Examination of Dissertation: Addressed comments
(Awelani Veronica Moila)

EXAMINER 1

Review: -

Definition of processing

- Defined in **Page 22**

Process mineralogy is a practical application of mineralogical methods and understanding to aid in mineral exploration, and to predict and optimise how an ore can best be mined and processed.

Understanding the nature and purpose of the investigation

Page (5-6) -rephrased

The main aim of this research is to evaluate the development of an efficient processing route for the extraction of rare earth elements from alternative sources (i.e. other heavy minerals). This study will focus on the following

- I have replaced the word investigate with "assess/examine/ evaluate" interchangeably throughout the thesis.

Acquaintance with and assessment of the relevant technical literature

Could the literature on the hydrometallurgical tests have been evaluated more critically?

- **Page 17**, shows an ideal flowsheet of processing REE. There are two methods of processing REE deposits, using an acid route or alkaline route, as shown in the flowsheet in **Page 18**.

- **Section 2.3** in **Chapter 2** outline the literature review of REE extraction. The hydrometallurgy evaluation of REE was based on the mineralogy findings.

Mastery of technique

1. Yes, the procedure is standard as referenced in Gupta & Krishnamurthy 2005. (i.e the temperature of the solution, pH, Washing time and leaching residence time)
   Yes, Washing is adequate to remove any entrainments
   Yes, the leaching residence time is sufficient

   Furthermore, the questions about residence time and washing time were not part of the research questions and hence they were not investigated and answered in Chapter 5. If only the leaching kinetics were one in question, this would have been investigated. Those questions were going to be addressed as a matter of research question, and looking into different kinetics of leaching (i.e time, PH, number of washing stages, water dosage, and time to stabilize the NaOH temperature.

2. As stated in **Page 40**, PSD data was derived from MLA. "The particle size distribution of the sample, as derived from the MLA is in two-dimension (2D). The 2D PSD derived

from the MLA showed that the retained wt% of the sample is in accordance with the way the sample was initially sampled and screened into the four size fractions as specified in **Chapter 3**. The PSD trend of the four sizes screened sample and the MLA derived PSD will always be underestimated relative to reality."

3. Yes, in **Table 9**, **Page 43** the sum of minerals in individual size fractions equal the values measured in head sample. When sample are prepared prior to AutoSEM analysis, they are prepared based on size fractions. The reason behind this is that the particles sizes of every sample are distributed differently. And in order to characterise all particles of different size range it is only vital that all particles are represented in the analysis, to avoid data biasedness or skewness. The data validation is presented in section **4.2.3.1, Page 44**

4. Leucoxene was identified through EMPA and MLA, **Pages 42,48,49,51, 59 and 60**.

5. Table 12 in **Page. 52** updated to 1 Decimal place

6. Please see Figure 16, shows the ideal liberation classes, with a reference as well.

7. Correct, the nature of the solid solution is that both Zr and REE have the same electron configuration of two electrons in the outer shell "S" orbital Refer to: https://www.oakparkusd.org/cms/lib/CA01000794/Centricity/Domain/934/Orbital%20Filling%20Diagrams_2014.pdf

8. Rephrased: The TREE content of final caustic crack is 3.9% before washing. After washing stages, the TREE % improved from 3.9% to 5.4 % after repulp wash, and 5.5 % after the second repulp wash. The improvement in TREE% was as a result of the removal of Na entrained from NaOH in the residues. (Error! Reference source not found.**)**.

   The TREE content of unwashed water leach test was 5.2% before water wash and after the water leach wash 1 test, the residue reading was 5.1% (Error! Reference source not found.).

Understanding of Scientific Methods

9. **Section 1.5**, Title changed to Research structure (**page 6**). **Section 1.3**, changed to Research aims (page 5)

10. **Pages 40** and **41**, Particle sizes can be determined by many techniques, and it can be determined by the Malvern laser Diffraction, and yes it depends on the purpose behind such analysis.

    There is PSD that can be determined from laser diffraction. However, the PSD in the study, was generated from the analysed polished sections that were subjected to the

MLA. There are different sets of reports or data that can be obtained from running the samples on the MLA (AutoSEM), such as the PSD report presented in this thesis (**Page 40 and 41**).

Yes, the surface area plays an important role in leaching, since the leaching solution has to be in contact with the exposed surface area of the mineral of interest. This is also the reason why liberation is done by surface area. If the surface area of the mineral of interest is not exposed, the leaching efficiency becomes poor. As described in detailed in (**Page 52, section 4.2.6.3**)

11. Yes, the test is standard test, as discussed in the book of Gupta, C. K. and Krishnamurthy, N. (2005) Extractive Metallurgy of Rare Earths. Boca Raton London New York Washington, D.C., p. 502 and by Mintek. The washing test is sufficient to remove NaOH entrainments. The residence time and the % of solids and amount of NaOH, temperature of the water and solution is required for the leaching test.

    The washed solids were dried at 50 degrees, to avoid further breakdown or formation of other phases/compounds at higher temperature of greater than 60 degrees.

Structure in and of the dissertation

Logic

Page (ii) Yes, it is truism, however this is necessary to mention in my study because this is what my thesis is about. It is known that Mineralogy will reduce unexpected cost.

As my literature review states, the mineralogy tool is treated like an adopted step child, which is only applied when metallurgist and engineers encounter issues with their pilot plants or processes. In my experienced as a mineralogy specialist, that has been an issue and this is still an issue. However, there are few clients, who opt to do mineralogy first to diagnose the problem upfront before embarking on any mineral processing campaign.

Page .23 Rephrase: It is vital to carry out detailed mineralogical studies since mineral liberation plays a key role in ore leaching. Meloy *et al.,* (1990) have made relevant contributions in the area of process mineralogy

The arguments

Mineral characterization- mineralogy is an important factor to be considered before embarking on any metallurgical campaign (**Page.19**).

The mineralogy testwork that was carried out demonstrated the importance of t carrying out mineralogy study beforehand, in which the testwork aided in metallurgy extraction process. In **Page.22,** I presented the literature review, where I stated that mineralogy is an important factor that has to be considered before embarking on any metallurgical campaign. Though the examiner expressed that as the author I am stating the obvious. However, as the author this statement is very vital since my work involves mineralogy as one of the main subjects of this study. Most engineers tend to use mineralogy when they encounter problems during the metallurgy testwork and not as a study that aid in process selection or a testwork that aid in cost reduction that comes with processing of ores.

The statement emphasizes that mineralogy should be conducted in the early stages of ore characterization before any metallurgical testwork begin.

In section 2.4, To what extent does the two parties set themselves apart?

The objectives of this study are different from those in Dr Ian Grey study. Dr Ian Grey of CSIRO, as mentioned Dr Ian Grey did a solid-state chemistry of particularly ilmenite, his interest was not on REE. Though the two minerals studied by myself and Dr Ian Grey are from a beach place deposit. In terms of ilmenite ($FeTiO_2$) Ilmenite is naturally an oxide, it is normally upgraded to a sellable ilmenite concentrate or undergo thermal reduction process to produce Ti metal or pig iron.

In the case of my study, the focus is on monazite and zircon for their REE content, monazite is a phosphate and zircon are a silicate. These two minerals had to undergo chemical cracking prior to converting them into oxides or hydroxide, unlike ilmenite which is a naturally occurring oxide. Monazite is a natural occurring REE and zircon was the only mineral investigated for its REE contents occurring in a form of solid solution.

Process mineralogy term defined in **Page 22**. The value of process mineralogy is explained from **pages 22 to 25**.

Page 38 now updated in **Page 37**, “The leach residues were assessed by manual operated Zeiss SEM, since they were no longer minerals but phases making mixed elemental compounds, in which the AutoSEM (MLA) has a difficulty in identifying”

Furthermore, as explained in the objectives, process mineralogy was conducted upfront on the ore as received. The mineralogy conducted on residues was to assess the efficiency of leaching process not to mineralogically quantify the residues.

Owing to the nature of the residues, it should be noted that SEM-EDS analyses were conducted on stub mounts of the residues, not on polished sections. The data are therefore viewed in a qualitative light, for comparative purposes. (**Page 68)**

However, the residues were assessed by manual operated Zeiss SEM as mentioned in the study, since they were no longer minerals but phases making mixed elemental compounds. The Automated SEM has a difficulty in quantifying leached products. Generally, automated SEM uses assigned BSE values of minerals, their densities, and the chemical composition of minerals, and this is based on the Species Standard Protocol (SIP) as a mineral list file. The leached products do not are phases not minerals.

Section 3.5, Process mineralogy here included the use of different mineralogical techniques (XRD, EPMA, SEM-EDS and MLA) to characterise a feed sample. Using the information derived, it was ascertained that monazite and zircon (and to a lesser extent, xenotime) are the main REE-bearing phases. Their deportment preferentially to the lower size fractions informed the choice of these fractions for further processing. As for the leach procedure, previous studies have shown that when monazite is the REE carrier, a cracking procedure (using NaOH) followed by washing and an acid leach constitutes the desired process for extracting REE.

Process mineralogy was performed beforehand or upfront to serve as a guideline for metallurgical testwork. However, the mineralogy of the residues is qualitative mineralogy, which was rather to assess the leachability of the ore and to verify if the ore was completely leached or still occurring as minerals.

Section 4.3 What sense of combination do you have in me? Just a “bringing together” or a “working together”
Combination refers to the use of various integrated mineralogy techniques.

CHAPTER 7 Conclusions Differ somewhat from the research aims

1.The research objectives do not differ. I have two objectives set out in this study, and these objectives were further explained based on what each objective entail and aims to serve. Furthermore, the research questions were also set out to aid in addressing the objectives. **Chapter 7** answers the research questions (Pages **5 and 6**)

2. Examiners insertions accepted

3. To mine REE as a by-product from the existing Ti-operation from waste.

Page 34, Section 3.5. Now **Page 33** The metallurgy test work routes selected did depend on mineralogical findings.

By metallurgy test work entails from ore beneficiation to leaching. And final stage of refinement. In this case mineralogy influenced the ore beneficiation, and the choice

of leaching- “NaOH (Caustic cracking) “, method was based on literature and work previously done.

Page 62, shows what influenced the metallurgy test work- “It is a continuation of the studies and findings observed in **Chapter 4**. In **chapter 4** it was stated that approximately 50 mass % of the sample reported to the two size fractions (i.e –150+106µm and –106µm), concentrating monazite and zircon (**Error! Reference source not found.**, taken from **Chapter 4**).

The two size fractions: –150+106 µm and –106µm were composited, and a mass of 400 grams (100% passing 45µm) was prepared for hydrometallurgical testwork. The naturally concentrated monazite and zircon in these size fractions showed that this fraction does not require ore upgrading and it is amenable to direct leaching”

Tables 7 & 8., on **Pages 39** and **41**. The mass in **Table** 7 is weighted mass (in 3D), and Table 8 is PSD measure using the MLA from prepared polished sections (in 2D). The PSD from MLA, are however it is two dimensional, as measured from a prepared polished section, which is unlikely that the two Tables will reconcile? The particle mass distribution in **Table 3** and **Table 7** are three dimensional, screened and weighted as particles, whereas **Table 8** is the mass distribution measured from a polished section mounted in epoxy and resin. For MLA analysis.

Section 5.2.1. Mass balance calculations and detailed Mass Balance is shown in **Appendix C and D**, Mass balance shows the calculation of leach efficiency. **Pages 122 to 130**

Section 5.2 Table 16 on **Page 63**, All the Tables are aligned to the left as per my Supervisor’s guidelines and Thesis requirements. **Page 63**

Section 6.3.2. The test was aborted before the Mass balance stage was reached, mentioned in **Pages 83** and **84**.

Section 5.3. The objectives were met by conducting mineralogy test work, it was demonstrated that with mineralogy being carried out beforehand, a number of metallurgical tests can be skipped. This demonstrated cost efficiency, since this prevented ore beneficiation and its cost **(section 7.1.3), Pages 87, 88 and 89.**

Exploration “refers” to evaluate. The synonym of exploration is research. Yes, I did explore (research/evaluate) the presence of REE in zircon not just in monazite only.

Chapter 7, forms part of the whole research and addressing further details on exploring “researching” a potential REE resources through zircon. Objective

Changed, I removed cost-effective and remained with economical on **Pages 6, 25, 84 and 86**

Page 83 now **Page 86**, this means it offers an opportunity to mine REE as a by-product from the existing Ti-operation from waste.

Literary Style and presentation

12. Replaced cost effective with cost-effective
13. Corrected to -Approximately 50 mass % of the sample, constituting the finer fraction, has concentrated monazite and zircon (Page ii)
14. **Colons** (:) are used in sentences to introduce that something follows, like a quotation, example or a list. **Semicolons** (;) are used to join two independent clauses, to separate main clauses joined by a conjunctive adverb or to separate items in a list that already **uses** commas. In Page 2 now 1 (section 1.1) I used a semicolon since I was joining two independent clauses.

    In Page 20 now Page 19I have updated the sentence and used a colon (i.e the leaching of rare earth elements involves two processing routes namely: - the acid route and the alkaline route (refer to **Error! Reference source not found.**). Page 58 and now 59, colon inserted

15. Monazite; a LREE or HREE, updated on Page 11 then Page 12
16. Punctuations after bulleted sentences removed on Page 57 now Page
17. Corrected on Page.ii – The mineral zircon was identified as an alternative source of REE, apart from monazite. Page .5 - The characterisation of REE from an existing heavy mineral
18. Corrected in page 18, changed “using ‘to “by”, first paragraph

    Page 22 now Page 21, updated the following sentences, replaced “using” to “with” and “a part” to” some”. These are transformed into soluble sodium salts that can be washed off with warm to hot temperature water.

    The resulting solids undergo selective leaching with diluted HCl. Often, caustic decomposition results in lots pure products

    If the ore contains fluorine (e.g. bastnaesite), some of the REE forms insoluble REE-fluorides that remain in the solid residue.

    Page 35, changed using to with on the following sentence. Selective leaching involved primarily, the dissolution of REE with HCl.

19. etc. removed on list prefixed on Page.x now p xvi

20. Corrected in Page. 5 to “The characterisation of REE containing minerals from an existing heavy mineral”. The heading 2.2.1 changed to Mineralogy of REE ores

21. Page.23 Multi-disciplinary, is “**composed of or combining** of” in this study as stated. The multi-disciplinary approach involves closely integrated mineralogy evaluation. Page.19 changed to” The gangue minerals **in a monazite concentrate** from beach placer deposits includes numerous heavy minerals”

22. Changed the hyphen minus to a subtraction sign “– “
23. Changed 4.0 hours to 4 hours on Tables 4, 5 and 6.
24. Yes, I know this, Noted
25. Referenced justified to the left
26. Updated the headings by putting stop texts, and shortened the list of figures, list of tables and table of contents titles. Changed from italics to normal. Line spacing is consistent, 1.15

27. Corrected ‘’Water (H_2O) leaching”; Section headings reformatted (section 3.5.2)
28. The two Tables 20 and 21 demonstrated the efficiency of the process, hence it is important to show that information through Tables, it is easy to link what is mentioned in the text to the Tables.

    The caustic cracking filtrates and water leach TREE % content is zero since the main aim of caustic cracking was to convert REE containing minerals into hydroxides. The zero reading, confirms the efficiency that No REE’s were lost to filtrates.

29. Sassolite spelling corrected in page 84
30. Noted, However X-Ray diffraction is a technique , see the reference and other published documents
    https://serc.carleton.edu/research_education/geochemsheets/techniques/XRD.html

31. Addressed in page. xvii
32. Changed to abbreviation “REE in page 4, and defined in for the first time in page (ii)
33. Changed on page 4 from “mined for titanium minerals” to “mined for titanium-bearing minerals”
34. Grain size and how is derived is defined in page 56, and also defined in the Glossary, Page xv and xvi
35. Changed to “The mineralogical characterisation involved the bulk mineralogy of the tailings feed sample by size in order to show the distribution of the minerals present across all the size fractions and the head sample” (Page. 38) then page 40

36. The PSD presented is from an MLA report, and as such, is in 2D. Particle size distribution is obtained from the analysed polished section, from the AutoSEM, which is where the PSD presented here was generated from. Sieves have been changed to size classes (section 4.2.2) and Table 8.

37. Changed to “titania production plant” (Page. 42)
38. In this section, I am still referring to them as minerals not yet phases, since that is prior to extraction (**Page 60**)

39. I know very well the difference between a backscattered electron image and a secondary electron image. Note that the residues were analysed as is, not in polished sections. The images in the document are not secondary electron images; they are Backscattered Electron Images of uneven surfaces, owing to powder/grain mounts of the residues being analysed. They therefore appear to be secondary electron images. (see **pages 69,71 and 73)**

40. Sentence changed from “The unreacted zircon proved” to “The unreacted zircon demonstrated” **Page 76**

41. Addressed in **Page 79** now then **Page 76**, “In order to break down the zircon, the alkali fusion method was used for this testwork. The choice of the method was based on the available and reliable method to dissociate zircon at Mintek chemical analytical laboratory.

42. Corrected **Page 91 to 98**, References now show consistency in punctuation.
43. Fixed numbering of preliminary pages
44. True, my readership will have to be people with a solid background of chemistry, metallurgy and chemical engineering. But it is worth defining for other readers or who are not familiar with the subject.
45. Changed to tailings sample (Page xvii)
46. Gg changed to Kilotonne in **Page 1**
47. Full reference updated in reference section and text, **Page 2**, Figure 1
48. Change Sulphate to Sulfate (Page 20, 79 and 95); Characterize changed to characterise in the main document
49. Noted, changed in Table 7
50. As addressed previously, this PSD was generated from the MLA data report, it was not obtained from the analysed polished sections. Additionally, the MLA PSD is two dimensional, and the weighted and screen PSD on page 30 is three dimensional.

51. Noted, however It is easy to follow the data when presented both on Table 13 and Figure 18 then Figure 17.
52. Noted, changed to “the majority of the world’s REE production was from the Mountain Pass…” on page 1.

53. Similar meaning, just different choice of words. I am comfortable with compared, as explained in page 47(i.e Monazite and zircon are more evident in this fraction

compared to +212 µm and -212+150 µm, with minor amounts of rutile and ilmenite present)

54. Changed to “During this process, the ore is mixed with 50 to 70 wt.% NaOH and decomposed at temperatures from 140 to 170 °C” (Page 20)
55. Noted, and changed in pages 41, 45, 58 and 89 (in areas that read well while using quantities instead of amounts)
56. Changed as the examiner suggested - In addition, the sample’s mineralogy was characterised to establish (Page 38)
57. Noted and corrected to ‘Based on some of the minerals identified in this sample, the mineral findings, Page 58
58. Corrected on page 1
59. Corrected in Page 25
60. Noted, however the two statements are relevant to the most important part of my study.
61. “Time” was removed from the listed parameter that affects the degree of decomposition. (page 77)
62. Changed in the text to pH of 10.9, Page 82
63. Noted, and changed to Monazite will be examined (Page 6)
64. Page 6 now Page 5, Changed to “mineralogy is used as a problem-solving tool”
65. Explained in the text as - The EMPA was used to determine the REE concentrations in the different minerals (Page 39)
66. Section 2.2 described as Mineralogy and Geology of REE. On page 20 now page 19, I have corrected the statement to “Gangue minerals in a monazite concentrate”. Page 49, No I meant mineral chemistry, since EMPA was used to determine the mineral chemistry. However mineral composition or mineral chemistry is based on preference, but they mean the same thing.
67. Yes, information will be lost
68. Page 99 to 106, images visibility enhanced, Page 107 it is EMPA data, Extra row deleted in Page 108, Tables B3 and B4 are differentiated since the other Table has Holmium and the other Table does not. Repeated heading deleted in Page 111.

    Pages 122 to 127, Herewith the correct mass for calculations. Mass of dry solids (311 grams) = 492 grams mass of washed solids multiplied by solids contents (63,27 %); Total Dry mass (374 grams) 311grams with the mass of sub samples included (12.9 g + 15.1g +34.8 g).
69. Table 15 resized, and Figure 15 and now Figure 16 unchanged, since reducing the size of the figures affect the visibility of the image annotations. The images were capture at that magnification to display the field of view of different particles within those size fractions.

EXAMINER 2

- **Demonstration of experimental errors by means of replicate analysis and data validation**: The MLA results was replicated.
  Table F.3 in Appendix shows the experimental errors obtained through reproducing the MLA data that was used as a guide for process selection. A 2 kg aliquot of the remaining sample (**Error! Reference source not found.**) was sub-sampled and screened into the four size fractions, and the same number of polished sections was prepared from subsamples, as for the first set of samples. These sections were subjected to MLA analysis using the same mineral standards reference file for processing. The repeated data is underestimated as a result of sampling and varying screened mass proportion between the original test and the repeat test.

  APPENDIX F, Table F.3 also shows the variance the repeated and the original data in terms of the variance %, STD deviation % and calculated average.
  (Mentioned in the document in **Page 31**, section 3.4.1). It was of importance to replicate the bulk modal of the sample, since the mineralogical findings were used for process selection. Failure to replicate the MLA (bulk modal data) will mean failure to obtain the same extraction efficiencies.

- Addressed in **Page 44**, section 4.3.2.1, **Validation of mineralogical results**. This was done by comparing a chemical assay measured data as control against the calculated chemical assay measured from the AutoSEM (MLA). The calculated values are derived using the mass proportions of the minerals present and their ideal chemical composition as well as the microprobe data for some minerals, with the aim to provide confidence in mineralogy data. The data validation results are presented in section 4.3.2.1

  XRD data is in **Page 132**, The XRD data was used to confirm the gangue minerals identified by MLA and some of the silicates that MLA could not differentiate. The XRD data tables are presented in **Appendix F**.

  See **page 41** and Section 4.2.3, “The bulk mineralogy was achieved by means of MLA and XRD. The X-ray diffraction analysis was undertaken on the sample to determine the bulk mineralogical composition, particularly the gangue phases which may affect test work to assist with the AutoSEM bulk modal mineralogy.

- Figure 8, in Page 29 shows the flowsheet of sample preparation and mineralogical methods used and the choice behind using those methods. Section 3.4, I have re-arranged the order of mineralogical testwork carried out and the reasons articulated in each sub-section.

The process mineralogy was conducted upfront on the ore as received, this included the use of different mineralogical techniques (XRD, EPMA, SEM-EDS and MLA) to characterise a feed sample.

Addressed in **Page 33**: -Subsequent to the detailed mineralogical analysis undertaken on tailing feed sample size fractions, the findings showed that monazite was the chief REE carrier, and that the 150+106µm and –106µm size fractions were naturally upgraded in monazite, and could be taken further for leaching testwork.

Addressed in **Page 33**, For hydrometallurgical testwork, previous studies at Mintek have shown that when monazite is the main REE carrier, a cracking procedure (using NaOH) followed by washing and an acid leach constitutes the desired process for extracting REE.

In **Page 37**, The mineralogy conducted on residues was to assess the efficiency of leaching process not to mineralogical quantify the residues (addressed in 3.5.4.1). However, the residues were assessed by manual operated Zeiss SEM as mentioned in the study, since they were no longer minerals but phases making mixed elemental compounds. The AUTOSEM's has a difficulty in identifying leached mixed phases products.

There is also clear explanation on both Section 3.4 and 3.5 (**Pages 31 &33**). Section 3.4 is Mineralogical Characterisation of the feed and Section 3.5 is Metallurgy testwork and product characterisation; however, this sets apart the mineralogy test conducted for feed and on leach residues.

- Chapter 6, forms part of the objectives set out in section 1.3. This chapter also follows on from the summary and discussion of Chapter 5, and the reasons behind characterisation of zircon are again introduced in chapter 6 (page 77).

- **Page 75**, The HREE and MREE are removed from the results Table. The TREE is inclusive of all REE analysed including the highest 65 % of Lanthanum, and 55 % is the overall REE extraction. The recommendations on improving extraction is in **Page 89 and 90, section 7.2**.

  In page 89, An extraction higher than 55 % could have been achieved if the ore was upgraded further, owing to highly liberated monazite. The presence of zircon, oxide minerals like rutile and silicate minerals in the leach concentrate could have impacted the extraction efficiency, by limiting REE dissolution.

  Section 7.2, Paragraph 2. In order to achieve a similar 90% extraction efficiency, the ore must first be screened to –150µm, then a physical separation method must be considered to reduce gangue presence, as well as zircon in the initial stages of

leaching, since the zircon did not react under the same conditions as monazite during caustic cracking.

The X-Y % reaction of Zircon versus monazite reaction cannot be plotted since the zircon leaching test was aborted due to leaching inefficiencies of zircon.

- Cost analysis summary diagram included in section 7.1.3. Comment addressed in **Page 89, paragraph 4 and 5**. "In conclusion, a combination of mineralogical techniques proved that conducting mineralogy beforehand is of good value. It also showed that mineralogy should be highly considered as a decision-making tool so as to cut down on unnecessary costs associated with processes that may not be necessary in designing a flowsheet (Demonstrated by Figure 28)

  The word "**Cost effective**" changed to efficient, suitable, efficiently and effective in Page (ii) an efficient and cost-effectively; Page ii,.5, 18 efficient; Page.18, 26 and 29 Suitable; Page.75 possible ways; Page.6 & 85 effective

Other minor comments:

- Removed in Page ii
- Reference removed in Page 93
- Section 4.2.2 Y axis is changed from 120 % to 100 %, Grain sizes are presented in terms of equivalent sphere diameter (ESD). Definition of mineral grain and particle define in the list of Glossary (page. xvi)
- Table 9 and Table 10, results reported as less than Zero <0.1
- Table 11 changed, and it shows the major REE containing minerals /REE species
- Section 4.2.6.3, Figure 18 then Figure 17 and Table 13, corrected "changed the liberation categories to the following"

  Completely liberated: (Free) 100% of the surface of the particle
  80-100% exposed: >80% and <100% of the free surface of the particle
  50-80% exposed: >50% and <=80% of the free surface of the particle
  20-50% exposed: >20 and <=50% of the free surface of the particle
  Locked: <= 20% of the free surface of the particle

- Page 53, bracket removed.
- Figure 18 now Figure 19, fixed. REE presented in the correct order. Y axis included. This is now added in section 4.2.6.4

  The Figure 18 represents Elemental Deportment. Elemental deportment entails the comprehensive understanding of minerals that contribute to grade, as well as penalty elements that can affect the efficiency of processing or affect the value of the final concentrate.

Mineral/elemental deportment mainly aids in the understanding of which minerals actually contribute to grade, as each mineral is likely to behave differently to comminution, flotation or leaching.

For deportment calculations, the mass percent data for each mineral species is used together with the estimated elemental content in the minerals (EMPA or literature compositions). Deportment calculations are used to give an indication of the relative contribution of the different minerals to the total selected elemental budget of the sample. Deportment indicates which minerals are the dominant contributors of element of interest in the sample.

- Table 14, caption changed to REE deportment is for the bulk sample.
- Now Figure 20, 22 and 23, Y axis maximum is changed from 120 % to 100 %; Grain sizes are presented in terms of equivalent sphere diameter (ESD). Number of grains updated in Figures 20 to 23 and Section, 4.2.6.5.
- Page 60 statement was incorrect and now removed.
- Page 63 changed to - The TREE content unwashed water leach test was 5.2% and after the water leach wash 1 test of the residues was 5.1 % (Error! Reference source not found.).

- Figure 22, Annotated as numbers points and the numbers are described in Table 23.

- Table 23, The EMPA data and SEM –EDS data cannot be compared to one another, since the EMPA analysis in Table 10 was conducted on a feed sample (before it was leached), whereas the SEM-EDS data in **Table 23** was for leached residues (no longer minerals but phases).
  The EMPA data and SEM-EDS are not comparable: -
  - Because of unpolished surfaces for the residues, which render these qualitative results, whereas EMPA is quantitative data
  - EMPA data is WDS and SEM data is EDS

The Table below shows elemental EMPA data of Monazite and Zircon

Mineral		F	Al	Si	P	Ca	Y	Zr	La	Ce	Pr	Nd	Sm	Eu	Gd	Dy	Ho	Th	U	Total
Zircon	34	-	-	14.7	-	-	0.2	49.8	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	0.1	99.8
Monazite	25	0.9	0.0	0.4	11.6	0.7	1.5	-	12.2	25.1	2.6	10.2	1.6	-	-	0.4	0.1	6.6	0.3	99.2

- Page 76, paragraph 2, is addressed by Table and Graph showing calculated ratio of Zr/Si, presented in appendix E (page **132);** mentioned in the document in Page 77.
- Page 77 added this “Zircon was targeted as the alternative resource of REE, since EMPA data showed that zircon contains fewer REE in its crystal lattice and this REE are different from the REE in monazite”.