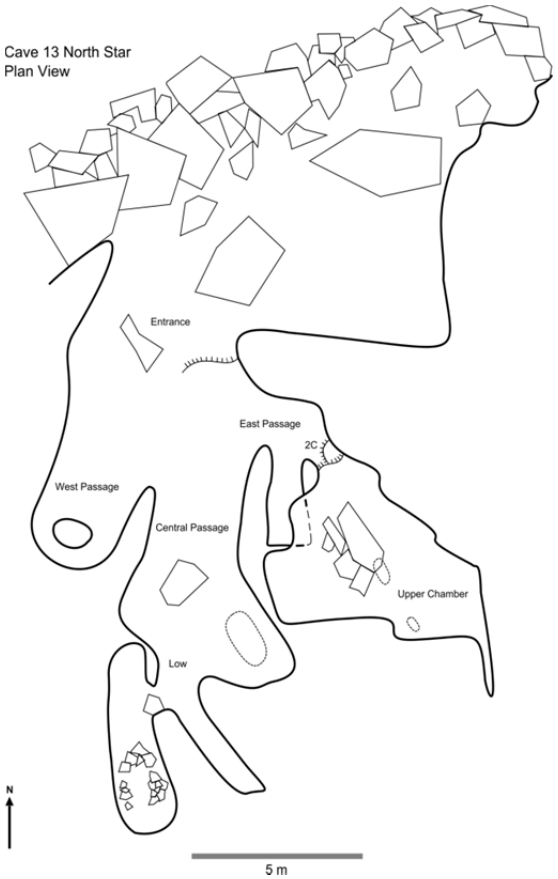

Fortescue Metals Group

Cave 13 Lateral Extent and Structural Assessment

March 2015

Executive summary

Fortescue Metals Group Iron Bridge (Fortescue) have been granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure 110 kilometres (km) south-south-east of Port Hedland. The development of the mine is subject to a range of conditions regarding the key environment factors identified during the course of the assessment and approvals process.

The Environmental Protection Authority (EPA) has recommended Condition 10 to mitigate the potential impacts to the Pilbara Leaf-nosed Bat (PLNB) colony of Cave 13 due to mining activities. This report is to describe the methods used to determine the lateral extent of Cave 13, provide a map of the lateral extent of Cave 13 and describe the geological and structural features of Cave 13.

This report is subject to, and must be read in conjunction with, the limitations set out in section 1.2 and 1.3 and the assumptions and qualifications contained throughout the Report.

GHD undertook a survey of the lateral extent of Cave 13 using a Leica DistoX2 combined electronic compass, clinometer and a laser distance range finder. The survey of Cave 13 was to an accuracy of within two percent for measurements. Cave survey data collected inside the cave was combined with scaled sketches of the cave and entered into the cave survey program WinKarst for processing. The resulting cave survey plot was then combined with the in-cave sketches to produce a plan view map showing the lateral extent of Cave 13 in Inkscape, at a scale of 1:100. A developed long section, and cross section was also be produced along the longest axis of the lateral extent of Cave 13.

Cave 13 consists of three passages, with an elevated chamber extending off the eastern passage. The majority of Cave 13 is lit at least partially by daylight, with some twilight zones located within the side chambers of the central passage, and in the lower portion of the eastern most passage. The upper chamber in the eastern most passage is within the dark zone of the cave.

The cave ceiling is generally low (less than 1.2 m) and bedding within the cave varies from nearly horizontal to near vertical. The dramatic changes in bedding dip and strike suggest the bedrock is heavily folded and micro-faulted, thus while individual chambers and passages may be parallel to localised bedding (Plate 5), the cave as a whole cannot be considered to be bedding plane controlled.

Cave 13 was surveyed to its full extent and was found to extend approximately 16 m into the side of the gully from the entrance. The cave is approximately 8 m in height from the entrance point.

The cave is structurally sound and is not liable to collapse in its current state. The cave is within heavily folded and faulted magnetite and is not structurally or bedding plane controlled, except at an individual passage scale.

The lateral extent of Cave 13 is substantially smaller than originally allowed for under Condition 10 and the exclusion zone could be reduced to within 25 m of the identified cave boundary, however as a precautionary approach a 50 m buffer is recommended.

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1. Introduction

Fortescue Metals Group Iron Bridge (Fortescue) have been granted approval to develop the North Star Magnetite open cut iron ore mine and associated infrastructure 110 kilometres (km) south-south-east of Port Hedland (Figure 1). The development of the mine is subject to a range of conditions regarding the key environment factors identified during the course of the assessment and approvals process. One of these key factors is terrestrial fauna including the direct impacts through the clearing of fauna habitat, including critical roosting habitat for the Pilbara Leaf-nosed Bat (*Rhinonicteris aurantia*).

The Environmental Protection Authority (EPA) has recommended Condition 10 to mitigate the potential impacts to the Pilbara Leaf-nosed Bat (PLNB) colony of Cave 13 due to mining activities. Cave 13 is located within the proposed Stage 2 pit shell of the North Star mine footprint (Figure 2). GHD understands that Cave 13 is an important roost location for the PLNB. One of the objectives of Condition 10 is to undertake a structural assessment to confirm the lateral extent of Cave 13.

Should the confirmed lateral extent of the cave be greater than the current predicted extent, the EPA expects that the Mine Exclusion Zone required by recommended Condition 10-2 would be amended accordingly through a formal change to conditions under s46 of the *Environmental Protection Act 1986*.

1.1 Purpose of this report

This report is to describe the methods used to determine the lateral extent of Cave 13, provide a map of the lateral extent of Cave 13 and describe the geological and structural features of Cave 13.

1.2 Scope and limitations

This report: has been prepared by GHD for Fortescue Metals Group and may only be used and relied on by Fortescue Metals Group for the purpose agreed between GHD and the Fortescue Metals Group as set out in section 1.1 of this report.

GHD otherwise disclaims responsibility to any person other than Fortescue Metals Group arising in connection with this report. GHD also excludes implied warranties and conditions, to the extent legally permissible.

The services undertaken by GHD in connection with preparing this report were limited to those specifically detailed in the report and are subject to the scope limitations set out in the report.

The opinions, conclusions and any recommendations in this report are based on conditions encountered and information reviewed at the date of preparation of the report. GHD has no responsibility or obligation to update this report to account for events or changes occurring subsequent to the date that the report was prepared.

The opinions, conclusions and any recommendations in this report are based on assumptions made by GHD described in this report (refer section 1.3 of this report). GHD disclaims liability arising from any of the assumptions being incorrect.

GHD has prepared this report on the basis of information provided by Fortescue Metals Group and others who provided information to GHD (including Government authorities), which GHD has not independently verified or checked beyond the agreed scope of work. GHD does not accept liability in connection with such unverified information, including errors and omissions in the report which were caused by errors or omissions in that information.

The opinions, conclusions and any recommendations in this report are based on information obtained from, and testing undertaken at or in connection with, specific sample points. Site conditions at other parts of the site may be different from the site conditions found at the specific sample points.

Investigations undertaken in respect of this report are constrained by the particular site conditions, such as the location of buildings, services and vegetation. As a result, not all relevant site features and conditions may have been identified in this report.

Site conditions (including the presence of hazardous substances and/or site contamination) may change after the date of this Report. GHD does not accept responsibility arising from, or in connection with, any change to the site conditions. GHD is also not responsible for updating this report if the site conditions change.

1.3 Assumptions

Magnetite in the cave has not significantly altered readings from the electronic compass function in the Leica DistoX2. Compass readings were compared between multiple instruments prior to commencing the survey to enable the most accurate measurements possible when subject to magnetite influence.

2. Methods

2.1 Lateral Extent Methods

GHD undertook a survey of the lateral extent of Cave 13 using a Leica DistoX2 combined electronic compass, clinometer and a laser distance range finder. The DistoX2 is a Leica Disto X310 which has been modified to incorporate compass bearing, inclination and Bluetooth. The main circuit board is replaced and a non-magnetic lithium polymer cell is installed, allowing for excellent accuracy (< 0.1°).

The survey was undertaken with regard to the cave survey and mapping standards of the Australian Speleological Federation (1997). The survey of Cave 13 was to ASF standard 5.5 that includes accuracy to within two percent for measurements (ASF 1997). The symbols used on the map conform to ASF survey symbols (ASF 1999, Appendix B).The survey was spatially referenced to the location of the solar panel used to power the permanently placed Songmeter 2, setup to record bat movements associated with Cave 13.

The survey was undertaken on 13th and 14th November 2014 and consisted of a series of linked stations, with distance, compass bearing and clinometer reading between each station recorded. At each station heights and widths were recorded to enable the most accurate representation of the internal cave space to be recorded. Photographs at significant survey stations and of major chambers were also taken. The survey included all areas of the caves that are within reasonable human accessibility without compromising safety standards of Fortescue or GHD.

Cave survey data collected inside the cave was then combined with scaled sketches of the cave to be entered into the cave survey program WinKarst for processing. The resulting cave survey plot was then combined with the in-cave sketches to produce a plan view map showing the lateral extent of Cave 13 in Inkscape (Inkscape.org ver 0.48), at a scale appropriate for the cave size (1:100). A developed long section, and cross section was also be produced along the longest axis of the lateral extent of Cave 13.

2.2 Structural Assessment

During the cave survey geological features and other relevant information was also be recorded for inclusion on the final map.

3. Cave 13 Assessment

3.1 Lateral Extent Assessment

Cave 13 is located on the southern side of a gully and has a 5 m wide opening that divides into three separate passages (Figure 2). The passage to the far right (western most edge) is 7 m in length and completely lit by daylight. The central passage is approximately 16 m in length, with several small side chambers sloping gently upwards into the hillside behind. The passage on the far left (eastern most passage) leads into a 1 m high chamber with a 45° inclined passage approximately 2 m high heading to the east (Plate 1). This inclined passage is approximately 1 m wide and leads into an elevated chamber 6 m wide and 3.5 m deep, and up to 2.5 m high in the central area. This elevated chamber has formed partially through roof decay. There is no evidence for any water activity within this chamber for an extended time period.

A plan view of Cave 13 is shown in Plate 2. A simplified long section, showing the caves vertical extent is shown in Plate 3.

The majority of Cave 13 is lit at least partially by daylight (Plate 4), with some twilight zones located within the side chambers of the central passage, and in the lower portion of the eastern most passage. The upper chamber in the eastern most passage is within the dark zone of the cave.

Plate 1 Looking up the 45° inclined passage to the upper chamber (field of view ~1 m).

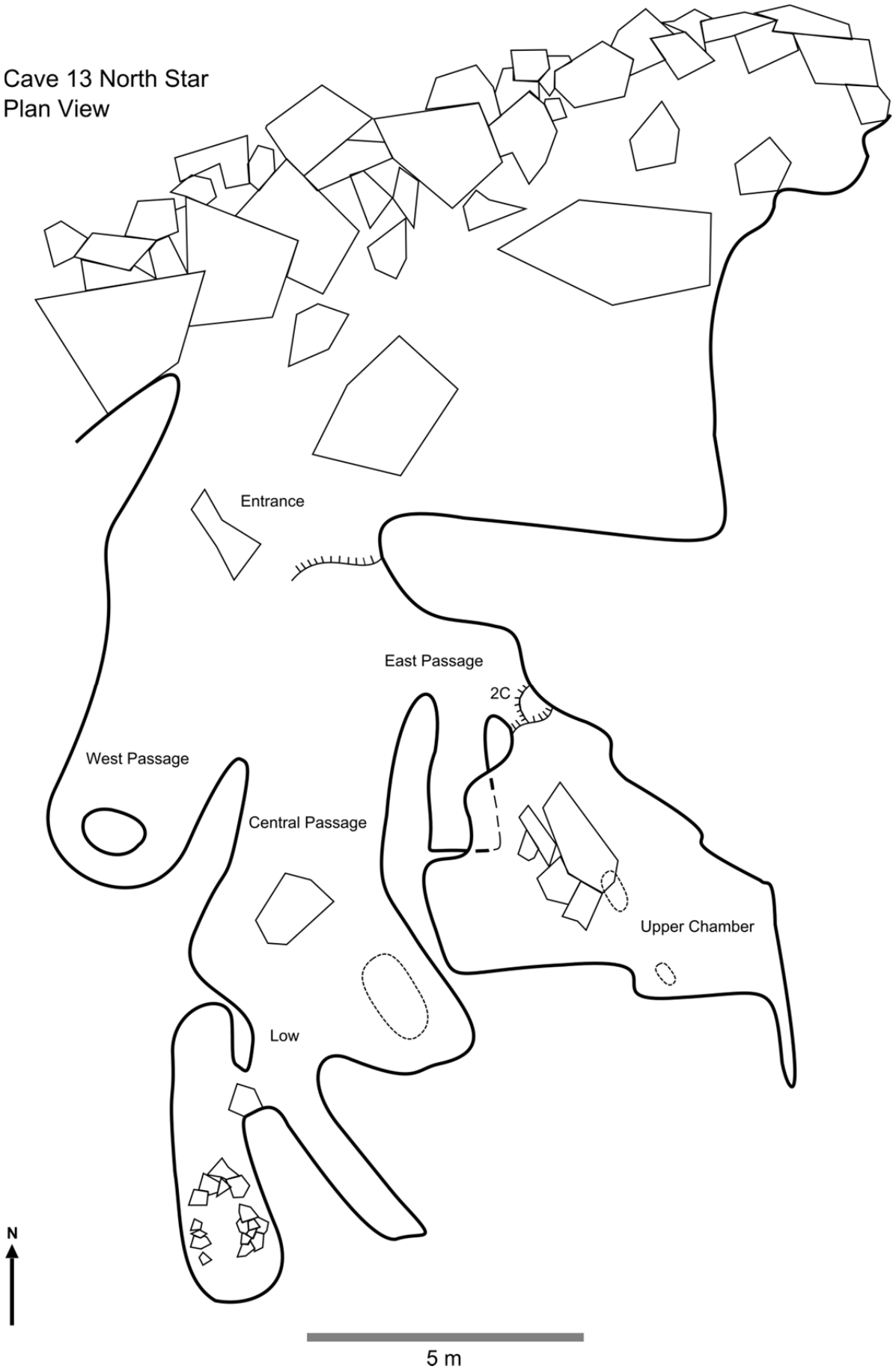


Plate 2 Plan view of Cave 13 to ASF Grade 5.5.

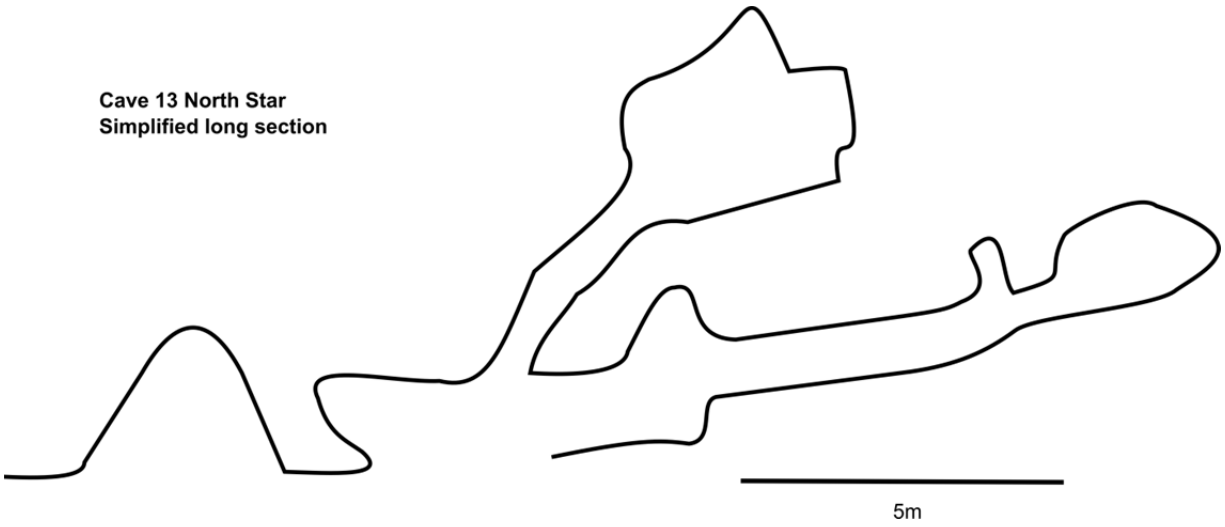


Plate 3 Simplified long section of Cave 13

Plate 4 View south into the eastern most passage (right) and central passage (field of view ~6 m).

3.2 Structural Assessment

The cave ceiling is generally low (less than 1.2 m) and bedding within the cave varies from nearly horizontal to near vertical. The dramatic changes in bedding dip and strike suggest the bedrock is heavily folded and micro-faulted, thus while individual chambers and passages may be parallel to localised bedding (Plate 5), the cave as a whole cannot be considered to be bedding plane controlled. All the avens (blind vertical shafts) observed within Cave 13 showed a strong associated with vertically bedded ironstone.

Cave 13 can be considered to be highly stable, and is not liable to any significant collapse within human timescales (i.e. 100s of years). There is no evidence of any recent water movement within the cave that may influence stability in the medium (50 years) term.

Plate 5 Bedding controlled side passage (field of view ~1 m)

4. Conclusions

Cave 13 was surveyed to its full extent and was found to extend approximately 16 m into the side of the gully from the entrance. The cave is approximately 8 m in height from the entrance point.

The cave is structurally sound and is not liable to collapse in its current state. The cave is within heavily folded and faulted magnetite and is not structurally or bedding plane controlled, except at an individual passage scale.

The lateral extent of Cave 13 is considered to be substantially smaller than originally allowed for under Condition 10 and the exclusion zone could be reduced to within 25 m of the identified cave boundary as the cave is considered to be structurally stable. However, it is recommended that a precautionary approach is applied to the protection of the cave and a 50 m exclusion zone is applied.

5. References

Australian Speleological Federation (ASF) (1997). ASF Cave survey and map standards. 17p.

Australian Speleological Federation (ASF) (1999). ASF Standard cave survey symbols. 8p.

Inkscape (2014). Inkscape vector drawing program Version 0.48. Available from www.inkscape.org.

Appendices

Appendix A - Figures

640,000 670,000 700,000 730,000

7,740,000 7,710,000 7,680,000 7,650,000

PORT HEDLAND
Finucane Island
Downes Island
Weerdee Is
Cooke Pt
REDBANK
WEDGEFIELD
ABORIGINAL RESERVE
Ord River
Ranges
Mt St George
NORTHERN
GREAT
Boodarie Hill
Boodarie
Bing
SOUTH HEDLAND
Pippingarra
Table Hill
Sandy Hill
STRELLEY
MARBLE BAR
Hedland
BULLANGANA
BOODARIE
PIPPINGARRA
Bullen Hill
Red Hill
Trig Hill
Beebingarra Ck
Petermarer Ck
Tabba Tabba Creek
Strelley River
Carlindie
West Strelley River
Shaw River
Port Hedland RD
WALLAREENYA
WALLAREENYA RD
Wallareenya
Cookes Hill
Wallaringa Peak
Turner River
INDEE RD
Mt Berghaus
Indee
Yule River
East Range
LALLA ROOKH RD
Fey Hill
Lalla Rookh
East Strelley River
INDEE
Tabba
Mt Dove
Newman
Magpie Creek
McPhee Hill
Chinnamon
Mt York
KANGAN RD
Gillam
Turner River
Pincunah Hill
Cleland Rock
YANDEYARRA
Mt Tinstone
Railway
Turner
West River
Mt Francisco
Obstinate Ck
ABYDOS ABORIGINAL COMMUNITY
Abydos
Pyramid Hill
NORTH STAR MAGNETITE / HEMATITE MINE
CAVE 13

1:380,000 Paper Size A3

0 2.5 5 10 15

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

Fortescue Metals Group Ltd

Pilbara Leaf-nosed Bat North Star Management Plan

Job Number	61-31473
Revision	0
Date	05 Mar 2015

Project Location

Figure 1

G:\61\31473\GIS\Maps\MXD\Cave 13 Lateral Extent\6131473_001_Rev0_Fig1_Locality.mxd

239 Adelaide Terrace Perth WA 6004 Australia T 61 8 6222 8222 F 61 8 6222 8555 E permail@ghd.com.au W www.ghd.com.au

Data source: FMG: Bat Cave 13 - 20141007, Mine footprint - 20141121; Landgate: Travellers Atlas 2004. Created by: AF

LEGEND

- Bat Cave 13
- GOV sourced tracks
- Proposed infrastructure
- Hematite Mine - Proposed project outline
- Magnetite Mine - Footprint

1:80,000 Paper Size A3

0 0.5 1 2 3

Kilometres

Map Projection: Transverse Mercator
Horizontal Datum: GDA 1994
Grid: GDA 1994 MGA Zone 50

N

Fortescue Metals Group Ltd
Pilbara Leaf-nosed Bat North Star Management Plan

Job Number	61-31473
Revision	0
Date	05 Mar 2015

Location of Cave 13 at North Star Mine Site

Figure 2

G:\61\31473\GIS\Maps\MXD\Cave 13 Lateral Extent\6131473_002_Rev0_Fig2_Cave13.mxd
239 Adelaide Terrace Perth WA 6004 Australia **T** 61 8 6222 8222 **F** 61 8 6222 8555 **E** permail@ghd.com.au **W** www.ghd.com.au

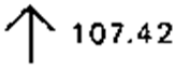
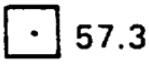
Data source: FMG: Bat Cave 13 - 20141007, Hematite Proposed Project Outlines, GOV Sourced Tracks, North Star Magnetite Proposed Infrastructure, North Star GV Project Proposed Infrastructure, Magnetite Mine Footprint - 20141121; Landgate: Imagery (Virtual Mosaic) - 20150218. Created by: AF

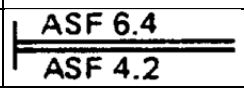
Appendix B – ASF Survey Symbols

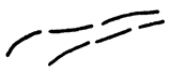
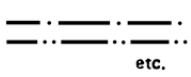
ASF Cave Survey and Map Standards

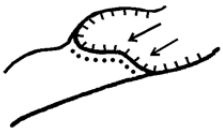
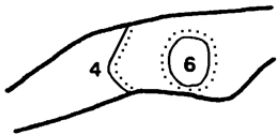
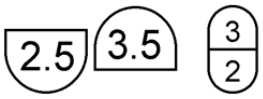
Table 1: Map Symbols

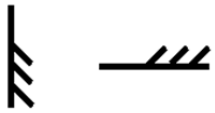
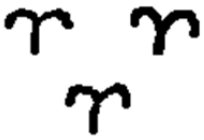
Revised April, 1999,
to provide partial conformity with UIS International Cave Symbols

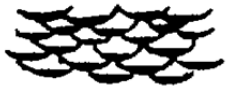
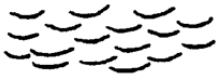
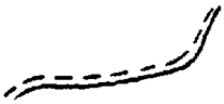
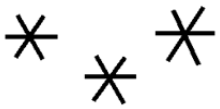
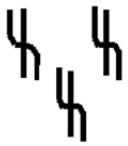
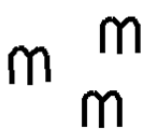
1. SURVEY STATIONS			
Ref.	Map symbol	Profile view (where appropriate)	Description
1.1			Horizontal datum point. (permanently marked control station with fixed co-ordinates)
1.2			Vertical datum point with altitude.
1.3			Combined horizontal and vertical datum point.
1.4			Permanently marked survey station.
1.5			Unmarked (but relocatable) survey station.
1.6			Unmarked natural feature used as a survey station. (Described in survey abstract)

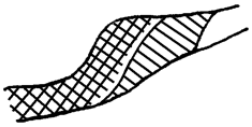
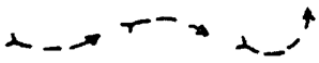
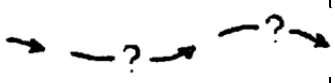
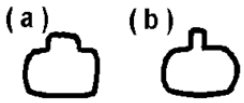
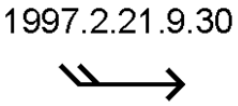
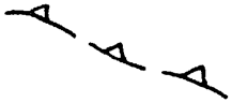
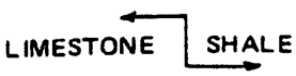
2. SPECIAL LINES			
Ref.	Map symbol	Profile view (where appropriate)	Description
2.1			Section line showing direction of view and reference letter.
2.2a			Change of survey grade

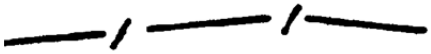
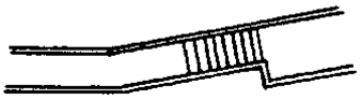
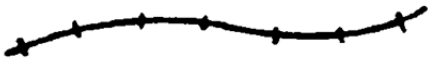
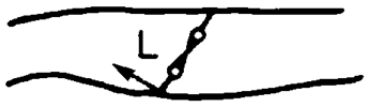
3. OUTLINES			
Ref.	Map symbol	Profile view (where appropriate)	Description
3.1			Outline. (Various thicknesses may be used for different sections, or levels). The outline should be heavier than all other lines.
3.2			Conjectural outline.
3.3			Outlines at significantly different levels or displaced from section plane.

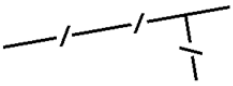
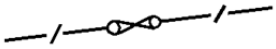
4. CHANGES OF LEVEL OR SLOPE			
Ref.	Map symbol	Profile view (where appropriate)	Description
4.1			Vertical change of floor level (cliff or pit), with height. *Symbol (tics) on lower side*
4.2			**Discontinued** (gradual change in slope of floor)
4.3 NEW			Horizontal entrance or pit (doline) at surface. Side sloping to passage. *(differs from UIS)*
4.4 NEW			Vertical entrance or pit (doline) at surface. Vertical or near-vertical walls. *(differs from UIS)*
4.5			Vertical change in roof level, (step or blind shaft), with height. Dots on lower side. *(differs from UIS)*
4.6			**Discontinued** (Gradual change in slope of roof)
4.7			Connecting shaft between levels.
4.8			Direction of downward slope of floor with (optional) gradient in degrees.
4.9			Direction of downward slope of roof with (optional) gradient in degrees.
4.10 NEW			Height from floor to roof, **NEW UIS symbol**
4.11 NEW			Depth of water; Air space above water; and combined water depth and air space. **NEW** *(not catered for in UIS, this is based on USA usage)*

5. MATERIALS			
Ref.	Map symbol	Profile view (where appropriate)	Description
5.1			Large rocks, boulders.
5.2			Rockfall, talus.
5.3			Pebbles, gravel.
5.4			Sand.
5.5			Earth, mud.
5.6 NEW			Roots (in situ). **NEW**. Vertical for hanging roots, horizontal for roots on floor.
5.7 NEW			Guano. **NEW** UIS symbol
5.8			Vegetable debris.

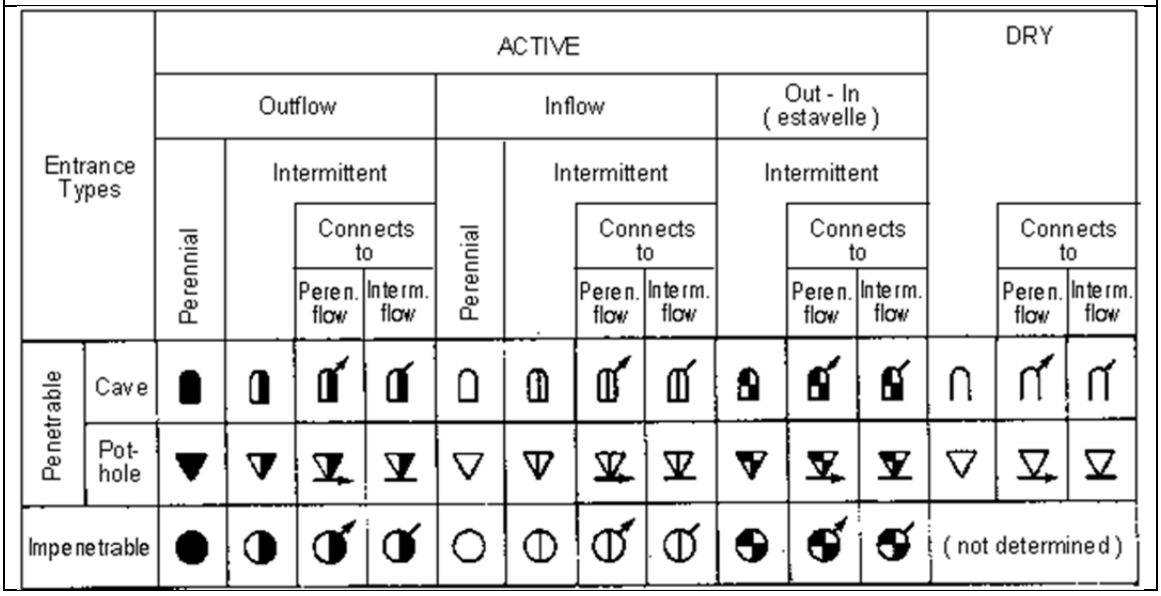
6. SECONDARY DEPOSITS			
Ref.	Map symbol	Profile view (where appropriate)	Description
6.1			Rimstone pool, gours, terraces, with water.
6.2			Rimstone dams, dry.
6.3			Flowstone. *Differs from UIS*
6.4 NEW			Stalagmite. **NEW UIS symbol**
6.5 NEW			Stalactite. **NEW UIS symbol**
6.6 NEW	 		Column, (speleothem, not bedrock). Small symbols are **NEW from UIS**, large symbol is for large formations (drawn to scale) and *differs from UIS*
6.7			Crystals.
6.8			Helictites.
6.9			Moonmilk.

7. PHYSICS			
Ref.	Map symbol	Profile view (where appropriate)	Description
7.1 NEW			Flowing water, with direction and volume of flow (L/s or cu m/s).
7.2 NEW			Standing water, (pool or lake).
7.3 NEW			Water without free surface to air.
7.4			Intermittent water course.
7.5			Conjectural water course.
7.6 New			Roof canyon: **NEW ASF version** - uses a variant of the Roof Step symbol (ASF 4.5), optionally combined with the new "deduced flow direction" symbol.
7.7 NEW			Current scallops (left); and non-directional Flutes (right). **NEW UIS symbols**
7.11 New			Deduced flow direction. **NEW UIS symbol** for all deduced flow directions.
7.8 NEW			Direction of Air Flow. **NEW UIS symbol**.
7.9			Limit of daylight.
7.10			Change in rock type.

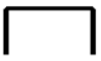
8. ARTIFICIAL CONSTRUCTIONS (e.g. Tourist caves)			
Ref.	Map symbol	Profile view (where appropriate)	Description
8.1			Hand rail.
8.2			Fence.
8.3			Formed path, with steps.
8.4			Permanent ladder.
8.5			Fixed line.
8.6			Door. (L) Locked, (U) Unlocked.
8.7			Gate. (L) Locked, (U) Unlocked.
8.8			Electric Light.
8.9			Power outlet.
8.10			Electric light switch.
8.11			Emergency light, (torch, candles).
8.12			Bridge: (T) timber, (C) concrete, (I) iron, (M) masonry.
8.13			Artificial embankment. *Symbols on lower side.*

9. SURFACE FEATURES			
Ref.	Map symbol	Profile view (where appropriate)	Description
9.1 New			Doline (degraded): **New version**. Use optional dashed line for the upper break-in-slope where that is well defined. For very small hollows, where there is no room for arrows, use the dashed line on its own.
9.2 NEW			Doline (cliffed): **New version**. Uses standard cliff symbol.
9.3 NEW			Cliff line: **New version**. Uses standard topographic symbol.
9.4			Fence.
9.5			Gate.
9.6			Karst field.

1.10 ENTRANCES
These are symbols for classifying entrance types on a surface map. The ASF has adopted the UIS
Speleological Conventional Signs (1978)



1.11 ENTRANCES
These are symbols for classifying entrance types on a surface map.
The ASF has adopted the UIS Speleological Conventional Signs (1978)

	Rockshelter
	Natural bridge - over perennial stream
	Natural bridge - over intermittent stream
	Artificial cavity - cave type
	Artificial cavity - pothole type
	Destruction of cave entrance - partial
	Destruction of cave entrance - complete

Appendix C – Cave 13 Survey data

CAVE SURVEY - DATA Craig and Tim

CAVE NAME – Cave 13 **DATE OF SURVEY -** 12/12/14 **GPS READING –**

Readings		Tape	Compass	Clinometer		Wall Distance (m)		Roof Height (m)	Station Height (m)	Notes
From	To	(m)	(degrees)	(degrees)	Station	Left	Right			
1	2	10.65	228	-0.5	1	2.3	Valley	Sky	1m	Front of cave/entrance NW corner solarcell
2	3	2.00	117	+24	2	6	3.05	2.7	50cm	Front of cave.
3	4	3.70	286	+5	3	3.25	Station 4	1.7	40cm	Station 4 on wall near detector.
3	5	5.80	218	+4.5	3	–	–	–	–	5 back ~~from~~ of cave unmarked.
3	6	6.09	187.5	+10	3	–	–	–	–	in cave
6	7	3.56	177.5	+12	6	2.9	0.8	1.2	0	In cave
7	8	3.59	141.5	+5	7	Stn 8	1.25	1.1	0	end of left side passage
7	9	2.27	279.1	+27						
3	10	3.74	125	+11						
10	11	2.00	123	+49	10	0.8	1.2	1	0.2	
11	12	2.64	193	+41	11	0.1	1.8	0.9	0.4	
12	13	2.52	182	+8	12	1.9	1.3	1.0	1.5	in main cavity
12	14	4.93	~~110~~	-4						in main cavity

Clinometer Calibration – **Compass Calibration –** **Sheet No. – 1 of**

Personnel –

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Document Status

Rev No.	Author	Reviewer		Approved for Issue		
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