E A R T H M A P S  C O N S U L T I N G

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Environmental Compliance Consultancy

Ground Penetrating Radar (GPR)

Survey:

Twin Hills: Possible Grave Sites

Report 1/1

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Contents

1. Introduction

Environmental Compliance Consultancy ('ECC') requested Earthmaps Consulting CC ('Earthmaps') to carry out a Ground Penetrating Radar (GPR) survey over five suspected grave sites at the Twin Hills Gold Project near Karirib (Figures 1, 2, 3).

A GPR survey was carried out at the site on the 7th and 8th of August 2023.

The aim of the survey was to:

i. Utilise the GPR responses in assisting to deteremine whether the suspected grave sites are grave sites or not.

2. Instrumentation and Method

GPR is routinely used in archeological investigations and assessments, and this includes the examination of grave sites, as is shown in the example in page 4.

The benefit of GPR is its non-intrusive nature and its high spatial resolution, compared to other geophysical survey techniques, resulting from its use of high frequency radio waves. However it must be pointed out that due to natural electrical ground conductivities, radio signals quickly loose intensity as they penetrate the ground. The higher the radio wave frequency, and the higher the spatial resolution, the more dramatic is this loss of signal. Therefore there is a strong trade-off between effective depth of penetration and the resolution of the radio-signal. In order to achieve penetration depths of between 1 and 2 m in most substrates, a signal frequency range as low as 300 to 200 MHz is required. The spatial resolution at this frequency range is no better than the size of a small gymnast ball (diameter of 40 cm). This means that smaller features than this will not be detectible by GPR at these frequencies. This means that contrary to popular perceptions, bones will not be visible in graves by using GPR, however a coffin will be detectible, provided that it is still in its original shape. Small objects such as bones can theoretically be detectible with radar frequencies in the 1 GHz range, however signals at such high frequencies would only be able to penetrate a few cm into the ground.

It must also be noted that as GPR is sensitive to electrical impedance constrasts, a void in the ground, created by a burried coffin, will be readily detected, however a burried body without a coffin, possibly only draped in a shroud, will be extremely difficult to detect, as its impedance contrast with the ground will be very low. Disturbed ground profiles may also be detectible however the soil profile gradually blends and settles back into the natural stratification, and therefore with passing years, graves will become more and more difficult to detect. In summary, recent, western-style graves with burried, intact coffins will be much more easy to detect and identify with GPR compared to ancient, traditional African graves without coffins. The substrate also influences the detectibility of graves, with homogenous, sandy substrate offering a clean GPR background wheras a rocky, inhomogenous substrate such as calcretes will return complex signals that can make the identification of burial sites difficult.

A Pulse EKKO PRO GPR system with a shielded 250 MHz antenna was used to survey profiles at three of the suspected sites. The shielded nature of the 250 MHz antenna is an important benefit as it does not suffer from above-surface reflections such as from trees or bushes, which can create strong radar reflections in un-shielded antennas. The 250 MHz antenna was moved along the survey lines in the standard parallel broadside (PL-BD) configuration.

The data was processed in Sensors & Software Inc. software and the GPR sections are displayed in Section 7 at the end of this report.

Note that in the absence of a depth calibration point in this area (such as open soil profile or pit) a radar velocity of 0.06 m/ns has been assumed for the processing, representing the radar velocity in clay-rich soil.

GPR Principles, Procedures & Applications 10-Case Studies

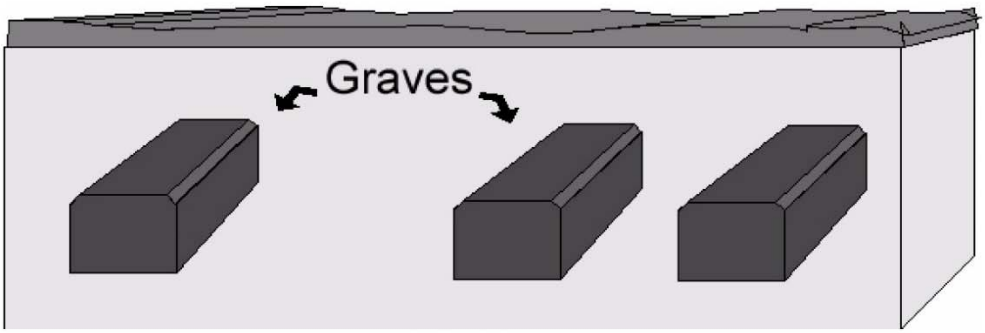
GRAVE LOCATION

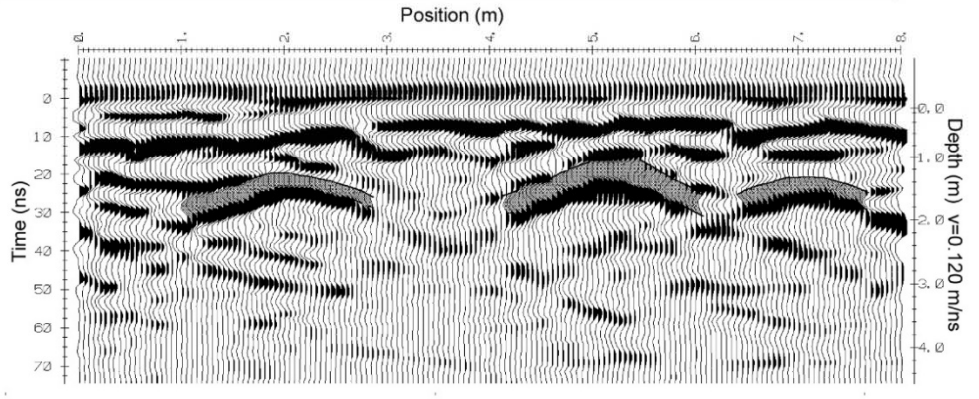
Location of unmarked graves in cemeteries is an unusual but regular application of ground penetrating radar. Where there are no markers or indications of grave locations development, construction projects can be quickly brought to a halt until the history of the site is evaluated.

Ground penetrating radar (GPR) systems respond to buried objects as well as disturbed soil, providing a powerful method to define unmarked grave locations. Other applications include forensic investigations and archaeological site evaluations.

In this case a pulseEKKO GPR system was used with a 200 MHz antenna. The data were acquired by students at the University of Calgary. The portable nature of the pulseEKKO system made data acquisition quick and easy. The soil at the site was silty sand.

Data compliments of University of Calgary, Department of Geography, Canada





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Source: Ground Penetrating Radar Principles, Procedures and Applications. A.P. Annan 2004

3. Results

3.1. Site PG2

No signs of a potential grave site were found at site PG2. The site is in the middle of a drill site (Figure 21) and it is possible that during the course of clearing the site the signs of the suspected grave site had been destroyed or obliterated. However no signs of a mound or stones that could frame a grave, or the remains of such signs, could be seen.

In the absence of any indication of a grave site no GPR was done at this site.

Conclusion: Site PG2 could not be confirmed or refuted as a grave site. However given the complete absence of any indications of a grave site it appears very unlikely that PG2 represents a grave site.

3.2. Site PG3

This site shows four mid-sized calcrete stone arranged in a loose square measuring 90 cm x 60 cm (Figure 3).

- The site is small and roughly square, which is unusual for a grave site which is normally elongate in the shape of a human body. The square shape and small size would suggest against a grave site.
- The ground around and inbetween the four stones is completely flat and pristine, showing no signs of disturbance or a built-up mound. This also suggests against a grave site.
- A line of GPR was surveyed across the stone feature (Figure 4) and the results are shown in Figure 5. The results show homogenous calcrete response throughout the line and no signs of ground disturbance.

Conclusion: Site PG3 is not a grave site.

3.3. Site PG4a

Site PG4a shows a small cluster of siliciclastic schist outcrop and a number of small stones with a packed appearance on the northern side, forming a small enclosure measuring 50 cm x 30 cm (Figure 6, 7).

- The enclosure is very small and in horizontal dimensions could encompass at best a very small child.

- More importantly bedrock is at surface, and at close inspection it was not possible to dig a hole deeper than 10 cm, before hitting hard bedrock within the enclosure. At best therefore the enclosure could have served the purpose of storing some implements. Certainly it could not have served as a burial site.

No GPR was done because of the evidence above. Furthermore the protruding outcrop would have lifted the antenna too far off the ground and rendered the data uninterpretable.

Conclusion: Site PG4a is not a grave site.

3.4. Site PG4b

Site PG4bc consists of two rough alignments of large, heavy stones, ending at a tree situated in the flood zone of the Okawayo River (Figures 8 – 9).

- The **northern stone line** measures 1.8 m x 0.8 m and thus has the dimensions which could cover an adult human body.
- No earth mound exists, and the base of the stones is flat, soft river sand. There is no sign that would indicate earth movement at or close to the stone line.
- The location within the flood zone of the Okawayo River implies that this area is prone to regular, possibly annual flooding and thus not be suitable for a long-term, secure burial site.
- Though the stone line is conspicuous and may have been arranged by humans, it is not entirely inconceivable that it may have been deposited by a large flood event.
- A GPR line was surveyed across the center of the stone line (Figure 10) and the results are shown in Figure 11. No conspicuous GPR signals exist that would indicate earth disturbed by human beings.

Conclusion: The northern stone line at Site PG4b may have been put in place by humans, however no evidence could be found that it constitutes a grave site.

- The **southern stone line** measures 2.8 m x 0.7 m, which is too long and too narrow for the dimensions of a normal human grave.
- No earth mound exists, and the base of the stones is flat, soft river sand. There is no sign that would indicate local earth movement at or near the stone line.
- The location within the flood zone of the Okawayo River implies that this area is prone to regular, possibly annual flooding and it would thus not be suitable for a long-term, secure burial site.
- Though the southern stone line is conspicuous and may have been arranged by humans, it is also possible that it may have been deposited by a major flooding event.
- A GPR line was surveyed across the center of the southern stone line (Figure 12) and the results are shown in Figure 13. No conspicuous GPR signals exist that would indicate disturbed earth,

except for a discontinuity at the southern end of the stone line at a depth of between 1.1 m and 1.6 m. However this is too deep to be reasonably caused by human excavation in unstable river sediments and is most likely of natural origin, such as a historic river bank scarp caused by a flood event.

Conclusion: The southern stone line at Site PG4b may have been put in place by humans, however there is no clear evidence that it represents a grave site.

3.5. Site PG4c

Site PG4c falls on a new drill road (visible in the left of Figure 4) and no evidence of a grave site could be found.

At the locality 601282, 7584946 *next to the drill road* there are four mid-sized calcrete stones lined up to form a 1.6 m stone line, however these stones show signs of having been moved recently (fresh disturbance of the ground beneath the stones). They may have formed part of an earlier structure that has recently been moved to the side of the drill road.

However there is no indication of a grave mound in the vicinity of site PG4c and therefore no GPR was conducted.

It must be noted that Site PG4c lies only 4.4 m south of Site PG4b, and the ground conditions of dense, pristine pedogenic calcrete, with no sign of a mound, are identical at both sites. Even though a drill road passes over PG4c, it seems highly unlikely that a grave site is present in this locality. Heavy vehicles passing over disturbed ground in an otherwise hard substrate would have created a depression, which is not evident at this site.

Conclusion: The overall evidence at Site PG4c rules out a grave site with a very high degree of confidence.

3.6. Site 478

Site 479 is situated south of the gravel road and was described by John Kinahan as follows:

Okawayo 478 -21.87046S 15.94964E

Three suspected grave cairns in a cluster approximately 5m in diameter (see Fig. 4).

At this locality, three shallow mounds of both fine and coarse calcrete gravel and stones could be identified, although they are not easily identifiable in photographs (Figures 14, 16, 18, 19).

From east to west they are two large mounds measuring 2.0 m x 1.2 m ('Mound 1) and 2.4 m x 1.5 m ('Mound 2'), as well as a small mound measuring 1 m x 0.7 m at the western end ('Mound 3')

Mounds 1 and 2 could be covering and adult human being, judging by their dimensions, while mound 3 could conceal only a small child. The dimensions and elongate shapes suggest that they could represent grave cairns and therefore a GPR line was surveyed across each mound running roughly from north to south.

Mound 1 (Figure 14)

The GPR data over Mound 1 (Figure 15) shows a strong reflector at a depth of 0.48 m centered beneath the mound (assuming a radar velocity of 0.06 m/ns applicable for clays). Although inhomogenous calcrete gravels are noisy environments for GPR this suggests a buried object beneath the mound.

Mound 2 (Figure 16)

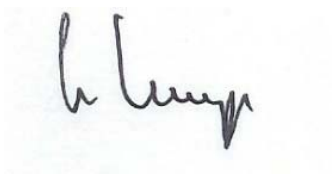
The GPR data over Mound 2 (Figure 17) shows distinct signs of disturbance of the surrounding stratification below the mound, which suggests digging across the stratification. A moderate amplitude reflector at 0.8 m depth may indicate a buried object at this locality, though this reflector is not very distinct.

Mound 3 (Figure 18, 19)

The GPR profile over Mound 3 (Figure 20), the smallest of the three mounds, does not show any clear evidence of ground disturbance. Lateral discontinuities can be seen corresponding with both edges of the mound, however there are other, similar discontinuities elsewhere in the profile. No conclusion can therefore be drawn with regards to the origin of this particular mound.

Conclusion: The balance of the GPR results at Mounds 1 and 2 indicate likely burial sites. The results at Mound 3 however are inconclusive.

Respectfully submitted,



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4. Figures

Figure 1: Locality Plan: Suspected grave sites

Figure 2: Suspected grave sites: Twin Hills mine area

Figure 3: Site PG3. View to the north-east

Figure 4: Site PG3 GPR survey line, view to the north. The drill road passing over Site PG4c is seen on the left.

Ground Penetrating Radar

Suspected Gravesites

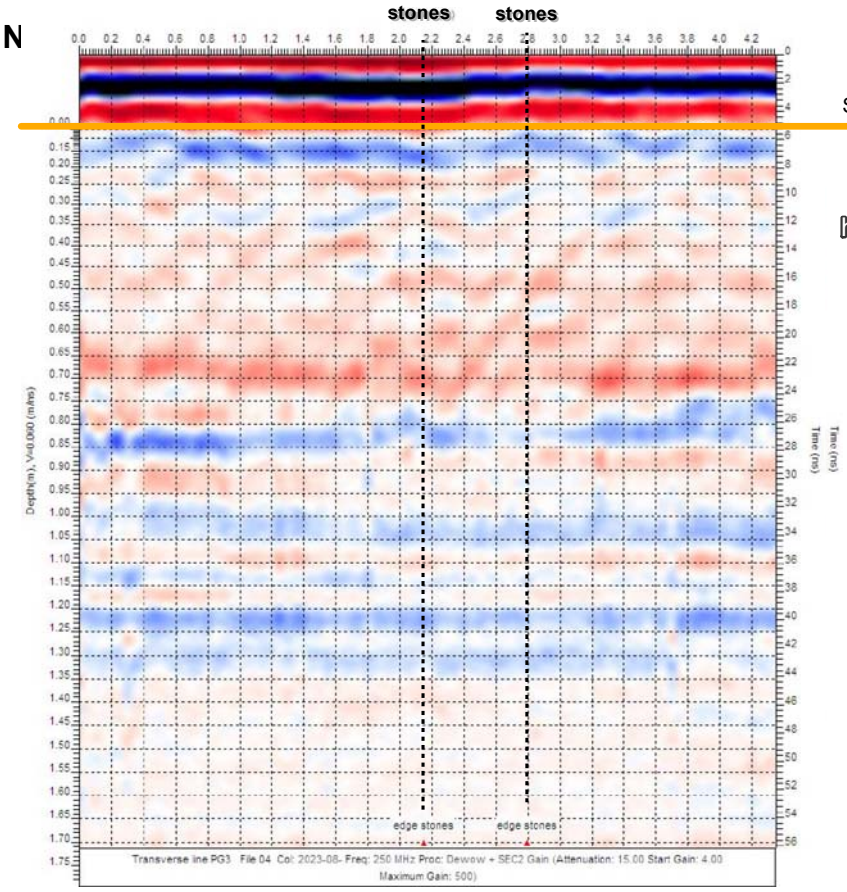
Site PG3

Twin Hills Project

250 MHz

locality:

601280, 7584953
WGS84 UTM33S



homogenous calcrete response

no sign of soil disturbance

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Figure 5 **Radar File: Line 04**

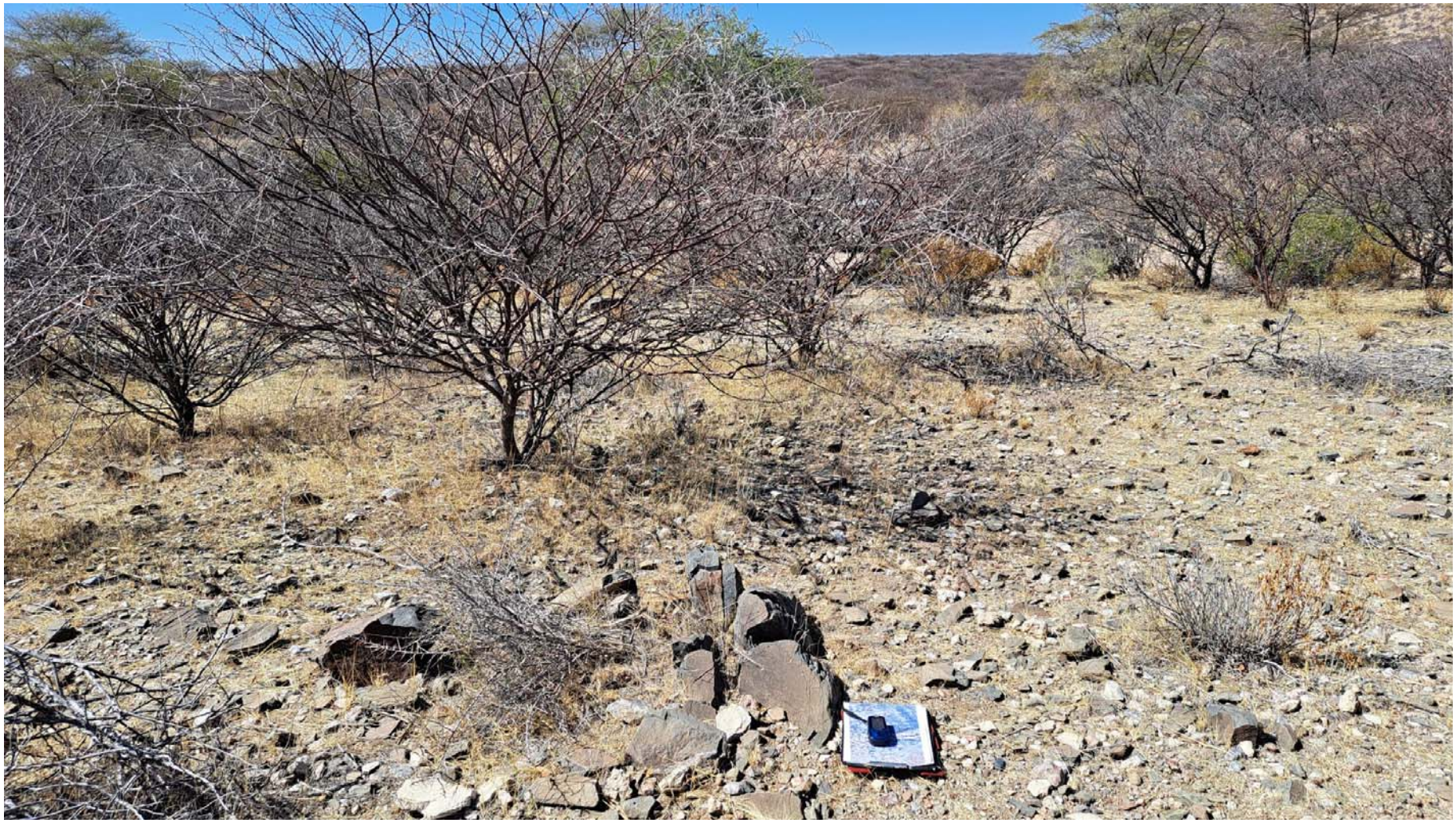

Figure 6: Site PG4a. View to the east.

Figure 7: Site PG4a. View from above, north to the top of the picture. The rocks in the bottom half are outcrop.

Figure 8: Site PG4b. View to the north. The southern stone line in the foreground, the northern stone line in the background.

Figure 9: Site PG4b. View to the north-west. The southern stone line in the foreground, the northern stone line in the background.

Figure 10: Site PG4b. The northern stone line GPR traverse

Ground Penetrating Radar

Suspected Gravesites

Site PG4a

Twin Hills Project

250 MHz

SW **NE**

locality:

601237, 7584954
WGS84 UTM33S

Northern Traverse

no sign of human activity

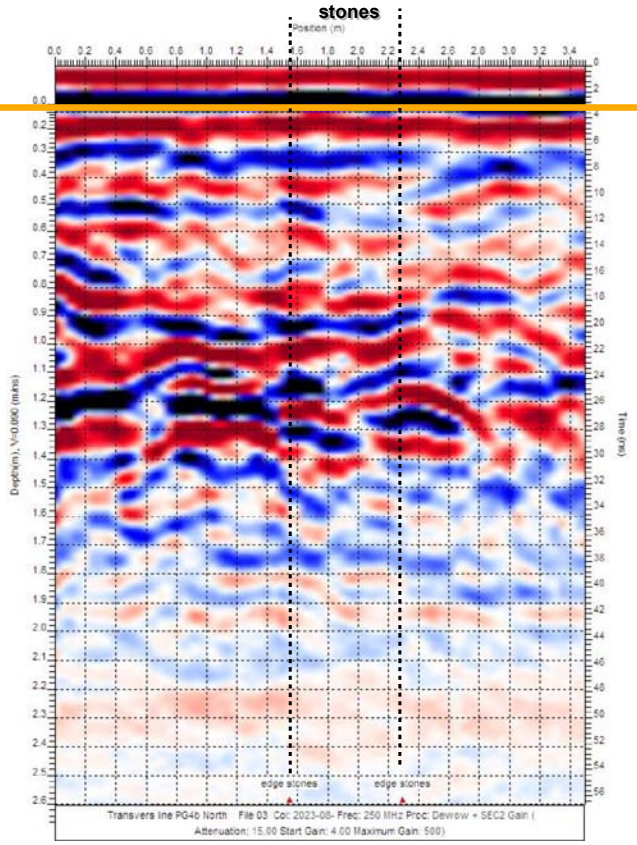

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Figure 11 **Radar File: Line 02**

Figure 12: Site PG4b. The southern stone line GPR traverse

Ground Penetrating Radar

Suspected Gravesites

Site PG4a

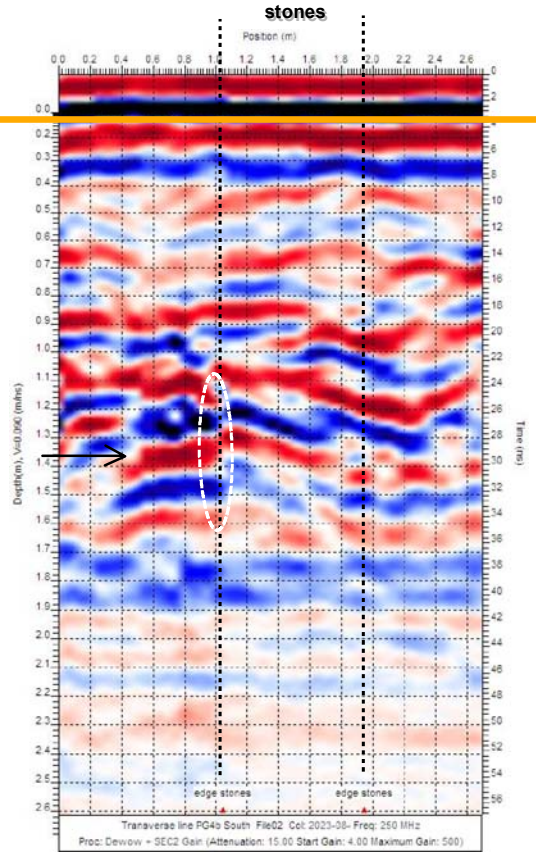
Twin Hills Project

250 MHz

SW **NE**

locality:

601237, 7584954
WGS84 UTM33S



Southern Traverse

sedimentary discontinuity

but too deep to be

caused by human activity

in a river bed

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Figure 13 **Radar File: Line 02**

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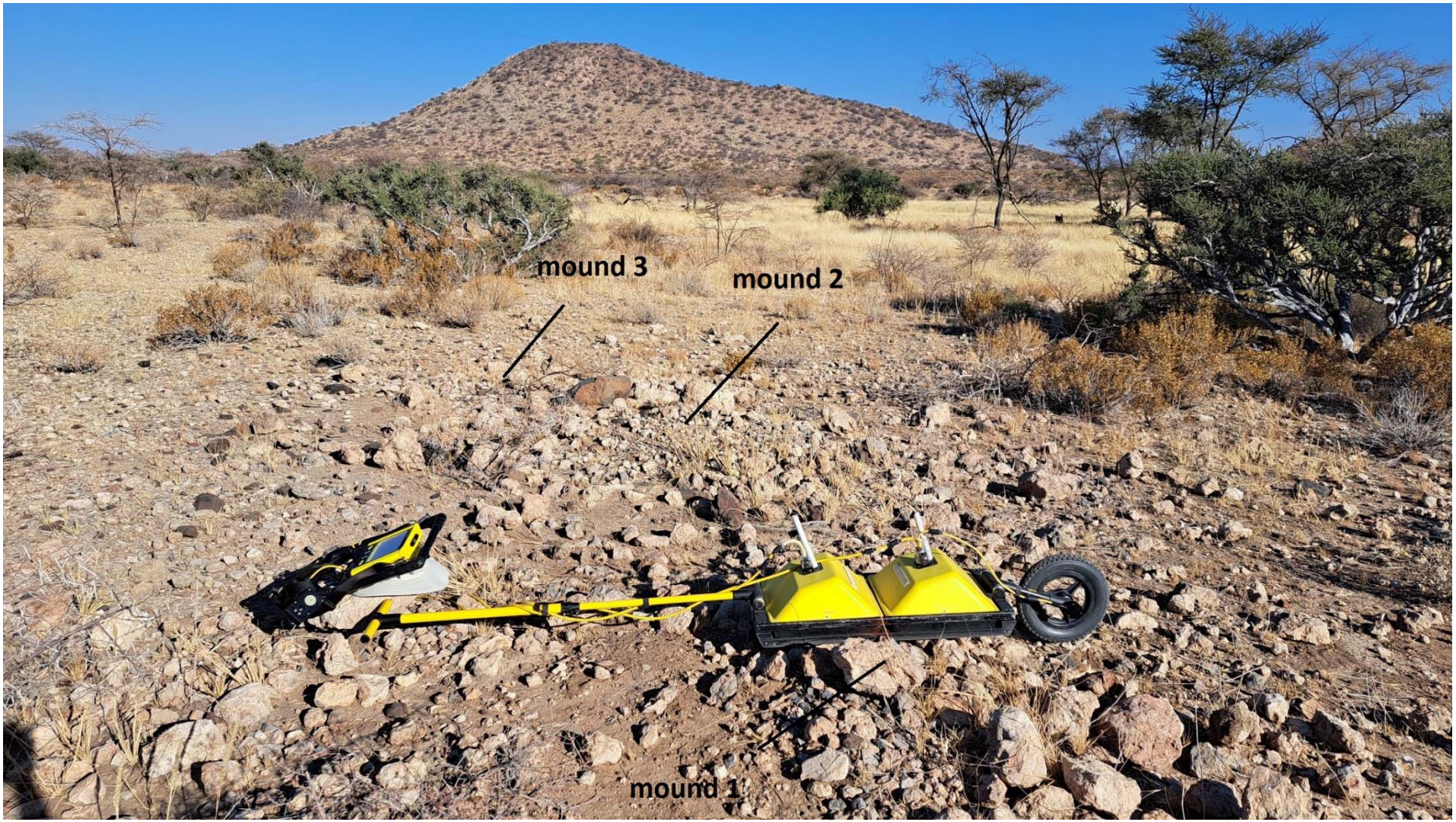

Figure 14: Site 478. GPR on ‘mound 1’. View to the east. Survey direction to the left.

Ground Penetrating Radar

Suspected Gravesites

Site 478

Twin Hills Project

250 MHz

locality:

598095, 7581215
WGS84 UTM33S

Mound 1

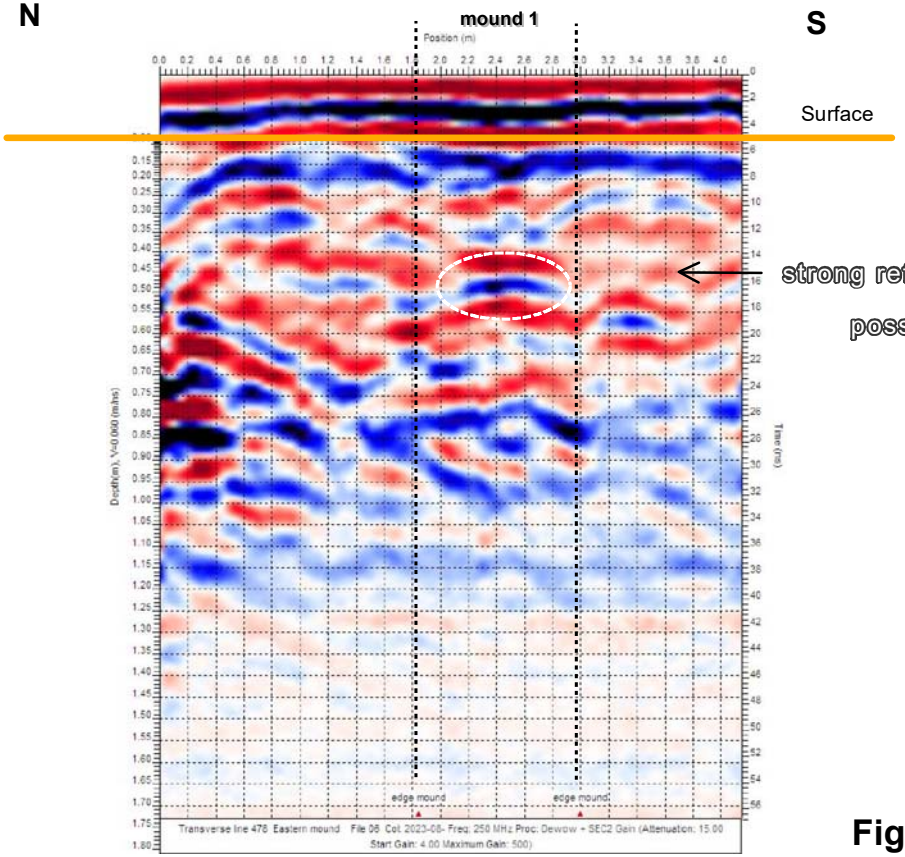

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Figure 15 **Radar File: Line 06**

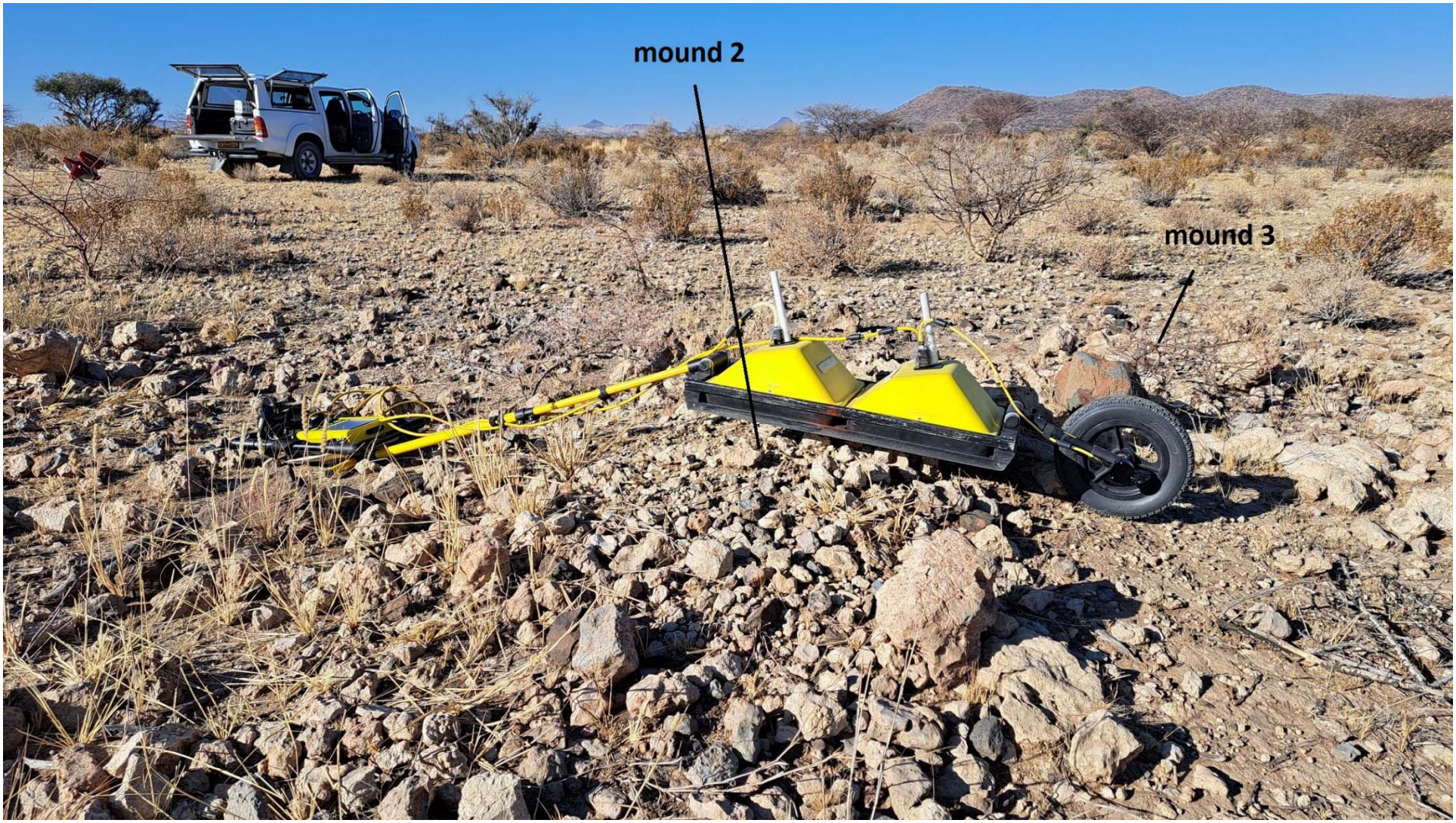


Figure 16: Site 478. GPR on ‘mound 2’. View to the south. Survey direction to the left.

Ground Penetrating Radar

Suspected Gravesites

Site 478

Twin Hills Project

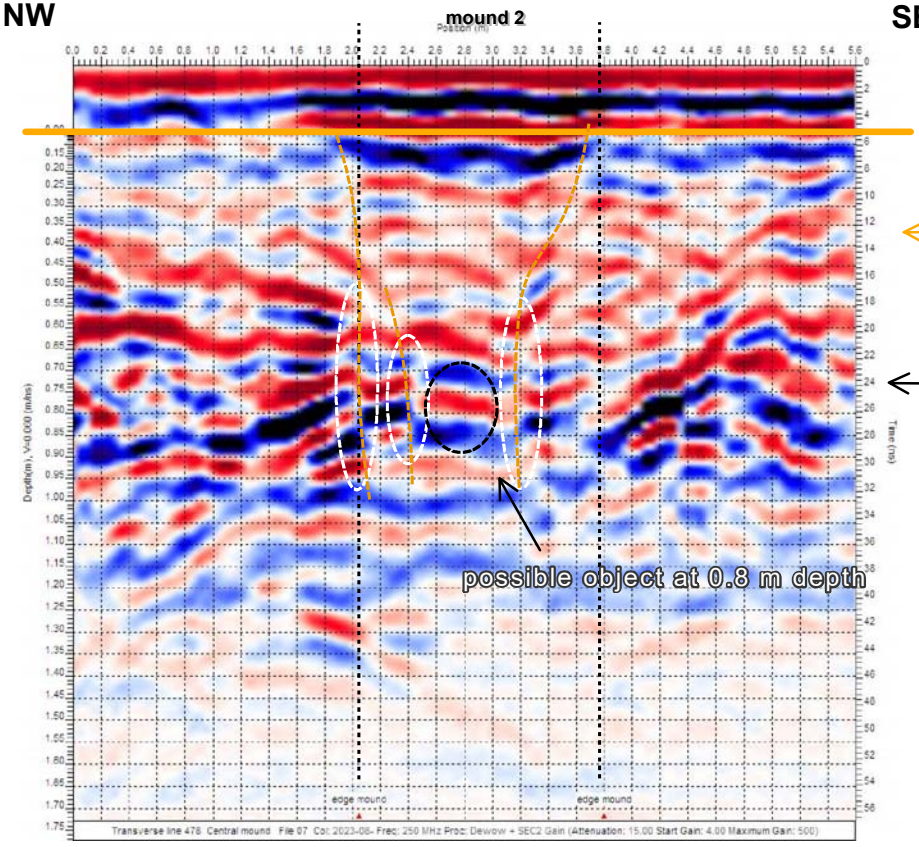
250 MHz

NW **SE**

locality:

598095, 7581215
WGS84 UTM33S

Mound 2



Earthmaps Consulting Aug 2023

Figure 17 **Radar File: Line 07**

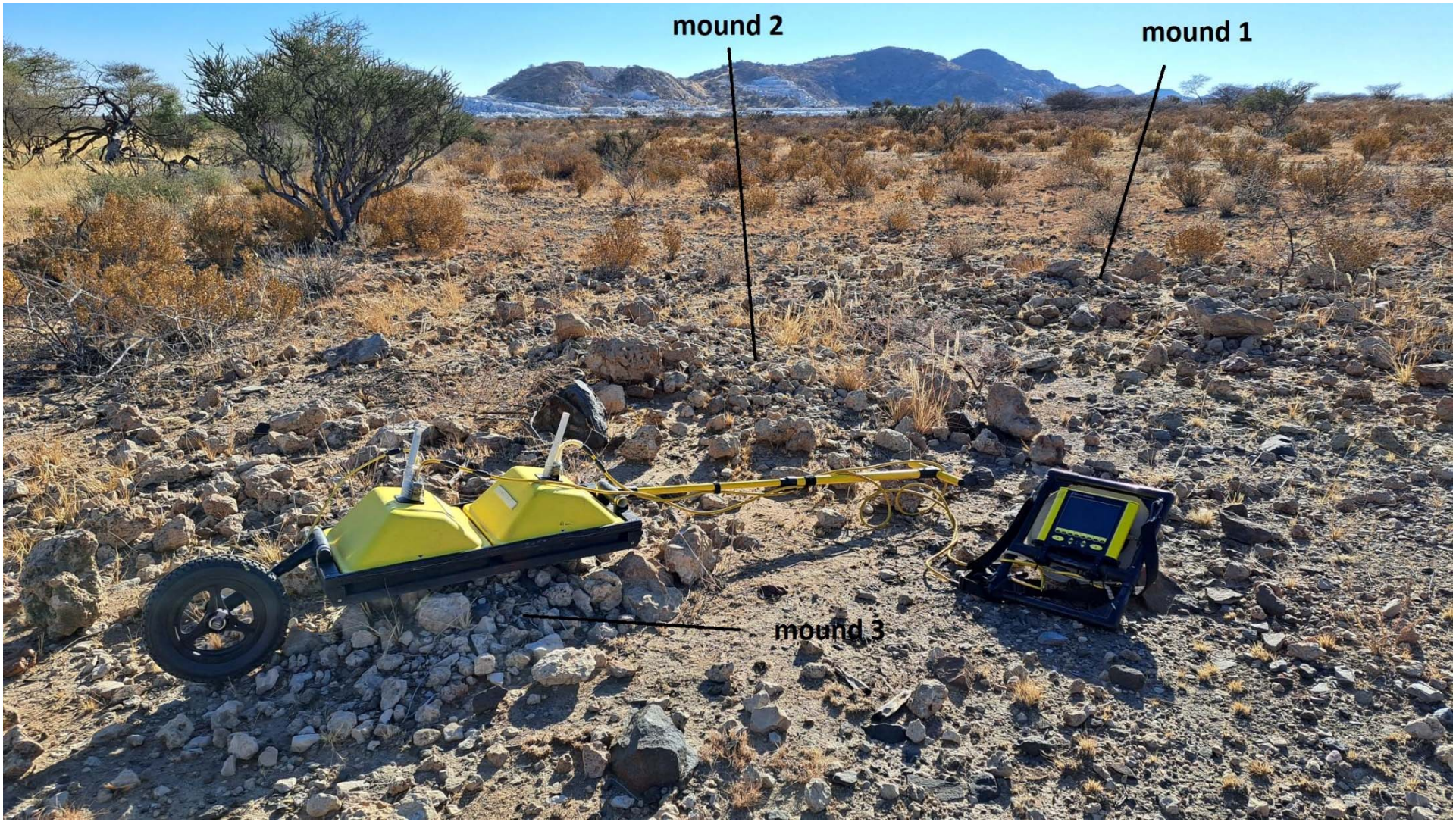


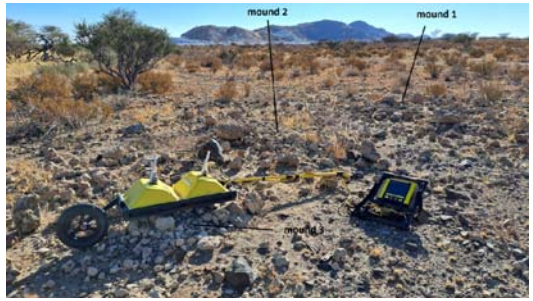
Figure 18: Site 478. GPR on ‘mound 2’. View to the east. Survey direction to the right

Figure 19: Site 478. GPR on ‘mound 2’. View to the east. Survey direction to the right

Ground Penetrating Radar

Suspected Gravesites

Site 478



Twin Hills Project

250 MHz

locality:

598095, 7581215
WGS84 UTM33S

Mound 3

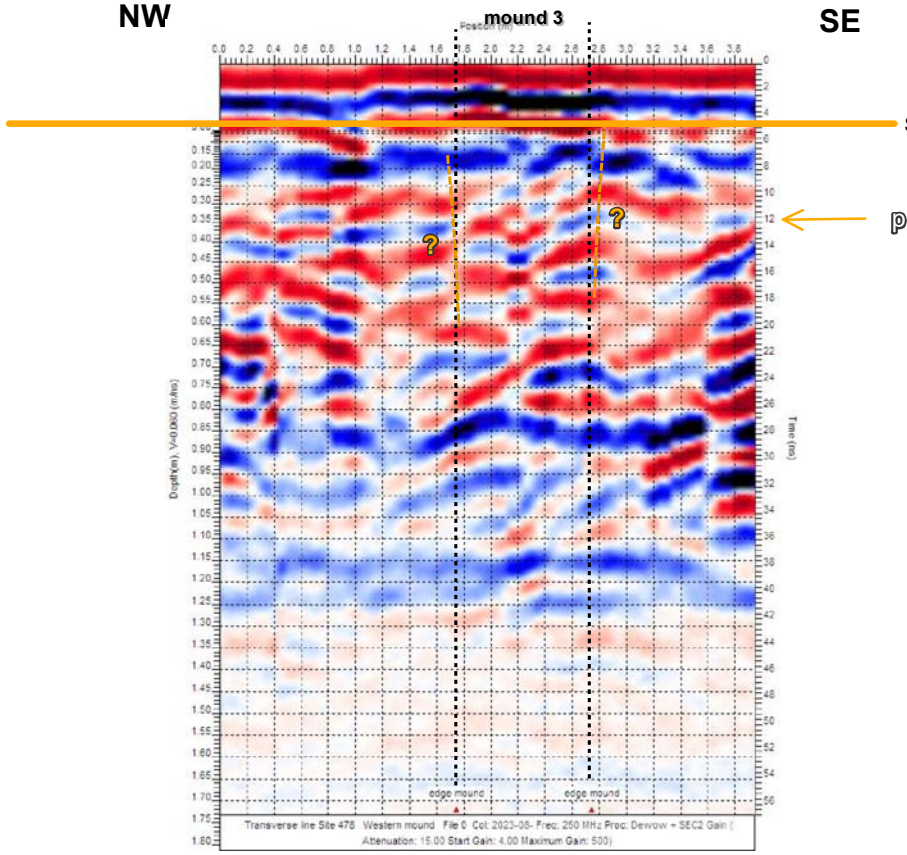


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Figure 20 **Radar File: Line 08**

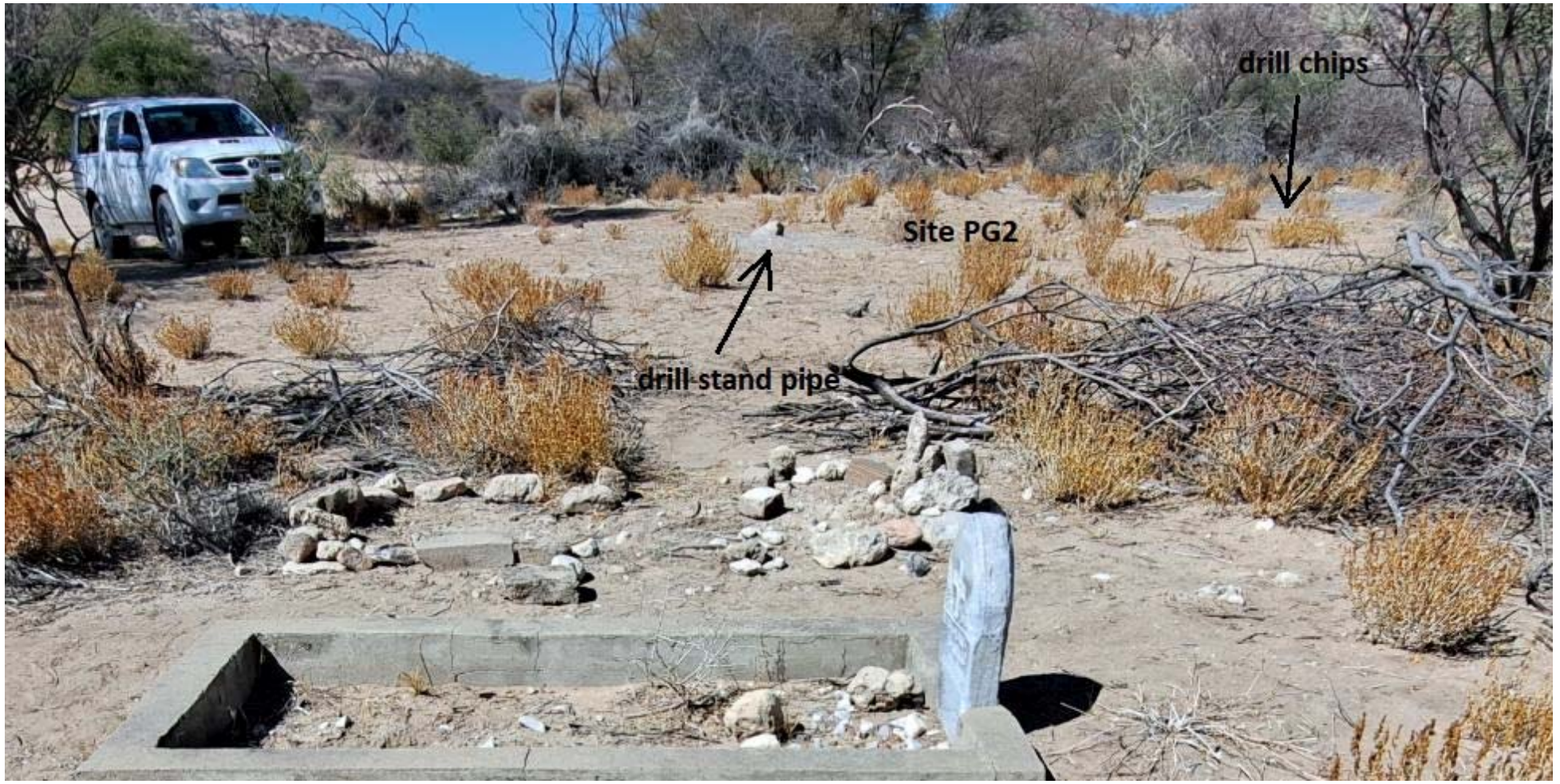

Figure 21: Site PG2. This is a drill site, and no indications of a grave site could be found. View to the south.