Research Article

Resurrecting the Archive

Revitalising records of Hogarth's excavations in the Gebel Asyut el-Gharbi necropolis, Egypt 1906–1907.

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Abstract

Inaccurate sketch maps from historic excavations may be the only source for the physical location and archaeological context of hundreds of archaeological features and objects. David George Hogarth's (1862–1927) sketch map of his excavations for the British Museum in 1906–1907 is the only map of early 20th century excavations in the north of the ancient Egyptian necropolis of Asyut. Flawed in many ways, these excavations have largely defied reidentification or spatial analysis. In this paper, GIS-based georeferencing is combined with the excavation records in the British Museum archive, a high-resolution satellite image of the site, and archaeological evidence to re-contextualise these excavations. This process revealed new aspects of Hogarth's excavation methods and improved the positioning of the tombs recorded in the sketch map. The results are significant for further analysis of the documented tombs, including those not recorded in the sketch map. Better contextualising Hogarth's excavations in relation to the topography of the Gebel Asyut el-Gharbi necropolis will revolutionise understanding of this now largely destroyed and otherwise poorly documented site, potentially allowing more tombs to be relocated. The combination of GIS, satellite remote sensing, documentary, and archaeological evidence represents a method for revitalising excavation archives of variable quality. It has considerable potential for future research under both the archaeological science and digital humanities umbrellas.

Keywords: geographic information systems (GIS), Asyut, Hogarth's excavations, georeferencing, archaeological archives, historic maps

إعادة إحياء الأرشيف: إحياء سجلات حفائر هوجارث في جبانة جبل أسيوط الغربي، مصر 1906–1907

الملخص

تعتبر الخرائط المرسومة التي اتسمت بكونها غير دقيقة المعدة من قبل الحفائر الأثرية المصدر الوحيد للمعلومات حول الموقع الفعلي والسياق الأثري لمئات المعالم والقطع الأثرية إذ تعد الخريطة التي رسمها ديفيد جورج هوجارث (1862–1927) خلال حفائره التي قام بها للمتحف البريطاني في عامي 1906 و1907 هي الخريطة الوحيدة المتاحة لعمليات التنقيب التي تمت في أوائل القرن العشرين في المنطقة الشمالية من الجبانة المصرية القديمة بأسيوط يشوب هذه الحفائر العديد من العيوب، خاصة أن إعادة تحديد موقعها أو تحليلها المكاني يشكل صعوبة كبيرة. لذا، تقدم هذه الورقة نهجا يجمع بين الإسناد الجغرافي القائم على نظام الجغرافيا المعلوماتية (GIS) مع سجلات الحفائر المحفوظة في أرشيف المتحف البريطاني، بالإضافة إلى صورة عالية الدقة لقطت للموقع بواسطة القمر الصناعي، وإلي جانب كل ذلك يجمع أيضا الأدلة الأثرية، وذلك بهدف إعادة تحديد سياق هذه الحفائر. وقد نجح هذا النهج المستخدم في الكشف عن جوانب جديدة لأساليب التنقيب التي اتبعها هوجارث، وكذلك نجح في التحسين من عملية تحديد موقع المقابر المسجلة علي الخرائط المرسومة. لدي تلك النتائج التي تم التوصل إليها أهمية كبيرة حيث إنها تتيح فرصة إجراء المزيد من التحاليل للمقابر التي تم توثيقها، بما في ذلك تلك التي لم يتم تسجيلها في خريطة

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المرسومة. حيث إن العمل على صياغة سياق أفضل لحفائر هوجارث ومقارنتها بطبوغرافية جبانة جبل أسيوط الغربي، سيؤدي إلى إحداث طفرة في فهم هذا الموقع الذي تعرض الآن للدمار إلى حد كبير والذي لم يتم توثيقه بشكل جيد في السابق، خاصة أن ذلك قد يتيح فرصة إعادة تحديد موقع المزيد من المقابر. إلي جانب كل ذلك يمثل الجمع بين نظم المعلومات الجغرافية والاستشعار عن بعد بالأقمار الصناعية وكذلك الأدلة الوثائقية والأثرية طريقة لإعادة تنشيط أرشيفات الحفائر ذات الجودة المختلفة. حيث إن هذه الطريقة تتمتع بإمكانات واعدة للأبحاث المستقبلية تحت مظلتي علم الآثار والعلوم الإنسانية الرقمية.

الكلمات الدالة: نظم المعلومات الجغرافية (GIS)، أسيوط، حفائر هوجارث، الإسناد الجغرافي، الأرشيفات الأثرية، الخرائط التاريخية.

1 Introduction

Integrating historic maps and excavation plans with other cartographic and archaeological survey data is important for locating historic excavations and contextualising extant artefacts, but this is not always straightforward. Egypt has been mapped since ancient times (El-Daly, 2005: 144, fig. 2; Haguet, 2018; Harrell, 2005; Harrell & Brown, 1992; O'Connor, 2014: 59–67) and over 200 years of excavations (Godlewska, 1988; Thompson, 2015: 96–108) have produced hundreds of maps and plans of varying accuracy and precision. Many maps can be related to other data through georeferencing in geographic information systems (GIS)(Bitelli, 1997; Carlucci, 2003; Chyla, 2012: 9; Chyla, 2017; Elfadaly et al., 2019: 6; Hinojosa Baliño, 2019; Stopková, 2018; Subias et al., 2013: 29–30; Trampier, 2014: 57–87; Ullmann et al., 2019: 187; Willems et al., 2017: 255–343; Wilson, 2016: 48–49). Some maps prove difficult to georeference (Subias et al., 2013: 29). Cartographic and other errors (Willems et al., 2017: 266) can make it impossible to relate historic maps to the current physical topography. Flawed and inaccurate sketch maps may be the only source for the physical location and archaeological context of hundreds of archaeological features and thousands of objects.

This paper demonstrates the potential of a flawed historic sketch map of Hogarth's excavations in the Gebel Asyut el-Gharbi necropolis in 1906–1907 (Hogarth, 1907a). The sketch map was georeferenced with high-resolution satellite imagery and published archaeological surveys. Evidence from unpublished archival records proved key in relating the sketch to the current landscape and revealing historic excavation methods. This research suggests that combining GIS, documentary and archaeological evidence is significant in re-contextualising historic maps whose value is inhibited by their poor quality.

1.1 Excavations in the Necropolis of Gebel Asyut el-Gharbi

The Gebel Asyut el-Gharbi necropolis served the ancient city of Asyut on the west bank of the Nile in Middle Egypt (Figure 1). Asyut was an important regional centre, which played a significant role during the First Intermediate Period and Middle Kingdom (El-Khadragy, 2012; Kahl, 2012a: 77–8; Kahl, 2012b: 4–5; Richards, 2005: 1–9, 52–58). In the absence of evidence from the town, the necropolis remains the only viable source of evidence for the political, social, and cultural dynamics at this important place.

Archaeological interest in the Gebel Asyut el-Gharbi is attested since the 4th century CE, but late 19th and early 20th century excavations were mostly poorly undertaken, badly recorded, and unpublished (Kahl, 2012a: 21–9). The ongoing 'Ancient Egyptian necropolis of Asyut: documentation and interpretation project' (hereafter 'The Asyut Project') provides new, well excavated, and detailed evidence (Kahl, 2012b: 6–11), but it is difficult to relate to the scant records of historic 19th and 20th century excavations (Kahl, 2012a: 27–9).

The north-western part of the necropolis is particularly poorly documented and badly damaged by looting, quarrying, and historic excavations (Kahl, 2012b: 6–7; Zitman, 2010b: 49–51). The only cartographic record of early 20th century activity in this area is a sketch map of 42 numbered tombs and various unsuccessful trials (Figure 2) made by David George Hogarth, director of the British Museum's excavations on the site between

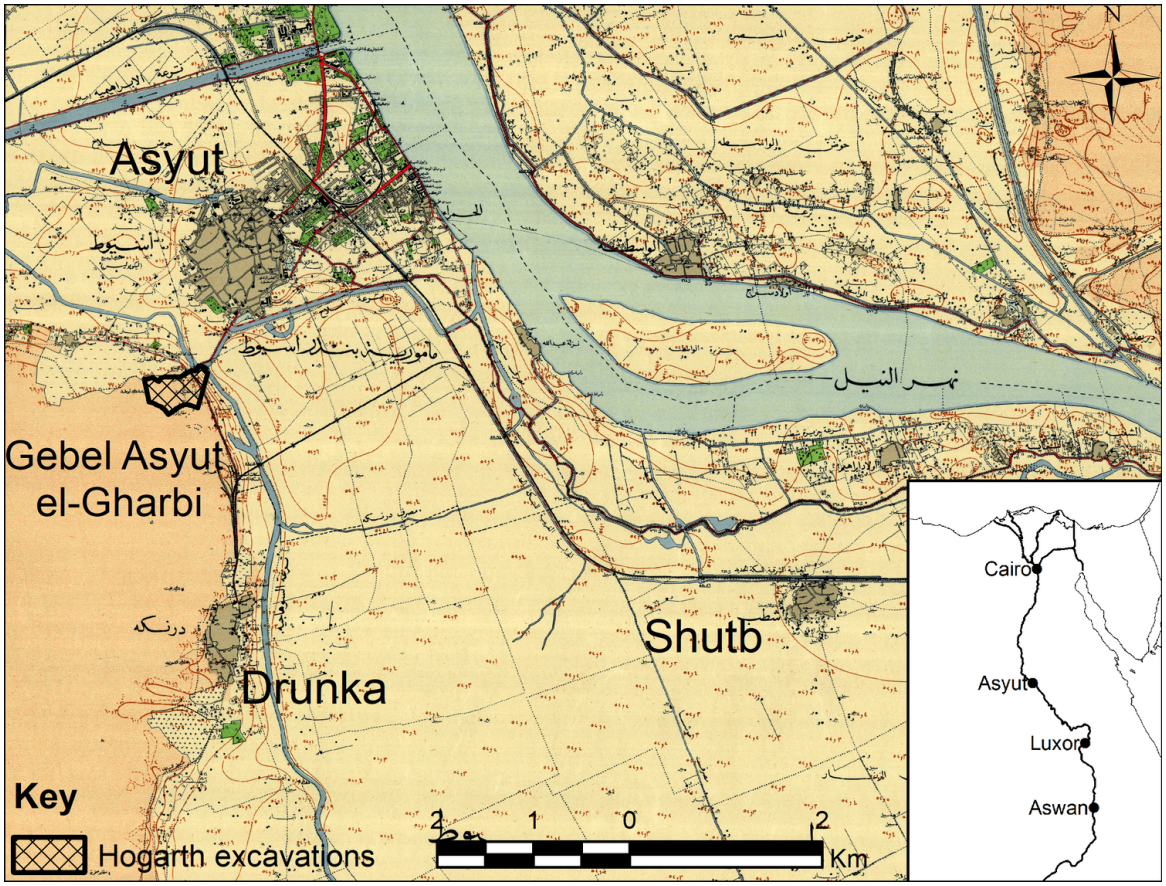

Fig. 1: The location of the Gebel Asyut el-Gharbi in Middle Egypt. (British War Office Survey of Egypt 1:25000 scale map of Asyut, from the Center for Ancient Middle Eastern Landscapes (CAMEL), Institute for the Study of Ancient Cultures, University of Chicago).

December 1906 and March 1907 (ZITMAN, 2010b: 49). The Museum retains *c.*564 artefacts allotted to them by the *Service des Antiquités*, and the unpublished fieldwork archive.

Hogarth never published his excavations, but the archive includes his unpublished excavation report (HOGARTH, 1907e) as an unfinished document of 15 pages (hereafter 'the report'). A notebook (HOGARTH, 1907b) entitled 'Assiut Tombs 1906–7', lists the 57 numbered tombs together with descriptions of each tomb and plans of many (hereafter 'the notebook'). The 'Register of Objects of Assiut 1906–7' (HOGARTH, 1907d) lists the artefacts found in each numbered tomb and the accession numbers of those allotted to the British Museum (hereafter 'the object register'). The object register also contains some limited additional information about the tombs. The sketch map entitled 'Assiut Sketch of the Gebel' (HOGARTH, 1907a) was sent to the British Museum enclosed in a letter dated 13 February 1907 and was found pasted into the correspondence book in the British Museum archive (hereafter 'the sketch map'). Drawn upside down, with north at the bottom, it shows 42 of the 57 numbered tombs within the British Museum concession, overlaid on an approximation of the topography of the Gebel el-Gharbi (Figure 2). The concession is represented as a dotted line. The 42 numbered tombs and other archaeological features are shown as labelled points, while 'unsuccessful trials' are marked by crosses. Hogarth's diary for 1907 (HOGARTH, 1907c) discusses the daily progress of the excavation, together with some personal and social details (hereafter 'the diary'). These documents comprise the excavation archive and contain the only contextual information for the objects excavated in 1906–1907.

Others have attempted to reconstruct a coherent record from Hogarth's artefacts and archive. RYAN (1988) discussed the report and described the numbered tombs and their artefacts. He questioned the accuracy of

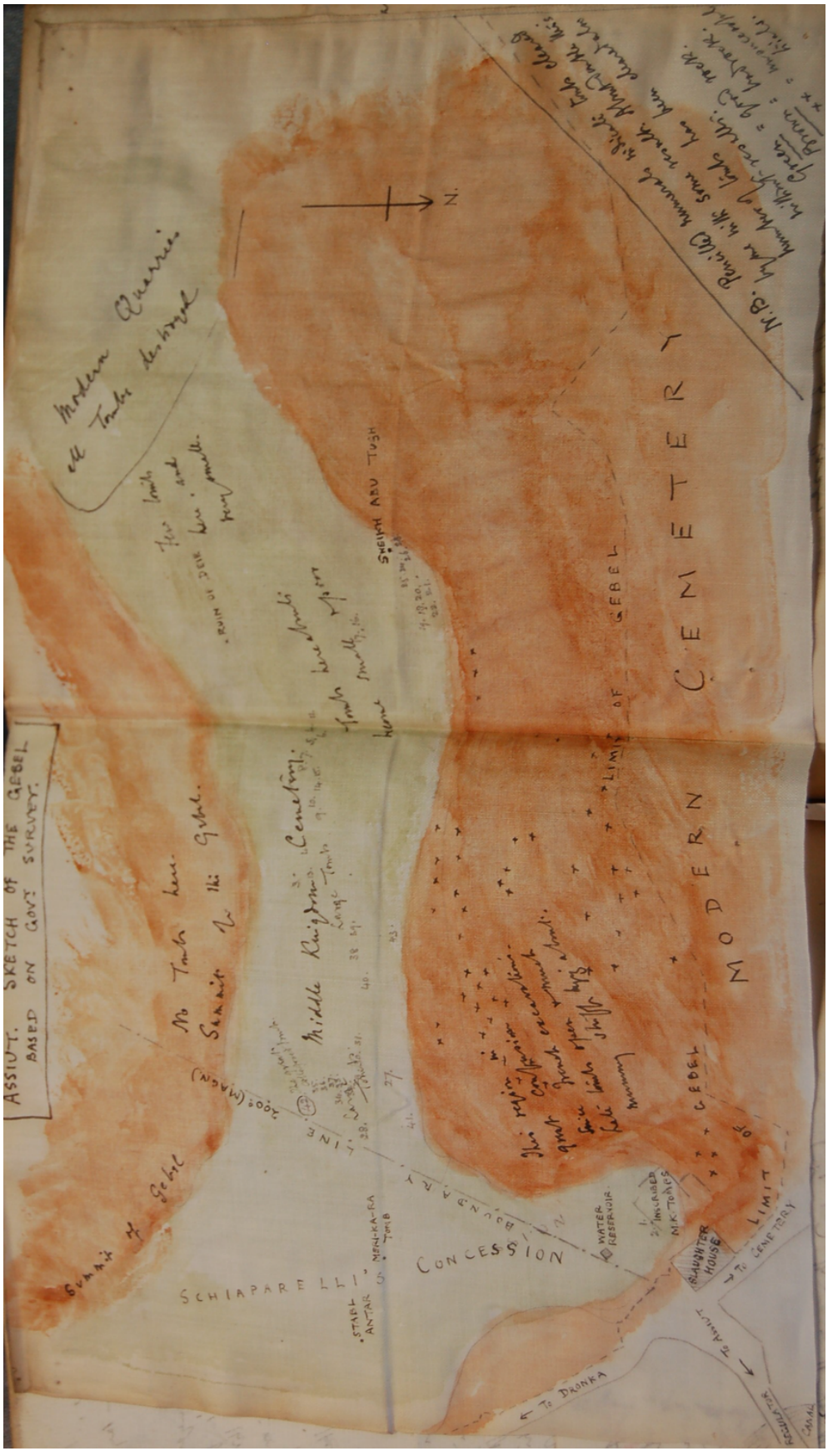

Fig. 2: The sketch map of Hogarth's excavations at the Gebel Asyut el-Gharbi. British Museum Dept of Egyptian and Assyrian Antiquities, Correspondence 1907 A-K, 321 (© The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence).

the sketch map but did not address the topographical context or spatial distribution of the tombs (RYAN, 1988: 3), drawing criticism from ZITMAN (2010b: 54). Zitman dated and listed the extant artefacts by tomb (ZITMAN, 2010a; ZITMAN, 2010b), reproduced the sketch map (ZITMAN, 2010b: 54; ZITMAN, 2010a: map 1), and proposed positions for the missing tombs (ZITMAN, 2010a: map 3, map 4). He did not attempt to georeference the sketch map or relate it to the extant physical topography, and this author found his maps impossible to georeference because of their inconsistent scales and representation of the terrain. Nevertheless, this research has demonstrated the accuracy of many of Zitman's conclusions, particularly in terms of the relative positions of the tombs.

Some of the tombs on the sketch map have been relocated. Hogarth's tombs 1 and 2 have long been identified with two of those leading off the courtyard of Middle Kingdom nomarch Djefahapy III's tomb (ZITMAN, 2010b: 322–4), which is also known as the 'Salakhana tomb' (DUQUESNE, 2009: 17). The Asyut Project (KAHL et al., 2018: 145–51) located Hogarth's tomb 3, the tomb of Mesehti (ZITMAN, 2010b: 17), tomb 42 (KAHL et al., 2006: 246), and possibly tomb 27 (KAHL et al., 2007: 84; PALANQUE, 1903: 119–21; ZITMAN, 2010b: 40–2; ZITMAN, 2010a: 6, map 3). Most of Hogarth's excavations have largely defied attempts at location or detailed analysis of their spatial distribution.

Locating the tombs on the sketch map in relation to the extant topography offers the only hope for understanding tomb distribution, providing an improved context for surviving artefacts, and relocating tombs on the ground. This research represents an attempt at relating Hogarth's sketch map and archival records to the physical topography of Gebel Asyut el-Gharbi as represented by a high-resolution satellite image. It builds upon Zitman's archival research (ZITMAN, 2010a; ZITMAN, 2010b), and the Asyut Project's published archaeological surveys, to revise and improve the cartographic positions of the tombs shown on the sketch map. It should be noted that, until further tombs can be re-located on ground, the tomb positions suggested in the maps and tables in this paper represent a revised hypothesis of tomb distribution, awaiting confirmation through archaeological fieldwork. Tomb positions should be treated as approximate since the errors in the sketch map and the vagueness of the written record are likely to render the suggested coordinates imprecise. Nevertheless, this research has revealed various important aspects of Hogarth's excavation methods (PETHEN, 2021: 232; ZITMAN, 2010b: 55) and produced a working hypothesis for how Hogarth's excavation archive is related to the extant physical topography. Re-contextualising the excavation archive through such archival research and future archaeological investigation will reveal further evidence for the history, society and culture of Asyut.

2 Methods and materials

A table of technical terms can be found after the conclusion (Table 5). It is provided as a quick reference, rather than an exhaustive discussion and focuses on how these terms relate to this research. More information on the technical terms and their usage can be found from the in-text references and the additional sources supplied in the table.

2.1 Materials

The sketch map was georeferenced in the ESRI ArcMap 10.6 GIS (CONOLLY & LAKE, 2006: 17–24, 72–83; PARCAK, 2009: 88–90; ZAKRZEWSKI et al., 2016: 53–4) using a base map created from pan-sharpened, orthorectified Worldview-3 satellite imagery. Two high-resolution 'ortho-ready' Worldview-3 satellite images were purchased from European Space Imaging. Image 10400100366C2E00 from 30 December 2017 covered the Nile valley and the modern town of Shutb, with a resolution of 0.37 m in the panchromatic band and 1.48 m in the multi-spectral bands. Image 104001003563DE00 from 28 October 2017 covers the Gebel Asyut el-Gharbi with a resolution of 0.32 m in the panchromatic band and 1.28 m in the multi-spectral bands. The 'ortho-ready' imagery required pan-sharpening and orthorectification to produce the best possible base mapping for

georeferencing.

This project also used the Asyut Project's published maps (Kahl, 2012b: pl. 14, pl. 16–9; Kahl et al., 2008: 208, fig. 1; Kahl et al., 2018: 138, fig. 1), which include crucial information for georeferencing the sketch map.

2.2 Methods

The method was divided into four components: Preparing the high-resolution satellite imagery by pan-sharpening and orthorectification (section Section 2.2.1 and Section 2.2.2); georeferencing the Asyut Project's published maps (Section 2.3.1) and the sketch map (Section 2.3.2); digitising the locations of Hogarth's numbered tombs from the georeferenced sketch map and comparing them with verbal descriptions in the notebook and diary (Section 2.4).

2.2.1 Pan-sharpening

'Pan-sharpening' the Worldview-3 data produced an image with the higher resolution of the panchromatic band and the spectral data of the lower resolution multi-spectral bands (Esri, n.d.). It was undertaken through the Image Analysis window of ArcMap (Esri, 2021c) using the Gram-Schmidt method, with 'Sensor' set to 'Worldview-3'. Pan-sharpening image 104001003563DE00 of the Gebel Asyut el-Gharbi produced a 0.3 m resolution, pan-sharpened, three band, true colour (RGB-532) image, reflecting the visible landscape, where each pixel represents 0.3 m on the ground.

2.2.2 Orthorectification

Orthorectification removes sensor distortions and improves the planimetric accuracy of the satellite image (Esri, 2021b) using a digital terrain model (DTM) containing height data at specified ground-distance intervals (Carlucci, 2003: 236–58; Carrara et al., 1997; Chapman, 2006: 58–64; Conolly & Lake, 2006: 72, 103–11; Parcak, 2017: 7–12; Zakrzewski et al., 2016: 58–62). I used a 2 m resolution Digital Surface Model (DSM) of the Asyut area, produced by Digitalglobe from a stereo-pair of Worldview-2 satellite images collected on 20 January 2010: Image 1030010003A02700 has a resolution of 0.67 m in the panchromatic band and 2.67 m in the multi-spectral bands; Image 103001000317AF00 has a resolution of 0.57 m in the panchromatic band and 2.29 m in the multi-spectral bands. DSM record the height of the surface, including buildings and other structures (Chapman, 2006: 72–7; Conolly & Lake, 2006: 90–111; Hageman & Bennett, 2000), but as these features are also visible in the Worldview-3 imagery, the DSM provided a suitable terrain model for its orthorectification.

The Worldview-3 satellite imagery was orthorectified using the 'Create Ortho Corrected Raster Dataset' tool of ArcMap (Esri, 2021a). In some areas it shifted by 25 m after orthorectification. Hereafter the pan-sharpened and orthorectified satellite image of the Gebel Asyut el-Gharbi is referred to as the 'Worldview-3 base map', as it formed the base-map for subsequent georeferencing and analysis.

2.3 Georeferencing

All georeferencing took place in the ESRI ArcMap software using the 'Georeferencer toolbar' (Esri, 2021d), and at least four ground control points (GCP) common to both maps. A Root Mean Square Error (RMSE) was calculated in ArcMap, giving a measure of the accuracy (Conolly & Lake, 2006: 82–3).

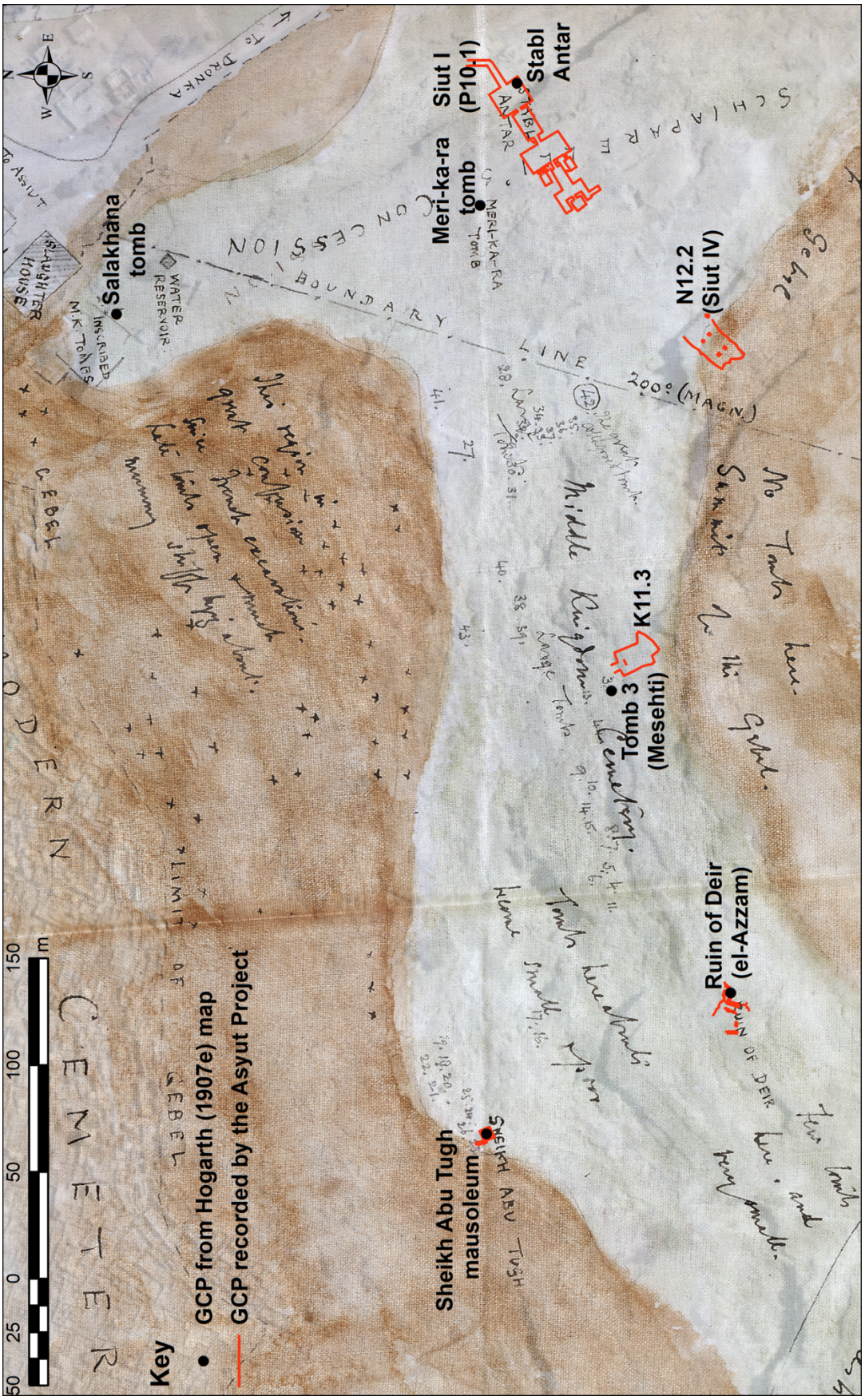

Fig. 3: The sketch map after georeferencing, with GCP from the Asyut Project maps (Sketch map © The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence; Asyut Project features digitised from KAHL (2012b: 16–7) and KAHL et al. (2018: 138, fig 1); underlying Worldview-3 imagery © 2018 Maxar Technologies Provided by European Space Imaging. Reproduced with permission).

2.3.1 Asyut Project Maps

The Asyut Project's maps (Kahl, 2012b: pl. 14, pl. 16–9; Kahl et al., 2008: 208, fig. 1; Kahl et al., 2018: 138, fig. 1) were georeferenced to the Worldview-3 basemap. GCP for georeferencing the Asyut Project's published maps included the mausoleum of Sheikh Abu Tugh (Asyut Project feature F10.1); the mudbrick building E11.1; the two wells in the outcrop in grid squares F13–G13; the Deir el-Meitin (P13.2); the turn of the causeway of tomb Siut I (P10.1); and tomb Siut V (M11.1). The georeferenced map of the Gebel Asyut el-Gharbi necropolis (Kahl et al., 2018: fig. 1) and the detailed maps of sections A and B of the necropolis (Kahl, 2012b: pl. 16–9) were all georeferenced with RMSEs less than the 1:3000 m, indicating a reasonable degree of accuracy (Conolly & Lake, 2006: 82–3).

2.3.2 Hogarth's sketch map of Gebel Asyut el-Gharbi

Hogarth's sketch map was georeferenced (Figure 3) using four GCP: the Sheikh Abu Tugh mausoleum, the Deir el-Azzam (labelled 'Ruin of Deir' in Hogarth's sketch); the Middle Kingdom tombs (Salakhana tomb); and the Stabl Antar/tomb Siut I/Asyut Project number P10.1 (Kahl, 2012a: 88). These GCP appeared in both the sketch map and in either the Asyut Project plans or on the Worldview-3 base map. However, Hogarth's use of points to represent substantial features will reduce the precision of the georeferenced sketch map. Tomb positions and coordinates derived from it will likely be precise to some meters at best and should be considered approximate.

Both Zitman (2010b: 17) and the Asyut Project (Kahl et al., 2007: 85; Kahl, 2012b: 6) suggest that Hogarth's Stabl Antar point is incorrectly labelled, and in fact represents the position of tomb Siut II/O13.1. However, shifting Hogarth's map to position the Stabl Antar point over Siut II/O13.1 resulted in substantial inaccuracies in the rest of the GCP and in the location of tomb 3, the tomb of Mesehti (Zitman, 2010b: 17), which is also known as K11.3 (Kahl et al., 2018: 145–51). When Hogarth's Stabl Antar point is aligned with the Asyut Project's Siut I/P10.1 all the other GCP and tomb 3 are correctly aligned with the Asyut Project maps and the Worldview-3 base map. Only the 'Meri-ka-ra tomb', tomb Siut IV/ N12.1 (Kahl, 2012a: 77–9) of Khety II is misaligned, 113 m north-east of its true location. I conclude that Hogarth's 'Meri-Ka-Ra tomb' is incorrect, while his Stabl Antar point is correctly positioned on tomb Siut I/P10.1 (Figure 3).

2.4 Digitising the tombs marked on Hogarth's sketch map

The 42 tombs on the georeferenced sketch map (Figure 3) were digitised as points in an ArcGIS File Geodatabase (Figure 4). These points were then compared to the Asyut Project maps, the Worldview-3 base map, Zitman's research (Zitman, 2010a; Zitman, 2010b), and the notebook, object register, report and diary to assess the accuracy of the georeferenced sketch map. This comparison confirmed that Zitman was accurate in his assessment and re-positioning of many of the tombs. It also revealed both general and specific errors in Hogarth's sketch map, suggested improved locations for various tombs and tomb groups, and exposed aspects of Hogarth's excavation and recording process.

3 Results

The georeferenced sketch map (Figure 3) had a RMSE of 0.27 m (Table 1), well within the 1:3000 m standard (Conolly & Lake, 2006: 82–3). This is a good result considering that the map is a sketch and was not drawn to scale.

The relatively positive RMSE likely obscures imprecision in the locations of the numbered tombs. This imprecision reflects the representation of both the GCP and the numbered tombs in the sketch map, where all structures are shown as single points irrespective of their size (Figure 3). Given that Hogarth does not indicate

Tab. 1: Georeferenced Maps of Gebel Asyut el-Gharbi, their scale and RMSE. The column 'Ideal RMSE <' gives an RMSE of 1:3000 m for a map of that scale.

Map	Scale	No. of GCP	Ideal RMSE <	Actual RMSE
Kahl (2012b: pl. 16)	1:560	4	0.19	<0.01
Kahl (2012b: pl. 17)	1:750	4	0.25	<0.01
Kahl (2012b: pl. 18)	1:750	4	0.25	0.02
Kahl (2012b: pl. 19)	1:750	4	0.25	0.06
Kahl et al. (2018: fig. 1)	1:2500	4	0.83	0.59
The sketch map	1:1750	4	0.58	0.27

which part of, for example, the Stabl Antar/ Siut I /P10.1 is represented by his point, it is impossible to know where to locate Hogarth's Stabl Antar point on the Asyut Project's plan of the tomb Siut I/P10.1. Similarly, the numbered tombs also vary in size, but are universally represented by single points. Such uncertainty in the precision of the GCP and the tombs represented will produce errors that propagate throughout the georeferenced data. Comparison with the archival records should correct some of these, but still there will be a degree of imprecision.

Table 2 gives the coordinates for the numbered tombs in Figure 4, representing their positions as shown in the sketch map after georeferencing. These coordinates are provided in the Universal Transverse Mercator Coordinate System Zone 36 North (Conolly & Lake, 2006: 20–1) which covers Egypt, is metric, and facilitates easy comparison. Owing to the imprecision in the GCP and because Hogarth presented structures of varying sizes as single points the coordinates given throughout this paper are likely to be quite imprecise and should be treated as approximate. For the same reason, the coordinates are also presented without decimal places.

3.1 Aspects of Hogarth's recording

Zitman (2010b: 52–4) gives a precis of many of the problems with Hogarth's material, but also suggests that 'Hogarth's remarks on the relative position [of tombs and ridges]. . . appear to be reliable' (Zitman, 2010b: 53). He is broadly correct, but only if the reader considers certain idiosyncrasies in Hogarth's recording practices, which affect how his verbal descriptions are understood.

3.1.1 Cardinal points

Comparison of the notebook and the georeferenced sketch map indicate that Hogarth's cardinal points are inaccurate as written. This was not identified by previous investigators but is very evident from a comparison of Hogarth's verbal descriptions, the tomb locations, and the Worldview-3 base map. The notebook describes tomb 4 as 'north' of tomb 3 (Hogarth, 1907b: 14), but tomb 4 is shown *c.*94 m west of tomb 3 on the georeferenced sketch map (Figure 4). Tomb 5 was described as 'immediately S.(outh)' (Hogarth, 1907b: 18) of tomb 4, but the sketch map (Figure 4) shows it east of tomb 4. Tomb 35 is described as 'above XXXIII and a little farther W(est)' (Hogarth, 1907b: 90), but the map shows it to the south of tomb 33. Hogarth's cardinal points are consistently offset by *c.*90° in an anticlockwise direction from reality (Table 3).

When Hogarth uses cardinal directions to describe tombs in relation to other fixed points, he is slightly more accurate. According to the notebook, Tomb 16 was 'in N.(orth) part of cemetery & about 100 yards to S.(outh) of Abu Tug' (Hogarth, 1907b: 46). Tomb 16 is south of Abu Tugh's mausoleum, but this is the western part of the cemetery, not the northern part. Tomb 23 was described as 'to N.(orth) of last series on higher slope E.(ast) of Abu Tug' (Hogarth, 1907b: 64). Again, tombs 23–26 are east of Abu Tugh's mausoleum, but

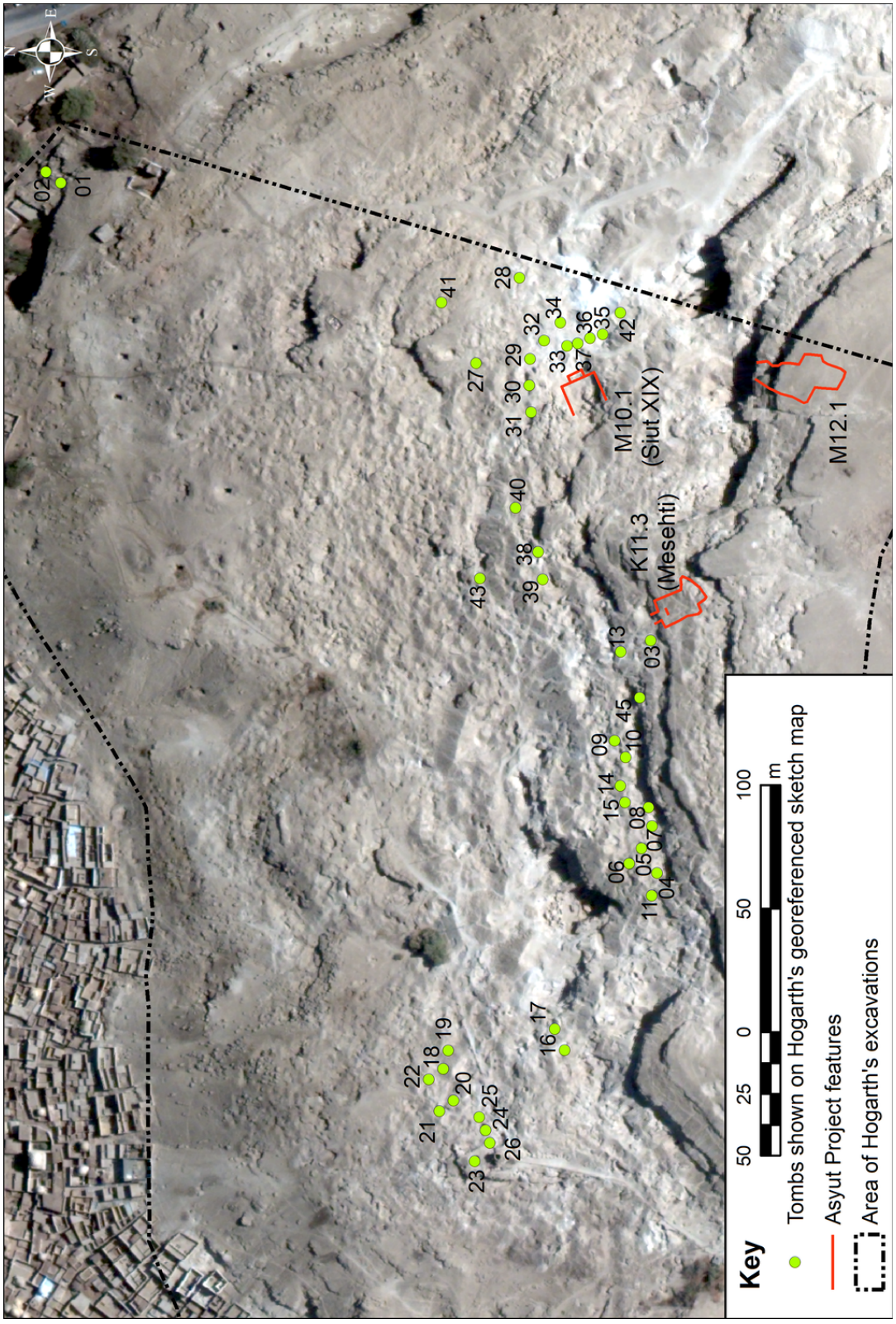

Fig. 4: The tombs as shown in the georeferenced sketch map, overlaid on the satellite imagery, with selected Asyut Project features. The tomb positions are approximate and subject to errors in the georeferencing. (Asyut Project features digitised from KAHL et al., 2018: 138, fig.1. Worldview-3 imagery © 2018 Maxar Technologies Provided by European Space Imaging. Reproduced with permission).

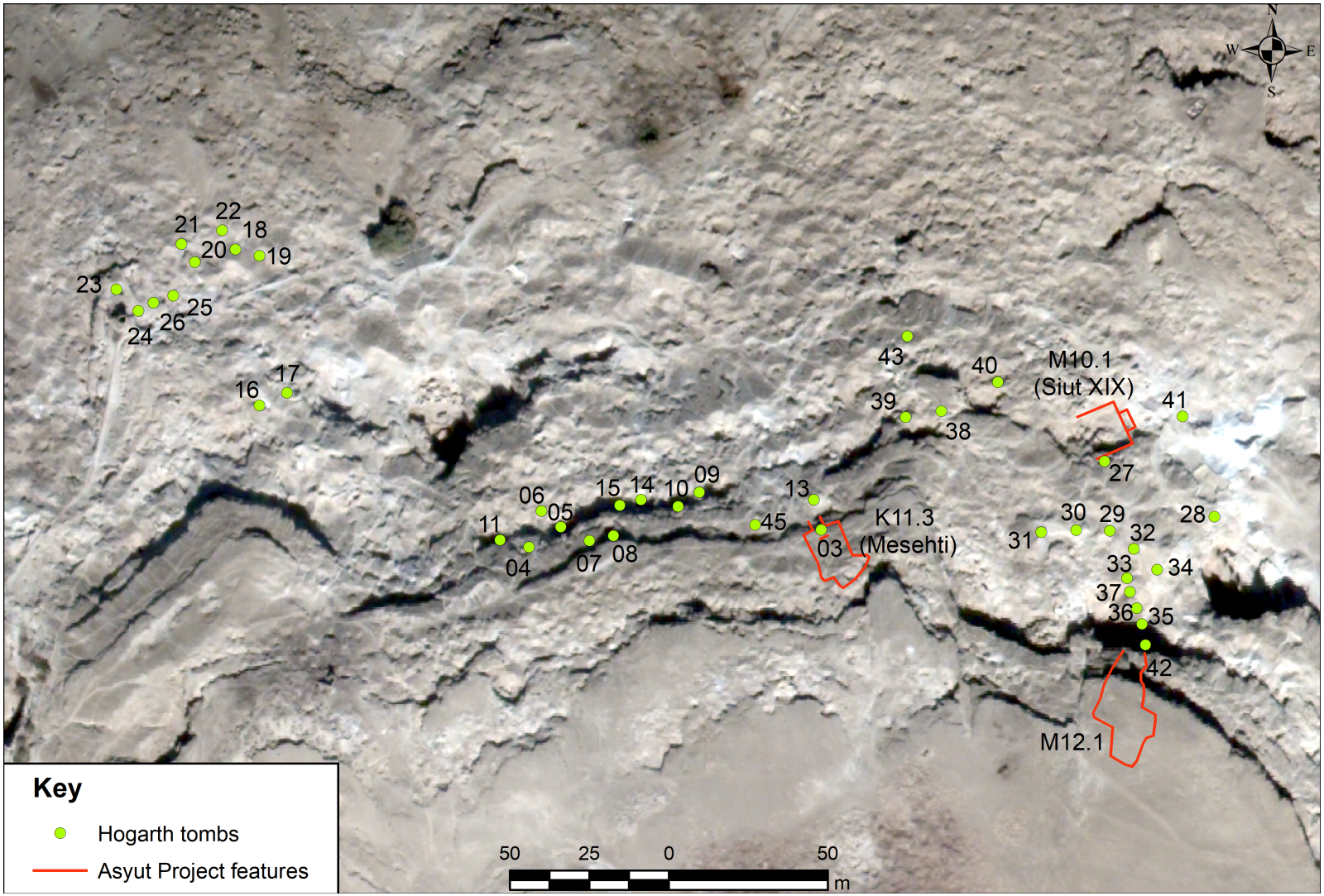

Fig. 5: The tombs from the sketch map after the shift in tombs 27–42 and 11–40; and the reordering of tombs 24–26. Tombs 1 and 2 lie beyond the north-east corner of the image. The tomb positions are approximate. (Asyut Project features digitised from Kahl et al., 2018: 138, fig.1. Worldview-3 imagery © 2018 Maxar Technologies Provided by European Space Imaging. Reproduced with permission).

Tab. 2: UTM 36 north coordinates for the numbered tombs after georeferencing (Figure 4). Owing to the imprecision in the GCP used for georeferencing, and because Hogarth located structures of varying sizes as points, these coordinates should be considered approximate.

Hogarth Tomb Number	X coordinate (m)	Y coordinate (m)
1	318917	3005986
2	318922	3005992
3	318732	3005747
4	318638	3005745
5	318648	3005751
6	318642	3005756
7	318657	3005747
8	318664	3005748
9	318691	3005762
10	318685	3005758
11	318629	3005747
13	318727	3005760
14	318673	3005760
15	318666	3005758
16	318566	3005782
17	318575	3005786
18	318559	3005831
19	318566	3005829
20	318546	3005827
21	318542	3005833
22	318554	3005837
23	318521	3005819
24	318534	3005814
25	318539	3005817
26	318529	3005813
27	318844	3005818
28	318879	3005801
29	318846	3005796
30	318835	3005797
31	318824	3005796
32	318853	3005791
33	318851	3005781
34	318861	3005784
35	318856	3005767
36	318854	3005772
37	318852	3005777
38	318768	3005793
39	318757	3005791
40	318786	3005802
41	318869	3005832
42	318865	3005760
43	318757	3005817
45	318709	3005752

Cardinal point as written by Hogarth	Cardinal point as shown in the georeferenced sketch map
North	West
South	East
East	North
West	South

Tab. 3: The cardinal directions as described by Hogarth in the notebook and diary compared to their position from the georeferenced sketch map.

tomb 23 is the westernmost of those tombs not the northernmost. Hogarth accurately described these tombs in relation to the mausoleum of Sheikh Abu Tugh, but his cardinal directions were out by the usual 90° when describing their position in terms of the necropolis, or their relationship with other tombs.

This shift is explicable in the context of Nile valley archaeology. When on the west bank of the Nile, facing the desert escarpment, north generally is to the right and south to the left. At Hogarth's concession the escarpment runs east-west. When Hogarth faced the escarpment in front of the mausoleum of Sheikh Abu Tugh, he had west on his right and east on his left! Hogarth did not account for this, and his cardinal points were shifted by 90° anticlockwise in common with the westward turn of the escarpment in his concession. Hogarth's cardinal directions have all been corrected in this paper, except in direct quotations, when the corrected direction is provided in square brackets.

3.1.2 Right and left

Hogarth describes objects, chambers, and tombs using 'right' and 'left' in the notebook and diary. Tomb 17 is described as 'to the left of XVI' (HOGARTH, 1907b: 50) and is marked to the east of tomb 16. Tomb 19 is described as 'to left of XVIII' (HOGARTH, 1907b: 56) and appears to the east of it. Tomb 20 was 'to right of XVIII & XIX' (HOGARTH, 1907b: 58) and is shown to the west of tomb 18 (Figure 4). Comparison between the georeferenced map and Hogarth's verbal descriptions revealed that the 'right' and 'left' are consistently those of a viewer facing the gebel.

3.1.3 Tomb numbering

As noted by ZITMAN (2010b: 54), Hogarth uses both Roman and Arabic numerals in his archival records. There is a rationale behind his usage (contra ZITMAN, 2010b: 54), although it is not archaeologically meaningful. Hogarth consistently uses Roman numerals for tomb numbers in the notebook, object register and report, while his sketch map uses exclusively Arabic numerals (Figure 2). In the diary, tombs are referred to by both Roman and Arabic numerals. In earlier diary entries for lower numbered tombs, up to tomb 29, Hogarth typically used Roman numerals. Tomb 27 appears as both 'XXVII' (HOGARTH, 1907c: 25–32) and '27' (HOGARTH, 1907c: 21, 23). Arabic numerals dominate the later diary entries and higher numbered tombs 30–57 in the diary. This is probably because Arabic numerals are much more efficient for writing higher numbers. Arabic numerals are used for tomb numbers in this paper, except in direct quotations from Hogarth's documents, which reflect his usage.

3.2 Missing tombs

Most of the *c.* 300 tombs excavated by Hogarth are absent from the map and irretrievably lost, as he did not consider them worthy of recording (ZITMAN, 2010b: 53). As with his pottery corpus (PETHEN, 2021), Hogarth appears to have updated his map as he worked. Since he sent it to the British Museum enclosed in a

letter of 13 February 1907, it does not show tombs 46–57, which were found on or after that date (Hogarth, 1907c: 44–61). Tombs 12 and 44 are absent from the map and this requires further explanation because they were found before it was sent to England.

3.2.1 Tomb 44

Hogarth (1907c: 39) discovered tomb 44 on 8 February 1907. It is absent from the sketch map because Hogarth confused it with tomb 45 when writing his notes and mislabeled the point for tomb 45 as '44' on the sketch map (contra Zitman, 2010b: 53; Zitman, 2010a: 67, map 3). It appears that there were two tombs numbered 'XLIV' in the notebook (Hogarth, 1907b: 107–8). The second of these entries was subsequently turned into 'XLV' by crossing out the 'I' (Hogarth, 1907b: 108). There is one tomb labelled '44' on the sketch map, just west of tomb 13 and partly obscured by the 'C' in 'Middle Kingdom Cemetery' (Figure 2). According to the notebook, tomb 44 was 'close to XLI' (Hogarth, 1907b: 107), which would place it 150 m from the position labelled as '44' in the sketch map. The description of tomb 45 in the notebook (Hogarth, 1907b: 108) matches the position marked '44' on the sketch map. It seems that Hogarth marked a point as tomb '44' on his sketch map, but then changed that tomb's number to '45' in his notebook without updating his sketch map. As Pethen (2021: 244) discovered, Hogarth's failure to update his records causes confusion. Tomb '45' is correctly marked on Figure 4, conforming with the description in the notebook.

3.2.2 Tomb 12

Hogarth (1907b: 38) discovered and excavated tomb 12 on 4–5 January 1907. He probably did not include it on the sketch map because it was disappointing. He described it as 'robbed . . . nothing but common refuse of red saucer' (Hogarth, 1907b: 38) and 'not worthwhile to plan' (Hogarth, 1907b: 37). All the objects listed under tomb 12 in the object register came from another tomb accessed from tomb 12 by a robbers' hole (Hogarth, 1907d: 16). It seems that Hogarth only recorded tomb 12 at all because of the objects from the adjacent tomb. This may explain why tomb 12 is missing from his sketch map, even though almost all the other tombs found before 13 February 1907 and listed in the notebook, are shown.

Tomb 12 thereby reveals something of Hogarth's excavation methods, and his criteria for numbering, planning, and describing tombs. It appears to have been important enough to get a mention in the notebook but perhaps was not significant enough for Hogarth to ensure it received a point on the sketch map. His actions imply that across the range of tombs excavated in 1906–1907, tomb 12 lies between those considered important enough to be given a tomb number, listed in the notebook and marked on the sketch map; and those tombs which only merited a brief mention in the diary.

Hogarth's habit of conflating artefacts retrieved from various tombs accessed by interconnecting robber tunnels under a single tomb number is highly significant for further analysis of the artefacts and tomb assemblages. The case of tomb 12 reveals that it is not enough (contra Ryan, 1988) to review the descriptions of the tombs in the notebook and the lists of objects by tomb in the object register. The archive must be considered in its entirety to ensure artefacts are associated with the correct sepulchre.

3.3 Specific errors in tomb positions

Comparison between the positions of the tombs on Hogarth's georeferenced sketch map, the Worldview-3 base map, and the archival records revealed specific errors in the positions of certain tombs.

3.3.1 Tombs 27–42

Tomb 27/Siut X should be close to M10.1/Siut XIX and may even be the same tomb (Kahl et al., 2007: 84; Palanque, 1903: 119–21; Zitman, 2010b: 40–2; Zitman, 2010a: 6, map 3). Tomb 42 is Asyut Project tomb M12.1 (Kahl et al., 2006: 246; Zitman, 2010b: 43), but both tombs 27 and 42 appear *c.*50 m north of M10.1 and M12.1, respectively, on the georeferenced sketch map (Figure 4). In Figure 5 this has been corrected and the entire cluster between tomb 27 and tomb 42 has been shifted *c.*50 m south so that tomb 27 aligns with M10.1, and tomb 42 with M12.1.

3.3.2 Tombs 11–40

Tombs 11–40, on the terraces in the centre of Figure 4, should be shifted southwards *c.*11 m so that Hogarth's tomb 3, the tomb of Mesehti, aligns with Asyut Project tomb K11.3 (Kahl et al., 2018: 145–51; Zitman, 2010b: 17). Encouragingly, when tombs 11–40 are shifted southwards until tomb 3 is in the correct location, they also line up roughly along the steps of the gebel in the Worldview-3 base map (Figure 5).

3.3.3 Tombs 24–26

The points marking tombs 24–26 on the sketch map are not clear (Figure 2). The numbers are aligned 25, 24, 26, from east to west in the georeferenced sketch (Figure 4), but in the notebook we read that tomb 24 'is the right hand (N. [west]) one of the group' (Hogarth, 1907b: 66), and tomb 26 is 'the centre of the group' (Hogarth, 1907b: 68). Hogarth either made an error in his map or failed to accurately relate the numbers to the points. Given the uncertainty in the labelling on the map, the verbal descriptions are more likely to be correct and have been incorporated into Figure 5 (as Zitman, 2010a: map 3).

3.3.4 Tombs 29–31

Tombs 29–31 should be closer together and located on a 'promontory' above tomb 27. On 26 January, Hogarth found 'five tomb doors, through two of which coffins could be seen' (Hogarth, 1907c: 26). He recorded that the tomb with the two doors contained a 'good painted coffin' and was on a 'promontory of rock' (Hogarth, 1907c: 27). This tomb must have been 29 as none of the other tombs excavated at this time contained a painted coffin (Hogarth, 1907b: 79–84; Hogarth, 1907d: 51–6). Hogarth (1907c: 28) later described tombs 29–31 as the 'XXIX group' in his diary entry of 28 January. The 'five tomb doors' (Hogarth, 1907c: 26) recorded in the diary entry of 26 January would then be: the two doors to tomb 29 (Figure 6); the single doors of tombs 30 and 31; and the door of a 'small, rifled tomb between the two doors of XXIX' (Hogarth, 1907b: 80), which was not numbered but shown in a drawing (Figure 7) marked with a '?'.

These drawings reveal that tombs 29, 30 and '?' were very close together. The dimensions given in Hogarth's plan of tomb 29 (Figure 6) indicate that tomb '?' occupied no more than two metres between the early and later doors of tomb 29. Yet Hogarth's georeferenced sketch map would imply *c.*21 m between tombs 29 and 31 (Figure 4). Clearly, tombs 29–31 should be much closer together, and the distances in the sketch map are a rough guide, rather than a precise measure.

The diary entry for 27 January reveals that the 'promontory' containing tombs 29–31 was above tomb 27 (Hogarth, 1907c: 27). The Worldview-3 base map shows a distinctive rounded promontory above and to the south of tomb 27 (Figure 8). Work around this promontory could certainly have sent stones rolling down into tomb 27, as described in the same diary entry (Hogarth, 1907c: 27). The feature in the Worldview-3 base map also matches the description of the 'XXIX group' (Hogarth, 1907c: 28) in that 'the rock turns sharply at both ends' (Hogarth, 1907b: 79). Conclusive proof that this feature contains tombs 29–31 requires relocation of these tombs on the ground, but it is the best candidate in the area.

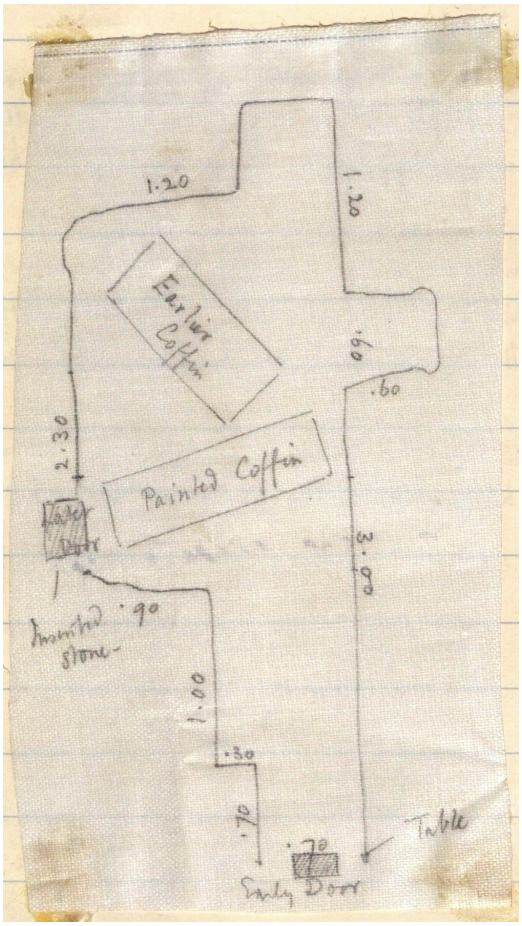

Fig. 6: Plan of tomb 29 from the notebook (HOGARTH, 1907b: 79), showing the two doors and two coffins. British Museum AES Archive 313 1.5.3. (© The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence).

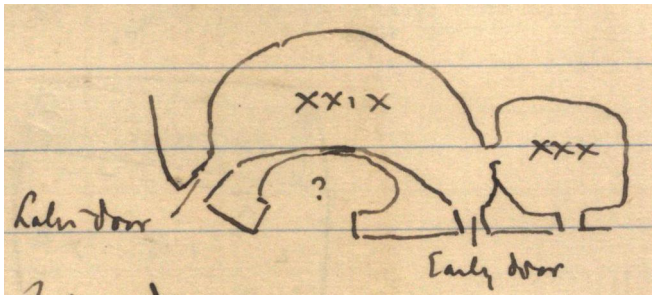

Fig. 7: The drawing of tombs 29, 30 and tomb '?' in the notebook (HOGARTH, 1907b: 80). *Image cropped.* British Museum AES Archive. 313 1.5.3. (© The Trustees of the British Museum. Shared under a Creative Commons Attribution-NonCommercial-ShareAlike 4.0 International (CC BY-NC-SA 4.0) licence).

This promontory is significantly smaller (*c.*7 m across) in the Worldview-3 base map (Figure 8) than the 21 m between tombs 29–31 in the georeferenced sketch (Figure 4). This is consistent with the description and drawings in the notebook that show tombs 29–31 as small and very close together (Hogarth, 1907b: 79–84). They would easily fit on such a promontory as shown in Figure 8.

3.3.5 Tombs 32 and 34

Tombs 32–37 are described in relation to each other and tomb 29 in the notebook and diary. The verbal descriptions indicate that the entire group should be shifted further south and the order of these tombs on the sketch map is also inaccurate in some places. Hogarth's records agree that tombs 32 and 34 should be close together and slightly south-east of tomb 29. The diary describes a tomb with a 'large door', broken roof, and an ushabti naming pharaoh Neb-maat-ra/Amenhotep III (Hogarth, 1907c: 28–30). Although the diary does not give the tomb number, the description matches tomb 34 as described in the notebook (Hogarth, 1907b: 88) and object register (Hogarth, 1907d: 62). This tomb (34) was 'round the corner' from tomb 29 according to the diary (Hogarth, 1907c: 28) and south-east of tomb 29 according to the sketch map (Figure 5). Tombs 32 and 34 are therefore shown south-east of tomb 29 in Figure 8.

The positions of tombs 32 and 34 relative to each other are debatable. On the georeferenced sketch map, tomb 32 is partially hidden by the 'large tombs' label (Figure 2), and is north and slightly west of tomb 34. The notebook entry for tomb 32 agrees that it was north-west of tomb 34 (Hogarth, 1907b: 84), but the equivalent entry for tomb 34 states it was 'to the NE' of tomb 32 (Hogarth, 1907b: 88). Whether or not we correct for the 90° anticlockwise shift in cardinal points, this latter description does not accord with the rest of the evidence. The diary states that tomb 32 was 'further W. [south]' (Hogarth, 1907c: 29) of tomb 34, which is equally inconsistent with the rest of the evidence. In Figure 8, tomb 32 is placed north-west of tomb 34 (as Zitman, 2010a: 6, map 3), since the sketch map and notebook entry for tomb 32 agree on this, and the diary is equivocal depending on how Hogarth's 'W' is interpreted. However, this positioning is debatable, and the conundrum can only be resolved by relocating both tombs.

3.3.6 Tombs 35–37

The sketch map (Figure 3 and Figure 4), notebook (Hogarth, 1907b: 90–4) and diary (Hogarth, 1907c: 31–5) agree that tombs 35–37 were just west of tomb 42, and higher and south of tomb 33. There is a discrepancy between the sketch map and the notebook on the precise positions and order of the tombs. The sketch map shows tombs 37, 36, 35 in line from north-west to south-east (Figure 3 and Figure 5), but the notebook orders them 36, 35, 37 north-west to south-east. The diary supports the notebook's order for tombs 35–37, against that shown on the sketch map (Figure 5). The diary entry for 31 January records 'two large tombs with fronts quarried, to N.[west]' of tomb 42 (Hogarth, 1907c: 31). The subsequent entry reveals that the first of these was tomb 35 (Hogarth, 1907c: 32). The second was to the north-west of 35 and 'opens into a catacomb of robbed tombs' (Hogarth, 1907c: 31). This second tomb must be tomb 36, the only one of the three that 'communicated with others below' (Hogarth, 1907b: 92). This is also consistent with 36 being on the 'right' of 35 (Hogarth, 1907b: 92), as stated in the notebook (Figure 8). The tomb with blue and yellow coffin fragments, mentioned in the diary on 1 February (Hogarth, 1907c: 32) must be 37 because it was the only one of these tombs that produced fragments of blue and yellow coffin (Hogarth, 1907d: 68). This tomb 37 was 'side by side with it (35) on left' (Hogarth, 1907c: 32) confirming that tomb 37 was 'left' of tomb 35 (Hogarth, 1907b: 94). The weight of the evidence lies with the verbal descriptions in the notebook and diary. It is much more likely that Hogarth made a single mistake in the sketch map than repeated, but consistent, mistakes in the descriptions in the notebook and diary. I have reordered the tombs 36, 35, 37 north-west to south-east in Figure 8 in accordance with the descriptions in Hogarth's notebook and diary (as Zitman, 2010a: 6, map 3).

The descriptions of tombs 35–7 in the diary also indicate they were closer together than they are shown on the sketch map, and that they lay to the west of the 'Great Tomb' [42] (HOGARTH, 1907c: 31, 35). If tomb 42 is Asyut Project tomb M12.1 (as ZITMAN, 2010b: 43), tombs 35–7 should run along the terrace north-west of tomb 42 in the satellite image (Figure 8).

3.3.7 Tomb 33

There is little precise information on the position of tomb 33, except that it is shown south-west of tomb 34 in the sketch map, and was recorded as being higher and north of tomb 35 (HOGARTH, 1907b: 90). Although it should clearly be shifted southwards with the rest of the group (as in Figure 8), its precise position is highly approximate at best.

4 Discussion

Georeferencing the sketch map was only the first stage in the process of locating the tombs Hogarth numbered. Comparison with the written archive revealed that Hogarth's recording was variously vague, imprecise, and occasionally inaccurate. Nevertheless, careful review of the map and archival descriptions in the context of the Worldview-3 base map made it possible to untangle some of his idiosyncrasies.

Figure 8 shows Hogarth's excavations in the necropolis of Gebel Asyut el-Gharbi re-contextualised with evidence from the georeferenced sketch map, documentary archives and the Worldview-3 base map. Figure 8 includes the most likely position of 40 of the numbered tombs marked on the sketch map. Most of the tombs are in the same positions as on Figure 5, except for tombs 29–37, which are shown in more detail on Figure 8. As there is no question about the position of Hogarth's tombs 1 and 2, and they are located some distance north-east of the other tombs at the edge of the gebel, they are not shown in Figure 5 or Figure 8. Figure 8 also reflects the areas excavated by Hogarth and, since higher tomb numbers typically indicate later discovery (PETHEN, 2021: 238–41), the chronological progress of the excavation.

The order and position of the tombs on Figure 8 is broadly consistent with that proposed by ZITMAN (2010a: 6, map 3, 4, 7), particularly the re-ordering of tombs 24–6, 32 and 34, and 35–7. The reconstruction in Figure 8 differs from Zitman's in taking full account of the physical topography, represented by the Worldview-3 base map. This made it possible to identify a good candidate for the promontory associated with tombs 29–31 and observe how tombs 11–40 fall across the terraces of the gebel (Figure 5).

Table 4 shows the final coordinates, after the tomb positions were revised using the archival records (Figure 8), and the distance each point shifted from its position in Figure 4 and Table 2. The coordinates in Table 4 are presented as a measure of how far the tomb positions shifted following archival research, compared to the tomb positions after georeferencing (Figure 4 and Table 2). They also offer an indication of where to begin in the process of relocating the tombs on the ground. However, there are probably inaccuracies in the tomb positions, particularly where the archival evidence was vague or contradictory. Owing to the imprecision in the GCP and because Hogarth presented structures of varying sizes as single points, even accurate tomb positions are likely to be quite imprecise and they should all be treated as approximate.

4.1 Further considerations

Seeing the tombs and landscape together in Figure 5 and Figure 8 facilitates comprehension of the progress of Hogarth's excavations across the site. Both Hogarth's descriptions and the tombs they record are more difficult to understand when divorced from the topography, because they are embedded in the physical landscape. Reading the archive in the light of the extant topography both clarifies and illuminates the excavations.

One of the difficulties with historic excavations is that errors, vagueness, and inaccuracy can make it seem

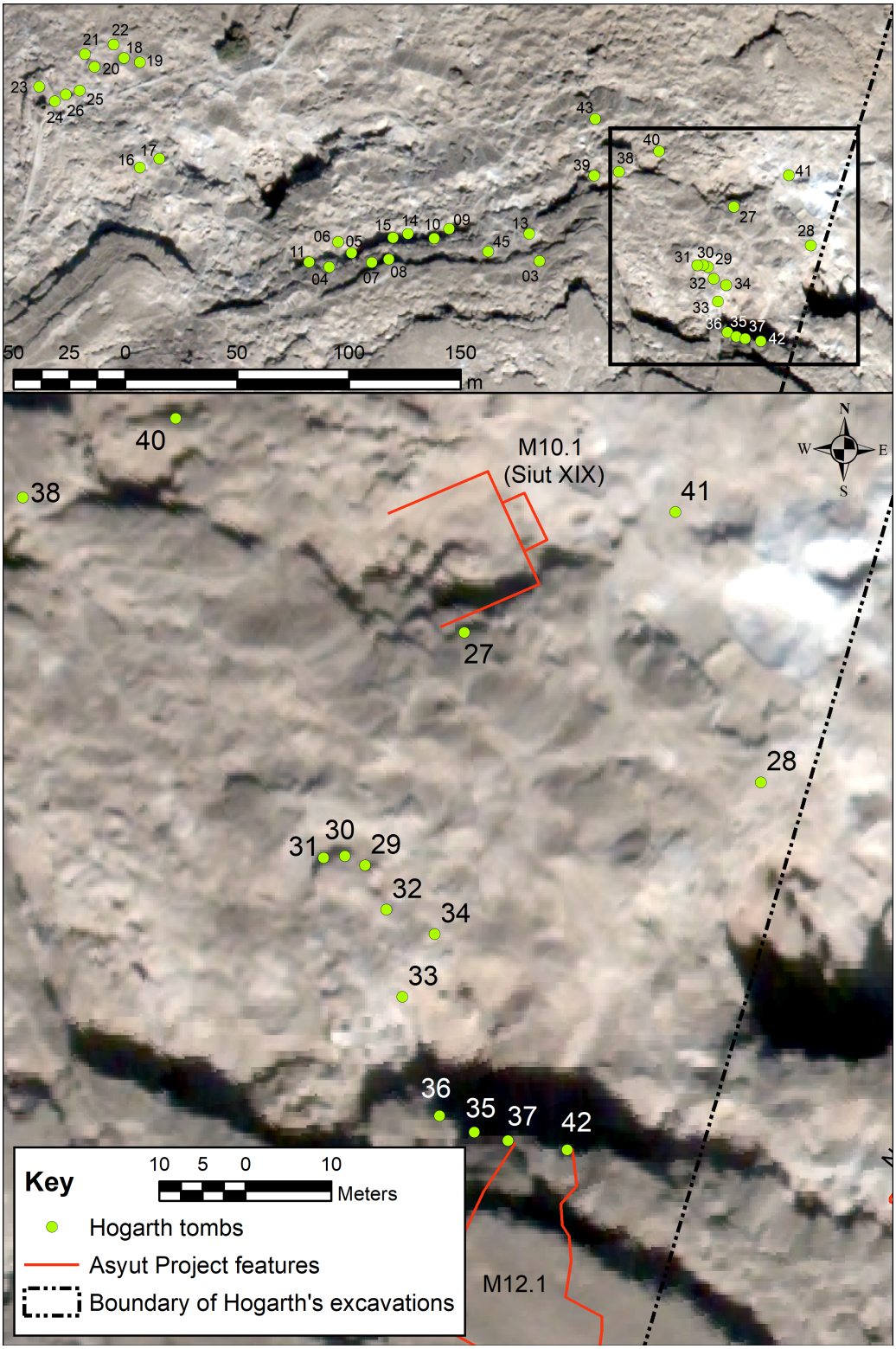

Fig. 8: Tomb positions following changes to tombs 29–31 and 32–37. Tomb positions are approximate. (Asyut Project features digitised from KAHL et al., 2018: 138, fig. 1 Worldview-3 imagery © 2018 Maxar Technologies Provided by European Space Imaging. Reproduced with permission).

Hogarth Tomb Number	X Coordinate (m)	Y Coordinate (m)	Shift (m)
1	318917	3005986	0
2	318922	3005992	0
3	318745	3005740	15
4	318651	3005738	15
5	318661	3005744	15
6	318655	3005749	15
7	318670	3005740	15
8	318677	3005741	15
9	318704	3005755	15
10	318698	3005750	15
11	318642	3005740	15
13	318740	3005753	15
14	318686	3005753	15
15	318679	3005751	15
16	318566	3005782	0
17	318575	3005786	0
18	318559	3005831	0
19	318566	3005829	0
20	318546	3005827	0
21	318542	3005833	0
22	318554	3005837	0
23	318521	3005819	0
24	318528	3005812	6
25	318539	3005817	0
26	318533	3005815	5
27	318832	3005765	55
28	318866	3005747	55
29	318820	3005738	64
30	318818	3005739	60
31	318816	3005739	58
32	318823	3005732	66
33	318825	3005722	65
34	318828	3005730	63
35	318833	3005707	65
36	318829	3005708	69
37	318837	3005706	73
38	318781	3005780	18
39	318769	3005779	18
40	318798	3005790	18
41	318856	3005779	55
42	318844	3005704	59
43	318770	3005804	18
45	318722	3005745	15

Tab. 4: Final UTM zone 36 north coordinates of the numbered tombs, after revision based on the Worldview-3 base map and archival records (Figure 5 and Figure 8). The last column shows the shift in metres from the coordinates given in Table 2. Owing to the imprecision in the GCP and point data, these coordinates should be considered approximate, although they are likely to be more accurate than those given in Table 2.

impossible to extract meaningful data. The shift in the cardinal points and Hogarth's usage of 'right' and 'left' only appeared when Hogarth's descriptions and sketch map were compared with the Worldview-3 base map in the GIS. These discoveries are of great significance for further research into Hogarth's excavations, including the layout of individual tomb chambers and the location of unmarked or unnumbered tombs.

Even when vagueness and imprecision have no obvious effect on the integrity of the data, they contribute to uncertainty about it. Hogarth's usage of both Roman and Arabic numerals for tomb numbers may not be archaeologically meaningful (as Zitman, 2010b: 53), but this research has shown that it is intelligible as a logical response to the complexity of Roman numerals. Comprehending the motivations behind this choice provides an explanation for this feature of the archive.

4.2 Future directions

This research has suggested possible coordinates and topographic positions for various tombs, but these are likely to be imprecise owing to the nature of the sketch map, with sometimes quite large structures shown as single points. The only way to provide certain locations for these tombs is to relocate and re-excavate them. The suggested coordinates provide a starting point for further investigation.

The georeferenced sketch map, revised tomb positions and knowledge of Hogarth's recording methods will assist in further research, including the location of the unmarked and/or unnumbered tombs mentioned in Hogarth's notebook and diary.

5 Conclusion

This paper demonstrated the potential of combining GIS, documentary, and archaeological evidence to re-contextualise poor quality archival descriptions and historic maps. Such methods raise the possibility of utilising historic or archival data previously written off as too inaccurate or imprecise for further research.

The results revealed that archival documents can both reveal and resolve problems with cartographic sources. High-resolution satellite imagery and recently published archaeological survey data from the Asyut Project made it possible to georeference Hogarth's sketch with a good RMSE. Comparison with the rest of the archive revealed systemic problems with Hogarth's recording methods and specific errors in the positioning of the tombs on the sketch map, but also enabled correction of some of those errors and improvements in the tomb's positions. A certain degree of imprecision remains, owing to the representation of substantial structures as single points on Hogarth's sketch map, and there may also be further unknown inaccuracies. Absolutely precise locations for these tombs can only be provided by their relocation and re-recording. Nevertheless, for the first time, it is possible to directly relate Hogarth's excavations to the topography of the Gebel Asyut el-Gharbi, suggest positions for the tombs left unmarked and/or unnumbered on Hogarth's sketch map; and potentially relocate the tombs for further research. The georeferenced tomb positions and insights into Hogarth's excavations offer the possibility of further research into the spatial arrangement of the Gebel Asyut el-Gharbi necropolis, contributing to improved understanding of the social and cultural dynamics within an important regional centre of the First Intermediate Period and Middle Kingdom.

6 Table of technical terms

Tab. 5: The following table is provided as a quick reference for the technical terms used in this paper. More information on the technical terms and their usage can be found from the in-text references and those additional sources supplied in the table.

Term (abbreviation)	Meaning
ArcMap	The central application of ESRI's ArcGIS Desktop proprietary GIS programme until 2024, when it will be formally replaced by ArcGIS Pro (Esri, 2021f).
Digital surface model (DSM)	A digital topographic model that captures the height of the land surface whether natural or artificial, at specified intervals. The recorded surface height may be ground level, natural or artificial features, (e.g. tree tops, or the tops of buildings) depending on the nature of the ground cover (Chapman, 2006: 72–7).
Digital terrain model (DTM)	A digital topographic model of the bare earth or ground level, encoding height data at specificed intervals (Conolly & Lake, 2006: 72, 103–11).
ArcGIS File geodatabase	A collection of files in a folder on a disk, containing spatial and non-spatial data, including linked relational databases, that can be displayed, queried or managed in ArcGIS progammes (Esri, 2021e).
Georeferencing	The process of assigning real-world geographic coordinates in a recognisable coordinate system to data, typically in a GIS (Conolly & Lake, 2006: 17–24, 72–93).
Geographic Information System (GIS)	A spatial, relational database progamme, used for capturing, checking, storing, analysing and displaying spatial data, most often relating to the surface of the earth (Parcak, 2009: 88–90; Zakrzewski et al., 2016: 53–4).
Ground Control Points (GCP)	A set of (usually at least 4) points which appear in data that requires georeferencing and also have known coordinates (Conolly & Lake, 2006: 82–3).
High-resolution satellite imagery	Satellite imagery with a cell size <5 m or better (Parcak, 2009: 72–3). The resolution of satellite imagery refers to the size of the cells (pixels) which make up the image. The smaller the cell size, the more detail is visible in the imagery. In an image with a resolution of 0.5 m, each cell is equivalent to 0.5 m on the ground, and the image will reveal details larger than 0.5 m. An image with 1 m resolution has cells equivalent to 1 m on the ground, and will only reveal details larger than 1 m.
Image Analysis Window	A window in ArcMap offering various analytical tools for raster processing (ESRI 2021a).

Tab. 5: Continued

Term (abbreviation)	Meaning
Multi-spectral band	The multi-spectral bands of a passive satellite image record how the surface of the planet reflects light within set parts of the electromagnetic-spectrum. The multi-spectral bands include the red, green and blue bands, as well as non-visible light, such as infrared. The exact values of the wavelengths recorded in each band vary depending on the satellite sensor. Multi-spectral bands are typically lower resolution than the panchromatic band. For more information see Parcak (2009: 43).
Ortho-ready	Sensor, radiometric and geometically corrected satellite imagery projected to a flat plane using a known projection and datum (For further information please refer to the European Space Imaging Core Imagery Product Guide 2014, Worldview Global Alliance, available from *European Space Imaging* and to the *European Space Imaging* imagery specifications website).
Orthorectification	The process of removing elevation-relation distortion from satellite imagery (Conolly & Lake, 2006: 296).
Panchromatic band	The monochromatic, highest-resolution band of satellite imagery. For Worldview-3 see Digitalglobe (2017).
Pan-sharpening	The process of fusing lower-resolution multi-spectral bands with the higher resolution panchromatic band to produce high-resolution colour images. One method of pan-sharpening uses the Gram-Schmidt orthogonalization (Esri, n.d.).
Root Mean Square Error (RMSE)	An automatically generated measure of the accuracy of the georeferencing process based on the difference between the desired and actual position of the GCP after georeferencing. For more information see Conolly and Lake (2006: 82–3).
Stereo-pair' satellite imagery	Two overlapping satellite images taken from different perspectives that can be stereoscopically processed to produce depth information and elevation data (Conolly & Lake, 2006: 72–6).
True colour image	True colour satellite imagery represents the red, green and blue multi-spectral bands covering the visible light spectrum, such that the red band is red, the green band is green, and the blue band is blue. The resulting raster image appears true to life as the human eye would see it. For more information see Parcak (2009: 43).
Universal Transverse Mercator projection zone 36 North (UTM zone 36 N)	The Universal Transverse Mercator is a projected coordinate system, which divides the planet into 60 zones aligned north-south, each of which is 6 degrees of longitude wide. It is conformal and provides metric measurements, but the correct zone must be used for the area of the planet concerned. Zone 36 North (of the equator) covers Egypt. For projections see Conolly and Lake (2006: 297).

Tab. 5: Continued

Term (abbreviation)	Meaning
Worldview	The Worldview series of satellites are a series of commercial high-resolution satellites, operational since 2007. This research uses Worldview-2 (launched 2009) and Worldview-3 (launched 2016) imagery. For more information see the *European Space Agency* Worldview Series Website.

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