of comparably much younger Nile sediments mixed with windblown sand covers almost the whole island. Within the soil profiles, pale yellow calcitic silt and very fine sand with calcitic nodules marks drier environmental conditions. The

213 Cf. Lindbo et al. 2010; Vepraskas and Lindbo 2012. "The presence of repeated hydration–dehydration cycles linked to floods" was also observed in pollen samples from Sai Island, here in particular for the Holocene period, see Florenzano et al. 2019, 25.
214 Cf. Gerasimova and Lebedeva-Verba 2010; Kooistra and Pulleman 2010; Kovda and Mermut 2010; Stolt and Lindbo 2010.
215 Montgomery 2007.
216 As noted by Draganits 2014.
217 Laity 2008.
218 Fairbridge 1968.

stabilised soil horizons, observed within these soil profiles of the old Nile terraces (for example, Profiles 5 and 9) and identified as soils formed under much wetter and humid environmental conditions, may represent old palaeosol. These palaeosols and the alluviated narrow floodplain areas in the island would have provided a naturally and seasonally replenishing soil and groundwater system available for agricultural use with both nutrient and fine soil additions and a seasonally high groundwater table. This is probably the essence of the sustainability of the agricultural system in this region since at least the Neolithic times.

2.2.3 Geoarchaeological research in 2016[219]

The 2016 season focused on geoarchaeological questions raised from the survey of 2015. Investigations were undertaken by Neogi and Taylor in the environs of the New Kingdom town and offsite from the 30th of January to the 19th of February 2016.[220] According to the aims of the AcrossBorders project, the objectives were specifically focused to questions relating to the 18th Dynasty. These were to sample on-site archaeological contexts to better understand the use of space and site formation processes (see Chapter 3.7); to place the archaeological site in its environmental context (see Chapter 2.6); to provenance the sandstones found within the New Kingdom town and to locate the Pharaonic sandstone quarry (see Chapter 2.3). The 2016 survey took the form of hand auger profiles, as well as opportunistic prospection of exposed and available sections and quarry outcrops.

Six boreholes were dug towards the western side of the New Kingdom town (see Figs. 51 and 53). A test trench to the west of the enclosure wall was opened in 2016, revealing, underneath a layer of pottery of later date and 19th and 18th Dynasty levels, a solid, sloping mud surface that resembles a glacis.[221] The question of the continuation of this slope was then addressed in 2016 by means of the augering. Taking these samples outside of SAV1 West proved to be quite difficult because the coarse sand was very dry and keeping it on the auger head was only possible by soaking the ground with water. For this reason, it was only possible to sample to a depth of 3.4m. In all the profiles the sediment comprised sand. Neither alluvium nor archaeological deposit was encountered but the probability that either of these were present at an unspecified depth is in general likely. For the New Kingdom, one can stress that no trace of an extramural settlement has been identified.

In addition to the work within and at the New Kingdom town, a thorough landscape survey was undertaken in 2016 to understand the nature of the deposits, especially towards the northern part of the island. This resulted in the collection of data to develop a surface map of the vicinity of the New Kingdom town (Pl. 13).[222]

2.3 Sandstones and Quarries of New Kingdom Sai

by Julia Budka

2.3.1 Sandstone variants

Several types of variants of Nubian sandstone, the most common rock identified on Sai Island, were documented during AcrossBorders' geoarchaeological seasons on Sai.[223] Because of its occurrence as bedrock, quartz sandstone was the preferred Pharaonic building stone from Esna in Upper Egypt to Gebel Barkal in modern Sudan.[224] In line with this, sandstone is also the rock type occurring most

219 Based on Neogi and Taylor 2016a.

220 Assisted in many respects by Dietrich and Rosemarie Klemm as well as by Martin Fera.

221 Budka 2017a, 18.

222 This surface map was created with the much appreciated help by Dietrich Klemm.

223 General literature on sandstone: Anonymous 2005; Klemm and Klemm 2008.

224 Harrell 2016, 11. Meroitic sandstone quarries are attested further southwards, towards the city of Meroe and Hamadab.

frequently in the New Kingdom town of Sai, of course especially within the Egyptian stone temple of the 18th Dynasty, Temple A.[225] It was one of the prime aims within AcrossBorders' geoarchaeological research to identify local and possibly non-local variants of the Nubian sandstone on-site.[226]

In the first season of the geological examination of Sai by AcrossBorders, Draganits noted well visible sandstone outcrops with traces of working by stonemason tools just east of the New Kingdom town (Chapter 2.2.1). But since these were according to him of small scale and low quality,[227] the search for the 18th Dynasty quarries continued in 2015. In the 2015 season, thirty-nine rock samples were collected for further scientific analysis from different sandstone outcrops of the island and from on-site debris.[228] These outcrops are mainly at Gebel Adou and the village of Adou, where at least four to five quarry places were marked; the period of quarrying was, however, of unknown date. The rest of the sandstone outcrops on Sai, particularly from the western side of the island, are coarse grained and friable and due to their inferior quality unlikely to have been worked into dressed stones.[229] The aim behind collecting sandstones from on-site debris in 2015 was to provenance their sources by characterising their mechanical and chemical properties. Back in 2015, a particularly high grade, fine-grained whitish sandstone found within the New Kingdom town and associated with Temple A could not be sourced on the island, but a potential source on the opposite bank of the river, near Gebel Abri seemed to be a possibility, as already proposed by Draganits.[230]

The study of the sandstones from Sai received fresh input in 2016 by the involvement of the long-standing experts of rocks in Northeast Africa, Dietrich and Rosemarie Klemm.[231] The primary research objective was to identify the exact provenance for the white temple building stone which is also attested from hieroglyphic texts at Kumma (see Chapter 2.4) and was tested with petrographic analysis of samples in 2016 (see Chapter 2.3.3).

2.3.2 Sandstone quarries of New Kingdom Sai[232]

Location

One of the main foci of AcrossBorders' 2016 fieldwork was locating the source of the building stone for the New Kingdom stone buildings at Sai.[233] Preparatory laboratory research on the basis of high-resolution "Google Earth" and Apple "maps" and lithologically processed Landsat-TM images conducted by Dietrich Klemm initially led to a localization of the clearly recognizable sandstone deposits from the wider area of the New Kingdom town on the east side of the island. These are the two "Inselberge"

225 For this temple and its building phases, see Azim and Carlotti 2012 (see also Chapter 1.2).
226 For general difficulties to classify different types of sandstone because of its very homogenous formation, see Klemm and Klemm 2008, 21.
227 Draganits 2014.
228 The samples were collected by Neogi, made into thin sections and analysed for the AcrossBorders project in Cambridge. However, a written report of these sandstone samples was never provided. Back in 2015, Neogi assumed over a dozen of variants of sandstone on Sai (for the revised grouping of four main types, see below).
229 Draganits 2014; Neogi 2015.
230 Draganits 2014.
231 Klemm and Klemm 1993; Klemm and Klemm 2008.
232 Based on the on-site observation and a German report of Dietrich and Rosemarie Klemm, who investigated the quarry sites on Sai from February 6 to 14, 2016. The results of the AcrossBorders geoarchaeologists, Neogi and Taylor, are also included in this chapter; see Neogi and Taylor 2016a.
233 Sandstone quarries on Sai were already mentioned as being located north and south of the fortress by Vercoutter 1958, 147, note 24; Vercoutter 1986, 8–10.

Gebel Abri on the eastern mainland, *c.* 4.5km from the Nile,[234] and Gebel Adou on Sai Island, *c.* 2km south of the New Kingdom town.[235]

At Gebel Abri (Pl. 14), slopes which could possibly be due to quarrying were detected with Remote Sensing Methods on the southern flanks. This was investigated by means of a foot survey in February 2016.[236] The detailed survey was carried out on the rock outcrops in the vicinity of Gebel Abri, to investigate if this was indeed the location of the sandstone used on Sai Island for Pharaonic building material. The results of this survey confirmed that although there are abundant sandstone outcrops in these locations, no quarry sites from Pharaonic times were identified and the stone was lithologically dissimilar. The slopes at the southern flanks thought as suspicious for quarry activities are in fact natural assemblages of rock waste.

Having ruled out the possible quarry source from outside the island, work focused again on possible quarry sites on Sai Island. At Gebel Adou with its well-recognizable threefold subdivision, quarrying was expected but no clear traces of it were to be found. Thus, also at the second "Inselberg" of the region, no Pharaonic quarrying activities were recognised.

Finally, in-depth inspections in the immediate vicinity of the New Kingdom town at the eastern shore of the island, between about 40m southeast of the French excavation house up to the abandoned part of the village of Adou, resulted in the localisation of a large number of relics of extensive quarrying activities (Pls. 15, 16 and 18).[237] Many of these relics have already fallen victim to weathering and were hardly visible.[238] Nevertheless, it was possible, though often not very clear, to find unquestionable scrapings for the excavation of cubic blocks of sandstone at various locations. All in all, it was in particular due to the expertise of Dietrich and Rosemarie Klemm that seven sandstone quarries were identified adjacent to the New Kingdom town itself (Pls. 15, 16). As illustrated by Pl. 17, two sandstone quarries are located just east of the town wall – these are the most convenient places for building material used within the town site (quarry sites 1 & 2, marked by numbers 4/5 and 6/7). Two other quarries used in the 18th Dynasty are also close by, being located in the northern part of the village of Adou (quarry sites 3 & 4, marked by numbers 9/10 and 8). Finally, three more quarry sites were mapped in the southern part of this village (quarry sites 5, 6 & 7, marked by numbers 12, 13 and 14). An eighth quarry site was documented by Taylor and Neogi and must remain unclear in its date; it possibly had also been used during the New Kingdom (Pl. 17, marked by number 11).

The sandstones from the exposed sections of the cliff just east of the New Kingdom town (quarry sites 1 & 2) were perceived as soft and not of high quality. With the removal of the overlain debris, however, stone very similar to the building material of the temple was clearly visible (Pl. 18). This is a particular whitish sandstone. Yet, it became obvious that the stone used within Temple A was of variable quality in terms of hardness, colour and other properties which were all in concordance with the lithological variation seen in the adjacent quarries. These were due to the sedimentary environment of deposition for each particular facies. Chisel marks (see below) and a cut-out for a column base provided compelling evidence for Egyptian quarrying very close to the New Kingdom town of Sai (Pl. 19). It is certain that the better quality sandstones were removed during antiquity at all New Kingdom quarries adjacent to the New Kingdom town, in particular in the area to the south of the Ottoman fort and around the village of Adou.

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234 Arkell reported a fallen, decorated sandstone block from the cliff at the south side of Gebel Abri of probable Meroitic date, see Arkell 1950, 32.

235 Cf. Geus 1996, 1170; van Peer et al. 2003, 187–193; Draganits 2014, 20–21. For a possible identification of Gebel Adou with *Nhr?* in Philä I, 277, 5–11 as source of a mineral, see Kockelmann and Rickert 2015, 200. I am grateful to Martina Ullmann for this reference. Vercoutter 1958, 147 also mentions quarries at Gebel Adou.

236 Participants: Dietrich and Rosemarie Klemm, Sayantani Neogi and Sean Taylor, assisted by Hassan Dawd.

237 Cf. already Vercoutter 1958, 147, note 24; Vercoutter 1986, 8–10.

238 This strong degree of weathering explains why both Dragantis in 2014 and Neogi in 2015 failed to recognise these quarry sites as being significant for New Kingdom Sai.

Chisel marks

New Kingdom chisel marks were identified on the sandstone outcrops of the quarries and on the blocks of stones used in the temple in 2016. This, therefore, clearly correlates the quarries with the New Kingdom architecture (in addition to furnishing corroborative evidence for the location of the ancient source of building stone).

Chisel marks appear in both the quarries and the undecorated portions of the in situ temple blocks of Temple A and are characteristic of the early New Kingdom.[239] There are mainly flat chisel traces of about 1 to 1.5cm width (Pl. 20), as they are also found in Egyptian sandstone quarries, for example at Gebel el-Silsileh, datable to the period of Hatshepsut–Thutmose III.[240] The recurring herringbone pattern of chisel traces (Pl. 21), resulting from quite hard bronze chisels, can be seen in Egypt in almost all quarries of the early New Kingdom up to and including the Amarna period.[241]

However, at stone blocks of Temple A two types of chisel marks have been identified, sometimes on the same block of stone. The first of these is the *c.* 1cm wide, systematic and regular linear parallel mark, characteristic of the Thutmoside period.[242] The other is chaotic, slightly haphazard, with *c.* 2–2.5cm wide marks in which the angles can be seen quite easily. It is thus characterised by the use of relatively broad flat chisels, whose lines are less parallel and occasionally completely discordant. These two distinct marks suggest different stages of the *chaine opératoire* for the rendering of stone to building blocks. Another possibility, stressed by Dietrich and Rosemarie Klemm, could be the involvement of different gangs of workmen for rendering the blocks. Whereas the well-attested, typical Thutmoside regular chisel marks clearly mirror the presence of Egyptian stone masons, specialised craftsmen and corresponding working groups, the unusual second type of chisel marks might attest to local workmen trained by the Egyptians, but nevertheless finding their own, specific way of stonework. This remains for now hypothetical and would have to be investigated on a broader scale, taking other Egyptian stone temples of the 18th Dynasty located in New Kingdom Nubia as comparison.

2.3.3 Petrographic analysis of sandstone from Sai[243]

Introduction

After the survey in 2016 and the observations on the chisel marks by the Klemms, it seemed obvious that the white sandstone for Temple A came from a relatively near source. In order to definitively prove this, Neogi and Taylor investigated whether it is possible to petrographically link the temple stone with similar properties in the quarries in question. Therefore, samples of the stone from the debris along the temple itself and from the quarries were taken (Tab. 4). Petrographic thin section manufacturing and examination were carried out in the Geology Department of the Ludwig-Maximilians-Universität in Munich, assisted by Dietrich Klemm.[244] What follows is a description of twenty of the samples taken from the quarries and on-site debris samples of the building stone from the town at Sai following established protocols of sedimentary geology.[245] Since Temple A was outside of AcrossBorders' work permission, the sampling of the relatively well preserved sandstone blocks directly from the still standing remains of the temple was not possible. However, NCAM kindly gave permission to sample some of the sandstone blocks originally deriving from the temple, located in the debris close-by.

239 On dating by chisel marks in Egyptian quarries, see Klemm and Klemm 2008, 194–201. For general aspects of chisel marks, see also Chudzik 2015, 30–31.

240 Klemm and Klemm 2008, 196. For the vast quarries at Gebel el-Silsileh, see Klemm and Klemm 2008, 180–201; Harrell 2013; Nilsson 2015.

241 See Klemm and Klemm 2008, 196–197.

242 Klemm and Klemm 2008, 196.

243 For general aspects of the geochemical examination of sandstone incl. further literature, see Klemm and Klemm 2008, 212–213. This chapter is based on a written report by Sayantani Neogi and Sean Taylor; Neogi and Taylor 2016c.

244 AcrossBorders received generous support by the chair of the department, Anke Friedrich, and her complete team.

245 See Folk 1951; Folk et al. 1970; Dickinson 1985; Pettijohn et al. 1987; Jerram 2001.

Sample Number	Brief description/reference
2	Cliff with rockslide; just east of the excavation house; 20°44.339´ N, 30°19.930´ E
3	Whitish sandstone?; from the cliff below Temple A; 20°44.245′ N, 30°19.923′ E
4	White sandstone from the cliff; 20°44.244′ N, 30°19.927′ E
5	Quarry Adou (yellow? not used for Temple A? left over?)
6	Source of white sandstone?; from the cliff near Temple A
7	Quarry Adou; temple material? (perhaps)
8	Source of white sandstone?; from the cliff near Temple A
9	Quarry Adou; probably used as building material
10	Sandstone from debris of the town/temple
11	Sandstone from temple debris
12	White sandstone from temple debris block
13	Sandstone from town/temple debris
14	Temple quality sandstone; from temple debris
15	Sandstone from temple debris
16	Sandstone from temple debris
19	Sandstone from temple debris
21	Sandstone from temple debris
25	Sandstone from natural outcrop/cliff; near the excavation house
28	Sandstone from natural outcrop/cliff; near the excavation house
50	Sandstone from temple debris

Tab. 4 Rock samples from Sai for petrographic analyses (thin-sections)

Petrographic thin section descriptions of the selected samples

Sample 2

This sample was collected from a natural sandstone outcrop to the east of the French excavation house (20°44.339´N, 30°19.930´E). Based on the quarry marks visible on the outcrop, this was thought to be the source of some of the sandstones used as building material during the New Kingdom time. This is an area which was in use until Christian times, as a quarry but also as a mooring area for ships (see below, Chapter 2.5).

The petrographic analysis revealed that this is a heterogenous quartz arenite of moderate sorting, fine-grained quartz, which are sub-rounded to round (Pl. 22). The groundmass is quite dense with some clasts of even smaller quartz grains, clays and siltstones. The quartz grains generally do not show much undulose extinction. Some re-crystallisation (overgrowth) structures are, however, visible. Though quartz is easily deformed, there are only few strongly deformed angular shaped quartz grains. Thus, not much deformation can be noticed from this sample, hence suggesting their non-metamorphic origin. It is cemented with maffic micromass and silicate cements to a greater extent followed by haematite cementation (Pl. 23). Though the minerals are dominated by quartz, there are few haematite, microcline and clastic feldspar, as well as biotite and muscovite mica flakes (Pls. 24, 25, 26). There is also an absence of magnetic minerals and plagioclase feldspar. This sandstone is matrix-supported and shows sub-mature development.

Sample 3

This sample was collected from a natural sandstone outcrop forming a cliff on which Temple A is located (20°44. 245′N, 30°19.923′E). A closer look revealed its whitish colour and hence the sample was thought to be the source of the raw material for the building blocks of the temple.

The petrographic analysis showed that the sandstone is a quartz arenite dominated by well-sorted quartz grains which are grain supported (Pl. 27). The sorting, therefore, is much better than Sample 2. The differences also lie in the fact that these fine-grained quartz particles are quite rounded and there is a better exhibition of bedding planes with parallel orientation. The presence of many elongated quartz grains gave it the bedding which is clearly valuable not only from an aesthetic point of view, but also for working, as this rock is easier to split. Subsidiary minerals include indeterminate maffic iron rich minerals, either magnetite or a species of haematite, some chlorite and small-grained micas, the latter being present in a quite high percentage (Pl. 28). This relatively immature sandstone has some deformed clasts resulting from Cretaceous diagenesis. Presence of some clay and haematite in the form of cementation can be noticed.

Sample 4

This sample was collected from the whitish sandstone cliff close to Temple A (20°44.244′N, 30°19.927′E). The petrographic analysis revealed that the sample has quite similar features as Sample 3 which was collected nearby. The structure is again moderately to well-sorted and can be classed as a quartz arenite with sub-rounded clasts (Pl. 29). The groundmass is quite dense with plenty of very fine-grained sediments including some argillaceous sediment such as mudstone. This recycled mudstone from another sedimentary environment is indicative of its fluvial property. That it is not highly rich in feldspar also reflects the igneous environment. Similar to Sample 3, some striations and bedding can be noticed. Subsidiary minerals also include magnetite, a high percentage of mica and rounded microclines (Pl. 30). The matrix is grain supported and the quartz grains are cemented with silica cements with zones having haematite (Pls. 31, 32). The origin of the haematite can be indicated from the oxidation of other minerals. Interestingly, not much plagioclase feldspar was observed to point towards its volcanic origin. This sandstone sample also has deformed quartz clasts of possibly metamorphic rocks and some recrystallised quartz.

Sample 5

This sample was collected from one of the quarries in the modern village of Adou (see Pl. 17). It seemed to be slightly yellowish in colour and was collected from an outcrop with some clear marks of quarrying. Assuming that the sandstones of better quality had already been taken away, the question arose why this sandstone was left.

The petrographic analysis revealed that this grain-supported quartz arenite is highly heterogeneous with poor sorting (Pl. 33). There is a mix of large and small-sized quartz grains, with patches of fine grains, finer than Samples 3 and 4. The quartz mineral grains are moderately sorted; angular and subangular quartz grains indicate a sub-mature textural maturity (Pl. 34). The groundmass is dense and is highly impregnated with haematite (Pl. 35). Subsidiary minerals, which are grain-supported, are abundant with microcline, zircon and mica. Unlike the Samples 3 and 4, this sample has more accessory minerals such as aggregates of zircons and frequent magnetite. The cement is silica-rich along with large zones of haematite and calcites precipitated through groundwater, which could well be due to later-on diagenesis. The abundance of haematite and opaque minerals such as magnetite has given this sandstone a reddish/yellowish colour.

Sample 6

This sample was collected from the whitish sandstone cliff between Temple A and the excavation house. The petrographic analysis, however, showed that the groundmass is that of a quartz arenite consisting of poorly sorted heterogenous angular and subangular quartz grains which are grain supported, indicating their textural maturity. Subsidiary minerals include mica (quite a few), magnetite, micrites, zircons and microcline. The cement is dominantly silica-rich, although there are zones of haematite.

Though expected to reveal similar characteristics as Samples 3 and 4 owing to its ‘whitish’ colour, this sample has properties more similar to Sample 2. While the colour can be explained through the presence of mica, the absence of bedding unlike that of Samples 3 and 4 can be a reason towards the reduced aesthetic value. Nonetheless, owing to its good cementing properties, it can definitely be regarded as good quality sandstone.

Sample 7

This sample was collected from the quarry of the village Adou with the intention of checking if its properties are similar to any of those of the debris of sandstones. The petrographic analysis revealed that this is a moderately grain-supported quartz arenite. There is a high content of very small sized sub-angular to angular quartz. There are patches of dark brown minerals which form a discrete impregnation in limonite, often superimposed on calcites. Accessory minerals include zonated brown zircon mineral grains, often exhibiting high interference colours. Other accessory minerals include a fair amount of mica. There are also illite coatings on several quartz grains, giving a chitonic-related distribution pattern. No bedding or overgrowth of minerals has been identified.

Sample 8

This sample was collected from the cliff adjacent to Temple A. The petrographic analysis showed that the sample has quite similar features as Sample 6. The micromass is moderately to poorly sorted and can be classed as a grain-supported quartz arenite with sub-angular clasts. Some quartz grains are quite big. Grain-supported microcline with illite coating can be observed. There are many in situ broken quartz rock fragments cemented with siliceous cements, indicating that this particular rock fragment was transported from a metamorphic province. The matrix has siliceous cements with zones of illite and haematite and some clay. No bedding has been observed as in Sample 3; there are some quartz overgrowths. Similarities with Sample 4 are that the quartz and feldspar ratio is the same.

Sample 9

This sample was collected from the quarry of the village Adou with the intention of checking if its properties are similar to any of those of the debris of sandstones. The petrographic analysis assays that this is a poor to moderately sorted quartz arenite. Mineral grains are sub-rounded and sub-angular quartz with subsidiary minerals of illite and microcline. It is grain-supported and the cement is primarily silica. There are dark brown zones of limonite along with concentrations of a fair bit of calcite which forms a component of the cement, the latter is often coloured with the superimposition of haematite. With heterogeneous, coarse grains and some bigger grains of muscovite, this sample is very similar to Samples 5 (see Pls. 33–35) and 7. The groundmass is again fine-grained with smaller quartz grains grading into the clasts.

Sample 10

This sandstone was collected from a pile of debris of sandstones within the New Kingdom town site. The petrographic study revealed that this is again a moderately to poorly sorted, fine-grained quartz arenite with subangular quartz grains which are grain supported. The matrix is heterogenous. Subsidiary minerals include mica, haematite, microcline, illite, and at least one big grain of chlorite. The cement is silica and a high concentration of limonite with a small component of calcite. There are inclusions of rock fragments including rounded mudstone clasts and micaceous schists. Though no bedding has been identified, the higher presence of colourless muscovite and very few overgrowths of quartz can be observed.

Sample 11

This sample was collected from a pile of debris of sandstone from near the temple debris. The petrographic analysis showed this to be quite similar to Sample 10. This is also a moderately to poorly sorted quartz arenite, consisting of silica-cemented quartz and microcline grains, the latter are grain supported.

The mineral grains are angular and subangular. There are dark brown limonite impregnations and illite and calcite rich zones of the cement. Subsidiary minerals again include mica, haematite, microcline and at least a few grains of rutile. The omnipresence of mica gives the impression that the quartz grains are mica-coated, thus having a chitonic appearance.

Sample 12

This sample from the debris of sandstones lying almost adjacent to a temple block of Temple A was collected because of its whitish colour, to see if its characteristics are similar to any of the samples collected from the nearby cliff. Under the microscope it appeared as a moderately to well-sorted, fine-grained sub-rounded to rounded quartz arenite consisting of grain supported quartz grains. Mineral components are dominantly mica, with a few microcline and rock fragments are some mudstone and quartzite. There are zones of dark brown staining of haematite and limonite which forms the part of the cement. Fine beddings, not highly pronounced though, can be observed.

Sample 13

This sandstone was also collected from a pile of debris of sandstones within the site and again looks similar to Sample 10. This quartz arenite has heterogeneous, sub-rounded and subangular mineral grains as well as matrix-supported mineral grains. The cement is again precipitated silica with dense accumulations of haematite and illite concentrations. Some calcitic concentrations can also be identified. Subsidiary minerals include micaceous quartzite, quartz, microcline, some chlorite, zircon and biotite. Similar to Sample 11, some of the quartz grains are mica-coated. Some very dense fine-grained dark fragments of mudstones can also be identified. No overgrowth of quartz and no bedding can be seen.

Samples 14, 15, 16 and 19

These sandstone blocks were all sampled from the debris of Temple A. The petrographic study revealed these to be a nicely sorted grain-supported quartz arenite in which mineral grains are rounded quartz and quartzite. These have a higher ratio of clasts to groundmass with plenty of embedded rock fragments, thus giving a monic-related distribution pattern. There are microclines, some rutiles with cleavages and diagenesis, zircons, tourmaline, schistic rock fragments, microcline, muscovite and quartzites. Sample 16 has some distinct biotites. The microcline twins have characteristic tapering. Similar to Sample 10, there are some coatings of mica/clay around the grains. The cement is lightly coloured; illite and limonite zones form a minor part of the silica rich cement. Sample 19 shows the presence of some quartz overgrowths, a slightly higher percentage of altered mica, few clinozoisite and some chlorite.

Sample 21

This sample was collected from a pile of debris of the sandstones from Temple A. The thin section analysis showed that the groundmass is that of a quartz arenite consisting of poorly sorted, very coarse heterogeneous angular and subangular clasts of quartz grains which are grain-supported. The finer matrix, on the other hand, is very fine-grained. Mineral grains include big chunks of re-crystallised metamorphic quartzites and plenty of microcline feldspars. The latter looks a bit more rounded which is perhaps the result of transportation; in addition, some of these are more weathered than others. There is a mixture of quartz and clay in the groundmass. Cementation is mainly by silica, the latter appears to be re-precipitated and had undergone diagenesis. There are a few grains of quartz with overgrowth, thus giving some environmental signatures by showing precipitation of silica within quartz grains. Distinct patches of small grained calcites with high interference colours can also be seen as part of the cementation with a superimposition of haematite, which could well be re-precipitated. With plenty of feldspars, a heterogeneous nature and an absence of bedding, this sample is different than the others. This specimen clearly falls out of the spectrum of the typical sandstones attested on Sai and it does not appear to be from the immediate vicinity of the site.

Sample 25

This sample was collected from a natural sandstone outcrop near the French excavation house. The petrographic study revealed that this is a matrix-supported heterogeneous quartz arenite cemented by siliceous cements and limonite. The grains are finer with moderate sorting, as in Sample 5. Within these angular to sub-angular shaped mineral grains there is dominance of quartz with some schistic rock fragments and microcline mineral grains. Though mainly silica-cemented, there are dominant patches of dark brown staining of haematite and limonite forming the part of the cement. No overgrowth of quartz was identified. Some fragments of mudstone and some euhedral zonated zircons, as in Sample 5, were identified as accessory minerals. The abundance of haematite has given this sandstone a reddish/yellowish colour.

Sample 28

This sample was also collected from a natural sandstone outcrop near the French excavation house. The petrographic study showed that this is again a well-sorted, fine-grained quartz arenite with subangular quartz grains which are grain-supported. The matrix is heterogeneous. Subsidiary minerals include biotite, haematite, microcline, illite and some greenish brown to brown pleochroic tourmaline. The cement is iron-stained limonite with some calcite. There are inclusions of rock fragments, including rounded mudstone clasts and micaceous schists. No bedding and overgrowth of quartz could be observed.

Sample 50

This sample derives from a pile of debris of the sandstones from Temple A. This grain-supported quartz arenite with very fine siliceous cement has very similar petrographic properties as Sample 21. It is also not very well-sorted with very coarse heterogeneous angular and subangular clasts of quartz grains. In fact, with a bigger range of clasts, patches of this thin section show even more heterogeneity than Sample 21. Some lithic clasts of mudstone rock fragments can be observed. Haematite forms a component of the cement for this sandstone.

Discussion

From the range of block samples collected from different outcrops, the sandstones from Sai can be divided into three main categories:

a) sandstones from the outcrop directly southeast of the French excavation house which forms the northern limit of the quarry area in the vicinity of the town (quarry 1)

b) sandstones from the whitish outcrops adjacent to Temple A (quarry 2)

c) sandstones from the quarries in the village of Adou (especially quarries 3 and 4).

The task was to petrographically characterise samples from these outcrops to establish their similarities/differences. The rest of the ten samples collected on-site was characterised as well and their local or external origin was investigated. After going through the petrographic analysis of the outcrop sandstones, it was possible to grade them into four types on the basis of their mechanical properties. These are presented in Tables 5–8.

Based on these grades, it has now been possible to estimate the source of the ten sandstone block samples collected on-site (Tab. 9). With moderate to poor sorting, sub-angular grains, a heterogeneous grain-supported matrix and a high concentration of limonite in the fabric, the source of Samples 10, 11, 13, 21 and 50 can be ascertained to the quarries from the village Adou (Grade 2). With moderate to well-sorted particles, fine sub-rounded to rounded grains, a grain-supported matrix and largely silicate cementing, Samples 14, 15, 16 and 19 can be determined as deriving from the quarries from the eastern sandstone cliff close to the excavation house (Grade 1). The whitish sandstones outcrops at the base of Temple A (Grade 3) can be proposed as the origin of Sample 12, with moderate to well-sorted, fine sub-

Grade 1 (sourced from the southeastern side of the French excavation house)	
Grain size	Fine grained
Sorting	Moderate to well-sorted
Roundness	Rounded to sub-rounded
Grain types	Clay, siltstones, haematite, microcline, muscovite, clastic feldspar (apart from quartz)
Matrix	Matrix-supported
Cementation	Mainly silicate cement with some haematite

Tab. 5 Petrographic features of sandstones belonging to Grade 1

Grade 2 (sourced from the village Adou)	
Grain size	Heterogenous mixture of large and small grains
Sorting	Moderate to poor
Roundness	Sub-rounded to sub-angular
Grain types	Abundant mica, microcline, frequent zircons, magnetite (apart from quartz)
Matrix	Grain-supported
Cementation	High impregnation of haematite with calcites

Tab. 6 Petrographic features of sandstones belonging to Grade 2

Grade 3 (sourced from the cliff adjacent to Temple A)	
Grain size	Fine grained
Sorting	Well-sorted
Roundness	Rounded
Grain types	Chlorite, abundant small-grained mica, mudstone (apart from quartz)
Matrix	Grain-supported
Cementation	Clay and haematite; bedded

Tab. 7 Petrographic features of sandstones belonging to Grade 3

Grade 4	
Grain size	Not very fine; heterogenous to some extent
Sorting	Poor
Roundness	Angular to sub-angular
Grain types	Mica, magnetite, zircon, microcline
Matrix	Grain-supported
Cementation	Mainly by silica with some haematite; no bedding

Tab. 8 Petrographic features of sandstones belonging to Grade 4

rounded grains and haematite and limonite stained cement with some characteristic bedding. It has not been possible to find any sandstone belonging to Grade 4 from the range of samples from on-site debris. Therefore, sandstones of Grade 4 can be interpreted as external material which was imported to Sai.

Sample no	Corresponding Grade
10	Grade 2 (village Adou)
11	Grade 2 (village Adou)
12	Grade 3 (adjacent to the temple)
13	Grade 2 (village Adou)
14	Grade 1 (close to the excavation house)
15	Grade 1 (close to the excavation house)
16	Grade 1 (close to the excavation house)
19	Grade 1 (close to the excavation house)
21	Grade 2 (village Adou)
50	Grade 2 (village Adou)

Tab. 9 On-site samples and their corresponding grades

Sandstones belonging to Grade 1 contain more silica. Such silica in sandstones is precipitated from water flowing through the sands through diagenesis. Extremely fine iron-oxide can often react with such water, thus forming rust, which can lead to normal alteration of sandstones. It can be expected that the current state of the concerned sandstones of Grade 1 were not covered by any protection (i.e. limestone) and hence have undergone diagenesis and deterioration before assuming their current forms. These are, therefore, relatively dense and good quality sandstones.

However, sandstones belonging to Grade 2 are harder and more durable and therefore of better quality owing to their calcite impregnation. If the silica content is not that high, there is lesser chance of water containing silica loosening the grains. Furthermore, the abundance of hard minerals such as zircons with very high refractive index makes this variety of sandstones colourful.

Temple A on Sai was, however, built with sandstones belonging to Grade 3, i.e. a group with plenty of silicate cement. The accessory mineral in these is an abundance of mica, giving it the 'white' colour (see Chapter 2.4).[246] In addition, the beddings make it perfect for a pristine polished look. The temple builders of Sai obviously had a clear choice between the aesthetic appeal and the durability of the sandstones available on the island. The aesthetics were noticeably preferred for temple buildings and this might have affected that the sandstone from Sai was also employed for other building projects in Nubia, as will be outlined in the following, taking textual sources into account (Chapter 2.4).

2.4 Textual sources for sandstone from Sai

by Martina Ullmann

2.4.1 References

The toponym *Š3ˁ.t*, i.e. Sai Island,[247] is mentioned five times in the inscriptions of the 18th Dynasty temple of Kumma (Semna East) as a source of building material for the temple:

> No.1: Hall C, jamb 37;[248] dedication text of Thutmose III in favour of Khnum-Ra, regarding a *ḥw.t-nṯr m jnr ḥḏ nfr n Š3ˁ.t* "temple in fine white stone from Sai".
>
> Nos. 2–5: Room F, jambs 59, 61, 63, 65;[249] dedication texts of Amenhotep II in favour of Khnum-Ra, regarding a *ḥw.t-nṯr m jnr ḥḏ nfr n Š3ˁ.t* "temple in fine white stone from Sai".

In all five occurrences *Š3ˁ.t* is written with the foreign land determinative (Gardiner sign-list N 25) and text no. 1 has in addition the club sign (Gardiner sign-list T 14).

Another inscription in the temple of Kumma mentions *T3-Stj* "Land of the bowmen/Nubia" as a source of stone:

> Hall C, hieroglyphic frieze 25;[250] dedication text of Thutmose III in favour of Khnum, regarding a *ḥw.t-nṯr m jnr ḥḏ nfr n T3-Stj* "temple in fine white stone from Nubia".

All other dedication texts in the temple of Kumma do not mention a source for the building material used.[251]

In the literature several other references for *Š3ˁ.t* as a source of stone for the building of temples have been discussed: A much damaged inscription at the façade of the 18th Dynasty temple at Semna (West) opposite of Kumma reports a decree of Thutmose III to Nehy, his viceroy of Nubia, regarding the transportation of stone by ships most probably in connection with the rebuilding of a temple.[252] Kurt Sethe, Urk. IV, 986.6 restored *Š3ˁ.t* as the provenience of the shipped stone.[253] But since the crucial part of the text had already been completely effaced at the time of Sethe, this reconstruction is in fact nothing more than a mere possibility. Unfortunately, several authors have adopted the restoration

[246] Cf. Harrell 2016, 21: "When iron oxides are absent, the rock has a light grayish to nearly white color which is the natural hue of the quartz sand grains."

[247] For the identification of the toponym *Š3ˁ.t* with Sai, see first Vercoutter 1956, 73; Vercoutter 1958, 147; Posener 1958, 57–60. For lists with references, see Zibelius 1972, 154–155 and most recently Devauchelle and Doyen 2009, 33–37. For Sai in Meroitic texts, see Rilly 2007 (see also above, Chapter 1.1, fn 13).

[248] Caminos 1998b, 50–51, pl. 41 right.

[249] Caminos 1998b, 74, pl. 58 right; 75, pl. 58 left; 76, pl. 60 right; 77, pl. 60 left.

[250] Caminos 1998b, 36, pl. 30.

[251] See in general the temple inscriptions published by Caminos 1998b and especially the building texts in Grallert 2001, 158–160.

[252] Caminos 1998a, 38–40, pl. 22. See also Spencer et al. 2017, 32.

[253] Sethe 1909, 986.6.

by Sethe without indicating that it is a conjecture and not a proven fact. Silke Grallert states with reference to the inscription mentioned above "*Nḥi*s Angaben belegen, daß für den Neubau Steine aus Saï herbeigeholt wurden, um einen alten Ziegeltempel zu ersetzen".[254] And Ingeborg Müller writes "Kalkstein (sic!) von der Insel Sai ist lediglich als Baumaterial für die Tempel in Semna, Kumma und Buhen erwähnt".[255]

Like in Kumma, there is an inscription in the temple of Semna which mentions *Tꜣ-Stj* "Land of the bowmen/Nubia" as a source of stone:

> Exterior face of the west wall, scene 22;[256] in the context of a coronation scene with Thutmose III there is a dedication text of this king in favour of Dedwen and king Senwosret III, regarding a *ḥw.t-nṯr m jnr ḥḏ nfr n Tꜣ-Stj* "temple in fine white stone from Nubia".

The other dedication texts in the temple of Semna do not mention a source for the building material used.[257]

Three inscriptions in the south temple of Buhen name *Tꜣ-Stj* "Land of the bowmen/Nubia" as a source of stone used in the temple:

> Courtyard, pilaster 3, north face;[258] only partly preserved dedication text of Thutmose III, mentioning *m jnr ḥḏ nfr n Tꜣ-Stj* "in fine white stone from Nubia".

> Entrance to vestibule, west face of south and north jambs 41 and 42;[259] only partly preserved dedication text of Hatshepsut, later altered for Thutmose II, mentioning *m jnr ḥḏ nfr n Tꜣ-Stj* "in fine white stone from Nubia".[260]

No other location in Nubia shows up in the dedication texts of the south temple of Buhen as a source for building material.[261]

Grallert presumes that stone from *Šꜣꜥ.t* was mentioned in the inscription of year 25 of Thutmose III on a pillar found at Sai Island (S.1).[262] The only partly preserved text talks about the construction of a temple at Sai under the responsibility of the viceroy Nehy, but the translation of the crucial part by Grallert as "… eine *ḥw.t-nṯr* zu bauen von [Neuem?] [aus Stein der] Festung von Saï"[263] is a mere conjecture and does not fill in adequately the destroyed space indicated by Jean Vercoutter.[264] That is not to say that the temple erected by Thutmose III at Sai (so-called Temple A) was not built from local sandstone (see Chapter 2.3), but just to indicate that no inscriptional evidence for it exists in the text of pillar S.1.

To sum up: The five dedication inscriptions in the temple of Kumma by Thutmose III and Amenhotep II are to date the only proven references for *Šꜣꜥ.t* as a source of stone for the building of temples.

254 Grallert 2001, 156.
255 Müller 2013, 79, 292, 356. For the temple of Buhen, where *Šꜣꜥ.t* as a source of stones is in fact not mentioned, and also for the identification of the stone from Sai as sandstone and not limestone, see below.
256 Caminos 1998a, 73–79, esp. 78, pl. 38, text column 22–23.
257 See in general the temple inscriptions published by Caminos 1998a and especially the building texts in Grallert 2001, 155–158.
258 Caminos 1974a, 20, pl. 19 left.
259 Caminos 1974b, 40–42, pl. 42.
260 The text on the north jamb 42 does not preserve the *Tꜣ-Stj* anymore, but since the inscriptions on the south and north jamb run parallel, it can be safely restored.
261 For stone from *ꜥnw* (Tura) in the Buhen inscriptions, see below.
262 For the pillar and the text in question, see Vercoutter 1956, 74–75; PM VII, 165; Minault-Gout 2007, 279 (S.1); Davies 2014a, 7–9 (see also this volume, Chapter 6, Doc. 5).
263 Grallert 2001, 154.
264 See also the new translation by Davies 2014a, 8: in the phrase quoted above (lines 2–3) "sandstone" might be reconstructed, but remains speculative; in line 6, only "stone" (*jnr*) is mentioned.

2.4.2 Stone from location NN

Egyptian building inscriptions regularly indicate the type of material used in construction – most often *jnr ḥḏ nfr/jnr ḥḏ nfr n rwḏ.t* "fine white stone/fine white hard stone" – but only rarely mention a special location as source for it.[265] With one exception: *ꜥnw* "Tura" is used more commonly in order to refer to the limestone quarries at Tura-Maʿasara, a few kilometres south of Cairo, which had been exploited at least since the early Old Kingdom.[266] But *ꜥnw* became such a popular source for fine white stone, i.e. stone of high quality in the perception of the Egyptians, that it was sometimes used as an expression for stone of good quality and not necessarily as its source.[267] An example for this kind of use of *ꜥnw* can be found in the south temple of Buhen:

> Southern room, north wall, jambs 70 and 71;[268] only partly preserved dedication texts of Hatshepsut, later altered for one of the Thutmoside kings, mentioning [*m jnr*] *ḥḏ nfr n ꜥnw* "[in] fine white [stone] from Tura".[269]

Both texts – like all the other building inscriptions in the temple – undoubtedly refer to the south temple at Buhen. The only stone used in the temple building is so-called Nubian sandstone, of which the exact provenance is unknown.[270] It certainly was not brought from the limestone quarries at Tura far away in the northern part of the Nile valley. "Fine white stone from Tura" here simply denotes a very light-coloured local sandstone.[271]

Nevertheless, some confusion does exist in the literature about the identification of the stone used in the temples at the Second Cataract: John Raymond Harris states that "a small limestone temple at Semneh is said to be of *jnr ḥḏ nfr n tꜣ-sty*, which in all probability refers to limestone from the neighbourhood of Aswan".[272] And Müller thought that limestone from *Šꜣꜥ.t* "Sai" and/or from *Tꜣ-Stj* "Nubia" had been used as building material for the temples in Semna, Kumma and Buhen (for the citation, see above) and – in all likelihood influenced by Harris – that the limestone from *Tꜣ-Stj* probably came from the area of Aswan.[273] We have seen above that "fine white stone from Sai" is only proven as a source for building material in the temple of Kumma, whereas "fine white stone from Nubia" is mentioned in Kumma, Semna, and Buhen. As a matter of fact, all three temples in question were not built from limestone but from sandstone.[274] The speculation about limestone quarries near Aswan is neither supported by the archaeological record nor the geology of the First Cataract area.[275]

A comparison between the Egyptian designations for the various stones used in construction or sculpting and the actual material employed shows very clearly that for the Egyptian terminology quite often the visual qualities of the stones were more important than the geological identification. Thus, the expression *jnr ḥḏ nfr* was used by the Egyptians to denote a light-coloured stone of good quality, regardless whether it was limestone or sandstone.

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265 For a convenient overview of Egyptian building inscriptions, see Grallert 2001.

266 Grallert 2001, 706–707 (index). See also Sethe 1933, 868–873; Harris 1961, 69–71; Klemm and Klemm 2008, 51–55. The toponym *Rꜣ-ꜣwy* can be used for the Tura quarries as well; see Sethe 1933, 867–868 and Harris 1961, 69–70.

267 Sethe 1933, 872–873; Harris 1961, 71; Karlshausen and de Putter 2017. The same might be true for other place names as well, like e.g. Hatnub as a source of calcite alabaster, which might sometimes denote calcite alabaster from some other quarry, but of a special high quality like the one from Hatnub, see Sethe 1933, 884 and Klemm and Klemm 2008, 161.

268 Caminos 1974b, 75–76, pl. 63 lower right and left.

269 The text on jamb 71 only preserves *ꜥnw*.

270 Caminos 1974a, 12; for Egyptian sandstones and its quarries, see Klemm and Klemm 2008, 167–213 and lately Harrell 2016.

271 See also Caminos 1974b, 75 fn. 2; Grallert 2001, 162.

272 Harris 1961, 69.

273 Müller 2013, 79, 356.

274 For Buhen, see Caminos 1974a, 12; for Kumma: Caminos 1998b, 3; for Semna: Caminos 1998a, 9, 12.

275 Klemm and Klemm 2008, 23–145.

A dedication text of Taharqa in the Temple of Mut (B 300) at the Gebel Barkal indicates that this temple, which consisted entirely of sandstone, had been built *m jnr ꜥnw ḥḏ nfr rwḏ* "in fine white hard Tura-stone".[276] Here again, *ꜥnw* specifies a good quality local (sand)stone, but not the source of the stone.

Apart from the special case of *ꜥnw,* it seems that the source of the stone was only indicated within building texts when the material in itself was in some way or the other special or when the location where it came from was an unusual one or when we have a combination of both. Thus, the texts regularly mention *Ḥw.t-nbw* "Hatnub" as a source of calcite alabaster[277] and *Ḏw dšr* "Roter Berg = Gebel el-Ahmar" is named twice as a place from where red coloured quartzite comes from.[278] Occasionally *ꜣbw* "Elephantine" is cited as a location for stone, esp. *jnr km* "black stone – black granite/granodiorite" or *mꜣṯ* "(rose) granite", but also just *jnr* "stone".[279] When looking at the ancient Egyptian quarrying area at Aswan, which extends about 20km^2,[280] it is clear that *ꜣbw* in the building inscriptions not just means the island of Elephantine, but the broader area within the First Cataract where the different quarry sites are to be found. The dedication text on one of the obelisks of Hatshepsut at Karnak states that two obelisks were made *m mꜣṯ rwḏ.t n.t ꜥ-rsy* "in hard granite from the southern district".[281] Undoubtedly *ꜥ-rsy* "southern district" is used here as an alternative designation for the quarrying area at Aswan. The dedication text on a door jamb, found at Balat in Dakhla oasis and most probably from the late 6th Dynasty, specifies the material used for it as *jnr ḥḏ nfr n Tꜣ-wḥꜣ.t* "fine white stone from the oasis".[282]

The only Nubian toponyms used to indicate the source of stone within Egyptian building texts are *Šꜣꜥ.t* "Sai" and *Tꜣ-Stj* "Nubia". As seen above, *Šꜣꜥ.t* in this context is only known from inscriptions in the temple of Kumma, which date to the time of Thutmose III and Amenhotep II and *Tꜣ-Stj* is mentioned in building texts in the temples of Kumma, Semna, and Buhen, which come from the reigns of Hatshepsut and Thutmose III. Thus, it seems that the use of *Šꜣꜥ.t* and *Tꜣ-Stj* as a source of building material of temples was very much limited in time and space. The most plausible explanation for this is in my point of view that during the first half of the 18th Dynasty the construction of temples in the area of the Second Cataract using mainly local Nubian sandstone was something new and unusual. Something which had not happened before in this way and that, therefore, was worth to be especially mentioned within the building texts of the temples in question.

2.4.3 Fine white stone from Sai

The textual evidence for stone from Sai used in the construction of the temple at Kumma can be linked to the geoarchaeological results of the AcrossBorders project. Several variants of Nubian sandstone were identified on Sai Island as well as seven sandstone quarries in the vicinity of its New Kingdom town (see Chapter 2.3 and Pl. 20). Back in the 1950s Vercoutter had already observed sandstone quarries at various locations on Sai Island, some of them very close to the river.[283] Somewhat misleading is his statement "that Lepsius when visiting the sandstone temples at Semna associated them with Sai."[284] Carl Richard Lepsius wrote in one of his letters to Christian Gottfried Ehrenberg and August Böckh from the island of Philae in September 1844 about the temples at Semna and Kumma:[285] "In both fortresses the highest and best position is occupied by a temple, built of huge blocks of sandstone, of two kinds,

276 Robisek 1989, 10–11, 114; Grallert 2001, 147.

277 Grallert 2001, 212–213 (18th Dynasty, private), 249 (Amenhotep I), 270–271 (Thutmose III), 278 (Thutmose III), 284 (Thutmose III), 285 (Thutmose III), 406 (18th Dynasty, private), 498 (12th Dynasty, private), 500 (Hatshepsut), 515 (6th Dynasty, private); Klemm and Klemm 2008, 161–163.

278 Grallert 2001, 255 (Hatshepsut), 271–272 (Thutmose III); Klemm and Klemm 2008, 216–219.

279 Grallert 2001, 215 (Thutmose III), 263 (Thutmose III), 311 (Horemhab), 526–527 (Ramesses III), 559–560 (26th Dynasty, private); Klemm and Klemm 2008, 233–267.

280 Klemm and Klemm 2008, 233–245, esp. fig. 355.

281 Sethe 1906, 362.11; Grallert 2001, 252.

282 Osing et al. 1982, 36–37 (no. 38), pl. 8; Grallert 2001, 560.

283 Vercoutter 1956, 73; Vercoutter 1958, 147–148 with fns. 24–26; Vercoutter 1986, 10.

284 Vercoutter 1958, 148, fn. 24; his abbreviated quotation of Lepsius changes somewhat the meaning of the original text.

285 Lepsius 1853, 508.

which must have been brought from a great distance through the rapids; for, southward no sandstone is found nearer than Gebel Abir, in the neighbourhood of Amara and the island of Sai (between 80 and 90 English miles), and northward, there is none nearer than the great division of the district at Wadi Halfa (30 miles distant)."[286] Thus, Lepsius thought of the Gebel Abir, i.e. Gebel Abri, as a possible source of sandstone, but not of Sai itself.

Gebel Abri is a widely visible "Inselberg" located close to Sai on the eastern mainland, about 4.5km from the Nile with abundant sandstone outcrops that must have caught the attention of the Lepsius expedition (see Chapter 2.1). But since during the investigation of the area by the AcrossBorders team in 2016 no quarry sites from Pharaonic times were identified (see Chapter 2.2), it seems highly unlikely that the Gebel Abri was used as a source of building material in the New Kingdom. Instead, the quarries identified on Sai Island, which show clear evidence of Pharaonic quarrying activities, must be considered as sources of sandstone used on Sai Island itself and possibly also for temples in the region of the Second Cataract.

Georges Posener picked up the observation of Jean Vercoutter when writing about the identity of the toponym *Šꜣꜥ.t* with Sai Island, supposing that the stone extracted from the quarries at Sai had been transported by river northward to Kumma in order to be used in erecting the temple there.[287] Caminos consented to this suggestion in his publication of the temple of Kumma: "the source of the sandstone was the ancient quarries in the island now called Sai, some 112km upstream from Kumma fort".[288] But more recently Didier Devauchelle and Florence Doyen expressed doubts about Sai Island as a source of building material used in Kumma, by referring to the great distance of 112km and the fact that navigating through the Dal Cataract and the region of the Batn el-Haggar was by no means an easy undertaking.[289] Furthermore, they point out that at least in later times (Napatan and Meroitic) and south of the Third Cataract quarries were usually located in the vicinity of the monuments they supplied with stone material.[290] Since one building inscription in Kumma mentions *Tꜣ-Stj* "Nubia" instead of *Šꜣꜥ.t* "Sai" as the source of the stone used (see above), they propose to consider both toponyms – at least in this context – as being comparable and essentially metaphoric, referring to a large, imprecisely defined region.[291]

This conclusion is by no means mandatory: alternatively, *Šꜣꜥ.t* in the Kumma texts may very well denote a much more restricted area, which is part of the larger region *Tꜣ-Stj*. This interpretation definitely conforms better to the overall use of these toponyms during the New Kingdom, which shows that *Tꜣ-Stj* should be understood as "Nubia" in a very broad sense,[292] whereas there is clear evidence that the toponym *Šꜣꜥ.t* in the 18th Dynasty designated the settlement which the Egyptians had established on the island of Sai at the very beginning of the 18th Dynasty.[293] But in comparison with other place names in Nubia, such as Miam, we may assume that at the same time it also referred to the larger surroundings of the town.[294] We know of several governors (*ḥꜣty-ꜥ*) of *Šꜣꜥ.t* in the 18th Dynasty[295] who were most likely responsible for a larger district that encompassed riverine areas on the eastern and western mainland. This at least can be deduced from what we know about the range of duties of governors in the New

286 Lepsius 1853, 509.

287 Posener 1958, 57.

288 Caminos 1998b, 3. Caminos suggested that parallel to Kumma the sandstone used in Semna also came from Sai (Caminos 1998a, 12).

289 Devauchelle and Doyen 2009, 36.

290 Devauchelle and Doyen 2009, 36 with fn. 21.

291 Devauchelle and Doyen 2009, 36.

292 *Šꜣꜥ.t*: Posener 1958, 57–60; Zibelius 1972, 154–155; *Tꜣ-Stj*: Gauthier 1929, 31–32; Thesaurus Linguae Aegyptiae, Lemma no. 169280 (http://aaew.bbaw.de/tla/index.html). See also the use of *Tꜣ-Stj* in epithets of various Egyptian gods, especially as *nb/nb.t Tꜣ-Stj* or *ḫntj Tꜣ-Stj* during the New Kingdom (Leitz 2003).

293 For the Egyptian presence on Sai, see Budka 2015a; Budka 2017c and this volume, Chapters 7 and 8.

294 Müller 2013, 47. See also Steindorff 1935, 21; Posener 1958, 58–59; Simpson 1963, 27; Caminos 1968, 7.

295 Posener 1958, 58; Devauchelle and Doyen 2009, 34–35; Minault-Gout and Thill 2012, 180–183; Müller 2013, 47, 209; Cressent and Raimon 2016, 28–34. Apart from Sai, we have evidence for *ḥꜣty-ꜥ*s in Nubia in connection with Aniba (Miam), Buhen, Faras, Soleb and Kawa, see Müller 2013, 47. See also Auenmüller 2018b and this volume, Chapter 6.

Kingdom.[296] These duties included the administration of state-owned agricultural land, pasture grounds for cattle and vineyards.[297] The Nauri decree also explicitly forbids the governors in Nubia to let personnel of the temple of Seti I at Abydos work in other districts (*w*).[298] Even though we cannot determine the precise geographical extent of the district *Š3ʿ.t* in the 18th Dynasty, we may safely assume that it encompassed only a small part of all of *T3-Stj*.

When we try to identify the source of the sandstone used in Kumma, we certainly also need to look at the geology and landscape of the Second Cataract and the Batn el-Haggar region immediately southwards. This is not a topic that can be dealt with here in any depth, but a few general remarks may nevertheless be helpful. Over a distance of about 160km from Wadi Halfa in the north to the Dal Cataract in the south the Nile flowed through a barren region mainly consisting of granite and gneiss.[299] The Second Cataract was characterised by a labyrinth of granite rocks and hundreds of small islands, which diverted the Nile into numerous small channels and rapids. In the Batn el-Haggar the bed of the Nile was very narrow and its course was broken by several rapids. Navigation, particularly upstream, was difficult and dangerous and impossible during the low water season. No sandstone formation is known in this part of the Nile valley.[300] Therefore, the sandstone used in the first half of the 18th Dynasty in the temples of Kumma and Semna, which are located at the southern end of the Second Cataract, must have been transported over a sizeable distance despite all difficulties, either from the region of Wadi Halfa in the north or from the south, where the nearest sandstone quarries known for being in use during the 18th Dynasty are the ones on Sai Island.[301] Since navigation upstream, that is from the sandstone area at Wadi Halfa through all of the Second Cataract to Kumma and Semna, was much more difficult than transportation northward, i.e. with the current, we should assume that, despite the longer distance, the stones were taken from the quarries at Sai. Alternatively, transportation could have gone overland, but regarding the heavy weight and the sizeable distance (from both directions), this seems highly unlikely. In this respect the inscription at Semna, reporting a decree of Thutmose III to Nehy, his viceroy of Nubia, is of interest, because it mentions – albeit in a much damaged context – the transportation of stone by ships (see above).

We have seen that the Egyptian building texts differentiate between fine white stone from *Š3ʿ.t* "Sai" and *T3-Stj* "Nubia". *Š3ʿ.t* in this context is only known from inscriptions in the temple of Kumma (Thutmose III and Amenhotep II) and *T3-Stj* is mentioned in building texts in the temples of Kumma, Semna and Buhen (Hatshepsut and Thutmose III). Since *Š3ʿ.t* is part of *T3-Stj* (see above), all the references could in principal pertain to stone from Sai. But in the case of the temple at Buhen this is highly unlikely because Buhen was located at the northern end of the Second Cataract, not far away from sandstone formations; therefore, there was no need to transport stone to be used in Buhen from quarries as far away as from Sai Island. In all probability, the toponym *T3-Stj* in the building texts at Buhen refers to local quarries north of the Second Cataract.[302]

In the case of the temples at Semna and Kumma, where, as we have seen, the sandstone came with all probability from Sai Island, the question arises: Why did the Egyptians use two different toponyms to indicate the same source of the stone material at the same time (Thutmose III/Amenhotep II)? Several solutions are possible: Whereas *Š3ʿ.t* indicated the precise location of the quarries, the broader term *T3-Stj* was used just as an imprecise but nevertheless correct variation. Alternatively, other Pharaonic

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296 Müller-Wollermann 1991, 48–54; Müller 2013, 46–49.
297 Müller-Wollermann 1991, 50; Müller 2013, 48.
298 Kitchen 1975, 52.15
299 See the description of the region by travellers in the 19th and early 20th century and in Adams 1977, 26–28. For the geology, the Geological Map of the Sudan, compiled and published in 2004 by the Geological Research Authority of the Sudan, was consulted. I wish to thank Dietrich and Rosemarie Klemm who drew my attention to this source and who generously provided me with a copy.
300 The Geological Map of the Sudan indicates two small sandstone areas to the north of Sai, close to the Dal Cataract, eastwards of the Nile. But we know nothing about any quarrying activity in this area in Pharaonic times.
301 For an – albeit incomplete – overview of ancient Egyptian sandstone quarries, see Harrell 2016, 31–34.
302 For possible sandstone quarries close to Buhen, see Harrell 2016, 33.

sandstone quarries than the ones on Sai Island might have existed not far from the southern end of the Batn el-Haggar, still unknown to us.[303] Those quarries might have been denoted with the more general toponym *Tꜣ-Stj* because there was no settlement of any importance nearby like on Sai.

An observation made by the Lepsius expedition in the temple at Kumma back in the early 1840s gives a hint that two different variants of sandstone were used: "Von gelbem Sandstein sind die Eingangspfosten und Säulen und Pfeiler des Vorhofes, die erste folgende lange Wand, von der nächsten langen die eingebauten Pfeiler und der Architrav darüber, sowie die Tür rechts von der Pfeilerwand; ferner der Architrav über der einzelnen Säule und die Deckplatten darauf, ferner die übrigen großen Deckplatten. Alles übrige ist von grauem Sandstein; jener, der weiße oder gelbe, aus dem auch der alte Teil des Semnetempels gebaut ist, heißt von *Tꜣ-Stj*, der graue von *Šꜣꜥ.t*."[304] Thus, Lepsius had combined the archaeological observation of two different variants of sandstone in the temple building with the inscriptions that mention *Šꜣꜥ.t* once in hall C (Thutmose III) and four times in room F (Amenhotep II) and *Tꜣ-Stj* once at another wall in hall C (Thutmose III). Since the building history of the early 18th Dynasty temple at Kumma is a very complex one,[305] it might very well be the case that the stones used were extracted from different sites, i.e. from a quarry located in *Tꜣ-Stj* as well as from a quarry on Sai Island.

The petrographic investigation of samples to be taken from various parts of the temple at Kumma and from the one at Semna and their comparative analysis with samples from the quarries on Sai Island (see Chapter 2.3) might help in acquiring more information about the use of the "fine white stone from Sai" in the future.

2.5 Harbour/landing place of the New Kingdom town[306]

by Julia Budka

As was mentioned throughout Chapter 2.2, the question of the harbour/landing place for the New Kingdom town of Sai was one of the foci of AcrossBorders' geoarchaeological research. This aspect is crucial for addressing the strategic position and function of the site during the so-called "re-conquest of Kush".[307] If we consider Sai as one of the most important administrative centres of 18th Dynasty Upper Nubia (see Chapter 7), a landing place and/or harbour seems mandatory to fulfil the respective needs.

The state of research on harbours of New Kingdom temple towns in Nubia is quite limited.[308] Some of the earlier Nubian Middle Kingdom fortresses have direct access to the waterline due to their location on the riverbank and were labelled as "Flusshafenfestung" by Carola Vogel.[309] In these cases, the access is provided by lateral walls of the fortresses that extend into the river, forming a harbour enclosure. These walls are made of quarry stone, can be up to 5m thick, may be equipped with pillars and protrude up to 12m deep into the river.[310] The fort wall facing the river often includes an offshore platform to which the ships could land.[311] Since the New Kingdom towns differ in terms of enclosure and defensive structures quite considerably from the Middle Kingdom fortresses, it comes as no surprise that there are

303 The sandstone quarries of the 18th Dynasty detected nearby Sesebi in recent years (Spence et al. 2009, 44) are located too far southward in my opinion and the same applies to sandstone from the area of Soleb, which was used in the temple there in the reign of Amenhotep III.

304 Lepsius 1913, 217.

305 Caminos 1998b, 1–4; Azim and Carlotti 2012, 44.

306 Based on the reports by Erich Draganits, Sayantani Neogi and Sean Taylor, see also above, Chapter 2.2.

307 Cf. Budka 2015b with further references.

308 See, however, the work on Middle Kingdom Nubian fortresses including the question of the harbour at Kerma by Manzo 2017.

309 Vogel 2004, 151.

310 Best illustrated by the example of Aniba, see Vogel 2004, 220–221 ("Phase III Hafen"). For the fortress of Mirgissa, see Azim and Gratien 2016.

311 Vogel 2004, 220–221.

no comparable massive quay walls or platforms preserved for the town of Sai.[312] However, some kind of landing place must be assumed for this New Kingdom town which is located directly at a cliff above the Nile. In general, natural landing bays are archaeologically hard to grasp, since they usually have no architectural buildings and did not result in manmade modifications of the shore. In the following, the most likely location for such a landing place for Sai will be discussed.

2.5.1 Sandstone cliff at the northeastern corner of the town

The first possibility, in this case also with some manmade modifications in the topography, is the sandstone cliff at the northeastern corner of the town. As was mentioned above (Chapter 1.2), a rock inscription of Thutmose I was documented by James Henry Breasted "on a huge piece of the cliff which had fallen out of the east face of the rocks north of the fortress, and now lies close to the river on the east shore of the island."[313] Such a royal inscription would of course make much sense at the landing place of a royal foundation like Sai. Unfortunately, the Thutmose I inscription has not been re-located since Breasted – but its former location along the cliff which showed some toppling failures (see Chapter 2.2.1) just northeast of the town is very likely.

Although the Pharaonic rock inscription which might have marked a landing bay is, therefore, lost and must remain unclear, there are other arguments for such a function of the steep cliff at the northeastern corner of the New Kingdom town. This place, site 8-B-522 according to the nomenclature by Friedrich Wilhelm Hinkel, clearly functioned as mooring area in Christian times, as is well-attested by medieval graffiti and mooring rings carved out of the rock for tying ships' ropes at a very high level of the cliff.[314] This usage might go back as early as the New Kingdom.[315] A Pharaonic landing place at 8-B-522, presumably at a lower level than the Christian one,[316] is therefore likely, with the eastern perimeter wall of the town located further towards the west (see Chapter 3.5). Details about the precise form of access from this landing place to the town must, however, remain unclear at the present state of research.

2.5.2 Along the east side/northeast of Temple A

The second possibility for a landing place at New Kingdom Sai is the broad Nile terrace east of the Pharaonic site, between the sandstone cliff in the north and the Ottoman fortress in the south. Of particular relevance to investigate whether any traces of a harbour or landing bay had been preserved in the Nile sediments just east of the town was a coring survey in transect undertaken by Neogi in this riverine alluvial platform during the field season of 2015 (Chapter 2.2.2). The survey did not reveal the presence of any potential built harbour but based on the topography it seems likely that a simple landing ground sheltered by the steep sandstone cliff was in operation, similar to those seen along the Nile today. Towards the end point of this coring, directly adjacent to the sandstone cliff in the platform, Profile 15 was observed (20°44'13.959495587478"N, 30°19'56.736878240482"E) and two blocks for soil micromorphology were collected, the descriptions of which are given below.[317]

312 For the New Kingdom, a massive quay construction is, for example, known for the temple of Soleb (Arnold 1992, 73–75; Arnold 1994, 240). This example follows the assumption by Schenkel 1977, 927 that harbours and quays are always necessary when sites and temples are not located directly at the river.
313 Breasted 1908, 100.
314 Hafsaas-Tsakos and Tsakos 2012, 85–87.
315 Budka 2017c, 71.
316 The Christian graffiti are commemorating "exceptional high waters of the Nile" (Hafsaas-Tsakos and Tsakos 2012, 86, with further references).
317 Based on the report by Sayantani Neogi and Sean Taylor; Neogi and Taylor 2015.

Sample 15 (East Section/1) (~385–395cm)

Description
Micromorphological observation (Pl. 36) has revealed the whole fabric to be very well-sorted. It is composed of homogenous fine material, i.e. sandy loam (c/f_{50}μ*m* ratio: 25:75) with low porosity (10–15%). The apedal fabric show very weakly developed channel microstructure. There are some sedimentary crusts towards the top and bottom of the thin section. The crusts are highly organic. Embedded in the groundmass are silt-sized minerals, mainly quartz and mica. The whole fabric has abundant highly humified organic matter, especially towards the top of the thin section, whereas it becomes sandier towards the bottom. Excremental pedofeatures are more common with channels infilled with the aggregates of groundmass material.

Interpretation
This thin section represents a well-sorted fluvial sedimentary deposit. Fragments of sedimentary crust have been eroded, transported and deposited at this location and are perhaps indicative of de-vegetated ground surface. At the top and bottom of the thin section intact sedimentary crusts are observed which indicate episodes of deposition of fine material. Elsewhere well-sorted sand and silts dominate, indicating that at times slightly coarser particles are transported and deposited, probably due to increased seasonal discharge of the river. The relative lack of voids and compact nature of this sediment suggests an unstable environment with very little opportunity for vegetation to become established.

Sample 15 (South Section/1) (~395–400cm)

Description
Microscopic observation (Pl. 37) reveals this sample to be more or less similar to Sample 15 (East Section/1), except it contains unsorted allochthones fragments of sedimentary structures within the groundmass, making things a bit more complicated. The sandy loam fine material is even less porous.

Interpretation
This is clearly sedimentary in nature. The fragments of crusts have themselves been eroded and transported from a sedimentary environment.

All in all, the alluvial platform sheltered by the sandstone cliffs and being located closely to the main stone temple of the New Kingdom town and its large magazine sector could very well have been used as a simple landing place for Pharaonic ships.

2.5.3 South of the Ottoman fortress/New Kingdom town

The third possibility for a landing place of New Kingdom Sai derives from descriptions by early scholars (see Chapter 1.2). Budge describes his arrival at the site as follows: “We found a convenient place on the bank and landed, and then climbed up a steep, rough path to the remains of what is called the “Castle of Sâî.”[318] Since this account is not perfectly detailed, it opens up two possibilities: 1) Budge and his consorts landed in the riverine bank east of the town described above; 2) they landed just at the base of the Ottoman fortress, accessing the site from the south. The latter seems more likely when considering the local topography – whereas it is indeed “steep and rough” to climb the site from the south, it is by no means “steep” when arriving from below Temple A, accessing the town and fortress from the eastern side. In addition, one can mention the southern gate of the New Kingdom town in favour of the second possibility.[319] This gate is a simple doorway located to the south of the so-called governors’ residence

[318] Budge 1907, 461.
[319] Adenstedt 2016, 25.

and its simplicity compares well to similar doors through enclosure walls in Middle Kingdom fortresses. These gateways in the fortresses are interestingly always connected with stairways towards the river.[320] An analogous setting is imaginable for the southern entrance into the New Kingdom town of Sai, even if no ancient walkway towards the river has so far been discovered and is presumably covered by Ottoman remains.[321] However, a stairway up towards the fortified town seems rather unsuitable to represent the main access from the river and the central landing place of the site.

2.5.4 Conclusive remarks

As was outlined in this chapter, no built harbour architecture could be found on Sai. One should rather consider natural landing places for which three possible candidates were discussed. The sandstone cliffs with mooring rings from presumably Christian times are a very likely possibility, but this also applies to the flat alluvial platform along the town's east side. Parallels from Middle Kingdom fortresses would also support an access from the southern side, which is, however, unlikely to represent the main entrance from the river.

The discovery by Draganits of two stones (Pl. 5) which resemble Bronze Age stone anchors in general[322] and in particular the Middle Kingdom anchors from Mirgissa[323] seems significant in this respect. One of the stones was found northeast of Temple A and thus very close to the broad Nile terrace sheltered by the sandstone cliff. The other stone was documented south of the Ottoman fortress. Thus, these anchor stones[324] may support the concluding assumption that more than one area along the eastern shore had been used as landing bays during the New Kingdom on Sai.

2.6 Placing the New Kingdom Town into the wider landscape of Sai

by Julia Budka

Beyond doubt, the prominent island of Sai lies in a strategic position along the Nile. For several empires, it had been a stronghold and a border region, e.g. the Kerma Kingdom, the Egyptian New Kingdom and the Ottoman Empire.[325] Field surveys in the years 2014, 2015 and 2016 on Sai Island primarily aimed at gathering data with which to understand human-landscape relations.[326] The objectives were specifically focused on questions relating to the New Kingdom occupation. These were to place the archaeological site in its environmental context, to understand the nature of any surface preparation prior to the establishment of the settlement. In order to achieve these objectives, a series of test pits, hand auger profiles as well as a reconnaissance of geological exposures, sections and quarry pits were carried out by the AcrossBorders' geoarchaeologists. As one of the main results, a surface map of the vicinity of the town was created in 2016 (Pl. 13). Besides the lithic specification of the geology of the island, a differentiation in old Nile sediments from the Pleistocene and much younger sediments forming the terraces of Sai was possible (see below).

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320 See Vogel 2004, 125 (citing the examples of Semna-West, Kumma and Quban); Vogel 2010, 428.
321 See Budka 2018a, 264.
322 Wachsmann 1998; see also Wachsmann 2000.
323 See Vila 1970, 188–189, pls. 14a, b; Manzo 2017, 84, fig. 6.7.
324 For anchors in Egypt, see Nibbi 2002; Zazzaro and Abdelmaguid 2016. To the best of my knowledge, the only Egyptian site in Sudan from where anchor stones have been reported is Mirgissa, see Manzo 2017, 84 (the function of the 22 stones found in the northern part of the fortress was still questioned by the excavator, see Vila 1970, 188–189). For some possible anchors/weights as well as large tethering stones from the AcrossBorders excavations on Sai, see Chapter 4.4.2.
325 For its role as most southern fortress of the Ottoman Empire cf. Alexander 1997. See also Elzein 2009.
326 Cf. Goldberg and Macphail 2006.

It became very clear that today's northern part of the island with predominately Christian remains was not part of the island's outlines in New Kingdom times.[327] During the heyday of Egyptian activity on the island, Sai was thus smaller. Its shape can be estimated towards the north by means of the palaeochannel which is still visible as depression nowadays. Furthermore, the inundation modelling for Amara West and its surroundings illustrates outlines for Sai which correspond to our assumptions.[328]

The fortified Egyptian town was built for several reasons on the eastern bank of the large island of Sai in the New Kingdom. This was probably the perfect place on the island from a strategic perspective, especially for controlling river traffic and to facilitate the landing and loading of ships (Chapter 2.5). The northeastern part of the town steeply drops off towards the Nile, in some areas with a height difference of about 8m. The sandstone cliff here was also used for quarrying purposes. One may, therefore, conclude the following three aspects for the specific location of the New Kingdom town: 1) quarry for building stones; 2) fortification aspect/protection from the Nile and 3) perfect mooring area/landing place for ships. The controlling aspect of river traffic is included in both 2) and 3).

One may stress that the stronger focus on a strategic position and the lesser need for facilities for agricultural purposes of the New Kingdom town is very similar to the Ottoman fortress. It furthermore differs considerably from the situation of the Neolithic and Kerma settlements. Other than these indigenous Nubian cultures, the Egyptians combined their strategic placement of a new fortified town on Sai with the exploitation of sandstone for their religious buildings. In addition, Egyptian tombs of the New Kingdom were typically dug into the bedrock and comprise a subterranean part with several chambers and a large shaft. Within the geology of Sai, such tombs therefore required sandstone outcrops and differ in this respect from Kerma tumuli set in the alluvium. The position of the large elite cemetery SAC5, where the pyramid tombs contemporaneous to the town were erected, is, therefore, another argument that the Egyptians were consciously placing their new sites along the eastern side of the island where both access to the river and suitable building material/building ground were available.

Whereas the advantages for the location of both the town and the Egyptian cemeteries along the sandstone cliffs/outcrops of Sai seemed quite straightforward, one of the other objectives of AcrossBorders' geoarchaeological research has been a deeper understanding of the nature of the land surface before the town was built and possible additional motives behind the placement of the site. In order to answer these questions, geoarchaeological samples were taken (see Chapter 2.3).

The micromorphological observations of the soil blocks collected from different depths of the soil profiles showed that the New Kingdom town at Sai Island was constructed on surficial drift geology. This comprised ancient alluvium and former Nile terraces of several hundred thousand years ago. An important question to address was whether the nature of the land surface had influenced the choice for the location. There certainly is a suite of other factors which are of more significance for the location of the site. These include the proximity to the river, the topographical properties of the site and the significance of the town on the island of Sai for resources.[329] However, it is likely to presume that the local geology had some influence on the choice of the site. The micromorphological investigations of the alluvium on and to the west of the site show that this material has significantly different properties to the modern sediments that are associated with ongoing geomorphological processes of the river Nile. Because they were formed during the Pleistocene, they have been subjected to soil forming processes during the early Holocene.[330] It is known that during this period it was significantly more humid. The increase in the content of organic matter and the development of channel microstructures indicate more moisture to the soil system. Any CaCO3 in the system would have been leached to lower parts of the subsoil. This is precisely what was observed with the re-deposition of CaCO3 at significant depths in the profiles on Sai. In addition, the ubiquitous presence of iron hydroxide features is also closely linked to alternating wetting and drying through fluctuations in the water table. It is in these conditions that

[327] For the Christian sites on the island see Tsakos and Hafsaas-Tsakos 2014, 986, fig. 1.
[328] Woodward et al. 2017, 232, fig. 6.
[329] Budka 2015a, 40–53. See also below, Chapter 7.
[330] Woodward et al. 2016.

secondary clays develop through weathering.[331] During the mid-Holocene Northeast Africa was affected by severe drying.[332] This can be perceived on Sai by the increase in CaCO3 due to the soil water balance tipping in favour of evapotranspiration. The surveys of the AcrossBorders project have revealed that many of the archaeological sections/trenches left open by the French excavators at Kerma, Meroitic and Post-Meroitic sites, located within the alluvium, show soil profiles with calcic properties.[333] These two properties, a relatively enhanced clay content due to the effects of moist conditions during the early Holocene and at the same time a much higher content of CaCO3, differentiates these soils from the more recent silts associated with Nile over-bank flooding.

The augering transect with six boreholes immediately to the west of the town wall, just outside of sector SAV1 West, revealed a sand-filled depression of at least 3.4m in depth (see Chapter 2.2.3). The general survey of Sai Island indicates that the bedrock geology for this depression to the west of the New Kingdom town is the palaeo-alluvium. The first impression for the topographical feature was thought to be a *wadi* but it is now likely to be the source of raw material for the mud bricks used for the architecture of the town. The extraction of this material would have created a ditch which enhanced the strategic capabilities of the wall itself. A ditch in front of the western town wall was already observed by Azim at the main gate.[334] The special properties of the alluvium would have been excellent for the production of mud brick (cf. Chapter 5.1.7.2). The presence of CaCO3 in the mud bricks would have significantly improved their strength. The higher clay content would also have improved the cohesion and working properties during the manufacturing process. However, no contemporaneous parallel for building a ditch in front of an enclosure wall of a New Kingdom temple town to use the extracted material as building material for the bricks are known, and this interpretation must remain tentative for now.[335] It is, however, possible that this palaeo-alluvium plain below the western edge of the New Kingdom town was another aspect which motivated its precise location on Sai Island.

331 Jenny 1980.

332 Jung et al. 2004.

333 W.R.B. 2014.

334 Azim 1975, 120–122. See also Adenstedt 2018.

335 Adenstedt 2018, 139 presents two ancient literary sources after Fields 2004, 31. According to Herodotus 1.179 the Babylonians fashioned bricks for their city wall ‘out of the earth which was thrown out of the fosse’ and Thucydides 2.78.1 notes that the Peloponnesians built a wall around Plataia, using ditches they dug outside the enclosure as source for the clay for the bricks.