MEMORANDUM

To:	**Audalia Resources Ltd**	**Date:**	23 July 2019
Attn:	Geoffrey Han	**Our Ref:**	PE19-00797
		KP File Ref.:	PE801-00369/01-A jl M19001
cc:	Brent Butler	**From:**	Jim Luo/Dave Morgan

RE: MEDCALF PROJECT – GEOTECHNICAL DESKTOP STUDY OF PIT NORTH SHELL STABILITY

1. INTRODUCTION

The Medcalf Project is a vanadium, titanium and iron project located approximately 470 kilometres south east of Perth near Lake Johnston, Western Australia.

Audalia Resources Ltd (Audalia) is developing this project and requested Knight Piésold Pty Ltd (KP) to conduct a geotechnical desktop study of the proposed pit slope profile and assess stability.

On 8 May 2019, Jim Luo of KP inspected the cores at the core yard and discussed the scope of work with Brent Butler and Geoffrey Han of Audalia.

The agreed scope of work is to:

- Assess the profile of the north shell slope in the Vesuvius open pit based on currently available information.

The site layout and Vesuvius open pit location are shown on figures 1.1 and 1.2.

This memorandum presents the preliminary stability assessment based on available information and provides recommendations for the next phase of development.

2. REGIONAL GEOLOGY AND STRUCTURES

Audalia has conducted a geological study for this project and the findings are summarised in the Geological Summary Report (Ref. 1). The relevant regional geological information is extracted below.

The Medcalf deposit is located in the Archaean aged Lake Johnston greenstone belt in the southern portion of the Youanmi Terrane, part of the Yilgarn Craton (Figure 1.2). This belt is a narrow north-northwest trending belt, approximately 110 km in length. It is located near the south margin of the Yilgarn Craton, midway between the southern ends of Norseman-Wiluna and the Forrestonia-Southern Cross greenstone belts.

The eastern and northern limits of the Lake Johnston Greenstone Belt are defined by the large northwest-trending Koolyanobbing shear zone. To the west, the greenstones are bound by granitoids and gneissic rocks which extend some 70 km west to the Forrestonia-Southern Cross greenstone belts. To the south, the greenstones appear to pinch out in granites.

The western margin of the Lake Johnston greenstone belt consists of a west facing succession of mafic and felsic volcanics, some sediment horizons, Banded Iron Formation (BIF) and three ultramafic units.

The volcanics and sediments are flanked and intruded by granitic rocks which disrupt the continuity of the greenstone belt. Pegmatitic doleritic dykes are common. The sequence is extensively faulted, and gently inclined. North and south plunging folds have been recognised. The boundaries of the greenstone belt are thought to be largely defined by strike parallel shears and faults.

The bedrock geology is widely masked by lateritic duricrust, deep oxidation and transported material. The average thickness of the regolith and weathered bedrock is 60 to 80 m. Weathering of ultramafic rock types is often intense with widespread development of silica-rich "cap-rock" in the saprolite zone.

The Regional structures strike approximately at 330° with the foliation dipping most commonly steeply to the east, with the only major exception being dips within the metabasalt along the western edge of Lake Johnston to the west.

The Lake Johnston greenstone belt is considered to be a western overturned limb of a broad regional anticline. The eastern limb is no longer preserved having been removed by one or a combination of the following factors:

- *Faulted out to a higher position followed by erosion to present levels*
- *Obliterated by late stage granite intrusion*
- *The unit corresponds to a thinner and less developed section of the pile.*

The third point above is also considered to be the reason for the general lensing out of the main layered intrusive toward the southern end.

The Medcalf layered sill has been intruded low in the greenstone succession and appears to be in the hinge zone of a major, gently north plunging regional anticline. The succession to the west of Medcalf is west-facing but is generally overturned, with steep easterly dips. To the east of Medcalf are the granite intruded remnants of the east-facing eastern limb of the regional anticline.

3. SEISMIC CONDITIONS

The seismicity of much of Australia is typical of an intra-plate region, characterised by low levels of seismic activity and earthquakes apparently randomly distributed in location and time. The correlation between recorded earthquakes and geological features is typically not well known or understood.

Seismic loading conditions depend on the earthquake magnitude that is dependent on the probability of occurrence, or the return period. Based on AS1170.4 (Ref. 5), an earthquake hazard factor for a structure is based on an average return period of 500 years. The International Building Code (2012, Ref .6) adopts an average return period of 2500 years. The peak ground accelerations (PGA) for both return periods have been assessed in this study.

Based on the site location (6,398,400 mN, 292,800 mE), the maps and grid values published by Geoscience Australia (Ref.2), the Peak Ground Accelerations (PGA) for 475 and 2475 year average return periods are summarised in Table 3.1 and shown on figures 3.1 and 3.2.

Table 3.1: PGA for Different Return Periods

Return Period (Year)	Annual Probability	PGA (g)
475	0.2%	0.02
2475	0.04%	0.08

4. SITE GEOTECHNICAL CONDITIONS

Some of the rock core samples inspected have decomposed to soils due to weathering and an assessment of rock strength based on weathered core samples is not considered appropriate.

The project site geotechnical conditions have been assessed based on the available resource drilling data and the core sample photographs of the four boreholes (MDD03, MDD05, MDD15 and MDD16) included in Appendix A. These four boreholes were drilled in proximity to the north shell of Vesuvius pit. The estimated ground conditions and geotechnical properties are discussed below.

4.1 SUBSURFACE PROFILES

By reviewing the site photographs and logs of boreholes MDD03, MDD05, MDD15 and MDD16, the subsurface profile at the north part of the open pit comprises the following layers:

- From surface to ~ 25 m: Siltstone/Ironstone/BIF, highly to extremely weathered with low to extremely low strength.
- From ~ 25 m to ~ 53 m: Siltstone, highly weathered, low to extremely low strength.
- Below 53 m: Basalt and associated Dolerite Sills, highly weathered to fresh with layers of completely weathered rock, low to very high strength.

The joint sets are generally sub-horizontal (photographs do not indicate a significant unfavourable joint set).

The Rock Mass Ratings (RMR) based on intact rock strength, Rock Quality Designation (RQD), spacing of discontinuity, conditions of the discontinuity and ground water conditions have been estimated for the above three layers and are summarised in Table 4.1.

Table 4.1: Average RMR of Stratigraphy

Stratigraphy Unit	Depth (m)	Average RMR	Rock Class	Description
Siltstone/Ironstone/ BIF	0 to 25 m	22	4 to 5	Very poor to poor rock
Siltstone	25 to 53m	35	4	Poor rock
Basalt and associated Dolerite Sills	Below 53 m	41	3 to 4	Fair to poor rock

The assessment indicates that conditions from existing ground surface to approximately 53 m comprise of very poor to poor rocks.

Below approximately 53 m, rock becomes poor to fair with relatively higher strength.

4.2 GEOTECHNICAL PROPERTIES OF SUBSURFACE MATERIALS

Based on the estimated RMR values and rock classes, the assumed shear strength parameters are summarised in Table 4.2.

Table 4.2: Assumed Shear Strength Parameters

Stratigraphy Unit	Depth (m)	Unit weight (KN/m^3)	Cohesion (KPa)	Friction Angle (Degrees)
Siltstone/ Ironstone/BIF	0 to 25 m	23	30	33
Siltstone	25 m to 53 m	23	50	33
Basalt and Associated Dolerite Sills	Below 53 m	24	150 to 500	32

4.3 GROUND WATER CONDITIONS

Audalia advised that no ground water was encountered in any bore holes developed to date and regional the ground water level is below the proposed pit base (~ 60 m below the existing ground surface).

The design basis assumes that the excavation of the pit will be carried out in dry / drained conditions.

5. PIT SHELL SLOPE STABILITY ASSESSMENT

5.1 PROPOSED NORTH PIT SHELL PROFILE

It is understood from Audalia that the maximum pit depth is 60 m and due to the low strength materials that will be encountered, the pit will be predominantly free dig using excavators.

The proposed north pit shell slope comprises 3 No. benches with bench heights of 25 m, 15 m and 20 m respectively. The top bench face angle adopted is 1V:1.5H and the two lower bench slope faces are steepened to 1V:1H. The bench widths are 4 m. Figure 5.1 shows the proposed slope profile.

5.2 STABILITY ANALYSIS METHODOLOGY

The pit slope stability was assessed using a limit equilibrium method. The programme SLOPE/W, developed by GEO-SLOPE International Ltd (Ref.3), was used for the stability analysis. The program calculates the magnitude of the mobilising forces in the slope and compares them to the resisting forces which are a function of the shear strength of the soil/rock structure. The ratio of the resisting to the mobilising forces is the Factor of Safety (FOS). When the de-stabilising forces are equal to the strength of the structure this ratio, the Factor of Safety, is equal to one and the slope is said to be "just stable". As the factor of safety increases, the probability of failure is reduced.

Critical failure surfaces are defined as those that give the lowest factor of safety and represent a failure surface that would likely cause significant damage if sliding was to occur.

According to the Guidelines for Open Pit Slope Design (Ref.4), acceptable minimum factors of safety depend on the consequence of failure. It is estimated that the consequence of north pit slope failure would be medium to high based on qualitative risk assessment for personnel safety and possible environmental impacts.

The adopted acceptable factors of safety for different loading conditions are summarised in Table 5.1 as per the guidelines.

Table 5.1: Acceptable Criteria for Pit Slope Stability

Slope Scale	Acceptable Criteria	
	Minimum Factor of Safety (Static)	Minimum Factor of Safety (seismic)
Localised / inter bench	1.1	NA
Overall / global slope	1.3 to 1.5	1.1

5.3 ANALYSIS RESULTS

The analysis results are summarised Table 5.2 and graphically shown on figures 5.2 to 5.6.

Table 5.2: Summary of Analysis Results

Slope Scale	Factor of Safety		
	Static Loading Condition	Seismic Loading Condition	
		Return period of 500 years	Return period of 2500 years
Overall	1.5	1.4	1.4
Lower bench	1.7	NA	NA
Upper bench	1.7	NA	NA

6. CONCLUSIONS AND RECOMMENDATIONS

The stability analysis results indicate that the proposed north pit slope profile has adequate factors of safety under static and seismic loading conditions.

The factors of safety against local bench slope instability meet minimum guideline values.

It is recommended that the following further works are undertaken prior to development:

1) Geotechnical investigation and testing to confirm:
   - the properties of highly to extremely weathered rock; and
   - orientation and conditions of joints in the highly weathered rock and fresh rock.

2) Maintain a safety bund of appropriate dimensions to prevent surface run-off from flowing into the pit and eroding the pit slope surfaces. The safety bund shall be at least 17m away from the crest of the pit slope as shown in Figure 5.1. In addition, surface water management shall be carried out to reduce the potential for surface erosion of the slopes.

3) Once development is started, the pit slope excavation needs to be inspected by an experienced geotechnical engineer. The routine inspection works shall include:

   - Check any excessive or abnormal settlements or cracking on ground surface around the pit and on benches.
   - Map unfavourable joint sets.
   - Identify loose or unstable rock blocks and zones.
   - Adjust local slope profiles based on in situ conditions if required.

4) The pit slope movements shall be monitored during and after excavation.

We trust that the foregoing provides adequate information for your purposes at this stage, however, please contact us should you require any clarification or additional information.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

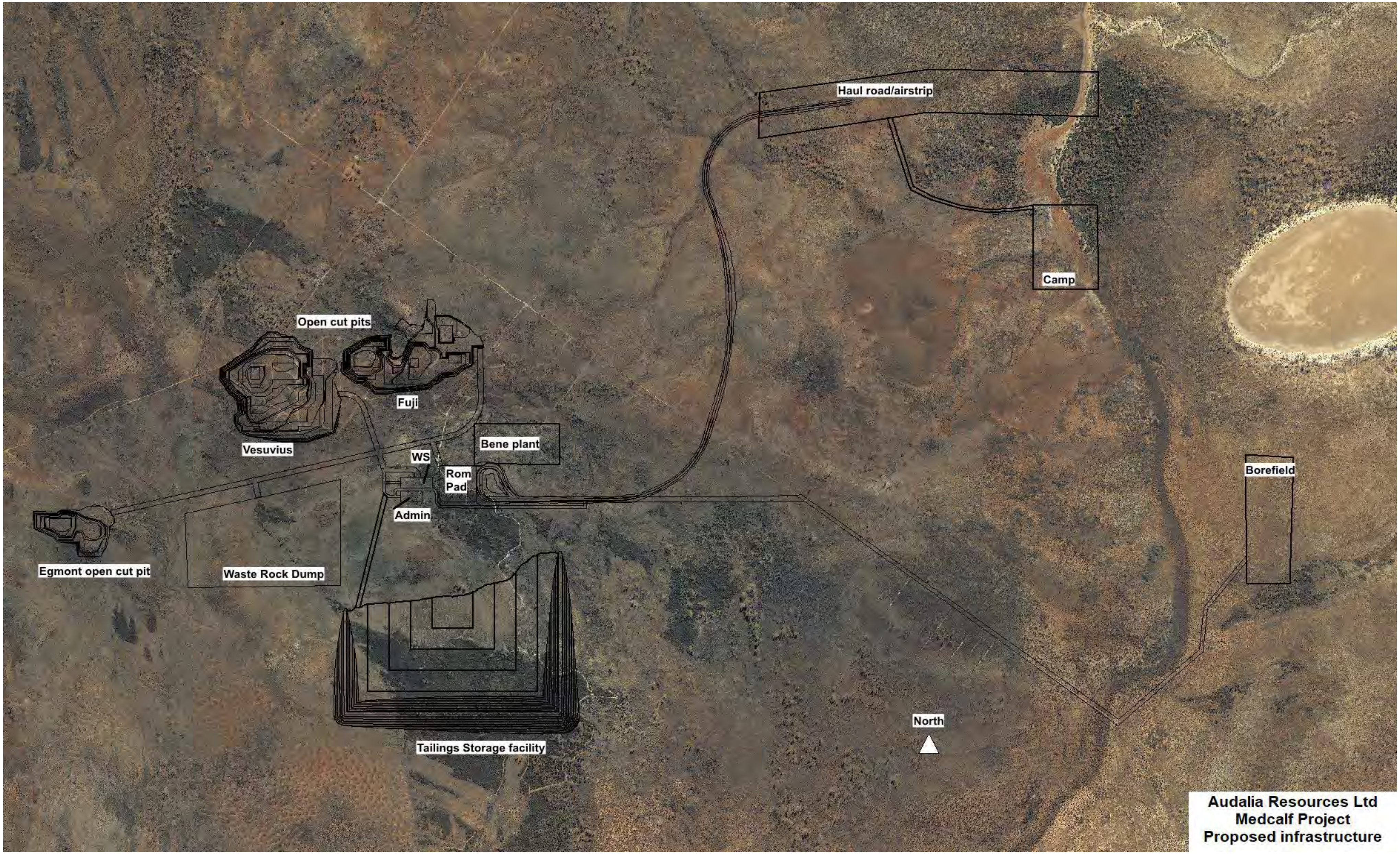
JIM LUO
Principal Geotechnical Engineer

DAVID MORGAN
Managing Director

REFERENCE

1. Audalia Resources Ltd, (Nov 2018), "*Medcalf Geological Summary*".
2. Allen, T.I. (2018), *The 2018 National Seismic Hazard Assessment For Australia: Data Package, Maps And Grid Values*. Record 2018/33. Geoscience Australia, Canberra.
3. GEO-SLOPE International Ltd., "SLOPE/W", 2007.
4. Read, J. and Stacey, P. (2009), Guidelines for Open Pit Slope Design, CSIRO Publishing.
5. AS 1170.4—2007 Structural design actions, Part 4: Earthquake actions in Australia
6. International Building Code (2012), International Code council, INC.

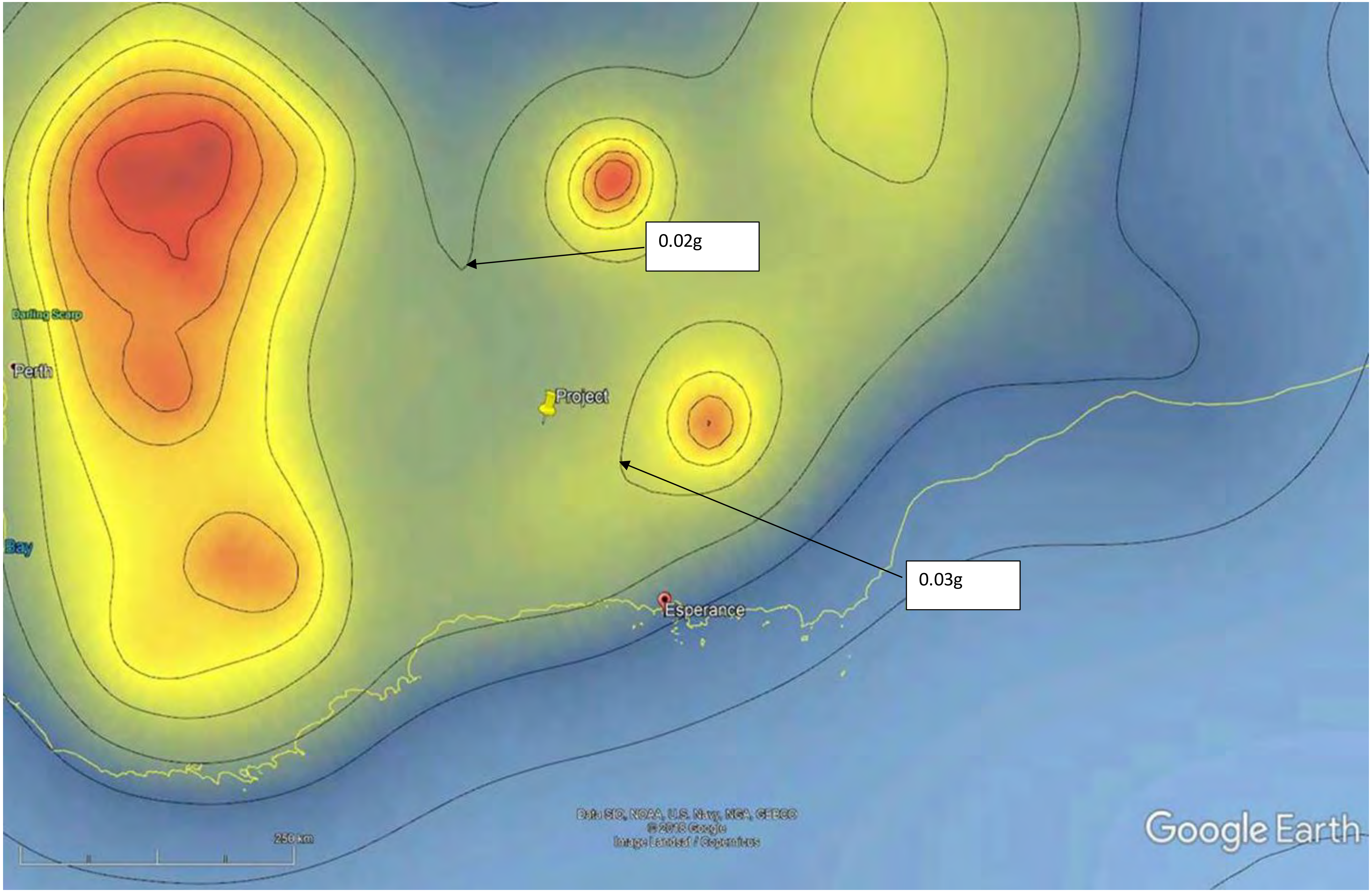
FIGURES


Haul road/airstrip
Camp
Open cut pits
Fuji
Vesuvius
WS
Bene plant
Rom
Pad
Admin
Borefield
Egmont open cut pit
Waste Rock Dump
Tailings Storage facility
North
Audalia Resources Ltd
Medcalf Project
Proposed infrastructure


292,400 mE
292,600 mE
292,800 mE
293,000 mE
6,398,400 mN
6,398,200 mN
MDD16
MDD15
MDD03
MDD05
MDD06
<-- Approximate Vesuvius pit boundary
MDD10
N
W
E
S
Audalia Resources Limited
Medcalf Project
Vesuvius Prospect
Geotech holes
0
20
40
80
metres

Regional geology showing greenstone belts and mine locations

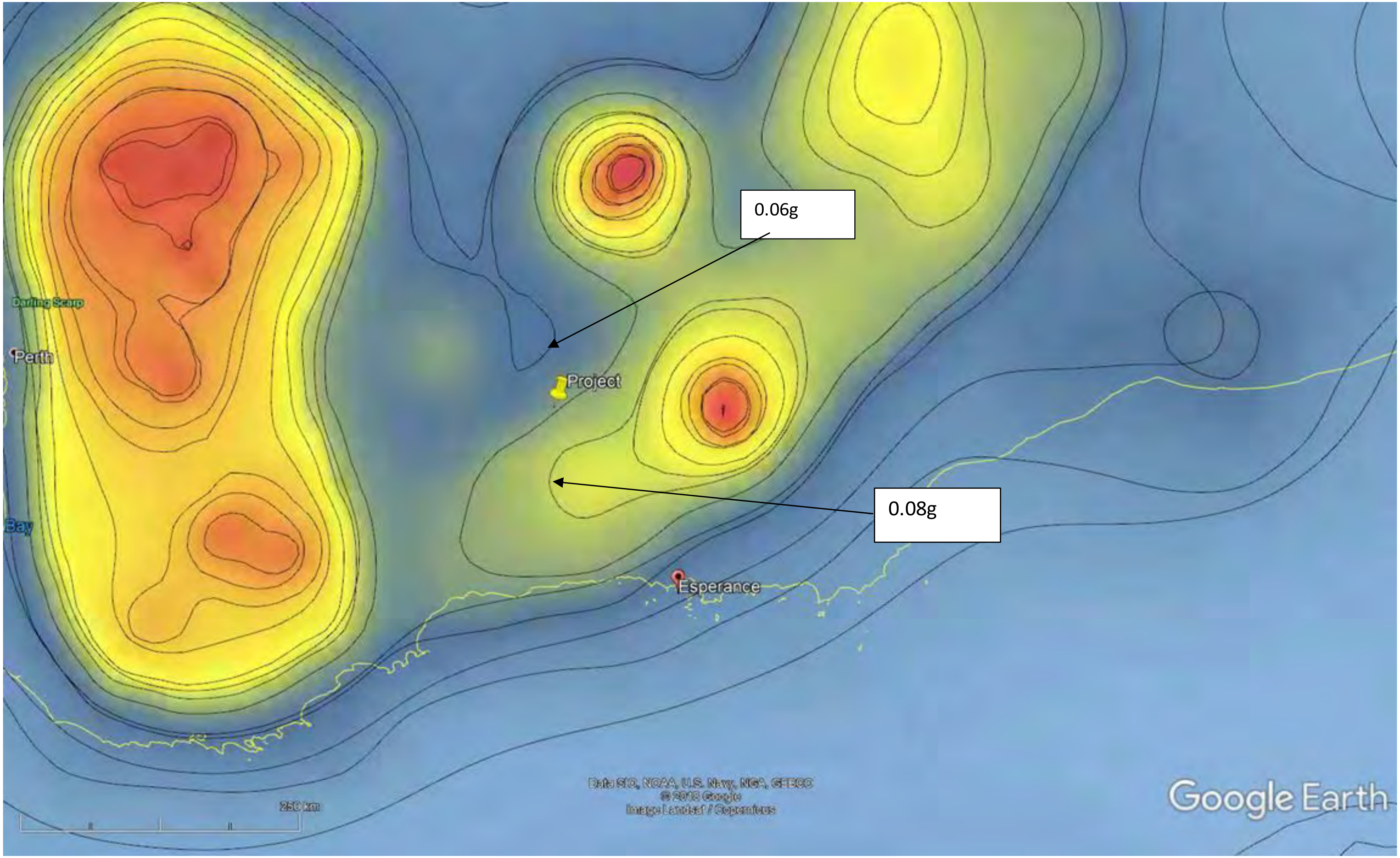
Figure 2.1

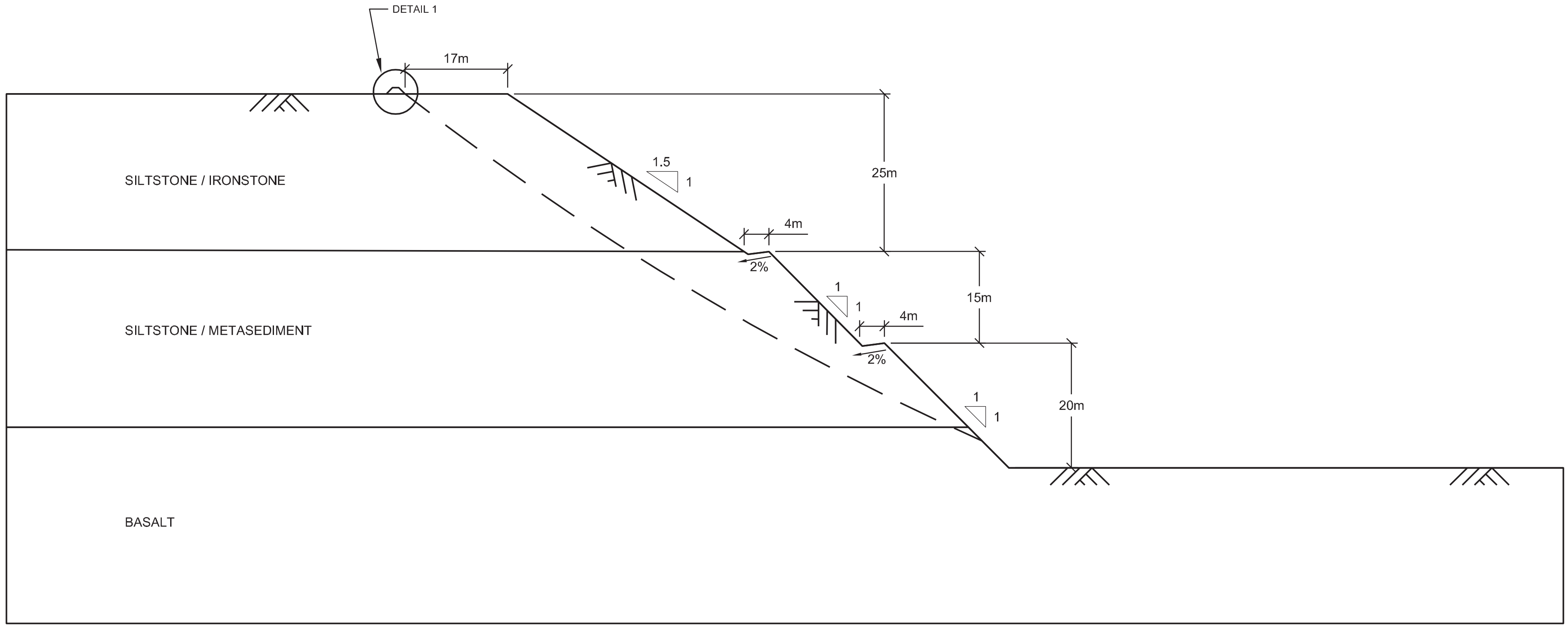


Knight Piésold CONSULTING

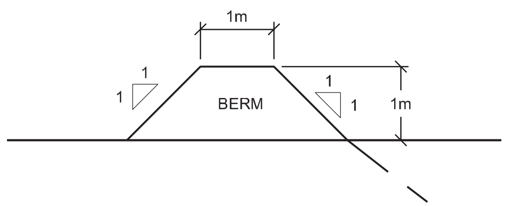
MEDCALF PROJECT
DESKTOP STUDY OF NORTH SHELL SLOPE STABILITY
PGA countours with 475 year return periodd

PE801-00369/01M19001
Figure 3.1

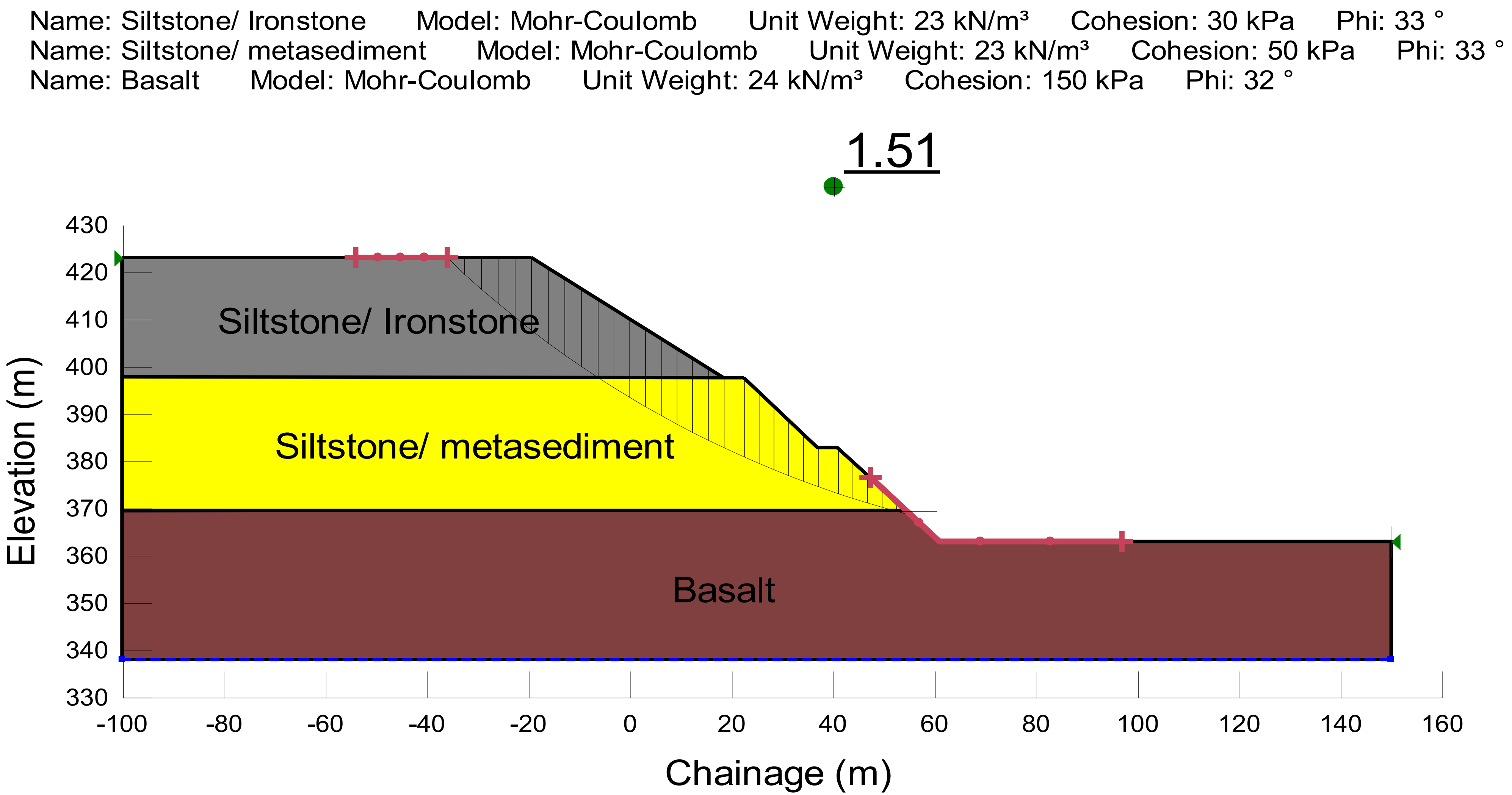

0.06g
0.08g
Darling Scarp
Perth
Project
Bay
Esperance
Data SIO, NOAA, U.S. Navy, NGA, GEBCO
Image Landsat / Copernicus
250 km
Google Earth



TYPICAL OPEN PIT SECTION

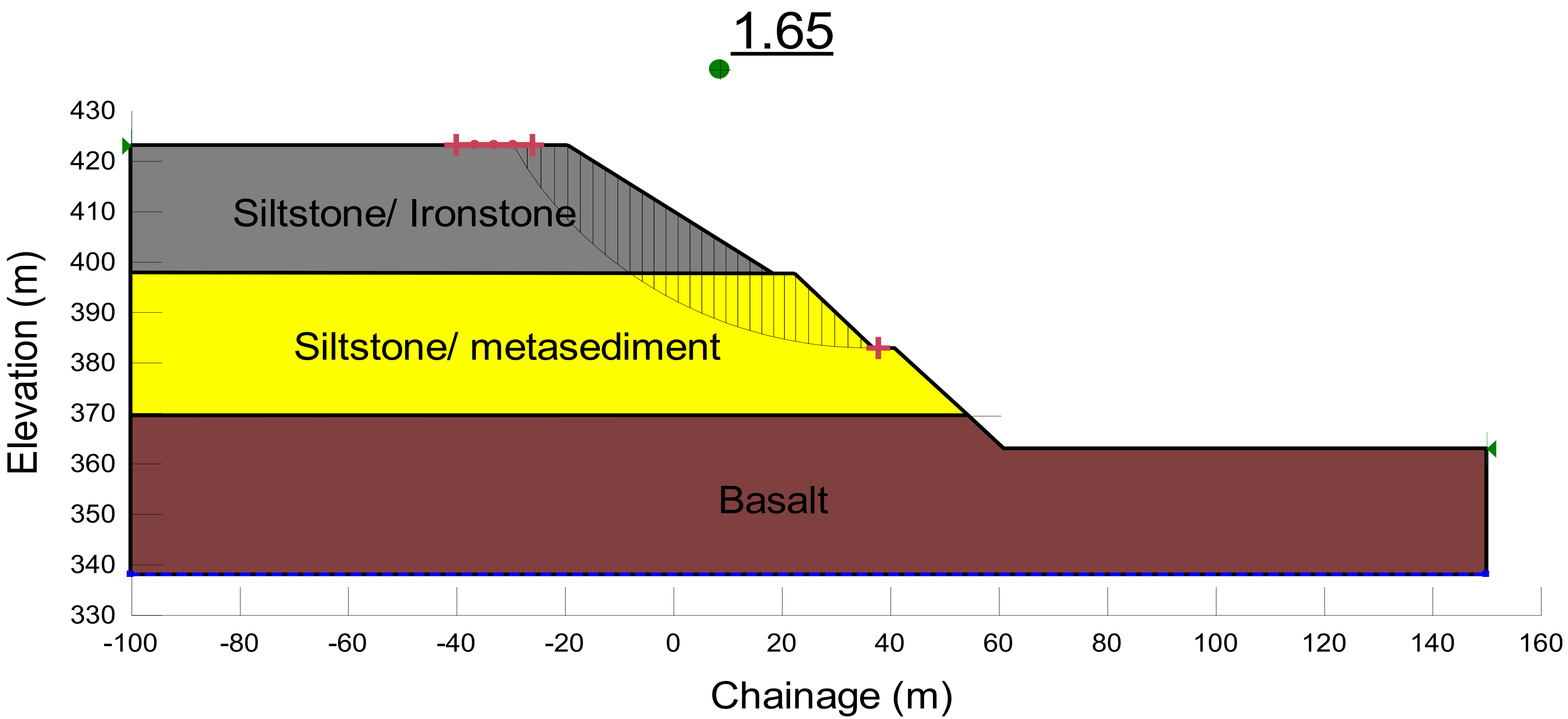


DETAIL 1



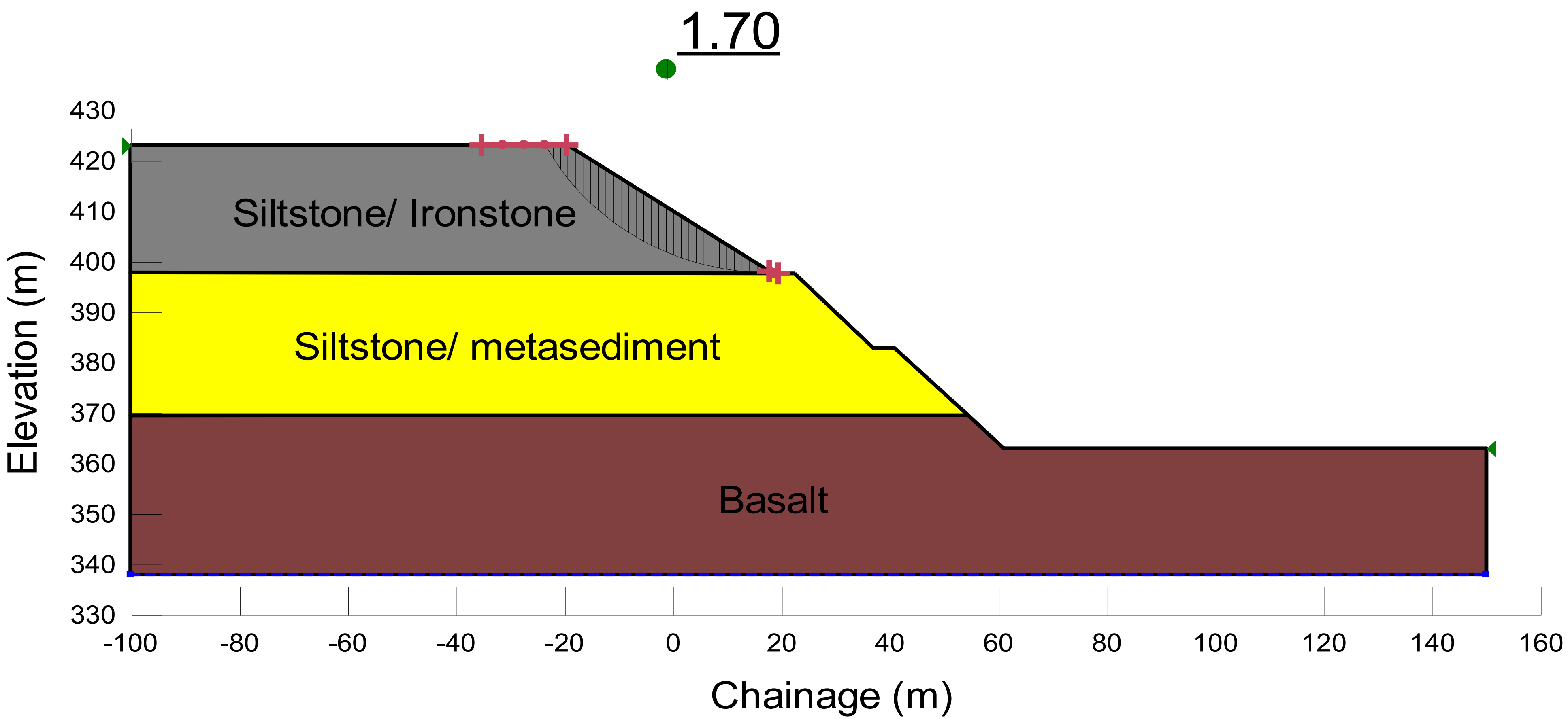
Golbal Failure Mode in Static Condition

Name: Siltstone/ Ironstone Model: Mohr-Coulomb Unit Weight: 23 kN/m³ Cohesion: 30 kPa Phi: 33 °
Name: Siltstone/ metasediment Model: Mohr-Coulomb Unit Weight: 23 kN/m³ Cohesion: 50 kPa Phi: 33 °
Name: Basalt Model: Mohr-Coulomb Unit Weight: 24 kN/m³ Cohesion: 150 kPa Phi: 32 °

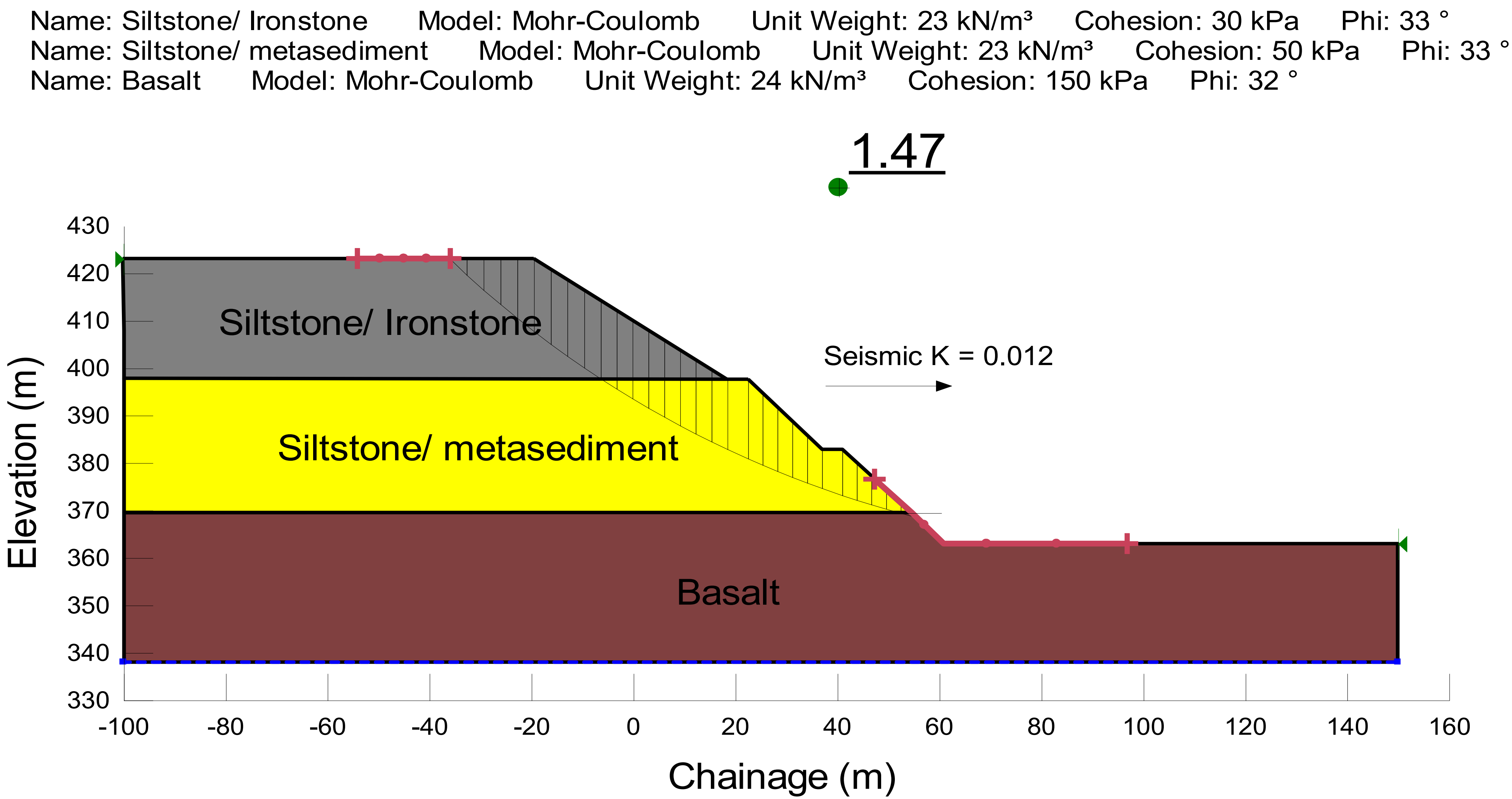


Local failure mode -Lower bench in Static Condition

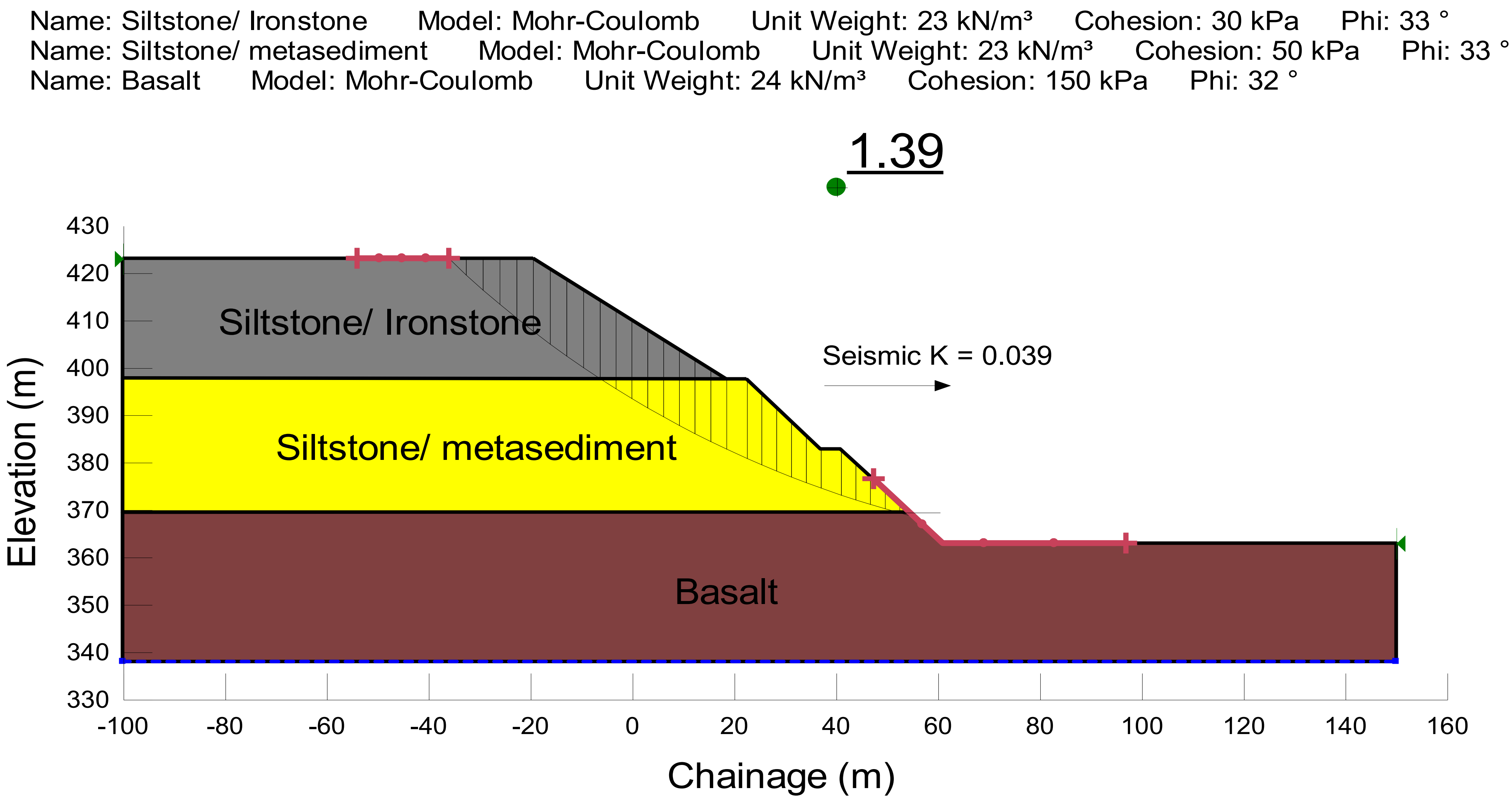
Name: Siltstone/ Ironstone Model: Mohr-Coulomb Unit Weight: 23 kN/m³ Cohesion: 30 kPa Phi: 33 °
Name: Siltstone/ metasediment Model: Mohr-Coulomb Unit Weight: 23 kN/m³ Cohesion: 50 kPa Phi: 33 °
Name: Basalt Model: Mohr-Coulomb Unit Weight: 24 kN/m³ Cohesion: 150 kPa Phi: 32 °



Local failure mode -upper bench in Static Condition



Global Failure Mode in Seismic Condition (500 year return period)



Global Failure mode in Seismic Condition (2500 year return period)

PHOTOS

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Plate 1 MDD-03 – 0.0-6.7m depth.

Plate 2 MDD-03 – 6.7-12.6m depth.

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Plate 3 MDD-03 – 12.6-18.4m depth.

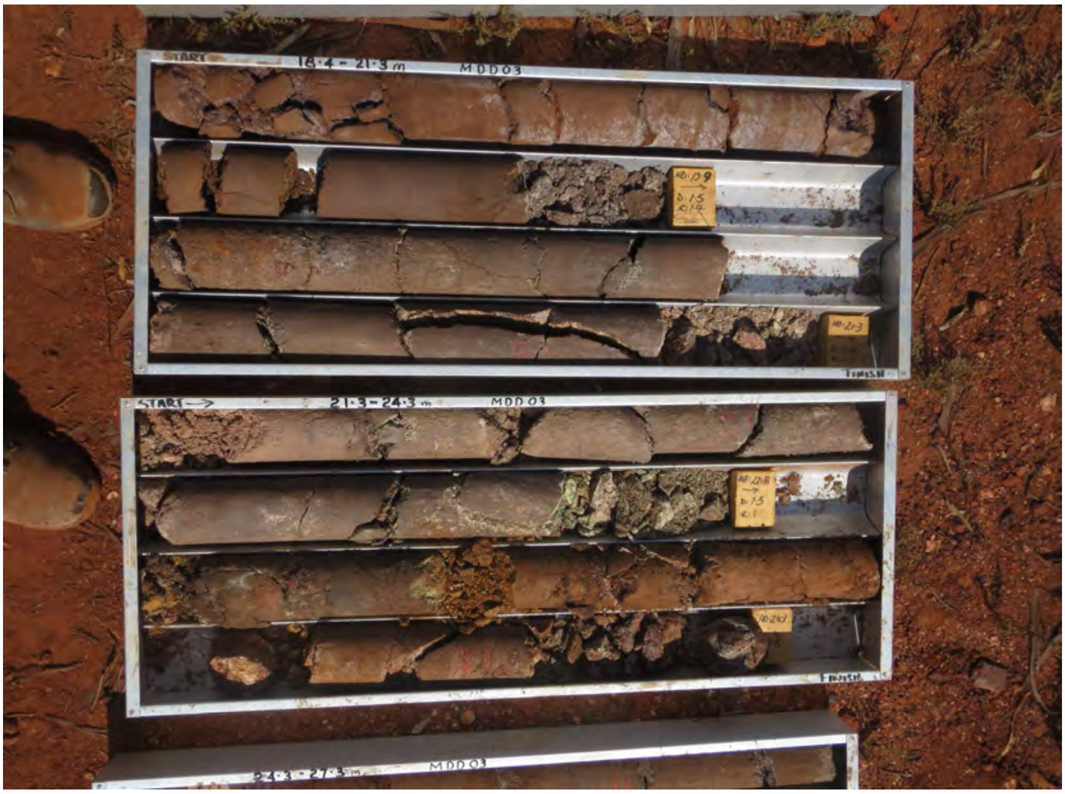

Plate 4 MDD-03 – 18.4-24.3m depth.

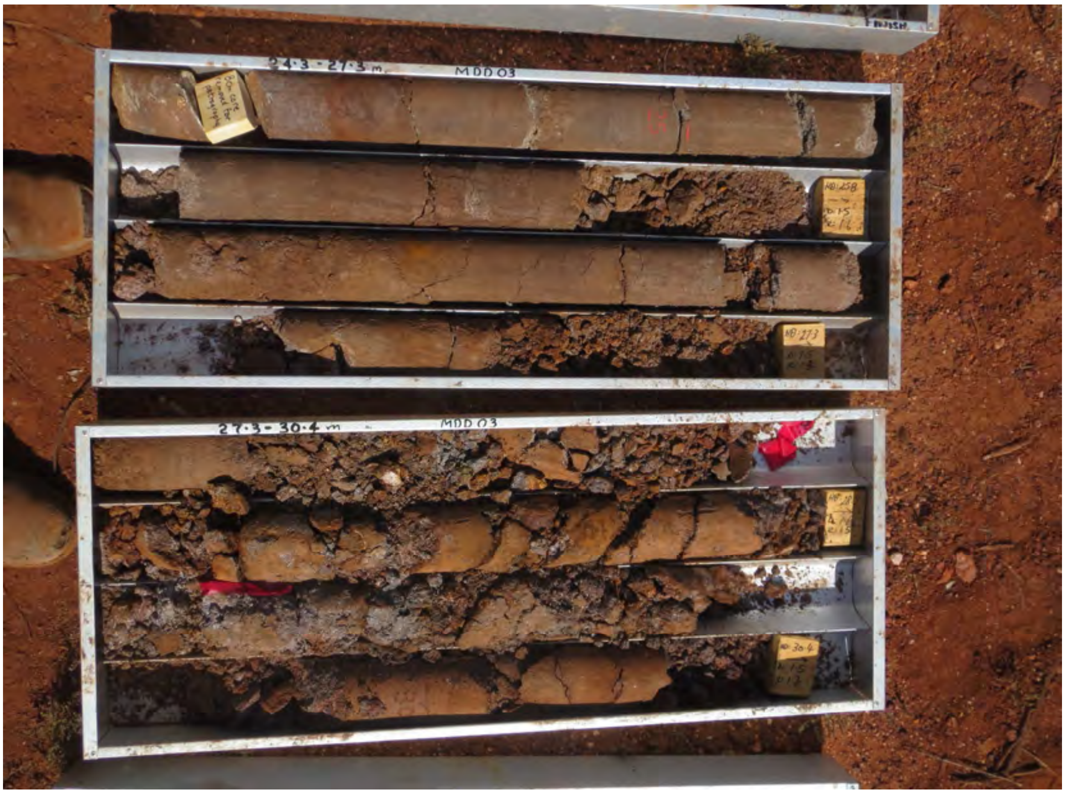

Plate 5 MDD-03 – 24.3-30.4m depth.

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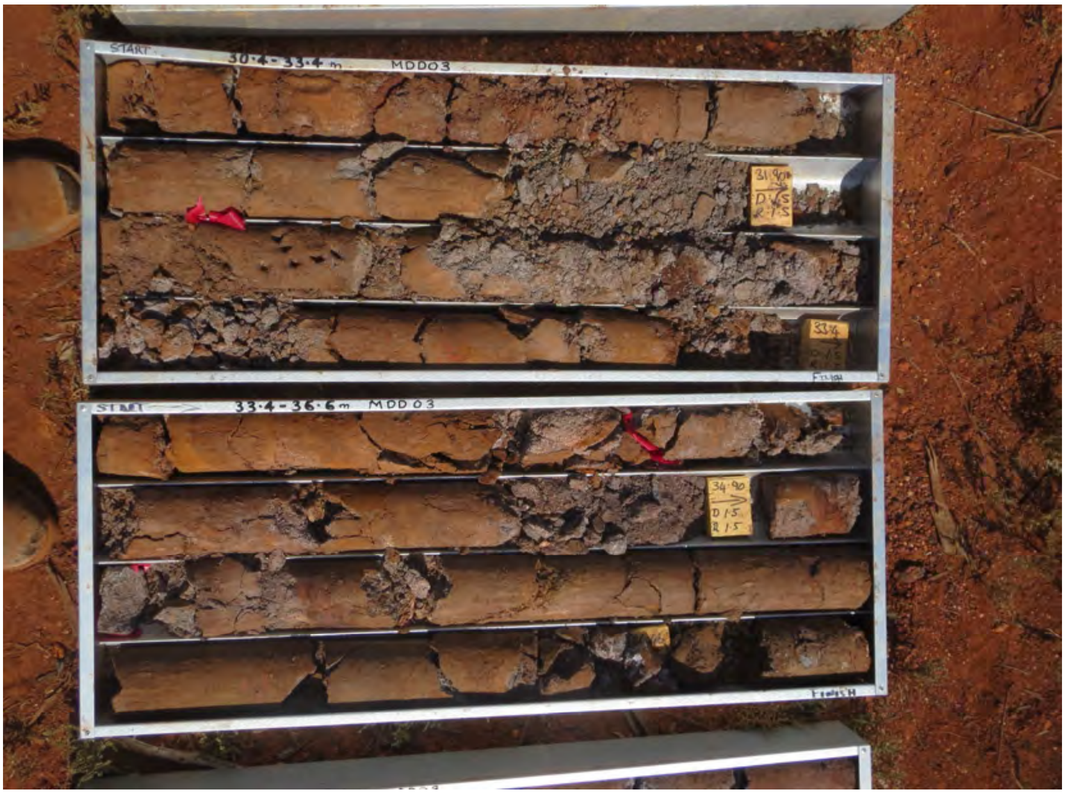

Plate 6 MDD-03 – 30.4-36.6m depth.

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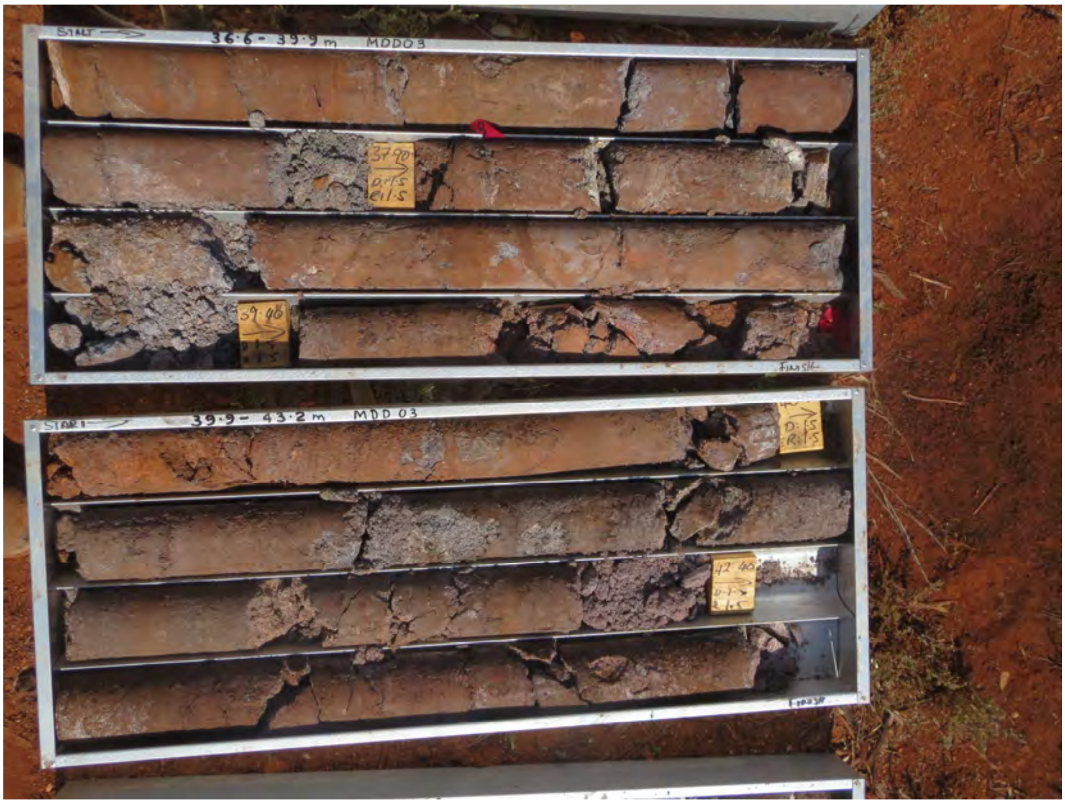

Plate 7 MDD-03 – 36.6-43.2m depth.

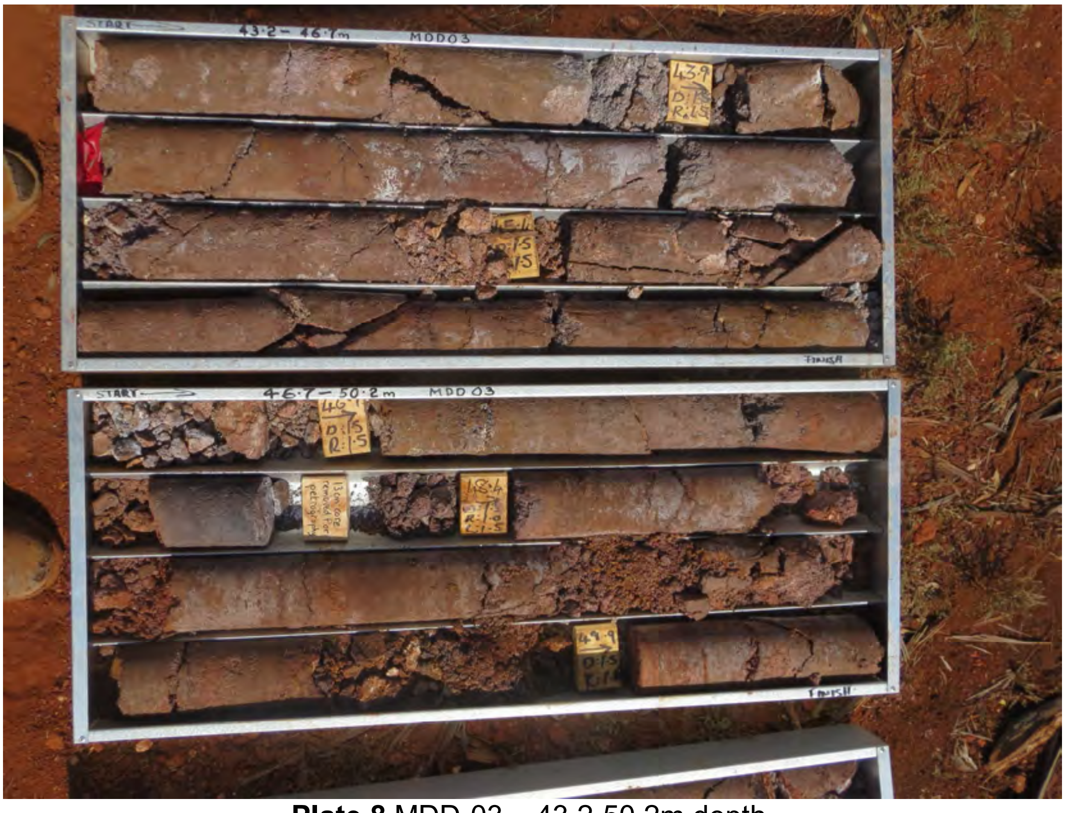

Plate 8 MDD-03 – 43.2-50.2m depth.

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Plate 9 MDD-03 – 50.2-53.3m depth.

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Plate 10 MDD-05 – 0-6.6m depth.

Plate 11 MDD-05 – 6.6-14.5m depth.

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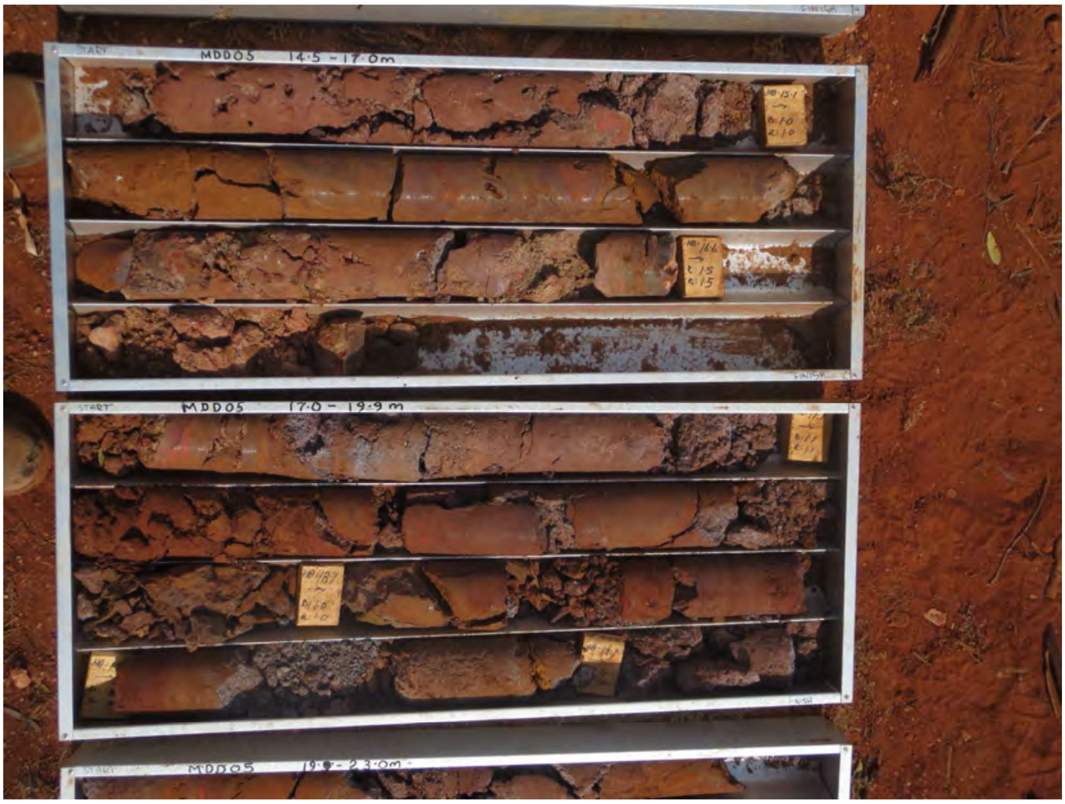

Plate 12 MDD-05 – 14.5-19.9m depth.

Plate 13 MDD-05 – 19.9-26.4m depth.

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Plate 14 MDD-05 – 26.4-32.5m depth.

Plate 15 MDD-05 – 32.5-39.2m depth.

Plate 16 MDD-05 – 39.2-40.7m depth.

Plate 17 MDD-15 – 0.0-7.4m depth.

Plate 18 MDD-15 – 7.4-13.4m depth.

Plate 19 MDD-15 – 13.4-20.1m depth.

Plate 20 MDD-15 – 20.1-26.7m depth.

Plate 21 MDD-15 – 26.7-33.1m depth.

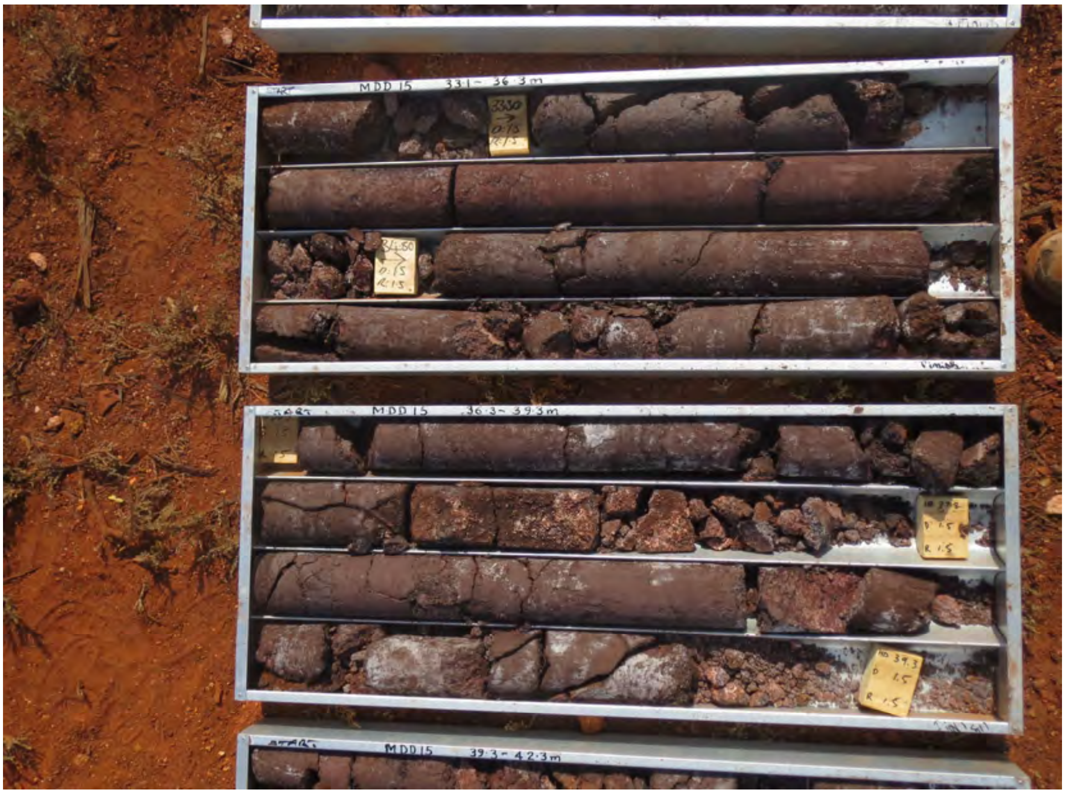

Plate 22 MDD-15 – 33.1-39.3m depth.

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Plate 23 MDD-15 – 39.3-45.3m depth.

Plate 24 MDD-15 – 45.3-52.1m depth.

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Plate 25 MDD-15 – 52.1-57.3m depth.

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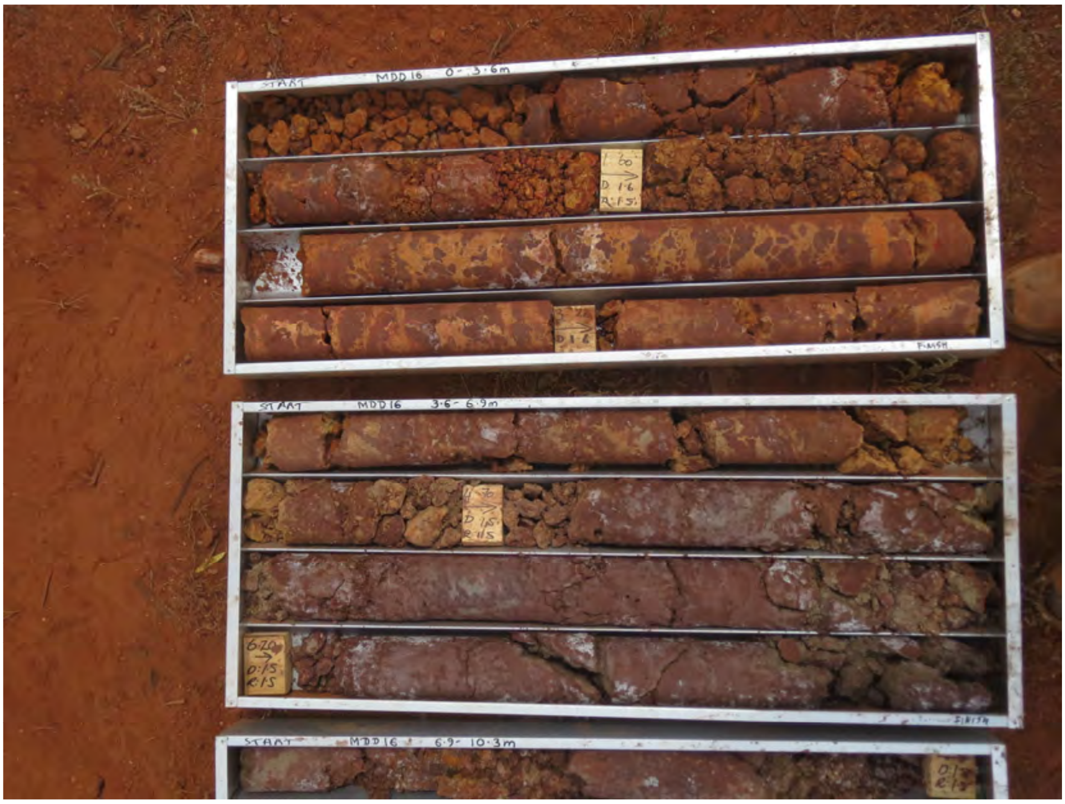

Plate 26 MDD-16 – 0-6.9m depth.

Plate 27 MDD-16 – 6.9-13.6m depth.

Plate 28 MDD-16 – 13.6-20.2m depth.

Plate 29 MDD-16 – 20.2-26.9m depth.

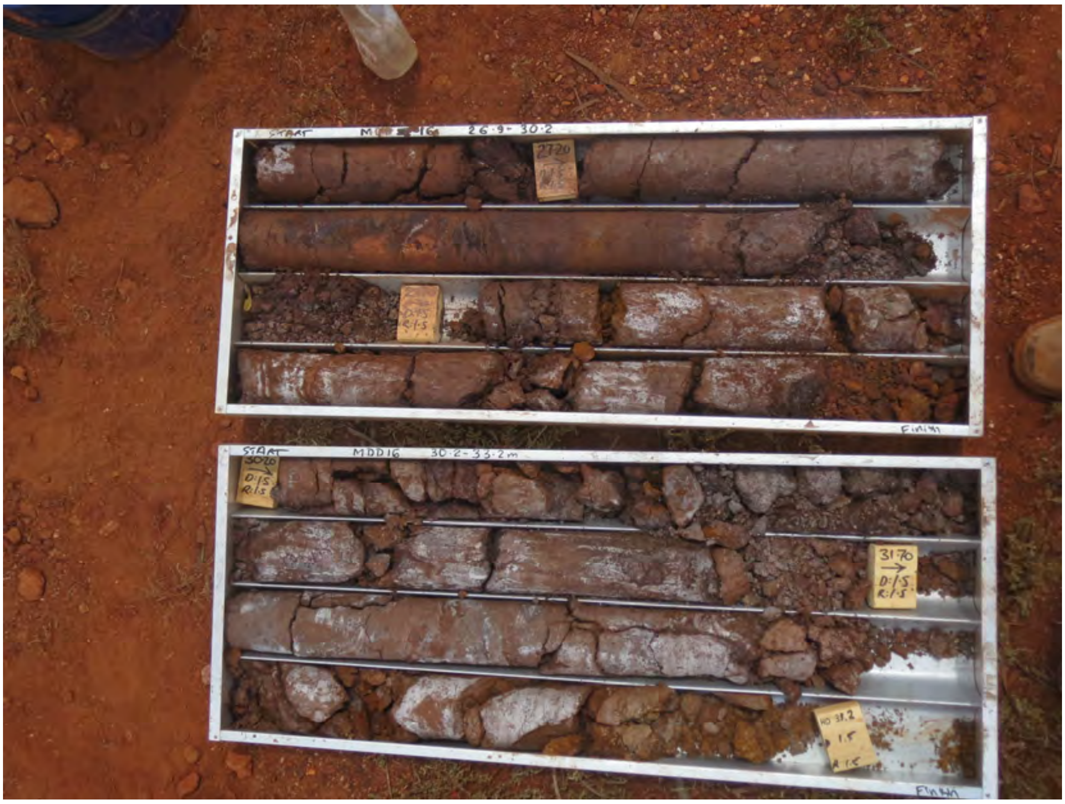

Plate 30 MDD-16 – 26.9-33.2m depth.

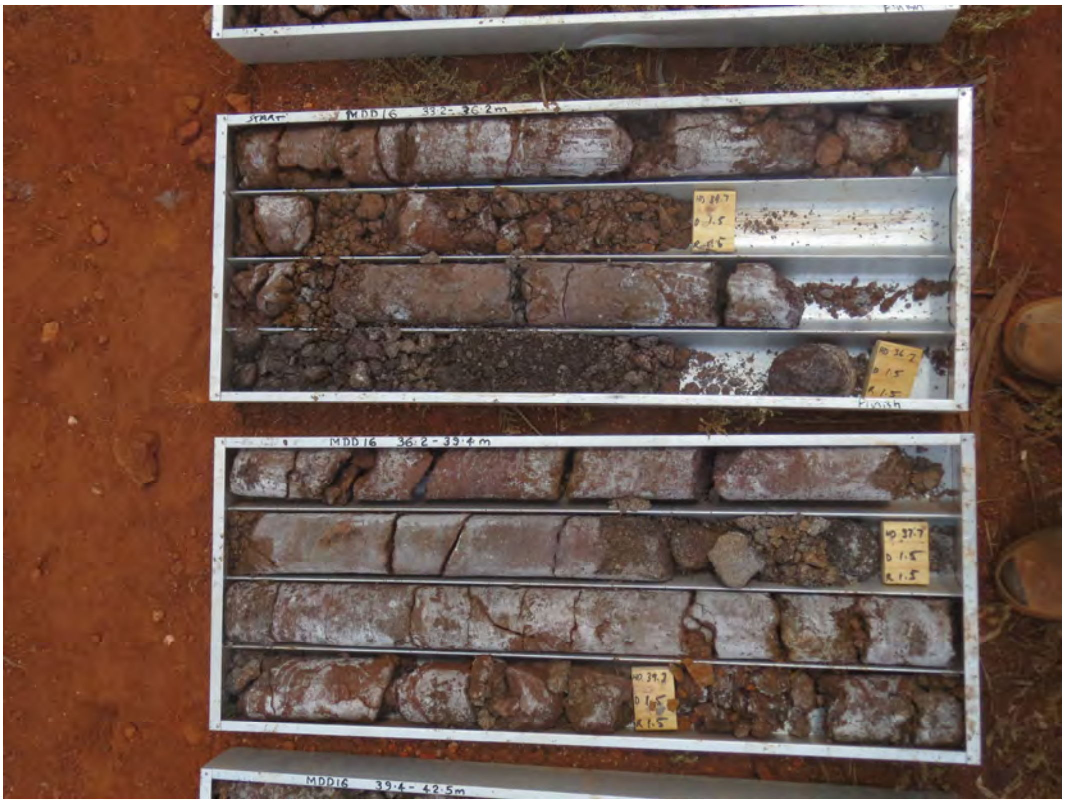

Plate 31 MDD-16 – 33.2-39.4m depth.

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Plate 32 MDD-16 – 39.4-45.4m depth.

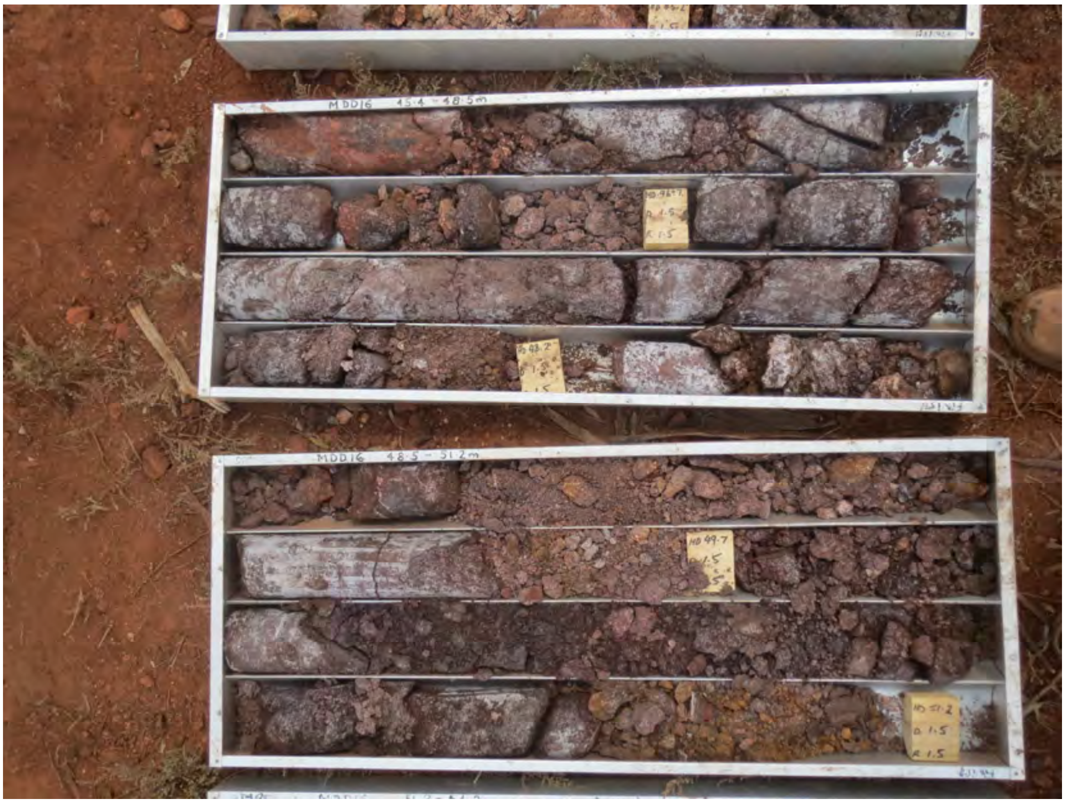

Plate 33 MDD-16 – 45.4-51.2m depth.

Plate 34 MDD-16 – 52.1-55.7m depth.