Rare Earth Elements (REE) at the Gcwihaba Resources (Pty) Ltd, Skarn Prospects

By Tsodilo Geologists

TSX: V listed Tsodilo Resources Limited through is Botswana subsidiary Gcwihaba Resources (Pty) Ltd. has shown that there is significant potential for Rare Earth Element (REE) production from its licenses in northwest Botswana. Currently the company has identified at least two significant skarn associated prospects (C26 and C27) that contain a standard suite of ordinary carbonate, silicate, and phosphate REE minerals of well-established metallurgy that can be exploited easily.

One of the two skarn prospects C27 has currently been modelled to an exploration target of conceptual Exploration Target of 76 Mt to 92 Mt of skarn with grades ranging from 0.05 % to 1 % Total Rare Earth Elements Oxide (TREO). This gives a range of contained TREO of 38,000 tonnes to 920,000 tonnes, which at current June 2020 REE oxide value, gives a range of in-situ REO value of ~400 million USD to ~10 billion USD.

The there is a standard suite of REE seen in the prospect and the tonnage and in-situ value of each element oxide is shown in Table 1 below.

Table 1. Table showing the REE that can be expected to be extracted from the C27 skarn prospect at the projected Exploration Target grades of 0.05% to 1% TREO, and tonnages of 76 Mt to 92 Mt.

	REE Oxide	**REE Names**	**Lower Tonnage of Each Element (extracted) (Grade 0.05% TREO% and 76 Mt)**	**Upper Tonnage of Each Element (extracted) (Grade 1% TREO% and 92 Mt)**	**Price Per Tonne USD (as of 24th May 2020, ISE)**	**In situ Value (USD) Lower**	**In situ Value (USD) Upper**
Light Rare Earth Elements (LREE)	CeO2	Cerium (Ce)	18,055	437,115	$1,700	$30,693,054	$743,094,998
	La2O3	Lanthanum (La)	11,885	287,753	$1,700	$20,205,262	$489,180,024
	Pr2O3	Praseodymium (Pr)	1,535	37,155	$43,000	$65,989,811	$1,597,648,047
	Nd2O3	Neodymium (Nd)	4,489	108,669	$42,413	$190,371,063	$4,608,983,639
	Sm2O3	Samarium (Sm)	463	11,205	$1,820	$842,349	$20,393,711
	Eu2O3	Europium (Eu)	97	2,341	$30,500	$2,949,577	$71,410,818
	Gd2O3	Gadolinium (Gd)	205	4,963	$27,750	$5,689,044	$137,734,756
Heavy Rare Earth Elements (HREE)	Tb2O3	Terbium (Tb)	51	1,225	$651,300	$32,948,126	$797,691,461
	Dy2O3	Dysprosium (Dy)	196	4,739	$276,050	$54,035,870	$1,308,236,855
	Ho2O3	Holium (Ho)	32	770	$58,230	$1,851,162	$44,817,598
	Er2O3	Erbium (Er)	62	1,507	$22,570	$1,404,852	$34,012,199
	Tm2O3	Thulium (Tm)	19	467	$22,500	$433,585	$10,497,314
	Yb2O3	Ytterbium (Yb)	66	1,602	$14,810	$980,071	$23,728,045
	Lu2O3	Lutetium (Lu)	23	548	$618,230	$13,983,598	$338,550,276
	Y2O3	Yttrium (Y)	824	19,942	$2,775	$2,285,705	$55,338,129
		Totals	**38,000**	**920,000**	**1,815,348**	**424,663,129**	**10,281,317,870**

REE have been identified in moderately high levels in 1m interval drill core ICP assays. These are seen in a number core drill holes in the Gcwihaba Resources (Pty) Ltd. (Gcwihaba) prospecting licenses in Northwest Botswana (Figure 1), Gcwihaba is a fully owned subsidiary of Tsodilo Resources Limited (Tsodilo).

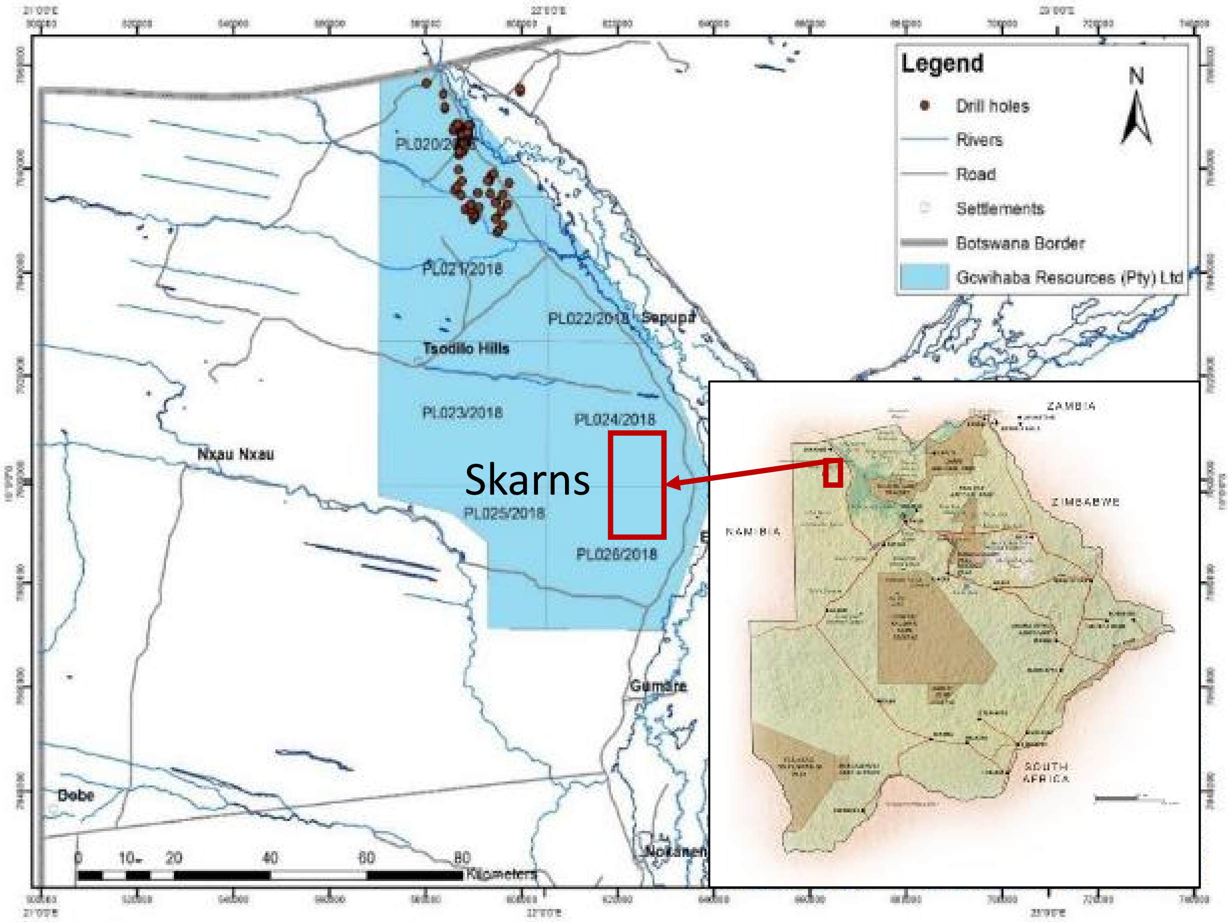


Figure 1. Location of the Gcwihaba licenses and Skarn rocks in Northwest Botswana.

By far the highest REE intersections can be seen in two “skarn” anomalies, these are the 1822C27 (C27), and the 1822C26 (C26) anomalies. These are located in the southern license areas (Figure 1 and Figure 2).

Table 1 shows the 1m interval half core ICP assay values over 1% TREO (where TREO is the Total Rare Earth Element Oxide Percent). The TREO is created by converting all REE assay values to their oxide percentages commonly in the form of REE_2O_3 % and summing them.

These intersections shown in Table 1 show the huge potential for a significant deposit with these skarn anomalies in the Gcwihaba licenses.

The holes that stand out as being very high in TREO% are listed below:

- 1822C27_6: C27 skarn anomaly - This hole has the highest TREO recorded at 1.49%. It has 2m of intervals over 1% TREO and 4 m of intervals all over 0.1% TREO.
- 1822C27_2: C26 skarn anomaly - This hole has 1m over 1% TREO but has a massive 45 m of intervals over 0.1% TREO.
- 1822C26_1: C26 skarn anomaly - This hole has 18 m of intervals over 0.1% TREO.
- 1822C26_3: C26 skarn anomaly – This hole has 11 m of intervals over 0.1% TREO.

Economic levels of TREO are currently between 0.02% TREO to 3% TREO (Paulick and Machacek, 2017), accordingly this makes the levels noted in the intervals above very much within the economic bracket for REE deposits.

Figure 2 shows the location of the C26 and C27 skarn anomalies as well as some other notable TREO% occurrences within the Gcwihaba licenses.

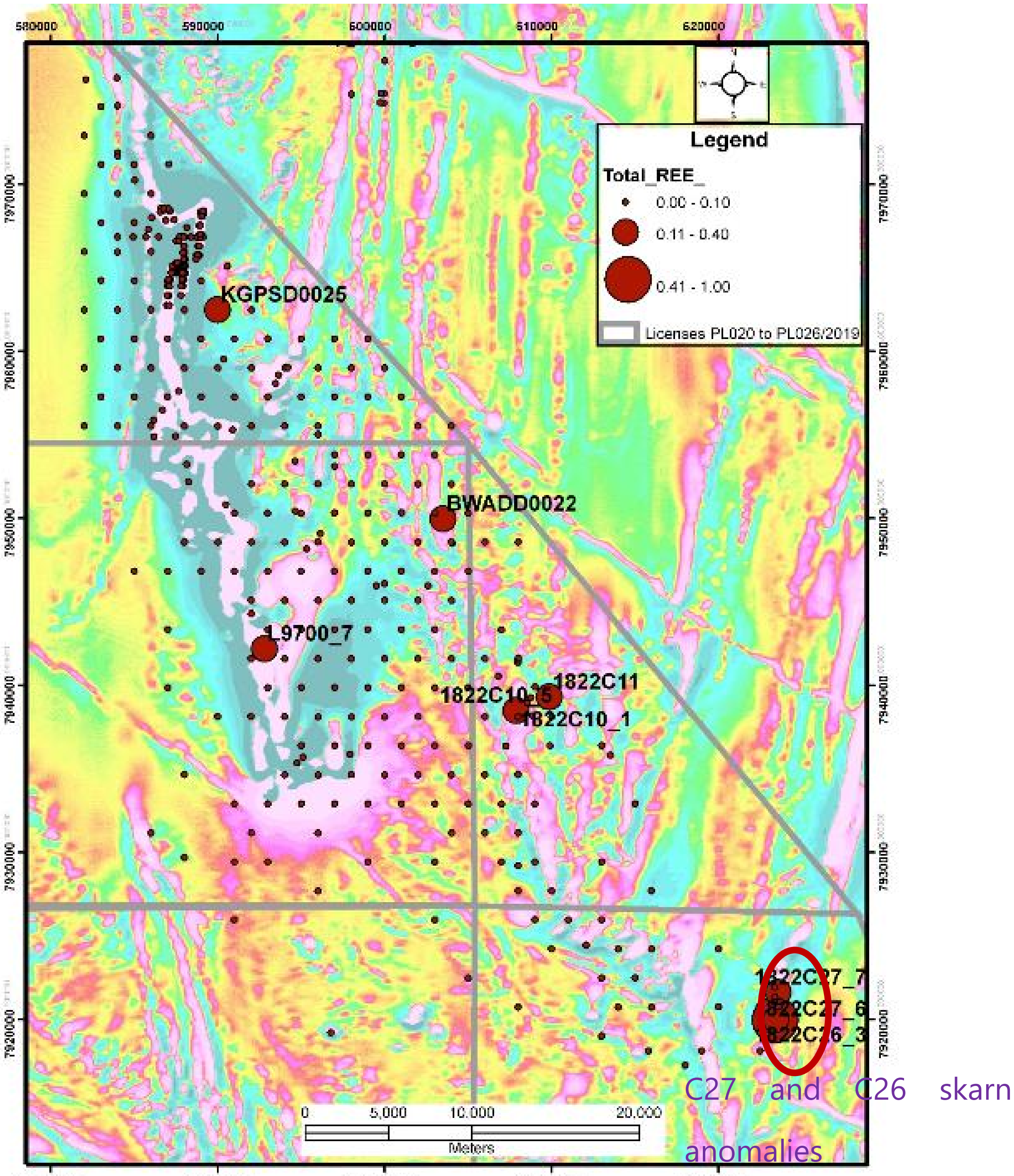


Figure 2. This shows the occurrences of the high Total Rare Earth Element Oxide (TREO) in drill holes within the Gcwihaba licenses. C26 and C27 skarn anomalies are very close together, but the conceptual Exploration Target only models the C27 skarn anomaly.

Figure 3 shows current global evaluation REE projects and mines in context to their TREO% and tonnages, showing that the values above 0.1% TREO in the Gcwihaba rocks are potentially economic, see Figure 3 showing the ranges of equivalent deposits compared to the ranges of TREO seen in the Gcwihaba rocks (Paulick and Machacek, 2017).

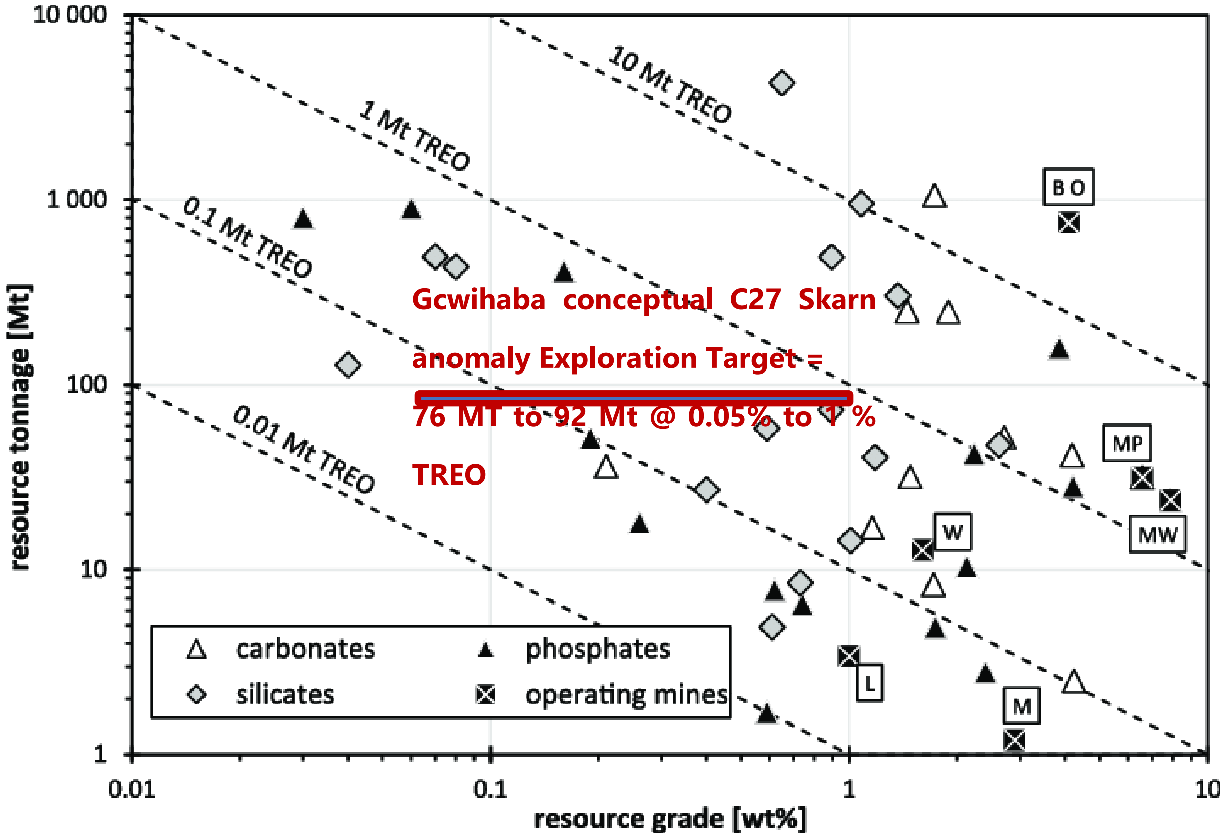
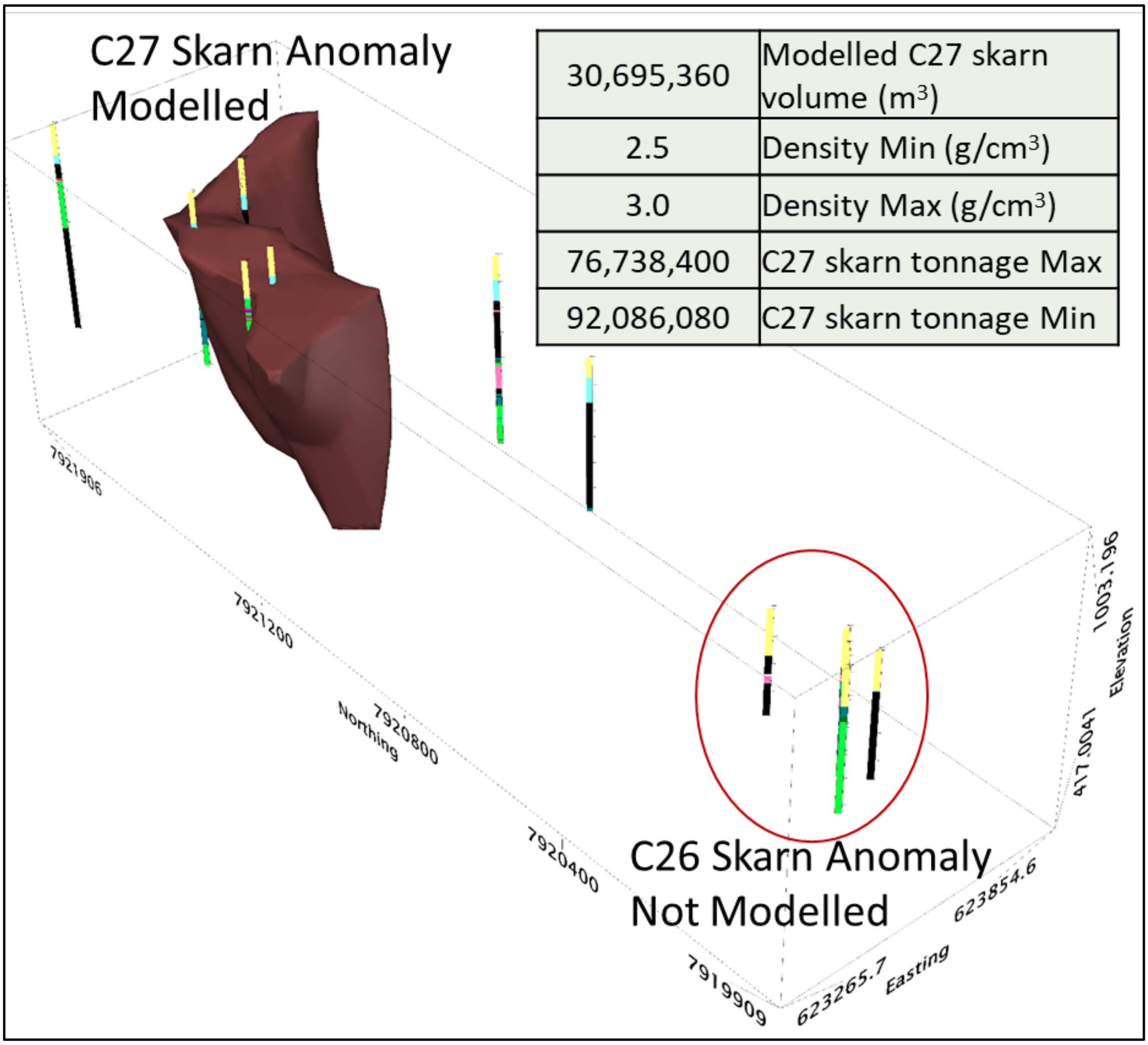


Figure 3. Tonnage and grade characteristics of REE projects defined outside of China during the recent exploration boom show some systematic trends according to the REE bearing minerals in the resources. (Source Paulick and Machacek, 2017).

Figure 4 shows the modelled skarn and tonnages, which are being used as a conceptual Exploration Target for the Gcwihaba C27 Skarn prospect. The conceptual C27 Gcwihaba Exploration Target shown in Figure 4 and Figure 5 has the C27 skarn anomaly tonnage ranging 76 Mt to 92 Mt of skarn with grades ranging from 0.05 % to 1 % TREO. It has to be noted that this is only for the C27 skarn anomaly and does not include the other known skarn anomalies such as the C26 skarn anomaly which also has some significant REE intersections. As such with more exploration the tonnage has the potential to increase, further exploration will also be focused on defining the REE grades.



30,695,360	Modelled C27 skarn volume (m³)
2.5	Density Min (g/cm³)
3.0	Density Max (g/cm³)
76,738,400	C27 skarn tonnage Max
92,086,080	C27 skarn tonnage Min

Figure 4. Geological modelling of the C27 skarn, with drill holes displayed. The conceptual Exploration Target volume, and density and tonnage ranges displayed. Note the holes within the C26 skarn anomaly have been circled in red, but not modelled.

This conceptual C27 skarn anomaly Exploration Target was generated by geologically modelling in 3 dimensions using the drill hole intersections of the C27 skarn anomaly. This allowed volumes representing the C27 skarn to be generated. These modelled volumes were then turned into the tonnages quoted by using a likely range of densities for this skarn material of 2.5 to 3.0 g/cm3.

This gives a range of contained TREO of 38,000 tonnes to 920,000 tonnes, which at current March 2020 REE oxide values, gives a range of in-situ TREO value of ~400 million USD to ~10 billion USD.

All references contained herein with respect to the potential quantity and grade of the conceptual exploration target for the C27 skarn anomaly derived by any method is at this stage of development is conceptual in nature. At the present time, there has been insufficient exploration to define a mineral resource and it is uncertain if further exploration will result in the target being delineated as a mineral resource. Any exploration target tonnages mentioned in this document are not mineral resources as defined in National Instrument 43-101 -- Standards of Disclosure for Mineral Project (NI 43-101).

Figure 5 shows the ground magnetic signatures of both the C27 and C26 skarn anomalies. The modelled volume shell is also shown. As you can see there is significant potential to expand the size of the modelled REE skarn beyond the modelled shell as displayed once more drilling has been conducted to the north of the current C27 drilling. The same is true for the potential for a resource of REE within the currently un-modelled C26 skarn which is also a sizable area.

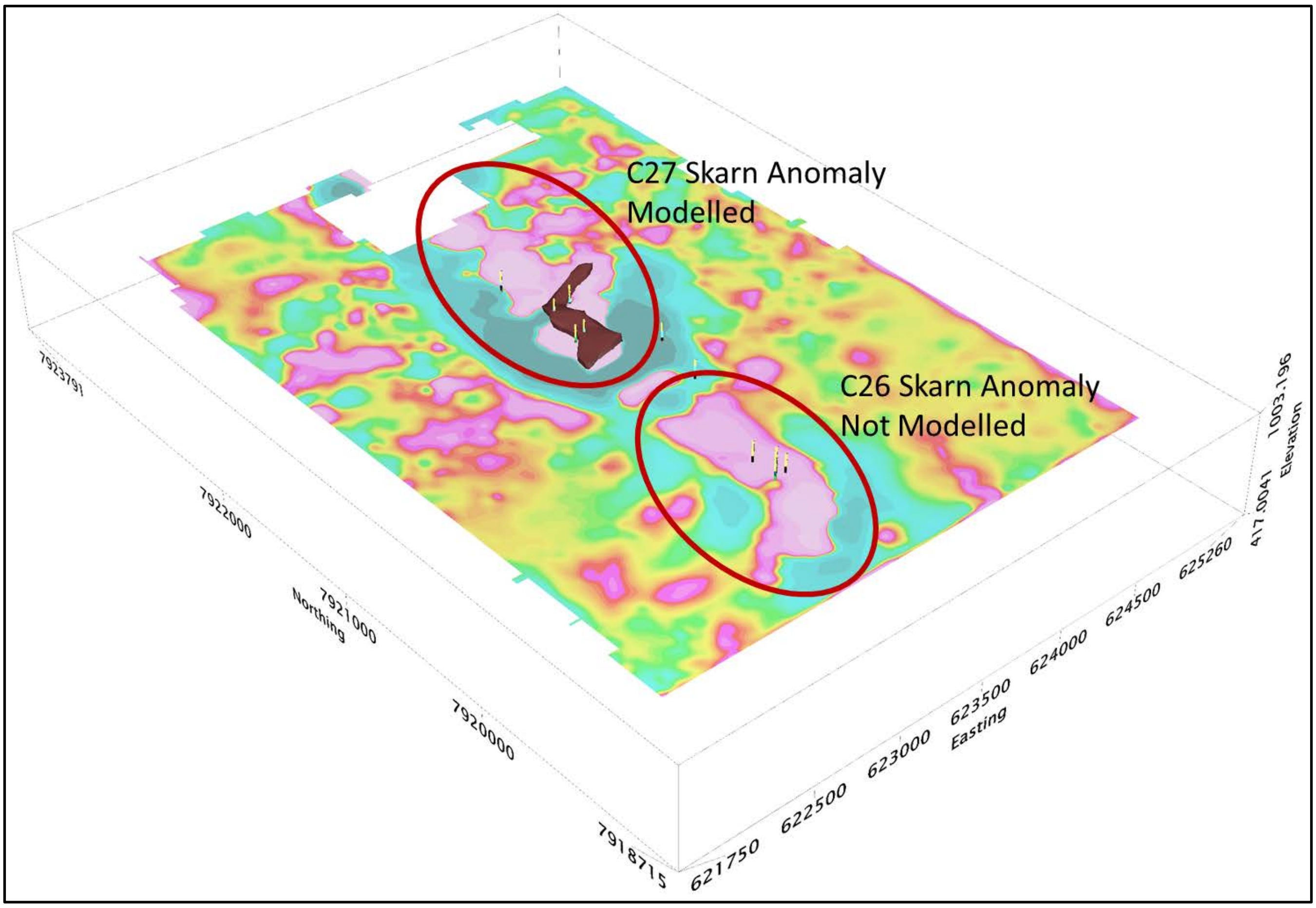


Figure 5. This figure shows the ground magnetic signature of the C27 and C26 skarn anomalies. Also shown is the current modelling for the C27 skarn REE. As you can see the size of the C27 anomaly is bigger than the current modelled area and as such shows the upside potential of the skarn for a larger REE envelope especially with more drilling to the north of C27.

Table 1. Shows the REE levels in the Gcwihaba rocks over 0.1% TREO.

HOLE_ID	FROM	TO	Interval (m)	Cu	Total REE Oxides (TREO) %
1822C27 6	160.5	161.5	1	0.009	1.491
1822C27 2	146.4	147.4	1	0.043	1.232
1822C27 6	159.5	160.5	1	0.009	1.114
1822C27 2	241.4	242.4	1	0.017	0.915
1822C27 6	161.5	162.5	1	0.014	0.887
1822C27 2	207.4	208.4	1	0.016	0.606
1822C27 2	177.4	178.4	1	0.125	0.513
1822C27 2	91.4	92.4	1	0.096	0.511
1822C27 2	168.4	169.4	1	0.087	0.499
1822C26 1	172.6	173.6	1	0.093	0.458
1822C27 2	216.4	217.4	1	0.009	0.457
1822C27 2	147.4	148.4	1	0.080	0.437
1822C27 2	193.4	194.4	1	0.019	0.426
1822C27 2	202.4	203.4	1	0.026	0.424
1822C27 2	164.4	165.4	1	0.051	0.405
1822C27 2	159.4	160.4	1	0.052	0.402
1822C26 3	109.4	110.4	1	0.034	0.399
1822C27 2	224.4	225.4	1	0.057	0.377
1822C27 2	160.4	161.4	1	0.083	0.370
1822C27 2	166.4	167.4	1	0.041	0.352
1822C27 2	210.4	211.4	1	0.034	0.347

1822C27_2	134.4	135.4	1	0.004	0.341
1822C27_2	223.4	224.4	1	0.074	0.333
1822C26_3	103.4	104.4	1	0.016	0.330
1822C27_2	144.4	145.4	1	0.016	0.323
1822C27_2	148.4	149.4	1	0.044	0.321
1822C27_2	162.4	163.4	1	0.073	0.290
1822C27_2	125.4	126.4	1	0.019	0.269
1822C27_2	176.4	177.4	1	0.171	0.269
1822C26_1	77.6	78.6	1	0.085	0.261
1822C27_2	203.4	204.4	1	0.014	0.258
1822C27_2	172.4	173.4	1	0.107	0.252
1822C27_2	105.4	106.4	1	0.015	0.239
1822C27_2	214.4	215.4	1	0.026	0.225
1822C27_2	126.4	127.4	1	0.007	0.222
1822C27_2	240.4	241.4	1	0.070	0.218
1822C27_2	213.4	214.4	1	0.009	0.215
1822C26_1	78.6	79.6	1	0.135	0.212
1822C27_2	165.4	166.4	1	0.061	0.211
1822C26_1	132.6	133.6	1	0.073	0.206
1822C26_1	125.6	126.6	1	0.092	0.200
1822C27_2	89.4	90.4	1	0.021	0.198
1822C26_3	104.4	105.4	1	0.027	0.191
1822C26_1	122.6	123.6	1	0.060	0.171
1822C26_1	123.6	124.6	1	0.036	0.169
KGPSD0025	51	52.2	1.2	0.002	0.168
1822C27_2	226.4	227.4	1	0.030	0.166
1822C27_7	211.5	212.5	1	0.042	0.165
1822C27_6	220.5	221.5	1	0.004	0.160
1822C26_1	94.6	95.6	1	0.038	0.160
1822C27_2	101.4	102.4	1	0.131	0.159
1822C26_3	110.4	111.4	1	0.037	0.158
BWADD0022	490	491	1	0.010	0.155
1822C27_7	221.5	222.5	1	0.066	0.154
1822C27_2	96.4	97.4	1	0.026	0.152
1822C10_1	92.5	93.5	1	0.005	0.151
1822C26_1	162.6	163.6	1	0.010	0.147
1822C27_2	225.4	226.4	1	0.032	0.144
1822C26_3	119.4	120.4	1	0.033	0.143
L9700_7	82.5	83.5	1	0.001	0.142
1822C27_2	180.4	181.4	1	0.087	0.141
1822C27_2	75.4	76.4	1	0.072	0.138
1822C26_3	123.4	124	0.6	0.012	0.137
1822C26_1	135.6	136.6	1	0.147	0.133
1822C26_1	189.6	190.6	1	0.149	0.131
1822C26_1	95.6	96.6	1	0.026	0.131
1822C27_2	74.4	75.4	1	0.071	0.128
1822C26_3	116.4	117.4	1	0.018	0.127
BWADD0022	491	492	1	0.029	0.125
1822C26_1	116.6	117.6	1	0.073	0.124
1822C26_1	80.6	81.6	1	0.011	0.121
1822C27_2	179.4	180.4	1	0.095	0.119
L9700_7	74.5	75.5	1	0.004	0.119
1822C26_1	82.6	83.6	1	0.028	0.118
1822C11	187.6	188.6	1	0.001	0.117
1822C27_2	173.4	174.4	1	0.085	0.117
1822C26_3	115.4	116.4	1	0.108	0.117
1822C26_3	124	125	1	0.077	0.116
1822C26_3	114.4	115.4	1	0.011	0.116
1822C27_2	76.4	77.4	1	0.072	0.115
1822C27_2	212.4	213.4	1	0.006	0.114
1822C26_3	117.4	118.4	1	0.016	0.109
1822C26_1	174.6	175.6	1	0.034	0.108
L9700_7	121.5	122.5	1	0.000	0.108
1822C10_5	89.6	90.6	1	0.001	0.108

1822C26 1	92.6	93.6	1	0.072	0.107
KGPSD0025	50	51	1	0.007	0.106
1822C27 2	242.4	243.4	1	0.031	0.105
1822C26 1	188.6	189.6	1	0.066	0.104
1822C27 2	199.4	200.4	1	0.004	0.104
1822C11	182.6	183.6	1	0.001	0.104
1822C24	203.4	204.4	1	0.011	0.103
L9690 5	181.4	182.4	1	0.005	0.103
1822C27 2	169.4	170.4	1	0.022	0.102
1822C27 2	209.4	210.4	1	0.083	0.101

Mineralogy

Dr. Joan Carles Melgarejo Barcelona group studied the mineralogy of these skarn anomalies and determined that the mineralogy of these REE occurrences within the skarn are a mixture of:

1. REE Carbonates: Bastnäsite, Ancylite, and Calcioancylite;
2. REE silicates: Allanite, Britholite, and Yttrialite; and
3. REE phosphates: Rhabdophane, Monazite, and Xenotime.

This mineralogy study into these skarn deposits showed that they exhibit typical skarn morphologies, in terms of some endoskarn and the main exoskarn forming within the carbonate rich lithologies (marble). The common skarn bulk mineralogy is pyroxene skarn (hedenbergite) and garnet skarn (andradite), some of these andradite garnet growths can be seen in Figure 6.

Trace minerals are common in the skarns, and the mineral association is very complex. Most of the secondary minerals are REE bearing.

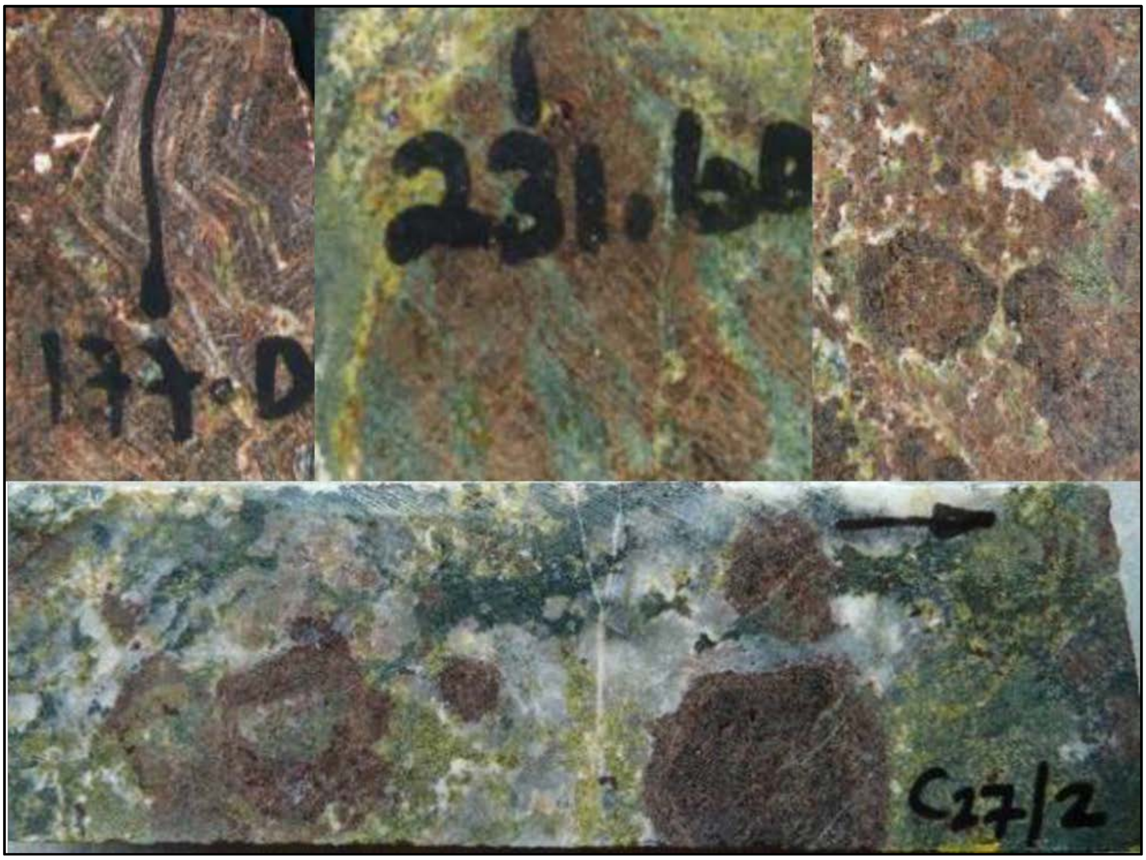


Figure 6. Garnet and Pyroxene exoskarn showing the very large dark red andradite garnet growths over printing the carbonate rich marble lithology. Also seen are the light green hedenbergite pyroxenes typical of this type of exoskarn.

This skarn overprinting on the base carbonates is caused by a fluid input from an intrusive which creates a metasomatism of the host rock by hydrothermal alteration processes. This hydrothermal alteration is the source of the carbonate, silicate, and phosphate REE minerals. The carbonate and silicate REE tend to dominate the REE minerals seen in the skarn such as Bastnäsite (REE carbonate fluoride, see Figure 7), and Allanite (REE Silicate see Figure 8) and Britholite (REE Silicate, see Figure 9). Although Monazite is common also (REE phosphate, see Figure 9).

These form alongside and the less common secondary phosphate REE such as Rhabdophane. Other minerals notes but of minor occurrence are Yttrialite (REE silicate) and Calcioancylite and Ancylite (REE Carbonates) and Xenotime (REE phosphate).

These REE minerals form in both the host rock and veins that can be both silicate veins, carbonate veins, and also sulphide veins.

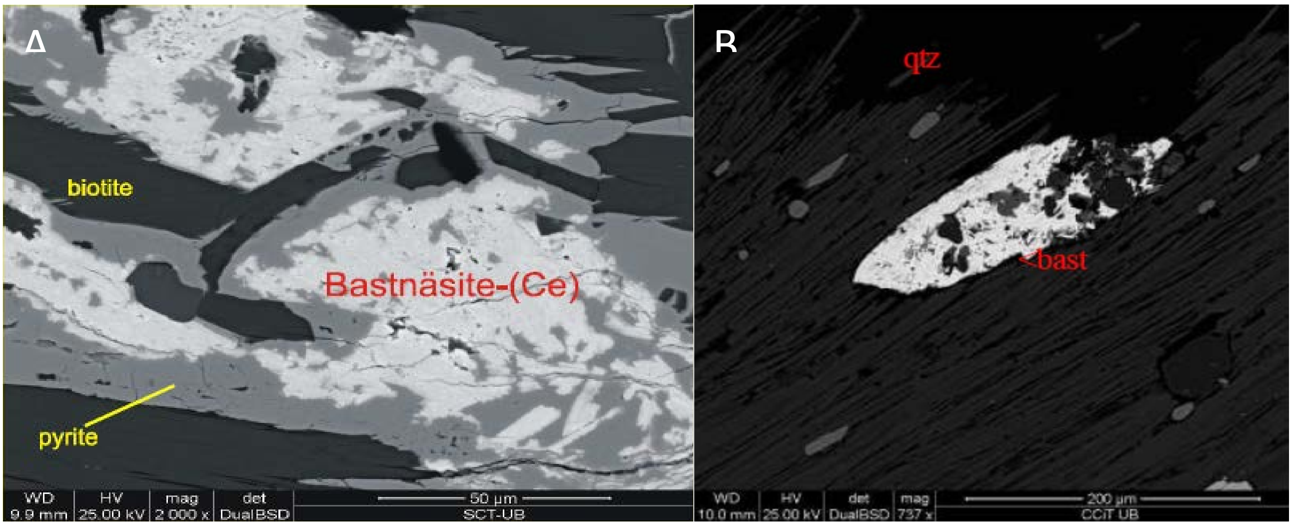


Figure 7. A. Bastnäsite (REE carbonate fluoride) replacing biotite and associated with pyrite. B. SEM image, of a Bastnäsite grain in quartz.

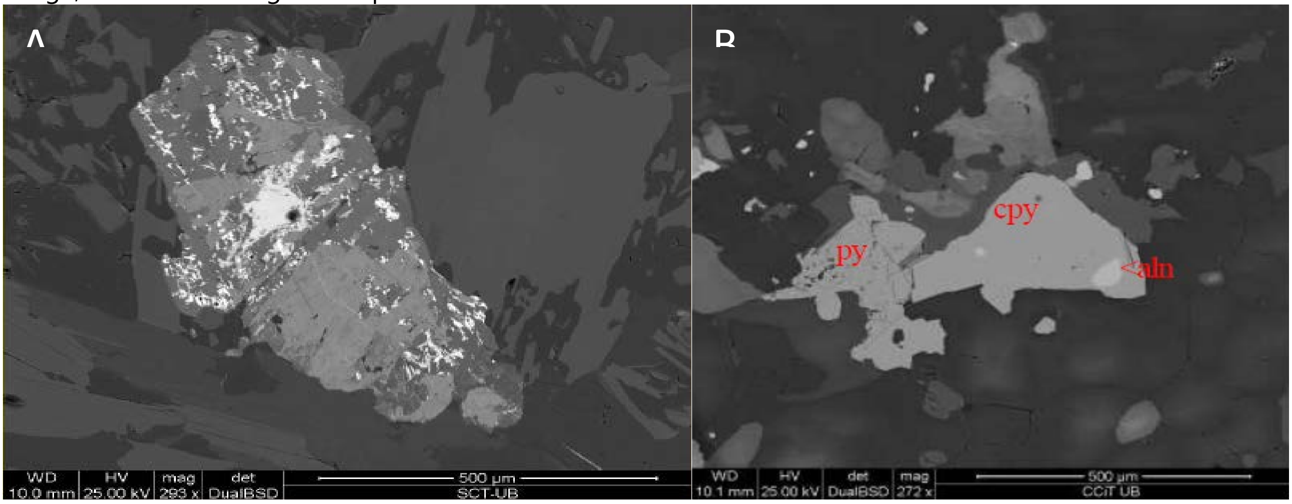


Figure 8. A. SEM image of a large allanite (REE silicate) crystal replaced by late brighter ancylite (REE carbonate). B. Allanite (aln) (REE silicate) in association with pyrite and chalcopyrite (cpy).

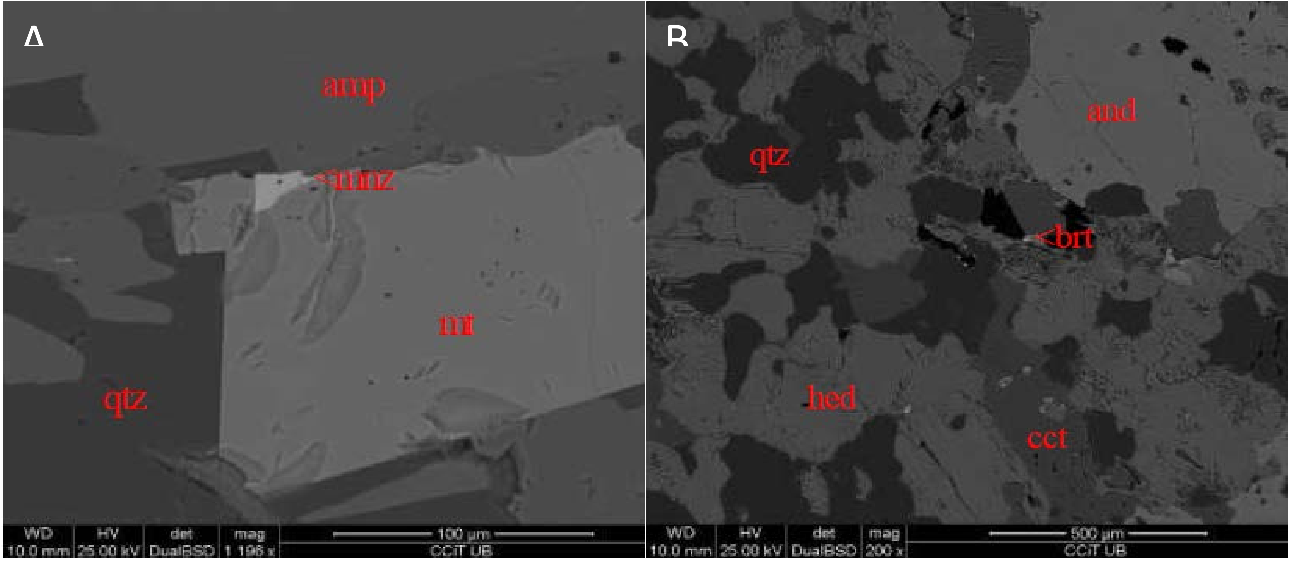


Figure 9. A. SEM image of monazite crystal (mnz REE Phosphate) associated with magnetite (mt), quartz (qtz) and amphibole (amp). B. SEM image of britholite (brt REE silicate), associated with quartz (qtz) and calcite (cct) between andradite (and) and hedenbergite (hed).

REE Associated with the Skarn Deposit Discussion

The calcsilicates found in the skarn cores correspond to true skarns, with all of the typical facies (endo and exoskarns).

The skarn is associated with alteration around a granitic like intrusive potentially probably close to the surface, where the fluids and intrusive were produced when a proximal but since eroded volcanic cauldron subsidence occurred, which produced the development of granite dikes which are seen within the skarn units as endoskarns. This mechanism of emplacement seems to be favorable for a strong interaction between the carbonates (marbles) and the intrusive to produce the exoskarns seen. Where these exoskarn rocks and are the main source of the REE minerals (REE carbonates, silicates, and phosphates). Moreover, the granites are also intruding into and through intruding mineralized black shale (phyllites) associated with the carbonates (marbles). Therefore the fluids associated with these granites could easily mobilize metals from the hosting black shales towards these skarns.

Therefore, a mobilization of REE and other metals from the black shales could likely by the mechanism for concentrations of metals in the skarns.

Conclusions

There is a conceptual Exploration Target of 76 Mt to 92 Mt of skarn with grades ranging from 0.05 % to 1 % TREO. This gives a range of contained TREO of 38,000 tonnes to 920,000 tonnes, which at current March 2020 REE oxide value, gives a range of in-situ REO value of ~400 million USD to ~10 billion USD.

As you can see there is significant potential for the development of a high grade REE mineral deposit within the skarn rocks of the Gcwihaba prospecting licenses that could extract REE metals for sales into the current high demand areas such as permanent magnets and battery alloys which have ever increasing demand due to the need for green energy (permanent magnets) and electronics and battery powered cars (batteries) etc. The expected global growth and demand for REE is shown in Figure 10.

Although supply is projected to remain even with demand for REE in the next few years, net demand is projected to outstrip net supply quickly and thus there will be an under supply of REE that will not be able to meet demand.

As more countries become developed, their demands for technologies using REEs will increase, resulting in larger total demands for REEs. Thus, the growth rate of supply will need to increase (Alonso et al., 2012).

As such new sources of REE are being searched for and it is anticipated that the Gcwihaba skarn REE deposit could be developed to meet some of this global demand for REE.

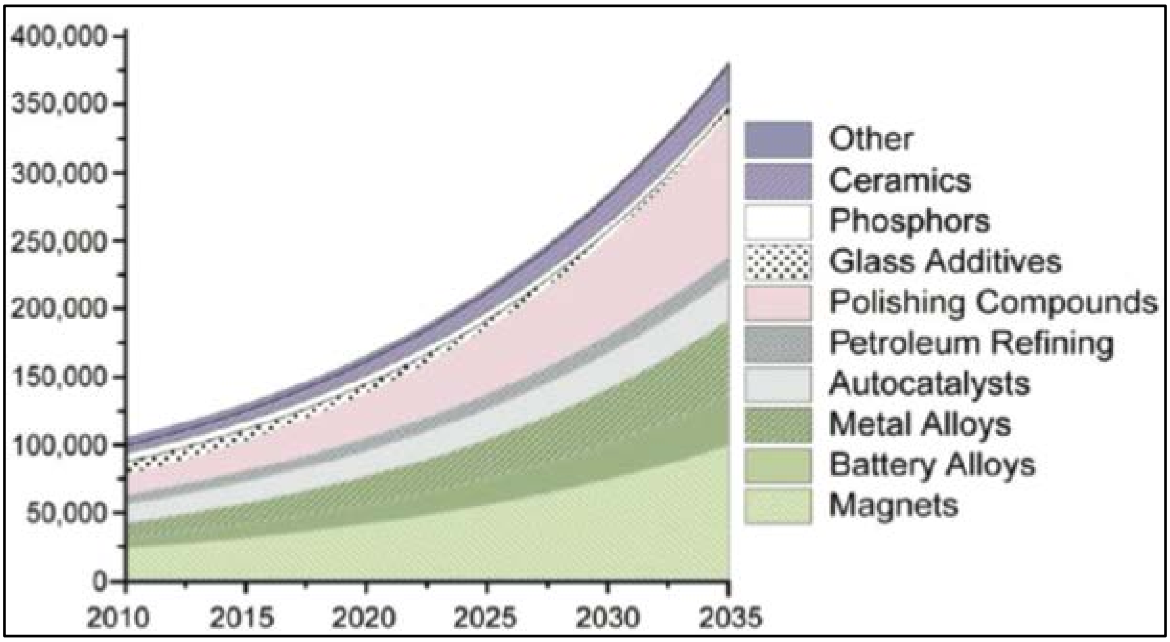


Figure 10. Projected global total REE demand growth, assuming historic growth. (Source Alonso et al, 2012).

References

Paulick, H., and Machacek, E. 2017. The global rare earth element exploration boom: An analysis of resources outside of China and discussion of development perspectives. Resources Policy 52 (2017) 134–153.

Alonso, E., Sherman, A. M., Wallington, T. J., Everson, M. P., Field, F. R., Roth, R., & Kirchain, R. E. (2012). Evaluating rare earth element availability: A case with revolutionary demand from clean technologies. Environmental science and technology, 46, 3406-3414.