9 November 2020

ASX CODE: MTB

KIHABE-NXUU POLYMETALLIC Zn/Pb/Ag/Ge/V PROJECT BOTSWANA

DRILL CORE FOR METALLURGICAL AND MINERALOGICAL TEST WORK

Further to the announcement released to the market on 21 October 2020, advising that the Company had assembled a team within Botswana to access site for the collection of drill core, whilst compliant with the local COVID-19 restrictions, the Company is pleased to provide the following update.

Around 1,310 kg of drill core has now been transported from Maun in Western Ngamiland, Botswana, to Johannesburg in South Africa. This drill core has now been distributed as follows:

- Around 1,000 kg of **Nxuu Deposit** drill core has been collected by Energy and Densification Systems (EDS) South Africa, for bulk test work on the EDS Vertical Milling process. It is expected that the bulk test work will commence on Monday 9 November and should take around two weeks to complete.

- Around 300 kg of **Nxuu Deposit** core has been collected by Intertek South Africa for couriering through DHL to Intertek, Maddington, Western Australia. Once at Intertek Maddington, STEINERT (Australia) Pty Ltd (STEINERT) will collect the core so that bulk Sensor Sorter X-ray test work can commence.

- Around 6 – 10 kg of drill core from the **Kihabe Deposit** has been collected by Intertek South Africa, to be couriered through DHL to Naples University, Italy, for mineralogical test work to be conducted to determine the host minerals for Vanadium and Germanium.

Nxuu Deposit

The Company has compiled the following Figures to provide a clear understanding of:

- The mineralised domain of Nxuu Deposit North

- The method applied in the selection of representative core samples for the proposed test work to be conducted by EDS, South Africa and STEINERT, Australia.

Figure 1 - Nxuu Deposit North Drill Hole Map broken down into Area A (bounded in black), AREA B (bounded in green) and AREA C (bounded in blue).

Figure 2 - Nxuu Deposit North AREA A, showing mineralised sections of holes drilled in this area.

Figure 3 - Nxuu Deposit North AREA B and AREA C, showing mineralised sections of holes drilled in these areas.

Figure 4 - Nxuu Deposit North AREA A, showing assay grades of mineralised intersections of holes drilled in this area.

Figure 5 - Nxuu Deposit North AREA B, showing assay grades of mineralised intersections of holes drilled in this area.

Figure 6 - Nxuu Deposit North AREA C, showing assay grades of mineralised intersections of holes drilled in this area.

Figure 7 - Nxuu Deposit North AREA A, showing intersections of drill holes in this area from which core was selected for test work.

Figure 8 - Nxuu Deposit North AREA B, showing intersections of drill holes in this area from which core was selected for test work.

Figure 9 - Nxuu Deposit North AREA B, showing intersections of further drill holes in this area from which core was selected for test work

Figure 10 - Nxuu Deposit North AREA C, showing intersections of drill holes in this area from which core was selected for test work.

Figure 11 - Nxuu Deposit North AREA C, showing intersections of further drill holes in this area from which core was selected for test work.

Kihabe Deposit

The Company has compiled the following Figures to provide a clear understanding of the method applied in the selection of representative core samples for the proposed test work to be conducted by Naples University.

Figure 12 – Drill Hole section of recent drilling conducted at the Kihabe Deposit, showing Zinc equivalent grade intersections for Zn/Pb/Ag.

Figure 13 – The same drill hole section as shown in Figure 12, showing Vanadium Pentoxide and Germanium intersection grades. It also shows intersections of the drill holes from which core was selected for mineralogical test work to be conducted by Naples University, Italy, to determine the host minerals for Vanadium and Germanium.

EDS Vertical Milling Process

EDS believe that their Vertical Milling Process will work efficiently on the Nxuu Deposit ore because it is so soft and oxidised. If so, the EDS Vertical Mill only requires 25% of the amount of power required to operate a conventional Ball/SAG/Rod mill. If this test work is successful it will have a significant saving on power requirements and power costs.

Attached as Appendix 1 is a paper headed "The Novel EDS Multishaft Mill shows Improved Liberation and Energy Efficiency in Comminution". This was presented by EDS to the International Mineral Process Congress in Cape Town, South Africa, held on 18 - 22 October 2020.

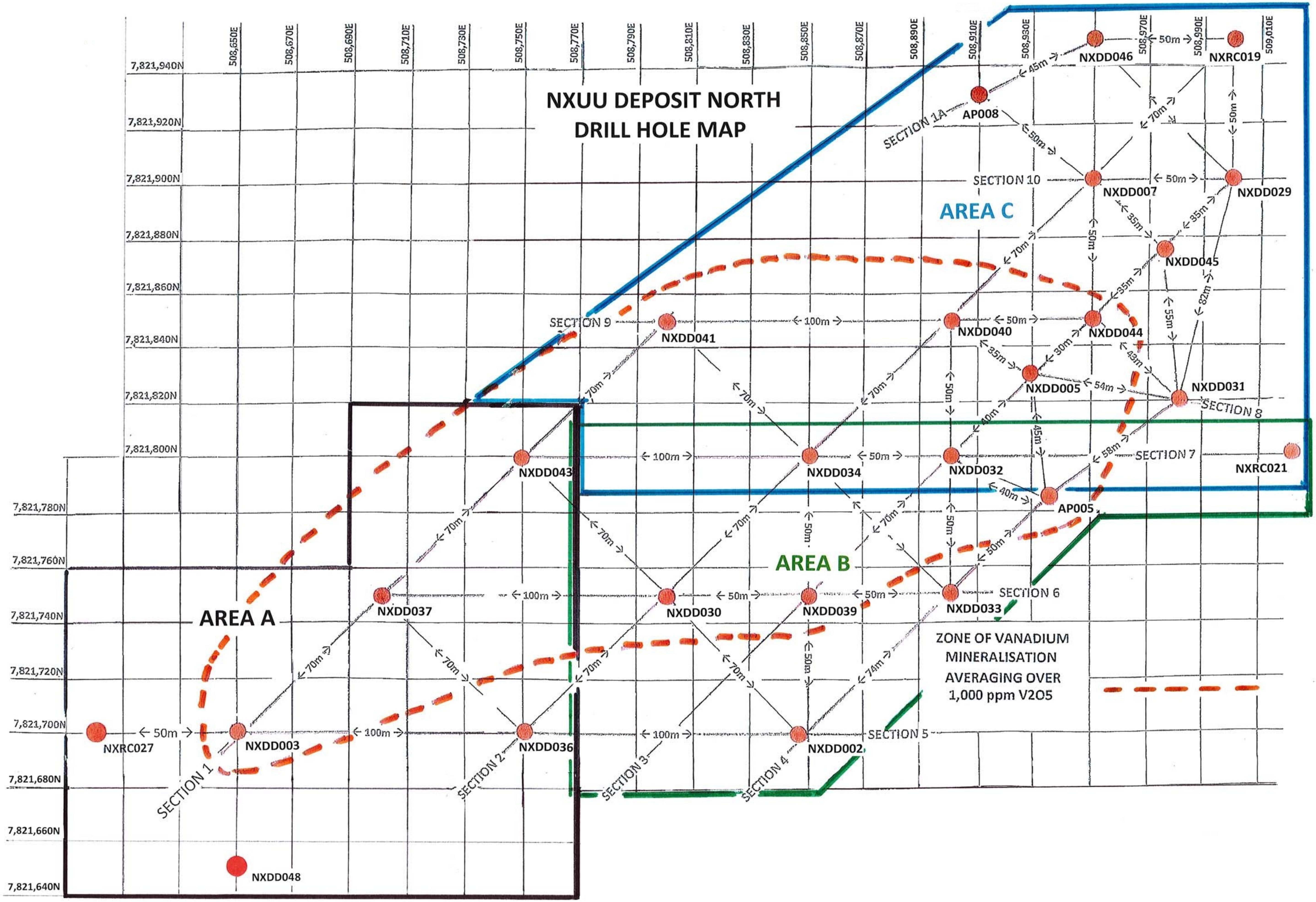
STEINERT Sensor Sorter X-ray Process

Initial Sensor Sorter X-ray test work conducted by STEINERT on the Nxuu Deposit soft oxidised ore gave very encouraging results. It showed that because the X-ray beam could penetrate the oxidised ore far more effectively than normal, 45% of all crushed product over 4mm was rejected as insignificantly mineralised. This left only 55% needing to be milled and subject to downstream treatment. As milling consumes the most amount of power in mining operations this could have a significant saving in power requirements and power costs.

Potential for successful results from both EDS and STEINERT bulk test work

Pending successful test work results from EDS and STEINERT the initial power requirement estimate of 20MW to get the Nxuu Deposit into production could be revised down to as low as 12MW – 15MW.

FIGURE 1



NXUU DEPOSIT NORTH
DRILL HOLE MAP
AREA A
AREA B
AREA C
ZONE OF VANADIUM
MINERALISATION
AVERAGING OVER
1,000 ppm V2O5
508,650E
508,670E
508,690E
508,710E
508,730E
508,750E
508,770E
508,790E
508,810E
508,830E
508,850E
508,870E
508,890E
508,910E
508,930E
508,970E
508,990E
509,010E
7,821,940N
7,821,920N
7,821,900N
7,821,880N
7,821,860N
7,821,840N
7,821,820N
7,821,800N
7,821,780N
7,821,760N
7,821,740N
7,821,720N
7,821,700N
7,821,680N
7,821,660N
7,821,640N
NXDD046
NXRC019
AP008
NXDD007
NXDD029
NXDD045
NXDD041
NXDD040
NXDD044
NXDD005
NXDD031
NXDD043
NXDD034
NXDD032
AP005
NXRC021
NXDD037
NXDD030
NXDD039
NXDD033
NXRC027
NXDD003
NXDD036
NXDD002
NXDD048
SECTION 1
SECTION 1A
SECTION 2
SECTION 3
SECTION 4
SECTION 5
SECTION 6
SECTION 7
SECTION 8
SECTION 9
SECTION 10

FIGURE 2

NXUU DEPOSIT NORTH AREA A SHOWING MINERALISED SECTIONS OF HOLES DRILLED

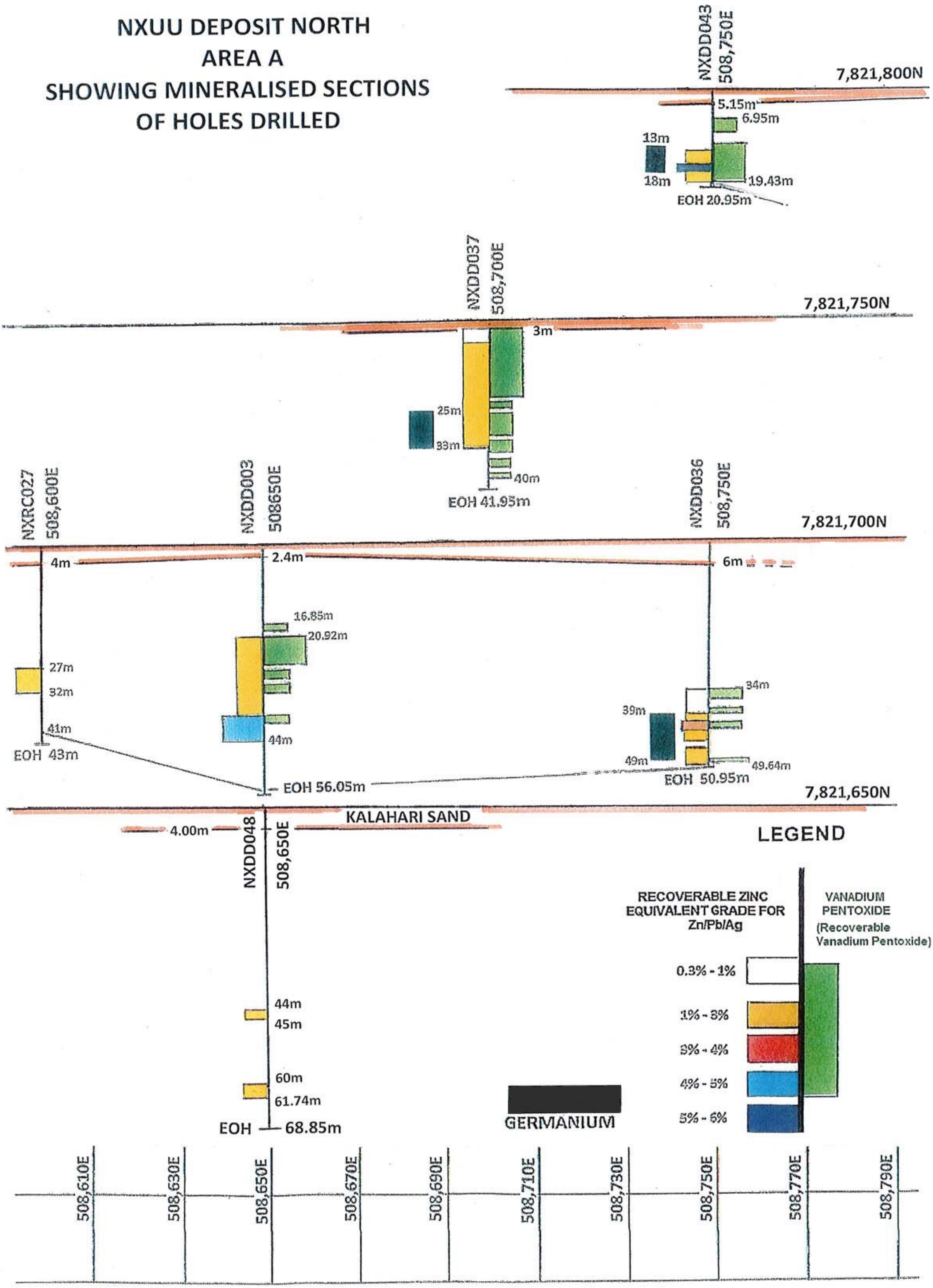
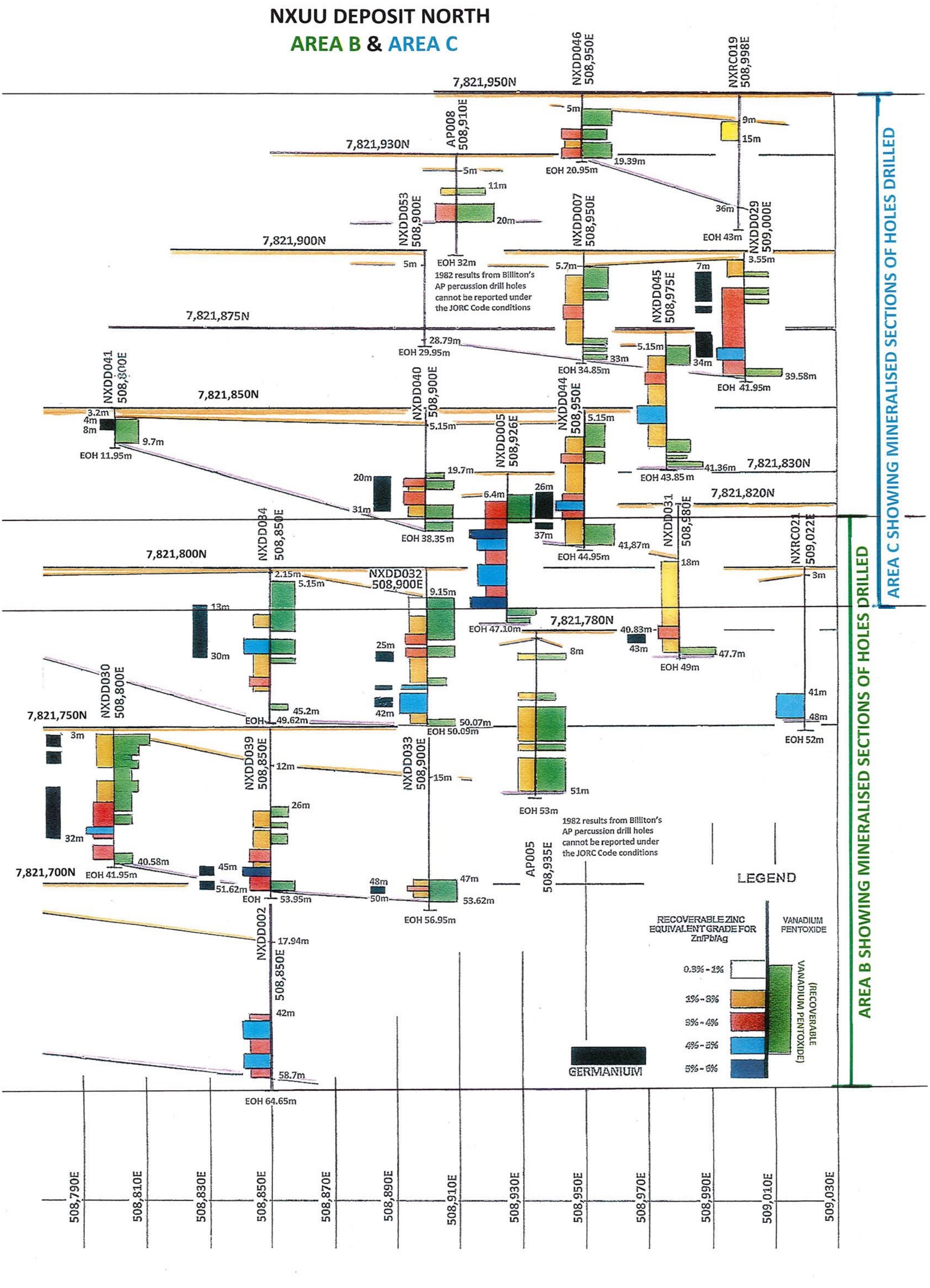
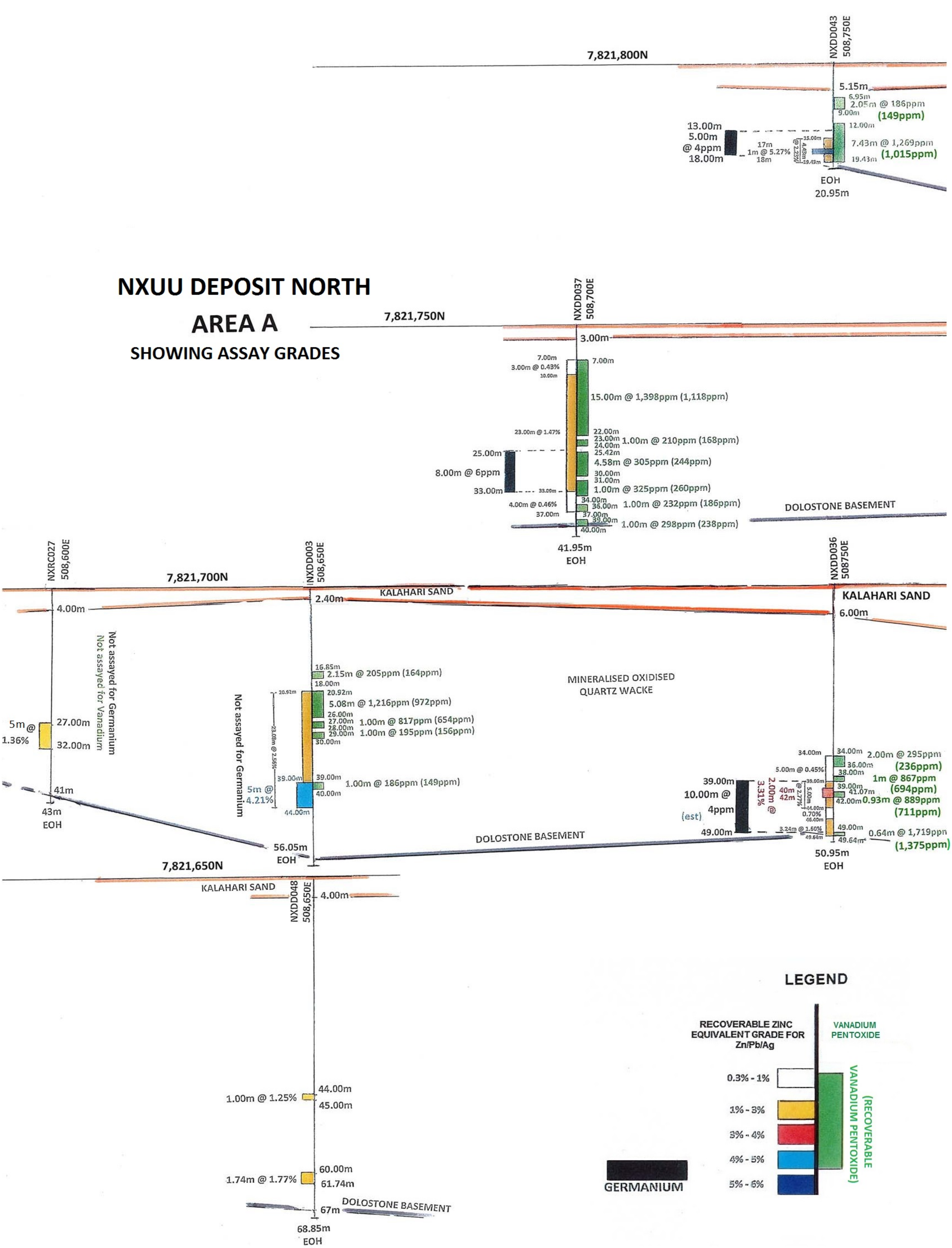


FIGURE 3

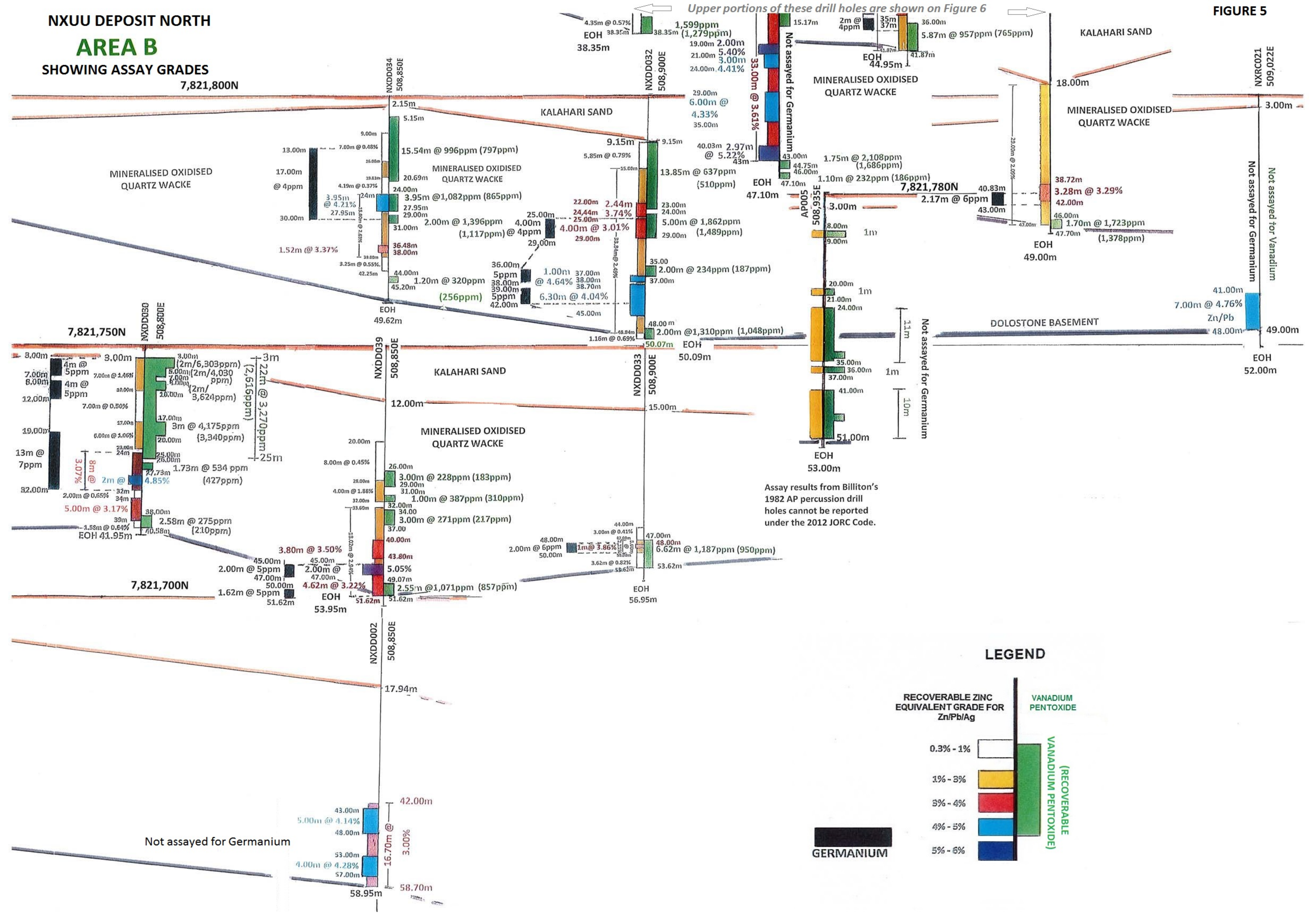


NXUU DEPOSIT NORTH
AREA B & AREA C
AREA C SHOWING MINERALISED SECTIONS OF HOLES DRILLED
AREA B SHOWING MINERALISED SECTIONS OF HOLES DRILLED
7,821,950N
7,821,930N
7,821,900N
7,821,875N
7,821,850N
7,821,830N
7,821,820N
7,821,800N
7,821,780N
7,821,750N
7,821,700N
NXDD046 508,950E
NXRC019 508,998E
AP008 508,910E
NXDD053 508,900E
NXDD007 508,950E
NXDD029 509,000E
NXDD045 508,975E
NXDD041 508,800E
NXDD040 508,900E
NXDD044 508,950E
NXDD005 508,926E
NXDD031 508,980E
NXRC021 509,022E
NXDD034 508,850E
NXDD032 508,900E
NXDD030 508,800E
NXDD039 508,850E
NXDD033 508,900E
AP005 508,935E
NXDD002 508,850E
EOH 20.95m
EOH 43m
EOH 32m
EOH 29.95m
EOH 34.85m
EOH 41.95m
EOH 11.95m
EOH 43.85m
EOH 38.35m
EOH 44.95m
EOH 47.10m
EOH 49m
EOH 52m
EOH 49.62m
EOH 50.09m
EOH 53m
EOH 41.95m
EOH 53.95m
EOH 56.95m
EOH 64.65m
1982 results from Billiton's AP percussion drill holes cannot be reported under the JORC Code conditions
1982 results from Billiton's AP percussion drill holes cannot be reported under the JORC Code conditions
LEGEND
RECOVERABLE ZINC EQUIVALENT GRADE FOR Zn/Pb/Ag
0.3% - 1%
1% - 3%
3% - 4%
4% - 5%
5% - 6%
VANADIUM PENTOXIDE
(RECOVERABLE VANADIUM PENTOXIDE)
GERMANIUM
508,790E
508,810E
508,830E
508,850E
508,870E
508,890E
508,910E
508,930E
508,950E
508,970E
508,990E
509,010E
509,030E

FIGURE 4



NXUU DEPOSIT NORTH
AREA A
SHOWING ASSAY GRADES
7,821,800N
NXDD043 508,750E
5.15m
6.95m
2.05m @ 186ppm
9.00m
(149ppm)
12.00m
13.00m
5.00m
@ 4ppm
18.00m
17m
1m @ 5.27%
18m
7.43m @ 1,269ppm
19.43m
(1,015ppm)
EOH
20.95m
7,821,750N
NXDD037 508,700E
3.00m
7.00m
3.00m @ 0.43%
15.00m @ 1,398ppm (1,118ppm)
23.00m @ 1.47%
22.00m
23.00m
24.00m
1.00m @ 210ppm (168ppm)
25.00m
25.42m
8.00m @ 6ppm
4.58m @ 305ppm (244ppm)
30.00m
31.00m
33.00m
1.00m @ 325ppm (260ppm)
4.00m @ 0.46%
37.00m
34.00m
36.00m
1.00m @ 232ppm (186ppm)
39.00m
40.00m
1.00m @ 298ppm (238ppm)
DOLOSTONE BASEMENT
41.95m
EOH
NXRC027 508,600E
NXDD003 508,650E
NXDD036 508750E
7,821,700N
KALAHARI SAND
4.00m
2.40m
6.00m
Not assayed for Germanium
Not assayed for Vanadium
5m @ 1.36%
27.00m
32.00m
41m
43m
EOH
16.85m
2.15m @ 205ppm (164ppm)
18.00m
20.92m
5.08m @ 1,216ppm (972ppm)
26.00m
27.00m
28.00m
29.00m
1.00m @ 817ppm (654ppm)
1.00m @ 195ppm (156ppm)
30.00m
39.00m
40.00m
1.00m @ 186ppm (149ppm)
5m @ 4.21%
44.00m
56.05m
EOH
MINERALISED OXIDISED
QUARTZ WACKE
DOLOSTONE BASEMENT
34.00m
2.00m @ 295ppm
36.00m
(236ppm)
38.00m
5.00m @ 0.45%
1m @ 867ppm
(694ppm)
39.00m
10.00m @
4ppm
(est)
49.00m
2.00m @ 3.31%
40m
42m
41.07m
42.00m
0.93m @ 889ppm
(711ppm)
49.00m
49.64m
0.64m @ 1,719ppm
(1,375ppm)
50.95m
EOH
7,821,650N
KALAHARI SAND
NXDD048 508,650E
4.00m
44.00m
1.00m @ 1.25%
45.00m
60.00m
1.74m @ 1.77%
61.74m
67m
DOLOSTONE BASEMENT
68.85m
EOH
LEGEND
RECOVERABLE ZINC EQUIVALENT GRADE FOR Zn/Pb/Ag
VANADIUM PENTOXIDE
0.3% - 1%
1% - 3%
3% - 4%
4% - 5%
5% - 6%
VANADIUM PENTOXIDE
(RECOVERABLE VANADIUM PENTOXIDE)
GERMANIUM



NXUU DEPOSIT NORTH
AREA B
SHOWING ASSAY GRADES
FIGURE 5
Upper portions of these drill holes are shown on Figure 6
7,821,800N
7,821,780N
7,821,750N
7,821,700N
NXDD034 508,850E
NXDD032 508,900E
NXDD030 508,830E
NXDD039 508,850E
NXDD033 508,900E
NXDD002 508,850E
AP005 508,935E
NXRC021 509,022E
KALAHARI SAND
MINERALISED OXIDISED QUARTZ WACKE
DOLOSTONE BASEMENT
15.54m @ 996ppm (797ppm)
3.95m @1,082ppm (865ppm)
2.00m @ 1,396ppm (1,117ppm)
1.20m @ 320ppm (256ppm)
13.85m @ 637ppm (510ppm)
5.00m @ 1,862ppm (1,489ppm)
2.00m @ 234ppm (187ppm)
2.00m @1,310ppm (1,048ppm)
1,599ppm (1,279ppm)
33.00m @ 3.61%
5.87m @ 957ppm (765ppm)
1.75m @ 2,108ppm (1,686ppm)
1.10m @ 232ppm (186ppm)
2.17m @ 6ppm
3.28m @ 3.29%
1.70m @ 1,723ppm (1,378ppm)
7.00m @ 4.76% Zn/Pb
22m @ 3,270ppm (2,616ppm)
3m @ 4,175ppm (3,340ppm)
1.73m @ 534 ppm (427ppm)
2.58m @ 275ppm (210ppm)
5.00m @ 3.17%
3.00m @ 228ppm (183ppm)
1.00m @ 387ppm (310ppm)
3.00m @ 271ppm (217ppm)
3.80m @ 3.50%
4.62m @ 3.22%
2.55m @1,071ppm (857ppm)
6.62m @ 1,187ppm (950ppm)
5.00m @ 4.14%
4.00m @ 4.28%
16.70m @ 3.00%
Not assayed for Germanium
Not assayed for Vanadium
Assay results from Billiton's 1982 AP percussion drill holes cannot be reported under the 2012 JORC Code.
EOH
LEGEND
RECOVERABLE ZINC EQUIVALENT GRADE FOR Zn/Pb/Ag
VANADIUM PENTOXIDE
0.3% - 1%
1% - 3%
3% - 4%
4% - 5%
5% - 6%
(RECOVERABLE VANADIUM PENTOXIDE)
GERMANIUM

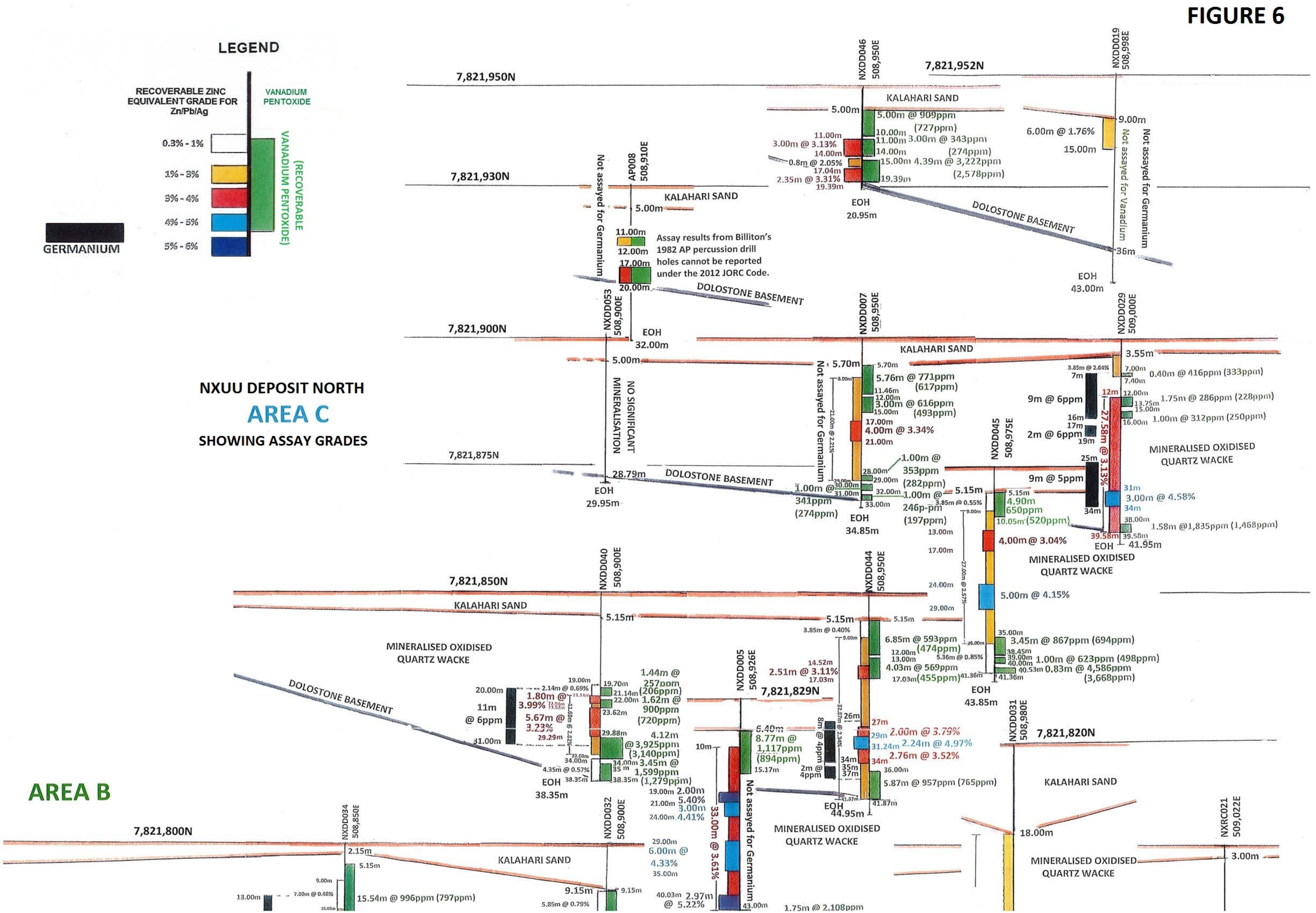


FIGURE 6
LEGEND
RECOVERABLE ZINC EQUIVALENT GRADE FOR Zn/Pb/Ag
VANADIUM PENTOXIDE
0.3% - 1%
1% - 3%
3% - 4%
4% - 5%
5% - 6%
(RECOVERABLE VANADIUM PENTOXIDE)
GERMANIUM
NXUU DEPOSIT NORTH
AREA C
SHOWING ASSAY GRADES
AREA B
7,821,950N
7,821,952N
7,821,930N
7,821,900N
7,821,875N
7,821,850N
7,821,829N
7,821,820N
7,821,800N
NXDD046 508,950E
NXDD019 508,998E
AP008 508,910E
NXDD053 508,900E
NXDD007 508,950E
NXDD029 509,000E
NXDD045 508,975E
NXDD040 508,900E
NXDD044 508,950E
NXDD005 508,926E
NXDD031 508,980E
NXDD034 508,850E
NXDD032 508,900E
NXRC021 509,022E
KALAHARI SAND
DOLOSTONE BASEMENT
MINERALISED OXIDISED QUARTZ WACKE
NO SIGNIFICANT MINERALISATION
Not assayed for Germanium
Not assayed for Vanadium
Assay results from Billiton's 1982 AP percussion drill holes cannot be reported under the 2012 JORC Code.
5.00m @ 909ppm (727ppm)
3.00m @ 343ppm (274ppm)
4.39m @ 3,222ppm (2,578ppm)
3.00m @ 3.13%
0.8m @ 2.05%
2.35m @ 3.31%
EOH 20.95m
6.00m @ 1.76%
EOH 43.00m
EOH 32.00m
EOH 29.95m
5.76m @ 771ppm (617ppm)
3.00m @ 616ppm (493ppm)
4.00m @ 3.34%
1.00m @ 353ppm (282ppm)
1.00m @ 341ppm (274ppm)
1.00m @ 246ppm (197ppm)
EOH 34.85m
0.40m @ 416ppm (333ppm)
1.75m @ 286ppm (228ppm)
1.00m @ 312ppm (250ppm)
9m @ 6ppm
2m @ 6ppm
9m @ 5ppm
27.58m @ 3.13%
3.00m @ 4.58%
1.58m @1,835ppm (1,468ppm)
EOH 41.95m
4.90m 650ppm (520ppm)
4.00m @ 3.04%
5.00m @ 4.15%
3.45m @ 867ppm (694ppm)
1.00m @ 623ppm (498ppm)
0.83m @ 4,586ppm (3,668ppm)
EOH 43.85m
1.44m @ 257ppm (206ppm)
1.62m @ 900ppm (720ppm)
4.12m @3,925ppm (3,140ppm)
3.45m @ 1,599ppm (1,279ppm)
1.80m @ 3.99%
5.67m @ 3.23%
11m @ 6ppm
EOH 38.35m
6.85m @ 593ppm (474ppm)
4.03m @ 569ppm (455ppm)
2.51m @ 3.11%
2.00m @ 3.79%
2.24m @ 4.97%
2.76m @ 3.52%
5.87m @ 957ppm (765ppm)
8m @ 4ppm
2m @ 4ppm
EOH 44.95m
8.77m @ 1,117ppm (894ppm)
33.00m @ 3.61%
2.00m 5.40%
3.00m 4.41%
6.00m @ 4.33%
2.97m @ 5.22%
1.75m @ 2,108ppm
15.54m @ 996ppm (797ppm)
18.00m
3.00m

FIGURE 7

NXUU DEPOSIT NORTH
AREA A
DRILL HOLES FROM WHICH CORE WAS SELECTED FOR TEST WORK

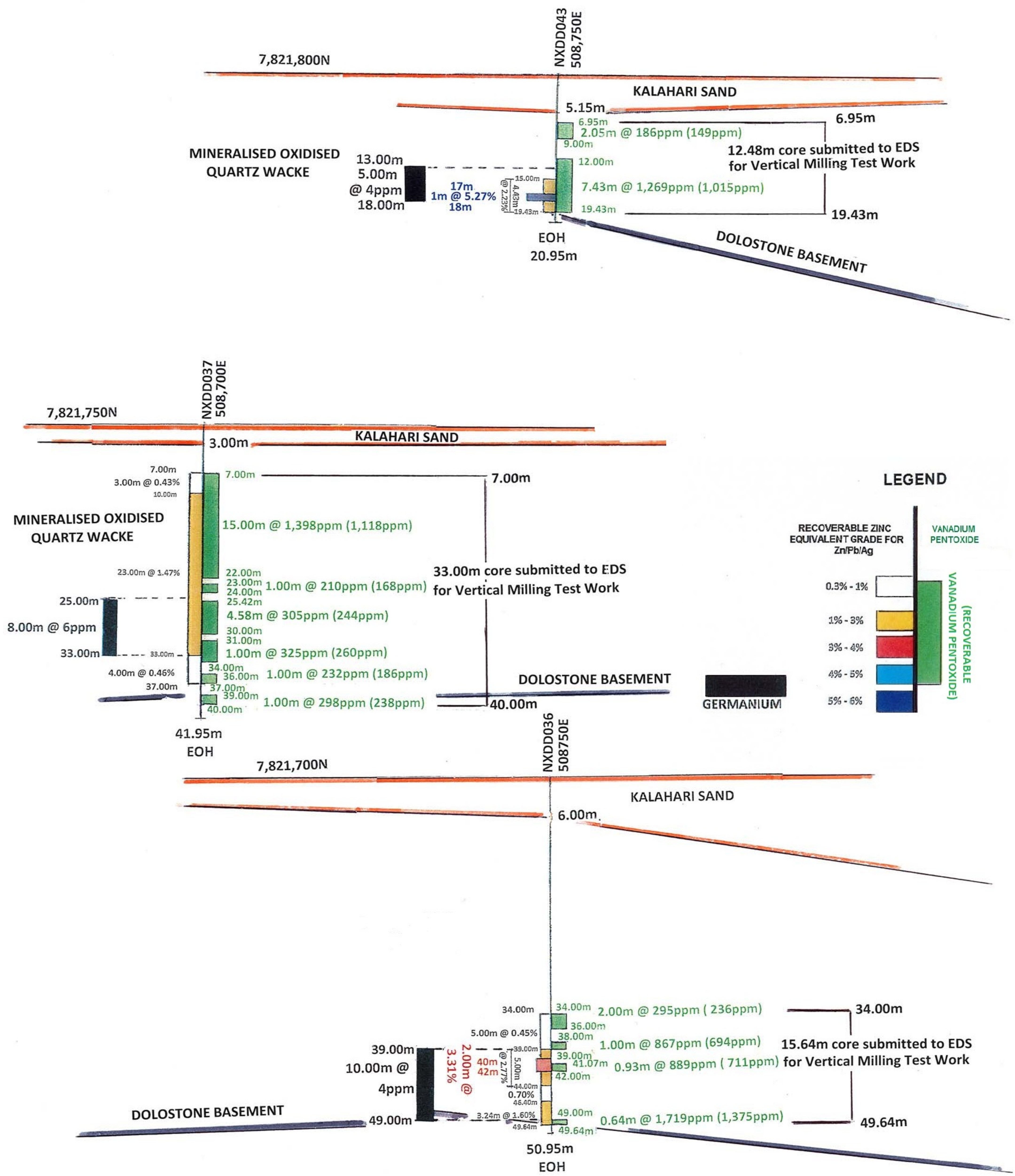
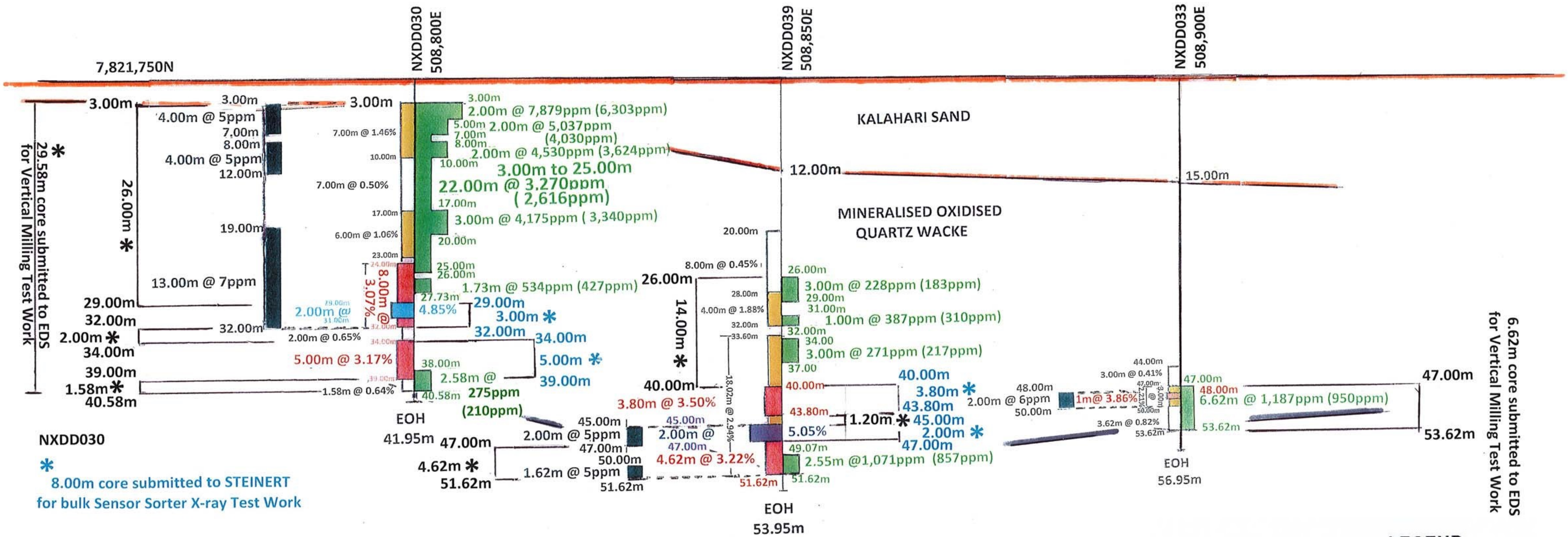


FIGURE 8

NXUU DEPOSIT NORTH
AREA B

DRILL HOLES FROM WHICH CORE WAS SELECTED FOR TEST WORK



NXDD030

*
8.00m core submitted to STEINERT for bulk Sensor Sorter X-ray Test Work

NXDD039

*
19.82m core submitted to EDS for Vertical Milling Test Work

*
5.80m core to be submitted to STEINERT for bulk Sensor Sorter X-ray Test Work

LEGEND

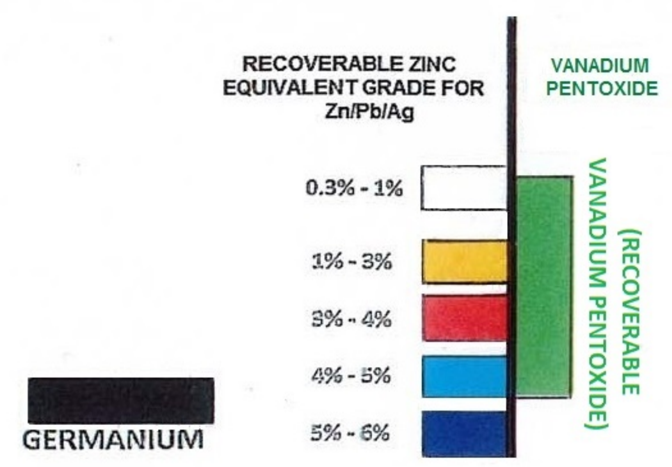
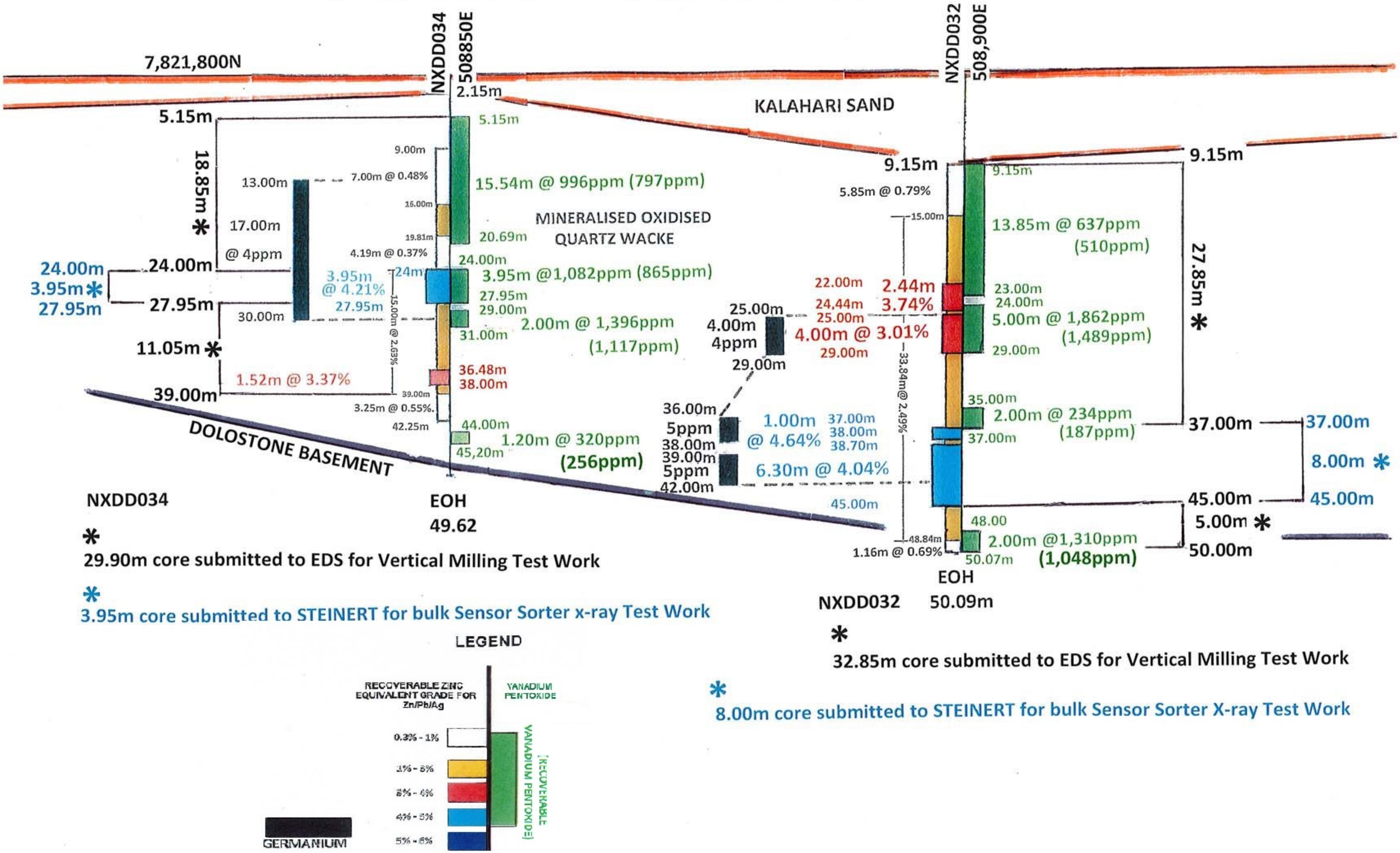


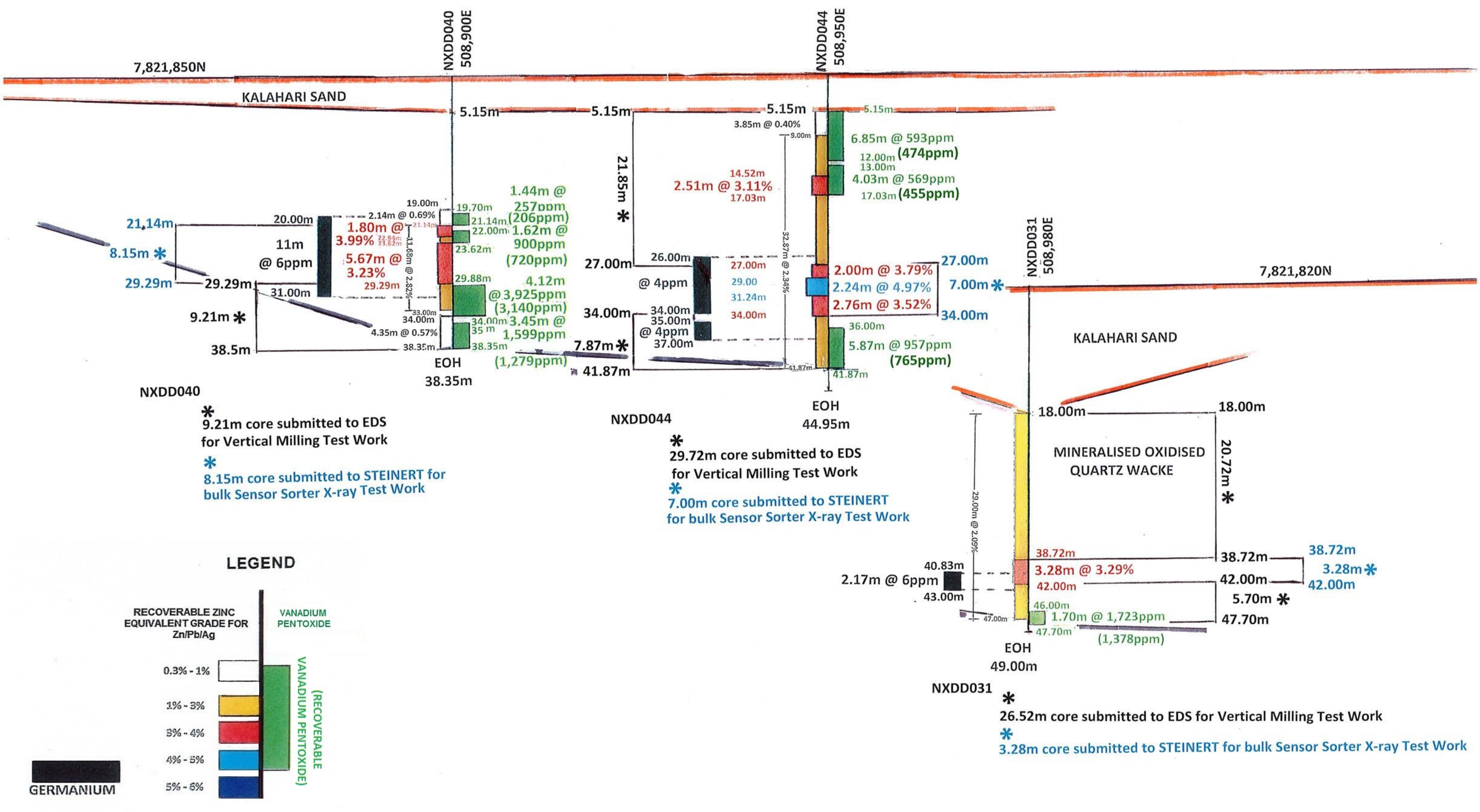
FIGURE 9

NXUU DEPOSIT NORTH
AREA B
DRILL HOLES FROM WHICH CORE WAS SELECTED FOR TEST WORK



NXUU DEPOSIT NORTH
AREA C

DRILL HOLES FROM WHICH CORE WAS SELECTED FOR TEST WORK



NXDD040

* 9.21m core submitted to EDS for Vertical Milling Test Work

* 8.15m core submitted to STEINERT for bulk Sensor Sorter X-ray Test Work

NXDD044

* 29.72m core submitted to EDS for Vertical Milling Test Work

* 7.00m core submitted to STEINERT for bulk Sensor Sorter X-ray Test Work

NXDD031

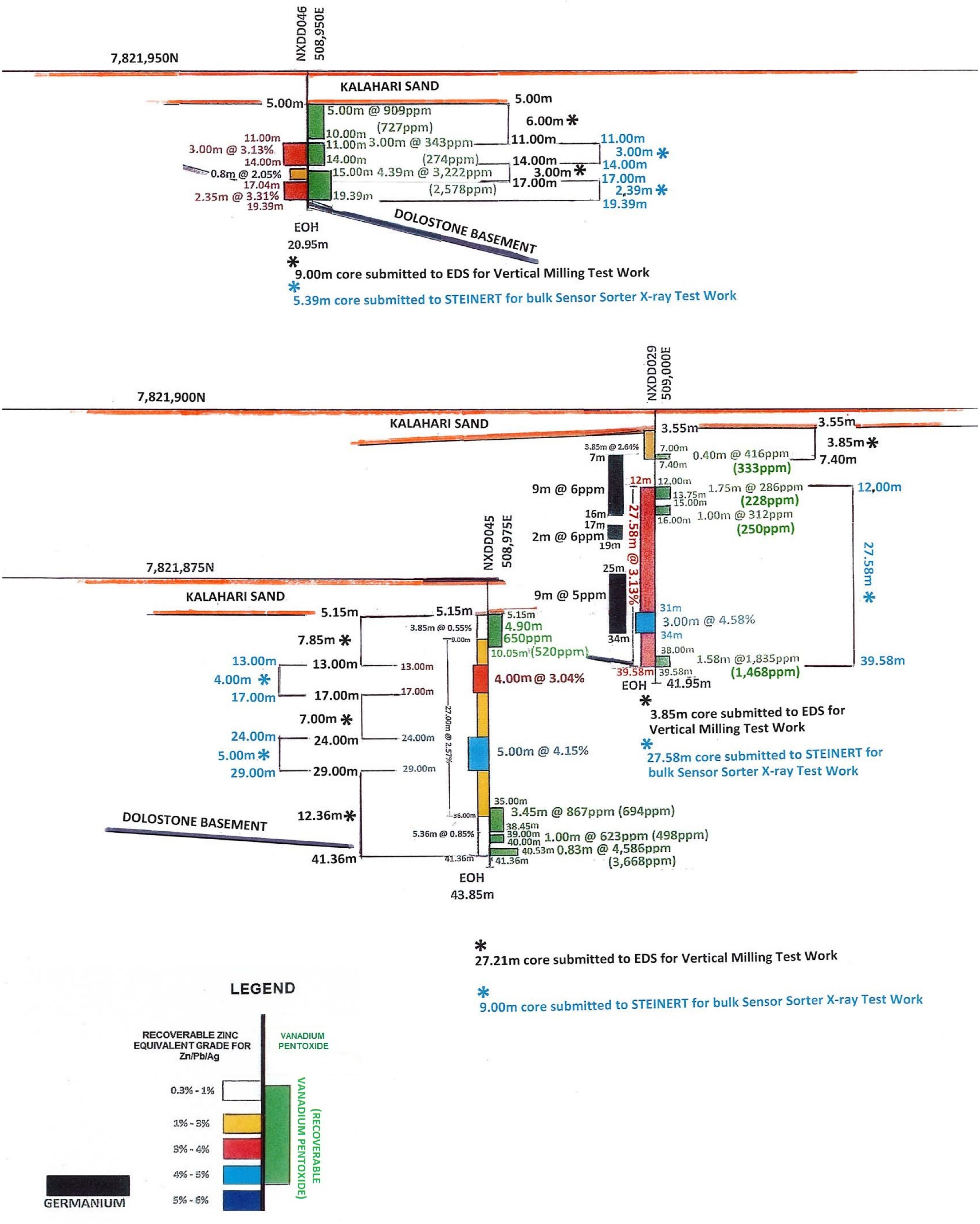
* 26.52m core submitted to EDS for Vertical Milling Test Work

* 3.28m core submitted to STEINERT for bulk Sensor Sorter X-ray Test Work

FIGURE 11

NXUU DEPOSIT NORTH
AREA C

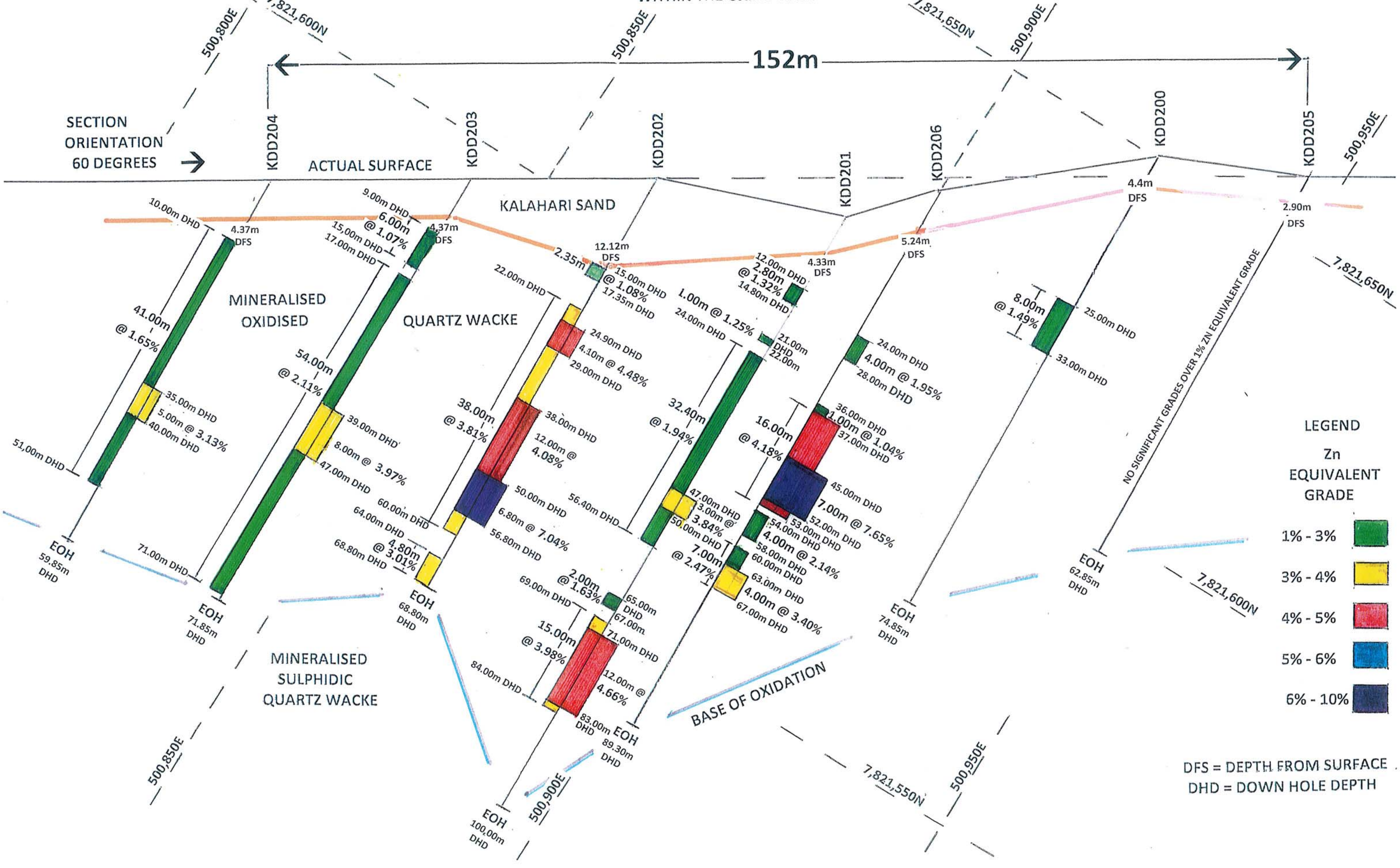
DRILL HOLES FROM WHICH CORE WAS SELECTED FOR TEST WORK

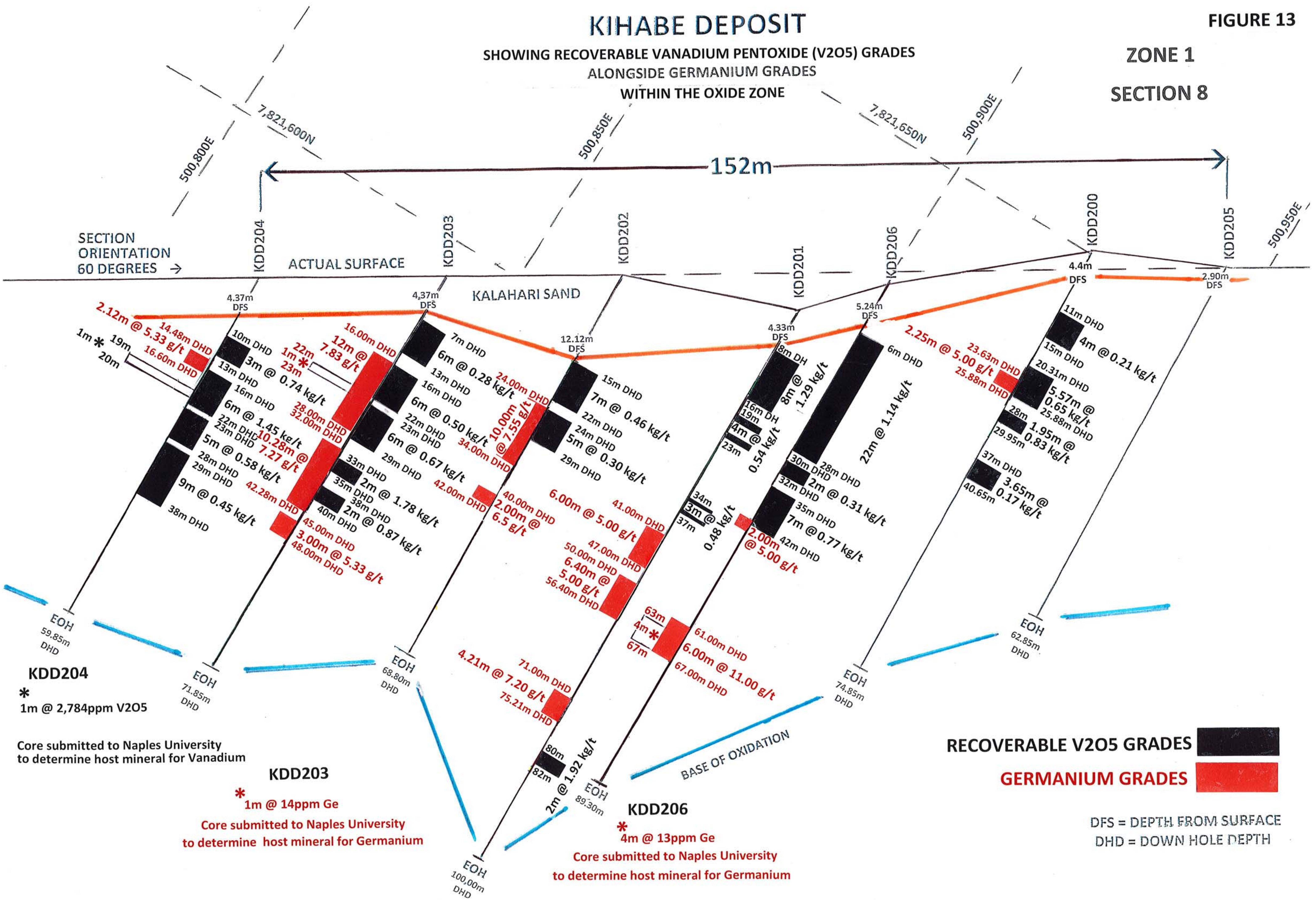


KIHABE DEPOSIT

FIGURE 12

SHOWING RECOVERABLE Zn EQUIVALENT GRADES FOR Zn, Pb & Ag WITHIN THE OIXDE ZONE





KIHABE DEPOSIT
SHOWING RECOVERABLE VANADIUM PENTOXIDE (V2O5) GRADES
ALONGSIDE GERMANIUM GRADES
WITHIN THE OXIDE ZONE
FIGURE 13
ZONE 1
SECTION 8
7,821,600N
7,821,650N
500,800E
500,850E
500,900E
500,950E
152m
SECTION ORIENTATION 60 DEGREES
ACTUAL SURFACE
KALAHARI SAND
KDD204
KDD203
KDD202
KDD201
KDD206
KDD200
KDD205
4.37m DFS
4,37m DFS
12.12m DFS
4.33m DFS
5.24m DFS
4.4m DFS
2.90m DFS
2.12m @ 5.33 g/t
14.48m DHD
16.60m DHD
10m DHD
3m @ 0.74 kg/t
13m DHD
16m DHD
6m @ 1.45 kg/t
22m DHD
23m DHD
5m @ 0.58 kg/t
28m DHD
29m DHD
9m @ 0.45 kg/t
38m DHD
EOH 59.85m DHD
16.00m DHD
12m @ 7.83 g/t
28.00m DHD
32.00m DHD
10.28m @ 7.27 g/t
42.28m DHD
45.00m DHD
3.00m @ 5.33 g/t
48.00m DHD
7m DHD
6m @ 0.28 kg/t
13m DHD
16m DHD
6m @ 0.50 kg/t
22m DHD
23m DHD
6m @ 0.67 kg/t
29m DHD
33m DHD
2m @ 1.78 kg/t
35m DHD
38m DHD
2m @ 0.87 kg/t
40m DHD
EOH 71.85m DHD
24.00m DHD
10.00m @ 7.55 g/t
34.00m DHD
42.00m DHD
2.00m @ 6.5 g/t
40.00m DHD
15m DHD
7m @ 0.46 kg/t
22m DHD
24m DHD
5m @ 0.30 kg/t
29m DHD
EOH 68.80m DHD
6.00m @ 5.00 g/t
41.00m DHD
47.00m DHD
50.00m DHD
6.40m @ 5.00 g/t
56.40m DHD
4.21m @ 7.20 g/t
71.00m DHD
75.21m DHD
80m
82m
2m @ 1.92 kg/t
EOH 100.00m DHD
8m DH
8m @ 1.29 kg/t
16m DH
19m
4m @ 0.54 kg/t
23m
34m
3m @ 0.48 kg/t
37m
30m DHD
32m DHD
2m @ 0.31 kg/t
28m DHD
35m DHD
7m @ 0.77 kg/t
42m DHD
2.00m @ 5.00 g/t
63m
4m
67m
61.00m DHD
6.00m @ 11.00 g/t
67.00m DHD
EOH 89.30m
6m DHD
22m @ 1.14 kg/t
EOH 74.85m DHD
2.25m @ 5.00 g/t
23.63m DHD
25.88m DHD
11m DHD
4m @ 0.21 kg/t
15m DHD
20.31m DHD
5.57m @ 0.65 kg/t
25.88m DHD
28m
1.95m @ 0.83 kg/t
29.95m
37m DHD
3.65m @ 0.17 kg/t
40.65m
EOH 62.85m DHD
BASE OF OXIDATION
1m 19m 20m
1m 22m 23m
KDD204
* 1m @ 2,784ppm V2O5
Core submitted to Naples University to determine host mineral for Vanadium
KDD203
* 1m @ 14ppm Ge
Core submitted to Naples University to determine host mineral for Germanium
KDD206
* 4m @ 13ppm Ge
Core submitted to Naples University to determine host mineral for Germanium
RECOVERABLE V2O5 GRADES
GERMANIUM GRADES
DFS = DEPTH FROM SURFACE
DHD = DOWN HOLE DEPTH

Nxuu Deposit Recoverable Zinc Equivalent Grade applying a 1% Zinc Equivalent Low Cut

As reported on 22 January 2019 the Zn equivalent grades were calculated as follows:

The Zinc Equivalent Grade for the Nxuu Deposit includes grades of Zinc, Lead and Silver, calculated by applying the average of five trading days LME closing prices for Zinc and Lead and the five trading days of USA closing prices for Silver, from 22 to 26 January 2018. Zinc and Lead grade values were then discounted to 93% to reflect the **RECOVERABLE** value based on metallurgical test work conducted by AMMTEC. Silver grade values were then discounted to 70% to reflect **RECOVERABLE** value of Silver as achieved in similar deposits.

- LME average closing Zinc price of US$ 3,464/t, being US$ 34.64 per 1% was reduced to **US$32.21 per 1%** to reflect a recovery of 93% as demonstrated in previous metallurgical test work conducted by AMMTEC.
- LME average closing Lead price of US$ 2,611/t, being US$ 26.11 per 1% was reduced to **US$24.28 per 1 %** to reflect a recovery of 93% as demonstrated in previous metallurgical test work conducted by AMMTEC.
- USA average Day Trade closing Silver price of US$ 17.23/oz, being US$ 0.55/g reduced to **US$0.38/g** to reflect a recovery of 70% based on recovery performance of similar deposits. (Refer to Estimated Silver Recovery below).

Combined total discounted US$ value of each assay including any or all of Zinc, Lead and Silver was then divided by the discounted calculated Zinc price of US$32.21 per 1% to arrive at the **RECOVERABLE** Zinc Equivalent Grade. Only resulting grades of over 1% Zinc Equivalent were then applied in determining widths of mineralised intersections reported to ASX.

To evaluate current zinc equivalent grades the Zn/Pb/Ag prices of January 2018 are compared with current day prices (6 November 2020) to reflect any impact on the Zn equivalent grades applied.

January 2018 prices	*US$*	*%*	*Current Prices*	*US$*	*%*
Zinc	*3,464*	*57*	*Zinc*	*2,614*	*58.71*
Lead	*2,611*	*43*	*Lead*	*1,838*	*41.29*
	6,075	***100***		***4,452***	***100***
Silver	17.23		Silver	25.56	

The Zn equivalent grade is calculated on percentage contribution relative to the grade and value of each metal. As there is little difference between relative value of these metals, the Company believes there is no need to recalculate the Zn equivalent grade for the current value despite the significant variance in current metal prices compared with those of January 2018. The Zn/Pb grades are the same as those used in January 2018. There is only a 1.71% variance in the contribution each metal makes according to their current prices.

Zinc Equivalent Recoverable Grade -Calculation Formula

- US$ Zinc price/t divided by 100 = US $ Zinc price per 1% X 93% Recovery X Zinc Grade % = US$A
- US$ Lead price/t divided by 100 = US $ Lead price per 1% X 93% Recovery X Lead Grade % = US$B
- US$ Silver price/oz divided by 31.1 = US $ Silver price per gram X 70% Recovery X Silver Grade g/t = US$C

US$A + US$B + US$ C divided by US$A = Zinc Equivalent Grade

Kihabe Deposit Recoverable Zinc Equivalent Grade applying a 1% Zinc Equivalent Low Cut

The holes on the Kihabe drill hole sections (Figures 12 and 13) were drilled in November/December 2017 and the zinc equivalent grade for zinc, lead and silver were calculated based on the same five trading day average prices from 22-26 January 2018 as were calculated for the Nxuu Deposit. The same 93% recoverable discount was applied to zinc and lead and the same 70% recoverable discount was applied to silver.

Forward Looking Statement

This report contains forward looking statements in respect of the projects being reported on by the Company. Forward looking statements are based on beliefs, opinions, assessments and estimates based on facts and information available to management and/or professional consultants at the time they are formed or made and are, in the opinion of management and/or consultants, applied as reasonably and responsibly as possible as at the time that they are applied.

Any statements in respect of Ore Reserves, Mineral Resources and zones of mineralisation may also be deemed to be forward looking statements in that they contain estimates that the Company believes have been based on reasonable assumptions with respect to the mineralisation that has been found thus far. Exploration targets are conceptual in nature and are formed from projection of the known resource dimensions along strike. The quantity and grade of an exploration target is insufficient to define a Mineral Resource. Forward looking statements are not statements of historical fact, they are based on reasonable projections and calculations, the ultimate results or outcomes of which may differ materially from those described or incorporated in the forward looking statements. Such differences or changes in circumstances to those described or incorporated in the forward looking statements may arise as a consequence of the variety of risks, uncertainties and other factors relative to the exploration and mining industry and the particular properties in which the Company has an interest.

Such risks, uncertainties and other factors could include but would not necessarily be limited to fluctuations in metals and minerals prices, fluctuations in rates of exchange, changes in government policy and political instability in the countries in which the Company operates.

Other important Information

Purpose of document: This document has been prepared by Mount Burgess Mining NL (MTB). It is intended only for the purpose of providing information on MTB, its project and its proposed operations. This document is neither of an investment advice, a prospectus nor a product disclosure statement. It does not represent an investment disclosure document. It does not purport to contain all the information that a prospective investor may require to make an evaluated investment decision. MTB does not purport to give financial or investment advice.

Professional advice: Recipients of this document should consider seeking appropriate professional advice in reviewing this document and should review any other information relative to MTB in the event of considering any investment decision.

Forward looking statements: This document contains forward looking statements which should be reviewed and considered as part of the overall disclosure relative to this report.

Disclaimer: Neither MTB nor any of its officers, employees or advisors make any warranty (express or implied) as to the accuracy, reliability and completeness of the information contained in this document. Nothing in this document can be relied upon as a promise, representation or warranty.

Proprietary information: This document and the information contained therein is proprietary to MTB.

Competent Persons' Statements:

The information in this report that relates to drilling results at the Kihabe Deposit fairly represents information and supporting documentation approved for release by Giles Rodney Dale FRMIT who is a Fellow of the Australasian Institute of Mining & Metallurgy. Mr Dale is engaged as an independent Geological Consultant to the Company. Mr Dale has sufficient experience which is relevant to the style of mineralisation and type of deposit under consideration and to the activity which he is undertaking to qualify as a Competent Person as defined in the 2012 Edition of the 'Australasian Code for Reporting of Mineral Resources and Ore Reserves (the JORC Code)'. Mr Dale consents to the inclusion in this report of the drilling results and the supporting information in the form and context as it appears.

The information in this report that relates to mineralogical and metallurgical test work results conducted on samples from the Nxuu Deposit fairly represents information and supporting documentation approved for release by Mr Chris Campbell-Hicks, Metallurgist, FAusIMM (CP Metallurgy),MMICA, Non-Executive Director of the Company, who reviewed the content of the announcement. Mr Campbell-Hicks has sufficient experience that is relevant to the style of mineralisation and type of deposit under consideration and to the activity being undertaken to qualify as a Competent Person as defined in the 2012 Edition of the JORC Code and has consented to the inclusion in respect of the matters based on the information in the form and context in which it appears.

Mr Campbell-Hicks has for a number of years whilst working with Coffey Mining and other consultancies and companies made contributions to numerous Scoping Studies, Pre-feasibility Studies and Feasibility Studies under the 2004 JORC Code, the 2012 JORC Code and the Canadian National Instrument (NI 43-101). As such he qualifies as a Competent Person for reporting on matters pertaining to metallurgy, process engineering and interpretation of test work results and data for the establishment of Design Criteria for such studies.

The following extract from the JORC Code 2012 Table 1 is provided for compliance with the Code requirements for the reporting of drilling results.

Section 1 Sampling Techniques and Data (Criteria in this section apply to all succeeding sections).

Criteria	JORC code explanation	Commentary
Sampling techniques	Nature and quality of sampling (eg cut channels, random chips, or specific specialised industry standard measurement tools appropriate to the minerals under investigation, such as down hole gamma sondes, or handheld XRF instruments, etc). These examples should not be taken as limiting the broad meaning of sampling. • Include reference to measures taken to ensure sample representivity and the appropriate calibration of any measurement tools or systems used. • Aspects of the determination of mineralisation that are Material to the Public Report. • In cases where 'industry standard' work has been done this would be relatively simple (eg 'reverse circulation drilling was used to obtain 1 m samples from which 3 kg was pulverised to produce a 30 g charge for fire assay'). In other cases more explanation may be required, such as where there is coarse gold that has inherent sampling problems. Unusual commodities or mineralisation types (eg submarine nodules) may warrant disclosure of detailed information.	**Mount Burgess Mining Diamond Core Holes** HQ Diamond Core was marked and collected in sample trays, visually logged and cut in half. Samples were collected as nominal 1m intervals but based on visible geology with minimum samples of 0.3m and maximum samples of 1.3m. Half of each core was retained on site in core trays and the other half was double bagged and sent to Intertek Genalysis Randburg, South Africa where they were crushed. A portion of each intersection sample was then pulverised to p80 75um and sent to Intertek Genalysis for assaying via ICPMS/OES for Ag/Co/Cu/Ga/Ge/In/Pb/V/Zn. **Mount Burgess Mining Reverse Circulation Holes** Individual meters of RC drill chips were bagged from the cyclone. These were then riffle split for storage in smaller bags, with selected drill chips being stored in drill chip trays. A trowel was used to select drill chip samples from sample bags to be packaged and sent to Intertek Genalysis, Randburg, South Africa where they were crushed. A portion of each intersection's sample was then pulverised to P80 75um and sent to Intertek Genalysis, Maddington, WA, for assaying via ICP/OES for Ag/Co/Cu/Pb/Zn. **Mount Burgess Mining Diamond Core Samples submitted to for Metallurgical Test Work** The remainder of the crushed samples were then sent from Intertek Genalysis Randburg to Intertek Genalysis Maddington, Western Australia where they were then collected by the Company for storage. Samples from various intersections from six drill holes NXDD030, NXDD033, NXDD037, NXDD039, NXDD040 and NXDD043, as shown in Figure 1 of the Company's announcement of 28 May 2019 to ASX, were selected by the Company for submission to for sensor sorter metallurgical test work. These samples were chosen to determine if Sensor Sorter X-ray Test Work developed by STEINERT could be used to pre-concentrate zinc, lead, silver, germanium and vanadium pentoxide mineralization prior to milling and flotation. Results of the +4mm STEINERT Metallurgical Test Work were reported on 20 August 2019.

	Drill type (eg core, reverse circulation, open-hole hammer, rotary air blast, auger, Bangka, sonic, etc) and details (eg core diameter, triple or standard tube, depth of diamond tails, face-sampling bit or other type, whether core is oriented and if so, by what method, etc).	**Mount Burgess Mining Diamond Core Holes** HQ diameter triple tube was used for diamond core drilling. As all holes drilled into the Nxuu deposit were vertical holes the diamond core was not orientated. **Mount Burgess Mining RC Hole** One vertical RC hole was drilled into the Nxuu Deposit mineralised zone.
Drill sample recovery	Method of recording and assessing core and chip sample recoveries and results assessed. • Measures taken to maximise sample recovery and ensure representative nature of the samples. • Whether a relationship exists between sample recovery and grade and whether sample bias may have occurred due to preferential loss/gain of fine/coarse material	**Mount Burgess Mining Diamond Core and RC Holes** Sample recoveries were in general high and no unusual measures were taken to maximise sample recovery other than the use of triple tube core for diamond core drilling. Mount Burgess believes there is no evidence of sample bias due to preferential loss/gain of fine/coarse material.
Logging	Whether core and chip samples have been geologically and geotechnically logged to a level of detail to support appropriate Mineral Resource estimation, mining studies and metallurgical studies. • Whether logging is qualitative or quantitative in nature. Core (or costean, channel, etc) photography. • The total length and percentage of the relevant intersections logged.	**Mount Burgess Mining Diamond Core Holes and RC Hole** Holes were logged in the field by qualified Geologists on the Company's log sheet template and of sufficient detail to support future mineral resource estimation: Qualitative observations covered Lithology, grain size, colour, alteration, mineralisation, structure. Quantitative logging included vein percent. SG calculations at ~5m intervals were taken in the DD holes. All holes were logged for the entire length of hole. Logs are entered into MTBs GIS database managed by MTB in Perth.
Sub-sampling techniques and sample preparation	If core, whether cut or sawn and whether quarter, half or all core taken. • If non-core, whether riffled, tube sampled, rotary split, etc and whether sampled wet or dry. • For all sample types, the nature, quality and appropriateness of the sample preparation technique. • Quality control procedures adopted for all sub-sampling stages to maximise representivity of samples. • Measures taken to ensure that the sampling is representative of the in situ material collected, including for instance results for field duplicate/second-half sampling. • Whether sample sizes are appropriate to the grain size of the material being sampled	**Mount Burgess Mining Diamond Holes and RC Hole** HQ Core was sawn in half on site. Half of each core was retained on site in core trays and the other half was double bagged and labelled noting Hole# and interval both within the bag and on the bag. Sample bags were then placed in larger bags of ~40 individual samples and the larger bags also labelled describing the contents. Field duplicates were inserted at regular intervals. All samples were assayed for Ag/Co/Cu/Ga/Ge/In/Pb/V/Zn. All RC sample bags were labelled with drill hole number and sample interval and collectively stored in larger bags with similar reference. Drill chip trays were all stored separately. All samples were assayed for Ag/Co/Cu/Pg/Zn.

Quality of assay data and laboratory tests	•The nature, quality and appropriateness of the assaying and laboratory procedures used and whether the technique is considered partial or total •For geophysical tools, spectrometers, hand-held XRF instruments, etc, the parameters used in determining the analysis including instrument make and model, reading times, calibration factors applied and their derivation etc. • nature of quality control procedures adopted (e.g. standards, blanks, duplicates, external laboratory checks) and whether acceptable levels of accuracy (i.e. lack of bias) and precision have been established.	**All Mount Burgess Samples** All samples, when originally assayed, were sent to Intertek Genalysis Perth, for assaying according to the following standard techniques: **Diamond Core Samples** (a) Ore grade digest followed by ICP – OES finish for Silver, Lead, Vanadium & Zinc (b) Nitric acid/hydrofluoric acid specific digest for Germanium and Indium (c) Also 4 acid digest for silver, lead, zinc, germanium and gallium followed by AAS **RC Samples** Ore grade digest followed by ICP-OES for Ag/Co/Cu/Pb/Zn All samples submitted for the Steinert Test Work, once separated through the Sensor Sorter X-ray process, were then submitted to NAGROM Laboratories for the upgraded concentrates to then be assayed by mixed acid digest with ICP finish for Vanadium, Lead, Zinc and Silver. Mount Burgess quality control procedures include following standard procedures when sampling, including sampling on geological intervals, and reviews of sampling techniques in the field. The current laboratory procedures applied to the Mount Burgess sample preparation include the use of cleaning lab equip with compressed air between samples, quartz flushes between high grade samples, insertion of crusher duplicate QAQC samples, periodic pulverised sample particle size (QAQC) testing and insertion of laboratory pulp duplicates QAQC samples according to Intertek protocols. Intertek inserts QA/QC samples (duplicates, blanks and standards) into the sample series at a rate of approx. 1 in 20. These are tracked and reported on by Mount Burgess for each batch. When issues are noted the laboratory is informed and investigation conducted defining the nature of the discrepancy and whether further check assays are required. The laboratory completes its own QA/QC procedures and these are also tracked and reported on by Mount Burgess. Acceptable overall levels of analytical precision and accuracy are evident from analyses of the routine QAQC data
Verification of sampling and assaying	The verification of significant intersections by either independent or alternative company personnel. • The use of twinned holes. • Documentation of primary data, data entry procedures, data verification, data storage (physical and electronic) protocols. • Discuss any adjustment to assay data.	**All Mount Burgess Samples** Assay results for samples were received electronically from Intertek Genalysis and uploaded into MTB's database managed by MTB at its Perth Office. Analytical results for Vanadium (V) from diamond core holes have been converted to $V2O5$ (Vandium Pentoxide) by multiplying the Vanadium grades by 1.785.
Location of data points	Accuracy and quality of surveys used to locate drill holes (collar and down-hole surveys), trenches, mine workings and other locations used in Mineral Resource estimation. • Specification of the grid system used. • Quality and adequacy of topographic control.	**All Mount Burgess Holes** Drill hole collar locations were recorded at the completion of each hole by hand held Garmin 62S GPS with horizontal accuracy of approx. 5 metres • Positional data was recorded in projection WGS84 UTM Zone 34S. The accuracy provided by the system employed is sufficient for the nature of the exploratory program. Downhole surveys were not conducted.
Data spacing and distribution	Data spacing for reporting of Exploration Results. • Whether the data spacing and distribution is sufficient to establish the degree of geological and grade continuity appropriate for the Mineral Resource and Ore Reserve estimation procedure(s) and classifications applied. • Whether sample compositing has been applied.	**All Mount Burgess Holes** Mount Burgess drilling campaigns were undertaken to validate historical drilling as well as to acquire further data for future resource estimation.. The data spacing and distribution is currently insufficient to establish the degree of geological and grade continuity appropriate for the estimation of Mineral Resources compliant with the 2012 JORC Code. Additional drilling is planned to determine the extent of mineralisation and estimate a Mineral Resource

		compliant with the 2012 JORC Code. Sample compositing was conducted on four Nxuu deposit drill holes, following receipt of assays from Intertek Genalysis, for the purpose of mineralogical and metallurgical test work.
Orientation of data in relation to geological structure	Whether the orientation of sampling achieves unbiased sampling of possible structures and the extent to which this is known, considering the deposit type. • If the relationship between the drilling orientation and the orientation of key mineralised structures is considered to have introduced a sampling bias, this should be assessed and reported if material.	**All Mount Burgess Holes** Mineralisation was typically intersected at -90 degrees at the Nxuu Deposit and the Company believes that unbiased sampling was achieved.
Sample security	The measures taken to ensure sample security.	**All Mount Burgess Holes** Samples were taken by vehicle on the day of collection to MTB's permanent field camp, and stored there until transported by MTB personnel to Maun from where they were transported via regular courier service to laboratories in South Africa.
Audits or reviews	The results of any audits or reviews of sampling techniques and data.	**All Mount Burgess Diamond Core Holes** An independent Geologist was engaged to review sampling and logging methods on site at the commencement of the program. **Mount Burgess RC Hole** MTB's Exploration Manager continually reviewed sampling and logging methods on site at the commencement of all programs.

Section 2 Reporting of Exploration Results (Criteria listed in the preceding section also apply to this section).

Criteria	JORC Code Explanation	Commentary
Mineral tenement and land tenure status	Type, reference name/number, location and ownership including agreements or material issues with third parties such as joint ventures, partnerships, overriding royalties, native title interests, historical sites, wilderness or national park and environmental settings.	The Kihabe-Nxuu Project is located in north-western Botswana, adjacent to the border with Namibia. The Project is made up of one granted prospecting licence - PL 43/2016, which covers an area of 1000 sq km. This licence is 100% owned and operated by Mount Burgess. The title is current at the time of release of this report, with a first renewal granted to 31 December 2020 and a second renewal application has been submitted for a further two year renewal to 31 December 2022. PL 43/2016 is in an area designated as Communal Grazing Area.
	The security of the tenure held at the time of reporting along with any known impediments to obtaining a licence to operate in the area.	The licence is in good standing and no impediments to operating are currently known to exist.
Exploration done by other parties	Acknowledgment and appraisal of exploration by other parties.	The Geological Survey of Botswana undertook a program of soil geochemical sampling in 1982. As a result of this program, Billiton was invited to undertake exploration and drilling activities in and around the project area. Mount Burgess first took ownership of the project in 2003 and has undertaken exploration activities on a continual basis since then.
Geology	Deposit type, geological setting and style of mineralisation.	The Kihabe-Nxuu Project lies in the NW part of Botswana at the southern margin of the Congo craton The Gossan Anomaly is centred on an exposed gossan within the project. To the north of the project are granitoids, ironstones, quartzites and mica schists of the Tsodilo Hills Group covered by extensive recent Cainozoic sediments of the Kalahari Group. Below the extensive Kalahari sediments are siliciclastic sediments and igneous rocks of the Karoo Supergroup in fault bounded blocks.
Drill hole Information	A summary of all information material to the understanding of the exploration results including a tabulation of the following information for all Material drill holes: easting and northing of the drill hole collar elevation or RL (Reduced Level – elevation above sea level in metres) of the drill hole collar dip and azimuth of the hole down hole length and interception depth hole length If the exclusion of this information is justified	Information material to the understanding of the exploration results reported by Mount Burgess is provided in the text of the public announcements released to the ASX. No material information has been excluded from the announcements.

Criteria	JORC Code Explanation	Commentary
	on the basis that the information is not Material and this exclusion does not detract from the understanding of the report, the Competent Person should clearly explain why this is the case.	
Data aggregation methods	In reporting Exploration Results, weighting averaging techniques, maximum and/or minimum grade truncations (eg cutting of high grades) and cut-off grades are usually Material and should be stated. Where aggregate intercepts incorporate short lengths of high grade results and longer lengths of low grade results, the procedure used for such aggregation should be stated and some typical examples of such aggregations should be shown in detail. The assumptions used for any reporting of metal equivalent values should be clearly stated.	**All Mount Burgess Holes** No data aggregation methods have been used. Vanadium results are reported without a top cut but the Company has used 100 ppm as a bottom cut. Vanadium Pentoxide results are reported by multiplying the Vanadium results by 1.785.
Relationship between mineralisation widths and intercept lengths	These relationships are particularly important in the reporting of Exploration Results. If the geometry of the mineralisation with respect to the drill hole angle is known, its nature should be reported. If it is not known and only the down hole lengths are reported, there should be a clear statement to this effect (eg 'down hole length, true width not known').	**All Mount Burgess Holes** The geometry of the mineralisation with respect to the drill hole angle is typically at -90 degrees at the Nxuu Deposit which is considered representative from a geological modelling perspective.
Diagrams	Appropriate maps and sections (with scales) and tabulations of intercepts should be included for any significant discovery being reported These should include, but not be limited to a plan view of drill hole collar locations and appropriate sectional views.	**Billiton Percussion Holes pre-fixed AP** The Company has no available information for these holes other than collar and survey data and assay results **All Mount Burgess Holes** Appropriate maps, sections and mineralised drill intersection details are provided in public announcements released to the ASX. Refer to the Company's website www.mountburgess.com.
Balanced reporting	Where comprehensive reporting of all Exploration Results is not practicable, representative reporting of both low and high grades and/or widths should be practiced to avoid misleading reporting of Exploration Results.	Exploration results reported in Mount Burgess public announcements and this report are comprehensively reported in a balanced manner.
Other Substantive Exploration Data	Other exploration data, if meaningful and material, should be reported including (but not	

Criteria	JORC Code Explanation	Commentary
	limited to): geological observations, geophysical survey results, geochemical survey results, bulk samples – size and method of treatment, metallurgical test results, bulk density, ground water, geotechnical and rock characteristics, potential deleterious or contaminating substances.	
Further work	The nature and scale of planned further work (eg tests for lateral extensions or depth extensions or large-scale step-out drilling). Diagrams clearly highlighting the areas of possible extensions, including the main geological interpretations and future drilling areas, provided this information is not commercially sensitive.	Further works planned at the Project include additional drilling and surface mapping at the Kihabe-Nxuu Zinc/Lead/Silver/Germanium and Vanadium Project. Further metallurgical test work will be conducted, including bulk testing to be conducted by STEINERT on the sensor sorter process. Bulk test work will also be conducted on the multishaft vertical milling process.

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The Novel EDS Multishaft Mill shows improved liberation and energy efficiency in comminution

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ABSTRACT

Energy & Densification Systems (EDS) has developed patented new technology crushing/milling equipment. The EDS Multishaft Mill is a compact vertical mill – utilising high-speed impacts to break down particles with large reduction ratios, low energy consumption and improved liberation. The milling action combines several processes to provide a multitude of output products to satisfy various specifications.

Comminution often accounts for more than 60% of the total power consumption on a mine. Two of the key problems to be solved in comminution is: to bring down the specific energy required to reduce particle sizes; and to improve liberation or improve the efficiency of the beneficiation and recovery of the required elements. The EDS Mill has shown extensive improvements in both these areas with energy efficiencies up to 75% better than conventional milling equipment and improving liberation beyond the standard beneficiation processes.

Conventional comminution equipment requires massive, heavy parts to be moved or rotated, consuming a lot of energy in doing so and not inputting that energy into the breakage of particles. In the EDS Mill, ramping up the relatively small shafts to speed is all that is required. Once at speed, the momentum, together with the minimal amount of constant drive required, means that the energy can be transmitted directly and efficiently into breaking down the particles.

The high-speed impacts allow for a shattering effect of the particles and this quickly generates a high ratio of fines. Furthermore, the single impact force breaks particles in a very different manner to conventional compressive force breakage. With compressive force breakage, the particle breaks from point to point. With high-speed impact force breakage, the force tends to migrate through the weakest areas of the particle, which tend to be the mineral boundaries. This, therefore, means that when the particles break, the various minerals are exposed and hence liberated.

Keywords: Comminution, High-speed impact, Liberation, Energy efficiency, Novel comminution, Crushing, Milling

1. Introduction

1.1. Ore comminution

Ore comminution entails the reduction in size of the run-of-mine/quarry raw material. The material is often transported and screened into various size ranges, each range having to follow a designated processing path. Without the reduction of the product to the required size range, the entire process would falter. Two of the key problems to be solved are: to bring down the specific energy required to reduce particle sizes; and to improve liberation or improve the efficiency of the beneficiation and recovery of the required elements. Thus, introducing scope for novel comminution devices to alter the conventional processes to become more efficient and provide major advantages.

1.2. EDS Multishaft Mill

Energy & Densification Systems, a company based in South Africa and founded in 2005, has developed and internationally patented the EDS Multishaft Mill. The mill utilises a series of rotating horizontal shafts with flingers attached, which impact gravity fed material at very high speeds as pictured in Figure 1. The material is impacted many times in an unpredictable and chaotic environment (milling chamber) before emitting below the mill (discharge section).

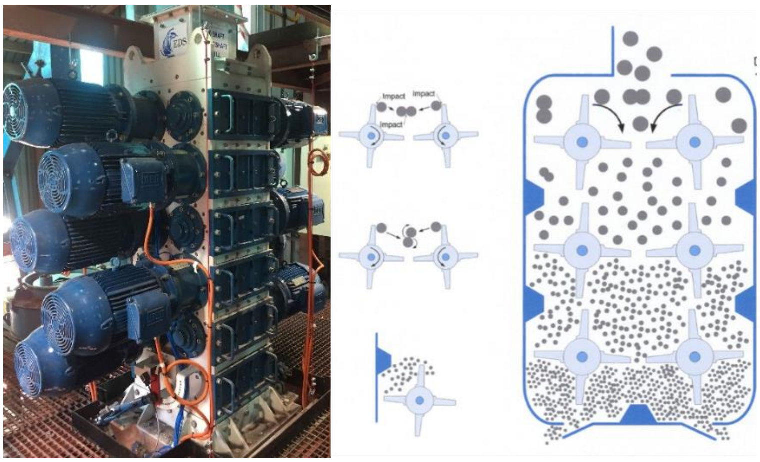

Figure 1. EDS 10 Shaft Multishaft Mill (left), principle of operation (middle) and schematic sketch of the mill internals (right).

Primarily, the mill operates by opposing flingers rotating towards one another, as depicted (Figure 1), in order to impact and accelerate particles and ultimately increase particle interactions. The novelty lies within the numerous stages, which provide high energy impacts. By including extra stages, as well as the discharge gates, retention time can be varied, thus allowing, on average, each particle to be impacted 24 times per second before exiting the mill (Bracey *et al*, 2016). Therefore, providing significant potential to break down particles and create a high ratio of fines.

1.3. Energy and efficiency considerations

It is well known that the comminution of ore can often account for up to 60% of the total electricity consumption (Tromans, 2008; La Nauze and Temos, 2002) for most cement and mining operations and there are suggestions that it could be 1.8% of global consumption (Napier-Munn, 2015). The reason for this high energy requirement is due to the use of crushing and milling machines with large electric motors. Most of the equipment needs to rotate extremely heavy components as well as media which in turn impact into each other. This is generally very inefficient.

1.4. Liberation

The most important process in mineral processing is liberation. This is defined as the separation of valuable mineral from gangue minerals and is mostly done in the comminution stage (Leißner *et al*, 2013). Many researches have focused on reducing the operational costs of grinding, as if the most important role of grinding, i.e. liberation, is sometimes forgotten (Wills and Atkinson, 1993). Liberation of valuable minerals from the gangues occurs in different types of breakage.

The most common breakage type would a compressive force breakage. This is when a particle has two forces acting at two different points (generally opposite each other) and acting towards each other. The other breakage type to consider is impact type breakage. This is when a particle is impacted by or against another object or particle. In this case, there is only one force acting on the particle at the point of impact.

2. Technology fundamentals

2.1. Breakage fundamentals

The application of energy to the material in the EDS mill is novel and aims to improve the way in which the energy is transferred to the material, effectively improving efficiency and promoting breakage. The high velocity of each flinger tip determines the energy input to the particles. The specific kinetic energy for each collision with a flinger can be quantitatively analysed through the tip speed of each flinger and Equation (1) below:

$$E_{cs} = \frac{E_k}{m} = \frac{0.5 \times m \times V_i^2}{m} = 0.5 \times V_i^2 \qquad (1)$$

The specific kinetic energy can range from 0.073 kWh/t up to 0.956 kWh/t. The kinetic energy used for these impacts with the flingers suggests each single impact has a moderate energy level according to general JK Drop Weight Test results. Impacts within the mill above 0.2 kWh/t will cause significant damage to particles (Tromans and Meech, 2003). The nature of the mill generates many impacts per particle, although, as indicated by some E_{cs} values, these impacts may not lead to significant breakage individually, but the sheer number of impacts (average 24 collisions per second) will lead to considerable reduction of feed material.

2.2. Energy efficiency and power consumption

Energy efficiency is equated as the ratio of energy that is transferred to the particles or breakage thereof to the total energy input to the system. The power consumption is simply derived as the total power consumed during operation of the specific equipment. Values are taken in kilowatt hours per ton of material processed through the machine (kWh/t).

Total power consumption comparison allows the client to directly compare electricity costs for each machine as this is what would be most important as it affects operating expenditure.

2.3. Liberation

According to Zhang, Y., 2018, the breakage of a conventional compressive force breakage mechanism is from contact point to contact point, no matter what the composition or makeup of the particle is. In most cases, the material would need to be broken down to very fine size ranges in order to get the exposure and liberation of the minerals to allow for high recovery grades. This further means that, in order to get to very fine sizing, more energy must be used to break down the particles.

Under impact loading, the particle has one single impact force acting on it. Unlike compressive force breakage, this force does not have another force point to move towards and hence dissipates to the weakest bonds/points within the particle, which is the mineral boundaries. An impact force would break on that path if the force is strong enough. In this case, the particle breaks up into its various compositional makeup and this would be regarded as preferential breakage. Figure 2 below shows the typical compressive force breakage of a particle as simulated by Zhang, Y., 2018, as well as the impact force breakage.

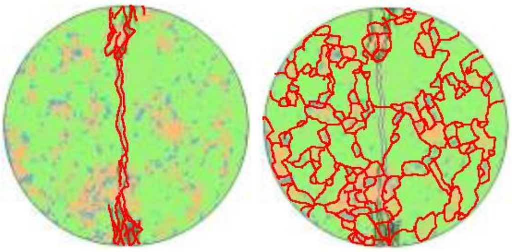

Figure 2. Particle breakage path due to compressive force breakage (left) and impact force (right)

3. Experimental

The EDS Multishaft Mill was tested on three different ore types, namely: chromite ore, gold ore and industrial minerals/cement. Other than testing performance and circuit evaluations of the equipment, the main goals were to investigate the improvement in specific power consumption as well as any downstream recovery and beneficiation improvements. In all cases, material was sent through the EDS mill and the product analysed directly. Total material through the mill for each ore type varied from 5,000 tons up to 26,000 tons.

It must be noted that all data and results obtained were compiled directly by the clients or by independent laboratories and test centres.

3.1. Chromite ores

There were four chromite ores (within the South African Bushveld Complex) from four separate sites that the EDS mill was tested on. The Complex is split into three chromitite seam groups, namely: lower (LG), middle (MG) and upper (UG) groups. These are further differentiated into layered seams by appending a number for each seam. Of the four ores tested, one was from the LG6 seam and the other three were from the MG2 seam. In some instances, the machine was compared directly to ball mills, horizontal shaft impactors (HSI) and vertical shaft impactors (VSI). Power consumption per ton, particle size distribution (PSD) outputs as well as chromite and silicate grades were considered. In all instances, the mill was set up in a single pass (open) circuit.

3.2. Gold ores

There were three gold ores from three different sites that were tested on the EDS mill. These varied from standard West Wits Ore (an auriferous quartz pebble conglomerate in the carbon leader reef) to a much harder sulphide ore (from a quartz-carbonate vein in the Kraaipan Greenstone Belt) and to a West African ore (rock matrix and geology unknown). Here, the EDS mill was compared directly to ball mills and the material was analysed either through sending, separately, all the EDS product to the flotation, leaching process or simply by doing lab assays on the products. Power consumption, PSD outputs, gold recovery %, system improvement as well as leaching time and cyanide usage were recorded.

Two of the sites were tested as the EDS mill being the final comminuting equipment and the third site was tested with the EDS mill as a pre-grinder for the current ball mill circuit.

3.3. Industrial minerals/cement

There were two different opportunities tested on the EDS mill. The first was utilising the mill as a pre-grinder for a ball mill on a limestone raw meal mix, and the second was to run a blast oxygen furnace (BOF) slag through the mill to produce a filler/crusher sand that could be used in a cement premix.

A dual chamber, central discharge ball mill was compared against. The EDS mill would receive the same material as the first chamber and the discharge material of both were compared.

Instead of using dolomitic material as a filler/crusher sand for premix, the EDS mill was tested to see if a BOF slag could be milled finer and used as a cheaper replacement for the general premix sand.

4. Results and discussions

4.1. Chromite ores

4.1.1. Performance

On all sites, the mill could operate at up to 120tph. The average feed material was a chromitite chips and had an average F80 of 18mm. The product varied depending on throughputs and feed material, nonetheless, large reduction ratios were obtained with P80s ranging from 850µm to 2.8mm

4.1.2. Power Consumption

In general, ball mills process chromite ore down to a -1mm specification between 9-12kWh/t. The EDS mill, for all sites, processed the ores at below 2kWh/t.

One of the major advantages of the EDS mill is the flexibility of the setups for the system. On chromite applications, the mill is set up to input enough energy to the particles to break the gangue material off the chromite particle, but without putting too much energy in to physically break down the harder chromite particle. This means that preferential breakage can occur not only to expose the minerals required but also to distribute minerals specifically within certain size fractions (grade engineering).

4.1.3. Chromite recovery

Figure 3 below shows the chromite results after milling. It can be seen from the data that, even before any gravity separation or other recovery technique, the milled product can be screened between 106µm and 425µm and would be a saleable chromite grade alone.

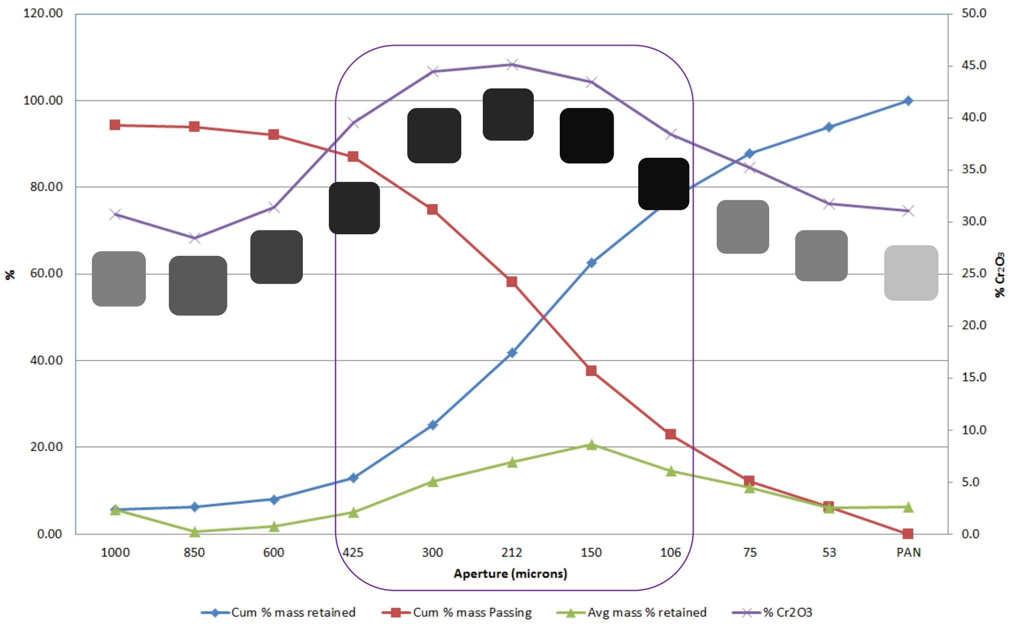

Figure 3. Chromite results from one of the sites after EDS milling

Furthermore, looking at the square blocks overlaid on the graph depicting the colour of the sample at that size fraction, there is a clear distinction between the darker colour in the chromite rich area and the lighter colour elsewhere. The above size fractions were captured under a microscope and Figure 4 below shows a 300µm sized product. It can clearly be seen that the particles are rounder in shape and look clean, that being without gangue on the chromite particles. The roundness of the particles assists in gravity separation (spirals) as it allows the material to flow smoothly and separate accurately from the unwanted non-chrome rich material.

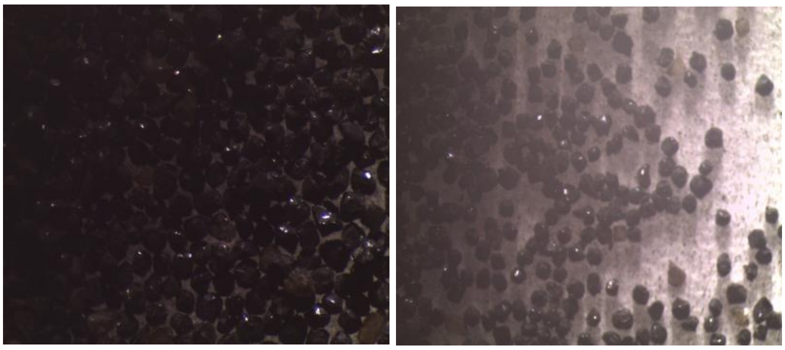

Figure 4. 300μm chromite ore particles at two different magnifications

One of the site ores was a run-of-mine discard dump that had too low a head grade for the main plant to process. This material was crushed to size, then processed through the EDS mill and thereafter analysed for a spiral recovery plant. With an average head grade of only 15%, saleable chromite concentrate at 42% and above could be achieved, together with less than 4% silicates and, furthermore, less than 4% chromite in tails. According to the client, they had tested this material through different conventional machines and none of them could produce a saleable product from that specific dump. The main aspect here is that the EDS mill is liberating the chromite effectively so that it can be cleanly separated from the gangue in the spirals.

Another site required the production of foundry and chemical grade chromite concentrate. For this to be possible, the concentrate needed to have more than 42% chromite, but specifically less than 1% silicates. After processing the material, they were able to easily produce these grades and with plenty room for error. Table 1 shows the data of the EDS mill in comparison to the best competitive equipment that the client had tested to date.

Table 1. Chromite, silicate and iron oxide contents of the EDS milled product and an HSI product.

Date	Sample ID	Analysis Required			
		4E g/t	%Cr2O3	% SiO2	% FeO
10-Jun-16	EDS 1 Foundry		44.85	0.43	29.71
10-Jun-16	EDS 1 Chem		45.73	0.08	29.28
10-Jun-16	EDS 2 Foundry		45.43	0.27	29.48
10-Jun-16	EDS 2 Chem		44.10	0.39	29.67
10-Jun-16	HSI Foundry		45.59	0.67	30.43
10-Jun-16	HSI Chem		45.21	0.63	30.50

The client had remarked that he had never seen figures as low as these highlighted in orange above and the red highlighted figure is exceptionally good. In Figure 5, the difference in particles under a microscope can be seen. This has been taken at 300 μm and it is clear that there is still some gangue material on the HSI product whereas the EDS product is clean and almost looks polished. Furthermore, the chromite crystals display their euhedral shapes, which is proof that breakage has occurred along the mineral boundaries and not across them.

Figure 5. 300µm chromite ore particles: HSI product (left) and EDS mill product (right)

4.2. Gold ores

4.2.1. Performance

The mill could operate at up to 50tph. The average feed material F80 was around 26mm. The product varied depending on throughputs and feed material, nonetheless, large reduction ratios were obtained with P80s ranging from 1.4m to 3.7mm in a single pass without recirculating the oversize material. There was also in the range of 20–35% in the 75µm final product specification.

4.2.2. Power consumption

In general, ball mills process gold ore down to a P80 of 75µm specification between 14-25kWh/t. The EDS mill could be set up in various circuit designs and layouts to achieve the final specification and would only consume 5-7kWh/t. One aspect, which is described in 4.2.3. below is that recovery can be done at coarser size fractions that the 75µm and this would mean less energy input to achieve this grind size and further lower the consumption rates of the EDS mill. Coarse flotation technology would need to be utilised for this to be successful and has major potential for the gold miners.

The EDS mill was also tested as a pre-grinder for ball mill circuits and in this case the power consumption (single pass, open circuit on the EDS mill) was reduced to 3.5kWh/t.

4.2.3. Gold recovery

Leach times and percentage recovery of gold is critical in a gold recovery process. By increasing recovery percentage, plant revenue increases and by shortening leach time, costs can be reduced, and throughputs of the plant increased.

From Figure 6 it can be derived that the EDS mill is making a significant difference to the recovery and leaching times of the process. The flatter leaching curve of the EDS product shows that majority of the grade is recovered early on in the leaching process and a few extra percent increase over the remaining time. It is important to note that the EDS product was screen at -300µm compared to the -75µm of the ball mill.

Furthermore, the cyanide consumption was reduced to a quarter of the ball mill product usage. This specific site had extremely abrasive ore (2 – 2.5kg/t of steel balls consumption). The iron in the product would act as "preg robbers" and consume cyanide. Another possibility is that the gold particles are well exposed in the EDS product and can be reacted with the cyanide sufficiently.

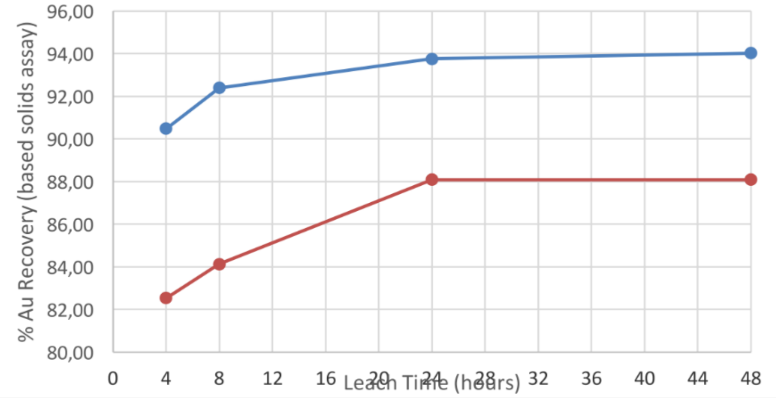

Figure 6. Leach time and % Au recovery for a -300µm EDS product (top blue line) vs -75µm ball mill product (bottom red line)

On one of the sites, the EDS was a pre-grinder to a ball mill circuit. The downstream effects of the EDS mill were drastic. Firstly, the ball mill throughput could be increased by over 30% due to the better feed to the ball mill from the EDS mill. There was also much more fines generation from the EDS mill that the ball mill didn't need to break down further. This meant that the ball mill could break down the bigger material in a shorter time period. Secondly, the same ball mill also consumed less steel balls after integration of the EDS mill to the circuit. Lastly, the leaching process was also positively affected, with leaching times halving from 24hrs to 12hrs, which also paired with slightly reduced cyanide and lime consumption too.

If the EDS mill is preferentially breaking the gold ore and exposing the gold particles, then the recovery process would easily capture the gold particles and ultimately increase recovery and revenues.

4.3. Industrial minerals/cement

4.3.1. Performance

The first site, where the EDS mill was used as a pre-grinder, pushed the mill operating capability up to 120tph. With a feed material that varied significantly from a 40mm top size up to 120mm top size, the mill as able to provide P80s between 1.9mm to 4.2mm. However, the -90µm percentage was up to 15% after milling which was higher than the first chamber of the ball mill. This was an improvement to the system as it would automatically classify this material out as final product before conveying the oversize to the second chamber. Due to the improved PSD of the EDS mill feeding the second chamber, the total throughput of the ball mill circuit increased by an extra 30tph from the average 120tph original feed rate.

The second site did not have a comparison to other technologies as the EDS mill was the first technology the client had tested for this BOF slag as a crusher sand for the premix. Throughputs up to 40tph could be achieved.

4.3.2. Power consumption

The pre-grinder setup consumed only 3.5kWh/t for the output obtained, which was compared directly to the first chamber of the ball mill, which was operating at 12.7kWh/t according to the client.

The BOF slag was run at approximately 2.5kWh/t.

Cement and industrial minerals is a small margin industry and cost sensitivity is high. Thus, being able to provide much lower energy usage, allows for cost reductions.

4.3.3. Final product testing

There was no testing of the final product (being clinker and ultimately cement) from the first site. The main goal of this site was to increase ball mill capacity so that the kiln could operate at maximum throughputs.

For the BOF slag material, the mill product was used in a premix to make concrete. Standard concrete lab testing was conducted on this material and 7, 14, 28 and 56 day strengths were recorded of the final concrete slab. Overall, the 7 and 14 day strengths were similar to the standard premix, however, the 28 and 56 day strengths were higher. Another aspect was that the water consumption was slightly lower too, due to the shaping of the product so that it has maximum surface area and water retention.

5. Conclusions

5.1. Chromite ore

The results on chromite material is significant. The liberation is high and this allows for easier recovery of the chromite and being able to produce higher value concentrates such as foundry and chem grades with less energy consumption. With the lower chrome in tails figure, tailings dumps and discard can be ignored as the value thereof has been significantly reduced. It would be beneficial to also investigate the PGM liberation of the tailings as the mill could also have improved the PGM recoveries.

5.2. Gold ores

The downstream benefits of using the EDS mill allow for flexibility and better cost structures in the gold recovery and, with the EDS mill being a viable option to retrofit to existing circuits, can be utilised to maximise any gold plant operation, reduce energy requirements and ultimately increase revenues.

5.3. Industrial minerals/cement

The increase on throughput on the ball mill circuit can allow for optimization of the kiln, which is generally the highest operating cost item and maximum utilisation would considerably improve cost structures of the entire plant setup. If the BOF slag could be used as a dolomite replacement, then the premix could be produced at a cheaper rate and this, coupled with the extra strength and lower water demand, could provide higher margins on the product, which makes a significant difference on bulk materials.

Acknowledgements

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Unfortunately, owing to non-disclosure and confidentiality agreements, the sites and clients cannot be disclosed, however, the results and findings from these operations can be used for the purpose of this paper.

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