Palaeontological heritage: Fossil Destruction Permit Report

WATERLOO SOLAR PV FACILITY ON WATERLOO 922-IN NEAR VRYBURG, VRYBURG MAGISTERIAL DISTRICT, NORTHWEST PROVINCE

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EXECUTIVE SUMMARY

A permit for fossil destruction for the Waterloo Solar PV Facility on farm Waterloo 922-IN near Vryburg, Northwest Province was issued by SAHRA in 2018 (SAHRA Case ID: 12416; Permit ID: 2717). Subsequent mitigation of construction phase impacts on scientifically important Precambrian stromatolites within the project area has involved (1) the setting aside of a small Heritage Conservation Area (No-Go) which has been securely taped-off to exclude disturbance by vehicles and other activities and will eventually be fenced; (2) two specialist palaeontological monitoring site visits by the present author, and (3) on-going *ad hoc* monitoring by Environmental Liaison Officers (ELOs). The specialist site visits show that, following bush clearance and site levelling, potentially stromatolitic bedrocks are rarely well-exposed at surface, and are usually damaged by machinery. Stromatolites are difficult to either recognise or collect from freshly excavated bedrock where rock surfaces are largely obscured by dust and soil and often scratched, while the window of opportunity to inspect excavations and record / collect fossil material is usually short due to rapid back-filling. Palaeontological monitoring during the construction phase is therefore often of limited value.

Extensive shallow gravel and bedrock excavations for V-drains and within the PV panel array footprint have, for the most part, not yielded scientifically useful stromatolite material, with the notable exception of a several well-preserved cushion and cauliflower head stromatolites noted within gravels from a shallow trench just south of the HV Substation footprint (These specimens are to be curated with previously collected material from the study area by the Council for Geoscience, Bellville).

In the author’s opinion, mitigation of construction phase palaeontological impacts has been seriously and adequately addressed by the developer in the case of the Waterloo Solar PV Facility. Pending any exceptional new fossil finds, no further specialist palaeontological site visits are recommended for this project. The responsible ELO is encouraged to rescue, where feasible, unusually well-preserved stromatolitic blocks exposed within the construction footprint – preferably with associated GPS location data and photographs - and to safeguard them within the fenced-off Heritage Conservation Area. A photographic record of the completed security fence surrounding the Heritage Conservation Area and any significant new fossil finds made by the ELO, together with collection data, should be sent to SAHRA (Address: Dr Ragna Redelstorff. 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) and to the present author at the earliest opportunity.

1. PROJECT BACKGROUND

The company juwi Solar ZA Construction 4 (Pty) Ltd ("juwi") is currently engaged in the construction of a 75 MW solar PV facility on the farm Waterloo 922-IN near Vryburg, Northwest Province. An initial palaeontological heritage assessment of the project area by Almond (2013) recorded the presence of scientifically-valuable fossil microbial reefs or reef mounds, known as stromatolites, of Precambrian age. A range of well-preserved to partially-eroded stromatolites are exposed here at surface within 2.6 billion-year-old shallow marine sediments of the Boomplaas Formation (Ghaap Group, Transvaal Group). Following authorisation of the solar PV project (DEA Reference 14/12/16/3/3/1/1805, as amended), more detailed recording as well as sampling of fossil stromatolites within the project area was undertaken by Almond (2017) under the aegis of a Fossil Collection Permit issued by SAHRA (The South African Heritage Resources Agency) in 2017 SAHRA CaseID: 10938). This last report proposed the delimitation of a small Heritage Conservation Area in the south-eastern corner of the solar PV project area within which no construction was to take place with the aim of conserving a representative sample of Boomplaas Formation fossil stromatolites. A Fossil Destruction Permit for stromatolites within the (unprotected) remainder of the project area was then issued by SAHRA (2018;SAHRA Case ID: 12416; Permit ID: 2717) on condition that the proposed heritage conservation area was fenced-off during construction. A detailed Heritage Management plan for the long-term conservation and management of fossil stromatolites on Waterloo 922-IN was subsequently developed by Muller and Orton (2018). Their recommendations (summarized in their Appendix 6) include:

- The establishment of a Management Committee;
- Fencing of the palaeontologically sensitive area, including a 30 m buffer zone;
- Development of a fossil Chance Finds Procedure;
- Palaeontological monitoring of all works within the 30 m buffer zone; and
- Reporting on the palaeontological monitoring and state of the fence and fossil site.

The description of the authorised access road to the PV site has now been slightly amended in order to allow the proponent to micro-site the road as needed within a 25 m corridor to avoid the Eskom servitude, as well as to accommodate geological limitations on site and other sensitivities (*i.e.* avoidance of large trees and the stromatolite "no-go" area) (*cf* Letter of Almond 2019).

2. MONITORING METHODOLOGY

The present author was appointed by juwi in 2018 to undertake palaeontological specialist monitoring during the construction phase of the Waterloo Solar PV Facility. Following discussions with juwi (Ms Nazley Towfie, Project Development Manager; Mnr Johan Botha, Construction Manager; Mr Thibaud Abadie, Project Manager) in the context of the evolving construction phase programme, it was provisionally decided to undertake two short site visits in 2019 to coincide with intervals when (a) bush clearance had already taken place and (2) substantial excavations into potentially fossiliferous Precambrian bedrocks were still open.

The primary focus of these site visits, which took place on 22-23 March 2019 and 5 July 2019, was to:

- Interact with the Site Manager and Environmental Liaison Officers (ELOs) regarding palaeontological heritage conservation and ELO monitoring during the construction phase;
- Assess the effectiveness of protection of the designated Heritage Conservation Area;

- Assess impacts on (now unprotected) stromatolite occurrences within the PV facility development footprint through examination of representative bedrock excavations (trenches for V-drains, underground cables / PV panel footings) and cleared areas (access roads, laydown areas, PV panel array areas);
- *Ad hoc* sampling of any newly-exposed stromatolite material of scientific value to add to the collections already made in 2017 and now curated by the Council for Geoscience, Bellville.

3. MONITORING VISIT OUTCOMES

(a) Interaction with construction phase Environmental Liaison Officers

During the two visits it was possible to meet on site with the Environmental Liaison Officers Mnr Reino le Fleur and Mnr Hein Potgieter to discuss stromatolite recognition and scientific significance, maintenance of the Heritage Conservation Area, as well as on-going ELO monitoring during the construction phase. The ELO officers as well as the Site Manager Mnr Johan Botha were very helpful in facilitating access to various parts of the site and in explaining construction phase activities of relevance to fossil conservation.

(b) Protection of the Heritage Conservation Area (HCA)

At the time of the site visits the Heritage Conservation Area (including 30 m buffer as shown in Figs. 1 to 3) was well-demarcated using security tape strung between vertical wooden poles (Fig. 5). The tape was being renewed at intervals to compensate for wind damage. These measures had effectively protected the designated core and buffer areas from disturbance by vehicle activity; they are designated as no-go areas for construction staff. The only negative observation was that a few loose stromatolitic blocks, whose fossiliferous nature was probably unrecognised at the time, had been utilised to brace the bases of some of the wooden poles (now rectified).

The protected HCA extends almost up to the edge of the (amended) alignment of the access road which bends round the eastern and southern edges of the area (Figs. 3 & 5). A foot survey around the outer periphery of the protected area confirmed that there were numerous undisturbed occurrences of *in situ* stromatolites (Fig. 6) as well as stromatolitic float blocks (*i.e.* blocks loose on the surface) just outside the protected area, notably along its south-western edge (*selected* fossil waypoints are shown in Fig/ 3). However, all these stromatolitic types are well-represented within the protected area itself, so unique fossil material is not considered to be vulnerable here. The western areas shaded in green in Figure 1 were largely undisturbed by July 2019, while those peripheral green-shaded areas in the east (some of which extend into a neighbouring property) had already been disturbed by access road and fence construction and vehicle activity at the time of the first site visit in March 2019. Several examples of crushed cherty stromatolites were observed within or alongside the access road in this region (Figs. 7) (This was anticipated and is *not* considered to be a significant heritage resource loss). Full-time professional monitoring of these green-shaded areas during construction, as recommended by Muller and Orton (2018), is regarded by the present author as too onerous, given that (1) they lie outside the recommended heritage conservation area and are therefore covered by the 2018 SAHRA destruction permit; (2) monitoring here is unlikely to yield unique or new types of stromatolite, and (3) these areas have already been briefly examined for potential fossil sampling in 2017.

The Heritage Conservation area will be fully fenced by the end of the construction phase. Care must be taken not to use or displace loose blocks of stromatolitic material during fence construction. The fence will have a gate that will also be required for continued access by Eskom along the existing 22 kV powerline servitude (Maroon lines in Fig. 3; see also pylons in Fig. 5). Intermittent Eskom maintenance activities here are not considered to pose a significant threat to the fossil site.

Figure 1: Satellite image of the south-eastern corner of the Waterloo Solar PV Facility on farm Waterloo 922-IN near Vryburg, Northwest Province (This figure and the following key have been abstracted from the Heritage Management Plan by Muller & Orton 2018).
Blue lines: Northeast and southeast edges of development footprint
Yellow line: Approved access road (*N.B. slightly amended in 2019 – see Figure 3)*
Red polygon: Core of sensitive stromatolite area enclosing the waypoints presented by Almond (2017: Appendix 1).
Orange shaded polygon: Buffer area around core area. This is the minimum area to be fenced.
Green shaded polygon: Areas that require full time professional palaeontological monitoring *(But see comments in text).*

(c) Impacts on fossil heritage outside the Heritage Conservation Area

During the two palaeontological site visits a representative sample of on-going bedrock excavations within the PV Solar Facility project area was examined with a view to assessing impacts on fossil heritage associated with the construction phase of the main PV site. Destruction of fossil material outside the Heritage Conservation Area has already been authorised under the aegis of the SAHRA Fossil Destruction Permit (2018); in this context a Chance Fossil Finds Protocol is perhaps redundant. However, the responsible ELOs have been encouraged to rescue, where feasible, unusually well-preserved stromatolitic blocks exposed within the construction footprint – preferably with associated GPS location data and photographs - and to safeguard them within the fenced-off Heritage Conservation Area. Outstanding fossil finds during the construction phase should be reported to the monitoring palaeontologist for possible mitigation.

Following bush clearance and spreading of compacted topsoil and gravels within the extensive flat areas earmarked for PV solar panel arrays, laydown areas and access roads, very little bedrock exposure is now visible (Figs. 7 & 10). Only limited bedrock excavation was necessary for the construction of the laydown areas and service roads. Very occasional small patches of cherty or carbonate bedrock, usually scraped and fractured, can be seen in these sectors of the project footprint, but no well-preserved stromatolites could be recorded here; if present, they are now sealed-in beneath a veneer of disturbed, freshly-compacted soil and regolith. Clearly, palaeontological surveying after rather than before bush clearance would *not* have been very effective, even in fossil-rich areas.

Shallow (*c.* 30 to 150 cm), trench-like excavations for V-drains along the margins of laydown areas and PV panel areas early on in construction have involved digging through thin to thick, gravelly soils and, locally, through carbonate bedrock (Figs. 15 & 21). Occasional stone artefacts – including cherty flakes and a classic, thin, almond-shaped biface (hand axe) – embedded within subsurface gravels exposed in the open trenches as well as among the excavated rubble suggest that the material overlying the bedrock is probably Pleistocene age or younger (Fig. 26). As usual, freshly-broken or weathered rock surfaces on excavated blocks are largely obscured by adherent dust and soil and perhaps obscured or defaced by scratches made by heavy machinery. Fossil stromatolites are very difficult to recognise under these circumstances (Figs. 18 to 20), although fine-scale stromatolitic lamination may occasionally be picked out by colour-contrast (*e.g.* occasional pale cherty or rusty-brown, ferruginous laminae) on cleaner broken or weathered rock surfaces (Figs. 16 & 17).

Extensive bedrock excavation (locally including blasting) has also proved necessary for the construction of shallow trenches for underground cables and panel footings in parts of the PV array areas (Figs. 11 to 13). A large volume of freshly-excavated and comparatively clean, grey carbonate blocks in the PV panel array areas was inspected in July 2019. Following excavation, the larger blocks are further broken up for transport and then the rubble is dumped in an existing borrow pit on Waterloo 922 (borrow pit location: 27 00 59.7 S, 24 47 25.1 E) (Fig. 14). Following infilling, the borrow pit will be rehabilitated with a covering of topsoil. Stromatolitic horizons here appear to be either very rare or, at most, subtle here - *i.e.* not obviously picked-out by colour-contrasting secondary mineralisation (chert / iron minerals). The great majority of the excavated bedrock appears to consist of massive to bedded non-stromatolitic carbonate, or occasionally of laminated pale grey carbonate with weathered siltstone interbeds. No well-preserved stromatolite horizons were recorded within excavated bedrock either in the PV panel array areas or in the borrow pit infill; freshly broken surfaces occasionally show fine stromatolitic lamination.

It is considered likely that richly-stromatolitic beds in the Boomplaas Formation developed mainly in shallow water settings close to shore or in the intertidal zone. Due to their different fine-scale properties (*e.g.* carbon context / porosity / permeability) the stromatolitic horizons were preferentially silicified during diagenesis (early post-burial history of rock). The resistant-weathering silicified beds tend to slow down erosional denudation of the landscape so these stromatolitic horizons commonly come to cap persistent land surfaces, giving the misleading impression that the entire rock unit is highly fossiliferous. The most easily-recognised (and collectable) stromatolites are generally those that have been preferentially silicified and naturally prepared out as 3d structures by protracted near-surface weathering. This is the case in the eastern sector of the PV facility project area where the Heritage Conservation Area is situated. Offshore, where deeper water conditions prevailed, the sea bed lay below the well-illuminated photic zone and photosynthetic benthic stromatolites did not grow. Here massive to laminated carbonate muds accumulated and in terms of thickness and volume these facies probably constitute the majority of the Boomplaas Formation. This may apply to much of the central and western sectors of the PV facility project area. If true, the negative impact significance of the construction phase of the solar facility as a whole in terms of fossil heritage resources would be much lower that originally feared.

(d) Additional *ad hoc* sampling of well-preserved stromatolites

A few richly-stromatolitic, newly-excavated carbonate blocks (since broken–up) were recorded in March 2019 in the eastern and northern sectors of the PV project area (Figs. 18 to 20). Locally, the rubbly reglolith overlying the comparatively fresh carbonate bedrocks contains a concentration of highly-silicified to weathered and leached stromatolitic blocks, most of which are not of scientific value. In March 2019 coarse, however, rubbly material excavated from a WSW-ENE trench between the footprints of the HV substation and a laydown area (Locs. 340-345, outlined by a red ellipse in Fig. 4) yielded numerous well-preserved stromatolitic blocks as well as much useless weathered material. Among these were several partial or intact specimens of small stromatolites of two distinct types (Figs. 21 to 25) that are informally named here:

(1) *stromatolitic cushions*: pillow-shaped stromatolite heads that are elliptical or rounded in plan view (*c*. 20-30 cm diam.), flattened to slightly domed in vertical section, with dimpled to pustulose upper surfaces and crenulated internal lamination. The lamination characteristically curves down steeply and then bends inwards (recurves) around the periphery of the cushion. This stromatolitic form has not been previously recorded from the study area.

(2) *cauliflower stromatolites*: small (*c*. 15-20 cm diam.), markedly conical stromatolitic heads with a thinly-laminated, tapering base surrounded by an expanding head of close-packed, superimposed stromatolitic buttons. This form has been previously recorded from Waterloo 922-IN by Almond (2013). In addition to isolated examples from excavated gravels, a large, inverted carbonate block containing several *in situ* examples of cauliflower head stromatolites was recorded in this area (Fig. 19); between the conical heads the bedrock was packed with smaller scale stromatolites showing pronounced lateral accretion (Fig. 20). Unfortunately this block was too large to collect and has since been broken-up, while by July 2019 the V-drain trenches had largely been back-filled. A representative collection (*c*. 20 blocks) of the smaller stromatolitic cushions and cauliflower heads from the main trench site described above was made in March 2019 and will be added to the Boomplaas Formation stromatolite material from farm Waterloo 299-IN already curated at the Council for Gesocience, Bellville (*cf* Almond 2017). As with modern coral reefs, contrasting stromatolite morphologies - large domes, cauliflower heads, micro-stromatolitic buttons, gently convex cushions, laterally-accreting medium-scale domes or columns – would have developed in different parts of the Precambrian microbial reef, depending on local environmental controls such as water depth, current activity, turbulence, sediment supply *etc*.

4. CONCLUSIONS & RECOMMENDATIONS

Mitigation of construction phase impacts on scientifically important Precambrian stromatolites within the Waterloo Solar PV Facility on Waterloo 922-IN near Vryburg has involved (1) the setting aside of a small Heritage Conservation Area (No-Go) which is currently securely taped-off to exclude disturbance by vehicles and other activities and will ultimately be fenced-off; (2) two specialist palaeontological monitoring site visits, and (3) on-going monitoring by ELO staff.

In general, the most readily recognised, collectable and scientifically useful fossil stromatolites are those that have been secondarily silicified during diagenesis and prepared-out at surface by natural weathering. Surveying and sampling of surface material as well as the designation of fossil-rich no-go areas *before* construction is the most effective way to mitigate solar facility developments in stromatolite-rich areas. Following bush clearance and site levelling, stromatolitic bedrocks are rarely well-exposed, and have usually been damaged by machinery. It is noted that surface disturbance due to access road construction is often considerably more extensive than anticipated from the project description (*cf* Figs. 8 & 9); this needs to be borne in mind during pre-construction heritage surveys. Stromatolites are not easy to recognise or collect from freshly excavated bedrock where rock surfaces are largely obscured by dust and soil and often scratched, while the window of opportunity to inspect excavations and record / collect fossil material is usually short due to rapid back-filling. Palaeontological monitoring during the construction phase is therefore often of limited value.

In the case of the Waterloo Solar PV Facility on Waterloo 922-IN a small Heritage Conservation Area featuring a representative sample of well-preserved stromatolites from the Boomplaas Formation (Ghaap Group) has been well-protected by security tape during the construction phase and will ultimately be fenced-off. This eastern sector of the project area where the Heritage Conservation Area is located appears to be the most stromatolite-rich. Extensive shallow gravel and bedrock excavations for V-drains and within the PV panel array footprint have, for the most part, not yielded scientifically useful stromatolite material, with the notable exception of a several well-preserved cushion and cauliflower head stromatolites collected from gravels excavated from a shallow trench just south of the HV Substation footprint (The specimens are to be curated by the Council for Geoscience, Bellville). Most carbonate bedrock excavated within the PV panel array footprints is massive to thin-bedded rather than stromatolitic. It may well be that well-developed stromatolitic horizons constitute only a minor part of the Boomplaas Formation succession but are over-represented on land surfaces because they are more weathering-resistant, and hence prominent, due to secondary silicification.

In the author's opinion, mitigation of construction phase palaeontological impacts has been seriously and adequately addressed by the developer in the case of the Waterloo Solar PV Facility. Pending exceptional new fossil finds, no further specialist palaeontological site visits are recommended for this project. The responsible ELO is encouraged to rescue, where feasible, unusually well-preserved stromatolitic blocks exposed within the construction footprint – preferably with associated GPS location data and photographs - and to safeguard them within the fenced-off Heritage Conservation Area. A photographic record of the completed security fence surrounding the Heritage Conservation Area and any significant new fossil finds should be sent to SAHRA (Address: Dr Ragna Redelstorff. 111 Harrington Street, Cape Town. PO Box 4637, Cape Town 8000, South Africa. Phone: +27 (0)21 462 4502. Fax: +27 (0)21 462 4509. Web: www.sahra.org.za) and to the present author at the earliest opportunity.

5. ACKNOWLEDGEMENTS

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6. REFERENCES

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7. QUALIFICATIONS & EXPERIENCE OF THE AUTHOR

Dr John Almond has an Honours Degree in Natural Sciences (Zoology) as well as a PhD in Palaeontology from the University of Cambridge, UK. He has been awarded post-doctoral research fellowships at Cambridge University and in Germany, and has carried out palaeontological research in Europe, North America, the Middle East as well as North and South Africa. For eight years he was a scientific officer (palaeontologist) for the Geological Survey / Council for Geoscience in the RSA. His current palaeontological research focuses on fossil record of the Precambrian - Cambrian boundary and the Cape Supergroup of South Africa. He has recently written palaeontological reviews for several 1: 250 000 geological maps published by the Council for Geoscience and has contributed educational material on fossils and evolution for new school textbooks in the RSA.

Since 2002 Dr Almond has also carried out palaeontological impact assessments for developments and conservation areas in the Western, Eastern and Northern Cape, Limpopo, Northwest, KwaZulu-Natal, Mpumalanga and the Free State under the aegis of his Cape Town-based company *Natura Viva* cc. He has served as a long-standing member of the Archaeology, Palaeontology and Meteorites Committee for Heritage Western Cape (HWC) and an advisor on palaeontological conservation and management issues for the Palaeontological Society of South Africa (PSSA), HWC and SAHRA. He is currently compiling technical reports on the provincial palaeontological heritage of Western, Northern and Eastern Cape for SAHRA and HWC. Dr Almond is an accredited member of PSSA and APHP (Association of Professional Heritage Practitioners – Western Cape).

Declaration of Independence

I, John E. Almond, declare that I am an independent consultant and have no business, financial, personal or other interest in the proposed development project, application or appeal in respect of which I was appointed other than fair remuneration for work performed in connection with the activity, application or appeal. There are no circumstances that compromise the objectivity of my performing such work.

Dr John E. Almond
Palaeontologist, *Natura Viva* cc

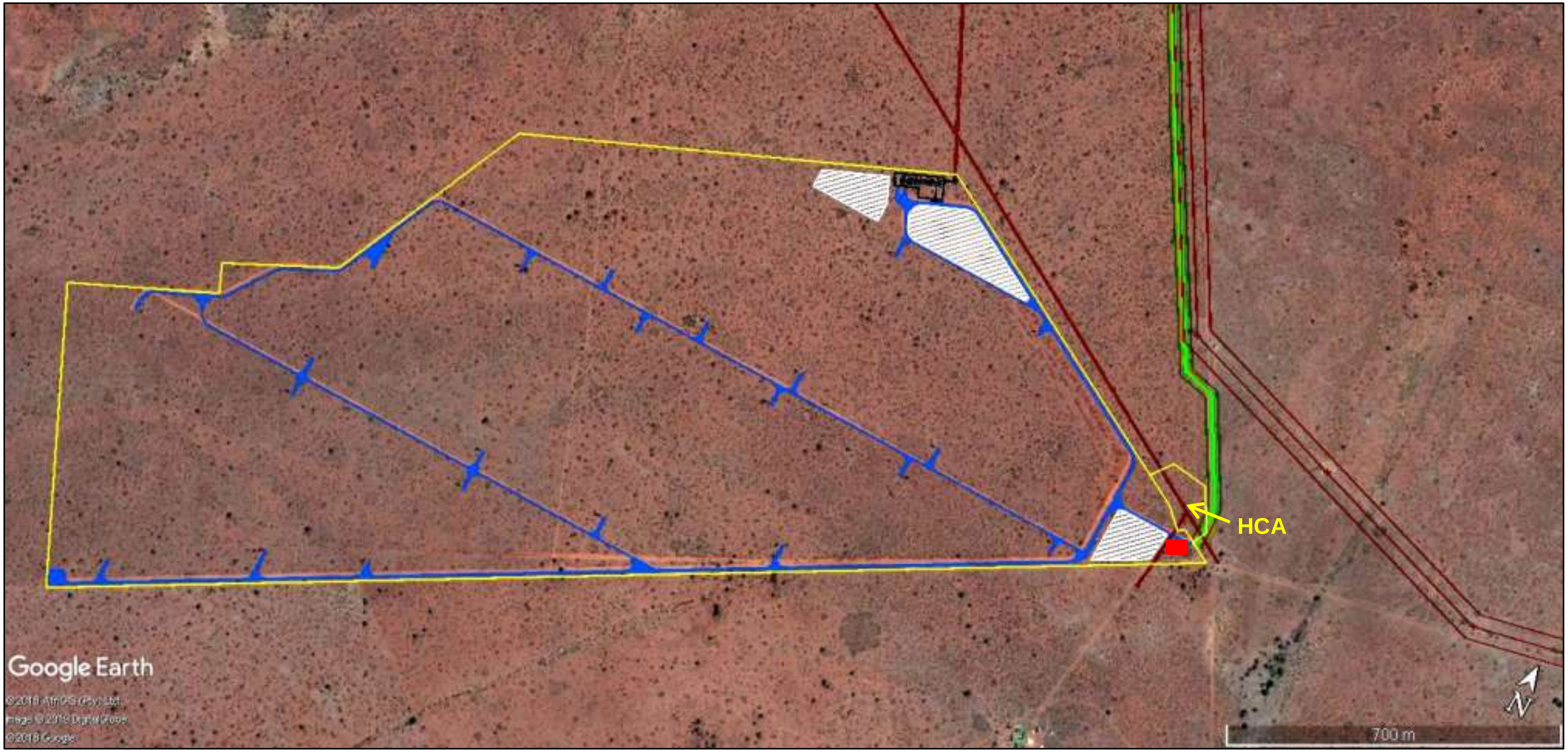

Figure 2: Google Earth© satellite image of the main footprint of the authorised Waterloo Solar PV Facility on farm Waterloo 922-IN near Vryburg, Northwest Province. Yellow line – fence with separately demarcated small Heritage Conservation Area (HCA). Blue lines - internal access roads. White hatched polygons – laydown areas. Black – HV Substation. Red – Operations and Maintenance Buildings. Green – main access road. Maroon lines – powerlines and servitudes (400 kV, 132 kV, 22 kV). The PV panel arrays are not shown here. *N.B.* North is towards the top RHS.

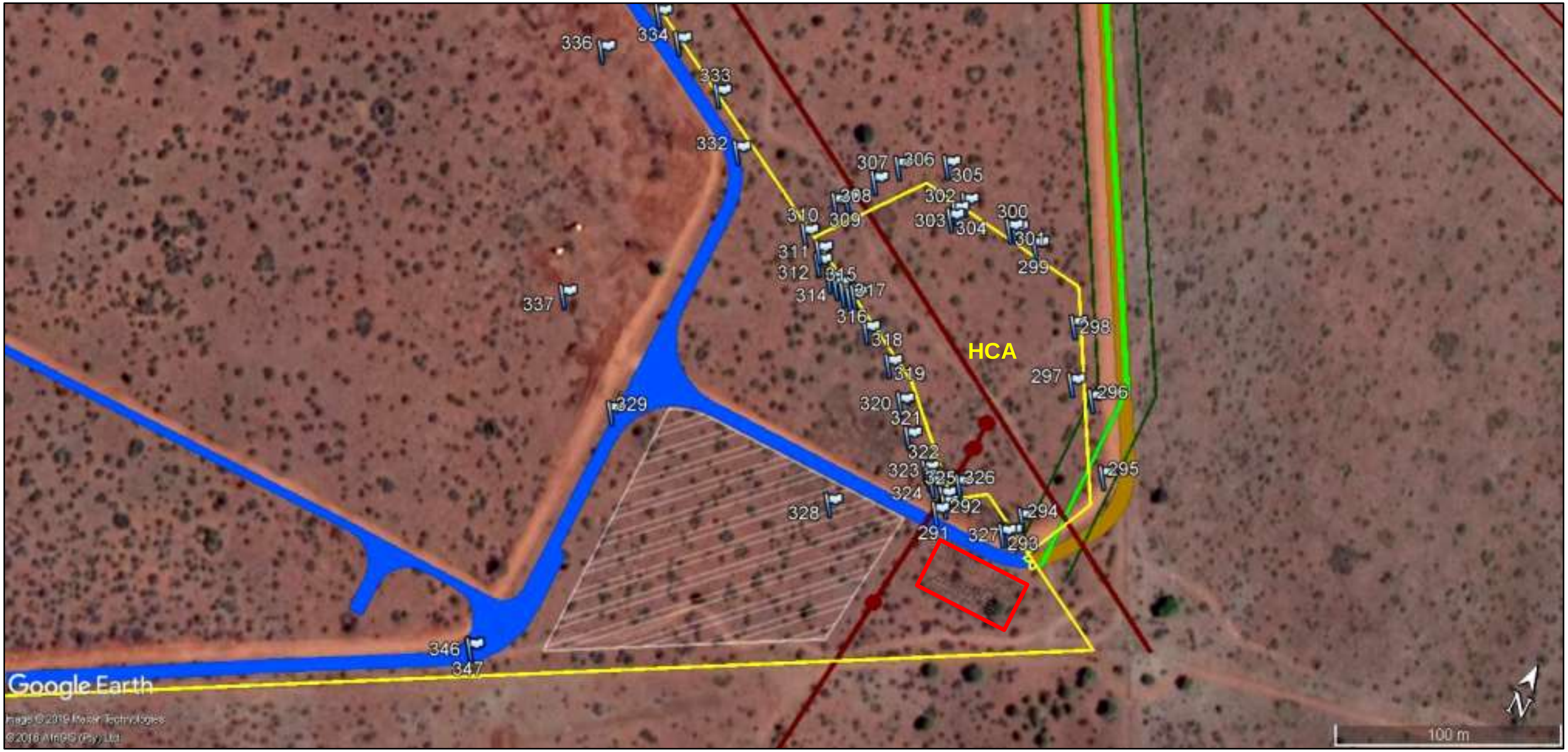

Figure 3: Google Earth© satellite image of the south-eastern corner of the main PV facility footprint (*N.B.* slightly displaced wrt the satellite image). Key as for the previous figure. Numbered waypoints refer to 2019 fossil and geological as well as a few incidental archaeological observations (See Appendix 1). The amended route of the main access road (ochre) bends round the eastern corner of the Heritage Conservation Area (HCA).

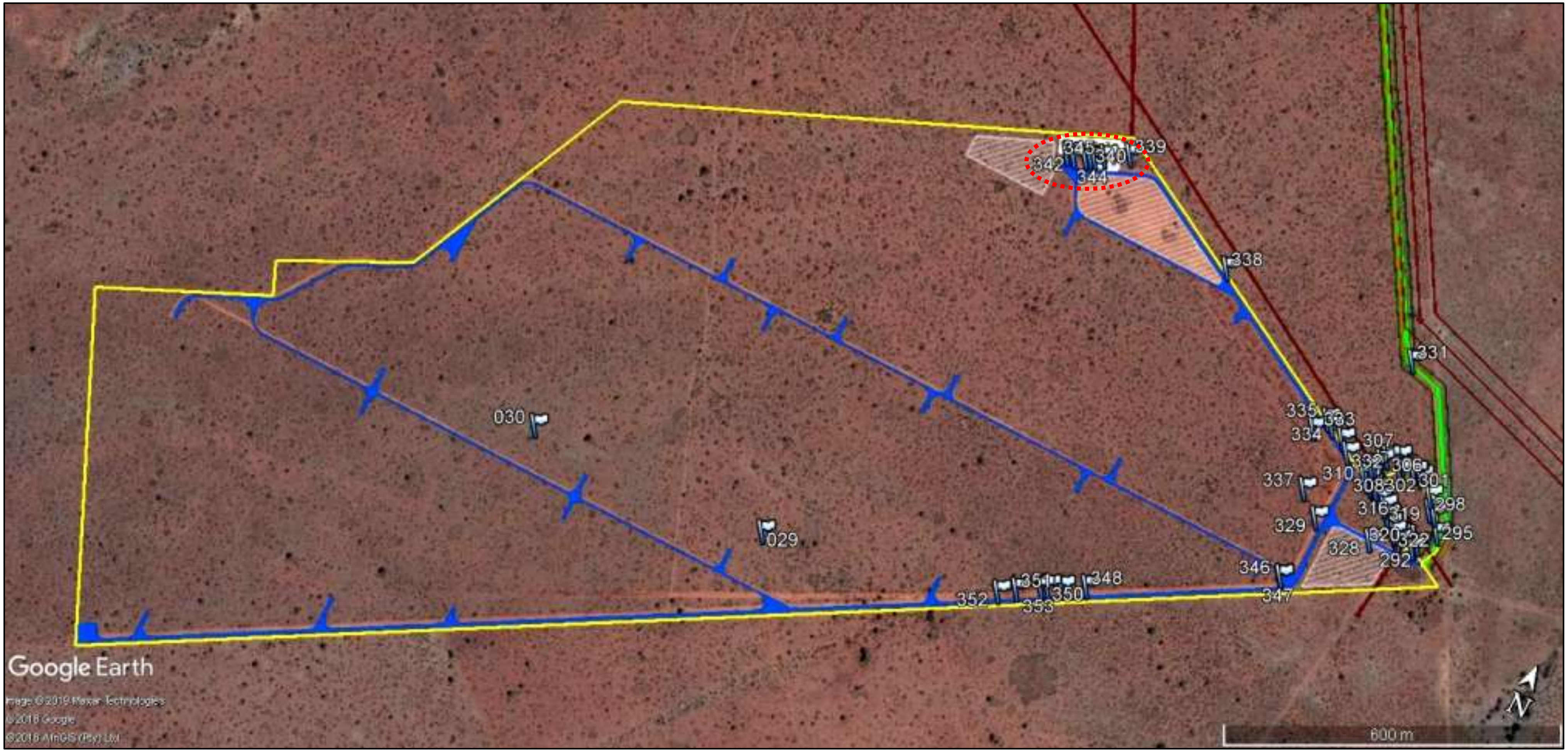

Figure 4: Google Earth© satellite image of the main footprint of the authorised Waterloo Solar PV Facility on farm Waterloo 922-IN near Vryburg, Northwest Province. Numbered waypoints refer to 2019 fossil and geological as well as a few archaeological observations (See Appendix 1). Most of these are concentrated around the Heritage Conservation Area in the east, but others are associated with ongoing bedrock excavations for V-drains, underground cables and PV panel footings. The red dotted ellipse outlines well-preserved stromatolites collected from rubble excavated from a shallow trench just south of the HV Substation footprint.

Figure 5: The small Heritage Conservation Area (HCA), viewed from the adjacent access road on the NW side and secured by security tape (July 2019). Note an existing Eskom 22 kV powerline already passes through the area.

Figure 6: Example of numerous undisturbed, well-preserved stromatolites observed outside the edge of the Heritage Conservation Area (Loc. 317). These stromatolite forms are well-represented within the HCA itself.

Figure 7: Surface scraping for the main access road that adjoins the HCA (background on RHS) has inevitably damaged silicified stromatolite domes (foreground).

Figure 8: Surface disturbance by vehicle activity during the construction phase often extends well beyond the edge of the access roads. This is important to note for pre-construction heritage walkdown surveys for comparable developments.

Figure 9: Displaced andesitic boulders along the W-E sector of the main access road (Loc. 330). The bedrocks here are igneous and therefore not fossiliferous.

Figure 10: Following bush clearance, site levelling and spreading of gravelly soil, there is virtually no bedrock exposure left within laydown areas (here due SW of the Heritage Conservation Area).

Figure 11: In some areas shallow trenches for underground cables in the PV panel array areas mainly intersect gravelly soils (Loc. 029).

Figure 12: Blocks of carbonate bedrock excavated from cable trenches are often soil-covered and scratched, compromising the search for well-preserved fossils (Loc. 029).

Figure 13: Blasting in areas where carbonate bedrock lies near-surface has yielded numerous blocks with fresh, clean surfaces – but in general the beds here do not reveal well-developed stromatolitic horizons (Loc. 030).

Figure 14: Rock rubble from the PV facility construction site has been dumped within an existing borrow pit on the farm Waterloo 922-IN (Loc. 031). The blocks seen here are dirty, scratched and no good stromatolite occurrences were noted.

Figure 15: Large blocks of Boomplaas carbonate bedrock recently excavated from V-drain trenches showing persistent patina of soil and extensive scratching (Loc. 338) (Hammer = 30 cm).

Figure 16: Clean, freshly-broken surfaces of grey carbonate may show fine stromatolitic lamination but well-preserved, intact stromatolites are not easily seen under these circumstances (Loc. 334) (Scale in cm and mm).

Figure 17: Fine concentric banding in some carbonate bedrocks may be due to inorganic precipitation rather than rhythmic microbial growth. The rusty-brown structures here are cubical pseudomorphs after pyrite, up to 1 cm across (Loc. 307).

Figure 18: Large blocks of Boomplaas Formation carbonate excavated from a V-drain trench showing a well-developed horizon of medium-sized, laterally-accreting stromatolites that are partially oscured by adherent soil (Loc. 335) (Scale is *c*. 15 long).

Figure 19: Inverted block of Boomplaas Formation carbonate excavated from a V-drain trench showing the conical, finely-laminated bases of two prominent-weathering cauliflower head stromatolites (Loc. 340) (Scale in cm). The specimen in the foreground is damaged.

Figure 20: Close-packed, medium-sized, laterally-accreting stromatolites build the bulk of the bed shown in the previous figure but are largely obscured by soil (Loc. 340).

Figure 21: Coarse rubbly chert and carbonate material excavated from a trench just south of the HV Substation footprint (Loc. 345). The gravels here contain weathered as well as well-preserved small stromatolites such as those shown in the following four figures.

Figure 22: Examples of stromatolites (arrowed) within gravelly material excavated from the trench shown above (Loc. 345) (Hammmer = 30 cm).

Figure 23: Several pieces of stromatolite cushions among recently excavated gravels (Loc. 344) (Scale is *c*. 15 cm long).

Figure 24: Good example of cushion-shaped stromatolite head with finely-pustulose or crenulated outer surface and wavy internal laminae. The lamination typically bends down steeply around the periphery of the cushion and may be recurved inwards (Loc. 343) (Scale in cm).

Figure 25: Two well-preserved examples of cauliflower stromatolitic heads with tapering bases and expanded tops composed of small buttons, here viewed from above (LHS) and the side (RHS) (Loc. 343) (Scale in cm).

Figure 26: Well-formed almond-shaped biface or hand axe (arrowed) of quartzite among cherty and carbonate gravels excavated from a V-drain trench (Loc. 350) (Hammer = 30 cm). Several other hand axes, cores and flakes were observed within or overlying the reworked gravels in this area, suggesting a probable Pleistocene or younger age.

APPENDIX: Vryburg Waterloo Solar PV Facility – additional fossil and geology waypoints (March and July 2019)

All GPS readings were taken in the field using a hand-held Garmin GPSmap 60CSx instrument. The datum used is WGS 84 (*N.B.* Buried stromatolites may be present in many areas where no fossil data is shown).

Loc	GPS data	Comments
029	S27° 02' 24.6" E24° 47' 23.1"	Ongoing trenching for underground cables within PV panel area.
030	S27° 02' 25.3" E24° 47' 06.9"	Ongoing trenching for underground cables within PV panel area.
031	S27° 00' 59.7" E24° 47' 25.1"	Existing farm borrow pit where bedrock rubble from PV site is being dumped. Large volume of freshly excavated grey carbonate blocks but no obvious stromatolitic horizons.
292	S27° 02' 08.3" E24° 47' 59.7"	Overturned block of carbonate with mini-stromatolitic buttons.
293	S27° 02' 08.3" E24° 48' 00.7"	Patches of scraped cherty bedrock within new access road area.
294	S27° 02' 08.0" E24° 48' 00.8"	Large *in situ* domal stromatolite in disturbed context, edge of approved access road.
295	S27° 02' 06.9" E24° 48' 01.7"	Crushed remains of large domal stromatolite within access road.
296	S27° 02' 06.0" E24° 48' 01.0"	Cherty core of large domal stromatolite.
297	S27° 02' 06.0" E24° 48' 00.6"	Cherty core of large domal stromatolite.
298	S27° 02' 05.2" E24° 48' 00.2"	Cherty core of large domal stromatolite.
300	S27° 02' 04.4" E24° 47' 58.6"	Cherty core of large domal stromatolite
301	S27° 02' 04.4" E24° 47' 58.5"	Embedded silicified carbonate block with mini-stromatolitic buttons.
303	S27° 02' 04.6" E24° 47' 57.6"	Large stromatolitic dome.
304	S27° 02' 04.7" E24° 47' 57.6"	Intersecting large stromatolitic domes.
305	S27° 02' 04.0" E24° 47' 57.2"	Chertified periphery of large stromatolitic dome.
306	S27° 02' 04.4" E24° 47' 56.5"	Core of large stromatolitic dome covered with stromatolitic buttons.
307	S27° 02' 04.7" E24° 47' 56.3"	Float block of stromatolitic chert with cuboidal vugs reflecting weathered out pyrite crystals.
308	S27° 02' 05.2" E24° 47' 55.9"	Well-rounded cobble of pale greyish-green igneous lithology (probably andesite) with several smooth facets, more pointed tip pecked – possibly a LSA grindstone / hammerstone.
309	S27° 02' 05.1" E24° 47' 56.0"	Small biface of pale quartzite.
310	S27° 02' 05.8" E24° 47' 55.7"	Truncated bases of several large stromatolitic domes.
311	S27° 02' 05.9" E24° 47' 56.0"	Truncated bases of several large stromatolitic domes.
312	S27° 02' 06.1" E24° 47' 56.1"	Truncated bases of several large stromatolitic domes.
313	S27° 02' 06.2" E24° 47' 56.4"	Truncated bases of several large stromatolitic domes.
314	S27° 02' 06.3" E24° 47' 56.5"	Truncated bases of several large stromatolitic domes.
315	S27° 02' 06.3" E24° 47' 56.7"	Truncated bases of several large stromatolitic domes, small stromatolitic buttons.
316	S27° 02' 06.3" E24° 47' 56.8"	Small stromatolitic buttons.
317	S27° 02' 06.3" E24° 47' 56.8"	Stromatolitic cushion or large domal core with buttons.
318	S27° 02' 06.6" E24° 47' 57.3"	Core of large domal stromatolite with buttons.
319	S27° 02' 06.9"	Large stromatolitic dome.

	E24° 47' 57.8"	
320	S27° 02' 07.3" E24° 47' 58.3"	Truncated bases of several large stromatolitic domes.
321	S27° 02' 07.7" E24° 47' 58.6"	Truncated bases of several large stromatolitic domes.
322	S27° 02' 08.0" E24° 47' 59.1"	Truncated bases of several large stromatolitic domes, dipping laminae with mini-stromatolitic buttons.
323	S27° 02' 08.1" E24° 47' 59.2"	Large stromatolitic domes partially replaced by black chert.
324	S27° 02' 08.1" E24° 47' 59.3"	Incomplete large stromatolitic domes with buttons.
325	S27° 02' 08.2" E24° 47' 59.6"	Incomplete large stromatolitic domes with buttons.
326	S27° 02' 08.0" E24° 47' 59.7"	Incomplete large stromatolitic domes with buttons.
327	S27° 02' 08.3" E24° 48' 00.8"	Large stromatolitic buttons.
328	S27° 02' 09.1" E24° 47' 58.0"	Laydown area mantled in compacted soil with fine gravels. Sparse small patches of scraped cherty bedrock exposure.
329	S27° 02' 09.3" E24° 47' 54.3"	V-drain trench along western side of laydown area excavated into sandy soil, gravels, with occasional blocks of carbonate bedrock. Excavated blocks largely covered in patina of soil that largely obscures any stromatolitic lamination present.
330	S27° 01' 23.1" E24° 47' 34.2"	New access road sector through outcrop area of Vryburg Fm andesitic lavas. Displaced blocks of andesite, chert, gravelly soils.
331	S27° 01' 58.8" E24° 47' 55.2"	Concentration of displaced sizable carbonate bedrock blocks near access road (dark grey to khaki ferruginous carbonate, thin-bedded).
332	S27° 02' 05.2" E24° 47' 54.1"	Large carbonate bedrock blocks excavated from V-drain trenches. No stromatolites observed.
333	S27° 02' 04.6" E24° 47' 53.4"	Large carbonate bedrock blocks, grey when fresh with possible mudrock intraclasts, excavated from V-drain trenches. No stromatolites observed.
334	S27° 02' 04.2" E24° 47' 52.5"	Large carbonate bedrock blocks excavated from V-drain trenches. One block showing good stromatolitic lamination, but mostly soil-covered.
335	S27° 02' 04.0" E24° 47' 52.0"	Excavated block of bedrock showing well-developed medium-sized, asymmetrical domical stromatolites but surface is patinated by adherent soil, obscuring details.
336	S27° 02' 04.8" E24° 47' 51.5"	Flat area following bush clearance. Soil covered very little bedrock exposure.
337	S27° 02' 08.2" E24° 47' 52.7"	Isolated small surface exposure of ferruginised stromatolitic bedrock, surface gravels within extensive cleared area.
338	S27° 01' 59.0" E24° 47' 41.8"	Large bedrock blocks excavated from V-drains, several showing major surface scratches due to machinery. No stromatolites observed within large blocks. Core of large, silicified stromatolitic cushion excavated from V-drain showing well-preserved lamination, pustulose internal and outer surfaces.
339	S27° 01' 55.8" E24° 47' 33.0"	Excavated block of multi-hued. laminated weathered siltstone excavated from V-drain trench. Grey limestone blocks showing complex, fine-scale colour banding due to either stromatolite growth or perhaps chemical precipitation. Abundant rusty-brown cubical pyrite pseudomorphs.
340	S27° 01' 56.9" E24° 47' 30.7"	Overturned large excavated blocks of carbonate bedrock containing several isolated cone-shaped, silicified stromatolites ("cauliflower heads") seen in ventral view. Main block rich in small-scale mini-stromatolites.
341	S27° 01' 57.3" E24° 47' 29.3"	Western end of trench yielding stromatolite-rich rubble. Large (20-30 cm diam.) cushion stromatolites, round to elliptical in plan view, with pustulose surfaces and internal laminae, steep to recurved marginal lamination tucked in beneath edges of the stromatolitic head.
342	S27° 01' 57.3" E24° 47' 29.8"	Stromatolitic cushions among excavated rubble.
343	S27° 01' 57.0" E24° 47' 30.5"	Stromatolitic cushions and cauliflower heads among excavated rubble.
344	S27° 01' 56.8" E24° 47' 31.0"	Stromatolitic cushions among excavated rubble.
345	S27° 01' 56.5" E24° 47' 31.5"	Stromatolitic cushions and cauliflower heads among excavated rubble.
347	S27° 02' 13.2" E24° 47' 54.0"	Large carbonate blocks, gravels of chert and weathered carbonate excavated from V-drain trenches along southern edge of PV project area.
348	S27° 02' 18.9" E24° 47' 43.2"	Excavated carbonate block with small domical stromatolites.
349	S27° 02' 19.5" E24° 47' 41.8"	Excavated block of thin-bedded to laminated carbonate and siliciclastics with microstromatolites.
350	S27° 02' 19.9" E24° 47' 41.0"	Teardrop-shaped quartzite biface (hand axe), crude larger biface, quartzite core and other flaked artefacts among gravels excavated from V-drain trench.

352	S27° 02' 21.5" E24° 47' 38.3"	Excavated block of laminated carbonate. No obvious stromatolites.
353	S27° 02' 20.1" E24° 47' 40.6"	Excavated angular blocks of dark brown ferruginous chert or silicified mudrock.