BHP

Western Ridge Subterranean Fauna Supplementary Information Technical Memorandum

12 January 2023

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Purpose

The purpose of this document is to provide additional information on subterranean fauna species and subterranean fauna habitats in the Western Ridge area to support the Western Ridge derived proposal (the Proposal).

This document provides an overview of the subterranean fauna values for the Proposal, and a detailed assessment focusing on troglofauna species only found within the potential impact (proposed pit) areas of the Proposal. The assessment analyses potential for their ranges to extend outside of proposed pit areas based on habitat connectivity and ranges of other species.

Relevant Proposal elements

The Proposal elements relevant to subterranean fauna and their habitats includes excavation of mine pits and groundwater abstraction. There is no re-injection of groundwater associated with the Proposal.

Existing environment

Groundwater

The hydrogeology of the Western Ridge area is discussed in detail in Section 8.3 of the Newman Hub (Western Ridge) Derived Proposal (BHP 2022, draft). In summary, the Western Ridge area is characterised by hydraulically connected regional (weathered dolomite and some tertiary detritals) and Marra Mamba orebody aquifers. The water table within and surrounding the Proposal is deep, ranging from greater than approximately 75 metres below ground level (m bgl) and up to 100 mbgl. Groundwater occurs in a fractured banded iron formation aquifer. Sampling of groundwater at the western end of the Proposal in late 2020 measured salinity of approximately 370 mg/L total dissolved solids.

Geology

Geology within the Development Envelope for the Proposal is structurally complex and comprises Marra Mamba Iron Formation, Wittenoom Formation, Mt Sylvia Formation, Mt McRae Shale and Brockman Iron Formations of the Hamersley Group and Jeerinah Formation of the Fortescue Group (Figure 1 and Figure 2). The Brockman Iron Formation is found in the Bill's Hill and Mt Helen areas in the form of a westerly plunging overturned syncline that terminates against the Whaleback Fault in the north-west (BHP 2018). The Marra Mamba Iron Formation is located in the Silver Knight and Eastern Syncline areas (Figure 2).

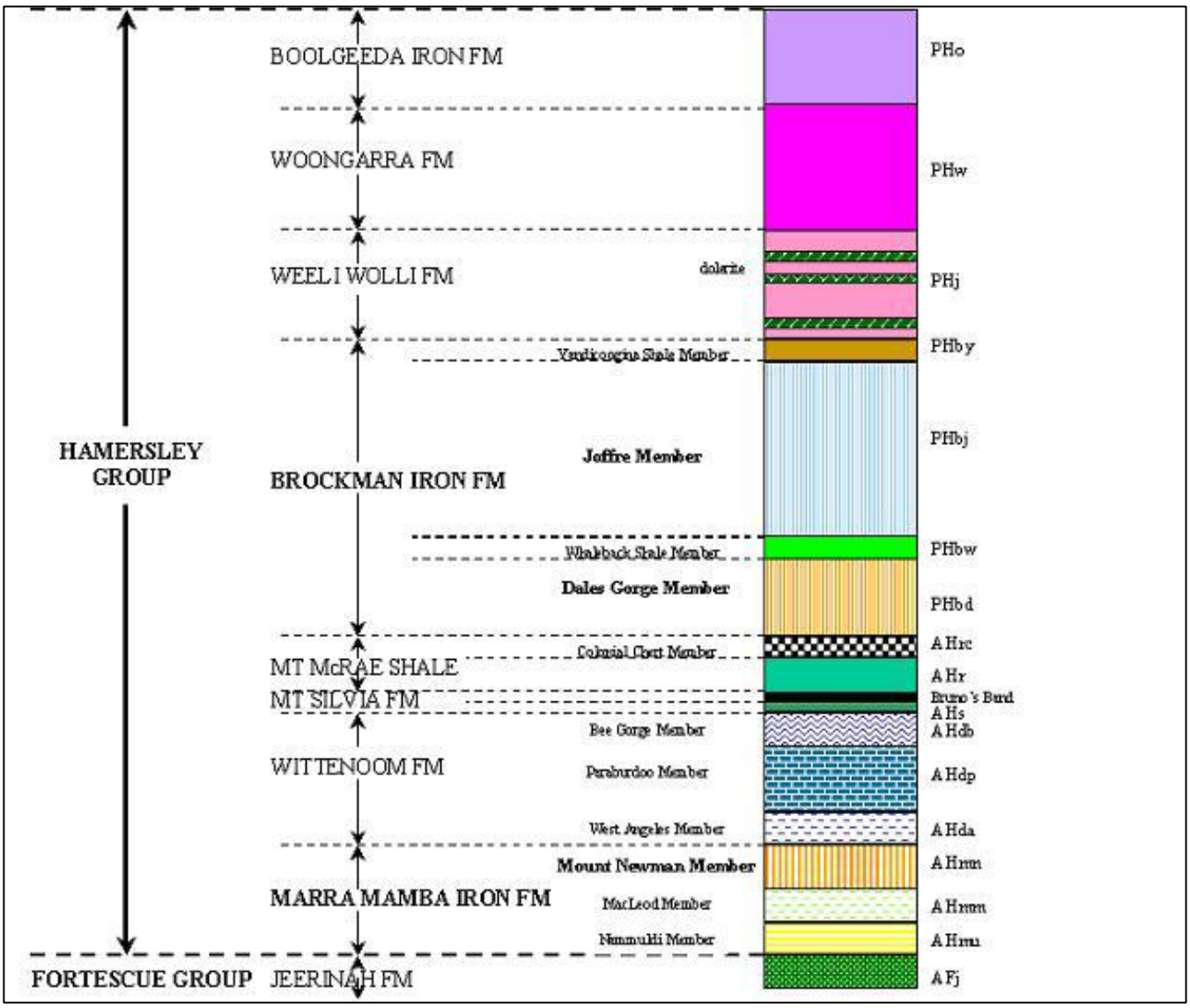
Due to the geological complexity of the area, further detailed discussions on the geology of the Development Envelope focuses on the Silver Knight area (Figure 2), where the troglofauna species discussed herein were recorded.

Silver Knight is located on the southern limb of the major syncline. Geology of the area comprises Wittenoom Formation, Marra Mamba Iron Formation and Jeerinah Formation (BHP 2021). The geology changes from flat lying bedrock in the west to steeply dipping in the east (BHP 2021). The Tertiary Detritals (TD) comprise mainly siltstone (ST3) of the TD3 and vuggy breccia (VB2) of the TD2 and had an average thickness of 20 m but became deeper (up to 105 m) in the paleochannel between Silver Knight and Mt Helen (BHP 2021).

The Whaleback Fault intersects the northwestern corner of Silver Knight (Figure 2) and several north northeast trending near vertical faults have been interpreted as inferred structures (BHP 2019a). Displacement of stratigraphy across these inferred faults is considered minimal, with no evidence of fault displacement showing in the drilling or water table. Complete overturning of the geology is seen in the southwest of the area (BHP 2021). An altered, overturned dolerite sill that pinches in and out has been interpreted in the southwest corner of Silver Knight (BHP 2021). This sill occurs deep in the Nammuldi Member and is not related to the geology in which troglofauna species are found.

A thin layer of hardcap is consistent across the Silver Knight area but thickens (up to 140 m) to the north in relation to the increasing depth of the detrital valley (BHP 2019a). Geological modelling interpreted the hardcap to continue below the base of detritals and topography where no drilling was undertaken.

Tertiary detritals present at Silver Knight include the quaternary detritals (sz), the siltstone (ST3), gravelly siltstone (GS3) and welded pisolites (WP3) of the Tertiary Detrital 3 and the calcrete (CA2), vuggy breccia (VB2) and clay (CY2) of the Tertiary Detritals 2 (BHP 2017).



Source: BHP Billiton Iron Ore (BHPIO) (2006)

Figure 1: Hamersley Group stratigraphic column.

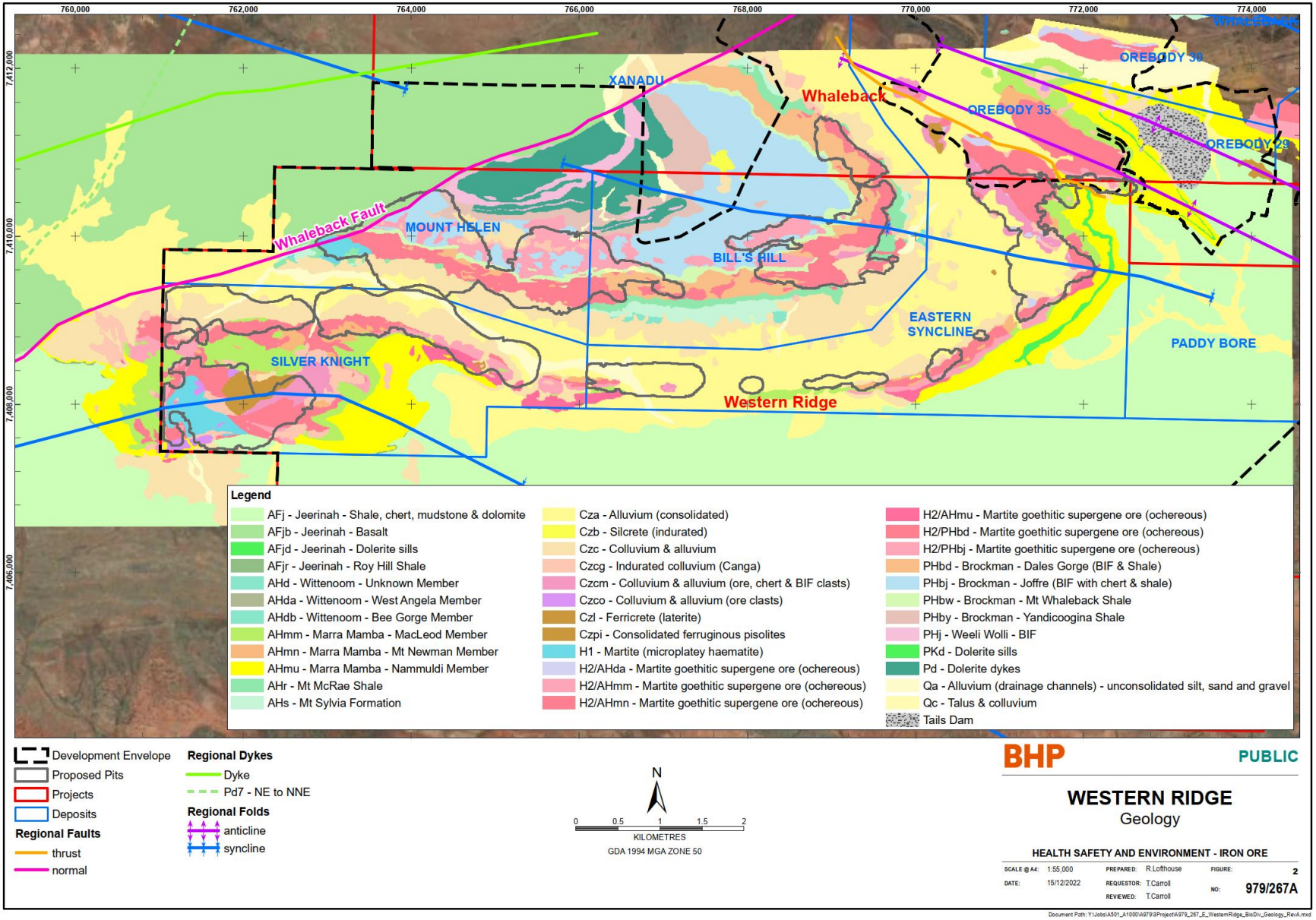


Figure 2: Geology of the Western Ridge area showing regional faults, folds and dykes and 1:20,000 geological mapping.

Subterranean fauna values

Stygofauna sampling

Figure 3 shows the locations of stygofauna sampling within the Project area. Sampling was first conducted over two rounds in 2010 by Bennelongia (2011) and then again over two rounds in 2019/ 2020 by Bennelongia (2021). Survey intensity and protocols used were in accordance with the Environmental Protection Authority (EPA) guidelines (EPA 2016a, b).

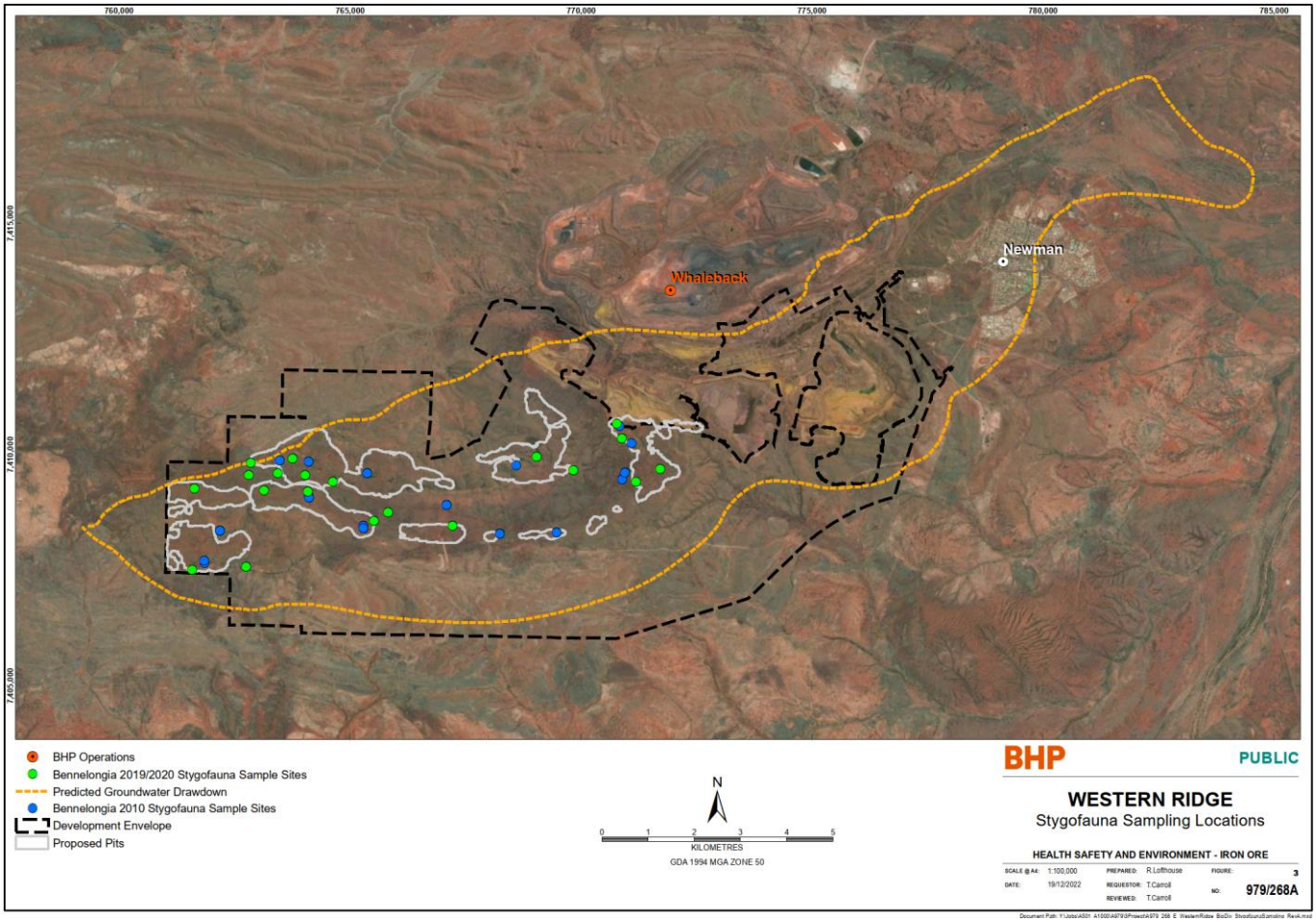


Figure 3: Western Ridge stygofauna sampling locations.

Stygofauna species

A relatively low diversity and abundance of stygofauna were collected from the predicted extent of groundwater drawdown for the Proposal, representing a depauperate community (Figure 4). This is likely to be due to depth to groundwater being deep (ranging from greater than approximately 75 mbgl and up to 110 mbgl) throughout the Western Ridge area. All taxa collected are either widespread in the Pilbara or have been recorded elsewhere within the Eastern Pilbara region:

- Nematoda sp. indet. – widespread in the Pilbara
- Enchytraeidae sp. E12 – widespread in the Pilbara
- *Enchytraeus* Pilbara sp. 2 (PSS) – widespread in the Pilbara
- Phreodrilidae sp. P11 – also found at Eastern Ridge and Ophthalmia with a linear range of 75 km
- *Pilbaranella* sp. 'C' – also found at Eastern Ridge and Homestead with a linear range of 20 km.

Given the widespread nature of the taxa found at Western Ridge, stygofauna are not discussed further herein.

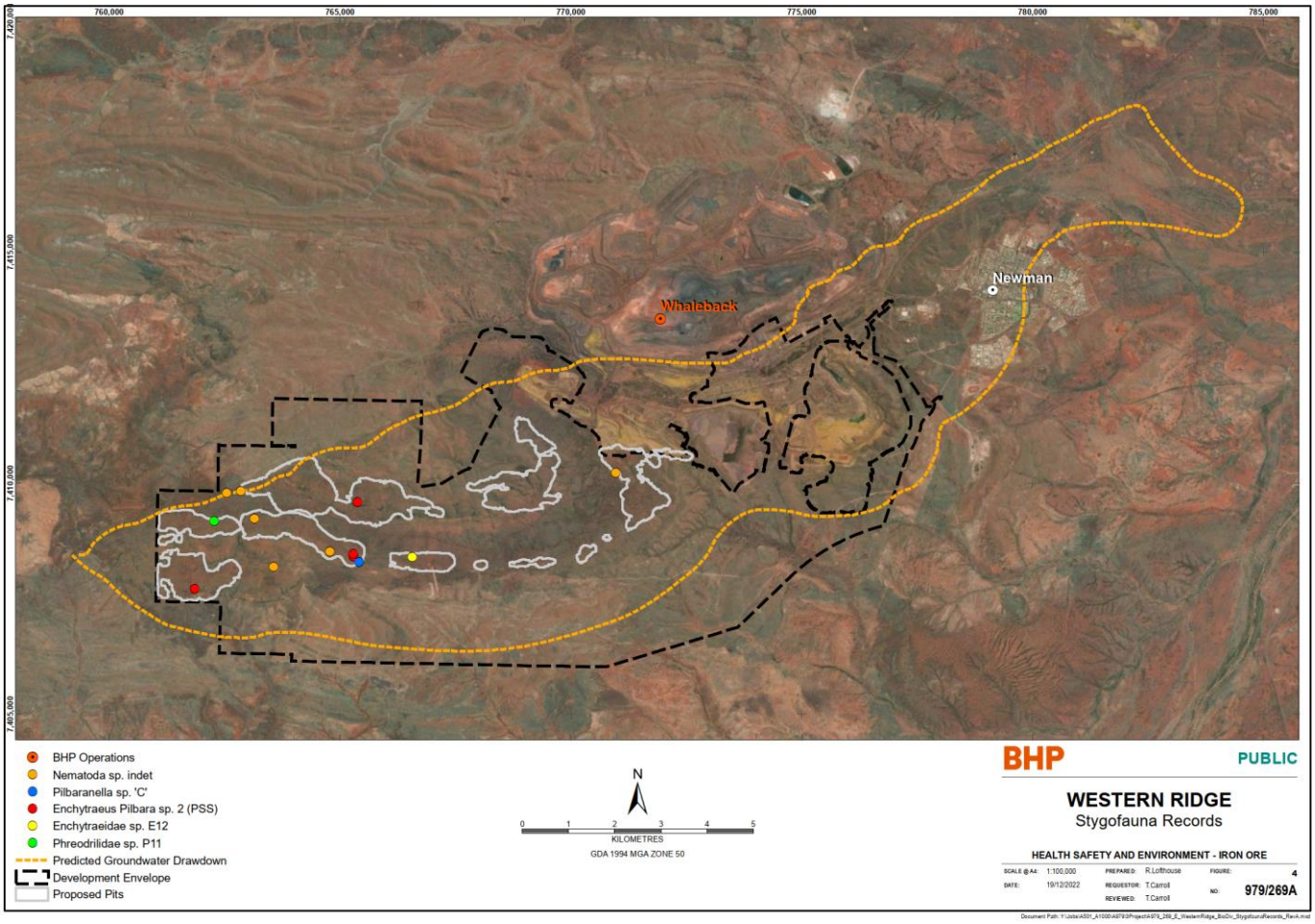


Figure 4: Stygofauna records at Western Ridge.

Troglofauna sampling

Figure 5 shows locations of troglofauna sampling within the Development Envelope and locations where troglofauna specimens were collected. Sampling was conducted in 2010 by Bennelongia (2011) and again in 2019, 2020, 2021 and 2022 by Bennelongia (2021 and 2022). The intent of the 2019/ 2020 programme was to improve sampling intensity to enable characterisation of the trolgofauna community present and align with EPA guidelines (EPA 2016a, b). When proposed impact areas were overlayed with the troglofauna records, five species recorded during the 2010 and 2019/ 2020 surveys were only known from the proposed pit areas. Targeted sampling conducted in 2021 and 2022 aimed to sample similar habitats to where these species had been recorded to improve knowledge of their distributions.

Over the surveys, 253 holes were sampled for troglofauna. Eighty-five holes were sampled in reference areas (34%) and 168 holes were sampled in potential impact areas (66%) (Figure 5). Of the 253 holes sampled, 74 holes (30%) yielded troglofauna specimens. In addition, troglofauna were recorded in three holes as stygofauna bycatch.

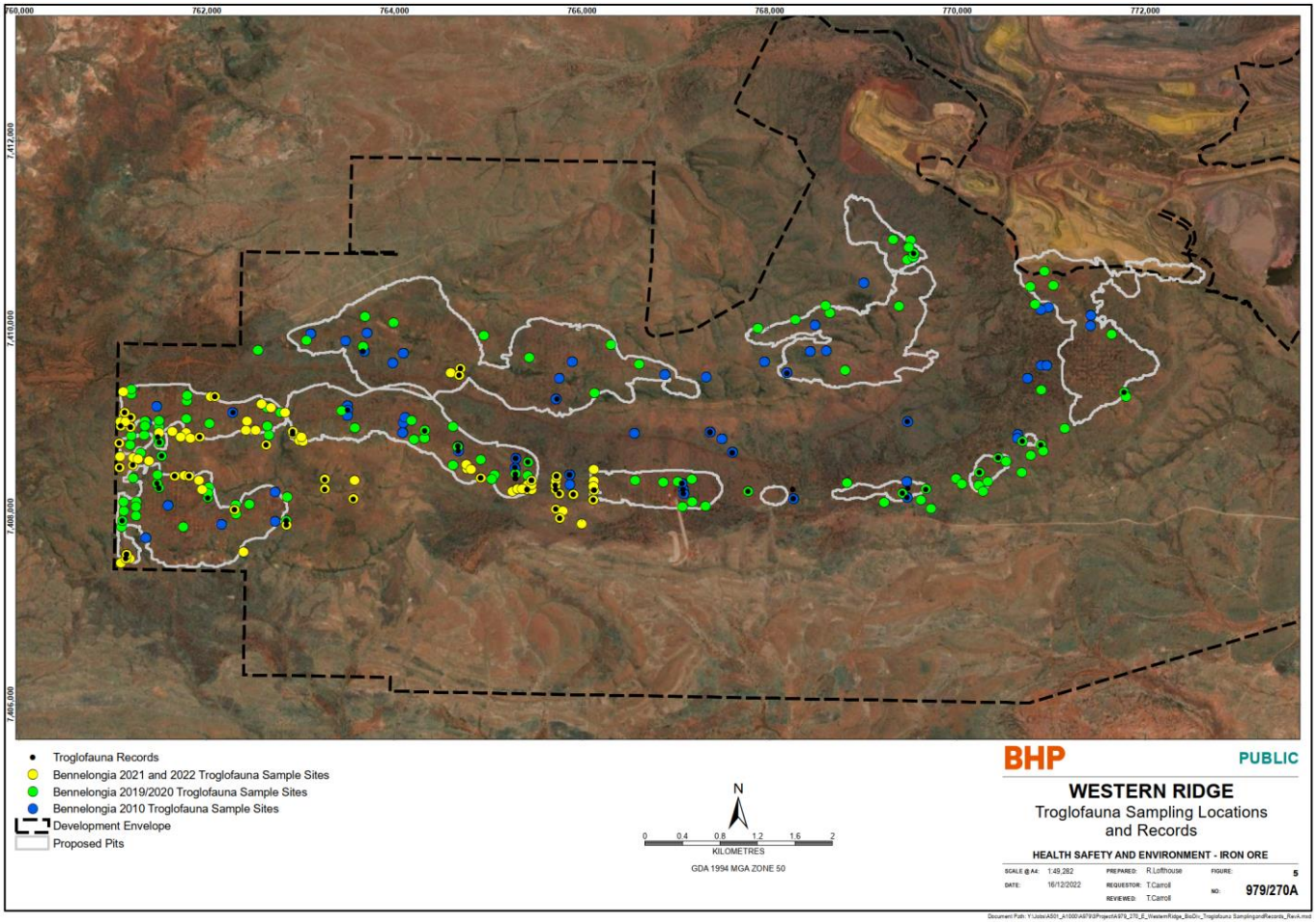


Figure 5: Western Ridge troglofauna sampling locations and distribution of troglofauna records.

Troglofauna habitat

Troglofauna are known to inhabit porous geologies above the water table that include channel iron deposits, banded iron formations, alluvium/colluviums in valley-fill areas, karst, calcrete, and weathered or fractured basalts and sandstone (EPA 2021).

All geologies present above the water table at Western Ridge were sampled for troglofauna (Table 1). Above water table stratigraphy of the 253 holes sampled was summarised into categories to compare with the number of holes sampled in each category, number of holes sampled that yielded troglofauna (77 including the three holes where troglofauna were recorded as bycatch) and the number of troglofauna species found within each category (Table 1). The purpose of this was to assist with determining suitability as troglofauna habitat within the Development Envelope. Twenty-eight categories were derived by grouping geological units into their geological member (e.g. N1 and N2 combined into Mount Newman Member). Given multiple members, and sometimes formations, occur together in a hole the convention used for describing the categories begins with the oldest and ends with the youngest geological unit. Detrital units TD2 and TD3 were also combined for simplicity. The limitations of this approach included:

- Bias towards number of holes sampled in certain geological units, particularly those associated with the proposed pit areas
- Exclusion of the vuggy textures associated with the hardcap layer from the analysis
- Loss of detail associated with detrital units (e.g. the vuggy breccia (VB2) and calcrete (CA2) of the tertiary detrital unit TD2), which may influence the suitability of troglofauna habitat.

The most frequently sampled category was the ‘MacLeod Member and Mount Newman Member’ (39 holes), followed by the ‘Mount Newman Member overlain by detritals’ (25 holes), the ‘MacLeod Member overlain by detritals’ (24 holes) and the ‘MacLeod Member’ (22 holes) (Table 1). Forty holes were sampled in the Brockman Iron Formation, including 12 holes in the Joffre Member and 15 holes in the Dales Gorge Members only. Interestingly, only six of

these holes yielded troglofauna; two from ‘Dales Gorge Member’ and four from ‘Mt McRae Shale and Dales gorge Member’.

The category with the most holes that yielded troglofauna was the ‘MacLeod Member and Mount Newman Member’ (17 of the 39 holes sampled), followed by the ‘MacLeod Member overlain by detritals’ (9 of the 24 holes sampled). ‘MacLeod Member overlain by detritals’ (9 holes) was the category that yielded the most species (11 species) followed by ‘MacLeod Member and Mount Newman Member’ (10 species) and ‘West Angela Member overlain by detritals’ (10 species).

Table 1: Geological categories, number of holes sampled in each category, number of holes sampled in each category that yielded troglofauna, and the total number of troglofauna species found in each category.

Geological categories	Number of holes sampled	Number of holes sampled that yielded troglofauna	Total number of troglofauna species
Detritals			
Detritals	7	2	2
Intrusives			
Dolerite dyke	3	0	N/A
Brockman Iron Formation and Mt McRae Shale			
Joffre Member	12	0	N/A
Whaleback Shale Member	2	0	N/A
Dales Gorge and Joffre	2	0	N/A
Dales Gorge and Whaleback Shale	1	0	N/A
Dales Gorge Member	15	2	2
Mt McRae Shale and Dales Gorge Member	8	4	5
Mt Sylvia Formation			
Mt Sylvia	1	0	N/A
Wittenoom Formation			
Bee Gorge Member overlain by detritals	3	2	3
Paraburdoo Member and Bee Gorge Member overlain by detritals	2	0	N/A
Paraburdoo Member overlain by detritals	2	0	N/A
West Angela and Bee Gorge Member overlain by detritals	2	0	N/A
Paraburdoo Member and West Angela Member overlain by detritals	1	1	2
West Angela Member overlain by detritals	16	5	10

Geological categories	Number of holes sampled	Number of holes sampled that yielded troglofauna	Total number of troglofauna species
Wittenoom Formation and Marra Mamba Iron Formation			
Mount Newman Member and West Angela Member overlain by detritals	10	5	4
Mount Newman Member and West Angela Member	4	1	1
Marra Mamba Iron Formation			
Mount Newman Member overlain by detritals	25	6	4
Mount Newman Member	6	1	1
MacLeod Member and Mount Newman Member overlain by detritals	14	5	5
MacLeod Member and Mount Newman Member	39	17	10
MacLeod Member overlain by detritals	24	9	11
MacLeod Member	22	5	4
Nammuldi Member and MacLeod Member overlain by detritals	3	3	3
Nammuldi Member and MacLeod Member	16	6	4
Nammuldi Member overlain by detritals	7	1	3
Nammuldi Member	2	0	N/A
Fortescue Group			
Jeerinah Formation overlain by detritals	4	2	1
Total	**253**	**77**	

Table 2 provides a description of the geological units that have been identified in the Development Envelope through geological mapping, drill hole logging and geological modelling. Descriptions are from the Australian Stratigraphic Units Database (Geoscience Australia and Australian Stratigraphy Commission 2019) and BHP (2019b). Based on the nature of the unit and how it relates to troglofauna habitat as described in EPA (2021) and information shown in Table 1, each formation has been assigned a suitability as habitat for troglofauna (i.e. whether it contain pores spaces suitable to support troglofauna):

- suitable
- potentially suitable
- unsuitable.

Table 2: Broad description of geological units from Western Ridge and their suitability as troglofauna habitat in the Western Ridge context.

Geological Formation	Description	Mapping code	BHP code	Suitability as troglofauna habitat
Tertiary Detritals				
TD3	Siltstone. Gravelly siltstone with welded pisolites.	CzD3	ST3 GS3	Unsuitable Potentially suitable (see Appendix A)
TD2	Calcrete. Vuggy breccia.	CzD2	CA2 VB2	Suitable Suitable
Brockman Iron Formation				
Joffre Member	Planar bedded to poddy banded iron formation layers with minor shale interbeds.	PHbj	J1, J2 J3 – J5, J6	Potentially suitable
Whaleback Shale Member	Alternating bands of shale and banded iron formation.		W	Potentially suitable
Dales Gorge Member	Predominantly well-banded banded iron formation made up almost entirely of chert and iron oxides. May be partially or fully enriched.	PHdb	D4, D3, D2, D1	Suitable, especially the D4, D3, and D2 units
Mt McRae Shale				
Mt McRae Shale	Lower unit consists of black carbonaceous shale and chert bands. Middle units are pyritic black shales with chert and the upper unit is a dolomitic shale.	AHr	R	Unsuitable
Mt Sylvia Formation				
Mt Sylvia Formation	Cherty banded iron formation units interbedded with cherts and shales.	AHs	S	Unsuitable
Wittenoom Formation				
Bee Gorge Member	Argillittes with beds of dolomite, chert, volcaniclastic material and banded iron formation.	AHdb	OG	Potentially suitable
Paraburdoo Member	Bedded dolomite with minor amounts of chert.	AHdp	OB	Unsuitable
West Angela Member	Shale, dolomite and dolomitic argillite.	AHda	WA1, WA2	Suitable (where hardcapped)
Marra Mamba Iron Formation				
Mount Newman Member	Banded iron formation, shale.	AHmn	N3, N2, N1	Suitable

Geological Formation	Description	Mapping code	BHP code	Suitability as troglofauna habitat
MacLeod Member	Shale with thin banded iron formation interbeds; chert.	AHmm	MM	Suitable
Nammuldi Member	Chert with thin banded iron formation horizons.	AHmu	MU	Potentially suitable (only where hardcapped)

The detrital units were found to have variable suitability as troglofauna habitat. The siltstone (ST3) of the TD3 is considered unsuitable as troglofauna habitat due to the homogenous silt (BHPIO 2017) nature of the rock type, which would not be expected to contain the pore spaces required for troglofauna habitat. One hole sampled, which was drilled to 15 m through the ST3 only, yielded troglofauna however the species recorded was the widespread *Lophoturus madecassus*. Gravelly sitlstone (GS3), the other TD3 unit logged in the holes sampled at Western Ridge, was considered potentially suitable as there is evidence of vuggy textures in the ST3 from drill hole WSR1586R. Both the VB2, which is described as an idurated goethite and limonite dominant unit with a vuggy texture and cavities with pisolites and clay infill (BHPIO 2017), and the CA2 of the TD2 are considered suitable habitat for troglofauna within the Development Envelope.

Fourteen holes were sampled that included the Joffre Member in the stratigraphy (Table 1) and none yielded troglofauna. Although the lack of troglofauna records suggests that the Joffre Member is unsuitable as troglofauna habitat, the J1 – J6 units consist of banded iron formation, which is considered potential habitat (EPA 2021). For this reason, the Joffre Member of the Brockman Iron Formation was considered potentially suitable as troglofauna habitat within the Development Envelope. The Dales Gorge Member would generally be considered suitable habitat, especially where enriched and or hardcapped. Of the 26 holes sampled in the Dales Gorge Member, troglofauna species were found in only six holes (23%) (Table 1). Given the inherent suitability of the D1 – D4 units as troglofauna habitat and the presence of records, the Dales Gorge Member is considered suitable habitat for the purpose of this assessment (Table 2).

Within the Development Envelope, the members of the Wittenoom Formation are considered to have variable suitability as troglofauna habitat, with the Bee Gorge being potentially suitable, the Paraburdoo Member unsuitable and the West Angela Member suitable where hardcapped (Table 2). Two holes sampled in the Bee Gorge Member yielded troglofauna species (Table 1). Both of these holes were overlain by detritals, specfically the ST3, and both contained a harcapped Bee Gorge Member between the depths of 20 – 30 m bgl. It is therefore likely that the hardcapped Bee Gorge Member formed the troglofauna habitat in the holes. There were five holes out of the 16 holes sampled, that yielded troglofauna in the ‘West Angela Member overlain by detritals’ category and when the detrital units were separated it became apparent that either the vuggy breccia (VB2) or the calcrete (CA2) of the TD2 were predominant in each of the five holes (Table 1). The top of the WA2 unit was also hardcapped in all of the five holes. It is therefore considered likely that the troglofauna recorded were inhabiting both the TD2 units and the hardcapped West Angela Member. In addition, three of the five holes that yielded troglofauna in the ‘Mount Newman Member’ and ‘West Angela Member overlain by detritals’ category contained hardcapped West Angela Member and it is this that is considered to be the likely habitat in these holes.

The Mount Newman Member and the MacLeod Member of the Marra Mamba Iron Formation are both considered to be suitable troglofauna habitat within the Western Ridge Development Envelope (Table 2). Of the six holes sampled in ‘Mount Newman Member’ only one yielded troglofauna and of the 25 holes sampled in ‘Mount Newman overlain by detritals’ a total of 4 troglofauna species were found in six holes (24%) (Table 1). The ‘MacLeod Member and Mount Newman Member’ category had both the highest number of holes sampled (39) and the highest number of holes that yielded troglofauna (44%) (Table 1). Eleven troglofauna species were found in the ‘MacLeod Member overlain by detritals’ and 4 species were found in the ‘MacLeod Member’ (Table 1). The Nammuldi Member is only considered potentially suitable troglofauna habitat where it is hardcapped. One hole in the ‘Nammuldi Member overlain by detritals’ yielded one species of troglofauna. In this hole the detrital unit was the ST3 and the Nammuldi was hardcapped, therefore its potential as habitat, when altered, could not be discounted.

Troglofauna species

A total of 27 species have been collected from the Development Envelope. Of the 27 species collected in the Development Envelope, fifteen species were collected in 2010 (Bennelongia 2011), seven additional species were collected in 2019/ 2020 (Bennelongia 2021) and another five additional species were collected in 2021/ 2022 (Bennelongia 2022). Eleven of the 27 species are only known from the Development Envelope. Seven troglofauna species are currently known only from the proposed mine pits:

- *Cryptops* `BSCOL065`
- *Hanseniella* `BSYM095`
- *Indohya* `BPS294`
- Palpigradi sp. B07
- *Prethopalpus* sp. indet.
- *Symphylella* `BSYM109`
- *Tyrannochthonius* `PSE053`.

Further information about each species is summarised below along with an assessment of their likely ranges extending outside of the proposed mine pits, based on geology, habitat continuity and known ranges of surrogate species.

One additional species (*Cryptops* `BSCOL064`) is known from three locations; two within the proposed mine pits and one location 5 m outside of proposed mine pits. While this species is known from outside of the potential impact areas, it is in close proximity to the pit edge (5 m) and as such, further discussion on this species has also been provided below.

***Cryptops* `BSCOL064`**

Cryptops `BSCOL064` was recorded on three occasions from three different drill holes. The first record of this species was during sampling in 2019 when a single animal (singleton) was caught in a trap set at 15 m bgl from drill hole WSR1644R, located approximately 100 m from the north-eastern proposed pit edge in the Silver Knight area (Figure 6). During sampling in 2022, this species was recorded from WSR3130R in a trap set at 10 m bgl, which is approximately 205 m northeast of WSR1644R and approximately 20 m within the proposed pit area. *Cryptops* `BSCOL064` was recorded again in 2022, approximately 4.7 km to the east of WSR1644R in a trap set at 15 m bgl within drill hole WSR0305R, which lies approximately 5 m outside of the Eastern Syncline proposed pit area. The depth of the traps at the three locations (WSR1644R, WSR3130R and WSR305R) corresponds to the hardcapped MacLeod Member (MM) (Table 3). The presence of this species in three locations over a range of approximately 4.7 km indicates there are pathways for dispersal outside of the proposed pit areas.

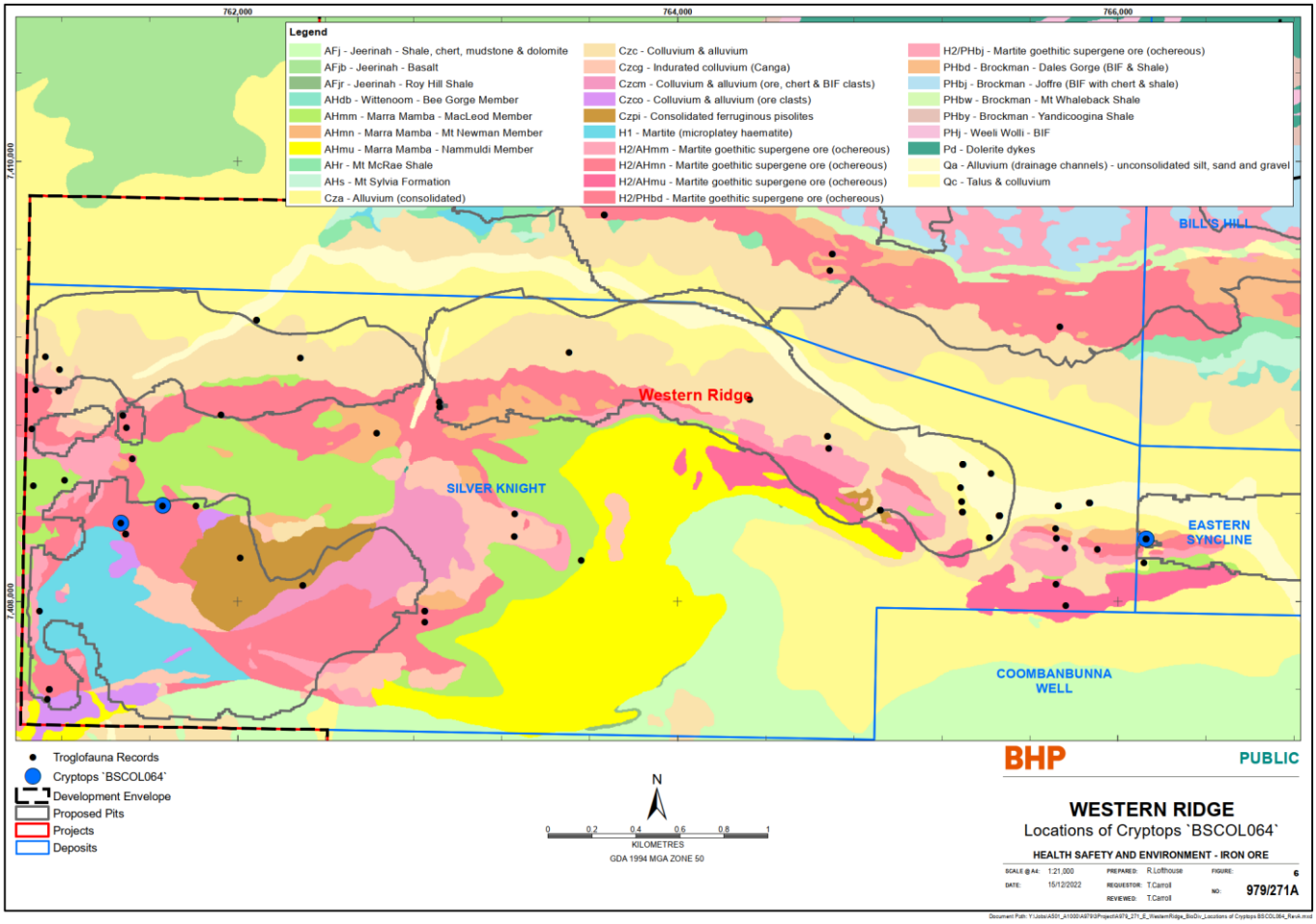


Figure 6: 1:20,000 geological mapping showing locations of *Cryptops* `BSCOL064` and other troglofauna records.

Table 3: Stratigraphy of WSR1644R, WSR3130R and WSR0305R and depth of traps (T).

Stratigraphy	WSR1644R	WSR3130R	WSR0305R
Hardcap	0 – 21 m	0 – 24 m	3 – 18 m
N1	0 – 3 m	0 – 9 m	40 – 81 m
MM	3 – 51 m **(T 15 m)**	9 – 45 m **(T 10 m)**	3 – 40 m **(T 15 m)**

Cryptops `BSCOL065`

Cryptops `BSCOL065` was recorded as a singleton in a trap set at 15 m bgl from drill hole WSR1586DTM, which is located approximately 230 m within a proposed pit in the Silver Knight area (Figure 7). The depth of the trap corresponds to the contact between the hardcapped N1 and the GS3 unit of TD3 (Table 4). Vuggy textures, indicating suitable troglofauna habitat, are evident in the core photos of WSR1586DTM (Appendix A) from 11 – 15 m bgl, which corresponds to GS3 and bewteen 15 – 19 m bgl, which corresponds to the hardcapped N1.

Figure 8 shows the N1 and the MM dipping below the water table within the proposed pit area. To the north of the proposed pit, the vuggy breccia (VB2) is extensive beneath the ST3 (Figure 8). Figure 9 shows the hardcap and ST3 extending out to the east, whilst the MM dips below the water table within the proposed pit area. The GS3 is also present to the east below a relatively shallow pit. The N1 and N2 is available to the east below a relatively shallow pit area and the hardcapped N3 extends beyond the proposed pit to the east. If *Cryptops* `BSCOL065` inhabits the hardcapped zone, it is likely that there are pathways for dispersal through the hardcapped material outside of the proposed pit extent to the north (Figure 8) and east (Figure 9).

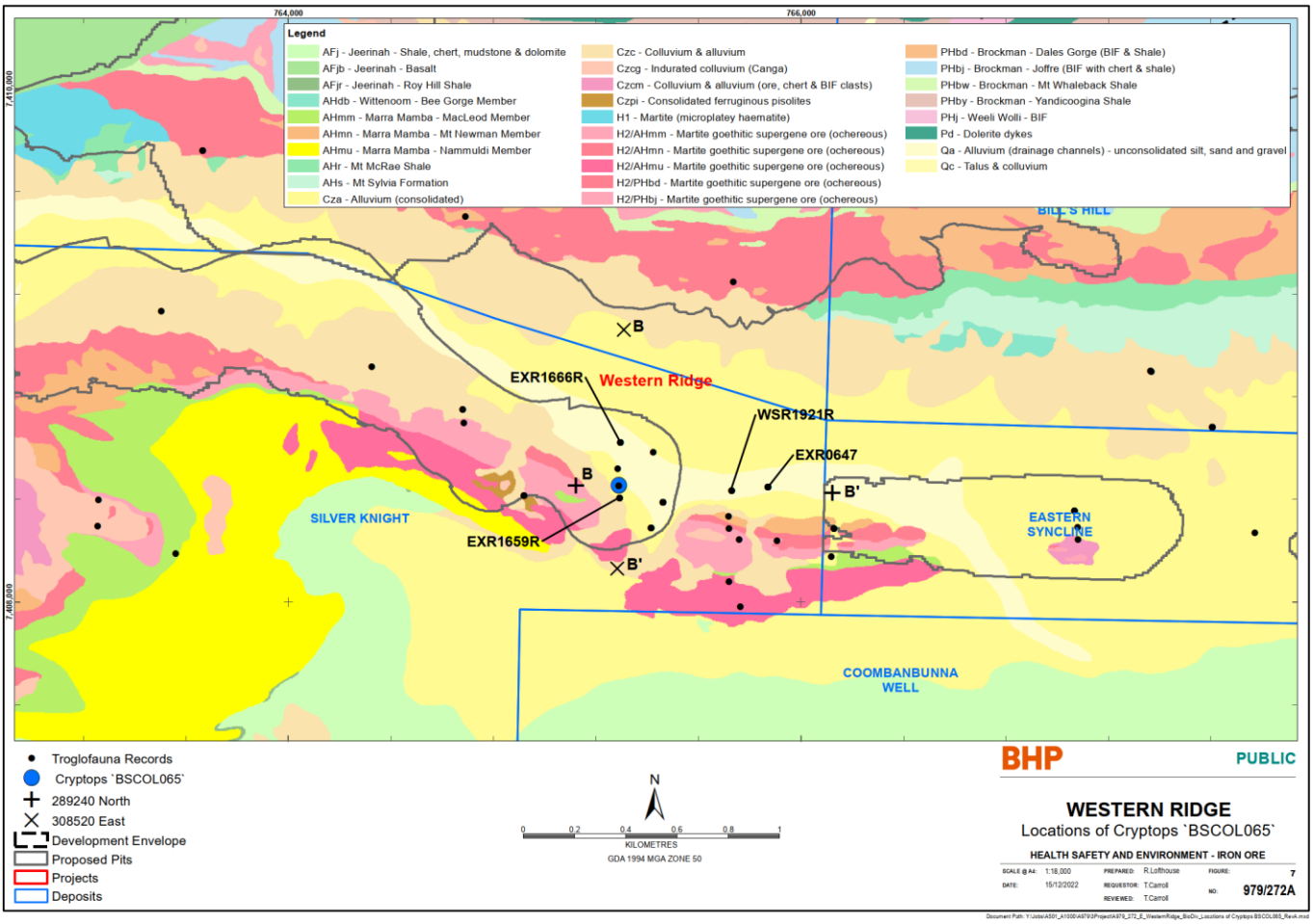


Figure 7: 1:20,000 geological mapping showing the location of *Cryptops* `BSCOL065`, other troglofauna records, and section lines and holes that are shown in Figure 8 and Figure 9.

Table 4: Stratigraphy of WSR1586DTM and depth of trap (T).

Stratigraphy	WSR1586DTM
Hardcap	15 – 18.4 m
TD3 (ST3) TD3 (GS3)	0 - 10 m 10 – 15 m **(T 15 m)**
N1	15 – 26 m
MM	26 – 99 m

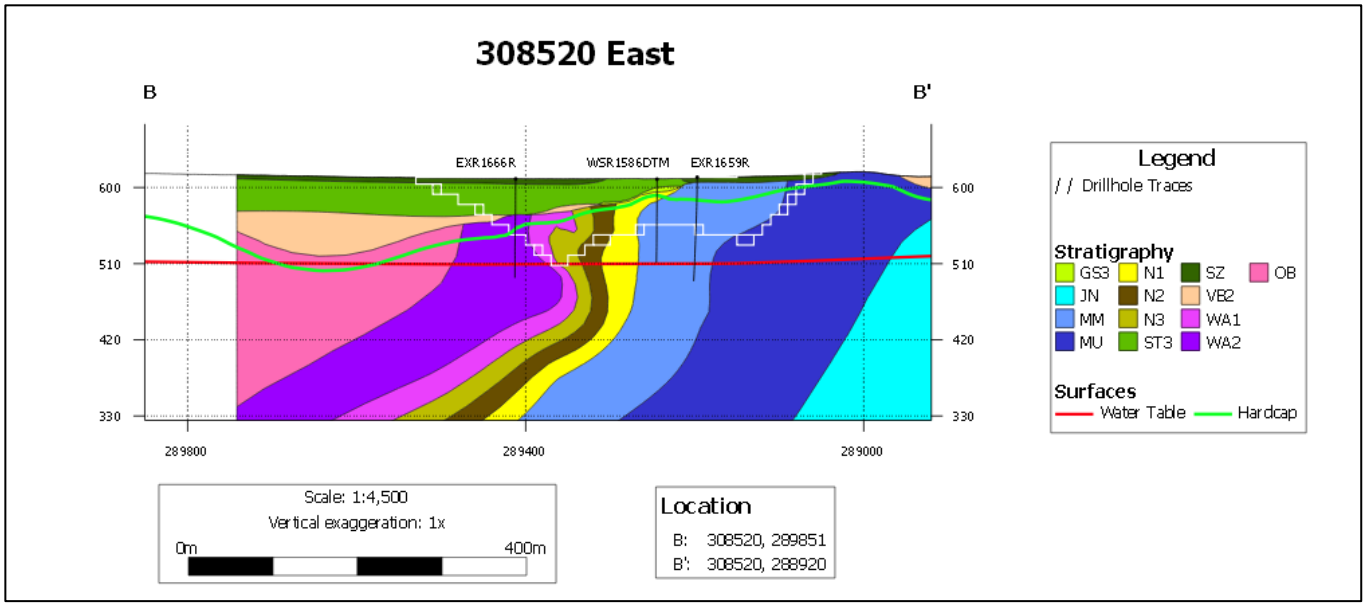


Figure 8: Cross section, facing east, showing the location and geological setting of WSR1586DTM, EXR1666R and EXR1659R.

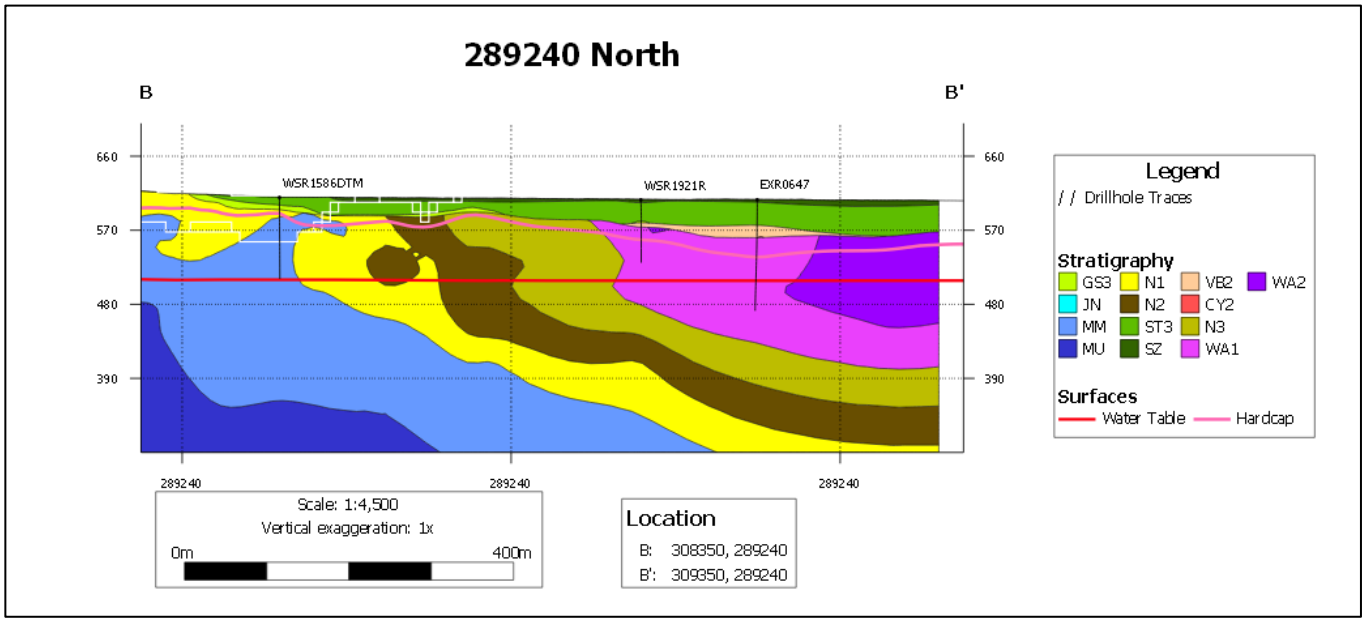


Figure 9: Cross section, facing north, showing the location and geological setting of WSR1586DTM, WSR1921R and EXR0647.

Hanseniella `BSYM095`

Hanseniella `BSYM095` was collected during sampling in 2020 as a singleton in from drill hole WSR1917R, which is located approximately 100 m within the eastern end of a proposed pit in the Silver Knight area (Figure 10). As this species was collected via a scrape sample, the exact depth of its collection is unknown. Table 5 and Figure 11 show that the detrital units VB2 of TD2, ST3 of TD3, and WA2 are the main units present above water table at WSR1917R. The VB2 and hardcapped WA2 likely comprises the troglofauna habitat in this area (Table 2). Figure 11 shows the distribution of extensive VB2 outside of the proposed pit to the north, with the connected hardcapped WA2 lying underneath. The VB2 and hardcapped WA2 also extends out to the east of the proposed pit above the water table (Figure 12). Given this, there are pathways for dispersal of this species outside of the proposed pit areas.

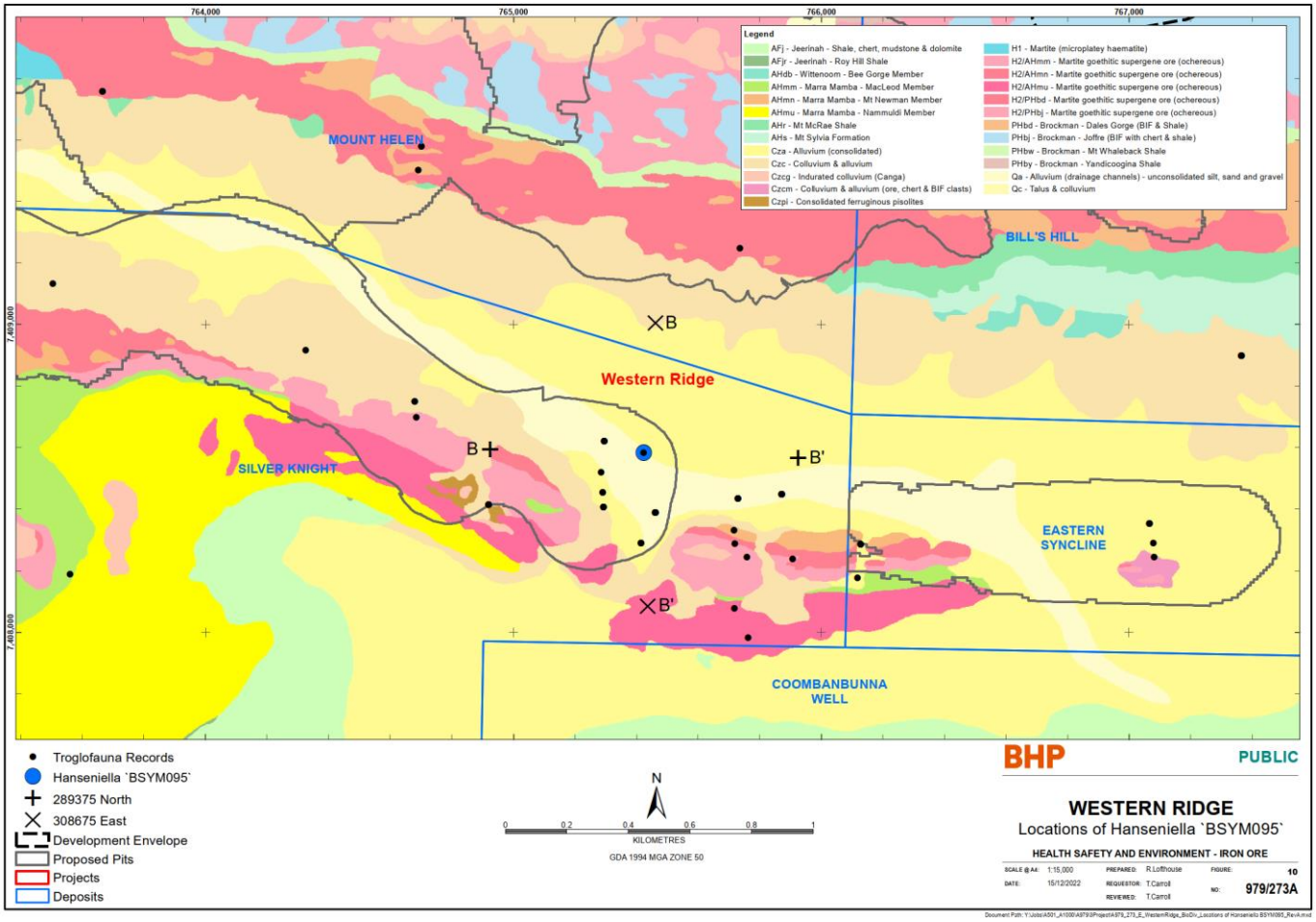


Figure 10: 1:20,000 geological mapping with location of *Hanseniella* `BSYM095`, other troglofauna records and section lines shown on Figure 11 and Figure 12.

Table 5: Stratigraphy of WSR1917R.

Stratigraphy	WSR1917R
Hardcap	60 – 72 m
SZ	0 – 3 m
TD3 (ST3) TD2 (VB2)	3 – 39 m 39 – 60 m
WA2	60 – 141 m

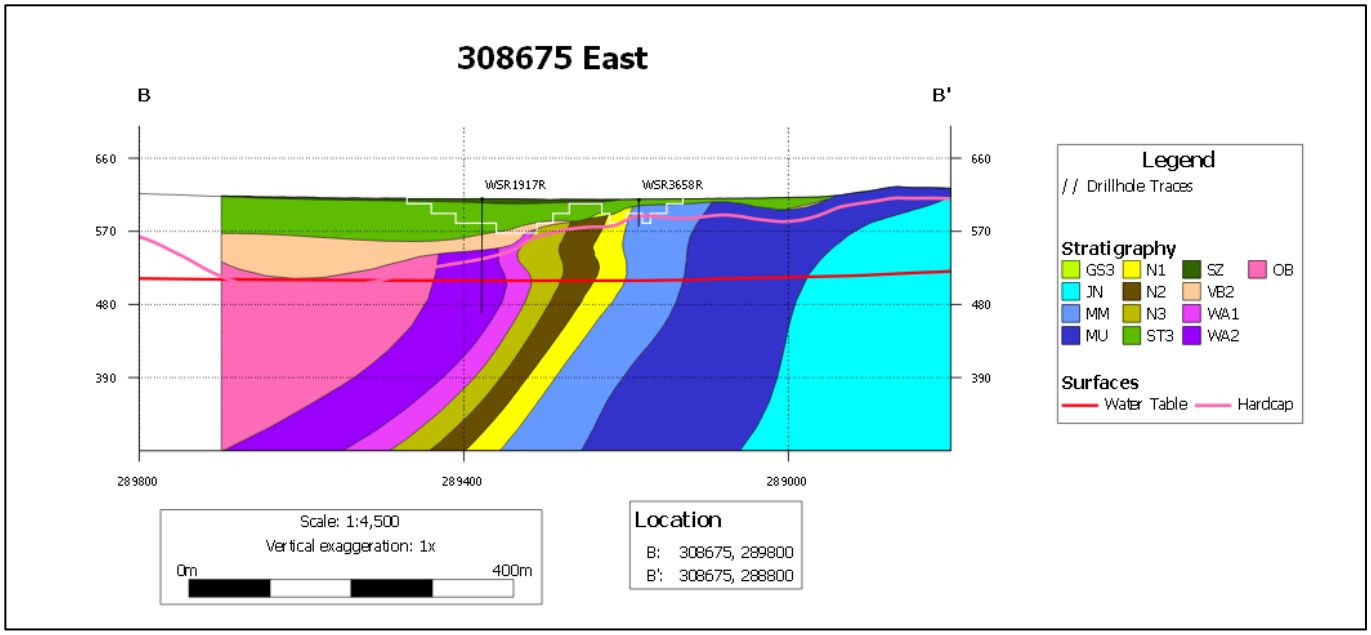


Figure 11: Cross section, facing east, showing the location and geological setting of WSR1917R.

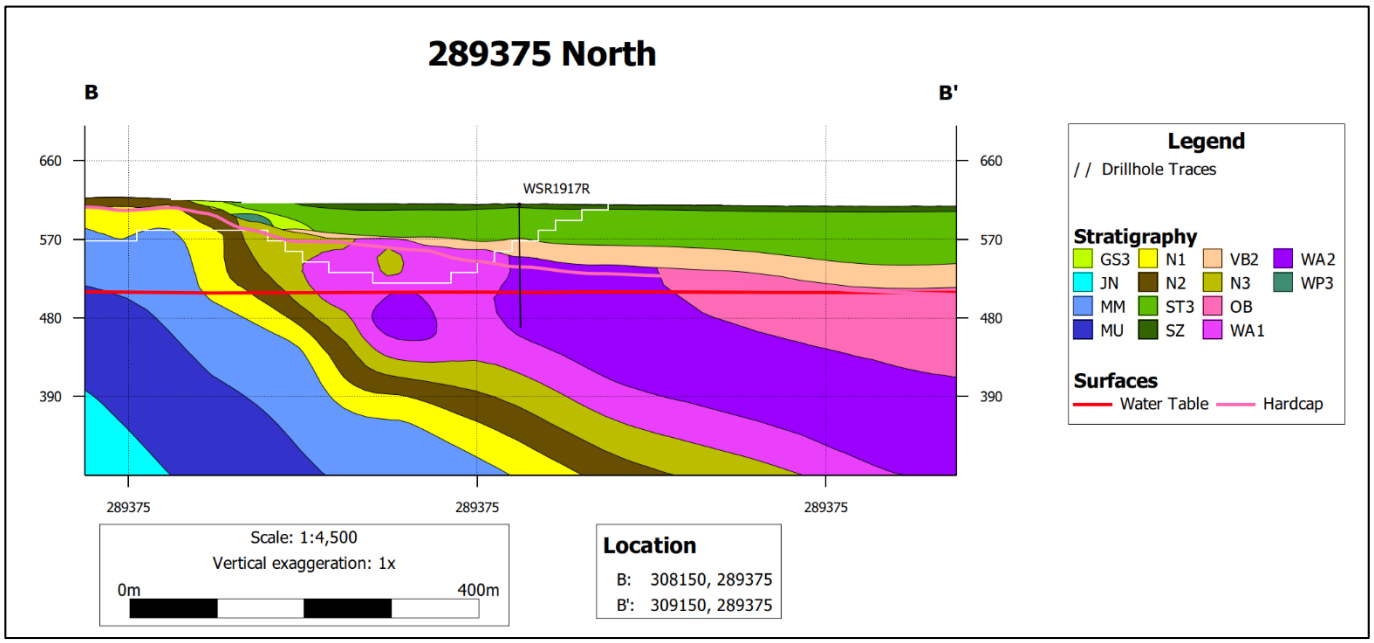


Figure 12: Cross section, facing north, showing the location and geological setting of WSR1917R.

Indohya `BPS294`

Indohya `BPS294` was recorded during sampling in 2020 as a singleton from drill hole WSR1659R, located approximately 150 m from the proposed pit boundary in the northeast, approximately 250 m from the proposed northern pit boundary and approximately 180 m from the western proposed pit boundary in the Silver Knight area (Figure 13). This species was found in a trap set at 20 m bgl, which corresponds to the MM (Table 6). Suitable habitat for this species is likely to be within the MM, hardcapped MM and/ or N1 (Table 6).

A species of Palpigrad, *Eukoenenia* `BPAL046`, was also recorded from WSR1659R during sampling in 2020. Interestingly, *Eukoenenia* `BPAL046` was also found in WSR1661R (approximately 340 m to the north), WSR1749R (approximately 840 m to the south east) and WRS1606R (approximately 720 m to the northwest) (Figure 13). These collections suggest there are pathways for dispersal throughout suitable habitat in this area. WSR1661R consists of the same habitat present above water table as WSR1659R (Table 6 and Figure 14). MacLeod Member daylights outside of the proposed pit approximately 150 m to the northeast and approximately 350 m to the west of the *Indohya*

`BPS294` record (Figure 13). Figure 14 shows troglofauna habitat of hardcap, N1 and MM extending to the north between proposed pits.

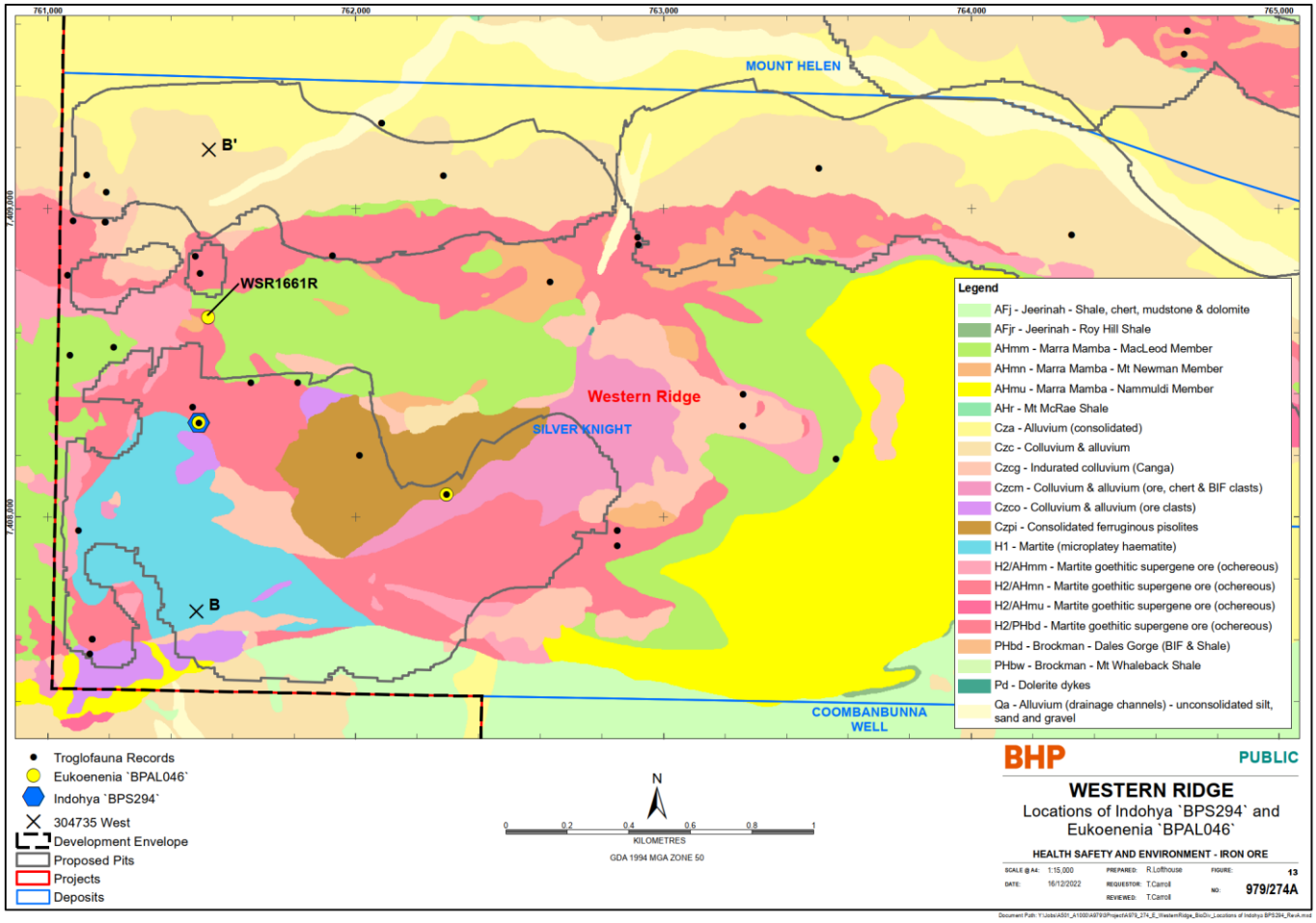


Figure 13: 120,000 geological mapping showing the location of *Indohya* `BPS294`, *Eukoenenia* `BPAL046`, other troglofauna records, location of the cross section line shown in Figure 14 and location of WSR1661R.

Table 6: Stratigraphy of WSR1659R and WSR1661R and depth of trap (T).

Stratigraphy	WSR1659R	WSR1661R
Hardcap	0 – 15 m	0 – 15 m
N1	0 – 12 m	0 – 6 m
MM	12 – 51 m **(T 20 m)**	6 – 45 m

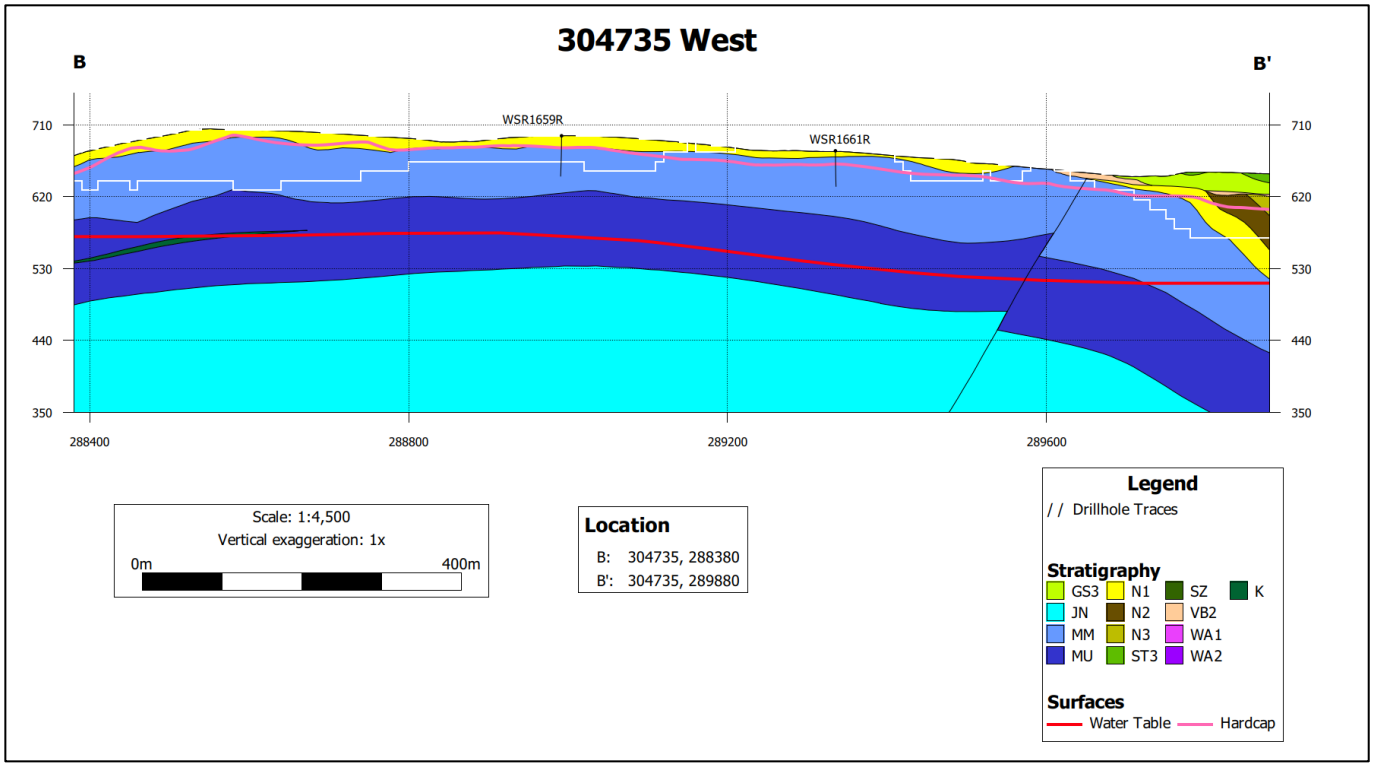


Figure 14: Cross section, facing west, showing the location and geological setting of WSR1659R and WSR1661R.

Palpigradi sp. B07

Palpigradi sp. B07 was recorded in 2010 from four locations in two different proposed pits within the Silver Knight and Mt Helen areas, over a linear range of approximately 1.6 km (Figure 15). All specimens of Palpigradi sp. B07 were either collected in scrape samples or in nets as bycatch of stygofauna sampling. An indeterminate Palpigradi specimen was recorded from WSR1919R in 2021, which is close to the Palpigradi sp. B07 records and is outside of the proposed pit areas (Figure 15). It is likely that this indeterminate record (Palpigradi sp. indet.) represents Palpigradi sp. B07 due to its proximity to Palpigradi sp. B07 (Bennelongia 2022). In 2020 another Palpigrad taxon was recorded, *Eukoenenia* `BPAL046`, in four locations further to the west (Figure 16). *Eukoenenia* `BPAL046` and Palpigradi sp. B07 could not be genetically compared but it is considered possible that they are the same species (Bennelongia 2022).

Based on the stratigraphy of the drill holes that this species was found in (Table 7), Palpigradi sp. B07 is considered to inhabit a range of units: hardcapped MM (EXR1659R), hardcapped WA2 (EXR1666R), hardcapped N3 and N2 (EXR0648) and hardcapped D1 (EXR1446R). Palpigradi sp. indet from WSR1919R likely inhabits the hardcapped N1 or unweathered N1 and/ or N2. The presence of Palpigradi sp. B07 in both Brockman Iron Formation and Marra Mamba Iron Formation, separated by detrital paleovalley indicates that there are pathways for dispersal within the detrital units (likely the VB2) between the Silver Knight and Mt Helen proposed pits. Given that this species has been recorded over a linear range of approximately 1.6 km, within habitats of both the Brockman Iron Formation and Marra Mamba Iron Formation, it is considered certain to have a range that includes areas outside of the proposed pits within the Development Envelope. The high likelihood that Palpigradi sp. indet. represents Palpiradi sp. B07 and possibility that *Eukoenenia* `BPAL046` and Palpigradi sp. B07 are in fact one species, further supports this conclusion.

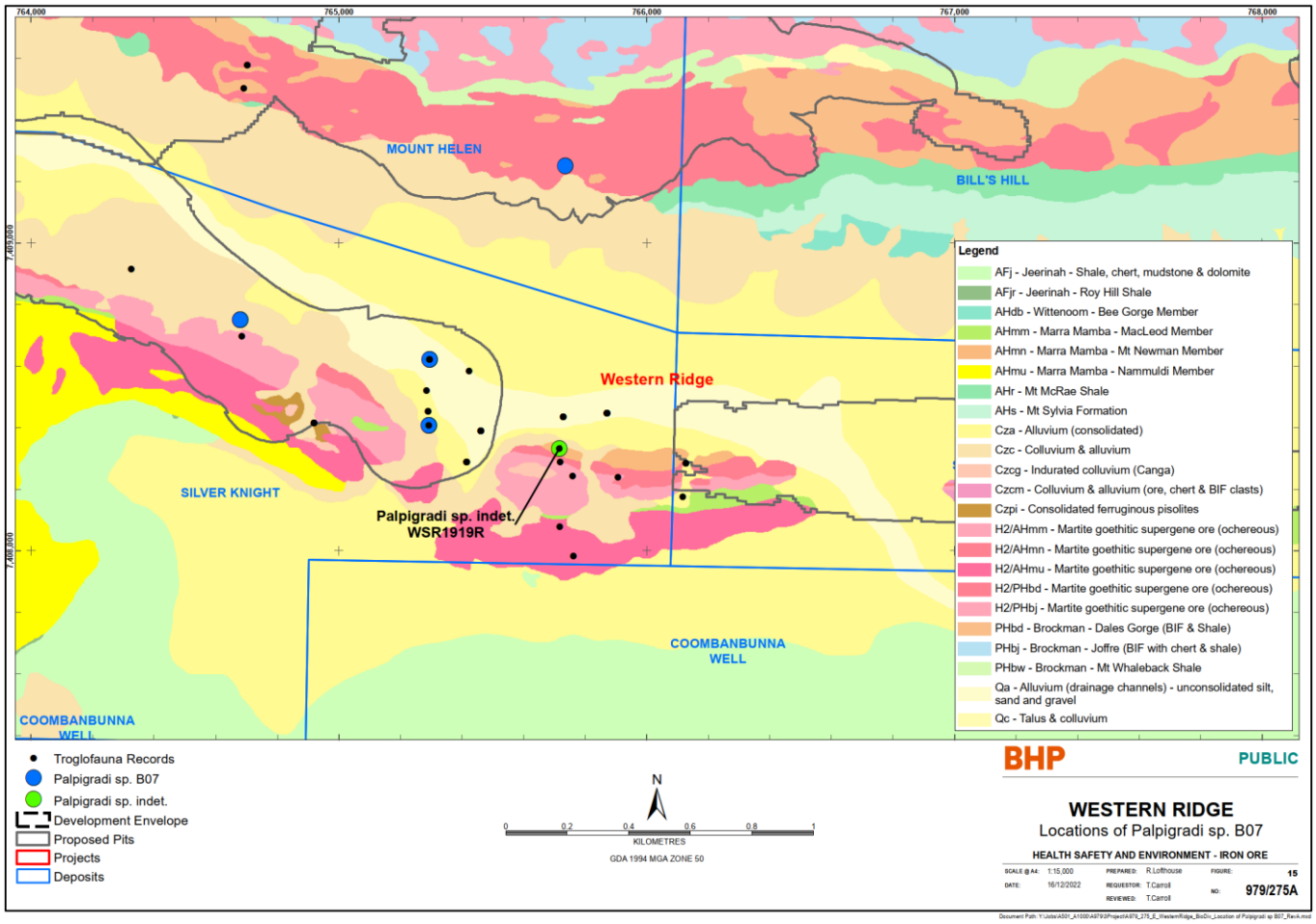


Figure 15: 1:20,000 geological mapping showing the location of Palpigradi sp. B07, Palpigradi sp. indet. and other troglofauna records.

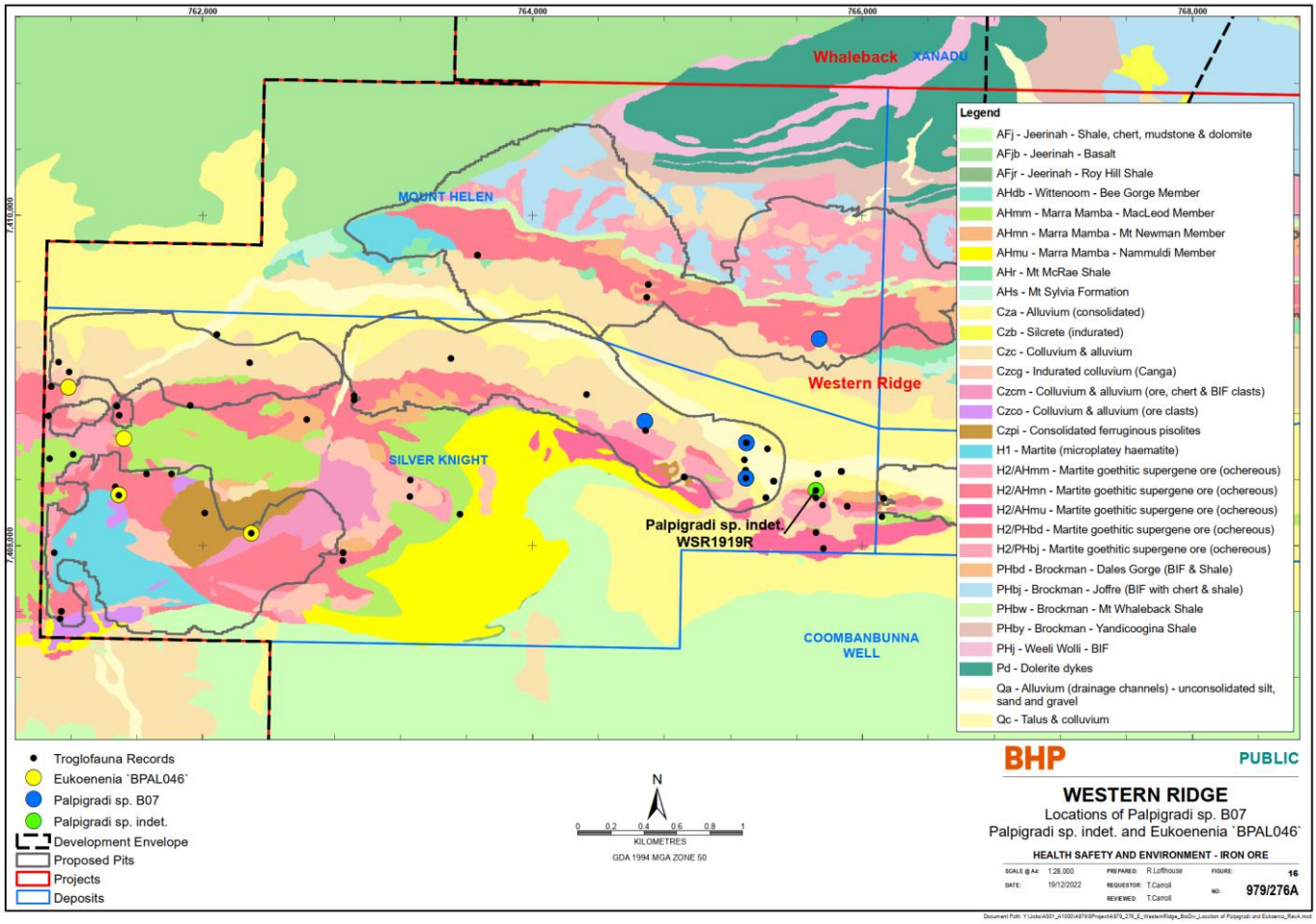


Figure 16: 1:20:000 geological mapping showing the location of Palpigradi sp. B07, Palpigradi sp. indet. and *Eukoenenia* `BPAL046`.

Table 7: Stratigraphy of EXR1659R, EXR1666R, EXR0648, EXR1446R and WSR1919R.

Stratigraphy	EXR1659R	EXR1666R	EXR0648	EXR1446R	WSR1919R
Hardcap	6 – 27 m	42 – 57 m	8 – 30 m	0 – 15 m	0 – 12 m
SZ	0 – 6 m	0 – 6 m			
TD3 (ST3) TD3 (GS3)		6 – 42 m	 0 – 8 m		
D1				0 – 18 m	
R				18 – 69 m	
WA2		42 – 117 m			
N3			8 – 23.7 m		
N2			23.7 – 39 m		30 – 51 m
N1			39 – 63 m		0 – 30 m
MM	6 – 123 m				

Prethopalpus sp. indet.

Prethopalpus sp. indet. was recorded as a singleton from a scrape sample in WSR2930R during sampling in 2021. This is the only record of *Prethopalpus* recorded from Western Ridge. WSR2930R lies approximately 50 m within the most south-western proposed pit area at Silver Knight (Figure 17). Based on the stratigraphy of WSR2930R, *Prethopalpus* sp. indet. likely inhabits the hardcapped MM (Table 8). Figure 18 shows the hardcapped MM extending to the north between the proposed pit areas, and Figure 19 shows the hardcapped MM extends out to the east and west beyond the proposed pit area. The geological model is cut by the tenure boundaries to the south and west of the *Prethopalpus* sp. indet. record (Figure 17).

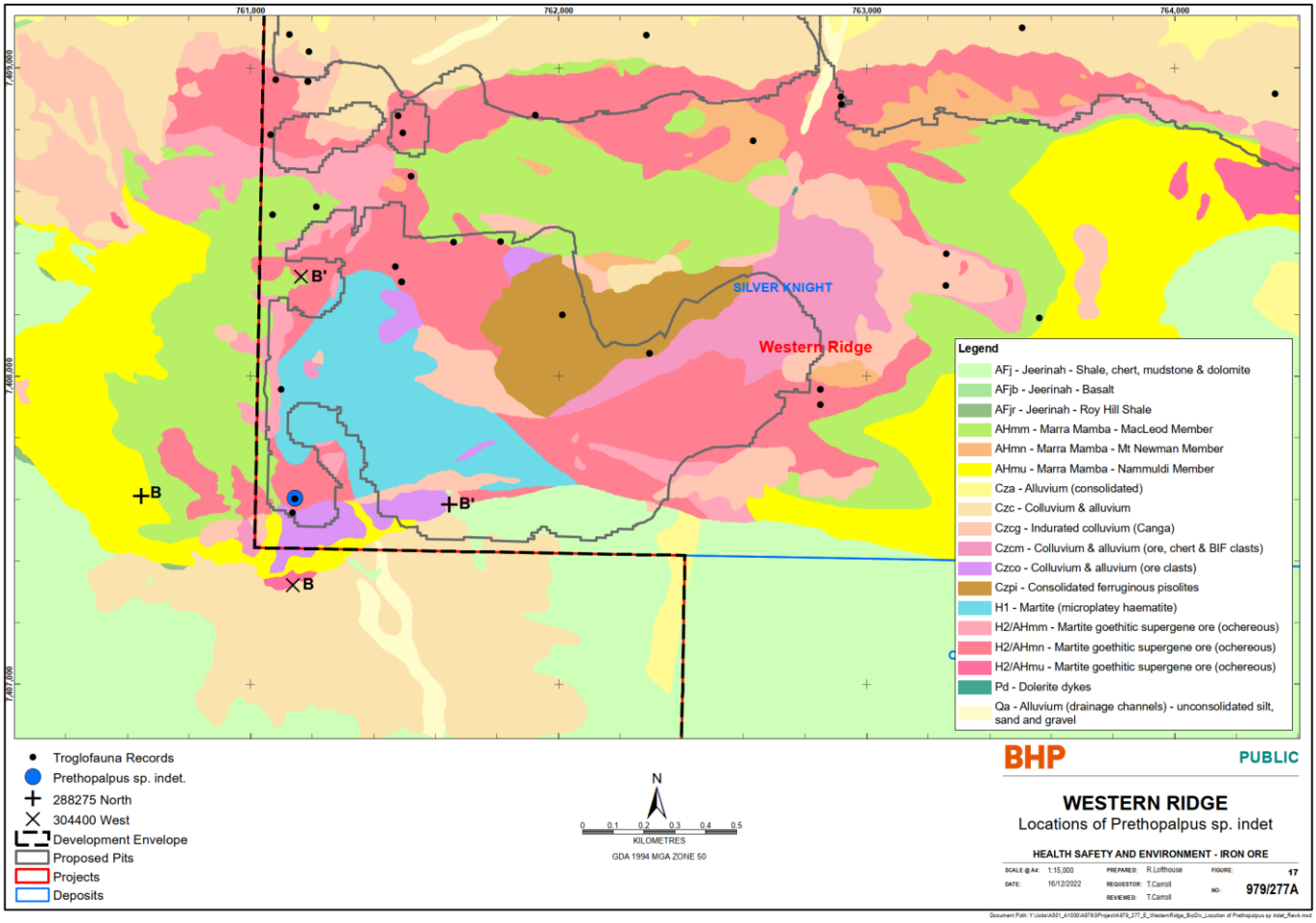


Figure 17: 1:20,000 geological mapping showing the location of *Prethopalpus* sp. indet. and the cross section lines shown in Figure 18 and Figure 19.

Table 8: Stratigraphy of WSR2930R.

Stratigraphy	WSR2930R
Hardcap	0 – 27 m
MM	0 – 31.6 m
MU	31.6 – 75 m

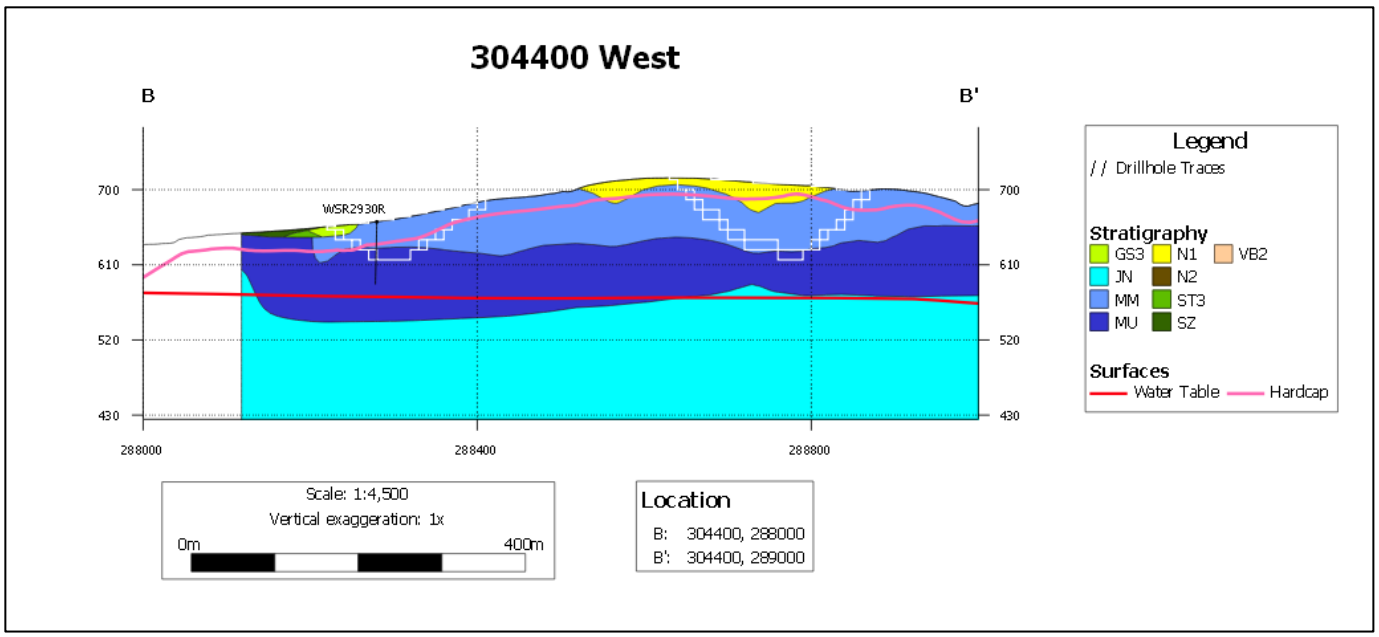


Figure 18: Cross section, facing west, showing the location and geological setting of WSR2930R.

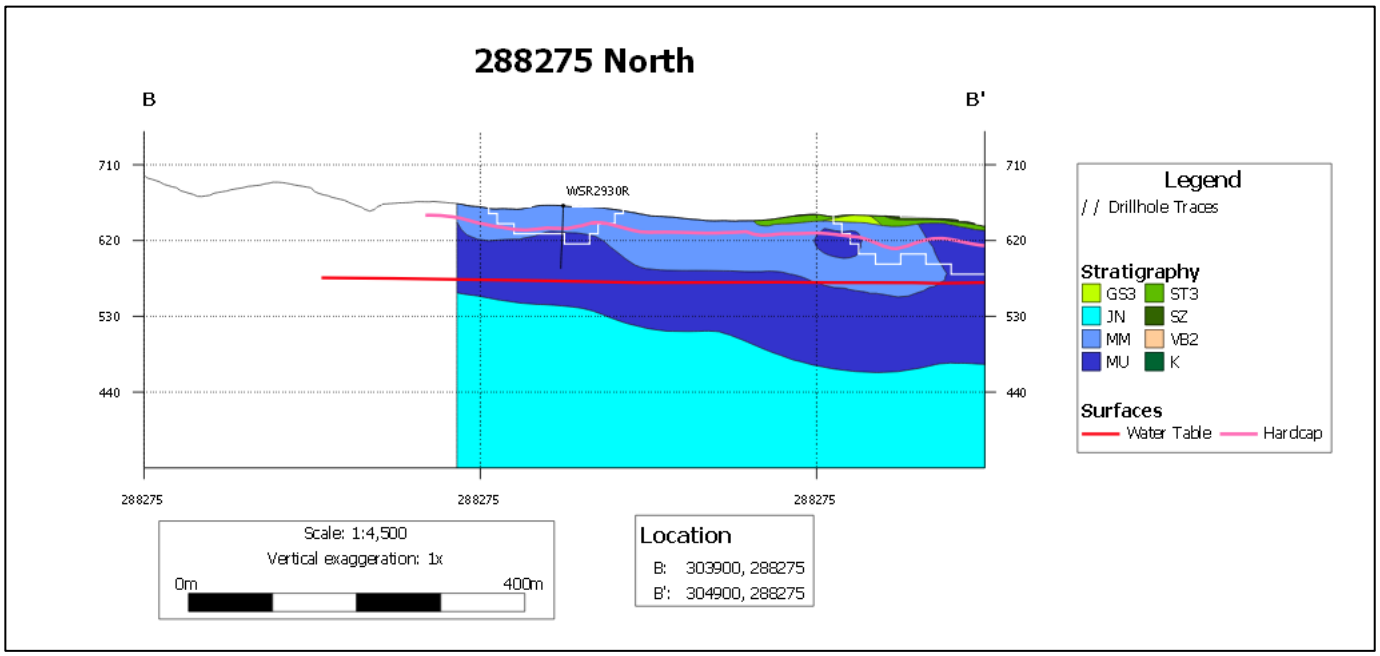


Figure 19: Cross section, facing north, showing the location and geological setting of WSR2930R.

Symphylella `BSYM109`

A single individual of *Symphylella* `BSYM109` was recorded from a trap at 30 m bgl within WSR3658R during sampling in 2022. The trap depth corresponds to MM (Table 9). WSR3658R lies approximately 40 m from the eastern edge of the proposed pit in the Silver Knight area (Figure 20). In 2010, a single individual of the widespread species *Symphylella* sp. B02 was recorded from EXR0784, approximately 3.2 km from the *Symphylella* `BSYM109` record (Figure 21). Unfortunately multiple attempts to sequence the *Symphylella* sp. B02 individual were unsuccessful, however it is considered possible that *Symphylella* `BSYM109` is actually the widespread *Symphylella* sp. B02 (Bennelongia 2022).

Based on the stratigraphy, it is likely that *Symphylella* `BSYM109` occurs in the hardcapped MM (Table 9). *Symphylella* sp. B02 also likely occurs in the hardcapped MM (Table 9). Cross sections though WSR3658R show hardcapped MM continuing above the water table to the south of, and below, the relatively shallow proposed pit (Figure 22) and to the west and east and below the proposed pit (Figure 23). It is likely that *Sypmylella* `BSYM109` could move between the hardcapped geological units (e.g. hardcapped MM to hardcapped N1 in the east) as there

are no obvious barriers present. The hardcap is also modelled to extend beyond the proposed pits in all directions (Figure 22 and Figure 23).

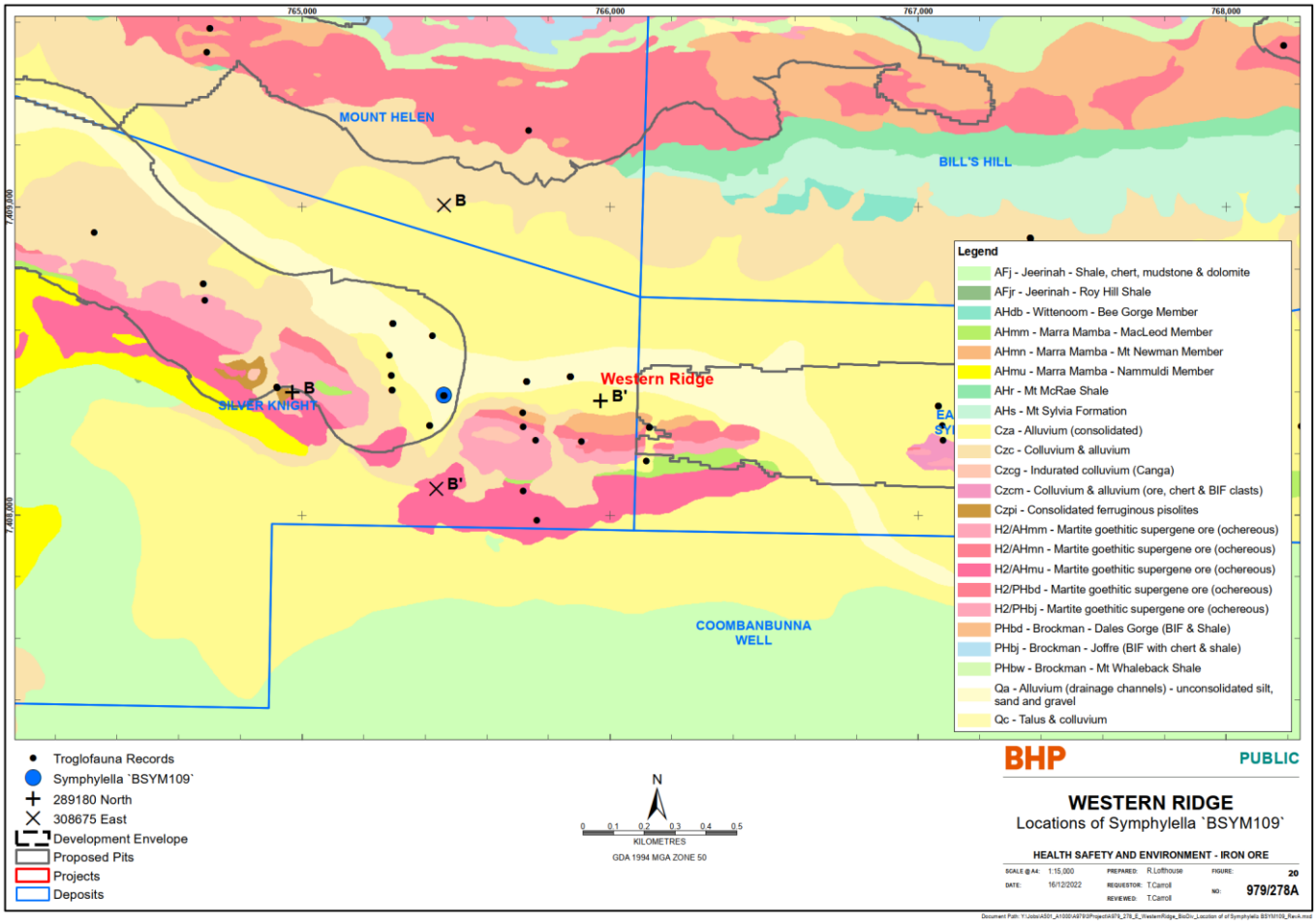


Figure 20: 1:20,000 geological mapping with the location of *Symphylella* `BSYM109`.

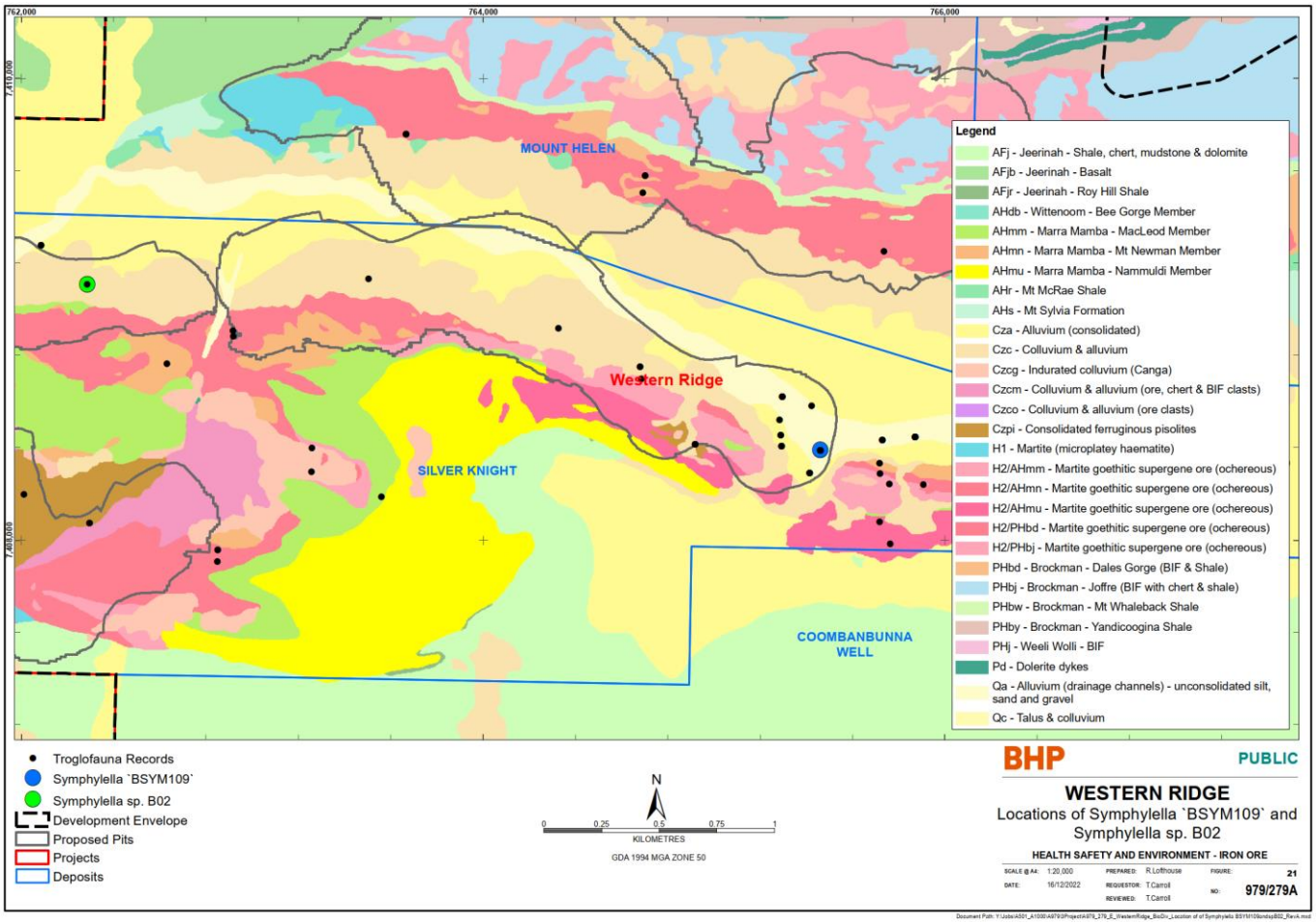


Figure 21: 1:20,000 geological mapping showing locations of *Symphylella* `BSYM109`, *Symphylella* sp. B02. and other troglofauna records.

Table 9: Stratigraphy of WSR3658R and EXR0784

Stratigraphy	WSR3658R	EXR0784
Hardcap	6 - 21 m	11.9 – 24 m
SZ		0 – 3 m
TD3 (ST3) TD3 (GS3)	0 – 6 m	3 – 6 m 6 – 12 m
MM	6 – 33 m **(T 30 m)**	12 – 72 m
MU		72 – 87 m

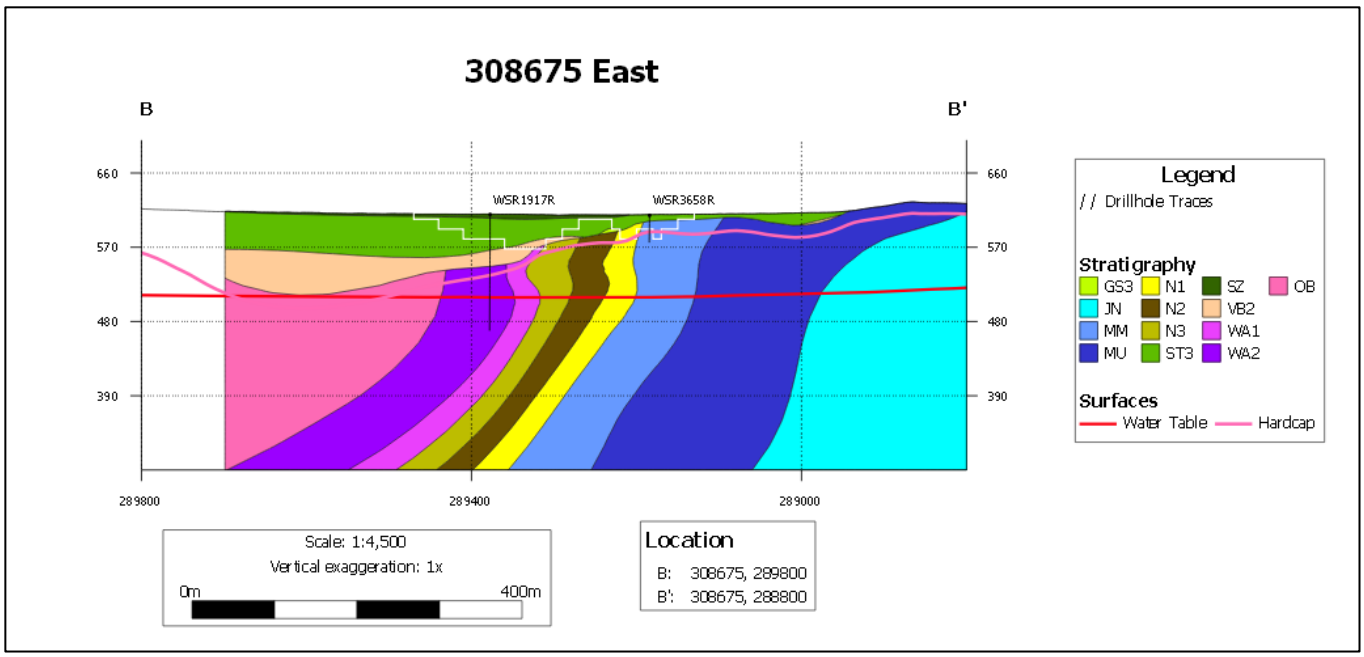


Figure 22: Cross section, facing east, showing the location and geological setting of WSR3658R.

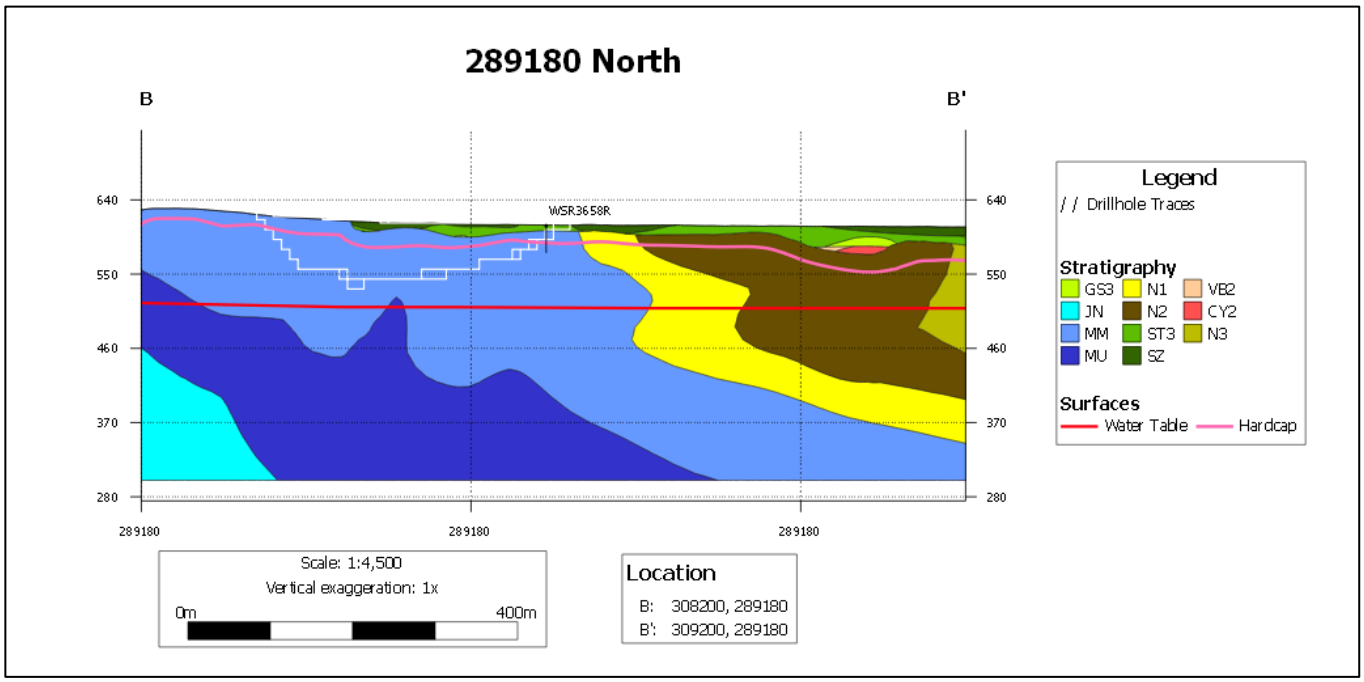


Figure 23: Cross section, facing north, showing the location and geological setting of WSR3658R.

Tyrannochthonius `PSE053`

Tyrannochthonius `PSE053` was recorded as bycatch in a net from stygofauna sampling and from a scrape in EXR1659R and EXR1666R respectively. These records are located within a proposed pit in the Silver Knight area (Figure 24). Likely habitat is the hardcapped WA2 within EXR1666R and the hardcapped MM within EXR1659R (Table 10). The occurrence of this species within different stratigraphy approximately 200 m apart suggests there are pathways for movement within and between the stratigraphic units. Hardcapped WA2 is present outside of the proposed pit to the north where it is overlain by the VB2 (Figure 25). Figure 26 shows the hardcap, MM and N1 to the east and the hardcap and MM to west of the proposed pit above water table. In addition, Palpigradi sp. B07 (discussed above) was also recorded within EXR1666R and hole EXR1446R, which is approximately 760 m to the north (Figure 24). This supports the suggestion that there are pathways for dispersal outside of the proposed pit to the north likely through the hardcap and vuggy breccia.

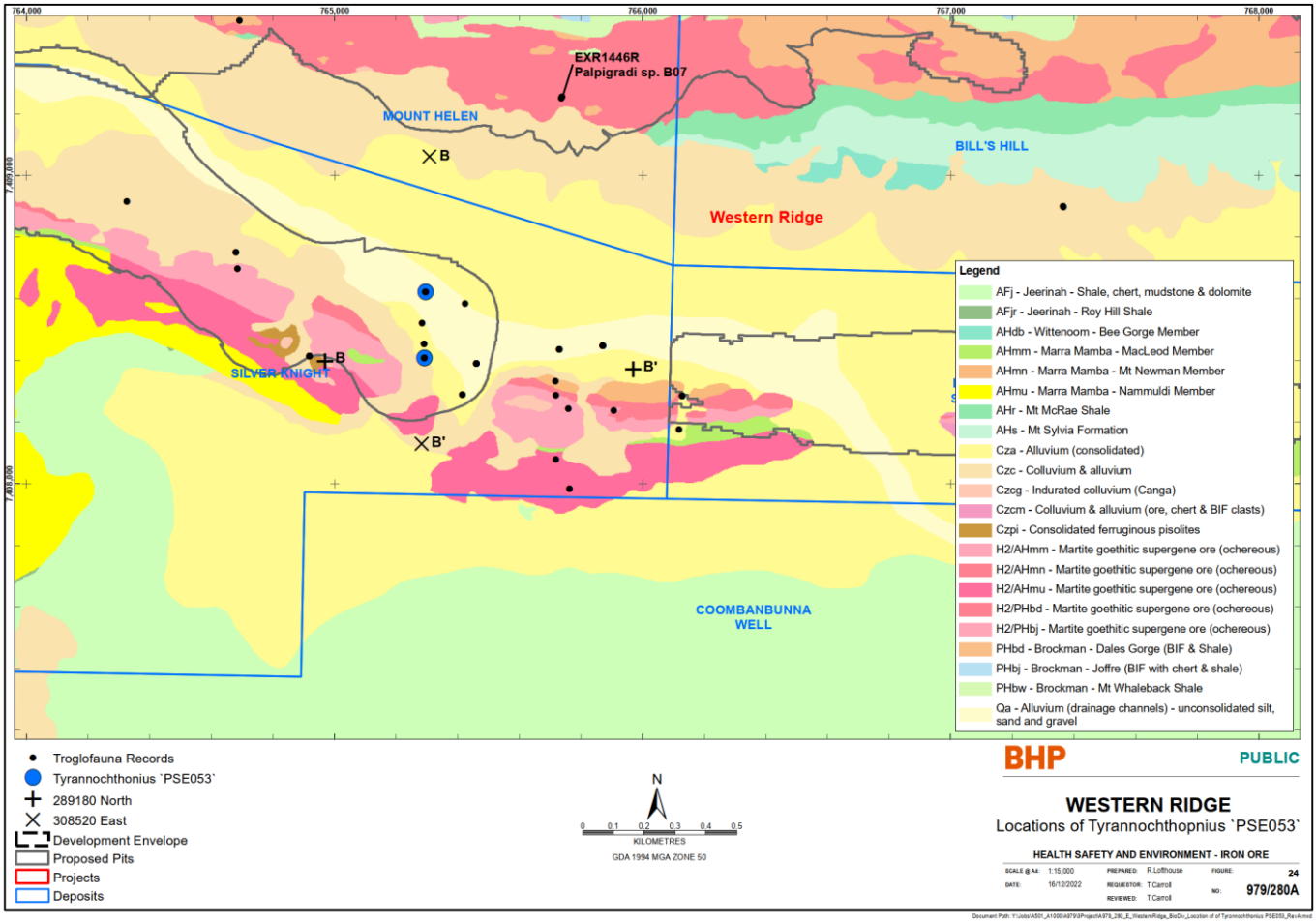


Figure 24: 1: 20,000 geological mapping showing location of *Tyrannochthonius* `PSE053`, EXR1446R, other troglofauna records and the cross section lines shown in Figure 25 and Figure 26.

Table 10: Stratigraphy of EXR1666R and EXR1659R.

Stratigraphy	EXR1666R	EXR1659R
Hardcap	42 – 57 m	6 – 27 m
SZ	0 – 6 m	0 – 6 m
TD3 (ST3)	6 – 42 m	
WA2	42 – 117 m	
MM		6 – 123 m

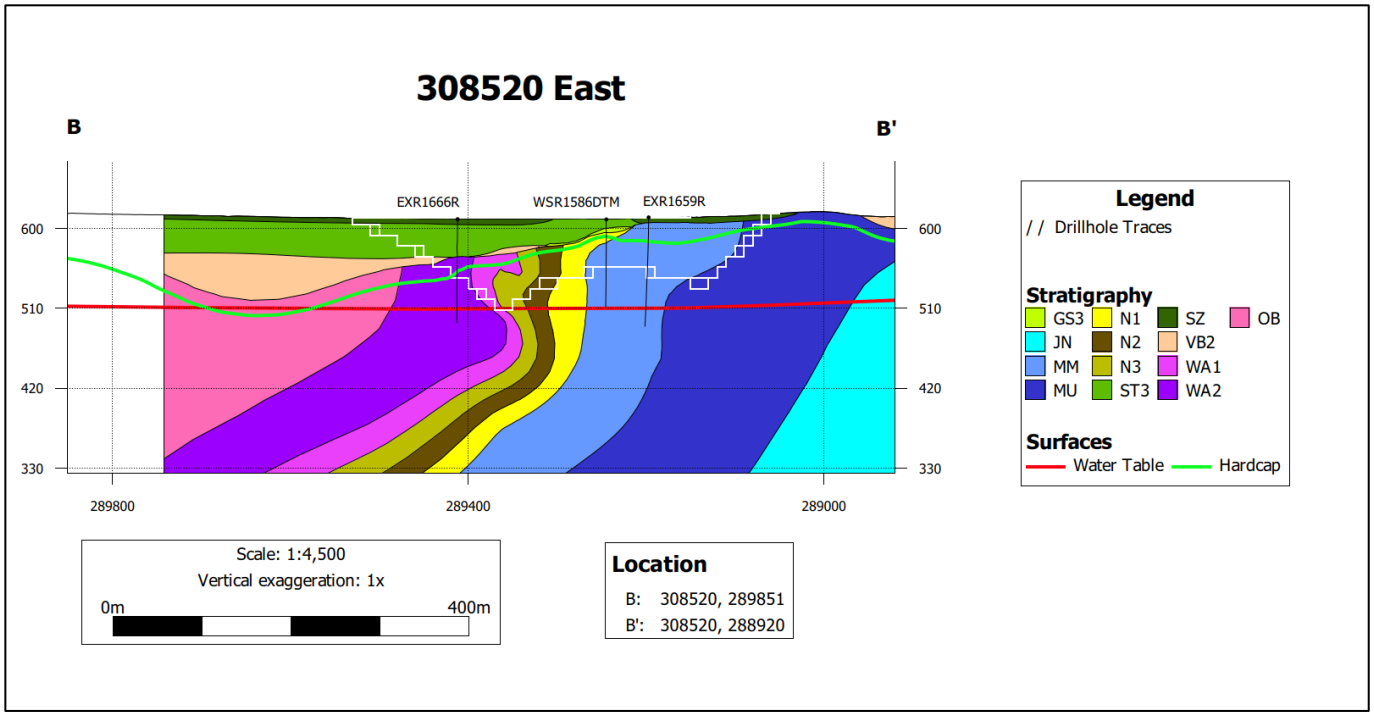


Figure 25: Cross section, facing east, showing the location and geological setting of EXR1659R and EXR1666R.

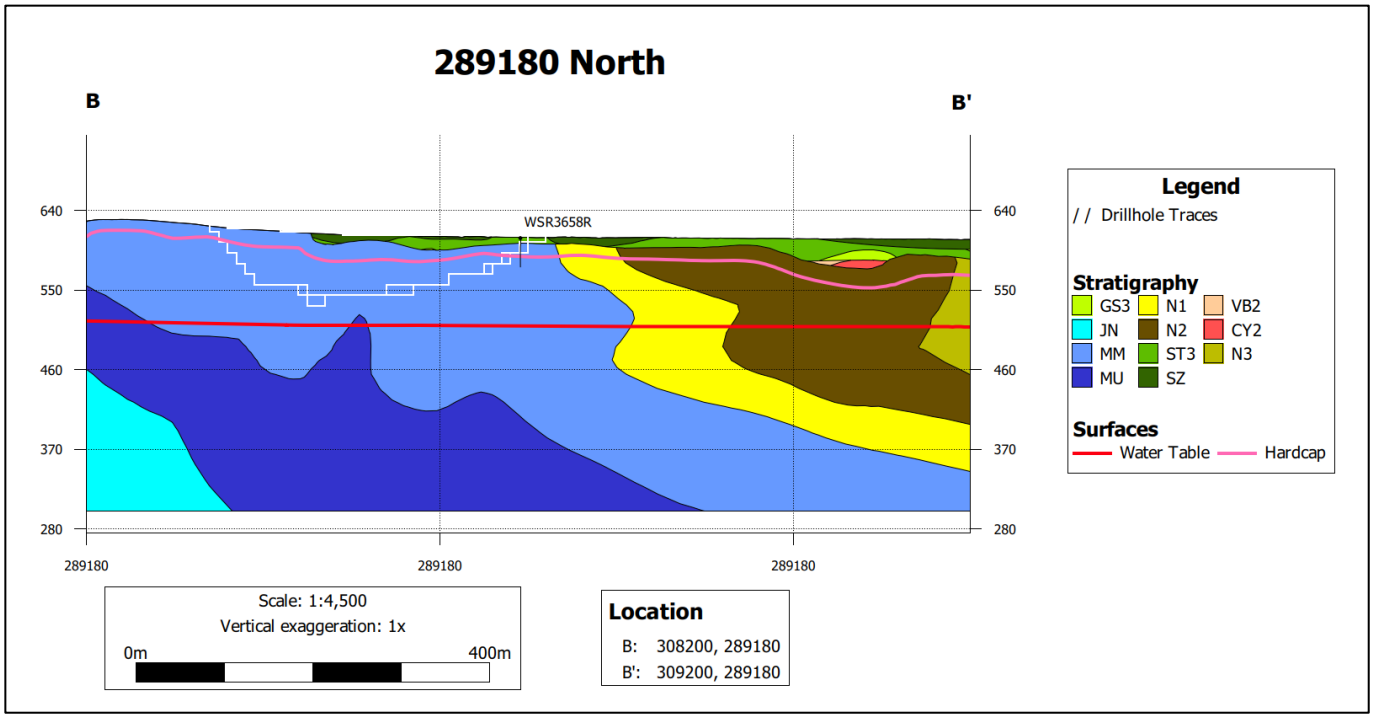


Figure 26: Cross section, facing north showing the extent of hardcapped MM to the east and west of the proposed pit.

Potential impacts to troglofauna

BHP has considered the potential impacts outlined in the EPA's Environmental Factor Guideline for Subterranean Fauna (EPA 2016c) and considers that the excavation of geologies known to support troglofauna (direct impact) is relevant to the Proposal.

As discussed above, suitable habitat for troglofauna in the Development Envelope is considered to be the hardcap, the vuggy breccia (VB2) and calcrete (CA2) within TD2 of the Tertiary Detritals, the Dales Gorge Member (particularly

units D2, D3 and D4) of the Brockman Iron Formation, the West Angela Member (where hardcapped) of the Wittenoom Formation, and the Mount Newman Member (N1, N2 and N3) and MacLeod Member (MM) of the Marra Mamba Iron Formation (Table 2). These units are extensive both inside and outside of the proposed pit areas (as illustrated in the figures presented above).

Of the seven troglofauna species that have only been recorded within the proposed pits, one is considered certain, two are highly likely, and four likely to have distributions outside of the proposed pits (Table 11). This assessment is based on continuation and availability of suitable habitat, proximity to the edge of the proposed pit, and likely (or known) range of the species, as detailed in Table 11.

The addition species, *Cryptops* `BSCOL064`, is known to occur outside of the proposed pits but is included in Table 11 for completeness.

Table 11: Likelihood of occurrence of the eight troglofauna species occurring outside of the proposed pits.

Species	Likelihood of occurrence outside of proposed pits	Rationale
Cryptops `BSCOL064`	Certain	This species occurs 5 m outside of the Eastern Syncline proposed pit and has a known lineal range of approximately 4.7 km. Given the distance between the records, most of which is outside of proposed pits. *Cryptops* `BSCOL064` is considered certain to occur outside of proposed mine pits.
Cryptops `BSCOL065`	Likely	Based on the core photos (Appendix A), *Cryptops* `BSCOL065` likely inhabits the vuggy textures of the GS3 (TD3) and the hardcapped N1. N1 and GS3 is available to the east below a shallow proposed pit area, and there are dispersal opportunities for this species through the hardcapped material to the north and east of the proposed mine pit.
Hanseniella `BSYM095`	Highly likely	Suitable habitat in the VB2 and hardcapped WA2 are extensive outside of the proposed pit areas to the north and east. Therefore, it can be expected that the species may occur outside of the proposed pits as pathways for dispersal through suitable habitat are widely available.
Indohya `BPS294`	Likely	Suitable habitat in the hardcapped N1 and MM and unaltered MM continues and is extensive to the north between proposed pits. *Eukoenenia* `BPAL046`, also recorded in WSR1659R, was found in WSR1661R approximately 340 m to the north in the same habitat present within WSR1659R, which suggests there are pathways for dispersal through this suitable habitat outside of the proposed pit areas.
Palpigradi sp. B07	Certain	Occurs over a lineal distribution of approximately 1.6 km, in a range of habitats from both the Marra Mamba Iron Formation and Brockman Iron Formation. There is a deep detrital sequence, which includes prospective habitat in the VB2, that occurs between the two proposed pits that Palpigradi sp. B07 occurs within. Therefore, it can be expected there are pathways for dispersal between the proposed pits. In addition, it is considered likely that Palpigradi sp. indet, which occurs outside of the proposed pits, represents Palpigradi sp. B07. There is also a possiblity that *Eukoenenia* `BPAL046` (also known from outside the proposed pits) and Palpigradi sp. B07 are the same species.

Species	Likelihood of occurrence outside of proposed pits	Rationale
Prethopalpus sp. indet.	Likely	Suitable habitat in the hardcapped MM and unaltered MM extends out to the east, west and north of the proposed pit areas.Therefore, it can be expected that the species may occur outside of the proposed pits as pathways for dispersal through suitable habitat are available.
Symphylella `BSYM109`	Highly likely (potentially certain – if same species as *Sympylella* sp. B02)	Suitable habitat in the hardcapped MM extends to the south, west and east of the proposed pit. There are also no obvious barriers between the geological units. Therefore, it can be expected that the species may occur outside of the proposed pits as pathways for dispersal through suitable habitat are widely available. Additionally, if *Symphylella* `BSYM109` is actually *Symphylella* sp. B02 then it is a widespread species. *Sympylella* sp. B02 occurs in the same habitat as *Symphylella* `BSYM109`.
Tyrannochthonius `PSE053`	Likely	Suitable habitat in the hardcapped WA2 and VB2 occurs to the north outside of the proposed pit. Additional habitat in the hardcap and MM extends to the east and west of the proposed pit. Habitat connectivity potentially is also supported and demonstrated by *Palpigradi* sp. B07 which occurs over a lineal distribution of approximately 1.6 km and was also recorded from EXR1666R.

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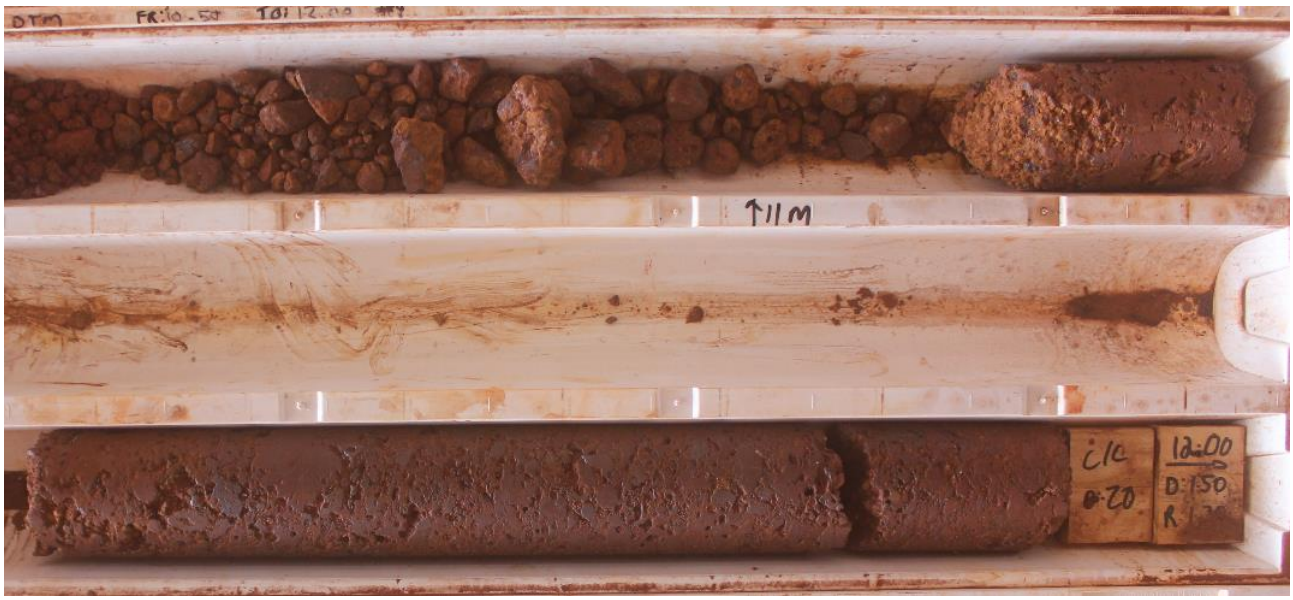
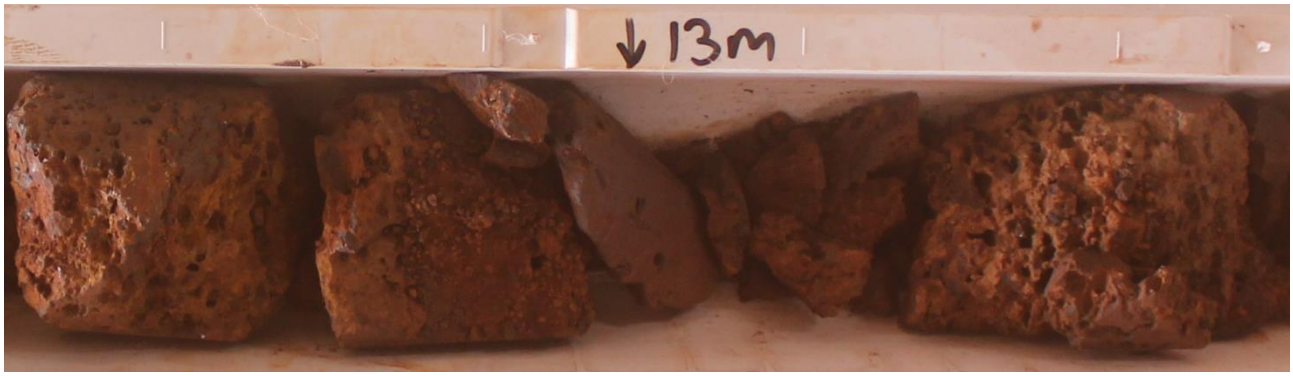
Appendix

Appendix A. Hardcap in WSR1586R.

Drill core photos from WSR1586R showing vugginess and cavities in the intervals from 11 – 12 m and 12 – 13.5 m within the TD3 (GS3) and 18.1 – 19.7 m within the hardcapped N1.




↓13m


↓19m
CAVITY
19.70
D:1.60
R:1.50