NI 43-101 PRELIMINARY ECONOMIC ASSESSMENT
ROUND TOP PROJECT
Sierra Blanca, Texas

PREPARED FOR

USA RARE EARTH LLC AND TEXAS MINERAL RESOURCES CORP

539 West El Paso Street
Sierra Blanca, Texas 79851

Report Date: August 16, 2019
Effective Date: July 1, 2019
Rev A.

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1 SUMMARY

Gustavson Associates, LLC (Gustavson) was commissioned by USA Rare Earth LLC (USRE) to prepare an updated Preliminary Economic Assessment (PEA) for the Texas Mineral Resources (TMRC) Round Top Rare Earth Element Project (Round Top Project or the Project). The Project is located in Hudspeth County, Texas. This technical report presents the results of the PEA in accordance with Canadian National Instrument 43-101 *Standards of Disclosure for Mineral Projects* (NI 43-101), June 24,2011, and Canadian Institute of Mining, Metallurgy and Petroleum (CIM) "Best Practices and Reporting Guidelines for Mineral Resources and Mineral Reserves", November 23, 2003. The effective date of this report is July 1, 2019.

1.1 PROPERTY DESCRIPTION AND OWNERSHIP

The Round Top Project is located approximately 8 miles northwest of Sierra Blanca in Hudspeth County, Texas; and approximately 85 miles southeast of El Paso, Texas. The Round Top Project consists of two 18-year Mining Lease Agreements with the General Land Office of the State of Texas (GLO). Mining Lease No. M-113629 consists of 860 acres on land that is owned by GLO, and Mining Lease No. M-113117 consists of 90 acres on land the surface of which is owned by TMRC. The lease agreements provide TMRC with the full use of the leased property, including all rights with respect to the surface and subsurface for any and all purposes, together with the rights of ingress and egress for the purposes of mineral exploration, development, and exploitation of minerals. TMRC has negotiated the terms of an option agreement with the GLO to purchase the additional surface needed to develop the mine, leach fields and plant site (The Option Area). There are various small tracts of private surface land near and within the Option Area. TMRC has to date purchased some 1300 acres of these tracts and continues the process of acquiring more. Although acquisition of these tracts is not necessary for the proposed development described in this PEA, TMRC believes it is prudent to purchase these tracts in the event of future expansion of the project area.

In November 2018, USRE entered into an option and development agreement with TMRC to acquire up to 80% interest in the Round Top project, subject to certain minimum expenditures, project milestones, and conditions. USRE is the operator under the agreement.

1.2 GEOLOGY AND MINERALIZATION

The Round Top Project consists of a Tertiary rhyolite intrusion that is enriched in both heavy and light rare earth elements (REEs) and other incompatible elements such as Li, Be, F, U, Th, Nb, Ta and Hf. The stratigraphy is relatively simple, with Tertiary rhyolite laccoliths cutting Tertiary diorite dikes and intruding Cretaceous marine sedimentary rocks. The Project is located in the Trans-Pecos region, and has been structurally affected by Laramide thrusting and folding, subduction magmatism, and Basin and Range crustal extension. The main structures on the property are landslide and slump faulting, and north-northwest-trending normal faults.

Round Top rhyolite is enriched in Heavy Rare Earth Elements (HREEs). Statistical review of the geochemical data shows that an estimated 70% of the total REE's grade being HREEs. REE mineralization occurs primarily as disseminated microcrystals of varieties of fluorite (such as yttrium-rich yttrofluorite) where HREEs have substituted for calcium, and as other REE-bearing accessory minerals. REE minerals occur mainly in vugs and as crystal coatings, suggesting late-stage crystallization from an incompatible element-rich fluid. Other incompatible elements were concentrated in these late magmatic fluids. Uranium occurs as fine disseminated grains of uraninite and coffinite. Niobium-tantalum bearing columbite is relatively abundant. Zircon also is relatively abundant and is the mineral containing the zirconium and hafnium. Several unidentified tin minerals are present, and thorium is contained in thorite and within zircon. Other petrographic elements are also present, some of which will be recovered during a sulfuric acid leach, and which are expected to produce economic minerals.

The Round Top rhyolite was divided into five different alteration phases based on the intensity of hematitic and hydrothermal alteration: gray rhyolite, pink rhyolite, red rhyolite tan rhyolite and brown rhyolite in the order of least to most altered. Hematitic alteration is a replacement of the magnetite by hematite and gives the rhyolite a red to pink color. Hydrothermal alteration was late and gives the rhyolite a tan to brown color. Mostly unaltered, gray rhyolite was also documented. The majority of the resource is comprised on pink-red and grey rhyolite. Tan and brown rhyolites are generally present at the basal contact of the laccolith and are more limited in extent.

1.3 EXPLORATION STATUS

Since January 2010, TMRC has conducted the following exploration activities: surface sampling, logging cuttings from historical reverse circulation drilling, aeromagnetic surveying, an aeroradiometric survey, stream sediment surveying, gravity surveying, and exploratory drilling. These studies showed the distribution of REEs. To date, 173 historical drill holes have been located, and, since 2011, TMRC has drilled 84 reverse circulation holes and 2 core holes. TMRC has analyzed 3,081 drill samples.

In early 2019, TMRC assayed previously collected RC samples to collect geochemical data for some additional elements from existing drill holes to expand the knowledge of lithium, zircon, and other elements which metallurgical test work had indicated might impact project economics.

1.4 MINERAL RESOURCE ESTIMATE

Table 1-1 below shows the measured, indicated, and inferred mineral resources estimated within the Round Top Project, with an effective date of July 1, 2019. There are no mineral reserves estimated for the Round Top Project. The mineral resource estimate was completed by Donald Hulse, a qualified person as defined by NI-43-101. This mineral resource estimate has been prepared in accordance with NI 43-101 and CIM. Mineral resources are reported using a $16/ton NSR cutoff. Mineral Resources are not Mineral Reserves and do not demonstrate economic viability. There is no certainty that all or any part of the Mineral Resource will be converted to Mineral Reserves.

1.5 MINERAL RESOURCE CLASSIFICATION

The mineral resource has been classified for the Round Top project as measured, indicated, and inferred. The classification of mineral resources is based on the average spacing of data points within the search area of the block as represented by the declustering weight calculated for each composite utilizing the GS-Lib declustering method. This differs from the previous method used of the distance to the nearest sample. The result is an overall increase in classification in the well drilled parts of the deposit and a decrease in the confidence of the estimate where it is based on a single composite. Figure 1-1 shows the mineral resource classification (measured as blue, indicated as green, and inferred as red) at an elevation of 5,060 feet (1542m).

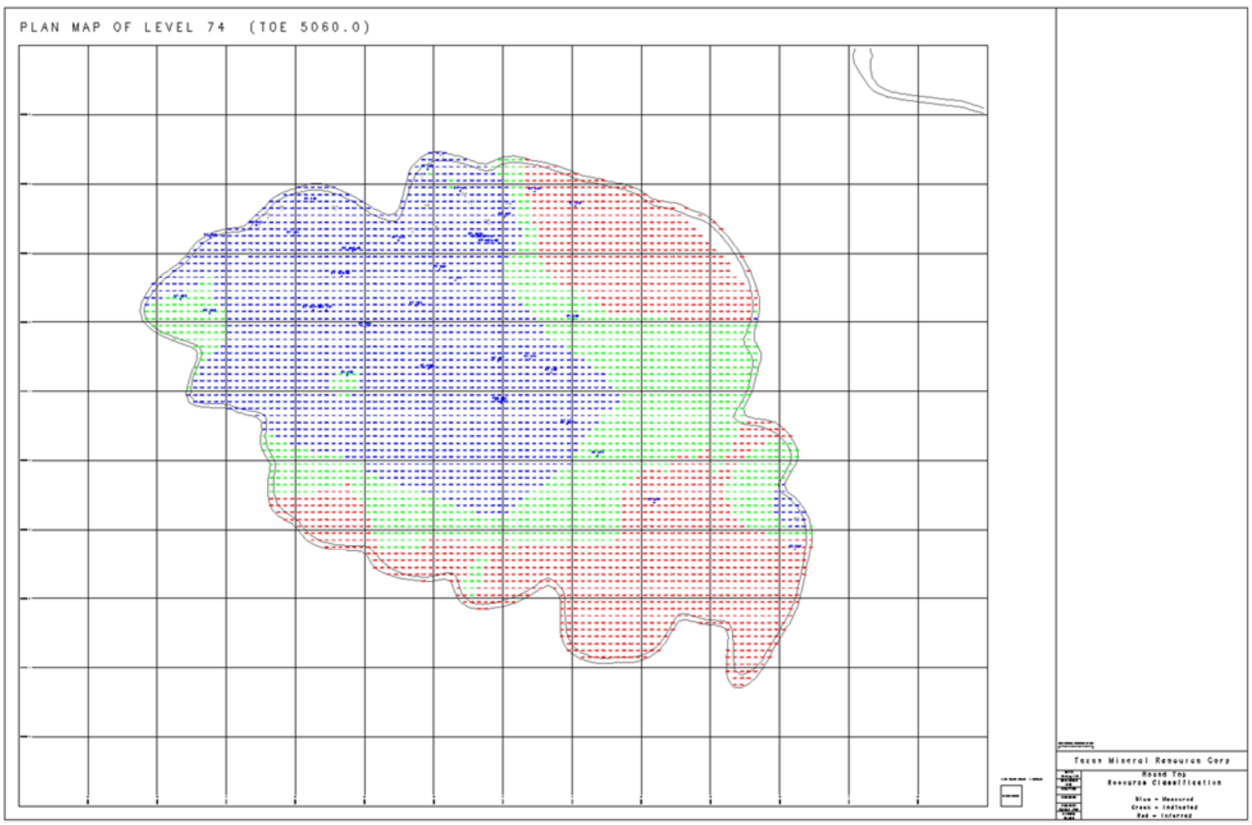


Figure 1-1 Plan View of Resource Classification

1.6 MINERAL RESOURCE TABULATION

The mineral resources are reported using a $16/ton NSR cutoff. The NSR value of each block in the resource model was initially calculated using the 7 most valuable elements. Due to the low geologic variability and high sales values of these 7 elements, all estimated model blocks within the Round Top rhyolite exceed the NSR cutoff, thus continuing to refine the calculation with other elements will only increase the NSR of the mineralized rock. By virtue of the block NSR exceeding the operating cost and with no required waste removal to expose the ore, the entire resource has potential for economic extraction.

Table 1-1 below shows the measured, indicated, and inferred mineral resources estimated within the Round Top Project, with an effective date of July 1, 2019. Quantities are rounded to reflect that these numbers are estimates. Mineral Resources are not Mineral Reserves and do not have demonstrated economic viability. There is no certainty that all or any part of the Mineral Resource will be converted to Mineral Reserves.

Table 1-1 Estimated Mineral Resource of Round Top Rhyolites

	Units	Measured	Indicated	M+I	Inferred
TONNAGE	*Metric Tons (x1000)*	200,000	164,000	364,000	735,000
Dy	*ppm*	30.31	30.41	30.33	29.61
Lu	*ppm*	8.83	8.64	8.79	8.49
Li	*ppm*	462.44	441.12	458.33	445.20
Hf	*ppm*	79.53	78.66	79.36	77.33
Zr	*ppm*	1,106.60	1,093.56	1,104.09	1,049.38
Al	*%*	6.58	6.46	6.56	6.52
K	*%*	3.30	3.28	3.30	3.21
Pr	*ppm*	10.29	10.18	10.27	9.97
Nd	*ppm*	27.91	27.77	27.88	27.55
Sm	*ppm*	10.07	10.04	10.06	9.85
Tb	*ppm*	3.46	3.47	3.46	3.30
Y	*ppm*	214.46	211.92	213.97	195.84
Sc	*ppm*	0.67	0.70	0.68	0.71
U	*ppm*	33.67	23.83	31.77	8.38
Be	*ppm*	32.99	28.64	32.15	18.22
Ga	*ppm*	70.32	46.86	65.80	16.96
Sn	*ppm*	137.73	136.60	137.51	134.94
Nb	*ppm*	175.26	119.87	164.58	46.52
Fe	*%*	1.06	0.97	1.04	0.82
Mg	*%*	0.03	0.02	0.03	0.01
Mn	*ppm*	503.96	334.47	471.28	118.86
Na	*%*	4.02	2.73	3.77	0.95

1.7 MATERIAL DEVELOPMENT AND OPERATIONS

This PEA, including the Round Top mine plan within this PEA, includes inferred mineral resource. Inferred mineral resources are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. No mineral resources in this PEA have been converted to reserves. Mineral resources that are not mineral reserves have no demonstrated economic viability. There is no certainty that the results of this PEA will be realized.

The Round Top mine plan employs a contract miner(s) to perform all mining functions at the site, drilling, blasting, loading, haulage and road maintenance. Typical open pit mining methods will be used, ore will be transported from the pit to a crushing plant located adjacent to the leach pads. A haul road will be pioneered to the top of the mountain and mining will begin at the upper most benches and progress downward. As mining proceeds to lower benches, a haul road will remain in the high wall to allow access to catch berms and additional mining areas. The pit is designed with sufficient area to allow for two separate working benches or faces.

The very nature of how the mineralization sits above regional topography creates a mine with very little waste material or cover. As such there is no waste rock storage facility planned for this project. Any surface material overlying the mineralization within the pit area is expected to be unconsolidated colluvium which will be used as construction materials for leach pads and roads.

The rhyolite will be mined in 20 ft. benches, the recommended height for the class of loader selected. Two 12m^3 wheel loaders will load 90 tonne haul trucks to reach a daily production rate of 20,000 tonnes. The general site layout, including pits, waste dumps, infrastructure, ponds, and heap leach pads, is shown on Figure 16-1.

Detailed geotechnical and hydrological studies have not yet been performed on the project and are recommended during the next stage of the project.

1.8 PIT DESIGN

The initial 20-year pit was designed based on the configuration of the rhyolite laccolith. The REE grades are nearly equal in all parts of the deposit with some small higher grade areas of yttrium. The distribution of petrographic elements is similarly consistent. Based on the resource model, the grades of material fluctuate minimally throughout the mine plan.

The initial 20-year pit was designed to keep all the mining to the northwest portion of Round Top Mountain. It was decided to mine this area first due to the highest drilling density in this area and in order to minimize the visual impact of the mining from the Interstate. Additionally, all the crushing and leaching facilities will be located north of Round top so this will minimize haul distances early in the life of the mine.

Pit slopes have been designed at 45° inter-ramp wall angle. Fracturing within the rhyolite is not yet completely understood and this may affect pit slopes, at least locally. Haul roads are designed at a width of 100 ft., which provides sufficient width for two-way haul traffic and a safety berm. The maximum grade of the haul roads is 10%.

Due to the consistency of REE grades throughout the rhyolite, it is the qualified person's opinion that traditional economic analyses of the pit limit are not meaningful as every block in the model has similar values. The overburden removal required for rhyolite production is minimal. The initial mine plan was developed to remove 20 years of rhyolite from the northwest portion of the hill, proximal to the crushing plant and processing facilities.

The preliminary pit design is shown in Figure 1-2. This pit contains nearly 22 years of production, although only 20 years have been presented in the economic model. A more detailed pit design will be done in future studies.

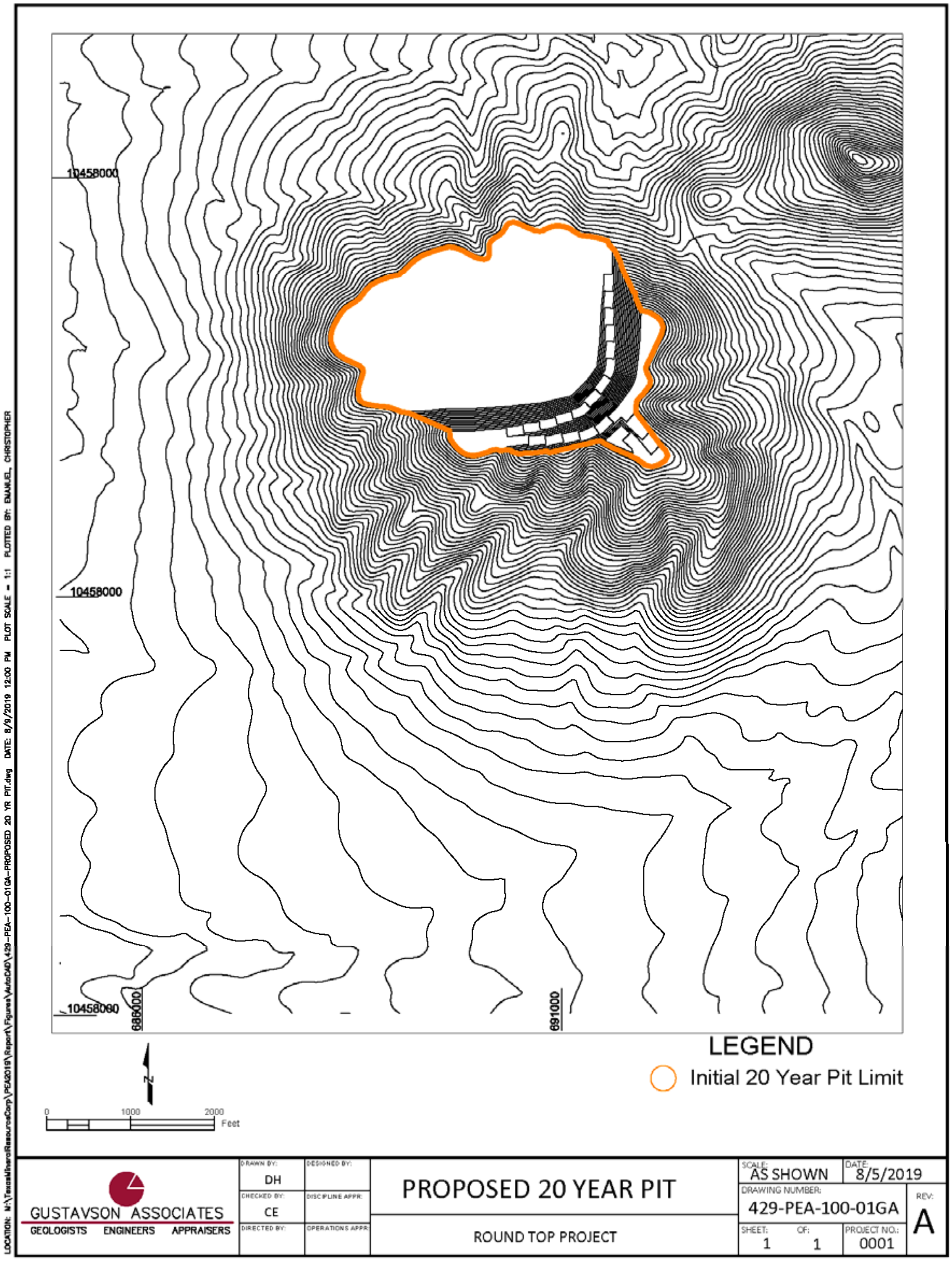


Figure 1-2 Preliminary Pit Design

Table 1-2 shows the material that the mine plan in the PEA assumes will be mined.

Table 1-2 Summary of Material included in the Mine Plan*

		Measured	Indicated	M+I	Inferred
TONNAGE	*Metric Tons (x1000)*	116,400	27,800	144,200	14,250
Dy	*ppm*	29.69	29.84	29.72	29.84
Lu	*ppm*	8.80	8.71	8.78	8.72
Li	*ppm*	446.55	421.80	441.78	436.68
Hf	*ppm*	79.69	79.55	79.66	79.33
Zr	*ppm*	1,115.32	1,135.46	1,119.20	1,108.85
Al	*%*	6.64	6.58	6.63	6.74
K	*%*	3.32	3.36	3.33	3.37
Pr	*ppm*	10.25	10.14	10.23	10.13
Nd	*ppm*	27.75	27.39	27.68	27.32
Sm	*ppm*	9.94	9.83	9.92	9.82
Tb	*ppm*	3.39	3.39	3.39	3.35
Y	*ppm*	212.08	210.97	211.87	209.03
Sc	*ppm*	0.67	0.68	0.67	0.67
U	*ppm*	31.77	31.21	31.66	35.13
Be	*ppm*	36.09	36.13	36.10	32.31
Ga	*ppm*	73.62	73.09	73.52	73.54
Sn	*ppm*	138.86	136.98	138.50	140.01
Nb	*ppm*	186.52	192.35	187.64	192.13
Fe	*%*	1.08	1.09	1.08	1.09
Mg	*%*	0.04	0.04	0.04	0.06
Mn	*ppm*	538.15	539.52	538.41	543.07
Na	*%*	4.21	4.28	4.22	4.10

*** Readers are cautioned that this is not a mineral resource estimate. The mineral resources estimate for the Round Top Project is shown in Table 1-1. Readers are cautioned that this is not a mineral reserve estimate. There are no mineral reserves declared for Round Top at this time.**

Waste products from mine activities include a stream that are expected to show hazardous waste characteristics, and a stream that does not show hazardous waste characteristics. As such, two on-site impoundments are expected to manage the two waste streams.

1.9 INFRASTRUCTURE, CAPITAL AND OPERATING COSTS

Infrastructure to support mining and processing activities (i.e., buildings, roads, water/wastewater systems, power, communication, and fuel) currently do not exist on site. A detailed description of TMRC's plans in respect of project infrastructure is outlined in Section 18.

The estimated unit operating costs for the operation are shown in Table 1-3.

Table 1-3 Operating Expenditures Summary

Item	Cost ($/Tonne)
Mining*	$ 2.67
Crushing & Conveying	$ 0.91
Heap Leach	$ 3.55
Recovery	$ 3.96
Rail Systems	$ 0.23
G&A	$ 1.78
Sub Total	$ 13.11
Contingency (20%)*	$ 2.50
Total	$ 15.61

*Contingency is applied to direct mining portion of the mining cost, but not to capital recovery or contractor profit.

The estimated capital costs for the project are shown in Table 1-4.

Table 1-4 Capital Cost Summary

Area	Initial Capital ($x1000)	Sustaining Capital ($x1000)
Mining Capital	NA*	NA*
Process Capital	$ 201,300	$ 175,600
Infrastructure	$ 25,200	$ 10,100
Pre-Production & Environmental	$ 27,850	$ 15,900
Mine Development	$ 8,350	$ -
Subtotal	$ 262,700	$ 201,600
Indirects, EPCM	*$ 22,000*	
Contingency (25%)	*$ 65,700*	*$ 50,400*
Total	$ 350,400	$ 252,000

*Because the project is planned as a contract mining operation, Mining capital is included as part of mining operating cost.

1.10 ENVIRONMENT AND PERMITTING

Table 1-5 includes a summary of the major federal and state environmental permits that may be applicable to the Round Top Project. An asterisk denotes an authorization that, based on current information, is expected to be required even without further factual and legal evaluation. These permits, including applicability criteria and agency process, are discussed in more detail in Section 20.

Table 1-5 Preliminary Permit Summary

Media	Permit	Agency	When Required
Air	New Source Review Permit to Construct	State TCEQ	Must be obtained prior to the start of construction.
	Title V Federal Operating Permit	US EPA	Application for permit must be filed prior to operating
Water	Construction Storm Water General Permit	State TCEQ	In advance of commencement of construction
	Industrial Storm Water Multi-Sector General Permit (MSGP)	State TCEQ	Prior to start of operation
	Public Water System Authorization	State TCEQ	Approval must be obtained prior to use of non-municipal water as drinking water source
	Water Rights Permit	State TCEQ	Must be obtained prior to using surface water
Operations	Petroleum Storage	TCEQ	Prior to storage of petroleum products on site
	Explosives permit	US Bureau of Alcohol, Tobacco, Firearms, and Explosives	Required prior to storage and use of explosives
Waste	Hazardous or Industrial Waste Management, Waste Streams, and Waste Management Units Registration	State TCEQ	Registration number must be obtained prior to engaging in regulated activity
	EPA ID Number for Hazardous Waste Activity Hazardous Waste Permit RCRA	U.S. EPA through the State TCEQ	ID number must be obtained prior to engaging in regulated activity
	Hazardous Waste Permit (including financial assurance)	State TCEQ	Must be obtained prior to commencement of hazardous waste treatment, storage, or disposal activities.
	Radioactive Material License	State TCEQ	Must be obtained prior to possession of materials containing NORM waste, as defined by THSC 401.003(26)

1.11 ECONOMIC ANALYSIS

The economic evaluation for the Round Top Project used spot metal prices for each product and recoveries for each metal based upon the latest test results and are presented in sections 17 and 19.

This PEA, including the mine plan, is preliminary in nature and includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. There is no certainty that the results of this PEA, including this mine plan, will be realized. Mineral resources that are not mineral reserves have no demonstrated economic viability.

Table 1-5 shows a projected pre-tax 10% net present value (NPV) of $ 1.56 billion. The estimated internal rate of return (IRR) for the project is 70%. Estimated annual pre-tax revenues are $375.4 million.

The life-of-mine capital costs estimate totals $602.4 million, which includes initial capital costs of $350.4million, and sustaining capital of $252 million dollars. Included in the capital costs estimate is a 25% contingency.

Table 1-6 Indicative Economics

	Base Case
Average Annual Revenue ($/yr)	395.5 million
Average Revenue Per Ton ($/T)	$ 54.18
Average Operating Cost ($/T)	$ 15.61
Average Operating Margin ($/T)	$ 38.58
Operating Margin	71%
Pre-Tax Project NPV 10%	$ 1.56 billion
IRR	70%
Payback (years)	1.4

1.12 CONCLUSIONS

The Round Top Project is an Eocene-aged peralkaline rhyolite-hosted REE deposit with a high ratio of HREEs to LREEs. The rhyolite body is a mushroom-shaped laccolith, slightly elongated northwest-southeast and dipping gently to the southwest.

The REEs are primarily contained in the minerals yttrofluorite and bastnaesite, which are very fine-grained and disseminated throughout the rhyolite mainly in microfractures, voids and coatings on predominantly alkali feldspar phenocrysts. There are different levels of alteration within the rhyolite, although analysis shows that the REE grades do not vary significantly with the rhyolite color or alteration. However, the recoveries or the strength and amount of solution required may vary with rhyolite type.

A resource model suggests the deposit contains an estimated measured and indicated resource of 364 million metric tons of mineralized rhyolite, with additional inferred resources of 735 million tons.

Open pit mining methods are proposed with on-site processing facilities employing acid heap leach extraction and a multi-step CIX/CIC and membrane technologies to produce various end products. Heap leach extractions have been demonstrated by bench scale test work, and recovery of REE and principal co-products is based on well-defined industrial processes, although they have not necessarily been proven using leach solutions form Round Top materials.

A preliminary mine plan suggests that part of the resource, containing an estimated 160 million metric tons of material, can be mined and processed according to the assumptions in this report. This material is sufficient for 22 years of mine production at a nominal 20,000 tonnes per day.

The PEA assumes a processing rate of 20,000 metric tons of rhyolite per day or 7.3 million tons per year and analyzes the first 20 years of the mine life. The Base Case NPV at a 10% discount rate is estimated to be $1.56 billion with 70% internal rate of return. The life-of- mine capital costs are projected to be $602.4 million including 25% contingency, which includes initial capital costs of $350.4 million and sustaining capital of $252 million dollars. Details are contained in Table 22-3. Sensitivity cases demonstrate that the project is economically robust under a range of product pricing and processing assumptions.

It is the qualified persons' opinion that the resource and economic model described in this report is suitable for preliminary economic evaluation, and assessment of the potential project viability for determination of advancement of the Project. The PEA results justify completion of additional laboratory scale and pilot scale plant testing and using these results to advance the Project to a pre-feasibility study.

This PEA, including the mine plan, is preliminary in nature and includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. No mineral resources defined in this PEA have been converted to reserves. Mineral resources that are not mineral reserves have no demonstrated economic viability. There is no certainty that the results of this PEA, including the mine plan, will be realized.

Principle risks to developing Round Top include the price and demand for REOs and to Lithium and Sulfate co-products, and finalization of the process flow sheet and its associated capital and operating costs parameters. Although the Round Top deposit is a low grade deposit, it is relatively insensitive to both operating and capital costs.

It will be necessary for TMRC to enter into memorandum of understanding (MOU) or letter of intent (LOI) agreements with intended end users prior to advancing beyond feasibility. The major focus of the MOU/LOI's will be toward the sale of potential CREEs that will be in demand past 2015. Although the Roskill market study shows a solid projected demand accompanying the increasing use of electronics, securing these agreements in advance will provide a measure of protection to the Project revenue.

1.13 RECOMMENDATIONS

1.13.1 General Recommendations

- The project warrants advancement to the feasibility stage based on the results of the PEA.
- Geotechnical and hydrological drilling and study of the proposed leach area and processing plant.
- Bench scale test work to advance metallurgical understanding of the project, followed by pilot heap leach and chemical plant to confirm the continuous operation of the process and generate final Capex and Opex figures for process.
- Conversion of resources to reserves

1.13.2 Geology and Resource Estimation

- The deposit shows extremely consistent mineralization throughout the rhyolite material. The more densely drilled portion of the resource volume is sufficient to support in excess of 20 years of mine life. Accordingly, additional exploration drilling is not recommended at this time, except that if new drillholes are needed for geotechnical determinations, material from these holes could be assayed and that information added to the database.
- There is an outstanding question with regard to Hafnium and Zirconium assays which needs to be addressed. The current chemical analysis appears to be depleted in these two elements. The 2013 analysis provides values that compare well with the values from the column leach tests, thus these values have been used in the estimate. The difference may be gravimetric segregation of the samples over time. This should be reviewed.

1.13.3 Metallurgy and Process Design

To advance the metallurgical and processing understanding of the project, the following bench test work and studies are recommended:

- Optimization of the heap leach process parameters (crush size, acid concentration, leach time PLS concentration, etc.) for optimum extraction of all products (REEs, U/Th, Aluminum Sulfate, Lithium and other sulfates.
- Optimization of the REE separation from impurities and other products (Phase 1), including resins, PLS concentration, etc.
- Optimization of separation of REEs in different groups (Phase 2) followed by separation of individual REE products (Phase 3).
- Develop and optimize process for production of lithium product (carbonate or hydroxide) aluminum sulfate and other sulfate products.
- Process for production of hafnium and zirconium products should be developed and optimized, as these materials have been demonstrated to report to the PLS and show significant economic potential.

Following the confirmation of the process in bench scale testing, run geometallurgical tests with different feed materials (predominantly red-pink vs. grey rhyolite).

Design and implement a 5,000 to 10,000 tonne heap leach test facility and chemical pilot plant to confirm the process flowsheet on a continuous basis and generate data for refining CAPEX and OPEX estimates to a feasibility level.

1.13.4 Geotechnical Exploration

A full geotechnical and hydrological study should be completed for the Round Top Project. Condemnation holes should be drilled and test pits excavated in the areas for the proposed facility and leach site.

1.13.5 Environmental Studies and Mine Planning

As stated in Section 20, monitoring as part of an environmental baseline study may require monitoring over several months or seasons in order to collect representative data. As such, it is recommended that a scope of an environmental baseline study should be determined followed by monitoring.

1.13.6 Market study for Feasibility

An updated market study should be generated, informed by the results of pilot plant test work. This should include identification of specific market partners for the various products at the purity levels produced by the pilot plant, as well as letters of intent or formal offtake agreements when possible.

1.13.7 Feasibility Study

The above recommended work should culminate in the completion of a feasibility study. The qualified persons' recommend continuing development, including various studies needed to advance the project, proceeding through to completion of a feasibility study at a cost of $16.55 million as outlined below. A pilot plant is included in the metallurgical budget. The budget is presented in Table 1-7 below.

Table 1-7 Proposed Budget through Feasibility Stage

Task		**Budget**
Geotechnical Studies	$	400,000
Environmental Studies	$	2,000,000
Metallurgy & Process Design		
Bench Scale Testing & Optimization	$	2,000,000
Pilot Plant	$	2,000,000
Metallurgy and Process Engineering	$	500,000
Heap Leach Contractor Design	$	400,000
Ground Water Wells / Hydrology	$	500,000
Power Evaluation / Power Line Upgrade	$	1,500,000
Pre-Feasibility Study	$	500,000
Feasibility Study	$	1,200,000
Subtotal	$	11,000,000
Project personnel	$	1,450,000
General and Administrative (project only)	$	800,000
Subtotal	$	13,250,000
Contingency 25%	$	3,300,000
Total (with contingency)	**$**	**16,550,000**

1.14 REVISION NOTE

This version of Round Top PEA, designated August 16, 2019; Rev A is revised from the previous version. Certain tables within the report have been updated to clarify the units displayed.

2 INTRODUCTION

2.1 TERMS OF REFERENCE AND PURPOSE OF THE REPORT

Gustavson Associates, LLC (Gustavson) was commissioned by USA Rare Earth LLC (USRE) to prepare a Preliminary Economic Assessment (PEA) for the Round Top Project (or the Project) located in Hudspeth County, Texas, U.S.A. The Round Top Project is owned by Texas Mineral Resources (TMRC), (formerly TRER), and is subject to a joint-venture and option agreement between USRE and TMRC, with USRE as the operating partner.

The purpose of this report is to present the findings of economic assessment in accordance with Canadian National Instrument 43-101 Standards of Disclosure for Mineral Projects (NI 43-101), NI 43-101 Form F1, and Canadian Institute of Mining, Metallurgy and Petroleum (CIM) "Best Practices and Reporting Guidelines." The effective date of this report is July 1, 2019.

In 2013, Gustavson Associates prepared a PEA report for the Round Top project for Texas Rare Earth Resources (TRER), which was subsequently renamed as Texas Mineral Resources (TMRC). TMRC will be used to refer to this entity throughout this document.

2.2 QUALIFICATIONS OF QUALIFIED PERSONS

Mr. Donald Hulse, P.E., SME-RM V.P. and Principal Mining Engineer for Gustavson, is a Qualified Person as defined by NI 43-101. Mr. Hulse acted as project manager during preparation of this report and is specifically responsible for report Sections 1 through 6, 14, 15, 16, and 18, and for the overall content of the report. Mr. Hulse is independent of TMRC and USRE.

Mr. Deepak Malhotra, PhD, SME-RM, President of Resource Development, Inc. (RDi) is a Qualified Person as defined by NI 43-101. Mr. Malhotra is specifically responsible for report Sections 13, 17 and the process costs portion of Section 20. Dr. Malhotra is independent of TMRC and USRE.

Mr. Thomas Matthews, MMSA Q.P., Principal Resource Geologist for Gustavson, is a Qualified Person as defined by NI 43-101 and is specifically responsible for report Sections 7-12, 19, and 22 through 26. Mr. Matthews is independent of TMRC and USRE.

Mr. Christopher Emanuel, SME-RM, Senior Mining Engineer for Gustavson, is a Qualified Person as defined by NI 43-101 and is specifically responsible for section 16, the mining costs portion of section 20, and section 22. Mr. Emanuel is independent of TMRC and USRE.

2.2.1 Details of Personal Inspection

Mr. Matthews visited the property on July 9, 2019 where he toured the property, reviewed surface geology, inspected drill core and reviewed RC sample inventory, and assessed infrastructure of the project.

Dr. Malhotra most recently visited the property on July 9, 2019 where he toured the property and reviewed sites available for locating processing infrastructure and pilot plant test locations.

Mr. Hulse visited the property on September 18, 2013 where he also toured the property, inspected drill core, and assessed the infrastructure of the project.

2.3 CONTRIBUTING AUTHORS

Mrs. Amanda Irons, Geologist with Gustavson Associates, contributed writing and text editing, assisted with database preparation and resource estimation, and prepared various figures and compilation and presentation of statistics for the report.

Mr. William Crowl, SME-RM, Associate Principal Geologist with Gustavson contributed peer review of the document.

Mr. Dan Gorski of TMRC provided detailed review and commentary on the document and the various financial models and information.

2.4 SOURCES OF INFORMATION

The information, opinions, conclusions, and estimates presented in this report are based on the following:

- Information and technical data provided by TMRC;
- Review and assessment of previous investigations;
- Assumptions, conditions, and qualifications as set forth in the report; and
- Review and assessment of data, reports, and conclusions from other consulting organizations and previous property owners.

These sources of information are presented throughout this report and in Section 27 – References. The qualified persons are unaware of any material technical data other than that presented by TMRC.

2.5 UNITS OF MEASURE

All measurements used in this report are in presented in the metric system, except those maps that are in Texas State Plane – feet as required by the State of Texas for permitting purposes, unless otherwise specified, and all references to dollars are constant 2019 United States dollars.

3 RELIANCE ON OTHER EXPERTS

The qualified persons relied on information provided by TMRC regarding property ownership and mineral tenure (Sections 1.1, 4.2.1 and 4.2.3). The qualified persons have not independently verified the status of the property ownership or mineral tenure.

Mr. Dan Gorski of TMRC performed the research underlying section 19 of this report. Mr. Matthews has verified the information and references provided.

4 PROPERTY DESCRIPTION AND LOCATION

4.1 PROPERTY LOCATION

The Round Top Project is located in Hudspeth County, Texas. The nearest town, Sierra Blanca, Texas, is approximately 8 miles to the northwest. Sierra Blanca, the county seat of Hudspeth County, is at the intersection of Ranch Road 1111, Interstate Highway 10, and 85 miles southeast of El Paso in the south-central part of the county. It is also at a junction of two main branches of the Union Pacific Railroad. The approximate center of the Round Top Project is located at 31.2766° N, 105.4742° W. Figure 4-1 shows the location of the Round Top Project within Texas.

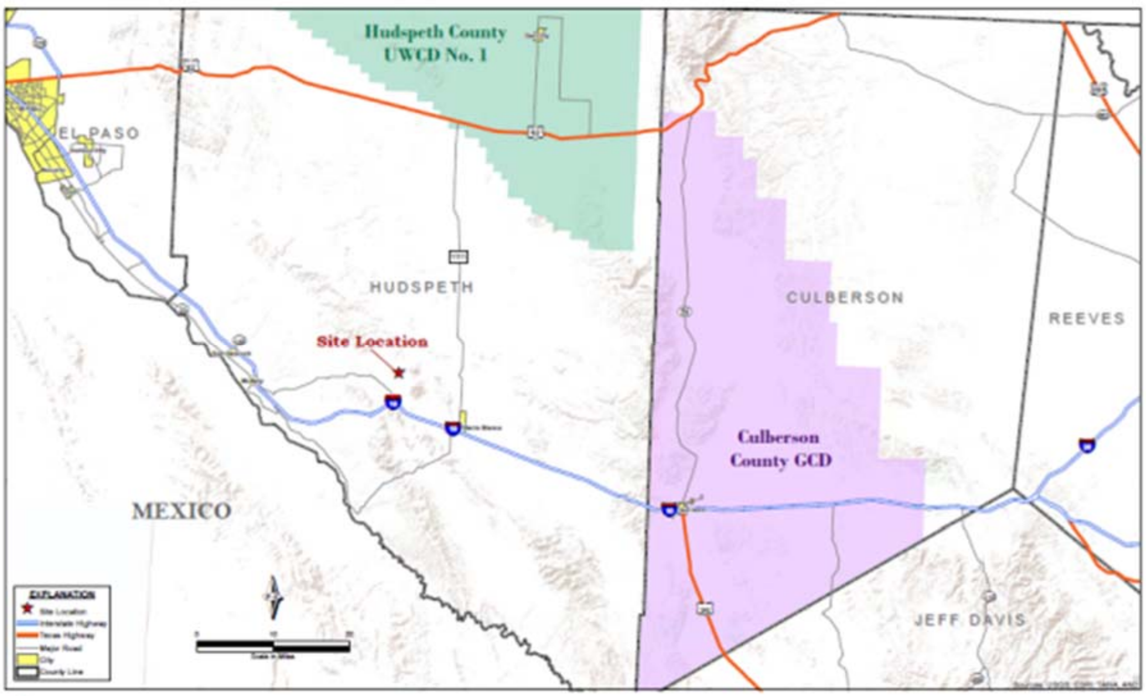


Figure 4-1 Location Map of Project Area

4.2 MINERAL TENURE, AGREEMENT AND ROYALTIES

4.2.1 Mining Leases

TMRC entered into a 19-year renewable Mining Lease Agreement (M-113117) with the GLO dated September 2, 2011, and amended March 29, 2012 in accordance to Chapter 53, subchapter B of the Texas Natural Resource Code. TMRC has also entered into an additional 19-year renewable Mining Lease (M-113629), dated November 1, 2011, with the GLO. Leases M-113117 and M-113629 (each a Mineral Lease and together, the Mineral Leases) represent approximately 860 and 90 acres, respectively, for a total of 950 acres in the project area, which would include the potential pit boundaries. The Mineral Leases provide TMRC with the full use of the property identified, including all rights with respect to the surface and subsurface for any and all purposes, together with the rights of ingress and egress for the purposes of mineral exploration, development, and exploitation of minerals.

The compensation pay schedule for the Mineral Leases is summarized below:

Table 4-1 Summarized Lease Agreements Pay Schedule

M-113117	
Anniversary Date 2013 -2014	$44,718.30
Anniversary Date 2015-2019	$67,077.45
Anniversary Date 2020-2024	$134,154.90
Anniversary Date 2025-2029	$178,873.20
M-113629	
Anniversary Date 2013-2014	$4,500.00
Anniversary Date 2015-2019	$6,750.00
Anniversary Date 2020-2024	$13,500.00
Anniversary Date 2025-2029	$18,000.00

Payments under the Mineral Leases represent rental and are intended to cover the privilege of deferring commencement of production. TMRC shall have a minimum advance royalty of $500,000.00 immediately upon sales of leased minerals in commercial quantities. Thereafter the royalty will become payable on or before the anniversary date of the Mineral Lease.

4.2.2 Royalty

The Mineral Leases contain a 6.25% statutory production royalty of market value of all minerals.

The royalty calculation contained in the Mining Lease and as agreed to in principle with the GLO is calculated based on

Royalty = 6.25% * (Gross Sales Revenue)

Under certain conditions, payment of the royalty may be adjusted to reflect all or a portion of processing costs at the discretion of the GLO commissioner. The above royalty calculation has not been finalized and therefore, in the economic section of this study a straight 6.25% royalty was taken on total gross revenue without subtracting any of the processing costs.

4.2.3 Surface Leases/Ownership

In an agreement dated March 6, 2013, TMRC purchased the approximately fifty-five thousand acres of fully paid up surface lease known as the West Ranch from the Southwest Range and Wildlife Foundation (Sentinel Mountain Associates, L.P.) (State of Texas Surface Lease SL 20040002). This lease covers the Option area and the area to the west. The area immediately to the east of the Project is also held by the Sierra Blanca Ranch LLC (Surface Lease SL 20060006).

Figure 4-2 identifies the approximate boundaries of the TMRC lease SL 20040002 (green) and 20060006 (blue).

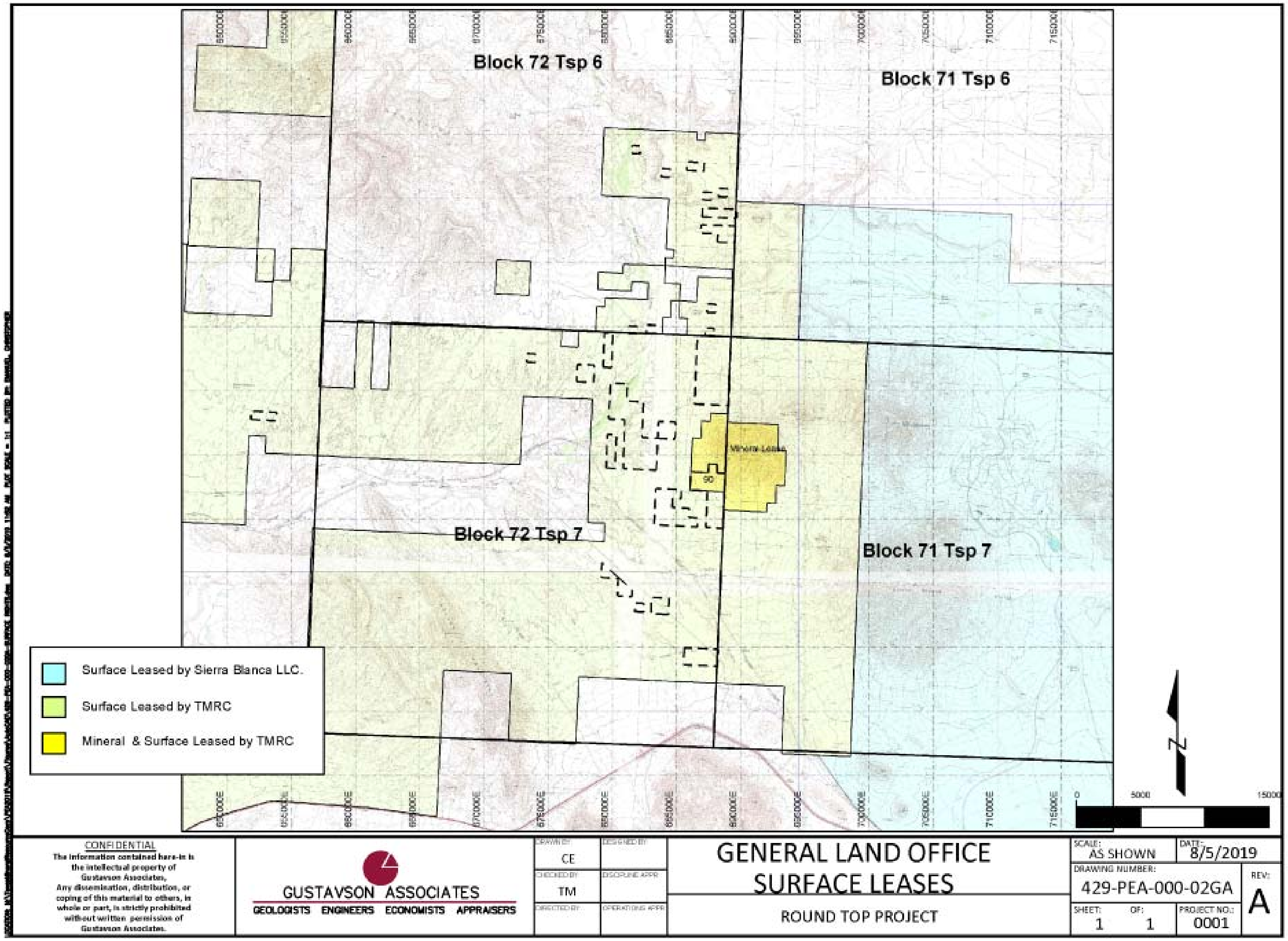


Figure 4-2 Surface Leases Adjacent and Including Round Top

TMRC is in the process of developing a plan to acquire more private land owners' surface rights that may be required for the development of the project, and believes it is a reasonable expectation that it will be able to acquire such surface rights prior to the completion of a feasibility study.

4.2.4 Surface Option Area

In a term sheet transmitted November 22, 2013, the conditions of an option agreement (Option Agreement) are defined. This option agreement will provide TMRC the option, at the time of its choosing, to purchase the surface acreage necessary to conduct its mining and processing operations. Figure 4-3 shows the surface option agreement.

4.2.5 Prospecting Permits

TMRC previously held 13 prospecting permits covering land in Hudspeth County. The prospecting permits allowed for exploration activities on approximately 7110 acres. Exploration activity is not currently being carried out and therefore the prospecting permits have been allowed to lapse. It is anticipated that the prospecting permits could be renewed in due course in advance of any additional exploration activities if required.

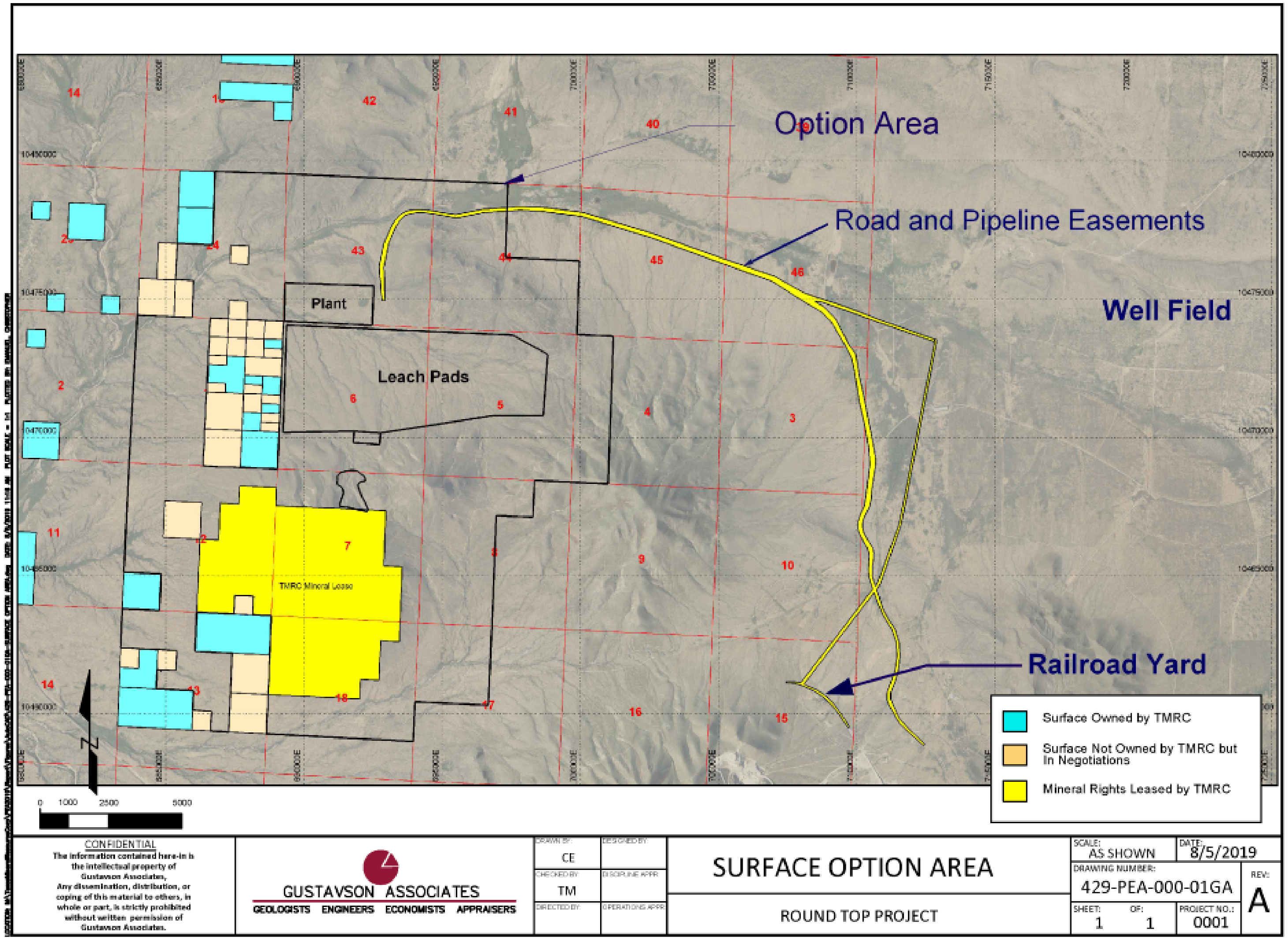


Figure 4-3 Surface Option Area

4.3 ENVIRONMENTAL LIABILITIES

The Round Top Project rhyolite has not been mined and has no known existing mining-related environmental liabilities. Drill roads and pads will be reclaimed in accordance with the GLO requirements and Texas Commission on Environmental Quality requirements. There is an existing adit in the Buda Limestone underlying the rhyolite from earlier beryllium exploration; however, there are no effluent flows from the adit, and no existing surface waste piles.

The permitting schedule for the Round Top Project may be influenced by the National Environmental Policy Act (NEPA) process due to the placement of a leaching facility if the drainage for the leaching facility is a “jurisdiction” drainage governed by the U.S. Army Corps of Engineers (USACE). NEPA typically requires baseline studies for at least one year, followed by a public review and comment period for scoping and development of an environmental assessment or environmental impact statement. Other anticipated permitting requirements include mine registration, air, ground and surface water, explosives, and utility location.

Proposed mining projects are typically evaluated for a range of social, economic, cultural, and environmental impacts in response to NEPA and state permitting regulations.

Environmental liabilities and permitting are discussed in greater detail in Section 20.

At this time there do not appear to be any other significant factors and risks that may affect access, title, right, or ability to perform work.

4.4 USA RARE EARTH / TMRC AGREEMENT

On August 28, 2018, TMRC executed an option and development agreement with Morzey Pty. Ltd., an Australian corporation, whereby Morzev could acquire a 70% interest in the project by completing a “Bankable Feasibility Study.” The agreement calls for the expenditure of $10,000,000 by Morzev after which any further expenses would be allocated pro-rata. After the feasibility study is complete, Morzev has the option of purchasing an additional 10% of the project by paying TMRC $3,000,000. On July 16,2019, Morzev nominated USA Rare Earth LLC, a Delaware Limited Liability Company, as Optionee.

5 ACCESSIBILITY, CLIMATE, LOCAL RESOURCES, INFRASTRUCTURE AND PHYSIOGRAPHY

5.1 ACCESSIBILITY

The Round Top Project is located approximately 8 miles northwest of the town of Sierra Blanca, Texas. The site is accessed from Interstate 10 through a series of paved and unimproved dirt roads. The property is not traversed by county roads and consists of a series of graded and primitive jeep roads. The nearest major airport is located in El Paso, Texas, 88 miles to the northwest. The site is approximately 3 miles north of Interstate 10. A railroad line is located approximately one to three miles from the Round Top Project and a spur line stops at a stone quarry within three miles of the Round Top Project.

5.2 TOPOGRAPHY, ELEVATION, VEGETATION AND CLIMATE

The Sierra Blanca area is considered semi-arid with generally mild temperatures. The prevailing winds are from the southwest. The average year-round temperature is approximately 62.6° F, average annual precipitation is 10.41 inches, average annual snowfall is 1.01 inches, and average annual wind speed is approximately 13.90 mph. The elevation of the Round Top Project ranges from approximately 4,000 feet to approximately 6,890 feet, and slopes are moderately steep on the sides of the Sierra Blanca Peaks. The moderate climate and minimal rainfall in the Sierra Blanca region should allow the mine to operate year-round.

The area surrounding the Project consists of sandy soils and clump grasses mixed with desert vegetation. Desert vegetation consists of high chaparral grass, grease wood, mesquite shrubs, cactus, and other shrubs and brush. Yucca plants are common on the surrounding property.

5.3 LOCAL RESOURCES AND INFRASTRUCTURE

The nearest population center to the Project is Sierra Blanca, Texas. The town of Sierra Blanca is approximately eight miles to the southeast of the Round Top Project site. The population was 533 in 2000 and 553 during the 2010 census. Skilled mining labor and support could be found in the El Paso area and in the mining areas of New Mexico and Arizona.

5.3.1 Rail Access

A major rail line parallels Interstate 10 approximately three miles west and south of the mine site. Approximately three miles from the Project site is a commercial rock quarry in operation which produces ballast for the railroad. The rock quarry operation has a rail road spur which is approximately three miles from the Project.

5.3.2 Power

Power is currently supplied to Sierra Blanca by El Paso Electric Company. El Paso Electric has approximately 1,643 megawatts of generating capacity. The existing line into Sierra Blanca is scheduled to be upgraded by El Paso Electric.

5.3.3 Water

Water for the project is planned to be supplied by a well-field located some 3 miles east of the plant site. There are four existing wells in this area. The wells were drilled in the 1970's as part of a land development scheme that failed. It is reported by verbal communication with various individuals, that these wells were intended to water the golf course and that two of them tested 900+ and 400+ gallons per minute respectively. Data obtained to date suggests that this water supply is adequate to supply the proposed heap leach operation. On June 21, 2019, TMRC made the lease payments to the GLO on ground water lease SL20150003 covering 13,120 acres. The principal aquifer in this area is the Cretaceous Cox sandstone. The regionally prolific Permian carbonate rocks at depth have not yet been tested. Figure 5-1 shows the location of the existing wells and the area to de developed. The quality of the water is expected to be adequate for process water needs and the water will require treatment to be potable.

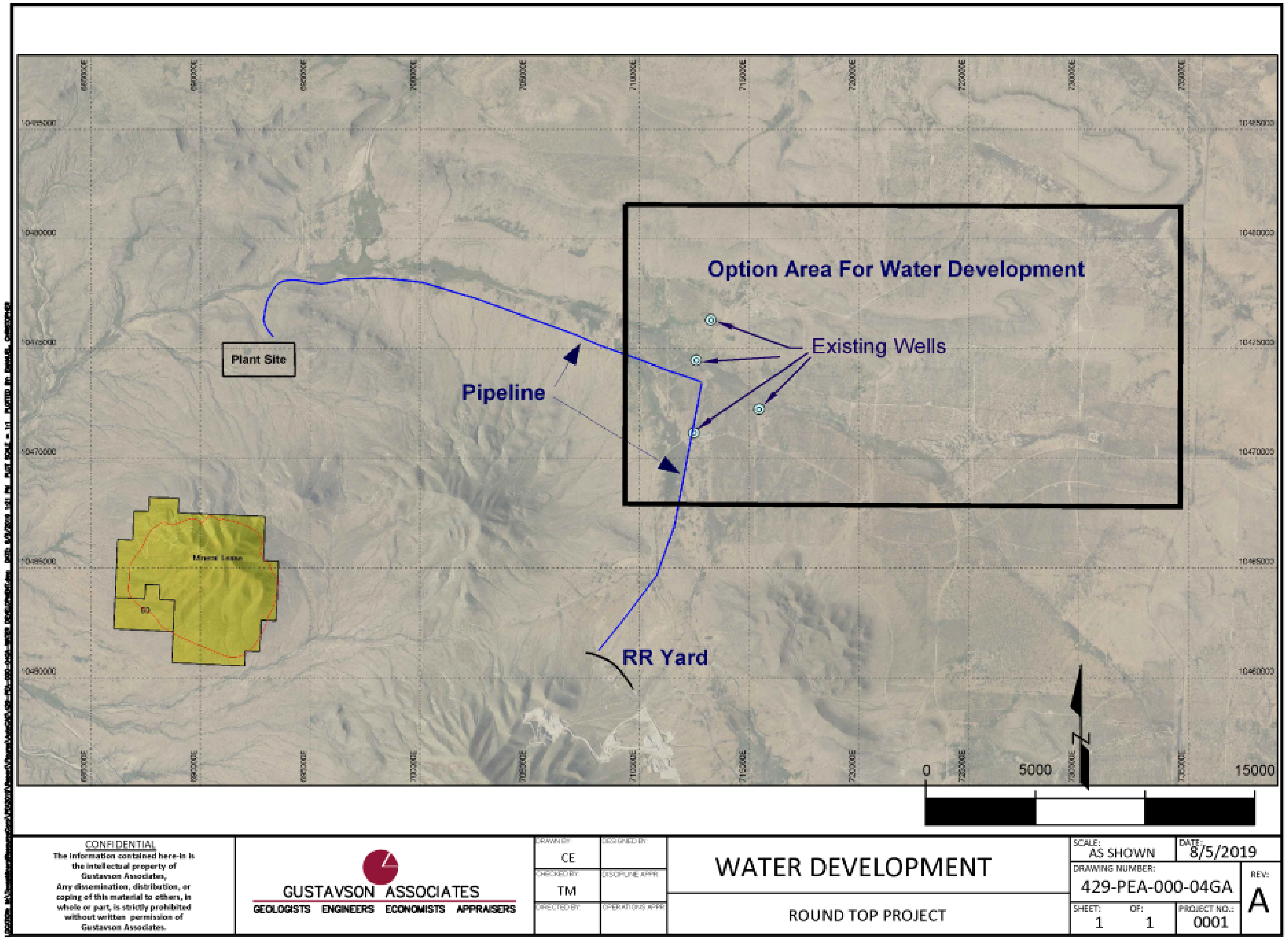


Figure 5-1 Potential Water Sources for Round Top Project, 2012

5.3.4 Natural Gas

Located approximately 28 miles to the north of the Round Top Project area is a transcontinental natural gas pipeline. The pipeline, with an eight-inch diameter pipe, is owned and operated by El Paso Natural Gas. The pipeline allows for the Project to consider utilizing an off take from the pipeline to the plant site for heating and other processing options. The use of the natural gas versus a propane system on site will need to be evaluated further. Expected uses of the propane/natural gas would be for heating the administration and process mine facilities, as well as for other processes requiring the input of energy. No large demand propane or natural gas fuel requirements are foreseen. Capital assessment assumes propane fuel basis.

6 HISTORY

Documented exploration began in Sierra Blanca in the 1970s when W.N. McAnulty initiated trenching and limited drilling of fluorite deposits in the vicinity of Sierra Blanca, Texas. McAnulty recognized and identified beryllium mineralization associated with the massive fluorite. Adverse economic conditions for fluorite precluded development. In the 1970s, several uranium companies identified anomalous radiation and associated mineralization associated with the beryllium-fluorite deposit.

During the 1980s, Cabot Corporation (Cabot), a large chemical company with a beryllium fabrication division, initiated exploration at Round Top for beryllium. In 1987, Cyprus Metals Company (Cyprus) entered into a joint venture with Cabot and took over the Project. The Cyprus exploration program drilled Sierra Blanca, Round Top and Little Round Top. Eventually, Cyprus focused on the Round Top Project, specifically the "west end ore zone". Extensive development drilling (82,000 feet), underground exploration drift (1,115 feet) and trial mining resulted in the completion of a feasibility study in June 1988 (Cyprus Sierra Blanca, Inc., 1988).

During the Cabot-Cyprus development project, the Texas Bureau of Economic Geology (BEG) conducted extensive research at Round Top and the surrounding area. The study identified beryllium mineralization and REE mineralization in the rhyolite. The research resulted in the three publications, one in 1987 on the mineralogy of the rhyolite (Rubin, et al., 1987), another in 1988 on the beryllium mineralization (Rubin et al., 1988), and another in 1990 on the detailed mineralogy and geochemistry of the rhyolite (Price et al., 1990). The 1990 Price, et al., publication, Geological Society of America Special Paper 246, is the most complete publication on Round Top.

In late 2007, Standard Silver Corporation, later to be renamed TRER in 2010, and then TMRC in 2013, acquired prospecting permits from the GLO. In 2008, upon opening the mine, approximately 76 pallets, each containing six plastic barrels of catalogued and packed Cyprus drill samples, were found. These samples were well labeled and Standard Silver (TMRC) had acquired from the GLO many of the drill logs from these holes. They were relogged extensively and analyzed as part of this report.

6.1 HISTORICAL RESOURCE ESTIMATES

Cyprus established a non-reported resource of 300,000 tons of BeO in conjunction with a 1988 internal feasibility study. This historical resource estimate would not qualify as a resource by 43-101 standards and was not considered in the present study.

In 2012, TMRC completed a PEA prepared by Gustavson Associates on the Round Top deposit (NI 43-101 Preliminary Economic Assessment – Round Top Project, June 22, 2012). The resource model in that PEA was updated in early 2013 with additional drilling and assay data and was documented in a resource statement by Gustavson Associates (Resource Estimate and Statistical

Summary – Round Top Project, September 30, 2013). The 2013 PEA was an update of the 2012 PEA and utilized the resource estimate from the September 2013 study.

The 2013 PEA is superseded by the present document. Neither USRE nor TMRC make any representation that any historical or superseded resource estimate is a current mineral resource estimate for the project.

6.2 HISTORICAL PRODUCTION

There is no known significant production reported from previous operators.

7 GEOLOGICAL SETTING AND MINERALIZATION

7.1 REGIONAL GEOLOGY

Regional geology is described by Price et al. (1990) and McAnulty (1980) and is summarized here from those two references. Geologic units exposed in the project area comprise Cretaceous sedimentary rocks, Tertiary igneous rocks and Quaternary alluvium.

Sedimentary rocks exposed in the Trans-Pecos region are Cretaceous marine and littoral deposits of the upper Comanchean and lower Gulfian Series. These sedimentary deposits are transgressive clastics and neritic carbonates that were deposited along the northern edge of the Chihuahua trough and on the southern margin of the Diablo Platform. The regional stratigraphy is shown in Figure 7-1.

Tertiary intrusive rocks include Eocene diorite and rhyolite. Round Top Peak is part of the Sierra Blanca rhyolite laccoliths and lies within the Trans-Pecos region or Texas Lineament Zone. The Trans-Pecos region is characterized by three geologic episodes - Laramide thrusting and folding, subduction magmatism, and Basin and Range crustal extension.

Laramide deformation started in the late Cretaceous and ended in the early Eocene. Deformation was caused by east-northeast compression and resulted in dominantly north-northwest-trending folds and thrusts. The folds and thrusts extend from Chihuahua, Mexico to the east and northeast to the Sierra Blanca area. Lying near the frontal thrust of this Chihuahua tectonic belt are the Sierra Blanca intrusions.

From middle Eocene to early Oligocene time, approximately 48 to 32 Ma, widespread magmatism occurred in the Trans-Pecos region. Dikes and faults with an east-northeast-strike dominate the region and suggest a continuation of the east-northeast Laramide maximum principal stress direction. Igneous rocks that were intruded during this episode have alkali-calcic and alkaline compositions. Based on these two compositions, the region is divided into a western alkali-calcic belt and an eastern alkaline belt. Lying within the alkali-calcic belt are the Sierra Blanca laccoliths, which include Round Top Peak. The Sierra Blanca laccoliths were intruded about 36 Ma, during the main Trans-Pecos magmatism phase.

Basin and Range extension and region-wide normal faulting began about 31 Ma. This extension and related minor volcanism postdate the intrusion of the Sierra Blanca laccoliths.

7.2 LOCAL GEOLOGY

The five mountains: Triple Hill, Sierra Blanca Peak, Little Blanca, Round Top, and Little Round Top, form the Sierra Blanca. They were intruded into Cretaceous age sedimentary rocks. The peaks are widely covered by colluvium and surrounded by alluvium but the Cretaceous rocks can be seen in arroyos along the flanks of the mountains and in outcrop to the north of the peaks. Buda

Limestone, the Del Rio shale, Espy limestone, Benevides formation, Finlay limestone and Cox sandstone are exposed at the surface in the Sierra Blanca Peaks area. Numerous titanium-rich hornblende-porphyry diorite dikes and sills are exposed along the flanks of the peaks and in localized areas of thin alluvium cover. The age of these dikes is about 48 Ma (Early Eocene), which predates the main phase of felsic magmatism (Price et al., 1990).

The rhyolite laccoliths cut and altered the diorite dikes and sills. The fine grain size and presence of vesicles in the rhyolite suggests near-surface intrusion. The age of the Sierra Blanca rhyolites is estimated to be 36 Ma (Late Eocene) based on one K-Ar date. Uplifted sedimentary cover was eroded from the tops of the Sierra Blanca laccoliths leaving the present surface expression of the peaks (Price et al., 1990).

The bases of the intrusive bodies are undulating and in contact with several different formations. Some of the rhyolite intrusions may be floored by a shallow thrust fault that truncates underlying Cretaceous sedimentary rocks. Strata on the flanks of the laccoliths are steeply dipping due to deformation from the underlying intrusion (McAnulty, 1980).

7.3 PROPERTY GEOLOGY

The Round Top Peak laccolith was intruded into Cretaceous age Washita and Fredericksburg Groups. The Cretaceous sediments were domed upward by the rhyolite intrusion and later eroded, exposing the Round Top Peak rhyolite. Sedimentary rocks exposed on the surface flanking Round Top Peak consist of the Buda Limestone and Del Rio clay and Espy limestone formations of the Washita group and the Benevides formation, Finlay limestone and Cox sandstone of the Fredericksburg group.

The rhyolite is cut by a set of faults that generally strike northwest and dip steeply southwest. Normal separation has been noted on some of these faults, but the orientation with respect to other regional faults suggests they may primarily be right-lateral strike-slip faults. The rhyolite is highly brecciated and moderately altered along these zones.

7.3.1 Stratigraphy

Figure 7-1 is a stratigraphic section of the Round Top area and Table 7-1 is a description of the strata immediately adjacent to the rhyolite.

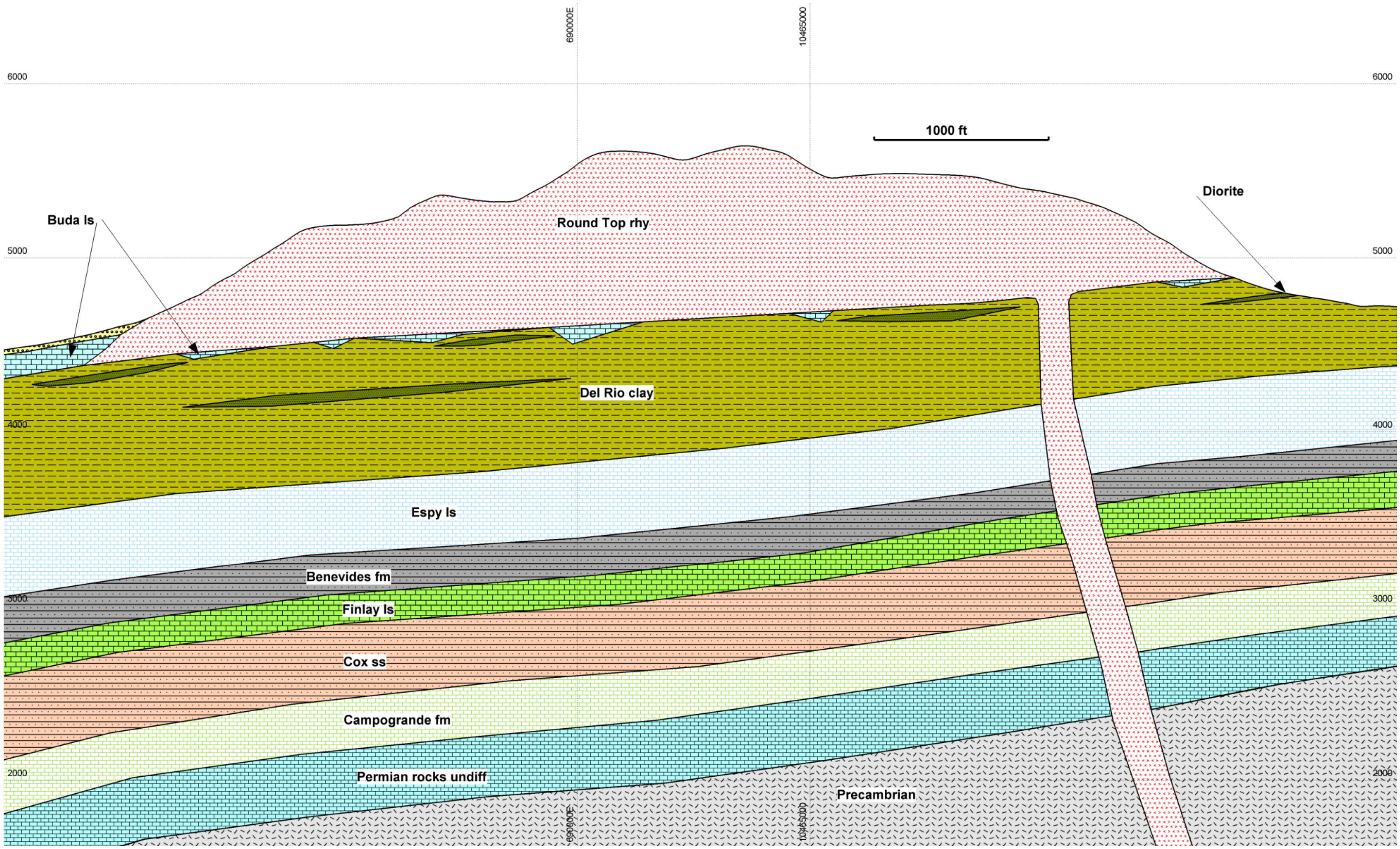


Figure 7-1 NW-SE Section Looking NE Through Round Top Mountain Showing the Underlying Sedimentary Rocks
(Source TMRC)

Table 7-1 Sedimentary Formations in the Round Top Peak Project Area

Formation	Age	Description
Gravel	Quaternary	Mixture of limestone, sandstone, intrusive rocks and conglomerate. Sand to boulder size, angular to sub-angular grains.
Buda Limestone	Cretaceous	Micritic limestone with thin shale partings and nodular limestone with fossil oysters.
Del Rio	Cretaceous	Dominated by olive brown to black fissile shale, with micritic limestone interbeds. Near the top of the formation is a massive limestone unit overlying a quartz sandstone bed.
Espy Limestone	Cretaceous	Gray nodular limestone interbedded with marl and shale.

Quaternary

Quaternary units in the project area are represented by colluvium and alluvium deposits. The lower slopes of Round Top Peak are covered with colluvium and talus slopes. Surrounding the mountain is Quaternary age alluvium. This alluvium is divided into two formations, the Madden and Balluco Gravels (Albritton and Smith, 1965). Near the flanks of the peak, these two formations contain abundant fragments of different colored rhyolite that eroded from Round Top Peak. In addition to the rhyolite, limestone, sandstone, and diorite are also present. The alluvium and colluvium are now being dissected and exposed in arroyos.

Tertiary

Tertiary rocks in the project area are represented mainly by the rhyolite intrusions, though the diorite dikes are also thought to be Tertiary in age. Round Top Peak is likely the youngest intrusion in the project area. The age of the rhyolite intrusions, ~36.2 Ma, is represented by one K-Ar date on an annite-rich biotite from Sierra Blanca Peak (Price et al., 1990).

Table 7-2 is a representative whole-rock analysis of the Round Top rhyolite. It contains >72% SiO_2, >10% Na_2O+K_2O and > 1% fluorine. The rock contains modal cryolite (Na_3AlF_6) and normative acmite and Na_2SiO_3 and can be classified as a peralkaline-cryolite rhyolite. The rhyolite has a fine-grained, microporphyritic texture consisting of quartz, alkali-feldspar, and Li-mica phenocrysts in an aphanitic groundmass. The cores of the alkali-feldspars consist of Na-plagioclase or albite, and the Li-mica is zoned with a brown interior grading outward to clear on the crystal margins. Cryolite occurs as discrete grains intergrown with groundmass quartz and as inclusions in quartz overgrowths on phenocrysts. Cryolite can also occur as clear crystals coating fractures and locally cementing rhyolite breccias. Rutilated quartz is also present and occurs in association with the cryolite as intergrowths.

The color of the rhyolite varies, and recent drill data indicates five different colors of rhyolite which indicate five alteration phases: gray, pink, red, tan, and brown. These different rhyolite colors represent different degrees of alteration that took place during the later stages of crystallization. The pink and red colors are caused by the increasing replacement of magnetite by hematite. The tan and brown coloration in the rhyolite indicates most of the iron has been removed or altered to goethite and/or limonite. The feldspars in the tan rhyolite are replaced by kaolinite, and in isolated locations this alteration phase can have fluorite-filled fractures. The gray rhyolite is essentially unaltered and has variable magnetite content. The gray, pink and red colored zones are generally tens to hundreds of feet thick and laterally extensive. Some of the rhyolite displays flow-banding with gray (unaltered) and pink (hematite altered) alternating bands. Some of the red rhyolite contains beige and gray discontinuous bands associated with microfractures. There is a crude vertical zonation with gray rhyolite predominating at the top of the laccolith, red and pink rhyolite predominating in the central zone of the body and gray and tan rhyolite mostly confined to the base of the rhyolite. Initial geochemical test work, based on a small number of composites and presented in Section 13, suggests that the gray and pink rhyolite units have a higher REE content, though the difference is subtle and in the current multi-element the REE's have a smaller influence on the project economics.

Cretaceous strata within the project area are cut by diorite dikes and sills that have an age of 48 Ma (McAnulty, 1980). These diorite intrusions were emplaced during a magmatic episode that took place after compressional folding in the Trans-Pecos region. On Round Top Peak, the diorite dikes and sills are exposed in bulldozer cuts on the flanks and along the back of the exploration decline on the north side of the mountain. They vary in thickness from under 2 feet to over 100 feet thick. In some locations, the sills are in direct contact with the rhyolite and are partially replaced and veined by fluorite. In addition to surface exposures, drill data indicates the rhyolite is locally in direct contact with the diorite sills, suggesting the rhyolite intrusion followed the pre-existing diorite intrusion pathways.

The dikes and sills are described by Price et al. (1990) to be a titanium-rich hornblende-porphyry diorite. Other investigators describe the rock type to be diorite (McAnulty, 1980). Albritton and Smith (1965) describe the dikes and sills as having a variable composition consisting of andesite, hornblende-andesite porphyry, and latite porphyry. Within the project area, the sills encountered during drilling and exposed in bulldozer cuts appear to be a hornblende-porphyry diorite.

Cretaceous

Formations represented by the Cretaceous Washita Group are exposed on the surface in drainages and on the flanks of Round Top Peak. The youngest Washita Group formation in the project area is the Buda Limestone. The Round Top rhyolite intruded along the contact of the Buda and the underlying Del Rio. Apparently, most of the Buda was wedged upward by the rhyolite but some blocks remain below the rhyolite contact. The Buda limestone, when present below the rhyolite, is the host of replacement beryllium/fluorite bodies and was the target of the Cabot/Cyprus exploration program in 1984-1988. Outcrops of Buda Limestone on the northern slope of Round Top Peak present as a micritic limestone interbedded with thin shale partings. Fossil oysters are found in the micritic limestone beds.

On the north side of the Round Top laccolith, the Del Rio Formation is exposed in a deep arroyo. The Del Rio Formation is also exposed on the east and south slopes of the peak. The exposed section is composed of olive brown shale with interbeds of quartz sandstone and nodular limestone. The olive brown shale grades into a black shale with depth. Drilling shows the Del Rio Formation is in direct contact with the overlying Round Top rhyolite. Under the rhyolite intrusion, the Del Rio is a black to brown shale or black fine-grained sandstone.

North of the project area the Espy limestone, Benevides formation, Finlay limestone and Cox sandstone can be found in outcrop. The Espy is a well-bedded gray, nodular limestone with interbedded marl and shale. The Benevides formation consists of interbedded brown to buff sandstone, cream to tan shale with thin interbeds of gray limestone. The Finlay limestone is a massive bedded gray fossiliferous limestone. The Cox is a coarse to fine sandstone with interbeds of shale and siltstone. The Cox is thought to be the principal aquifer in the subsurface to the east of the project area. The Campogrande formation is not exposed in the area but is thought to be sequence of limestone, marl, siltstone and shale. Permian rocks are likewise not exposed in the area but likely are carbonate rocks equivalent to the Bone Spring and Victorio Peak limestones. These Permian rocks have the potential of being prolific aquifers. What is called the Precambrian basement is a mixture of metamorphic and igneous rocks.

7.3.2 Structural Geology

On the slopes of Round Top Peak, the dominant structures are slumps and landslide faults. These structures are mostly found on the south and east side of the mountain. Steep and divergent structural attitudes and hummocky topography characterize the slumps and landslide faults. On Round Top Peak, the upper Espy and Del Rio Formations were deformed by landslide faulting.

Drill data and the geologic model indicate Round Top Peak, including the rhyolite, is cut by a number of northwest trending faults that developed during early Basin and Range tectonism, some of which are shown in Figure 7-2. These faults are steeply dipping, ranging from 75 degrees to near vertical. Normal separation on these faults varies from 50 to 100 feet (ft) and the faults offset the intrusive floor. In addition to normal slip, these faults also may have experienced right-lateral strike-slip shearing. Brittle fracturing and brecciation in the rhyolite were common in the vicinity of the faults.

Drill data indicates some of these faults are filled with fault gouge, clay, and breccia. Rhyolite along these fracture zones are highly brecciated and commonly brown in color from hydrothermal or groundwater alteration. On the west side of the laccolith, the faults are closely spaced varying from 100 ft to 500 ft and on the east side they are over 500 ft apart. The east side is subsequently less fractured.

Faults on the west side of Round Top Peak show late-stage hydrothermal mineralization and alteration. These faults are mineralized with fluorite, chalcedony, calcite and clay replacing angular rhyolite breccia fragments. Calcite, clay and fluorite fill open spaces within the fault zones and in adjacent fractured rocks.

Slickensides have been noted in the rhyolite at the contact with Cretaceous sedimentary rocks. There may have been post-rhyolite movement along a low-angle fault between the rhyolite and older rocks.

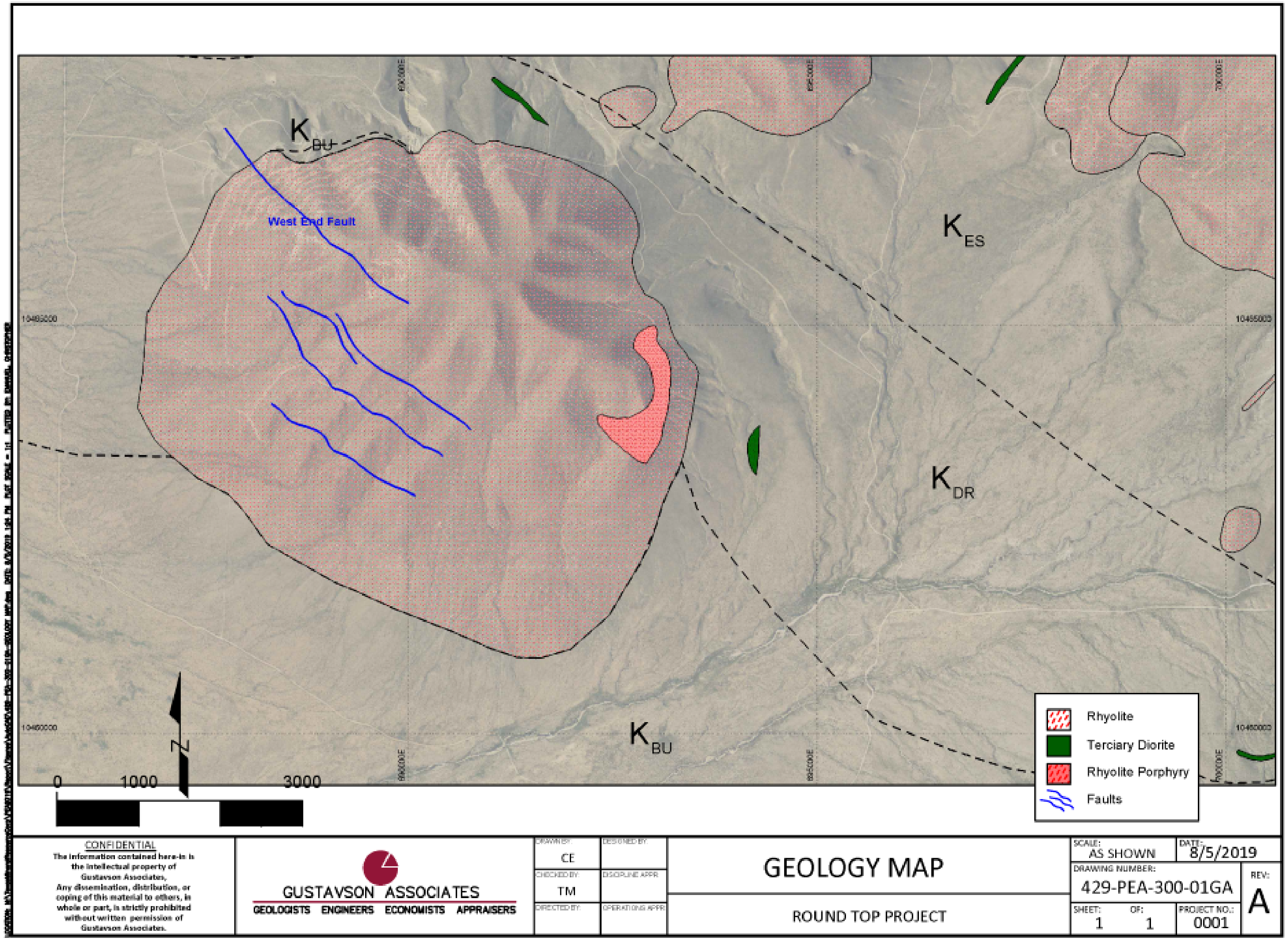


Figure 7-2 Round Top Peak Geology

7.4 MINERALIZATION

REE mineralization is hosted by the Round Top Peak laccolith. The rhyolite is fine grained with a microporphyritic texture. The porphyry phenocrysts consist of alkali-feldspar with albite cores, clear quartz grains, and minor brown to clear Li-mica. Within the quartz grains or crystals, inclusions along planes of crystallization have been observed. The groundmass is aphanitic and consists of quartz, feldspar, and mica with vugs or vesicles. The vugs may be lined with quartz, feldspar, fluorite, cryolite, and li-mica crystals. Some vugs are filled with kaolinite or fluorite and are surrounded by coarsely crystalized minerals. The vugs occur in bands and can be locally clustered in isolated locations. Late-stage fractionation of volatile components, such as F, CO_2 or H_2O, from the crystallizing rhyolite probably formed these vugs.

Round Top Peak displays some pegmatitic characteristics, including an abundance of cryolite, lithium rich micas, rutilated quartz and vapor rich fluid inclusions (Price et al., 1987). Peralkaline rhyolites and pegmatites can contain an abundance of incompatible elements including REEs. The Round Top Peak rhyolite is enriched in incompatible elements including Li, F, Rb, Y, Zr, Nb, Sn, Ta, Pb, REE, Th, and U.

Isolated zones of brown rhyolite are present and are often related to fault structures or near the contact between the rhyolite and sedimentary rocks. In these brown zones, the iron minerals are replaced by goethite and limonite giving the rhyolite a brown color. Tan rhyolite is found along the contact between the rhyolite and sedimentary rocks. Tan rhyolite can also occur as mottling in the red and pink rhyolites located near mineralized faults and the contact between the intrusive and sedimentary rocks. The tan rhyolites were probably altered by vapor phase or hydrothermal fluids and consist of kaolinite clay and residual quartz phenocrysts. Magnetite and hematite are absent or present in only trace amounts. Degree of alteration varies and can be represented by a complete replacement of the feldspars by kaolinite to a partial replacement. Multiple colored fluorites often occur as fracture fillings and replacements in the tan rhyolites that contact the sedimentary rocks.

REE distribution and grades were not affected by the hematitic alteration of the rhyolite. However, the vapor phase or hydrothermal alteration of the tan rhyolite had an impact on the REE grade. The more intensely altered tan rhyolite zones can have a lower REE grade than the other four rhyolite phases.

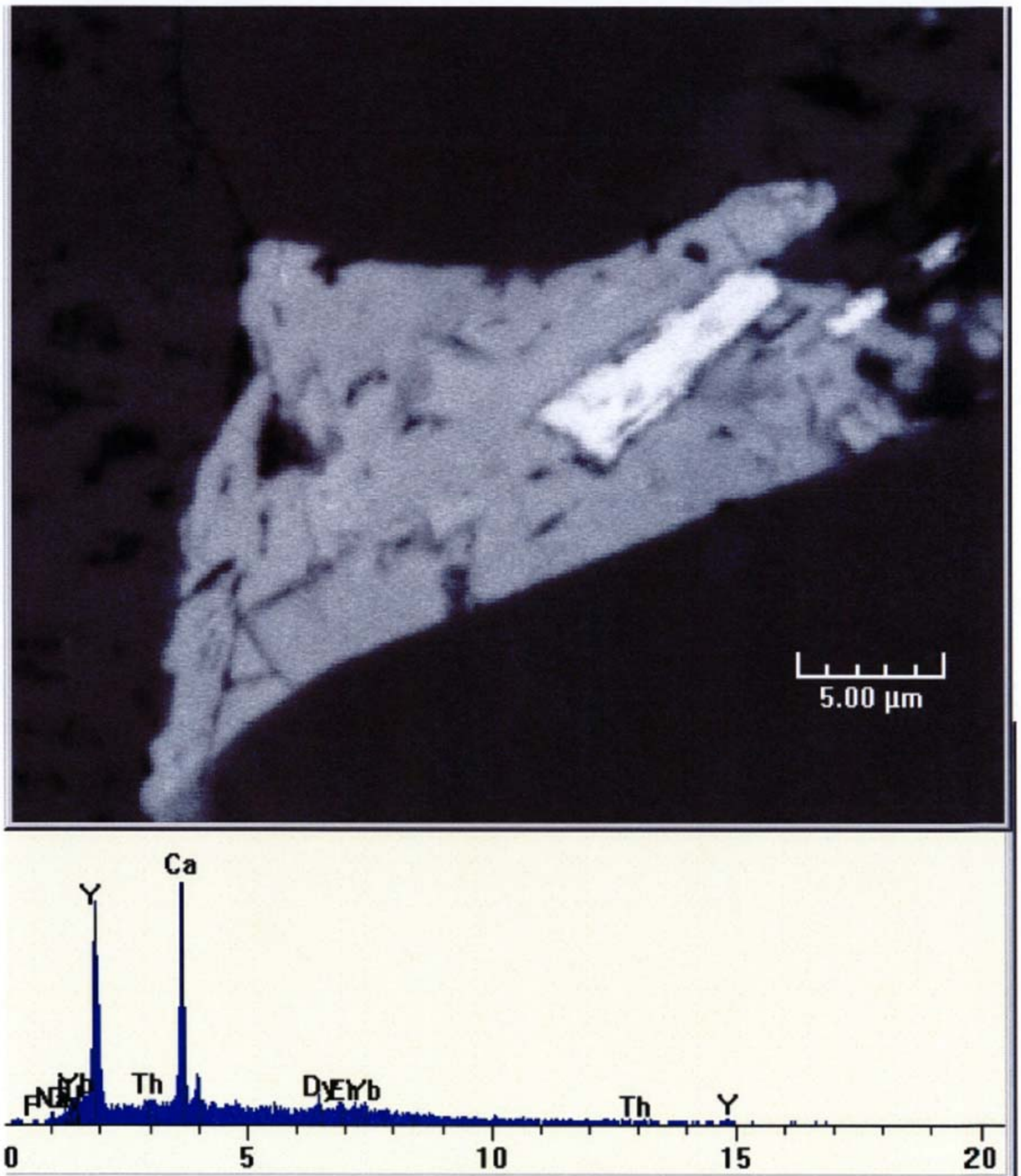
7.4.1 Mineralogical Studies

Mineralogical studies on Round Top Peak have been conducted by a number of past workers including Rubin et al. (1987), Price et al. (1990), Rubin et al. (1990), and McAnulty (1980). Additional studies were undertaken by TMRC as part of a preliminary metallurgical study. Major phases making up about 90-95% of the rhyolite volume are represented by albite, potassium feldspar and quartz. Accessory minerals are dominated by trioctahedral Li-mica, Fe-rich biotite, magnetite altered to hematite, zircon, and cryolite. The rhyolite is enriched in incompatible elements consisting of Li, Be, F, Zn, Rb, Y, Zr, Nb, Sn, Pb, U, Th, and HREEs and LREEs. These elements formed a variety of accessory minerals disseminated throughout the rhyolite intrusion with the REE-bearing minerals being the most important. QEMSCAN analysis by Hazen Research indicates that an yttrium-rich fluorite (Yttrofluorite) is the main host of yttrium and REEs. The yttrium-rich fluorite is fine-grained, usually less than 10 micrometers in diameter but as large as 40 micrometers. Some of the fine fluorite is encapsulated in silicate gangue.

Table 7-2 Rare Earth Minerals Identified from Round Top

Mineral	Formula	Specific Gravity	Hardness	Substitution and Trace Elements
Yttrofluorite	$(Y,HREE, Ca)F_{3-x}$	3.18	4	A variety of fluorite, Y HREE and LREE substitutes for Ca
Yttrocerite	$(Y, HREE,LREE,Ca)F_{3-x}$	3.18	4	A variety of fluorite, Y and Ce substitutes for Ca,Y+Ce/Ca 1:5 other REE in minor amounts
Xenotime	$(Y, HREE)(PO_4)$	4.4-5.1	4-5	
Bastnaesite	$(Y, Ce,La)(CO_3)F$	4.90 – 5.2	4 - 4.5	Other REE can substitute for Y,Ce, and La in minor amounts
Ancylite(La)	$Sr(La,Ce)(CO_3)_2(OH).H_2O$	3.95	4-4.5	None known
Cerianite (Ce)	$(Ce^{4+},Th)O_2$	7.21	not determined	Other REE can substitute for Ce along with Nb, Ta, and Zr
Cerfluorite	$(Ce, LREE, Ca) F_{3-x}$	3.18	4	A variety of fluorite REE Substitute for Ca
Aeschynite-(Ce)	$Ce,Ca,Fe)(Ti,Nb)_2(O,OH)_6$	4.2-5.34	5-6	Th can substitute for Ce

Round Top rhyolite is enriched in HREE with up to 70% of the total REE grade being HREEs. The most common rare earth minerals are yttrofluorite, cerfluorite and yttrocerite, which are varieties of fluorite. These fluorite varieties contain mostly HREE and yttrium where the REEs substitute for the Ca sites in the fluorite crystal lattice. Samples examined by Price et al. (1990) and submitted for a metallurgical study contracted by TMRC showed the presence of these REE fluorite varieties. Most of the HREEs that occur at Round Top are probably found in these varieties of fluorite. An example of yttrofluorite is shown in Figure 7-3.



Backscatter image of yttrofluorite between quartz/feldspar. Bright, elongated inclusion is rich in Th, La, Ce and significant Sr, indicating possible ancylite (?) - 3000X.

Figure 7-3 Photo Micrograph of Yttrofluorite Crystal

The metallurgical study conducted for TMRC showed bastnaesite to be present in several of the submitted samples. Bastnaesite is a LREE mineral and most of the LREE found at Round Top are most likely in this mineral and in the fluorite variety cerfluorite.

Xenotime is not as common as the fluorite varieties or bastnaesite; this mineral was identified by Price et al. (1990) in four out of 15 samples. Xenotime was not identified in the samples submitted for metallurgical study. This is a rare mineral at Round Top Peak and reflects the low phosphate whole rock composition of the rhyolite. Xenotime is a Y and HREE mineral that when present, in spite of its rarity, can contribute to the HREE grade.

Ancylite-(La), cerianite-(Ce) and aeschynite-(Ce) are rare minerals at the Round Top Project and have been identified from a few samples. Ancylite-(La) and cerianite-(Ce) were not recognized by past investigators but were tentatively identified from samples submitted for preliminary metallurgical testing. Rubin et al. (1987) identified priorite from one sample, which is a variety name for aeschynite-(Ce). Aeschynite-(Ce) was identified in one sample from a mineralogical study on Round Top Peak conducted by the University of Texas, Austin Department of Geological Sciences. The rarity of these minerals implies they are not major contributors to the total REE grade at Round Top Peak.

The rare earth minerals are evenly distributed throughout the rhyolite intrusion as finely disseminated grains. Scanning electron microscope (SEM) backscatter images show the grain sizes vary from <5 microns to >100 microns. SEM images show the rare earth minerals occur as interstitial fillings and coat earlier crystallized phases. These minerals are often associated with other accessory minerals that crystalized from other incompatible elements. The even distribution of the rare earth minerals and their occurrence as interstitial fillings and grain coatings suggest these minerals crystallized from a fluid that fractionated from the crystallizing rhyolite intrusion. Most of the REE minerals occur as varieties of fluorite, suggesting the REEs were transported as fluorine complexes in the fractionated fluid.

7.5 ALTERATION

The Round Top rhyolite was divided into five different alteration phases based on the intensity of hematitic and hydrothermal alteration: unaltered gray rhyolite, pink rhyolite, red rhyolite, tan rhyolite and brown rhyolite. Hematitic alteration is a replacement of the magnetite by hematite and gives the rhyolite a red to pink color. Hydrothermal alteration was late and gives the rhyolite a tan to brown color.

The gray rhyolite represents essentially unaltered rhyolite and has a slightly finer grain size than the red and pink rhyolite zones. The gray rhyolite appears to have less interstices and vugs than the red and pink zones. The volatile components that influenced the red and pink zones were still evolving and fractionating from the melt when the gray rhyolite was crystallizing. Gray rhyolite may have red mottling and/or a light pink color flow-banding that suggests separation of a volatile phase during emplacement of the rhyolite which partially oxidized the magnetite and deposited REE minerals. These mottled and banded sections are often located near the transition zones between the gray and red/pink rhyolites.

The pink rhyolite also underwent hematitic alteration but not as strongly as the red rhyolite. An abundance of interstices and vugs have been observed in this zone. The contact between the red and pink rhyolite is gradational and not well defined. Pink rhyolite can be mottled with red and gray rhyolite, especially near the transition zone between the different alteration phases. The abundance of interstices and vugs was probably caused by a high concentration of volatile components entrapped in the cooling rhyolite magma. These trapped fractionated fluids deposited REE fluorite varieties in interstices and vugs and caused the oxidation of magnetite to hematite.

Tan rhyolite is commonly found along the contact between the rhyolite intrusion and underlying sedimentary rocks. Tan rhyolite mottling and stringers can be found in the red, pink and gray rhyolite zones that are adjacent to the tan rhyolite zone and hydrothermally altered faults. Rhyolite in this zone underwent intense alteration: the feldspars and mica may be completely replaced by kaolinite leaving unaltered quartz phenocrysts. Hematite and magnetite are partially or totally absent or can be replaced by goethite. Tan rhyolite developed from different degrees of vapor phase or hydrothermal alteration. As a result of this type of alteration, secondary fluorite, chalcedony and minor amounts of uranium minerals can be found in this zone.

Brown rhyolite is the least common alteration phase found on Round Top Peak. Brown rhyolite can be found adjacent to the contact between the rhyolite intrusion and hosting sedimentary rocks, or adjacent to open fractures and faults. This alteration phase occurs as thin zones and lenses and may be associated with the tan rhyolite. Feldspars are partially replaced by clay, and secondary fluorite may be present in isolated locations. The brown color is caused by an abundance of disseminated limonite replacing magnetite and hematite. Brown rhyolite probably developed from ground water passing through open fractures and traveling along the contact between the rhyolite and sedimentary rocks. Perched ground water was encountered in some drill holes on the flanks of Round Top Peak and brown rhyolite was found above these zones.

8 DEPOSIT TYPE

The rhyolite itself comprises the REE mineralized body. Magmas with a peralkaline composition are known to have high concentrations of incompatible elements such as U, REE, Th, and Zr. Incompatible elements that occur at the Project are reported by Rubin et al. (1987) to be Li, Be, F, Zn, Rb, Y, Zr, Nb, Sn, REEs, Th, and U.

The rhyolite magma that developed Round Top Peak probably cooled too quickly to develop a coarse-grained texture or to develop zones with high REE concentrations. A quick cooling rate would cause a fine-grained texture of the rhyolite and even distribution of the REE minerals. The rhyolite magma was saturated in fluorine, which is reflected in the high percentage of fluorine accessory minerals that are distributed throughout the rhyolite mass. As the magma cooled, fluorine saturated fluids exsolved from the crystallizing magma. These fluorine rich fluids accumulated in interstices and vugs between the earlier crystallized minerals and deposited REE minerals and other accessory minerals in the interstices. The REE deposit at Round Top Peak can be classified as quartz saturated peralkaline (A-1) granite with a rhyolitic texture and a composition similar to certain pegmatites.

9 EXPLORATION

TMRC has been conducting exploration activities in the district and on Round Top Peak since January 2010. Exploration consisted of surface sampling, logging cuttings from historical reverse circulation (RC) drilling, aeromagnetic survey, aeroradiometric survey, stream sediment survey, a gravity survey, and RC and core drilling.

9.1 SURFACE SAMPLING

Surface samples were taken at the beginning of the program in January 2010 to confirm the data that was published by past investigators. These samples were taken from outcrops exposed on historical drill roads on the north side of Round Top Peak. A chip sample was taken from each type of rhyolite alteration phase and submitted to Activation Laboratories for REE analysis. A total of six samples were submitted for analysis and analytical results confirmed the data published by past investigators.

9.2 LOGGING HISTORICAL RC CUTTINGS

RC cuttings from a drill program conducted in the 1980s by Cyprus were stored in the exploration decline on the north side of Round Top Peak and represent almost all their drill holes. These RC cuttings were removed from storage and logged by TMRC geologists using a binocular microscope. Samples for analysis were selected and split from the stored RC cuttings. The samples were analyzed for REEs and selected samples were analyzed for uranium and beryllium. A total of 1,227 samples were submitted to ALS Chemex for analysis.

9.3 AEROMAGNETIC AND AERORADIOMETRIC SURVEY

An aeromagnetic and aeroradiometric survey was conducted by Aeroquest Airborne during the month of May 2011. The purpose of the survey was to map the magnetic and radiometric characteristics of the Round Top and Little Round Top rhyolite intrusive complex and explore for additional REE mineralized intrusions in the area surrounding the project. The survey acquired about 616-line kilometers of magnetic gradiometer and radiometric data using a Bluebird Heli-TAG tri-axial gradiometer system and RSI gamma ray spectrometer system. Radiometric and magnetic data were compiled and interpreted by Thomas V. Weis and Associates.

9.3.1 Summary of Results of Aeromagnetic and Aeroradiometric Survey

The total aeromagnetic intensity reduced to pole, shown in Figure 9-1, generally displays magnetic high responses for Round Top, Little Round Top and Little Blanca Mountain. At Round Top and Little Round Top, the magnetic responses are near surface and cut off at depth. This suggests there is no feeder zone directly under these two peaks and drill data also indicate the shallow nature of the intrusions with no feeder dike being encountered. To the southeast of the Round Top intrusion and located between Sierra Blanca Mountain and Little Blanca Mountain, there is a deep-sourced magnetic anomaly. This magnetic anomaly may be caused by the local magma source for the Round Top and Little Round Top intrusions. Sierra Blanca is generally nonmagnetic.

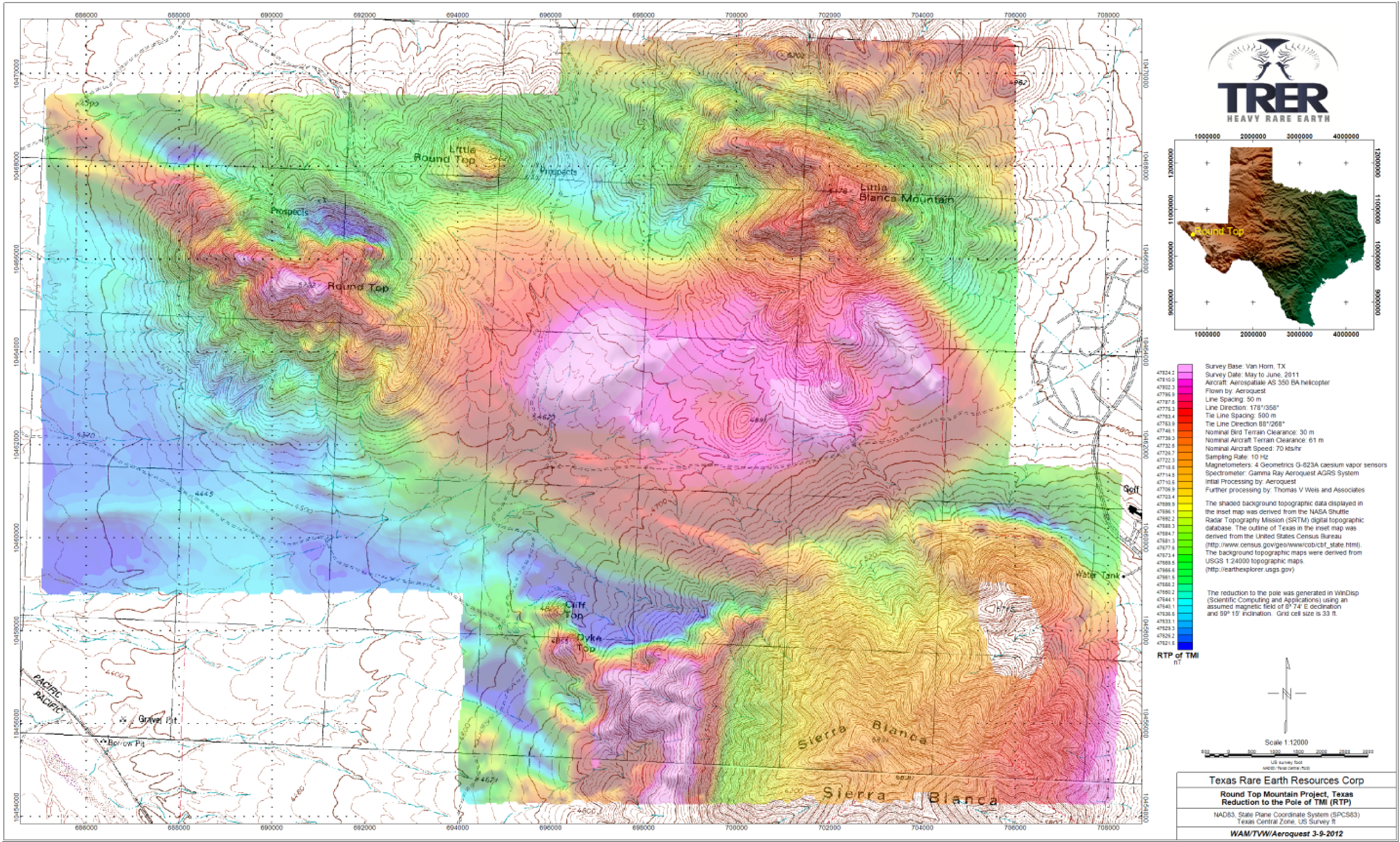


Figure 9-1 Aeromagnetic Map of Total Magnetic Intensity Reduced to Pole

Gamma ray spectrometer data, shown on Figure 9-2, can be used to map lithology and structure in the survey area. Between the Little Blanca Mountain, Round Top, and Little Round Top intrusions to the north and the Sierra Blanca intrusion to the south there is a major radiometric contrast. Radiometric data indicates the southern area is low in thorium. In contrast, the peaks to the north are high in thorium. The contact between these two areas is the drainage in Blanca Flats which could be interpreted to be a major east west structural zone. Round Top and Little Round Top have characteristic circular radiometric responses that map the rhyolite intrusions. Little Blanca Mountain has a generally noisy radiometric character that is not directly associated with the shape of the intrusion. Sierra Blanca has no direct radiometric response.

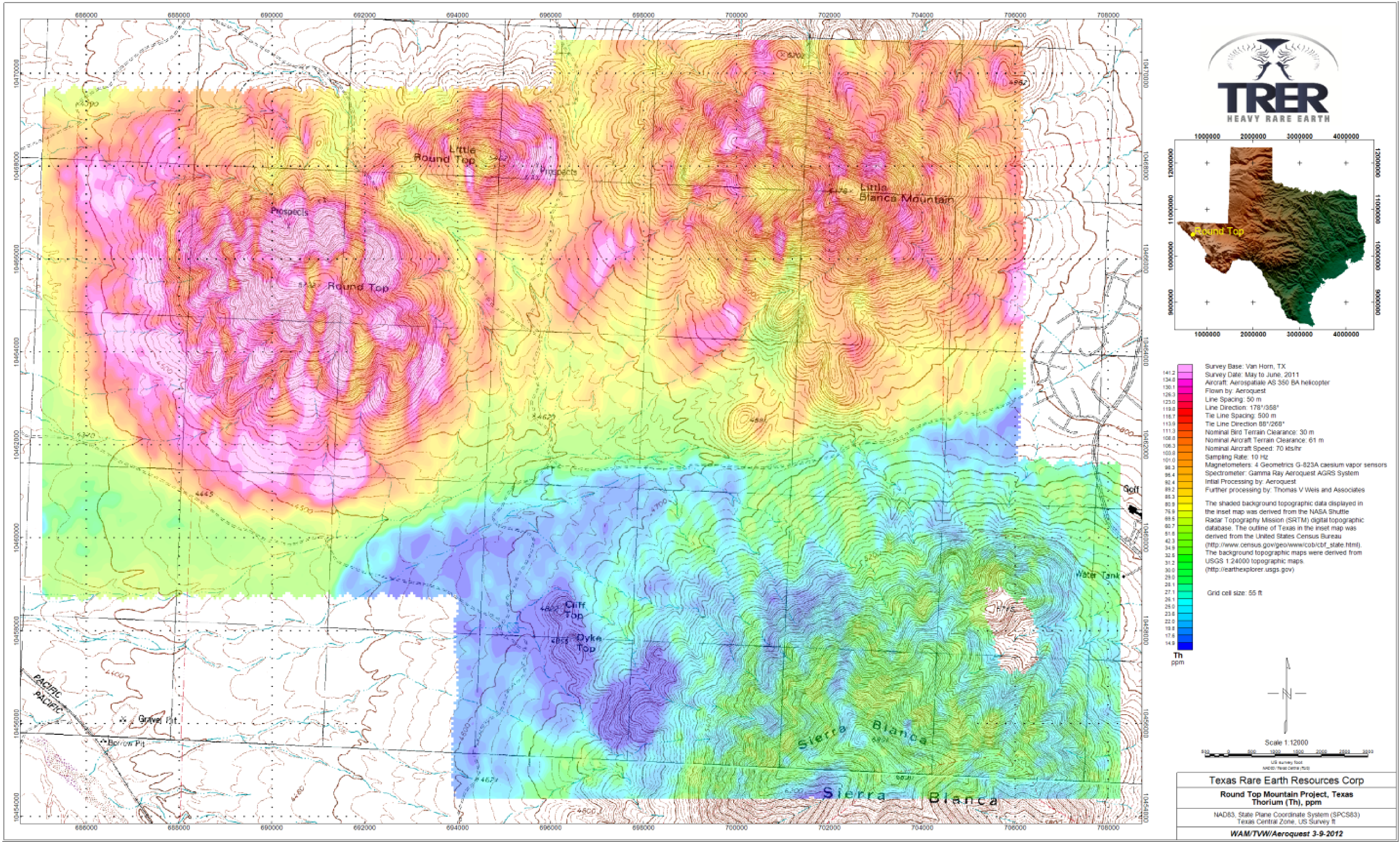


Figure 9-2 Aeroradiometric Map of Thorium Distribution

9.4 STREAM SEDIMENT SURVEY

A stream sediment survey was conducted on Round Top Peak and the other peaks in the area in the winter and spring of 2011. The purpose of the survey was to determine the distribution of REEs in the rhyolite complexes and locate possible beryllium and uranium deposits associated with the rhyolite intrusions. The survey was conducted by MLS International and the results were compiled in a report received by TMRC October 28, 2011.

9.4.1 Summary of Results of Stream Sediment Survey

Total stream sediment samples taken from drainages defined zones of potential mineralization exposed in contacts between the rhyolite and sedimentary rocks. Indicators for mineralization were defined to be F greater than 1% and some combination of Be, Pb, Zn, As, and U. These indicators were used to delineate a wide zone of potential beryllium and uranium mineralization along the north flank of Little Blanca with some potential on the east flank. This mineralization would be confined to the contact between the rhyolite intrusion and the sedimentary rocks. REEs were found to be evenly distributed in the sampled drainages, indicating the uniform distribution of REEs in the rhyolite intrusions.

9.5 GRAVITY SURVEY

A gravity survey was conducted on the Round Top Peak and the surrounding area from September to October 2011. The purpose of the survey was to map lithologic variations and structure in the project area. Focus of the survey was on the late-stage rhyolite units related to the REE mineralization at the Round Top and Little Round Top complexes. In addition, the survey will be used to explore for additional rhyolite intrusive complexes associated with mineralization in the surrounding area and at depth. The survey was conducted by Magee Geophysical Services. The survey was conducted on a 100-meter grid using three Lacosta and Romberg Model-G meters. Compilation and interpretation of the data was conducted by Thomas V. Weis and Associates.

9.5.1 Summary of Gravity Survey Results

Gravity survey results shown in Figure 9-3 show the rhyolite as gravity lows and sedimentary rocks as gravity highs. A gravity low occurs along the axis of Round Top Peak and is associated with the low density of the rhyolite. A similar low occurs on the Little Round Top intrusion. Another gravity low occurs to the south of Round Top and does not have a topographic expression. A gravity low extends from the north side of Round Top to the southeast and merges with a gravity low trending south from Little Round Top. From the juncture, a linear gravity low, coincident with a probable NW-striking fault that goes through the saddle between Round Top and Little Round Top, continues to the southeast into a general gravity low coincident with the buried magnetic high anomaly. The linear gravity lows may be rhyolite dikes and sills that fed the laccoliths from a buried central intrusive body in the district, marked by the coincident magnetic high and gravity low beneath the valley surrounded by the four Sierra Blanca peaks. To the northeast of the project area, an anomalous gravity high was defined which may be a thick section of sedimentary rocks, such as limestone. Refer to Sections 10 and 11 for further descriptions of sampling.

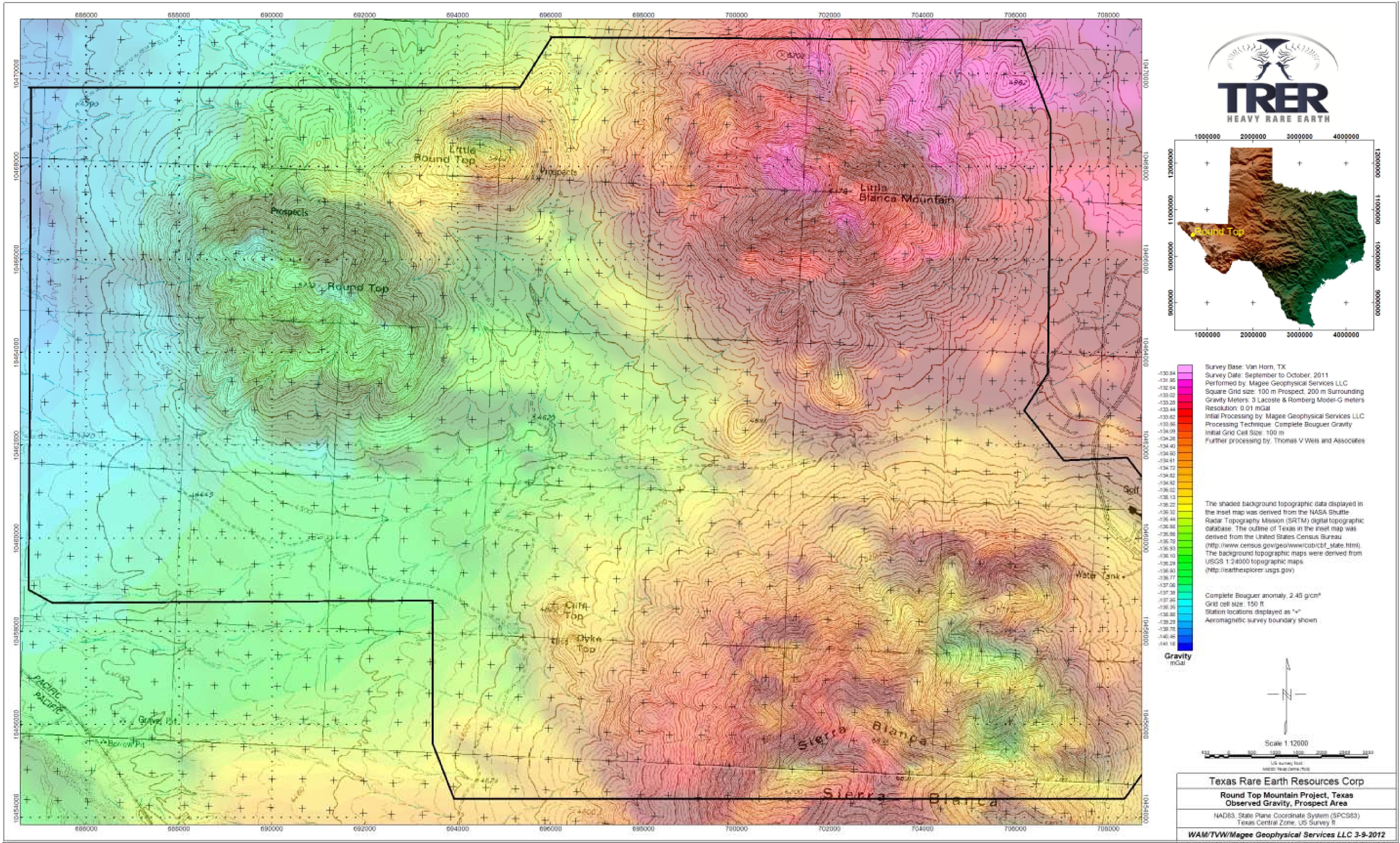


Figure 9-3 Map of Observed Gravity Values

10 DRILLING

10.1 INTRODUCTION

The drilling data from previous operators in the Round Top area had not been consistently maintained. Ninety-five of the 173 locatable holes were not used in the mineral resource estimate due to lack of verifiable assay or geologic information.

Though incomplete, reliable data begins with Cyprus's 1987 campaign which consisted of 44 identifiable RC holes totaling 9,262 ft and 2 diamond core holes totaling 347 ft. This drilling was mostly confined to the north side and flank of the mountain where the contact between the rhyolite and basal sedimentary rocks is exposed (Figure 10-1). Collar locations of some of these drill holes were preserved on maps made available to TMRC by the GLO. Cyprus RC cuttings were kept in plastic sample bags that were stored in barrels in the decline; many of these cuttings were logged and sampled by TMRC in 2010.

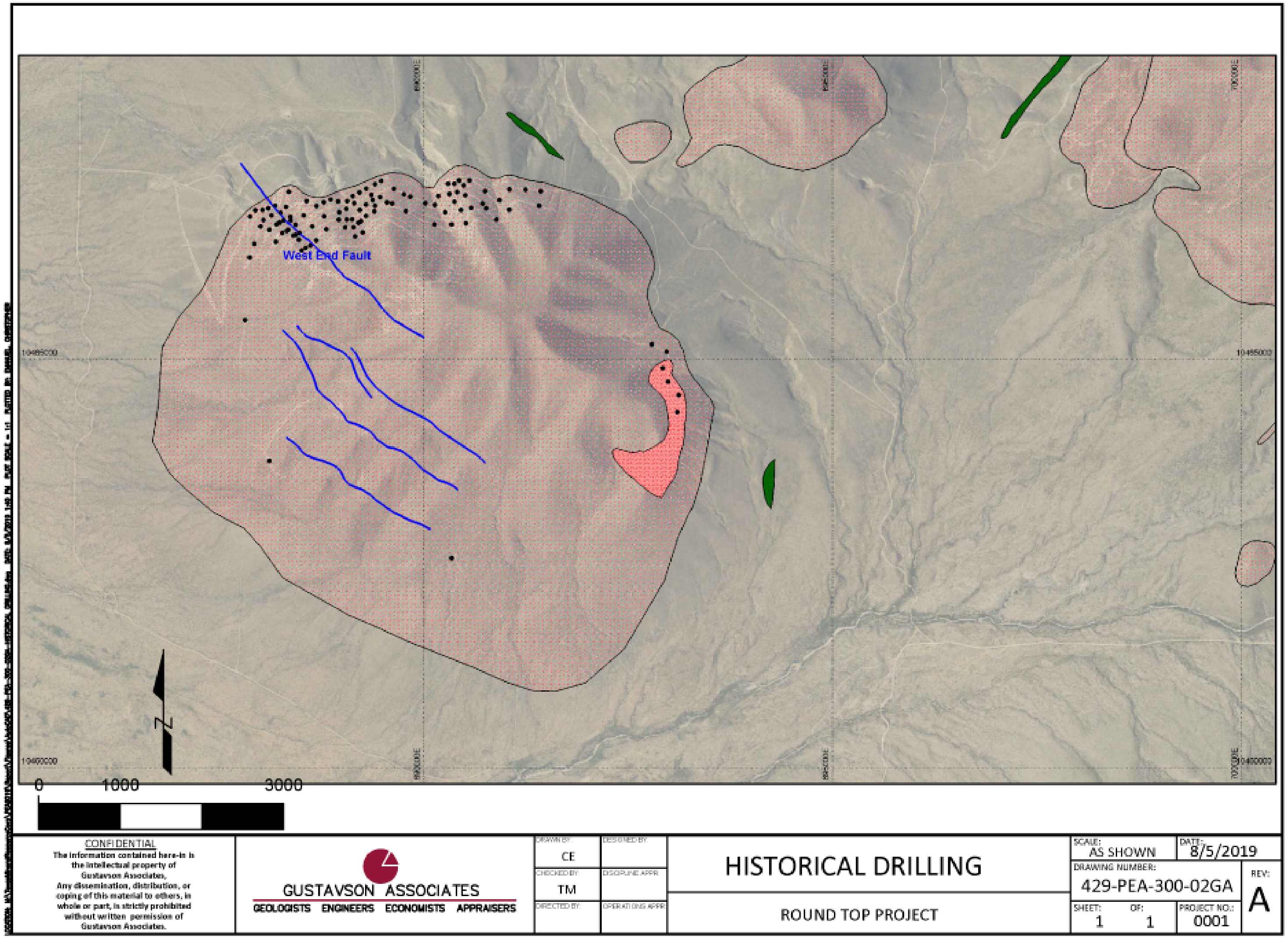


Figure 10-1 Historic Drill Hole Locations on Round Top Peak

TMRC drilled an additional 64 RC holes in 2011 totaling 26,915 ft. This campaign was designed to 1) define the extent of the Round Top rhyolite; 2) validate historical drill data; and 3) provide sample support for the geologic and resource models.

In 2012, an additional 16 RC holes and 2 diamond core holes were completed. Of the 18 new holes, totaling 10,483.5 ft, all but one was assayed. Assay results and drilling logs were received by Gustavson in January 2013.

10.2 DRILLING PROCEDURES AND CONDITIONS

Round Top Peak is steep and consists of highly fractured, variably altered rhyolite. Drill sites are prepared by leveling a pad and digging a sump for the drill rig if necessary. Drill holes at the Project are typically collared in bedrock or in rhyolite-derived alluvium farther out on the plain. Ample water from wells is available for drilling. The water table has not been intersected by the drill holes, although rare small perched groundwater intervals have been encountered.

RC methods were used for nearly all the drilling at the Project to date. TMRC's RC drilling was generally carried out with either a pneumatically-driven downhole hammer (generally in less-fractured rock) or a Tricone RC bit (generally in more-fractured rock). Hole diameters were 5.25 inches and all drilling was done wet except when the top 15-20 ft of the hole was being cased. After completing a hole, all material and waste were removed from the site. The holes were allowed to cave in and were filled and covered with soil and cuttings.

TMRC's core drilling at the Project has been advanced with NQ, HQ, and PQ size core (1.875, 2.5, and 3.345 in. diameter, respectively). As the core program is in its initial stages, with only one hole completed and a second one in progress, results are preliminary. Drilling had been difficult for the first 200 ft with excessive water and drill fluid loss due to the highly fractured bedrock. The first two hundred feet are now drilled with an RC rig and PW casing is put down. The PQ core recovery below that depth now commonly ranges to 95+% and five-foot-long runs of intact core have been obtained. The current core holes are twinning previous RC holes and a comparison of REE values in samples generated by the two methods will be forth coming. The location of TMRC drill holes are shown in figure 10-2 below.

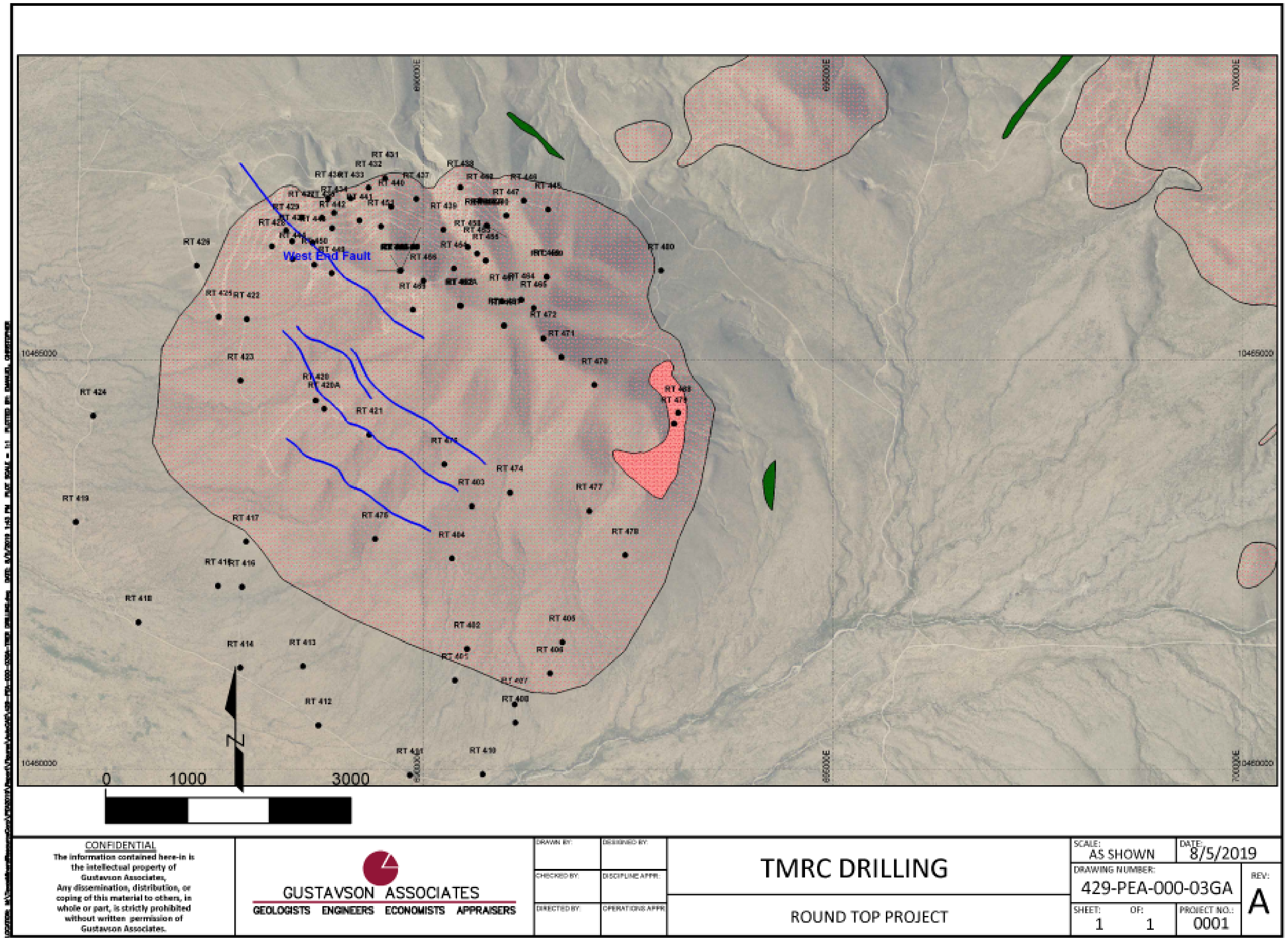


Figure 10-2 TMRC Drill Holes

10.3 DRILL HOLE COLLAR SURVEYS

Location information of Cabot drill holes is not available. Cyprus drill holes were plotted on maps and many have been located and surveyed in with GPS. All TMRC drill hole collars have been surveyed with a Trimble GeoExplorer 6000 series GeoXH model hand-held GPS unit capable of submeter horizontal accuracy. Elevations are commonly taken from topographic maps or digital elevation models. Coordinates are converted for database entry to Texas Central State Plane system in feet using NAD 83 datum.

10.4 DRILL HOLE LOGGING

RC chips were logged on site in field notebooks as the hole was drilled, with field notes later entered into Microsoft Excel. A representative split from each sample run was kept in a chip tray; trays were labeled with the drill hole number and interval and are stored at the Sierra Blanca field office. An additional 100 drill holes, or portions thereof, from previous drilling campaigns were relogged to be consistent with terminology used by TMRC.

Core geotechnical logging, RQD analysis and recovery determination are performed at the drill site. Then the core is transported to a core warehouse in Sierra Blanca, where it is logged by depth for color, textures, structures and mineralogy by TMRC geologists.

10.5 DOWNHOLE SURVEY

All currently drilled RC and core holes are surveyed for downhole deviation using a reflex gyro instrument (RT 452-A, -A60, -A70). The instrument reports accuracy within +/- 0.2 degrees and can survey vertical holes. Cyprus's drilling campaign used vertical holes which were not downhole surveyed.

10.6 EXTENT AND RESULTS OF DRILLING

Drill hole spacing at ground surface is more closely spaced on the north side and flank of the mountain, ranging from 200 – 800 ft and averaging 400 – 500 ft, with drill hole spacing spreading out to over 2,500 ft on the alluvial fan. Little rhyolite was encountered on the alluvial fan and future drilling in this area of the Project, at its current density, should be considered for reconnaissance purposes.

Drill data show that the rhyolite was extensively faulted and displaced by normal faults with up to 100 ft displacements. A number of these faults have been mineralized by fluorite and chalcedony. Thickness of the rhyolite increases to the south and east and extends into the sedimentary rocks beyond the surface expression of the rhyolite.

11 SAMPLE PREPARATION, ANALYSES AND SECURITY

11.1 REVERSE CIRCULATION PROCEDURES

11.1.1 RC Handling Procedures

RC cuttings were collected from the splitter by the geologist and/or geologic technician for every 5 ft interval. Cuttings were collected in buckets that were lined with sample bags. Both sample bags and buckets were labeled with the hole number and with the start and finish of each sample interval. The number of buckets for each sample interval was logged and each sample was marked with a bucket number.

Buckets were closed and sealed on-site by the geologist, geologic technician or drill helper. Buckets were transported to the sample processing/storage facility, a warehouse in El Paso, Texas. The warehouse is posted restricting no unauthorized personnel in the storage/processing area, and employees are aware of this policy. The warehouse was locked and bolted at all times when not occupied.

Hole number(s) and footages on each bucket label are checked against the contained samples. Each bucket's samples are lined up in rows by hole and drill run. The drill site log for the number of buckets per interval is checked to verify all samples were transported to the warehouse.

Wet sample bags were placed on drying racks located outside the warehouse in a locked gated enclosure adjacent to the warehouse. In the summer months, the samples are air dried without added heat. In the winter months, heaters were placed under the racks, which were covered with plastic tarps.

The dry sample bags were put back in the buckets and stored at the warehouse facility in El Paso. Overflow from the storage space in El Paso was transported to Sierra Blanca and stored in a large metal building near the Round Top Project. Security at the property is provided by a watchman at the property entrance or, on inactive days, a locked gate.

11.1.2 RC Sample Preparation Procedures

Dried samples are weighed and the total weights for each sample interval are entered into a spreadsheet, from which percentage recovery is determined.

Initially, each sample representing five feet of drilling was made into a single sample. Where there were multiple buckets for a sample interval, the buckets were combined into a single sample, which was split using a Jones riffle splitter into a one kg sample and placed in a plastic bag.

Later in the program, when uniform concentrations of REEs had been confirmed, five-foot sample intervals were composited in 10 to 30-foot intervals based on lithologic characteristics determined by the geologic logging. For a single lithology, up to six samples were split and composited into approximately a 2 kg sample.

The bags were weighed and labeled with a sample number, without footage being indicated, and these data were entered into a spreadsheet. Blanks, duplicates and standards were inserted at various intervals and receive a sample number in sequence.

All samples were prepared by ALS Chemex in Reno, Nevada, and analyzed by ALS Chemex, a certified laboratory in Vancouver, B.C., Canada, by inductively-coupled plasma mass spectrometry (ICP-MS).

11.2 QA/QC PROCEDURES

For control purposes, one or two blank samples of barren material were included with each batch of 10 to 20 samples. At least one blank sample was included per hole. The blank samples comprise limestone or shale cuttings from the bottom of RC holes.

One standard was put in the sample stream every 20 samples to independently assess laboratory performance. Standards were made from the composited samples of one RC drill hole and prepared by Shea Clark Smith, Minerals Exploration & Environmental Geochemistry.

Duplicate samples were put in the sample stream at a rate of one per 10 to 20 samples to assess the reliability of the grade determination. Gustavson was not provided with these data, though the analysis of samples for the column leach testing supports the grade distributions seen in the exploration data.

11.3 SAMPLE SHIPMENT AND SECURITY

Samples were securely bagged and packed in cardboard shipping boxes, with each box containing 10 to 15 samples. Each box contained a list of its contents and was numbered on the outside as one of the total number of boxes in that shipment. The outside of each box was labeled with the laboratory's and TMRC's addresses. An analytical request form was submitted with each batch of samples.

Boxes were shipped by a commercial carrier to ALS Chemex in Reno, Nevada, for sample preparation and analysis. When the boxes arrived at the lab, a work order number for the batch was assigned and sample numbers recorded. Sample receipt verification was sent back to TMRC.

11.4 CORE HANDLING PROCEDURES

TMRC uses the following core handling, logging, and sampling procedures:

Core was placed by the drill helper in a labeled 4 ft long cardboard core boxes, from left to right, with the start and finish of each run labeled on a wooden block. After geotechnical logging, TMRC personnel transport the core to the core logging facility and lay it out in order of increasing hole depth.

The core logging facility was a secured building located four blocks from the field office in Sierra Blanca, Texas. Only authorized personnel were permitted to enter the facility. The building was locked and bolted at all times when not occupied.

Core box labels were checked for accuracy, and aluminum labels recording hole number, box number and depth interval were affixed to the boxes. All core was stored inside the logging facility in Sierra Blanca.

11.4.1 Core Logging Procedures

Paper forms, including location, date drilled, diameter, azimuth, dip, fracture counts, density, and recovery, were used for logging. These data were entered into spreadsheets designed for each data set. These include spreadsheets for geology, recovery, density, sample numbers, and engineering data.

Core was washed and logged for lithology, textures, structures, mineralogy and color by TMRC geologists. All cores were photographed in the box after the drilling mud and fluids have been washed from the core.

11.4.2 Core Sampling Procedures

At the TMRC core facility the drill holes were continuously sampled on five-foot intervals.

Sample intervals were marked on the core and boxes with a lumber crayon by a TMRC geologist. A labeled aluminum sample tag was stapled to the interior of the sample tray at the beginning of each sample interval. The core was cut in half with a water-cooled diamond-bladed saw. Once sawed, one half was returned to the core tray and the other half was placed in a labeled sample bag. Before the sawed half was placed in the sample bag, the sample interval was checked against the sample interval recorded on the sample bag.

Some samples were additionally used for metallurgical tests, which required that one of the sawn halves be halved again to create quarters. Quarter core was submitted for the metallurgical tests while the remaining quarter was retained for the geologic record.

11.4.3 Core Sampling QA/QC Procedures

QA/QC procedures for core samples are the same as RC cuttings, with blanks, standards and duplicates submitted about every 20 samples.

11.4.4 Core Sample Shipment and Security

Securely bagged samples were placed in boxes, with approximately 10-15 samples per box. Each box contains a list of its contents and was numbered on the outside as one of the total number of boxes in that shipment. The outside of each box was labeled with the laboratory's and TMRC's addresses. An analytical request form was submitted with each batch of samples.

Boxes were shipped by a commercial carrier to ALS Chemex in Reno, Nevada, for sample preparation and analysis. When the boxes arrived at the lab, a work order number for the batch was assigned and sample numbers recorded. Sample receipt verification was sent back to TMRC.

11.5 SPECIFIC GRAVITY MEASUREMENTS

Specific gravity measurements were taken from the core at the core logging facility in Sierra Blanca. Since there are no core drying facilities available, the measurements being taken were for wet core. It was recommended that these measurements be confirmed and competed for dry core at an independent laboratory. An independent laboratory determined the dry density for the crushed rock quarry on Sierra Blanca Peak to be 2.53 g/cm^3.

11.6 HISTORIC DRILL HOLES

No information is available concerning the sampling and assaying methods used in the historical drilling conducted by Cabot and Cyprus. When the property was shut down, the cuttings from the Cyprus RC drilling program were stored in barrels in the exploration decline. The samples are in plastic bags that were placed in sealed barrels, covered with plastic sheets and strapped to wooden pallets.

Since no accurate logs of the historical drill holes or assay results can be located, it was decided to make detailed logs of the historical drill holes. During the detailed logging, certain drill holes and isolated intervals were selected for assay. To facilitate the logging, the pallets were removed from the mine and broken down. The individual barrels were returned to the mine and lined up along the right rib.

The barrels were systematically opened, and the individual sample bags removed. Most of the individual samples were in plastic bags and represented a few pounds of cuttings. Some intervals were much larger and contained up to 20 pounds or more material. In some barrels, the top layer of samples was poorly preserved, and the bags were deteriorated from sun damage. Other barrels were filled with water from being left open in the rain before they were placed in the decline. Most of these samples were salvaged and placed in new plastic bags and labeled with the proper hole number and interval. Some samples were lost due to the deteriorated nature of the sample bags and others could not be identified.

When the samples were removed from the decline, they were transported to a motor home near the property gate that was converted to a logging facility. At the logging facility a portion of the sample was washed in a screen and placed in a chip tray labeled with the hole number and interval. The chips were allowed to dry and were examined with a binocular microscope. The sample bags were checked for radioactivity and intervals with over three times (3X) the background level was noted. Geologic data was entered into a spreadsheet.

Holes and intervals were selected for assay based on the known location of the hole and observed mineralization in the RC chips. Hole intervals with elevated radioactivity and intervals with suspected beryllium mineralization were selected for assay. Larger samples were split into two parts one part for assay and the other part was returned to the decline. In some cases, there were not enough chips to take a split and the entire sample was submitted for assay. The sample split for assay was placed in a properly labeled bag with the sample number and interval. A tag with the sample number was placed in each individual bag. Sample numbers and corresponding intervals were entered into a spreadsheet. The sample bags were placed in shipping boxes and a label identifying the contents was placed in each box. An analytical request form was placed in one of the boxes for each batch of samples submitted to the laboratory. Samples were transported to ALS Chemex by a commercial carrier. When the samples arrived at the laboratory the sample numbers were recorded and assigned a work order number. Sample receipt verification was emailed to TMRC. It the qualified person's opinion that the historical samples were prepared and handled in a manner consistent with industry best-practice standards and that the historical data used in the current Round Top Project resource model is valid.

A total of 1,227 historical drill samples from 67 drill holes, were reanalyzed.

It is the qualified person's opinion that the sampling, sample preparation and QA/QC procedures followed by TMRC are consistent with best-practice industry standards.

12 DATA VERIFICATION

Dr. M. C. Newton, forrmer Chief Geologist of Gustavson, made six visits to the Project site during the 2011 and 2012 drilling programs. Mr. Newton made four two-week long trips to the site in 2011, a two-week long visit in March of 2012 and his most recent visit was for a week in May of 2012. Mr. Newton offered recommendations on QA/QC sampling procedures and observed and supervised both RC and drill core sampling from drill to courier.

As part of Mr. Newton's data verification procedure, he oversaw the review and comparison by employees of Gustavson of the certified laboratory reports from ALS Chemex with entries in the TMRC database. It is the qualified person's opinion that the sampling, sample preparation and QA/QC procedures followed by TMRC are consistent with best-practice industry standards.

Gustavson compared assay data provided by TMRC with PDF assay certificates by ALS Minerals for all holes drilled by TMRC, which were the 400 series holes (RT 401 – RT 480). There was no discrepancy between these data sources. The assay data for historical drill holes (200-300 series drill holes) were generated by TMRC through re-assaying and these data were similarly verified by cross-checking TMRC delivered data with laboratory assay certificates. No discrepancies were found. Of the 173 historical drill holes, 95 were not used in the resource estimation due to incomplete assay or geological information.

12.1 VERIFICATION OF THE QUALITY CONTROL PROGRAM

During the 2011 drilling program, for the RC sampling, all water was saved, and no fines were lost as two to eight bag-lined buckets were used to capture all material from one of two ports on a rotary splitter. The qualified person took samples at the drill rig, transported samples to the warehouse in El Paso, placed sample bags to dry, split samples and supervised their boxing up for shipment and delivered them to the courier office.

Two standards were developed by an independent laboratory, Minerals Exploration Geochemistry of Washoe Valley, Nevada, by compositing 80 and 100 ft intervals of rhyolite from a single Round Top RC drill hole. The standards were well homogenized, not pulverized and split to 0.75 grams and placed in a plastic bag like the other RC samples. Multiple aliquots of the two standards were analyzed by three different laboratories by ICP-MS to determine a range of acceptable values.

Blanks are derived from limestone and shale RC samples that have been analyzed and are known to be barren of REEs. Duplicates of RC and core samples are taken periodically and inserted at random in the sample stream at some distance from the duplicated sample. All samples, standards, blanks and duplicates are given only a sequential sample number and all look like RC samples and are therefore blind to the laboratory.

Mr. Matthews has reviewed the procedures used for drilling, sampling and assaying, and the available standards database. It is Gustavson's opinion that the sample database used in the current Round Top Project resource model is valid for resource estimation.

13 MINERAL PROCESSING AND METALLURGICAL TESTING

13.1 INITIAL CHARACTERIZATION AND SCOPING STUDIES

Between 2011 and 2013, TMRC initially completed scoping level metallurgical testwork for the Round Top Project in Texas. The primary objective for the scoping level studies was to evaluate the various processing options for recovery of Rare Earth Oxides (REO) values contained in the resource.

Several initial sets of testwork were performed on various samples from the property at different metallurgical laboratories. They were:

1. Preliminary Metallurgical Test Program on Round Mountain Project, MSRDI Report dated September 7, 2011 (Phase I Study).
2. Progress Report No. 2 – Round Top, MSRDI Report dated January 5, 2012 (Phase II Study).
3. Beneficiation Study of Round Top, Texas, Rare Earth Element plus Yttrium Ore, Hazen Research, Inc. Report dated October 15, 2013.
4. Preliminary Data Package for a Hydrometallurgical Laboratory Process Development Study for the Round Top, Texas Rare Earth-Yttrium Ore, Hazen Research, Inc., Dated October 31, 2013.
5. Heap Leach Characteristics Studies, Resource Development Inc. Report "Results of Scoping Bucket Static Leach Tests" dated July 16, 2013 and Resource Development Inc. Report "Results of Preliminary Column Leach Tests" dated September 24, 2013.
6. TMRC Progress Summary, Tusaar Corp, Extraction of rare earth elements and separation of uranium and thorium from rare earth elements, report received at RDi November 2013.

These reports were reviewed, and the findings are summarized and presented in this section.

13.1.1 Metallurgical Characterization

This phase consisted of characterization of several classes of material from the Round Top deposit. Five RC drill samples of rhyolite designated "red", "pink", "grey", "tan" and "brown" were examined analytically for rare earth oxides (REO) and mineralogically for bulk minerals. Preliminary attrition scrubbing tests were also run in this phase.

The results are summarized as follows:

1. Yttrium and dysprosium oxide values in the heads varied from 84 parts per million (ppm) to 199 ppm and from 26.5 to 38.2 ppm, respectively. Total Rare Earth Oxides (TREO) varied from 512 to 672 ppm.
2. The main gangue mineral was potassium feldspar, while the REO is contained variously in bastnaesite, yttrofluorite, yttrocerite, columbite, changbaiite and kasolite.

3. All of the composites were of similar grade and mineralogy.

13.1.2 MSRDI Report on Gravity, Magnetic, and Flotation Separation

This phase evaluated several methods of potentially upgrading a composite sample (all five lithologies combined). These included gravity, magnetic and flotation methods. Two series of diagnostic leach tests were also performed on whole ore samples at different particle size suites.

The test results indicated the following:

1. Magnetic and gravity methods did not preferentially upgrade the material.
2. Flotation tests indicated that sulfonate collector gave better overall results than the fatty acids and amines. The best results indicated REO recovery of about 77% with 36% of the weight.
3. Leaching tests were run to evaluate hydrochloric, nitric and sulfuric acids, alkaline lixiviant and effects of temperature. The results for all of the acids were better than with alkaline conditions. The kinetics of leaching with acids was relatively fast and acid consumption was relatively low.

13.1.3 Hazen Flotation and Magnetic Separation Study

The objective of this phase of study was to investigate Rare Earth Element plus Yttrium (REE+Y) recoveries and particularly Heavy REE (HREE) recoveries utilizing flotation, magnetic separation, attritioning and gravity separation methods. The goal was to make a 10:1 concentration ratio at 75% recovery of the Total REE (TREE). Mineralogical characterization and comminution studies were also performed. Limited tests were also performed to evaluate leaching extraction of REE+Y.

The highlights of the test results indicated the following:

1. The head analyses of the four composites were from 0.029% to 0.031% TREE, 0.014% to 0.016% HREE and 0.22% Y.
2. Ball mill work index tests were conducted with a closing size of 75 microns (200 mesh) rather than the customary 150 microns (100 mesh). The BWi values varied from 14.6 to 17.6 kWh/t for the composites. Abrasion index tests were performed on two of the composites and were 0.9863 and 0.9070 grams.
3. Mineralogical examination identified the main mineral as a yttrium-rich fluorite with xenotime, bastnaesite and monazite as minor minerals. Minerals were closely associated all the way down to about ten microns, with some silica and zircon encapsulation observed in a leach residue.
4. Dispersion and attrition did not have positive effects with the material.
5. Gravity tests did not produce desired results.

6. Magnetic separation was marginally successful in removing 25% of the iron while rejecting only about 3% to 5% of the REE+Y.

7. Extensive flotation testwork was performed on the Barrel #10 and 53460-1 samples. General flotation conditions were established with a 270 mesh (51 microns) grind, two stage depressant (sodium silicate) and collector (oleic acid) conditioning and three stage rougher flotation. The results of that test were recoveries of 73% and 71% and upgrading ratios of 9.1 and 8.1 for yttrium and dysprosium, respectively.

13.1.4 Hazen Hydrometallurgical Processes Study

The objective of this phase of the study was to investigate hydrometallurgical processes for extraction of REEs. These included acid bake-water leaches, acid leaches of whole ore and flotation concentrates, solid-liquid separation and treatment of leach solutions.

Highlights of the leaching part of the program are as follows:

1. The acid bake was optimized with a three hour bake at 325ºC and acid ratio of 0.22, resulting in a yttrium extraction of 94%.

2. The best sulfuric acid agitated leach tests were run at a 61-micron grind for 4 hours at 90-95ºC. The acid to ore ratio was 0.16. Extractions were 76% to 83% and 82% to 94% for dysprosium and yttrium, respectively.

3. Static leach tests were performed on minus one-half inch crushed material with various sulfuric acid strengths. Yttrium extractions were the highest (up to 45%) with the highest acid strength.

4. Acid consumptions were evaluated for various agitated leach tests on whole ore and flotation concentrates. The results showed higher acid consumptions for flotation concentrates and finely ground and not deslimed whole ore samples.

Additional tests were performed to evaluate chemical treatment methods for pregnant leach solutions.

The highlights are as follows:

1. The resins, including strong cation and chelating types, were contacted with whole ore PLS. The results were inconclusive.

2. One test was performed contacting neutralized PLS solution with DEHPA. The results were inconclusive.

3. Aluminum precipitation from PLS was performed by neutralization at Ph of around 3 to 3.5 to form goethites and jarosites. A considerable amount of REE's were co-precipitated in the tests.

13.1.5 RDi Initial Heap Leaching Tests

The primary objective of this phase of the study was to determine the amenability of heap leaching for extraction of REE's. The program included static leach tests (bucket leach tests) to evaluate the relative leachability with sulfuric acid of various size fractions of the material as well as with various acid strengths. Two open-circuit column tests were run at two different acid strengths to generate heap leaching design data.

The highlights of the leaching test results were as follows:

1. The sulfuric acid strength for the 63-day static bucket tests was 10 g/l. The best extractions occurred with the ½ inch by 1-inch crush size. Yttrium, dysprosium HREE+Y and TREE+Y extractions averaged from 42% to 49%. Yttrium and dysprosium extractions from the ½ inch by 1-inch fraction were 61.1% and 57.5%, respectively.

2. The second series of static bucket tests used a ½ inch crush size and tested various acid strengths from 5 g/l to 100 g/l. A summary of the test results is shown in Table 13-1. Higher acid strengths resulted in higher extractions for all metals in every case. The acid consumption was not linear with the acid strength. Extractions were higher than any recoveries in previous flotation work.

Table 13-1 Summary of Bucket Static Leach Tests

Test No.	Acid Strength g/l	Extraction, %					Acid Consumption
		Y	Dy	U	TREE+Y	HREE+Y	Kg/mt
SL-10	5	24.6	21.4	4.8	24.8	27.3	9.2
SL-6	10	47.4	42.8	13.3	43.3	47.5	13.1
SL-7	30	70.5	64.9	21.2	62.2	68.4	19.4
SL-8	50	77.4	74.8	28.4	67.4	74.1	21.6
SL-9	100	84.0	79.4	30.7	73.4	79.9	29.6

3. Two open-circuit columns were run to generate data for preliminary heap leach design and to compare two different acid strengths (35 g/l vs. 75 g/l). A summary of the data from the columns is shown in Table 13-2. The extractions were higher for the 75 g/l acid strength, being 82.8% and 79.9% for HREE+Y and TREE+Y, respectively. Yttrium and dysprosium extractions were 91.3% and 87.2%, respectively. Acid consumptions were 22.3 and 26.2 kg/mt for the 35 g/l and 75 g/l cases, respectively. Kinetics were relatively fast in each case.

Table 13-2 Summary of Percent Extractions for Selected Elements

Element	Column 1, Days (Low Acid)			Column 2, Days (High Acid)		
	20	40	60 (1.)	20	40	60 (1.)
HREE + Y	63.0	69.6	73.2	78.7	81.3	82.8
TREE +Y	62.5	68.8	72.4	74.5	78.0	79.9
Y	79.0	87.4	89.6	86.0	90.0	91.3
Dy	74.4	81.2	83.3	83.0	86.2	87.2
U	21.6	24.9	26.2	26.4	29.6	31.0
Th	81.4	86.9	89.2	85.5	89.1	90.8
Lu	56.5	62.9	65.0	61.6	65.6	67.0
Ho	73.6	80.2	82.2	82.6	85.5	86.4
Er	69.9	76.4	78.6	79.2	82.2	83.3
Tm	62.7	69.0	71.1	73.7	76.7	77.7
Yb	59.8	65.9	68.0	69.7	73.2	74.4
Tb	76.6	83.1	85.3	82.7	85.9	87.0
Be	2.3	4.3	5.6	4.9	8.0	9.7
Li	10.1	22.0	30.3	26.8	45.4	58.5

13.1.6 Tussar Pregnant Leach Solution Testing

The objective for this phase of the work was to gather basic information regarding removal of iron, aluminum, uranium and thorium from pregnant leach solution followed by selective removal of REE's. The program included pH adjustments to drop out iron followed by contact with Column 1 media which is designed specifically for uranium and thorium removal. The remaining solution was contacted with Column 2 media which is specific for removal of REE's.

The highlights of the test results are summarized below:

1. The program was preliminary in nature but did indicate that the uranium and thorium could be partially removed with little or no REE removal in the first stage contact.
2. In the second stage contact, much of the uranium and thorium not removed in the first stage was recovered. The REE removal is low but encouraging that it will work.
3. More experiments were required to understand the chemistry of the unique solutions from leaching the Round Top ore.
4. The Tussar work was superseded by work conducted for TMRC by K-Tech Inc., described below.

13.2 PEA METALLURGICAL TEST WORK

Based on evaluation of preliminary test work, TMRC and its consultants concluded that the Round Top rhyolite ores are amenable to acid heap leaching, and that this approach constitutes the best technological and economic approach to recovering REE's.

Subsequent testing has been focused on refining the heap leach characteristics of the Round Top Rhyolite, and on testing to simulate separation of non- REE impurities in the pregnant leach solution from the REE fraction.

Metallurgical studies were undertaken at Resource Development Inc. (RDi) and K-Technologies Inc. The following reports were reviewed to prepare this section of the report:

1. Results of Scoping Bucket Static Leach Test, RDi report dated July 16, 2013.

2. Results of Preliminary Column Leach Tests – Revised, RDi report dated September 26, 2013.

3. Phase 0/1 Study Stage 1 Final Report, K-Technologies, Inc., November 24, 2014

During the development of the technology for the extraction and separation of the REE's, it became apparent that some of the "undesirable" (Non-REE) minerals could potentially be by-products/coproducts of the REE'S (i.e., aluminum sulfate, lithium, uranium etc.).

13.3 HEAP LEACH TEST WORK AT RDI

RDi undertook two series of test work consisting of static bucket leach tests initially with the objective of investigating the potential for heap leaching the ore from the prospect. The first series of tests were performed on various sizes from two inch to minus quarter inch at a 10 g/l sulfuric acid concentration. The second series of test were performed on nominal one half inch crushed material to evaluate the extraction characteristics using various acid strengths between 5 and 100 g/L sulfuric acid.

The highlights of the test work indicated the following:

- All the test work was performed on the Red Ryolite samples.

- The crushed ore had the screen analyses given in Table 1.

- The head analyses of the sample and the various size fractions are given in Tables 2 and 3. The comparison of calculated and assayed heads for the elements showed identical values. Also, the assays of the different size fractions were similar. Hence, reasonable to conclude that the minerals are fairly uniformly distributed in the deposit.

- The extractions of the minerals of interest are given in Table 4. Extraction of yttrium and dysprosium averaged 48.6% and 44.5%, respectively.

- The highest extractions for all minerals of interest was from the ¼ x ½ inch size fraction. Extractions dropped significantly in the minus ¼ inch fraction.

- The acid consumption was reasonable for the coarse fractions but increased significantly for the finer size fractions.

Based on the first series of tests, it was reasonable to conclude that heap leach of the ore was feasible at nominal 1-inch crush size.

Table 13-3 Screen Analysis of Pink / Red Rhyolite

Screen Analysis of the Crushed Rhyolite Sample	
+2 inch	10.3
2 x 1 inch	70.4
1 x ½ inch	10.8
½ x ¼ inch	4.0
-¼ inch	4.5

Table 13-4 Selected Head Assays

Selected Head Assays			
Element	Level	Assay	(1) Calculated
Y	ppm	210	193
Dy	ppm	28	29
U	ppm	35.3	35.8
Be	ppm	19	
Ce	ppm	71	
Nd	ppm	29.1	
Th	ppm	182	
Hf	ppm	78.6	
Zn	ppm	580	
MnO	ppm	0.065	

Note: (1) Based on Bucket Leach Tests SL-1 to SL-5

Table 13-5 Assays by size fraction

Assays of the Different Size Fractions of the Sample										
Fraction	Weight, %	Yttrium		Dysprosium		Uranium		TREE + Y	
		Assay	Calc.	Assay	Calc.	Assay	Calc.	Assay	Calc.
Combined	100.0	210	193	28	29	35.3	35.8	499	495
+2 inch	10.3		196		28.1		35.4		482
2 x 1 inch	70.4		191		29.2		35.9		499
1 x ½ inch	10.8		198		29.1		36.3		489
½ x ¼ inch	4.0		189		27.9		35.7		470
-¼ inch	4.5		198		28.7		33.6		500

Table 13-6 Summary of Extractions of Selected Elements

Summary of Extractions of Selected Elements								
Size Fraction	Weight %	Extraction, %						Acid Consumption Kg/mt
		Yttrium (Y)	Dysprosium (Dy)	Uranium (U)	Thorium (Th)	TREE +Y	HREE +Y	
Combined	100.0	48.6	44.5	12.5	40.8	42.5	44.0	15.2
+2 inch	10.3	32.3	27.5	7.7	22.4	28.0	29.0	13.2
2 x 1 inch	70.4	50.3	45.6	11.3	39.5	43.1	45.4	12.8
1 x ½ inch	10.8	61.1	57.3	18.5	56.7	54.4	55.5	18.4
½ x ¼ inch	4.0	57.6	57.7	22.0	65.5	53.6	52.9	23.8
-¼ inch	4.5	20.8	23.8	19.3	43.7	27.4	20.9	41.9

The second series of tests, consisting of bucket static leach tests, evaluated the effect of concentration of sulfuric acid on extraction of REE's. The test results, given in Tables 5 to 7, indicated the following:

- The higher acid strengths resulted in higher extractions for the metals of interest. Yttrium and dysprosium extractions varied from 24.6% and 21.4% to 84.0% and 79.4%, respectively. Total rare earth elements plus yttrium (TREE + Y) and heavy rare earth elements plus yttrium (HREE + Y) extractions varied from 24.8% and 27.3% to 73.4% and 79.9%, respectively.

- The higher the initial acid concentration in solution, the higher the acid consumption in the tests.

- Acid consumption generally drops off after 11 days of leaching thereby indicating that acid consumers in the ore were extracted (Table 6).

- Aluminum and iron levels in the 25/26-day solutions varied from 0.955 g/l to 3.52 g/l for aluminum and 0.069 g/l to 1.85 g/l for iron (Table 7). A very distinct break occurred for iron between 10 g/l and 30 g/l acid strength. The aluminum appeared to be consistently increasing with acid concentration.

Table 13-7 Summary of Bucket Static Leach Extractions

Summary of Bucket Static Leach Tests							
Test No.	Acid Strength g/l	Extraction, %					Acid Consumption Kg/mt
		Y	Dy	U	TREE+Y	HREE+Y	
SL-10	5	24.6	21.4	4.8	24.8	27.3	9.2
SL-6	10	47.4	42.8	13.3	43.3	47.5	13.1
SL-7	30	70.5	64.9	21.2	62.2	68.4	19.4
SL-8	50	77.4	74.8	28.4	67.4	74.1	21.6
SL-9	100	84.0	79.4	30.7	73.4	79.9	29.6

Table 13-8 Acid Strength vs. Acid Consumption

Relationship of Acid Strength vs. Acid Consumption					
Test No.	Acid Strength g/l	Residual Level, g/l			
		Day 4	Day 11/12	Day 18/19	Day 25/26
10	5	2.50	3.76	3.75	3.75
6	10	6.25	7.50	7.50	8.75
7	30	25.0	26.3	28.8	28.8
8	50	45.0	46.2	48.7	50.0
9	100	91.2	96.2	97.5	100.0

Table 13-9 Iron and Aluminum Extraction

Iron and Aluminum Levels in Solution					
Test No.	Acid Strength, g/l	Extraction, %		Leachate, g/l	
		Al	Fe	Al	Fe
10	5	1.4	0.7	0.955	0.069
6	10	2.0	0.9	1.37	0.097
7	30	3.0	5.3	2.07	0.545
8	50	3.8	9.5	2.65	0.966
9	100	5.2	18.7	3.52	1.85

13.4 COLUMN LEACH TEST AT RDI

Two open-circuit column leach tests were performed using pink / red rhyolite sample used in the static bucket leach tests. However, the samples were stage crushed to nominal 0.5 inch. The test conditions for the two tests are summarized in Table 8.

Table 13-10 Test Conditions for Column Leach Tests

Test Condition for Column Leach Tests	
Column diameter	4 inches
Column charge height	71 inches
Column charge weight	20 kilograms
Column 1 acid strength	35 g/l H_2SO_4
Column 2 acid strength	75 g/l H_2SO_4
Solution application rate	0.005 gal/min/ft^2
Leaching time	60 days
Rinsing time	23 days
Column 1 acid consumption	22.3 kg/mt
Column 2 acid consumption	26.1 kg/mt

The leach tests were performed for 60 days. Solution samples were composited periodically, weighed and submitted for analyses. On completion of the leaching, the columns were rinsed with water and the residue was removed, dried and submitted for analyses.

The test results are summarized in Table 9. The test results indicate the following:

- The total rare earth plus yttrium (TREE+Y) extraction was 72.4% at 35 g/L sulfuric acid concentration and 79.9% at 75 g/L sulfuric acid concentration. The leach time was 60 days.
- The total acid consumption for 35 g/L and 75 g/L were 22.3 kg/mt and 26.1 kg/mt, respectively.
- The extraction of heavy rare earth elements plus yttrium (HREE + Y) was 73.2% and 82.8% for 35 g/L and 75 g/L, respectively.
- The yttrium and dysprosium extractions were 87% to 91% in the column leach tests.
- The extraction of uranium in the column leach tests were only 31%.

Table 13-11 Summary of Column Leach Extractions for Selected Elements

Summary of Extractions for Selected Elements Extractions, %						
	Column 1, Days			Column 2, Days		
Element	20	40	60	20	40	60
HREE+Y	63.0	69.6	73.2	78.7	81.3	82.8
TREE+Y	62.5	68.8	72.4	74.5	78.0	79.9
Y	79.0	87.4	89.6	86.0	90.0	91.3
Dy	74.4	81.2	83.3	83.0	86.2	87.2
U	21.6	24.9	26.2	26.4	29.6	31.0
Th	81.4	86.9	89.2	85.5	89.1	90.8
Lu	56.5	62.9	65.0	61.6	65.6	67.0
Ho	73.6	80.2	82.2	82.6	85.5	86.4
Er	69.9	76.4	78.6	79.2	82.2	83.3
Tm	62.7	69.0	71.1	73.7	76.7	77.7
Yb	59.8	65.9	68.0	69.7	73.2	74.4
Tb	76.6	83.1	85.3	82.7	85.9	87.0

The column leach kinetic curves are shown in Figure 13-1 and Figure 13-2. Based on the limited test work, it is reasonable to conclude that one can leach not only REE's but also other elements (Al, Fe, Li, Mg, etc.) to produce potential by products. These elements had to be selectively removed anyway in order to produce the REE's.

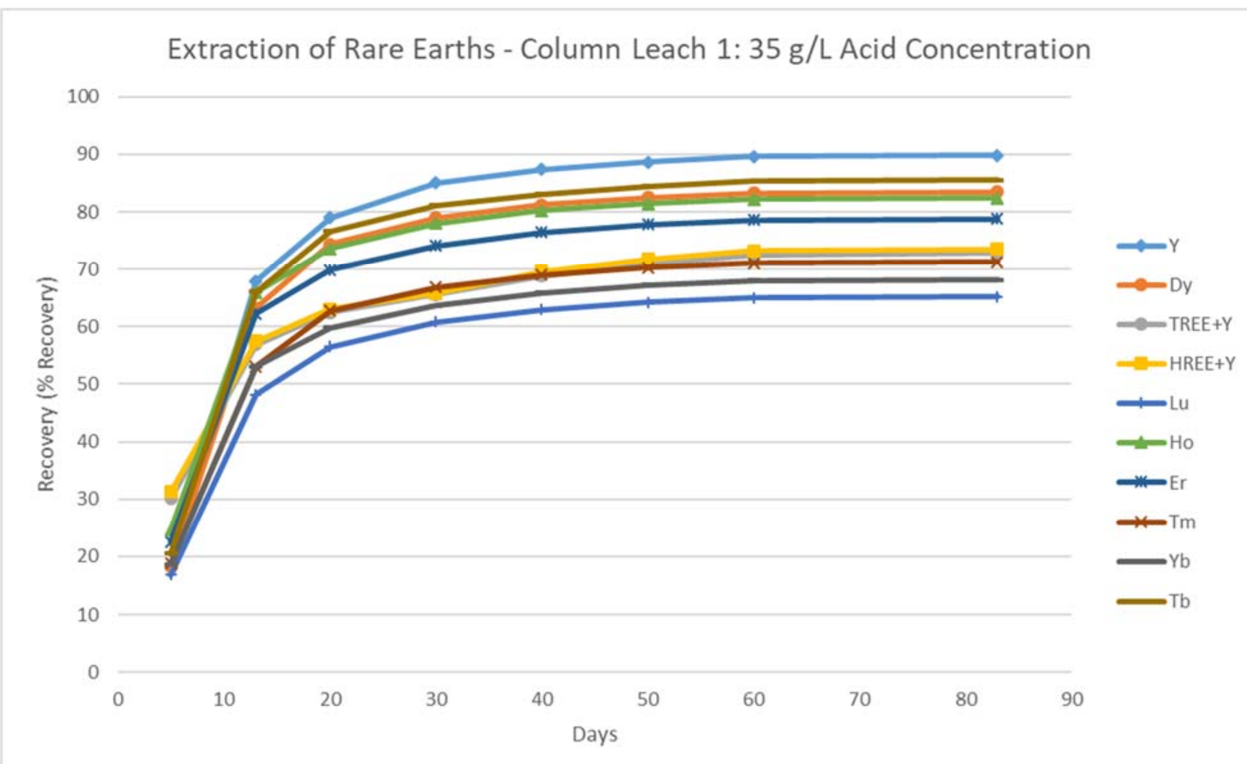


Figure 13-1 Column Leach 1

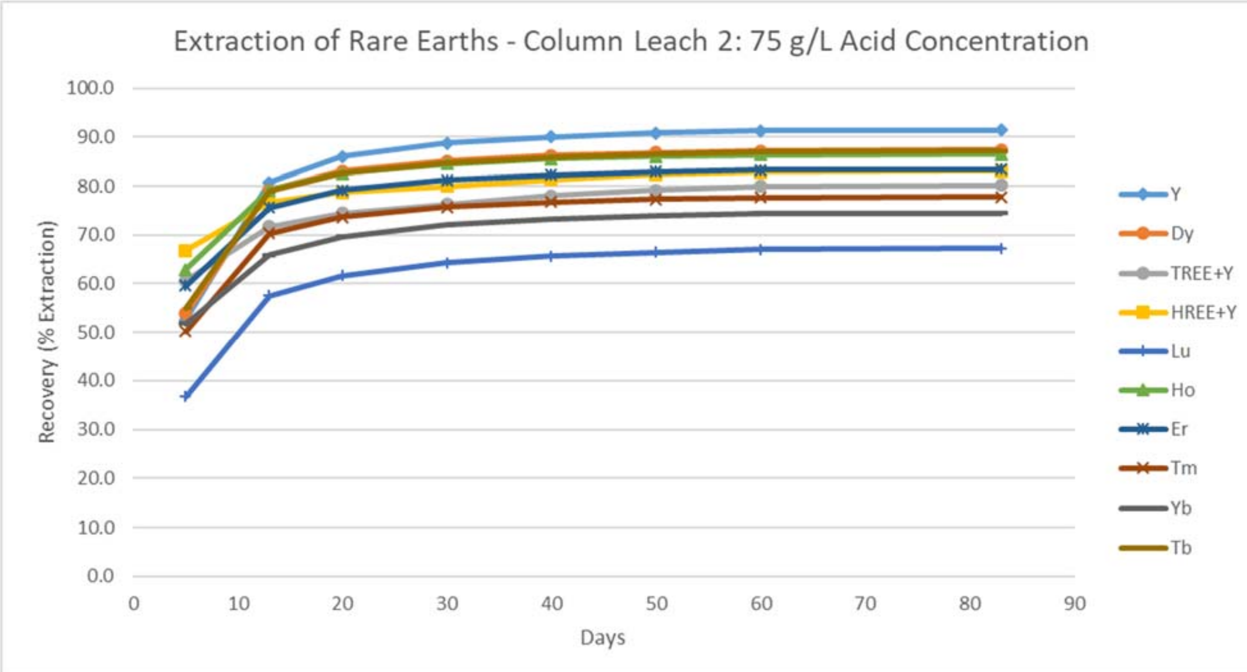


Figure 13-2 Column Leach 2

13.5 METALLURGICAL TEST WORK AT K-TECHNOLOGIES, INC.

K-Technologies, Inc. undertook a Stage 1 bench-scale testing program to separate the non-rare earth impurities species (non-RE's) in the pregnant leach solution (PLS) from the rare-earth fraction (RE's). Initial test work was performed on PLS generated in the column leach tests at RDi. However, due to the limited PLS available at RDi, K-Tech made up synthetic samples of PLS for the study.

K-Tech envisioned a three-stage development program consisting of the following:

Stage 1: Separation of the non-RE's fraction from the RE's
Stage 2: Separation of the RE's fraction into groups of light RE's, mid RE's and heavy RE's
Stage 3: Separation and purification of the HRE group into individual purified HRE's

K-Tech has only completed Stage 1 testing on this deposit. However, they have worked on all the phases for other projects.

The separation test work utilized K-Tech's static columns which simulate what can be expected in the continuous ion exchange and ion chromatography (CIX/CIC) equipment. The simulated PLS solution made up by K-Tech was a sulfate material that had free acid content of 10 g/L H_2SO_4 which was similar to the PLS generated at RDi in Column testing. A second solution was also prepared with about 20 g/L H_2SO_4 with the objective of assaying the impact of free acid content on the loading characteristics of the RE's on the strong cation 1X resin. Two resins, Dowex 50 and Purolite SST-60, were tested and the latter had better results and was used in subsequent test work. Sulfuric acid was used as the regeneration solution.

13.5.1 Loading Characteristics:

During the loading tests, it was observed that RE's had a preference for the resin compared with the impurities. The feed sample has non-RE's to RE's ratio of 23 to 1. For 10 g/L free acid case (Test 1), the amount of RE's loaded on to the resin compared to the amount of impurities was a ratio of 5 to 1, demonstrating that a substantial rejection of impurities was achieved. Similarly, for 20 g/L free acid case (Test 2), the ratio was 9 to 1. In both tests, the trend showed that further loading of the resin with feed solution could potentially achieve further impurity rejection.

13.5.2 Crowding/Regeneration Response:

Even though the RE's loaded preferentially on the resin compared with the impurities, the ratio of 5:1 or 9:1 was higher than the target 3:1 impurities of RE's ratio for Stage 2 processing. Hence, additional techniques were employed to further reduce the impurities during resin regeneration phase. The techniques of resin crowding and gradient elution were employed in subsequent tests.

A concentrated solution of RE's was prepared using a lower impurity RE material. The concentrated solution was fed to the 1X resin after additional loading of the feed solution. As the crowding solution flows through the resin, the higher RE's in the crowd material displace impurities that are on the resin from the loading step. The spent crowd solution is recovered for recycle of any contained Res. The crowding test was run on the Test 2 loaded resin (20 g/L free acid). The impurities to Res ratio in the regeneration solution was reduced from 9:1 to 0.17:1 which was well below the 3:1 target.

13.5.3 Gradient Elution Testing:

For the gradient elution testing, the resin was contacted with a progressively weaker to stronger sulfuric acid regeneration solution. The weaker strength regeneration solutions tend to remove the non-RE's impurities, and as the strength of the regeneration solution increases the RE's are then removed. This technique was applied to Test 1 loaded resin. The impurities to RE's ratio was reduced to 0.29:1.

In Summary, the Stage 1 Process assessment demonstrated that CIX technology can be applied to the PLS from the leaching system to remove RE's from the PLS and effect a substantial rejection of the associated impurities.

14 MINERAL RESOURCE ESTIMATE

The effective date of the mineral resource estimate for the Round Top Project is July 1, 2019. The resource estimation was completed by Donald Hulse, VP Mining for Gustavson, a qualified person under 43-101 standards. This mineral resource estimate has been prepared in accordance with NI 43-101 and CIM Standards.

14.1 DATA USED FOR REE GRADE ESTIMATION

Gustavson created a 3-Dimensional (3-D) block model for estimating mineral resources at the Round Top Project. Drill hole data, including collar coordinates, down hole surveys, sample assay intervals, and geology logs, were provided by TMRC as Microsoft Excel files. The Round Top Project drill hole database contains lithology, assay, and REE grades as individual elements. Exploration drilling at Round Top has been completed by three companies: Cabot, Cyprus, and TMRC. In the 1980s a Cabot-Cyprus Joint Venture began exploration drilling for beryllium mineralization associated with massive fluorite outcrops at the contact of the rhyolite and the underlying limestone. A portion of the RC drill chips (43) were preserved and logged and assayed for REEs by TMRC. The drilling totaled 108 holes and approximately 45,000 ft. of drilling.

In 2019, TMRC reanalyzed 157 samples from 34 drill holes with whole rock analysis. This allows the determination of the economics of different byproducts has led Gustavson to focus on seven elements with the highest economic impact for this 2019 study.

At the effective date of this report, TMRC had completed 87 drill holes totaling 34,700 ft. with final assays and certificates for 85 drill holes with a total of 3,081 sample intervals. Only assays within the rhyolite were used in the resource estimation. This amounted to 74 TMRC drill holes with 1,594 20 ft. composites.

14.2 ESTIMATION METHODOLOGY

14.2.1 Geologic Model

Modeled elements within the Round Top project area are zoned by lithology. A geologic model was created from drill log data provided by TMRC. The initial data contained 20 different lithologic classifications. These were grouped into 6 lithologies. Using these grouped lithologies, a lithologic model was created using Leapfrog™ Mining Software. Figures 14-1 and 14-2 display the geologic model created in Leapfrog. The lithologic model was then imported into MicroModel™ for resource estimation and is shown in cross-section in Figure 14-3. The final model included the lithologies; Red/Pink Rhyolite, Grey Rhyolite, Brown Rhyolite, Cover, Basal Sedimentary Rocks, and Little Round Top Rhyolite. The unit referred to as Basal Sedimentary Rocks includes Cretaceous marine limestones and black shales and pre-rhyolite Tertiary diorite.

The final lithologic model was then tied back into the drill hole database as modeled lithologies. In most cases, the REEs and other elements modeled in this study are normally distributed throughout the rhyolite body independent of rhyolite color. While there was some evidence of Eu enrichment at the top of the basal sedimentary rocks, the resource was only estimated for the grouped Round Top Rhyolites. Table 14-1 summarizes the categorization of the lithologic model.

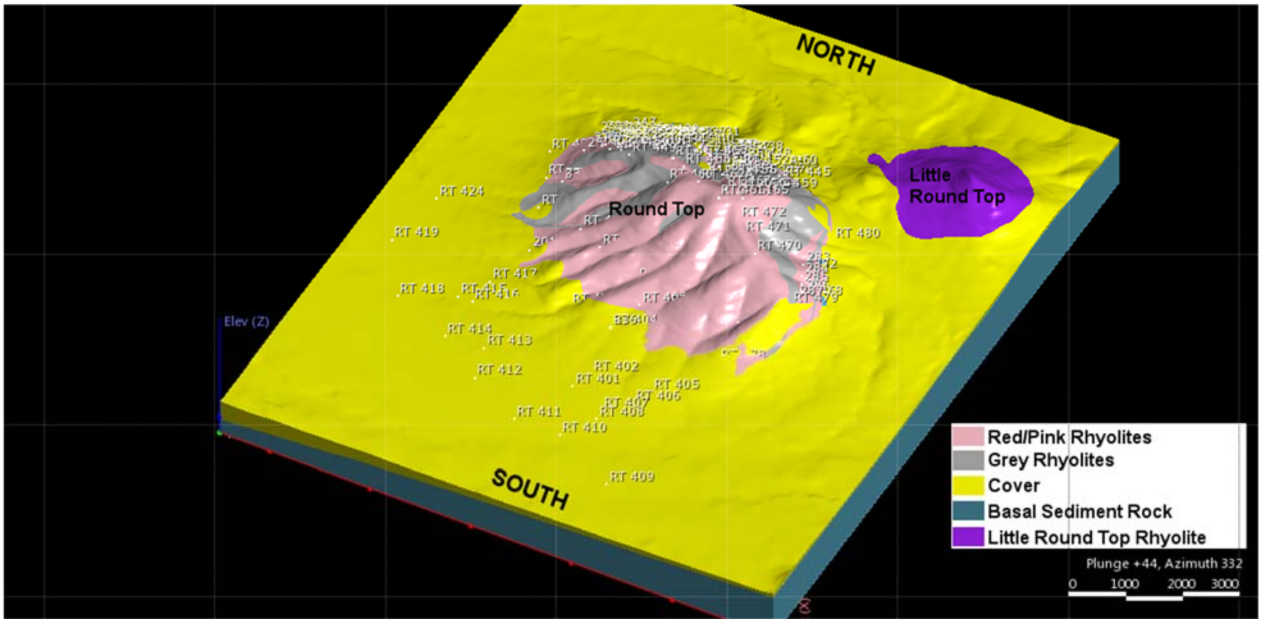


Figure 14-1 Aspect View of 3-D Lithologic Model Created in Leapfrog Including Drill Collar Locations

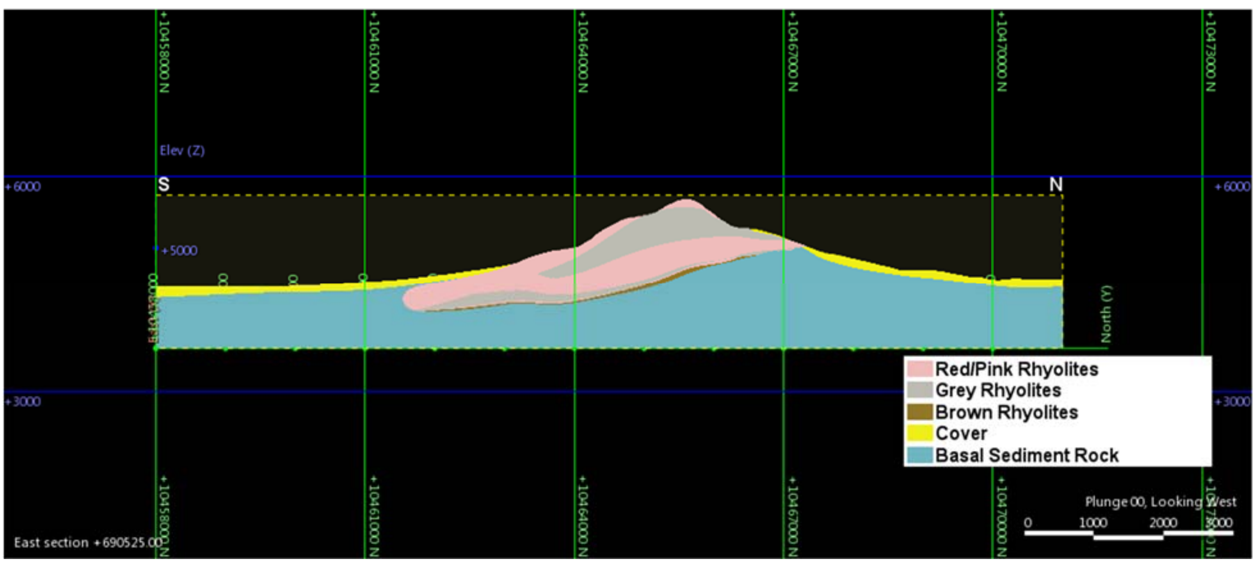


Figure 14-2 North/South Cross Section of Lithologic Model at 690525E with a 50' Thickness from Leapfrog

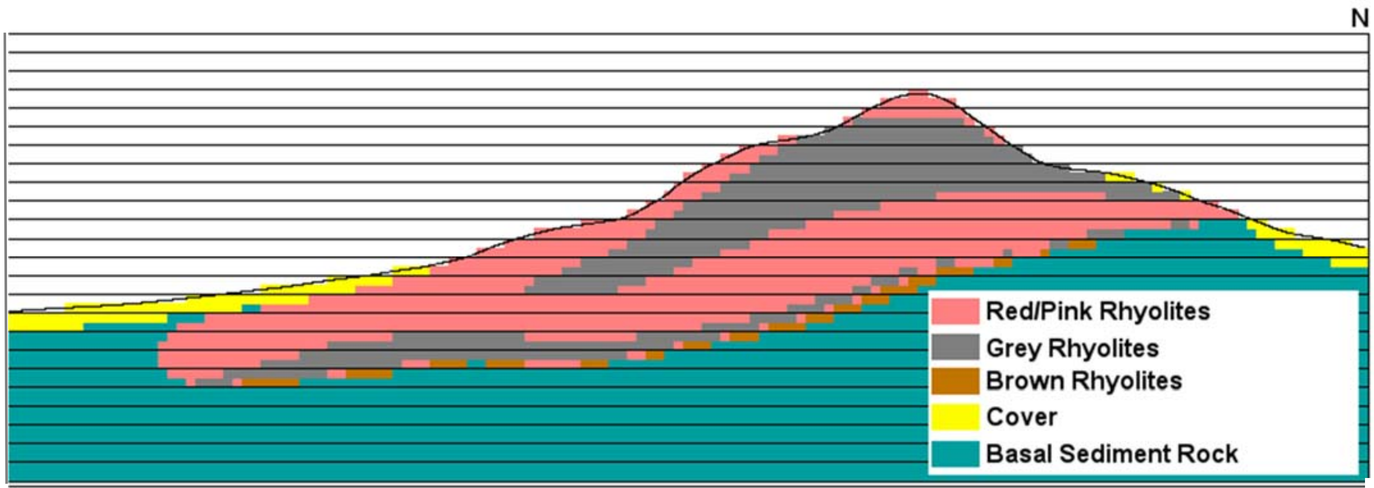


Figure 14-3 North/South Cross Section of Lithologic Model at 690525E After Import to Micro Model

Table 14-1 Geologic Model Summary

Original TMRC DH Database		Leapfrog Lithology		Micro Model Code	Backmarked Modeled Lithology		Block Model
Name	**Instances**	**Layer Name**	**Description**	**Code**	**Code**	**Instances**	**Count**
gry rhy	670	GR1, GR2	Grey Rhyolite	3, 5	3, 5	800	37,635
rd rhy	587	RP1, RP2, RP3	Red/Pink Rhyolite	2, 4, 6	2, 4, 6	1,579	88,325
pk rhy	485						
tan rhy	128	BrownRhy	Brown Rhyolite	7	7	51	3,687
brn rhy	2						
Rhy	428	N/A	Rhyolite with no color information split between Grey and Red/Pink Ryolite based on Leapfrog lithologic model	N/A	N/A	N/A	N/A
Qg	459	COVER	Cover	1	1	416	80,702
Qal	7						
LS	60	BASALSEDS	Basal Sediments	8	8	182	631,894
gry ls	43						
bk sh	32						
Sh	16						
gry sh	4						
bk slty ss	2						
bk ls	1						
Breccia	15		Ignored	Based on litholigic model	N/A	N/A	N/A
dio	8						
Diorite	4						
gry dio	2						
bk dio	1						
(blanks)	128						
nd	13						
			Little Round Top Rhyolite (from geologic map)	10	N/A	N/A	12,911

14.2.2 Statistical Data

The drill samples from Round Top have been analyzed in two different campaigns, 2013 and 2019, with a different suite of elements analyzed each time.

The 2013 resource estimate modeled 15 rare earth elements including Y, plus 6 other elements, totaling 20 elements. These elements are: Cerium (Ce), Dysprosium (Dy), Erbium (Er), Europium (Eu), Gadolinium (Gd), Hafnium (Hf), Holmium (Ho), Lanthanum (La), Lutetium (Lu), Niobium (Nb), Neodymium (Nd), Praseodymium (Pr), Samarium (Sm), Tin (Sn), Tantalum (Ta), Terbium (Tb), Thorium (Th), Thulium (Tm), Uranium (U), Yttrium (Y), and Ytterbium (Yb). Tungsten (W) was also considered for analysis, however, discrepancies between historical and TMRC assay results for W made accurate resource estimation for this element impractical.

Further data collection included 17 additional elements. The grades were based on whole rock analyses carried out in 2018 and 2019 on selected samples in the northern part of Round Top that is scheduled for early mining. These elements are: Aluminum (Al), Beryllium (Be), Calcium (Ca), Fluorine (F), Iron (Fe), Gallium (Ga), Potassium (K), Lithium (Li), Magnesium (Mg), Manganese (Mn), Sodium (Na), Nickel (Ni), Rubidium (Rb), Titanium (Ti), Thallium (Tl), and Zirconium (Zr). Gustavson also revisited six elements that had new assay data evaluated from the previously drilled samples. These include: Cerium (Ce), Hafnium (Hf), Lanthanum (La), Thorium (Th), Uranium (U), and Yttrium (Y).

A statistical summary of the sample data collected in 2019 is presented in Table 14-2. Table 14-3 shows the statistical summary of the sample data from the 20 elements that were used in the economic model.

The present model is considered by Gustavson to yield a reasonable estimate of the mineral resource available within the rhyolite body. However, it is important to note that a mineral resource is not a mineral reserve and does not have demonstrated economic viability.

Table 14-2 Descriptive Statistics of Sample Analysis from 2019

Element	Unit	Minimum	Maximum	Mean	Median	Standard Deviation
Al	%	5.6	7.4	6.6	6.64	0.36
Be	ppm	7.4	166.5	34.5	26.8	26.73
Ca	%	0	2.2	0.3	0.08	0.56
Ce	ppm	0	1100	78.5	80.05	23.8
Dy	ppm	0	199	29.9	31.7	7.49
F	ppm	3770	20001	13121.3	13325	4794.71
Fe	%	0.9	1.5	1.1	1.09	0.1
Ga	ppm	67.6	79.1	73.5	73.8	2.5
Gd	ppm	1.1	134	10	10.35	3.07
Hf	ppm	12.6	91.3	35.5	31.6	17.91
K	%	2.6	3.6	3.2	3.25	0.16
La	ppm	0	20	18.2	18.9	2.56
Li	ppm	319	950	459.8	440	92.4
Lu	ppm	0	18.6	8.5	9.01	1.78
Mg	%	0	0.2	0.1	0.03	0.05
Mn	ppm	363	1110	532.4	528	99.47
Na	%	3.2	4.9	4	3.99	0.43
Nb	ppm	136	367	204.6	191.75	47.67
Nd	ppm	5.4	510	28.1	28.4	10.27
Ni	ppm	0.4	8.8	1.6	1.34	1.11
Pr	ppm	1.5	138	10.2	10.4	2.93
Rb	ppm	1560	2090	1894.2	1910	107.78
Sc	ppm	0.5	1.4	0.7	0.73	0.12
Sm	ppm	0	138.5	10.1	10.4	3.12
Sn	ppm	0	271	134	140	26.6
Tb	ppm	0	28.1	3.4	3.62	0.89
Th	ppm	104	195.5	173.6	176	14.29
Ti	%	0	0.1	0	0.01	0
Tl	ppm	5.1	8.8	6.9	6.97	0.63
U	ppm	16.2	94.7	37.2	34.8	13.06
Y	ppm	97.9	250	209.7	217	24.25
Zr	ppm	0	1460	1045.1	1080	180.977

Table 14-3 Descriptive Statistics of Samples of Elements Used in the Economic Model

Element	Unit	Minimum	Maximum	Mean	Median	Standard Deviation
Al	%	5.6	7.4	6.6	6.64	0.36
Be	ppm	7.4	166.5	34.5	26.8	26.73
Dy	ppm	0	199	29.9	31.7	7.49
Fe	%	0.9	1.5	1.1	1.09	0.1
Ga	ppm	67.6	79.1	73.5	73.8	2.5
Hf	ppm	12.6	91.3	35.5	31.6	17.91
K	%	2.6	3.6	3.2	3.25	0.16
Li	ppm	319	950	459.8	440	92.4
Lu	ppm	0	18.6	8.5	9.01	1.78
Mg	%	0	0.2	0.1	0.03	0.05
Mn	ppm	363	1110	532.4	528	99.47
Na	%	3.2	4.9	4	3.99	0.43
Nd	ppm	5.4	510	28.1	28.4	10.27
Pr	ppm	1.5	138	10.2	10.4	2.93
Sc	ppm	0.5	1.4	0.7	0.73	0.12
Sm	ppm	0	138.5	10.1	10.4	3.12
Tb	ppm	0	28.1	3.4	3.62	0.89
U	ppm	16.2	94.7	37.2	34.8	13.06
Y	ppm	97.9	250	209.7	217	24.25
Zr	ppm	0	1460	1045.1	1080	180.977

The relative closeness of values represented by the mean and the median, the median usually within 5% of the mean, as well as the histogram distributions, suggest that the elements are normally distributed throughout the rhyolite body.

14.2.3 Hafnium and Zirconium

2019 hafnium and zirconium grades show a marked difference between the previous analysis and the current analysis. During the 2012 campaign, all of the drill samples were analyzed for a complete elemental package including zirconium and hafnium. The resource model is based on 239 samples selected from the much larger data set. The original analyses did not include Lithium and the samples were sent for re-analysis to include lithium and the other major rock forming minerals in early 2019. The analysis package also included zirconium and hafnium.

Both the 2012 and the 2019 samples were sent to ALS Geochemistry in Reno, Nevada. The averages for Hf and Zr for the 2012 analyses were 87.6 and 1114.2 respectively, these values agree with the values of the larger data set from the entire drilling program. The samples re-analyzed in 2019 yielded averages of 35.4 Hf and 436.3 Zr. These differences cannot be explained by routine analytical error. However, the samples used in the column leach testing were sent to Acctlabs in Canada. The head analysis for these samples was 78.6 Hf and 1063 Zr.

In addition, mass balances were calculated for all elements during the column leach testing. The mass balances for hafnium and zirconium closely support the Acctlab analyses for the respective elements and are in agreement with the 2012 data set. Recovery conclusions in this report are based on these mass balance calculations. Based on the confidence derived from the mass balance calculations in the leach testing, we have elected to use the 2012 analytical data for the resource modeling. Investigation will be undertaken to determine the reason for the discrepancy in the two sets of data from ALS. Sample cumulative frequency plots were also generated for the 21 elements used in the economic model. Example plots in Figure 14-4 show the distribution of the elements within the deposit. All other plots can be seen in Appendix C.

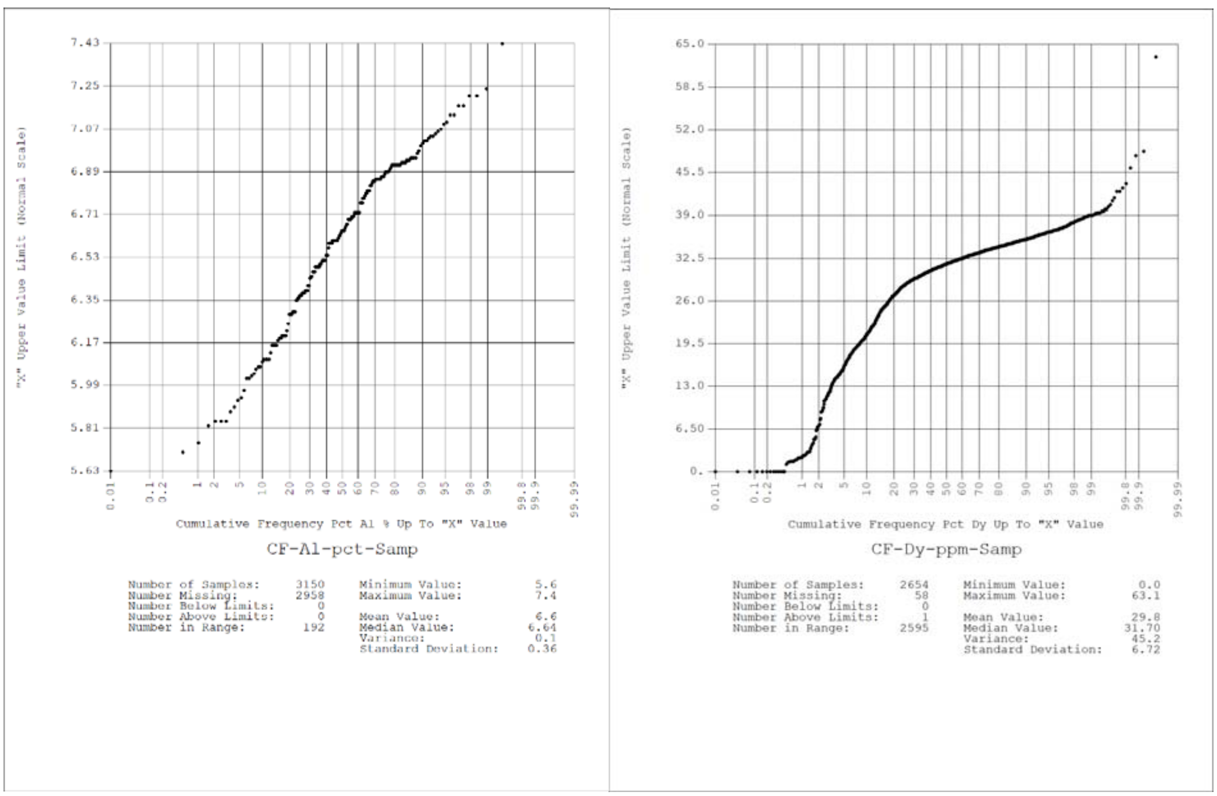


Figure 14-4 Cumulative Frequency Plots of Aluminum and Dysprosium

14.2.4 Capping

Log transformed cumulative frequency plots based on sample data demonstrated that there were some values well above the trend line. Capping limits were set by determining the point at which the data deviated from the trend line. Capping limits were set before compositing. Table 14-4 summarizes the cap limits of the elements used in the economic model.

Table 14-4 Sample Capping

Element	Units	Cap Value	Number Capped
Al	%	7.25	1
Be	ppm	100	5
Dy	ppm	44	5
Fe	%	1.3	7
Ga	ppm	No Cap	0
Hf	ppm	95	102
K	%	3.52	5
Li	ppm	650	6
Lu	ppm	10.5	13
Mg	%	0.192	4
Mn	ppm	660	11
Na	%	4.8	1
Nd	ppm	42	12
Pr	ppm	15	11
Sc	ppm	1	5
Sm	ppm	13	19
Tb	ppm	5	6
U	ppm	70	277
Y	ppm	235	780
Zr	ppm	1300	10

14.2.5 Compositing

A 20 ft composite was used for resource estimation based on a planned bench height of 20 ft. Composite length had little to no influence on the grades of REEs. The composites were coded as being within the rhyolite or not. Statistical analyses based on the composites in rhyolite are shown in Table 14-5. Compositing resulted in cumulative frequency plots with established trends and histograms with well-defined normal distributions. Table 14-6 summarizes the capped statistics of the elements used in the economic model. Note that the statistical changes are minimal. Note that dysprosium and lutetium have a higher number of composites as they represent more of the deposit and are from the original assay analyses.

Table 14-5 Descriptive Statistics of Composite Analysis from 2019

Element	Unit	Minimum	Maximum	Mean	Median	Standard Deviation
Al	%	5.6	7.2	6.6	6.62	0.35
Be	ppm	7.37	100	31.007	26.8	17.096
Ca	%	0.01	2.24	0.197	0.05	0.37
Ce	ppm	0	337.825	78.157	79.4	11.426
Dy	ppm	0	44	30.423	31.513	4.959
F	ppm	3770	20001	13210.9	13650	4684.039
Fe	%	0.89	1.3	1.083	1.07	0.077
Ga	ppm	67.6	79.1	73.352	73.575	2.527
Gd	ppm	0	15	10.005	10.311	1.548
Hf	ppm	12.6	80	35.406	34.6	16.529
K	%	2.57	3.52	3.26	3.27	0.148
La	ppm	0	129.425	19.93	20	3.471
Li	ppm	319	650	458.139	449.5	72.988
Lu	ppm	0	10.5	8.75	9.02	1.182
Mg	%	0.001	0.192	0.046	0.02	0.052
Mn	ppm	363	660	513.862	515	68.977
Na	%	3.23	4.8	4.084	4.11	0.418
Nb	ppm	136	367	194.262	183.5	41.188
Nd	ppm	0	42	27.927	28.325	3.299
Ni	ppm	0.44	8.81	1.477	1.28	1.003
Pr	ppm	0	15	10.199	10.4	1.181
Rb	ppm	1560	2090	1911.098	1930	94.274
Sc	ppm	0.52	1	0.728	0.7	0.093
Sm	ppm	0	13.5	10.09	10.337	1.354
Sn	ppm	0	165	137.222	140.5	17.368
Tb	ppm	0	4.71	3.459	3.6	0.54
Th	ppm	0	236.75	177.166	181	21.218
Ti	%	0.009	0.044	0.012	0.011	0.003
Tl	ppm	5.05	8.79	6.961	7.01	0.526
U	ppm	0	70	42.575	41.7	9.97
Y	ppm	0	235	211.259	222	32.778
Zr	ppm	299.5	1300	1095.208	1100	89.443

Table 14-6 Descriptive Statistics of Capped Composites of Elements Used in the Economic Model

Element	Unit	Minimum	Maximum	Mean	Median	Standard Deviation
Al	%	5.6	7.2	6.6	6.62	0.35
Be	ppm	7.37	100	31.007	26.8	17.096
Dy	ppm	0	44	30.423	31.513	4.959
Fe	%	0.89	1.3	1.083	1.07	0.077
Ga	ppm	67.6	79.1	73.352	73.575	2.527
Hf	ppm	12.6	80	35.406	34.6	16.529
K	%	2.57	3.52	3.26	3.27	0.148
Li	ppm	319	650	458.139	449.5	72.988
Lu	ppm	0	10.5	8.75	9.02	1.182
Mg	%	0.001	0.192	0.046	0.02	0.052
Mn	ppm	363	660	513.862	515	68.977
Na	%	3.23	4.8	4.084	4.11	0.418
Nd	ppm	0	42	27.927	28.325	3.299
Pr	ppm	0	15	10.199	10.4	1.181
Sc	ppm	0.52	1	0.728	0.7	0.093
Sm	ppm	0	13.5	10.09	10.337	1.354
Tb	ppm	0	4.71	3.459	3.6	0.54
U	ppm	0	70	42.575	41.7	9.97
Y	ppm	0	235	211.259	222	32.778
Zr	ppm	299.5	1300	1095.208	1100	89.443

Composited cumulative frequency plots were also generated for the 20 elements used in the economic model. Example plots in Figure 14-4 show the distribution of the capped elements within the deposit. All other plots can be seen in Appendix D.

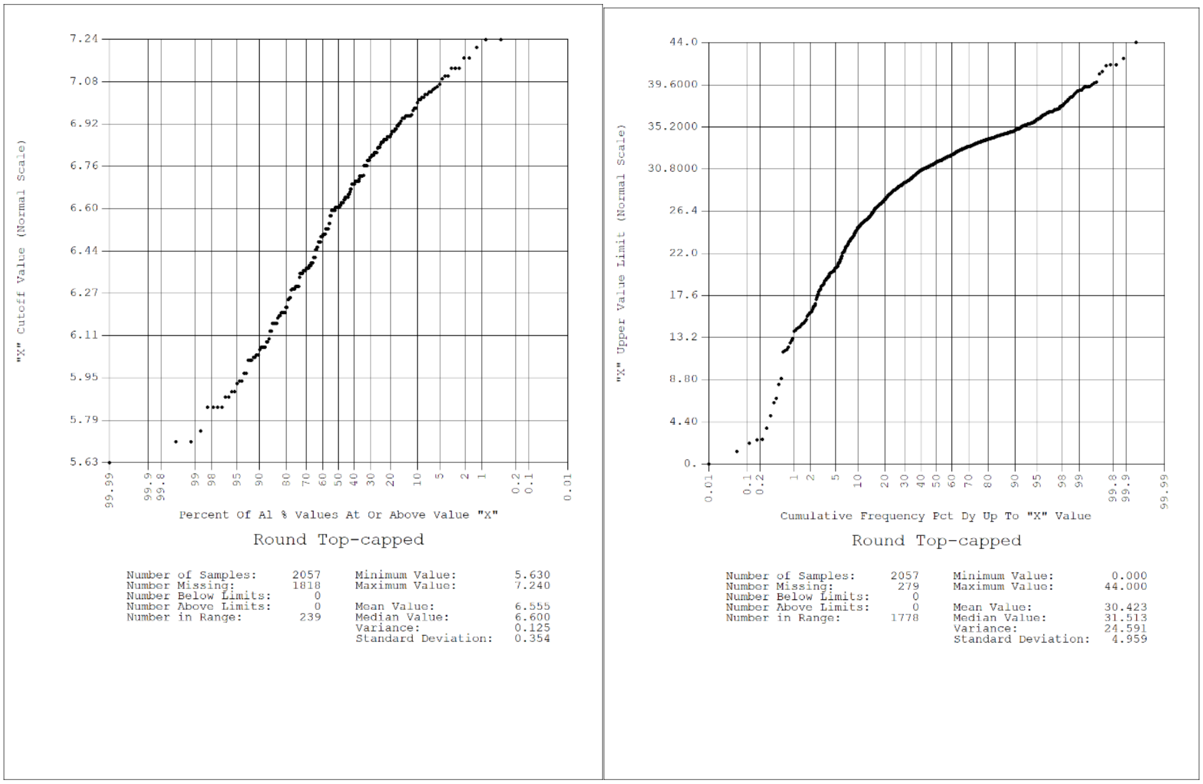


Figure 14-5 - Cum. Frequency of Al and Dy - capped (scaled)

14.2.6 Variography

Geostatistical analysis, the method of investigating the spatial relationship of data, was used in order to set the foundation for grade model interpolation. The primary tool used for geostatistical calculation is the variogram, a graphical representation of the difference between any two samples separated by a given distance in a given direction.

General relative variograms were calculated for each of the modeled elements. Variography was fit with a spherical model. Given the normal distribution of the data, omnidirectional variograms were used to calculate the ranges and sills of the variogram. Down hole variograms were used to determine the nugget. Examples of omnidirectional variogram can be seen in Figure 14-6 and Figure 14-7. Drill hole spacing is more clustered in the north and dispersed to the south. As a result, all omnidirectional variograms required two ranges and sills to accurately describe the spatial relationship of the data. After the variograms were calculated, the variograms were normalized to easily compare the variance between elements. Modeled estimation variance will thus be a relative variance to the estimated grade. Normalizing scales total sill to 1 and sets the nugget as a proportion of that. The ranges are unaffected by normalization.

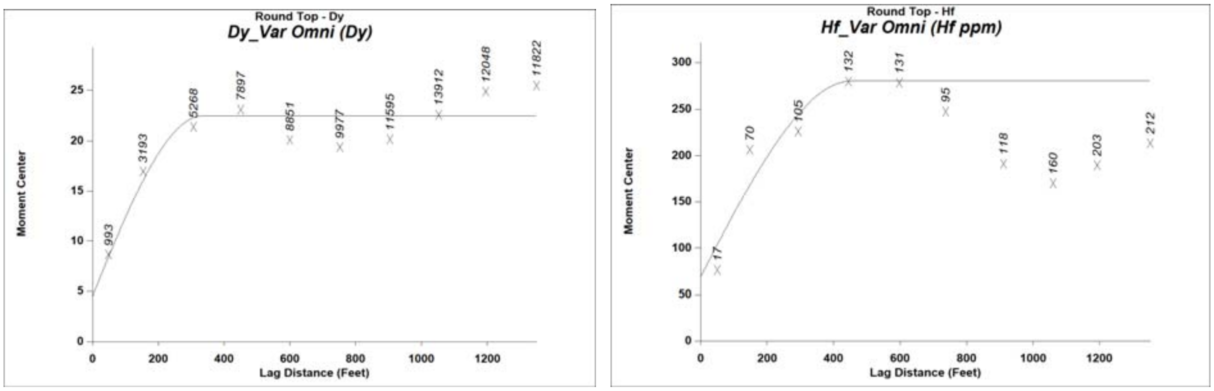


Figure 14-6 - Omnidirectional Variograms for Dy and Hf

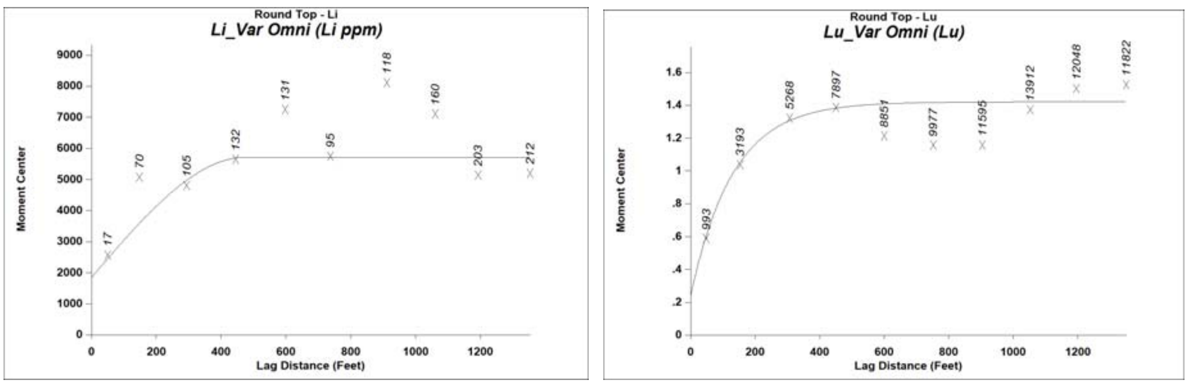


Figure 14-7 - Omnidirectional Variograms for Li and Lu

Table 14-7: Normalized Variogram Models of Economic Elements

Element	Model	C0	C1	A
Al	Spherical	0.15	0.85	540
Be	Spherical	0.25	0.75	240
Dy	Spherical	0.2	0.80	350
Fe	Spherical	0.3	0.70	250
Ga	Spherical	0.25	0.75	224
Hf	Spherical	0.25	0.75	450
K	Spherical	0.2	0.8	480
Li	Spherical	0.3	0.7	500
Lu	Exponential	0.15	0.85	130(390)
Mg	Spherical	0.4	0.6	250
Mn	Spherical	0.2	0.8	480
Na	Spherical	0.2	0.8	85
Nd	Spherical	0.3	0.7	113
Pr	Spherical	0.3	0.7	110
Sc	Spherical	0.45	0.55	300
Sm	Spherical	0.15	0.85	110
Tb	Spherical	0.15	0.85	115
U	Spherical	0.23	0.77	155
Y	Spherical	0.5	0.5	125
Zr	Spherical	0.35	0.65	400

14.3 MINERAL GRADE ESTIMATION

14.3.1 Estimation Method

Ordinary kriging was used to estimate the resource model. Kriging is a weighted average estimator which uses variograms to take geologic controls and local sample spacing into account. An inverse distance squared estimation method could have been used, since the boundary of the rhyolite is the only geologic control taken into account. However, kriging handles the declustering of data more effectively than the inverse distance squared method. Declustering was necessary because of the higher density of drill holes in the northern part of the project area compared to the southern part.

14.3.2 Search Parameters

Grade estimations were done for 20 modeled elements. Due to the normal distribution of the data, an isotropic model was used with a search range of 1,000 ft. Before a block could be given an estimated value, 3 points had to be found with only 2 points from the same drill hole. This ensures that grade estimations are not coming from a single hole. Eu exhibited statistics which differed from the other elements. As a result, slightly different modeling parameters were used for this element. Specifically, the search range was left at 1,000 ft, and 5 points had to be found with only

2 points coming from the same drill hole before a block could be estimated. Finally, the normalized variogram was entered for each element.

This study has modeled the elements which will produce economic products or by-products. The grades were based on whole rock analyses carried out in 2018 and 2019 on selected samples in the northern part of the hill scheduled for early mining. Based on the analysis of the economic potential, only the 20 elements that provide economic value were modeled, the list is shown in Table 14-8.

Table 14-8 - Elements Estimated in Model

Element	Symbol
Aluminum	Al
Dysprosium	Dy
Beryllium	Be
Gallium	Ga
Hafnium	Hf
Iron	Fe
Lithium	Li
Lutetium	Lu
Magnesium	Mg
Manganese	Mn
Neodymium	Nd
Niobium	Nb
Potassium	K
Praseodymium	Pr
Samarium	Sm
Sodium	Na
Terbium	Tb
Uranium	U
Yttrium	Y
Zirconium	Zr

Because the re-assayed holes were selectively sampled, the search was increased from 1,000 to 1,500 ft. to complete the estimate for the petrographic elements. These elements are listed in Table 14-9.

Table 14-9 - Elements Estimated with Extended Search

Element	Symbol
Aluminum	Al
Beryllium	Be
Gallium	Ga
Iron	Fe
Lithium	Li
Manganese	Mn
Potassium	K
Scandium	Sc
Sodium	Na
Zirconium	Zr
Aluminum	Al

These elements, especially the petrographic elements, are statistically very well behaved and Gustavson believes that the longer search is reasonable. Due to mine equipment constraints the model was rebuilt with 20 ft. benches and estimated from 20 ft. composites. Due to the shorter composites, a minimum of five composites were used with a maximum of three from any one hole, again requiring at least 2 drill holes to create an estimate.

14.3.3 Model Validation

The model was checked primarily by statistical methods as well as a visual inspection of the model. The visual checks were completed on bench levels. Visual inspections confirmed grade estimates were only being done inside the rhyolite boundaries, and there were no model blowouts affecting the resource estimate. The statistical checks are valid for the entire model.

The mean, median, and maximum from the composites were compared with the block model. Ideally, the mean, median and maximum in the block model will be slightly lower than the composited data. While this held true for the majority of the elements modeled, there were six instances where the mean and median rose in the block model and one instance where only the mean rose. There were no instances where the maximum rose. Generally, these increases were all less than or equal to 1.5%, consistent with the normalized distribution of the data. Because the impact of these elements on the overall model is low, the model is still considered by Gustavson to be accurate.

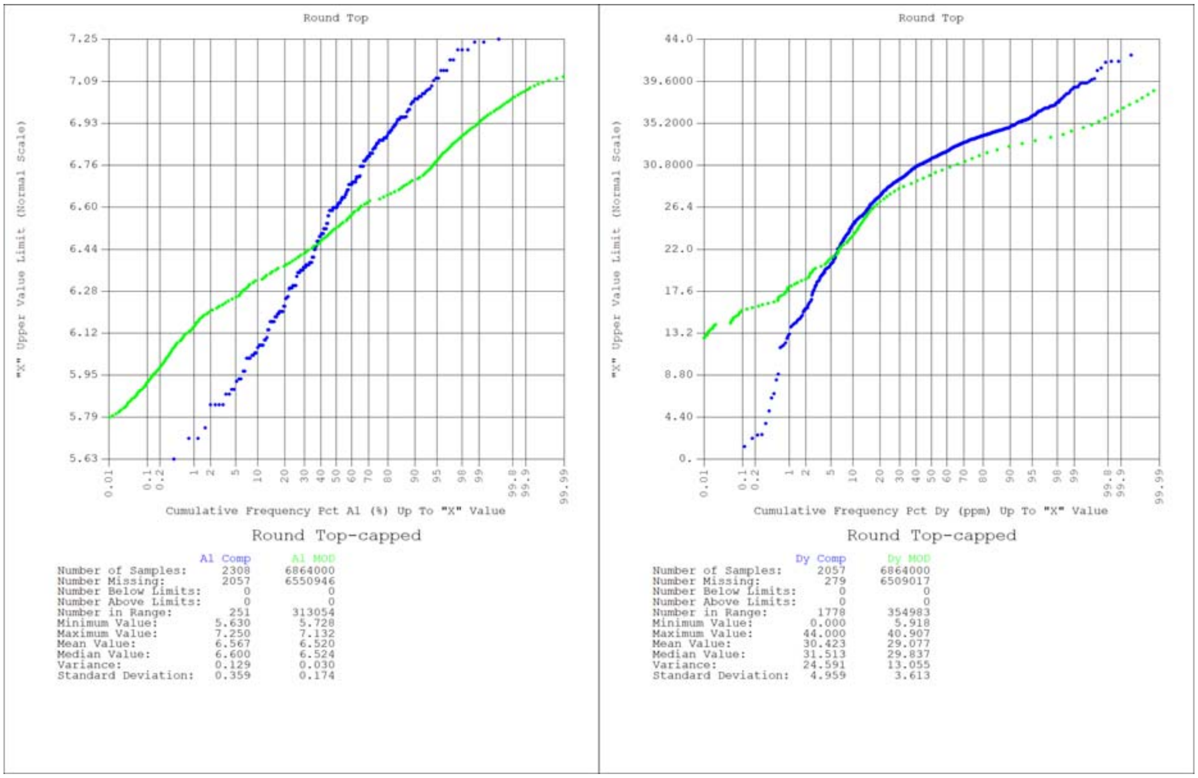


Figure 14-8 - Composite-Model Cum Frequency Comparisons for Al and Dy

14.4 MINERAL RESOURCE CLASSIFICATION

The mineral resource has been classified for the Round Top project as measured, indicated, and inferred. The classification of mineral resources is based on the average spacing of data points within the search area of the block as represented by the declustering weight calculated for each composite utilizing the GS-Lib Declustering method. This differs from the previous method used of the distance to the nearest sample. The result is an overall increase in classification in the well drilled parts of the deposit and a decrease in the confidence of the estimate where it is based on a single composite. Figure 14-9 shows the mineral resource classification (measured as blue, indicated as green, and inferred as red) at the elevation of 5,060

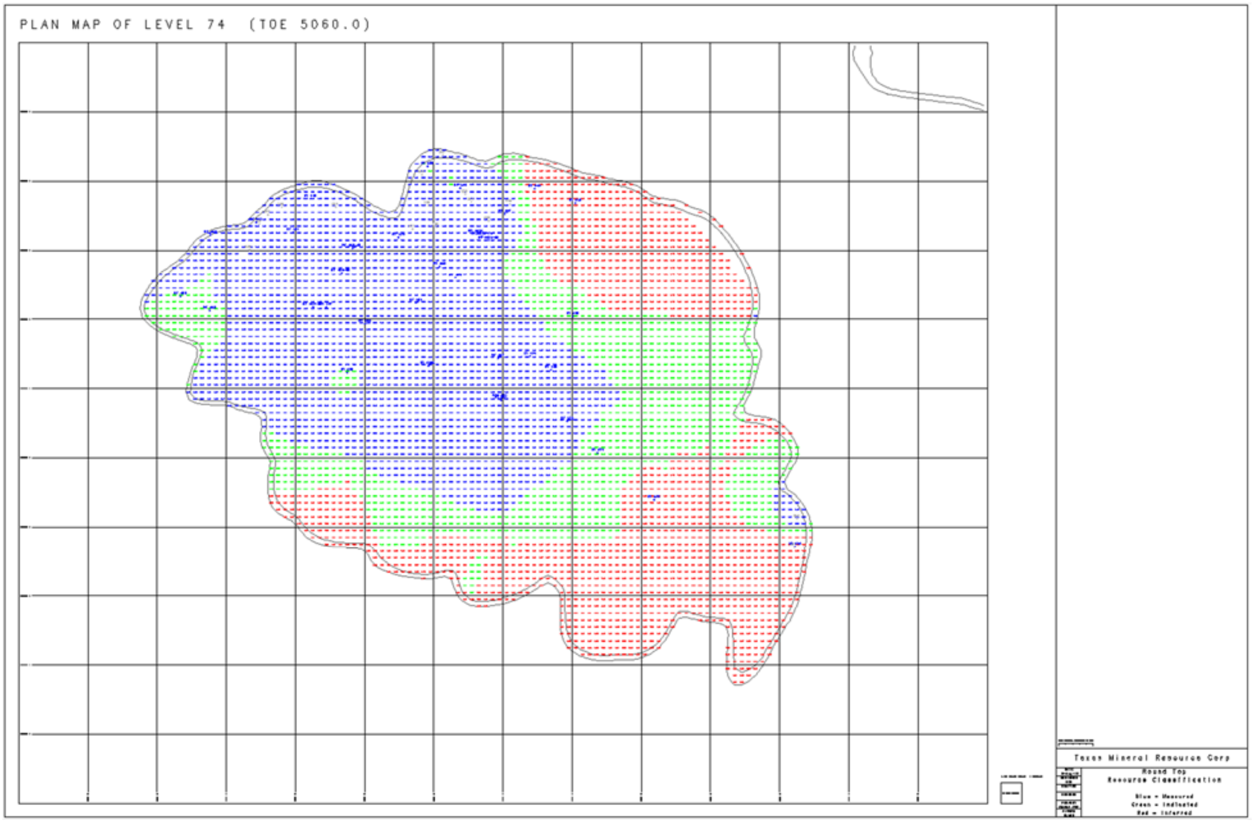


Figure 14-9 Plan View of Resource Classification

14.5 MINERAL RESOURCE TABULATION

The mineral resources are reported using a $16/ton NSR cutoff. The NSR value of each block in the resource model was initially calculated using the 7 most valuable elements. Due to the low geologic variability and high sales values of these 7 elements, all estimated model blocks within the Round Top rhyolite exceed the NSR cutoff, thus continuing to refine the calculation with other elements will only increase the NSR of the mineralized rock. By virtue of the block NSR exceeding the operating cost and with no required waste removal to expose the ore, the entire resource has potential for economic extraction.

Table 14-10 below shows the measured, indicated, and inferred mineral resources estimated within the Round Top Project, with an effective date of July 1, 2019. Quantities are rounded to reflect that these numbers are estimates. Mineral Resources are not Mineral Reserves and do not have demonstrated economic viability. There is no certainty that all or any part of the Mineral Resource will be converted to Mineral Reserves.

14.5.1 Cutoff Grade

Cutoff grade describes blocks where the value of the metals or products within a block exceed the cost expected for recovery of those products. For multi-material mines such as Round Top, it is most useful to determine cutoff grade on a NSR (Net Smelter Return) basis. NSR

Value indicates the dollar value of the block, which equals the sum of the recoverable values of each salable material.

$$value\ (NSR) = \sum_{element=1}^{n} grade * recovery * factor * price$$

- Grade is the grade estimated for the element
- Recovery is the combined recovery to product for the element (generally leach extraction x process recovery) (Table 17-1)
- Factor is an elemental conversion factor which adjusts for the mass difference between the element and the product. (for example, Yttrium Oxide (Y_2O_3) is 1.27 times heavier than the mass of Y alone because of the oxygen content.) (Table 17-1).
- Price is the price for each product.

Table 14-10 Estimated Resource of Total Rhyolites

		Measured	Indicated	M+I	Inferred
TONNAGE	*Metric Tons (x1000)*	200,000	164,000	364,000	735,000
Dy	*ppm*	30.31	30.41	30.33	29.61
Lu	*ppm*	8.83	8.64	8.79	8.49
Li	*ppm*	462.44	441.12	458.33	445.20
Hf	*ppm*	79.53	78.66	79.36	77.33
Zr	*ppm*	1,106.60	1,093.56	1,104.09	1,049.38
Al	*%*	6.58	6.46	6.56	6.52
K	*%*	3.30	3.28	3.30	3.21
Pr	*ppm*	10.29	10.18	10.27	9.97
Nd	*ppm*	27.91	27.77	27.88	27.55
Sm	*ppm*	10.07	10.04	10.06	9.85
Tb	*ppm*	3.46	3.47	3.46	3.30
Y	*ppm*	214.46	211.92	213.97	195.84
Sc	*ppm*	0.67	0.70	0.68	0.71
U	*ppm*	33.67	23.83	31.77	8.38
Be	*ppm*	32.99	28.64	32.15	18.22
Ga	*ppm*	70.32	46.86	65.80	16.96
Sn	*ppm*	137.73	136.60	137.51	134.94
Nb	*ppm*	175.26	119.87	164.58	46.52
Fe	*%*	1.06	0.97	1.04	0.82
Mg	*%*	0.03	0.02	0.03	0.01
Mn	*ppm*	503.96	334.47	471.28	118.86
Na	*%*	4.02	2.73	3.77	0.95

14.6 POTENTIAL RISKS IN DEVELOPING THE MINERAL RESOURCE

At the date of this PEA, there are some risks that could materially affect the potential development of the Mineral Resources. These are two classes of risk.

Processed Material Disposal

The enriched material and adjacent rock contain trace values of radioactive elements. It is not yet known whether the residual material after processing will be classified as treated rock or as a contaminated mineral material. Although there seems to be no doubt that the project can be permitted, the classification of the processed material could change the costs for disposing of or treating this material. These costs could have an adverse impact on the project economics including, but not limited to, the results of the PEA described herein.

Recovery and Separation of Pure Products

There is a good understanding of the elements that will report to the pregnant leach solution. It has also been shown that industrial processes exist which allow salable products to be recovered from the solution. The degree of refinement/purification of the products to meet market criteria, and the capital and operating costs associate with this process so are believed to be reasonable, however not all of the processing steps have been tested on a bench scale and no part of the plant has been tested on a pilot plant scale for Round Top material. Such testing may render some of the products estimated as part of the resource model as uneconomic. Mineral Reserve Estimate

Under NI 43-101 and CIM Standards, declaration of mineral reserves requires completion of Pre-Feasibility Study or a Feasibility Study to demonstrate economic viability. There are no mineral reserves on the Round Top Project at this time.

15 Mineral Reserve Estimate

Under NI 43-101 and CIM Standards, declaration of mineral reserves requires completion of Pre-Feasibility Study or a Feasibility Study to demonstrate economic viability. There are no mineral reserves on the Round Top Project at this time.

16 MINING METHODS

This PEA, including the Round Top mine plan within this PEA, includes inferred mineral resource. Inferred mineral resources are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. No mineral resources in this PEA have been converted to reserves. Mineral resources that are not mineral reserves have no demonstrated economic viability. There is no certainty that the results of this PEA will be realized.

The Round Top mine plan will employ a contract miner(s) to perform all mining functions at the site, drilling, blasting, loading, haulage and road maintenance. Typical open pit mining methods will be used, ore will be transported from the pit to a crushing plant located adjacent to the leach pads. A haul road will be pioneered to the top of the mountain and mining will begin at the upper most benches and progress downward. As mining proceeds to lower benches, a haul road will remain in the high wall to allow access to catch berms and additional mining areas. The pit is designed with sufficient area to allow for two separate working benches or faces.

The very nature of how the mineralization sits above regional topography creates a mine with very little waste material or cover. As such there is no waste rock storage facility planned for this project. Any surface material overlying the mineralization within the pit area is expected to be unconsolidated colluvium which will be used as construction materials for leach pads and roads.

The rhyolite will be mined in 20 ft. benches, the recommended height for the class of loader selected. Two 12m3 wheel loaders will load 90 tonne haul trucks to reach a daily production rate of 20,000 tonnes. The general site layout, including pits, waste dumps, infrastructure, ponds, and heap leach pads, is shown on Figure 16-1.

For purposes of the PEA, it has been assumed that mining and processing operations will operate 24-hours per day, 7-days per week.

Detailed geotechnical and hydrological studies have not been performed yet on the project and will be done during the feasibility stage of the project.

16.1 PIT DESIGN

The initial 20-year pit was designed based on the configuration of the rhyolite laccolith. The REE grades are nearly equal in all parts of the deposit with some small hot spots for yttrium. The distribution of petrographic elements is similarly consistent. Based on the resource model, the grades of material fluctuate minimally throughout the mine plan.

The initial 20-year pit was designed to keep all the mining to the northwest portion of Round Top. It was decided to mine this area first due to the highest drilling density in this area and in order to minimize the visual impact of the mining from the Interstate. Additionally, all the crushing and leaching facilities will be located north of Round top so this will minimize haul distances at the beginning.

Pit slopes have been designed at 45° inter-ramp wall angle. Fracturing within the rhyolite is not yet completely understood and this may affect pit slopes, at least locally. Haul roads are designed at a width of 100 ft., which provides sufficient width for two-way haul traffic and a safety berm. The maximum grade of the haul roads is 10%.

Due to the consistency of REE grades throughout the rhyolite, it is the qualified person's opinion that traditional economic analyses of the pit limit are not meaningful as every block in the model has essentially the same value. The overburden removal required for rhyolite production is minimal. The initial mine plan was developed to remove 20 years of rhyolite from the northwest portion of the hill, proximal to the crushing plant and processing facilities.

The preliminary pit design is shown in Figure 16-2. A more detailed pit design will be done in future studies.

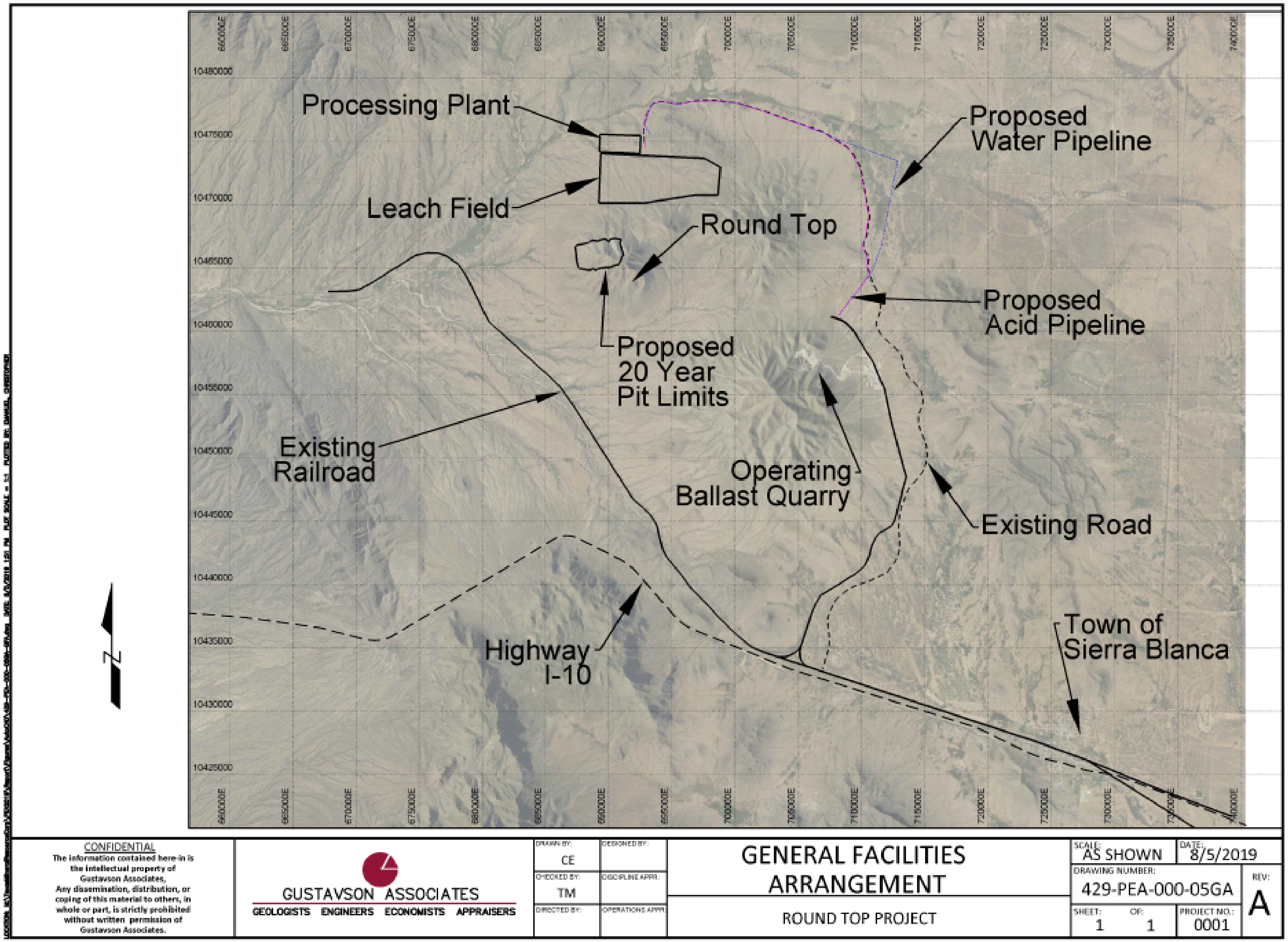


Figure 16-1 General Arrangement

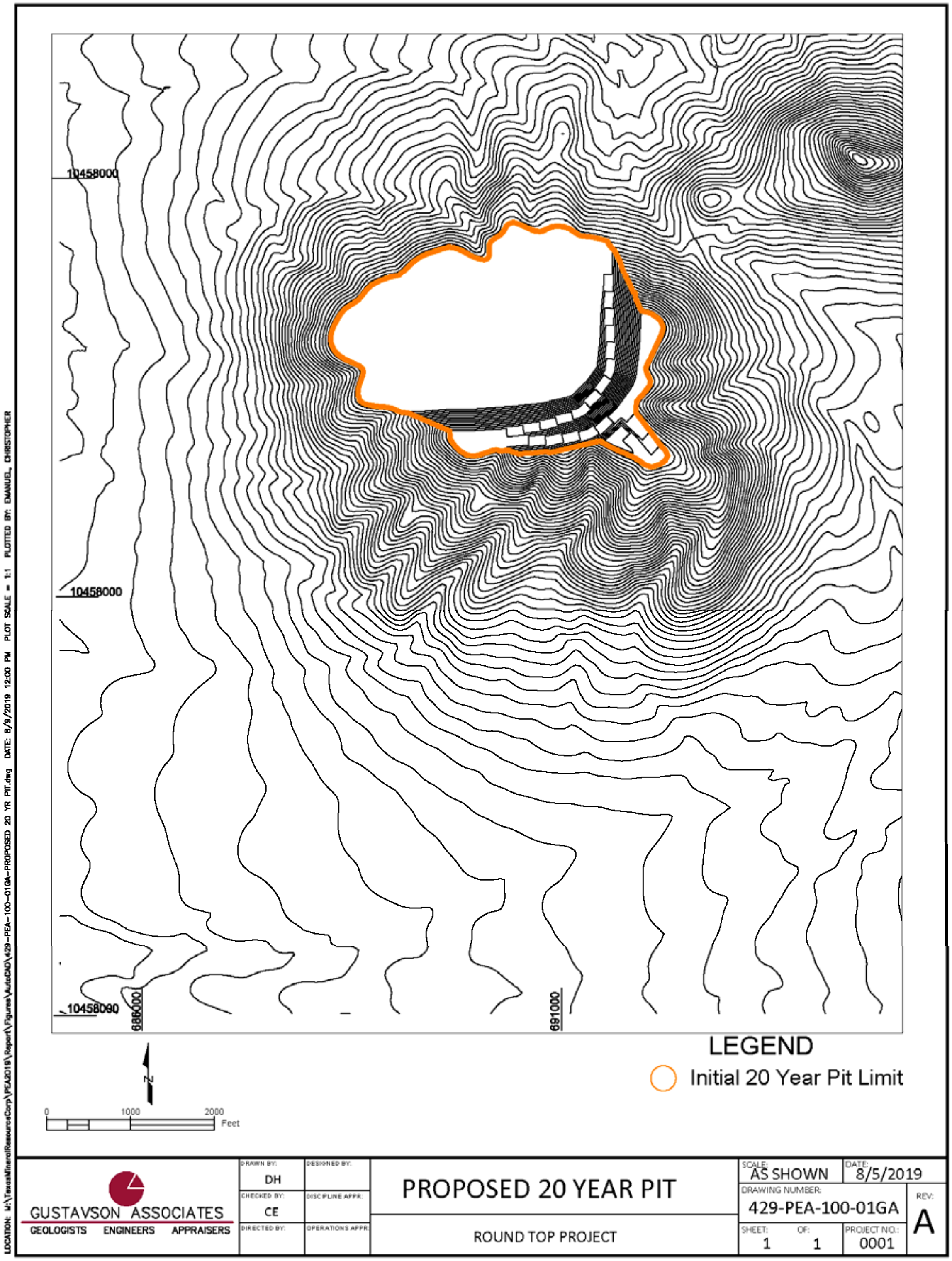


Figure 16-2 Preliminary Pit Design

The in-pit mineral resource estimate for this project is presented in Table 16-1. There are no mineral reserves estimated for Round Top at this time.

Table 16-1: In Pit Resource Estimate

		Measured	Indicated	M+I	Inferred
TONNAGE	*Metric Tons (x1000)*	116,400	27,800	144,200	14,250
Dy	*ppm*	29.69	29.84	29.72	29.84
Lu	*ppm*	8.80	8.71	8.78	8.72
Li	*ppm*	446.55	421.80	441.78	436.68
Hf	*ppm*	79.69	79.55	79.66	79.33
Zr	*ppm*	1,115.32	1,135.46	1,119.20	1,108.85
Al	*%*	6.64	6.58	6.63	6.74
K	*%*	3.32	3.36	3.33	3.37
Pr	*ppm*	10.25	10.14	10.23	10.13
Nd	*ppm*	27.75	27.39	27.68	27.32
Sm	*ppm*	9.94	9.83	9.92	9.82
Tb	*ppm*	3.39	3.39	3.39	3.35
Y	*ppm*	212.08	210.97	211.87	209.03
Sc	*ppm*	0.67	0.68	0.67	0.67
U	*ppm*	31.77	31.21	31.66	35.13
Be	*ppm*	36.09	36.13	36.10	32.31
Ga	*ppm*	73.62	73.09	73.52	73.54
Sn	*ppm*	138.86	136.98	138.50	140.01
Nb	*ppm*	186.52	192.35	187.64	192.13
Fe	*%*	1.08	1.09	1.08	1.09
Mg	*%*	0.04	0.04	0.04	0.06
Mn	*ppm*	538.15	539.52	538.41	543.07
Na	*%*	4.21	4.28	4.22	4.10

16.1.1 Mining Equipment

Table 16-2 lists the estimated initial mine equipment requirements prior to production. Purchase of the initial mining equipment and sustaining capital for equipment replacement is modeled as part of the contract mining cost, rather than capital cost to the operation.

Table 16-2 Initial Mine Capital Equipment List

Model (Cat Equivalent)	Unit	Cost Capital (x1000)	# of Units	Total Capital (x1000)
Cat 992K	Wheel loader	$2,200	2	$4,400
Cat 777	Haul Truck	$1,103	8	$8,824
Cat D9	Dozer	$1,136	1	$1,135
Cat 14M	Motorgrader	$473	1	$473
Cat 972K	Wheel Loader	$317	1	$317
Sandvik D50KS	Blasthole Drill	$817	2	$1,674
	Powder Truck	$214	1	$214
	Crane	$395	1	$395
	Fork Lift	$46	1	$46
	Mechanics Trucks	$86	2	$172
	Pickups	$46	4	$184
	Water Truck	$253	1	$253
Total				**$18,089**
	Contingency	25%		$4,522
Grand Total				**$22,611**

16.1.2 Support Equipment

Support equipment to the mining fleet is provided in Table 16-2

16.1.3 Estimated Mining Costs

In order to estimate mining contractor costs, mining costs were estimated assuming the owner as the operator then an additional 15% is added to costs as an estimate of contractor profit. Owner cost are estimated by determining the required mining fleet each year based on haulage distances and typical machine productivity. Required machine hours are tabulated and multiplied by typical hourly operating costs from InfoMine Mining Cost Service. Mine staffing is based on the fleet size for each year and is multiplied by typical labor rates provided by InfoMine.

Average mine operating cost is estimated to be $2.67 per metric tonne for contractor mining activities. This includes contractor profit and capital recovery. This price per tonne is an average over the life of mine. Contingency is added at 20% of direct costs. (No contingency is applied to Capital recovery or Contractor profit figures.) The breakdown is shown in Table 16-3.

Table 16-3 Mine Operating Expenditures

Description	LoM (x$1000)	$Tonne RoM
Production		
Drilling & Blasting	$ 121,540	$ 0.83
Loading & Hauling	$ 114,471	$ 0.78
SubTotal Production	$ 236,011	$ 1.62
Mine G&A		
Mine Support	$ 50,814	$ 0.35
Mine Administrative	$ 11,995	$ 0.08
SubTotal G&A	$ 62,809	$ 0.43
Direct Operating Expenditures	$ 298,820	$ 2.05
Contractor Expenses		
Capital Recovery	$ 46,641	$ 0.32
Contractor Profit 15%	$ 44,823	$ 0.31
SubTotal Mining Opex	$ 390,284	$ 2.67
Contingency at 20% of Direct	$ 59,764	$ 0.41
Total Mining Opex	$ 450,048	$ 3.08

17 CONCEPTUAL PROCESS FLOWSHEET AND PRODUCT RECOVERIES

The conceptual process flowsheet was developed for recovery of rare earth elements, lithium, aluminum sulfate and sulfate products based on scoping study testing and use of known technologies for production of lithium carbonate and sulfate products. Additional testing is recommended for techno-economic assessment of the process flowsheet.

17.1 PROCESS FLOWSHEET

The process flowsheet is given in Figure 17-1 to Figure 17-4. The run-of-mine (ROM) ore will be stage crushed to three stages to nominal 0.5 in (P_{80} of 12.5 mm). The crushed ore will be conveyed and stacked on the heap pads using conveyors, grasshoppers and radial stackers. Sulfuric acid will be dripped on to the ore on the conveyor for acid cure prior to leaching.

The ore will be leached for 30 to 45 days. The pregnant solution for the first 10 days, having a higher metal concentration, will be sent to PLS pond 1. The remaining solution will be pumped to PLS pond 2. The PLS from pond 2 will be recycled back to the heap and contacted with fresh ore. (Figure 17-2)

The PLS from pond 1 will be pumped to the rare earth extraction circuit. Scoping level study indicated that continuous ion exchange (CIX) and continuous ion chromatography (CIC) will extract the rare earth elements (Stage 1) and uranium and thorium from the PLS. A brief background on the development of CIX and CIC is given in Appendix E. The PLS after U/Th separation will go to additional recovery circuits. (Figure 17-3)

The REE's from Stage 1 (CIX) will be sent to Stage 2 RE group separation where the rare earths are separated into three products, namely heavies, medium and lights. These products are then processed to recover individual rare earth products using CIC cascade circuits in Stage 3.

The PLS from U/Th circuit will be send to a separate CIX-CIC plant for recovery of Zr, Hf, Be, Ga, Mg and Mn.

The next stage is lithium recovery circuit using membrane technology to recover lithium as lithium carbonate followed by recovery of $Al_2(SO_4)_3$, and other sulfate products in a standard chemical process.

The process flowsheet is conceptual at this time because only parts of it has been tested on the Round Top ore (i.e., heap leach and extraction of REE's). However, the technology for the different sections of the flowsheet is well known and in commercial use in the industry.

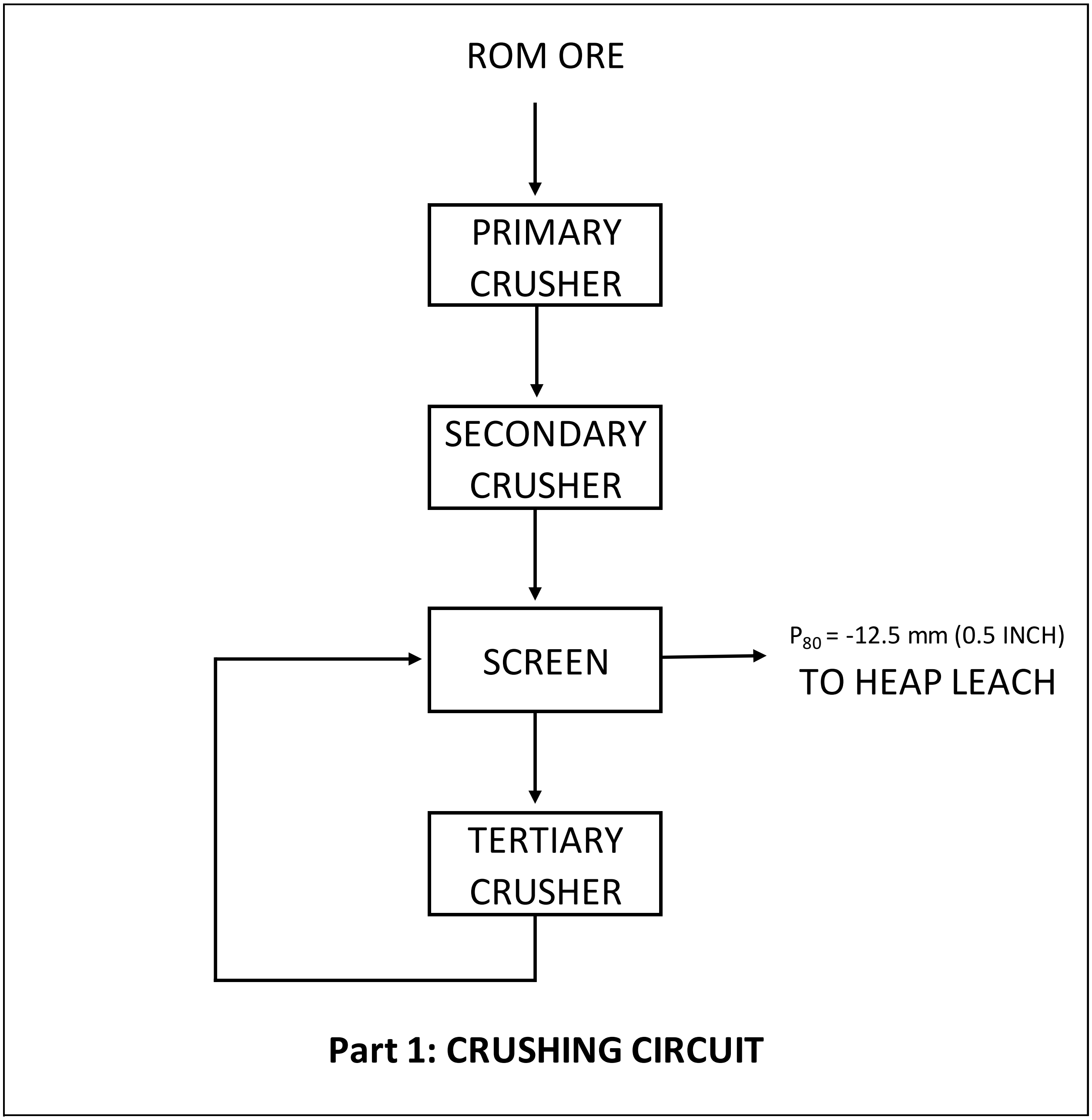


Figure 17-1 Crushing Circuit

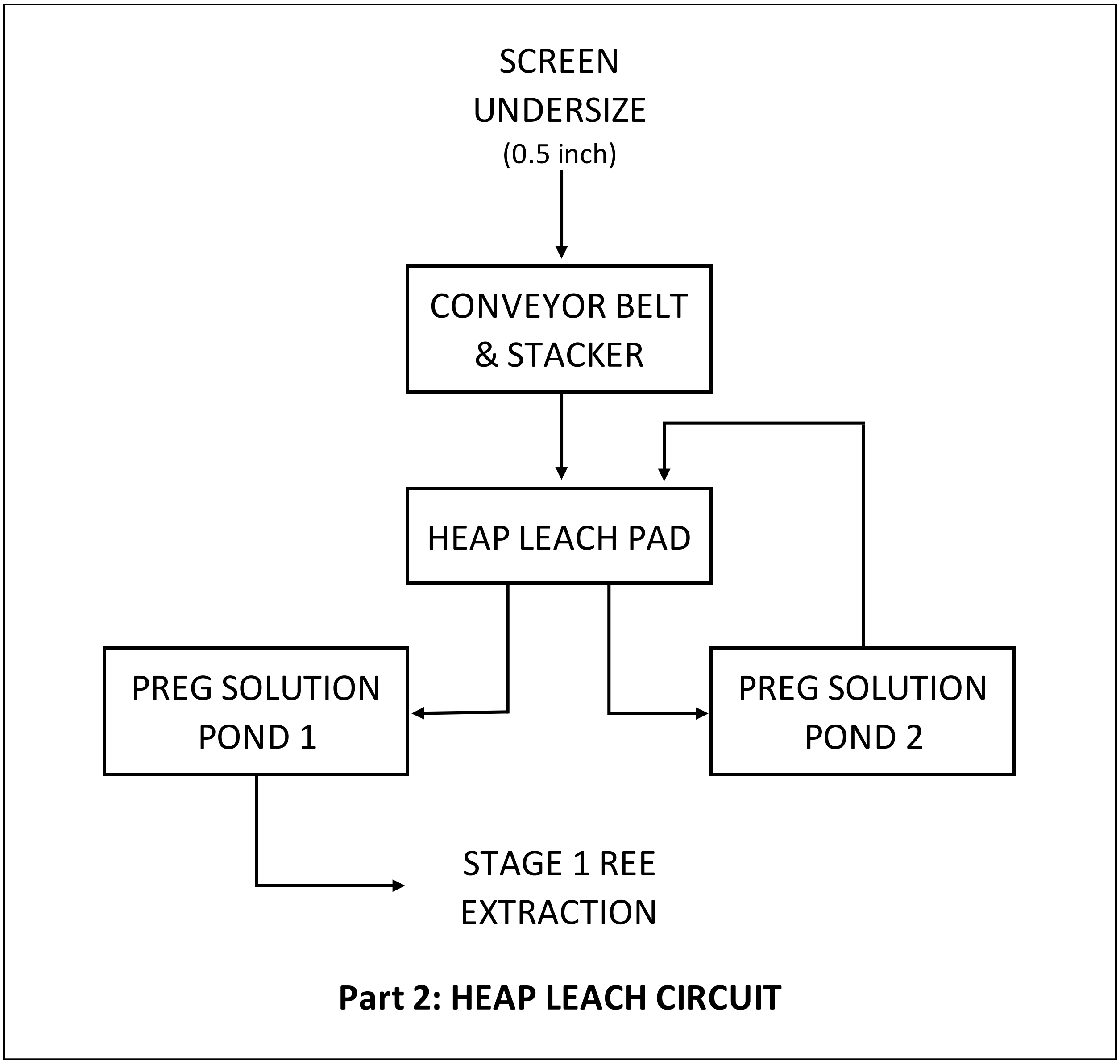


Figure 17-2 Heap Leach Circuit

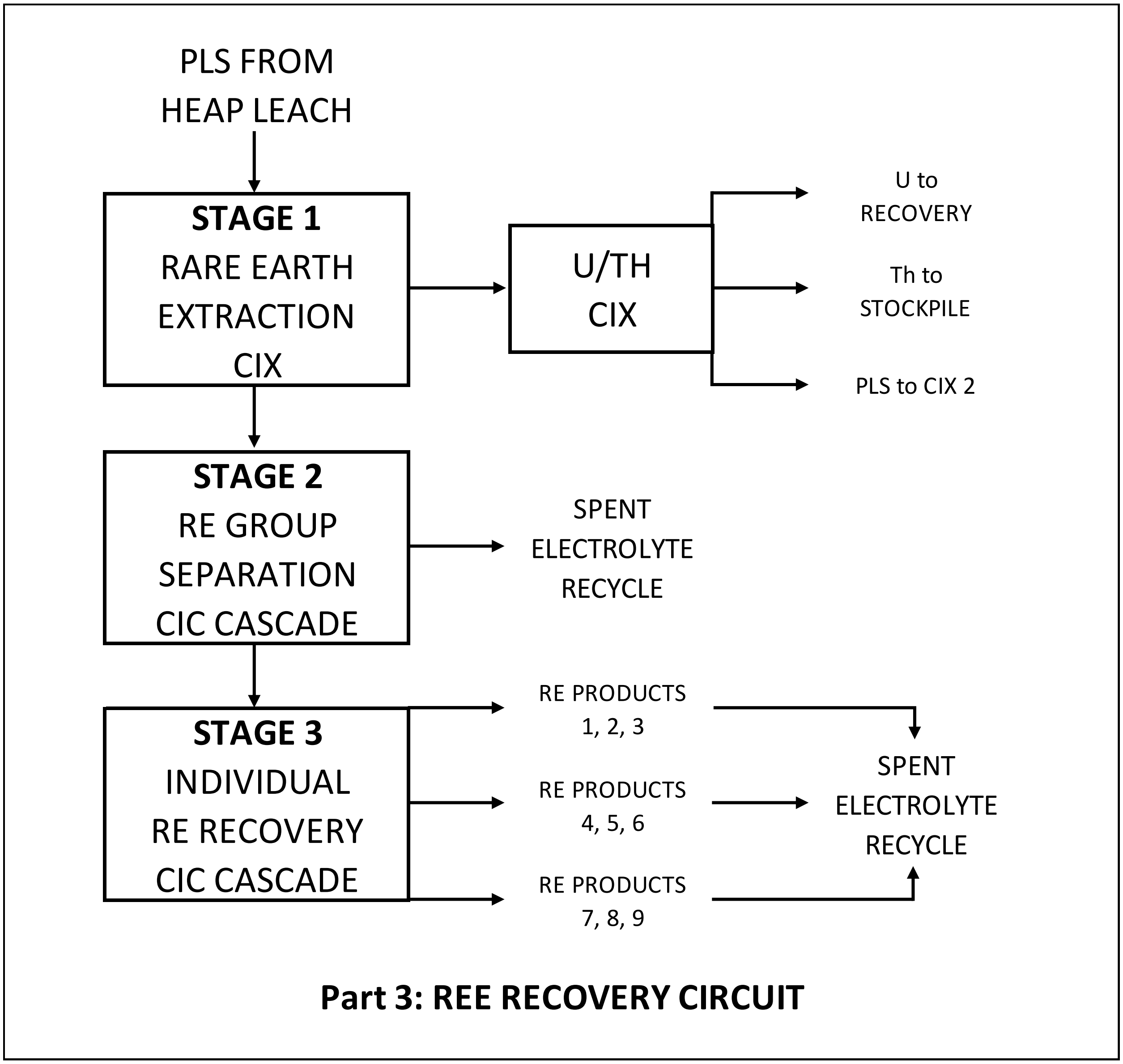


Figure 17-3 Rare Earth Elements and U/Th Recovery from PLS

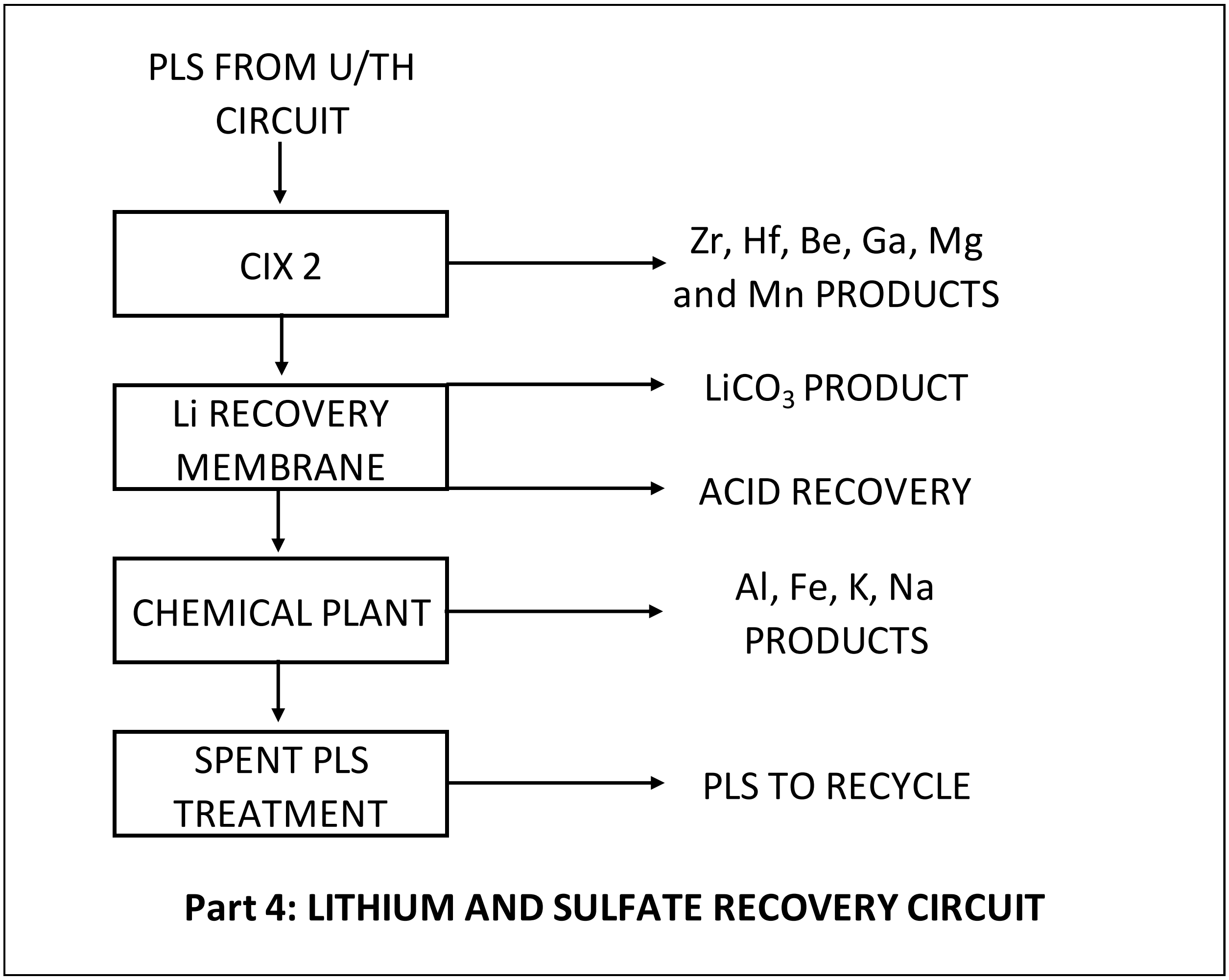


Figure 17-4 Lithium and Sulfate Recovery from PLS

17.2 RECOVERY

The extraction of the various elements of interest was based on the limited leach data generated in the column leach tests performed at RDi. Leach extractions for each element are shown in Table 17-1 Recovery and Elemental Conversion Factors, below.

The recovery of each product using a 95% process recovery factor to compensate for losses during the various processing steps down stream. Proposed pilot plant testing should refine the process recovery assumptions for a steady state system.

Table 17-1 Recovery and Elemental Conversion Factors

Element	Leach Extraction	Process Recovery	Overall Recovery	Elemental Conversion Factor	Product
Yttrium	93%	95%	88%	1.27	Yttrium Oxide
Praseodymium	81%	95%	77%	1.17	Praseodymium Oxide
Neodymium	81%	95%	77%	1.17	Neodymium Oxide
Samarium	83%	95%	79%	1.16	Samarium Oxide
Europium	75%	95%	71%	1.16	Europium Oxide
Gadolinium	91%	95%	86%	1.15	Gadolinium Oxide
Terbium	87%	95%	83%	1.15	Terbium Oxide
Dysprosium	87%	95%	83%	1.15	Dysprosium Oxide
Thulium	78%	95%	74%	1.14	Thulium Oxide
ytterbium	75%	95%	71%	1.14	Ytterbium Oxide
Lutetium	67%	95%	64%	1.14	Lutetium Oxide
Scandium	68%	95%	65%	1.53	Scandium Oxide
Uranium	31%	95%	29%	1.18	Uranium Oxide
Lithium	61%	95%	58%	5.32	Lithium Carbonate
Zirconium	6%	95%	5%	1.35	Zirconium Oxide
Hafnium	6%	95%	6%	1.18	Hafnium Oxide
Beryllium	9%	95%	9%	4.77	Beryllium Hydroxide
Gallium	6%	95%	6%	1.34	Gallium Oxide
Aluminum	7%	95%	7%	6.34	Aluminum Sulfate
Iron	37%	95%	35%	2.72	Iron Sulfate
Magnesium	93%	95%	88%	4.95	Magnesium Sulfate
Manganese	50%	95%	48%	2.75	Manganese Sulfate
Potassium	7%	95%	7%	3.23	Potassium Sulfate
Sodium	4%	95%	3%	3.09	Sodium Sulfate

Elemental conversion factors in Table 17-1 are used to account for the change in product mass when converting from atomic mass of elemental content in the block model to atomic mass of the compound being sold. (IE, Yttrium Oxide (Y_2O_3) is 1.27 times heavier than the mass of Y alone because of the oxygen content.)

17.3 PRODUCTION RATE

The process is designed to operate at 20,000 metric tonnes per day. Leach pads and the process plants are scaled to operate 24 hours per day, 365 days per year, with 95% availability, with a nominal production of 7.3 million tonnes per annum. Crushing and conveying are dependent on material availability and maintenance schedules and are scaled and designed to operate at 70% availability.

17.4 PRODUCTS AND RECOVERIES

There are a number of elements which report to the PLS for the Round Top project from which marketable products can be separated. The REE recovery circuit is scaled and designed to recover 8 individual rare earth oxides. Recovery of the remaining products have not yet been demonstrated by test work conducted on Round Top ores at an industrial scale, but are assumed based on similar process plants designed by K-Tech. Further test work is recommended to fully demonstrate the viability of the process and to finalize capital and operating cost parameters.

17.5 RECOMMENDATIONS

To advance the metallurgical and processing understanding of the project, the following bench test work and studies are recommended:

- Optimization of the heap leach process parameters (crush size, acid concentration, leach time PLS concentration, etc.) for optimum extraction of all products (REEs, U/Th, Aluminum Sulfate, Lithium and other sulfates.
- Optimization of the REE separation from impurities and other products (Phase 1), including resins, PLS concentration, etc.
- Optimization of separation of REEs in different groups (Phase 2) followed by separation of individual REE products (Phase 3).
- Develop and optimize process for production of lithium product (carbonate or hydroxide) aluminum sulfate and other sulfate products.
- Process for production of hafnium and zirconium products should be developed and optimized, as these materials have been demonstrated to report to the PLS and show significant economic potential.

Following the confirmation of the process in bench scale testing, run geometallurgical tests with different feed materials (predominantly red-pink vs. grey rhyolite).

Design and implement a 5,000 to 10,000 tonne heap leach test facility and chemical pilot plant to confirm the process flowsheet on a continuous basis and generate data for refining CAPEX and OPEX estimates to a feasibility level.

18 PROJECT INFRASTRUCTURE

The proposed mine and process plant site locations are presented in Figure 18-1. All skilled and unskilled staff will be sourced from local towns, principally El Paso. Capital and operating cost provisions have been included for daily bus transportation. Consequently, no provision has been made for on-site housing facilities, although TMRC's ownership of fee acreage in the area will leave the option open for on-site housing for key personnel.

The mine and process plant will operate on either a two-12 hour or three-8 hour shifts per day, 24 hours per day, seven days per week.

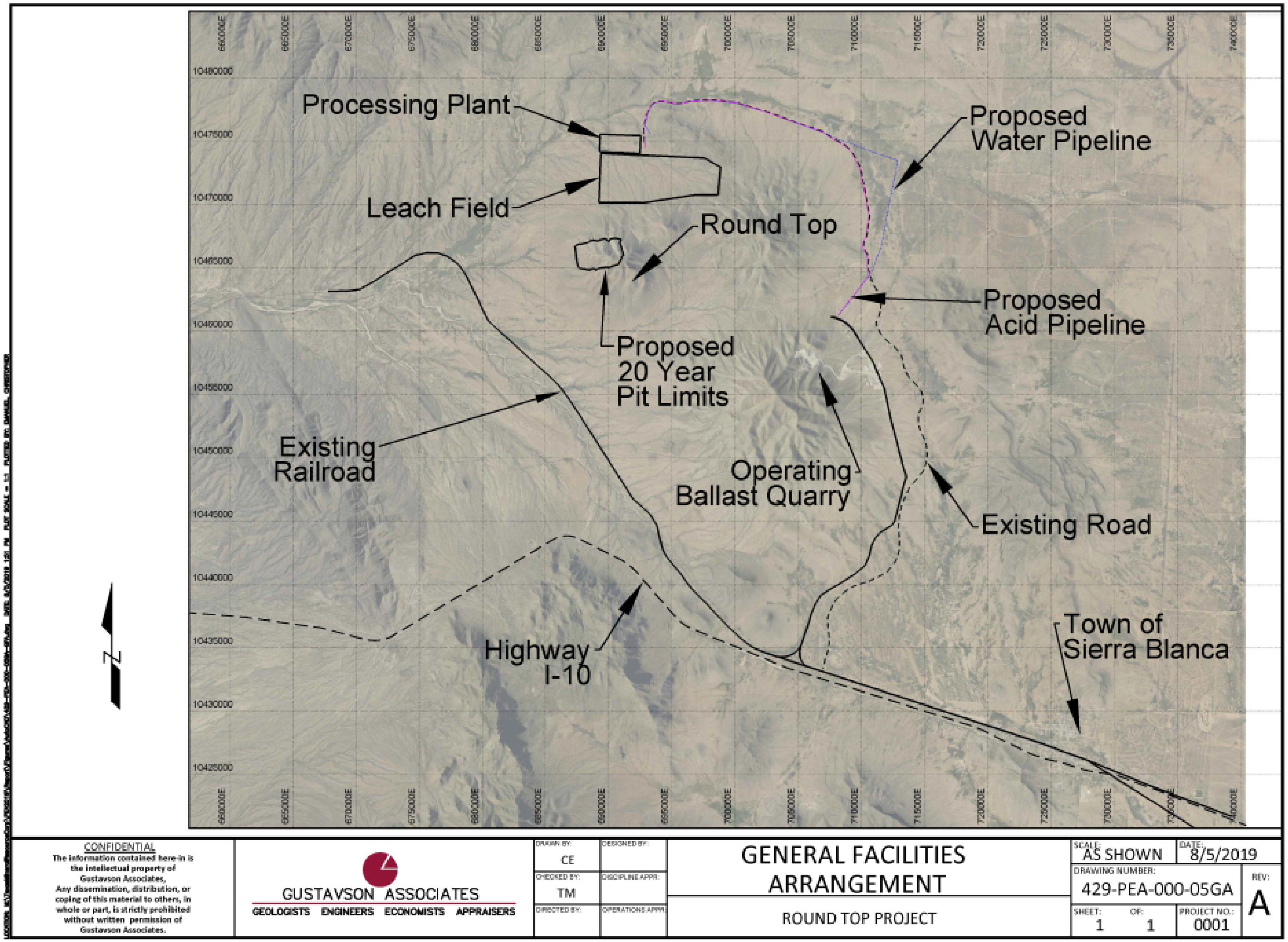


Figure 18-1 General Facilities Arrangement

18.1 FACILITIES

18.1.1 Administration/Office Building

There will be one administration building which will house management and staff and serve as the change house to service the mine and processing facility. The office and administrative buildings will include offices, toilet facilities, and lunch room etc. The office will also have adequate rooms for training of personnel.

18.1.2 Warehouse and Laboratory

One warehouse and one laboratory are planned for the project. The warehouse and laboratory will be located at the process facility. The laboratory will contain adequate equipment for ore control and management of processing.

18.1.3 Truck Shop and Maintenance

The truck shop will consist of three large bays and a single wash bay with sufficient work space to allow the mining contractor to conduct maintenance on the mine fleet. The truck maintenance shop will be located proximal to the mine area.

18.1.1 Processing Facility

A Processing facility will be constructed. The processing facility will consist of heap leach pads, solution ponds and equipment for the treatment of pregnant solutions in order to recover rare earth elements. Purification and separation facilities will be housed in the same processing facility.

18.2 ROADS

Temporary and permanent roads will be constructed to support the Round Top Project. Temporary access roads will be constructed with an average 50 ft wide running surface and a total average road disturbance width of 70 ft. Roads will be constructed using standard construction practices and to minimize surface disturbance, erosion, and visual contrast, and to facilitate reclamation. Roads will be constructed following Best Management Practices (BMP). Temporary access roads will be reclaimed as soon as they are no longer needed. Temporary road reclamation will include re-grading and reseeding the road area with an appropriate seed mix.

Access roads during operation will be 2-way, 2 lane gravel roads. Each lane will be 20 ft wide for a total of 40 ft running surface. Road shoulders will be between three and five ft wide.

Cattle guards will be installed on gravel and other access roads, where necessary. Cattle guards will be constructed to a load rating appropriate for anticipated truck traffic. Culverts would be placed to allow pre-existing drainage patterns to prevail. Topsoil will be re-spread over the borrow ditch areas up to the running surface after completion of grading.

18.3 SECURITY

The guard house at the main gate to the mine site will be manned around the clock. Standard security measures and operating procedures will be followed to ensure the security of the site.

The perimeter of the mine site and leach facility will be fenced to keep grazing cattle out.

18.4 SEPTIC SYSTEMS

Currently the process plant, administration building, laboratory warehouse and maintenance facility will likely use septic systems. Portable toilets will be placed at the mining areas, crushing areas and others where necessary.

18.5 WATER

Surface water management facilities will be constructed to minimize potential adverse impacts of runoff from the Round Top Project site to downstream receiving areas. Controls will ensure that non-point sources of suspended solids and other potential surface water contaminants are contained and not released from the project area.

There is a single perennial drainage that runs through the property that will need to be rerouted. Rainfall runoff and run-on will be managed by constructing protective berms around all disturbed areas and surface facilities at the mine site, process facilities and roads and rail locations. Collection ponds will be constructed immediately as required and will be identified during the Pre-feasibility study. We have assumed the Project will have to provide containment of the 100-year, 24-hour storm event. To further minimize runoff and mass movement of sediments, stockpiles (except the waste rock from mine excavation) will be revegetated and lined as appropriate.

Process water for the project is planned to be supplied by a well-field located some 3 miles east of the plant site. There are four existing wells in this area. Information available to date suggests that this water supply is adequate to supply the proposed heap leach operation. On June 21, 2019, TMRC paid the fees due to maintain this option with the Texas General Land Office. The principal aquifer in this area is the Cretaceous Cox sandstone. The prolific Permian carbonate rocks at depth have not yet been tested. Figure 5-1 shows the location of the existing wells and the area to de developed. The quality of the water is expected to be adequate for process water needs and the water will require treatment to be potable.

It is anticipated a reverse osmosis water treatment system will be installed to deliver potable water to the office, warehouse, and process plant.

Fire water will be supplied to the office, warehouse/laboratory, truck shop, and process plant from a water storage tank located adjacent to the processing facility. Diesel driven pumps will deliver fire water via underground piping to fire hydrants located next to the various buildings.

18.6 POWER

Power is currently supplied to Sierra Blanca by El Paso Electric Company. El Paso Electric has approximately 1,643 megawatts of generating capacity. The existing line into Sierra Blanca is scheduled to be upgraded by El Paso Electric. For this study, it is assumed that TMRC will be responsible for building a line that can carry adequate power from Sierra Blanca to the proposed site.

18.7 FUEL

Diesel will be purchased in bulk and stored on site at a refueling station. Delivery of diesel by rail in leased tank cars is anticipated. Diesel will be stored in tanks with adequate capacity and fuel trucks will be used to refill the support equipment. Most vehicles on the mine site will run on diesel; eliminating the need for gasoline, which would be purchased at gas stations in Sierra Blanca. Light duty diesel trucks will refill at the fuel station. All buildings will be heated with electricity or propane delivered from and stored in tanks located on the project site.

18.8 COMMUNICATIONS

Communications will be comprised of separate systems including: optical fiber, telephone, and radio. Systems will run independently. In the instance one system of communication is lost, other systems will be available.

18.9 PRODUCT STORAGE AND LOADING FACILITIES

Each of the products will be stored separately in appropriate containers in a secure location. The storage facility will be climate controlled. The material can be shipped to customers via vehicle transport or rail.

18.10 HEAP LEACH FACILITY

The Heap Leach Facility will be sized to process and contain all material from the mine. The Heap leach facility will be lined and have a leak detection system. The Run of Mine material is currently assumed to be non-hazardous. The Heap Leach Facility is only conceptual at this point and further detailed design including a geotechnical investigation will be undertaken during the pre-feasibility study.

18.11 WASTE FACILITIES

Due to the geology of the Round Top Project there is not expected to be any significant mine waste to dispose of for this project. Small amounts of colluvium will be used as road fill during construction. All topsoil will be stored and used for reclaim at the end of the project.

19 MARKET STUDIES AND CONTRACTS

Early metallurgical studies for the Round Top deposit focused on extraction of Rare Earth Elements from the rhyolite material. The rhyolite has been demonstrated to be amenable to acid heap leach, which puts a significant fraction of the REE into solution, along with a number of other elements. Further work conducted since the 2013 PEA was focused on producing Rare Earth Oxides from the pregnant leach solution (PLS). As part of this process, it became clear several other products would be separated from the PLS. Most of these products have some value.

Based on observed leach recoveries and recoverable products, the revenue from the Round Top operation can be divided into three revenue streams. The rare earth elements "group", which includes Yttrium and Scandium, comprise one stream. A group of elements designated "tech metals" comprise the second, and the third consists of a variety of industrial sulfate products.

In the initial heap leaching studies done in 2012 the objective was the recovery of the rare earth elements. Therefore, there was no attempt to value and monetize the other elements that were recovered from the leached rhyolite. The emphasis at the time was to suppress the uptake of these other elements by restricting the acid strength of the leachate.

The deflation of the 2010-11 rare earth 'bubble" depressed the prices of the various rare earth elements, but the electric vehicle industry demand for lithium has increased its price to a level where it is now the single highest value element recovered. Economically significant amounts of hafnium, beryllium, gallium and zirconium also leached from the rock. Together, these elements are categorized as the "tech metals" in this analysis.

The third revenue stream is from the variety of major element sulfates that are extracted. At observed recoveries, there will be an aggregate of approximately 390,000 tons produced annually of aluminum, iron, magnesium, manganese, potassium and sodium sulfate. Nearby rail facilities at Round Top provides ready access to markets for these relatively low unit value but highly profitable by-products.

19.1 RARE EARTH STREAM

19.1.1 The Geopolitics of Rare Earth Production

Rare Earth elements began to be economically important in the 1960's. Prior to that time they had been chemical curiosities with interesting properties. Fig. 19.1 traces the supply and demand as these elements developed into the vital components of almost all technology that they are today.

China's decision in the 1980's to heavily invest in rare earth production and technology was the implementation of national strategic policy. Since that time, they have, in addition to monopolizing the production of rare earth materials, acquired much of the downstream technology. They have used their control of the source to influence or coerce the end users to locate their facilities in China. They have had considerable success.

In response to a territorial dispute with Japan, China in 2010 began to flex its muscles. Japan is the largest end user of rare earth products and is extremely vulnerable to interruptions of supply. Following an incident involving ships from the respective countries, China briefly disrupted supply; the alarm of the end users was profound. The resulting turbulence in the market caused by a large price spike stimulated much activity and effort on the part of the junior mining companies to explore and develop non-Chinese sources. Fig. 19.2 demonstrates this price turbulence using Praseodymium and Neodymium as examples, but the price history of the other Rare Earth elements was similar or even more dramatic during this time period.

Chinese rare earth prices sharply declined after 2012 although still at levels higher than in 2010 and have since stabilized at current levels. It is now clear that any new rare earth project must be economically competitive with the Chinese subsidized production. Most of the greenfield projects that began in the 2010-2011 period were based on unrealistic forward price projections and for the most part have been abandoned.

While the strategic importance of a non-Chinese supply remains and while the long-term outlook for increasing usage of these elements is clearly favorable, the inability of companies to develop deposits that can compete economically with current Chinese production has effectively stalled private sector development.

The reality is that any potential new producer must be economically viable at current spot rare earth prices. It cannot be reasonably expected that China will raise prices enough to stimulate any serious competition to their prevailing monopoly.

(Sources; Charalampides G, etal; US Government, various public sources)

19.1.2 Rare Earth Production and Price History

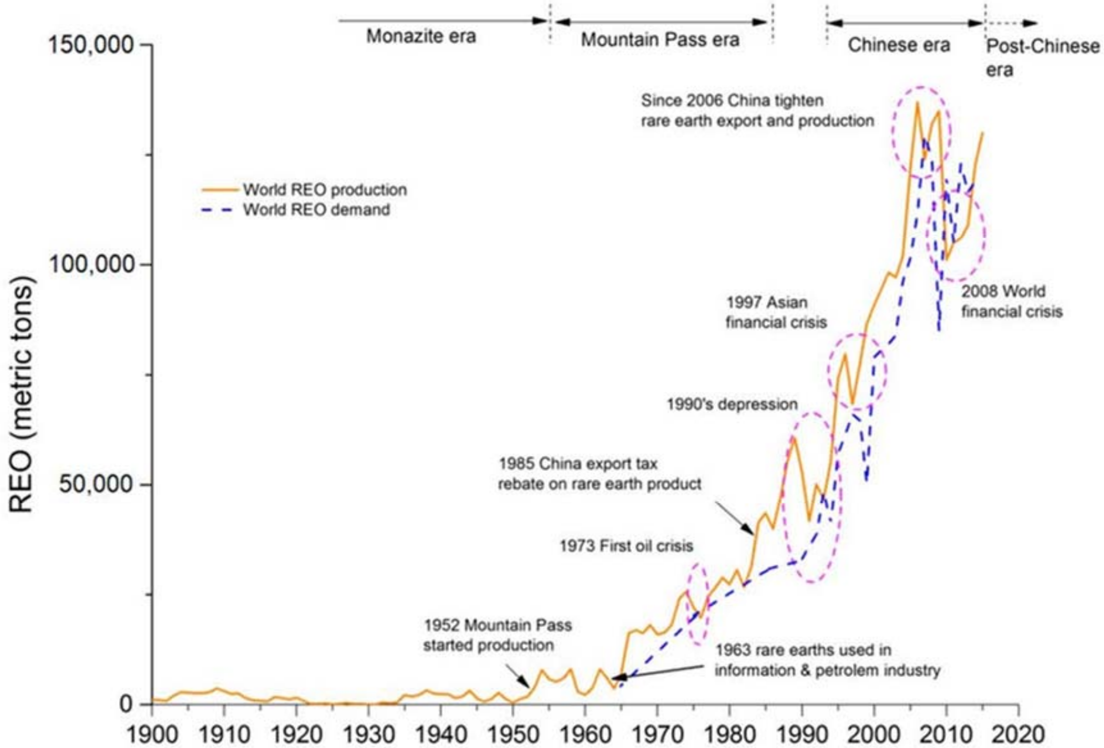


Fig. 19.1 Summary of rare earth production and demand since 1900 (*From: Zhou, et al., 2017)*

Fig. 19.2 Price variation of the magnet metals Neodymium and Praseodymium since 2010.

19.2 RARE EARTH USES

Fig. 19.3 shows the principal usage categories of the rare earth elements.

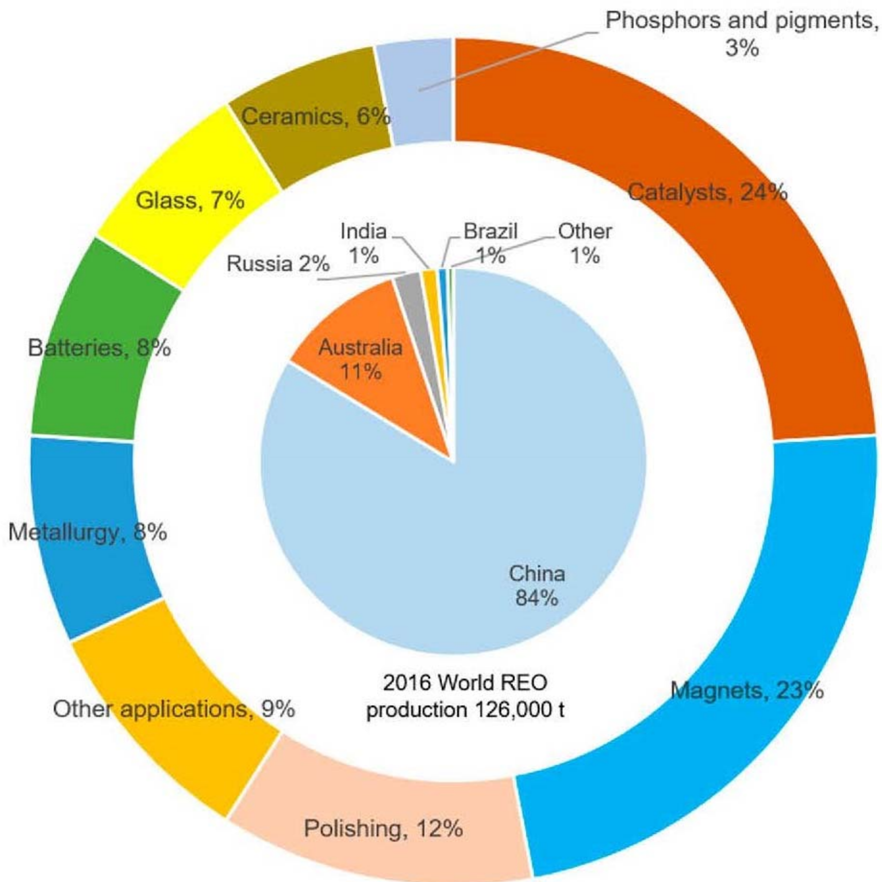


Figure 19.3 Distribution of global rare earth production and consumption in 2015 (*From: Zhou, et al., 2017*)

19.2.1 Catalysts

The use of rare earth elements, principally lanthanum, as catalysts in the petroleum refining process and cerium in automotive catalytic converters is relatively old technology. Free world demand for cerium is relatively strong but this market can easily be met by production from Mount Weld in Australia. Supply and demand relationships are relatively stable and are not likely to change.

19.2.2 Magnets

The most important use for rare earth at this time is for the production of high strength magnets. These magnets are now vital to almost all sectors of manufacturing as they enable the production of small, powerful electric motors. Everything from automotive seat adjustments to the positioning controls of satellites to the guidance of "smart" munitions depends on these motors.

Growth of this market has been steady and is expected to continue. There are a number of factors that could decrease these growth projections such as the failure of green energy to live up to industry expectations and reduced rare earth content in magnets, but this downside risk is mitigated by factors that could lead to a substantial increase in magnet demand such as expanded use of hybrid electric propulsion in the marine and automotive sectors including trucking and in heavy equipment, particularly in the electrification of underground mining equipment.

19.2.3 Polishing

Lanthanum, cerium and praseodymium are the REEs used in this sector. Supply and demand relationships are long-established and little change is expected.

19.2.4 Other Applications

This category includes the use of rare earth metals in lasers. The importance of lasers, in medical, military and in communications applications is significantly increasing every year.

The major development in cellular communications and data transfer is the rollout of 5G – fifth generation – networks. Concerns over the system security of 5G providers like China's Huawei have become a point of contention in U.S.-China relations, with ramifications worldwide. In May 2019, Huawei "was added to the US Department of Commerce's Bureau of Industry and Security Entity List…, following an executive order from President Donald Trump effectively banning Huawei from US communications networks." As a result, it appears that U.S. cellular carriers will be part of an evolving 5G network developed without reliance on Chinese hardware.

The backbone of 5G is high-bandwidth optical fiber, which depends on several heavy rare earths not presently produced outside of China. Erbium-doped fiber lasers (EFL or EDFL) is one candidate for 5G transmissions, with others being Yttrium-doped fiber lasers (YDFL) or Thulium-doped fiber lasers (TDFL).

19.2.5 Metallurgy

Lanthanum, cerium, praseodymium, neodymium, and samarium are the rare earth elements used in the traditional metallurgical applications. The supply demand relations in this sector are stable and are not expected to materially change.

There is significant potential for expanded use of rare earths as an alloying agent for aluminum. Scandium alloys are well known for their superior hardness and strength. Due to the scarcity of scandium, the use of scandium-aluminum alloy is limited. Research has suggested that the heavy rare earth elements holmium, erbium, thulium and especially ytterbium may be substituted for scandium in the manufacture of high strength aluminum alloy. However, this research has been limited by the rarity of these elements. The ability of Round Top to produce an adequate and dependable supply of these four heavy rare earth elements could stimulate the development of these high strength aluminum alloys.

19.2.6 Batteries

REEs are used in nickel-metal-hydride batteries. Some of this demand will be lost as Li-ion batteries gain market share.

19.2.7 Glass

The glass industry used approximately 8,000 tons of REEs in 2011. The REEs used in this sector include lanthanum, cerium, praseodymium and neodymium.

19.2.8 Ceramics

Ceramics accounted for 7,000 tonnes of REEs in 2011. REE's needed are lanthanum, cerium, praseodymium, neodymium, and yttrium.

(Sources; Information on REE uses is from the USGS Mineral Information website, from other public accessible sources and from industry communication)

19.3 RARE EARTH ELEMENT DESCRIPTIONS

19.3.1 Lanthanum and Cerium

Lanthanum and Cerium are the lightest of the lanthanide series and can be described as the “industrial” rare earth elements. They are used for a variety of long-established applications in the chemical and refining sectors. Demand is large and stable, as is supply.

19.3.2 Praseodymium and Neodymium

Praseodymium and Neodymium are the principal “magnet” metals. These magnet metals are necessary for the production of small, powerful electrical motors that are vital for all stages of modern manufacturing technology. Demand for these elements is growing rapidly and any new production of them is expected to be readily adsorbed.

19.3.3 Samarium

Samarium is used in certain types of magnets, as an additive to types of glass and ceramics and in the chemical industry. Demand and supply are considered to be stable.

19.3.4 Gadolinium

Gadolinium is used in MRI imaging and has other limited technical uses.

19.3.5 Terbium and Dysprosium

Terbium and Dysprosium are in significantly growing demand. Both have many and varied uses in metallurgy, electronics and in the nuclear industry. Their principal use is that, when alloyed in the magnet metals, it allows them to retain their magnetic strength at elevated temperatures.

19.3.6 Holmium

Holmium is among the least abundant of the rare earth elements. It has the strongest magnetic attraction of any element. It is found in mineable quantities in relatively few rare earth element ore bodies. Holmium finds modest employment in the production of very powerful magnets and in nuclear control rods (due to its ability to absorb large quantities of stray neutrons). Holmium is used in the production of high-powered infrared lasers and may have considerable potential for increased use in the military applications of these lasers.

19.3.7 Erbium

Erbium traditionally has had limited uses in phosphors and certain types of lasers. However, it is a likely dopant to be used in the laser amplifiers to be deployed in the developing 5G communication network.

19.3.8 Thulium

Thulium is an exceedingly scarce metal. It is the rarest of the rare earth elements. Thulium is currently so rare that it has little influence on supply/demand dynamics in the world of rare earth element mining, distribution, or in the manufacturing of end-use products. It can be used in medical (and other) lasers, as well as to make safer X-ray equipment. The element also shows potential in the development of superconductive materials.

19.3.9 Ytterbium

Ytterbium is another heavy rare earth element whose many potential uses have been hobbled by its scarcity. Ytterbium is beginning to find a variety of uses, such as in memory devices and tuneable lasers. It can also be used as an industrial catalyst and is increasingly being used to replace other catalysts considered to be too toxic and polluting. A considerable body of research indicates that ytterbium can replace or partially replace scandium in high performance aluminum alloys used in aerospace and potentially for aluminum armor plate. *(Sources; materalstodday.com; Nguyen, O. T., 2014; other public sources)*

19.3.10 Lutetium

Lutetium is the heaviest of the rare earth elements. Like the rest of the heavy rare earth elements, it is exceedingly rare. World production was 81 metric tonnes in 2016. Lutetium is principally used in scintillation crystals of PET scan machines. The Lutetium 177 isotope is used in targeted cancer treatment. Although small, the demand is steady and growing. *(Sources; contacts within the industry, USGS, various public sources)*

19.3.11 The Potential of the Heavy Rare Earth Elements

The production from Round Top has the potential to change the dynamic of the above five heavy rare earth elements: holmium, erbium, thulium, ytterbium and lutetium. Because of their scarcity, they have not seen the research needed to develop their uses. Holmium is known to be the most efficient magnet metal. All are known to be very effective in various laser applications and all are candidates for use in the 5G network now coming into use. Their effectiveness in high-powered lasers will likely expand their demand as these lasers are developed by the military.

These elements also show promise as substitutes for scandium in the manufacture of high strength aluminum. The commercial potential of these elements has not been fully explored, and it might be expected to expand radically pending an increased and dependable supply.

Yttrium is not an element of the lanthanide series but occupies the site directly above them in the periodic table and has many chemical characteristics similar to the heavy rare earth elements. It can be characterized as an industrial metal with varied uses, metallurgy, lasers, phosphors in fluorescent lighting, LED lighting and others. Demand, while not strongly growing, is expected to remain relatively stable.

Scandium is sited directly above yttrium in the periodic table. Like yttrium, it shares chemical characteristics with the rare earth elements. Scandium is known to be superior as an alloy in making high strength, high temperature aluminum alloy.

(Sources; REE sourcing is from the USGS Mineral Information website, from other public accessible sources and from industry communication)

19.4 RARE EARTH PRICING

Table 19-1 shows current spot market Rare earth pricing, Asian Metal Pages, July 24, 2019. Items listed as Marketed are part of the current economic analysis (although quantities of some metals are quite low, and they have little impact on the overall economics.) Elements listed as Warehoused are not part of the current economic analysis.

Table 19-1: Rare Earth Oxide Price Assumptions

Rare Earth Oxide Pricing			
Element	**Source**	**FOB China $/kg July 2019**	**Marketed/ Warehoused**
La	Asian Metal Pages, 24 July 2019	$ 1.68	Warehoused
Ce	Asian Metal Pages, 24 July 2019	$ 1.90	Warehoused
Pr	Asian Metal Pages, 24 July 2019	**$ 54.50**	**Marketed**
Nd	Asian Metal Pages, 24 July 2019	**$ 44.00**	**Marketed**
Sm	Asian Metal Pages, 24 July 2019	**$ 1.83**	**Marketed**
Eu	Asian Metal Pages, 24 July 2019	$ 33.50	NA
Gd	Asian Metal Pages, 24 July 2019	$ 28.46	Warehoused
Tb	Asian Metal Pages, 24 July 2019	**$ 575.50**	**Marketed**
Dy	Asian Metal Pages, 24 July 2019	**$ 270.50**	**Marketed**
Ho	Asian Metal Pages, 24 July 2019	$ 58.59	Warehoused
Er	Asian Metal Pages, 24 July 2019	$ 27.00	Warehoused
Tm	No Quote		Warehoused
Yb	Asian Metal Pages, 24 July 2019	$ 16.08	Warehoused
Lu	Asian Metal Pages, 24 July 2019	**$ 618.63**	**Marketed**
Y	Asian Metal Pages, 24 July 2019	**$ 3.60**	**Marketed**
Sc	Asian Metal Pages, 24 July 2019	**$ 1,040.76**	**Marketed**

Eight elements: praseodymium, neodymium, samarium, terbium, dysprosium, lutetium, yttrium and scandium, are marketed in this analysis. They have stable demand by North American and European manufacturers.

The magnet metals, praseodymium, neodymium, samarium, dysprosium and terbium are widely used, and the Round Top production is not a significant percentage of the market.

Lutetium is an important product from Round Top, but the lutetium market is small. Less than 100 tonnes per year being consumed, although this figure is stable and growing. It is used principally in scintillation counters in PET scan equipment, which is made by US or European manufactures. Round Top is projected to produce approximately 47 tonnes of lutetium oxide annually, approximately half the world consumption. The price of lutetium may have to be discounted in order to gain access to this market.

Yttrium is a low unit value rare earth element, but it comprises a relatively large percent of the Round Top production, approximately 1,800 tonnes annually. The yttrium price also may have to be discounted to access the market.

Scandium is a relatively high-priced metal with limited uses, principally golf clubs and Smith and Wesson revolver frames. This market is unlikely to change in the near term due to its scarcity.

The light rare earth elements, lanthanum, cerium and gadolinium will be stockpiled pending development of a profitable market for them.

The heavy rare earth elements: holmium, erbium, thulium and ytterbium, will be stockpiled in the near-term, as materials science technology drives applications that may lead to commercial markets.

19.5 TECH METALS

A significant amount of several high unit value metals, other than rare earth elements, have been shown to report to the pregnant leach solution in Round Top test work. Pricing assumptions are derived from Alibaba bulk spot pricing FOB China, from Asian Metal Pages spot prices, and from industry communications, with no adjustment. In this analysis these are designated "tech metals"; they are projected to account for approximately 51% of the anticipated revenue stream.

19.5.1 Lithium

Lithium is the most important of these, comprising approximately 32% of Round Top's anticipated revenue stream. The most important use of lithium is in rechargeable batteries for mobile phones, laptops, digital cameras and electric vehicles. Lithium is also used in some non-rechargeable batteries for products such as heart pacemakers, toys and clocks.

Lithium metal is made into alloys with aluminum and magnesium, improving their strength and making them lighter. A magnesium-lithium alloy is used for armor plating. Aluminum-lithium alloys are used in aircraft, bicycle frames and high-speed trains.

Lithium oxide is used in special glasses and glass ceramics. Lithium chloride is one of the most hygroscopic materials known and is used in air conditioning and industrial drying systems (as is lithium bromide). Lithium stearate is used as an all-purpose and high-temperature lubricant. Lithium carbonate is used in drugs to treat manic depression, although its action on the brain is still not fully understood. Lithium hydride is used as a means of storing hydrogen for use as a fuel. *(Source: Royal Society of Chemistry, USGS)*

19.5.2 Hafnium

Global hafnium market consumption is approximated at 69.5 metric tons in 2017 and is expected reach 122 metric tons by 2022. Hafnium is a silvery, metallic element separated from ores of zirconium and used in nuclear reactor control rods, as a getter for oxygen and nitrogen, and in tungsten filament alloys. Hafnium exists in a ratio of about 1:50 to zirconium, in its ore. It is produced as a by-product during the purification process of zirconium.

This market is driven by many factors, such as growing demand from aerospace industry and gas turbines, increasing use in nuclear applications, semiconductors industry and photographic applications.

Based on application, the market has been segmented into super alloys, optical coatings, nuclear, plasma cutting, and others. However, nuclear reactor closures and limited availability creates incentives for end-users to seek substitutes, thus potentially decelerating market growth. *(Source: Royal Society of Chemistry, USGS)*

19.5.3 Beryllium

Beryllium, when alloyed with copper, makes a tough, spring-like, metal with high electrical conductivity. It is found in almost all electronic applications, particularly in connectors. It is used to make high quality ceramics such as those in spark plugs. The metal is used in oil field tools because of its strength, hardness, light weight and its non-sparking characteristic. In aerospace it is widely used because of its light weight and strength. Probably its most important use is in the housings for nuclear warheads because of its properties as a neutron moderator and donor. Recent research has shown that adding beryllium oxide to uranium oxide pellets can produce more efficient and safer nuclear fuel. Beryllium oxide works to cool the fuel pellet, which allows it to operate at lower temperatures, giving it a longer life. *(Source: Royal Society of Chemistry, USGS, industry contacts)*

19.5.4 Gallium

Gallium arsenide has a similar structure to silicon and is a useful silicon substitute for the electronics industry. It is an important component of many semiconductors. It is also used in red LEDs (light emitting diodes) because of its ability to convert electricity to light. Solar panels on the Mars Exploration Rover contained gallium arsenide.

Gallium nitride is also a semiconductor. It has particular properties that make it very versatile. It has important uses in Blu-ray technology, mobile phones, blue and green LEDs and pressure sensors for touch switches.

Gallium readily alloys with most metals. It is particularly used in low-melting alloys.

It has a high boiling point, which makes it ideal for recording temperatures that would vaporize a standard thermometer. *(Source; Royal Society of Chemistry, USGS)*

19.5.5 Zirconium

Zirconium does not absorb neutrons, making it an ideal material for use in nuclear power stations. More than 90% of zirconium is used in this way. Nuclear reactors can have more than 100,000 meters of zirconium alloy tubing. With niobium, zirconium is superconductive at low temperatures and is used to make superconducting magnets.

Zirconium metal is protected by a thin oxide layer making it exceptionally resistant to corrosion by acids, alkalis and seawater. For this reason, it is extensively used by the chemical industry.

Zirconium (IV) oxide is used in ultra-strong ceramics. It is used to make crucibles that will withstand heat-shock, furnace linings, foundry bricks, abrasives and by the glass and ceramics industries. It is so strong that even scissors and knives can be made from it. It is also used in cosmetics, antiperspirants, food packaging and to make microwave filters.

Zircon is a natural semi-precious gemstone found in a variety of colors. The most desirable have a golden hue. The element was first discovered in this form, resulting in its name. Cubic zirconia (zirconium oxide) is a synthetic gemstone. The colorless stones, when cut, resemble diamonds.

Zircon mixed with vanadium or praseodymium makes blue and yellow pigments for glazing pottery. *(Source; Royal Society of Chemistry, USGS)*

19.5.6 Uranium

Uranium is principally used in the nuclear power industry as nuclear fuel in reactors. U_3O_8, usually known as yellowcake, is the input material for a process of isotope separation, refining, and fuel production.

Table 19-2: Tech Metal Pricing

Product	Source	FOB China $/kg June 2019
Li Carbonate	Asian Metal Pages, 24 July 2019	$ 13.75
Hf	Alibaba June 2019	$ 864.00
*Be Hydroxide	Industry Communication	$ 220.00
Ga Oxide	Alibaba June 2019	$ 162.00
Uranium Oxide		$ 56.10
Zr Oxide	Alibaba June 2019	$ 15.12

*No published prices for Be hydroxide are available, price is estimated based on conversation with various industry sources.

19.6 INDUSTRIAL SULFATE PRODUCTS

In addition to the high unit rare earth and tech metals recovered in the leach solution, a relatively large and economically significant amount of what are designated "industrial sulfate" products are recovered. Comparative pricing was sourced form Alibaba and Asian Metal pages FOB China. Industrial Sulfates account for 21% of the projected revenue stream.

Table 19-3: Industrial Sulfate Pricing

Product	Source	FOB China $/kg June 2019
Al Sulfate	Alibaba June 2019	$ 0.21
Fe Sulfate	Alibaba June 2019	$ 0.10
Mg Sulfate	Alibaba June 2019	$ 0.13
Mn Sulfate	Asian Metal Pages, July 24 2019	$ 1.19
K Sulfate	Alibaba June 2019	$ 0.43
Na Sulfate	Alibaba June 2019	$ 0.20

19.6.1 Aluminum Sulfate

Aluminum sulfate has a wide range of applications due to its physiochemical properties. It has commercial as well as industrial applications. Growth is expected to be steady.

Aluminum sulfate is a universally used water treatment chemical. The ever-rising demand for fresh water will drive the growth of the water treatment chemicals market, which in turn, is estimated to create opportunities for the global aluminum sulfate market. Data on actual consumption is difficult to find but thought to be very large. The water treatment segment is expected to witness the highest volume growth going forward.

Aluminum sulfate is used in poultry farms to lower the pH of litter and thus, decrease ammonia volatilization. The annual global demand for the poultry industry alone is approximately 90 million tons. Thus, the poultry market is witnessing huge demand, which is expected to rise further in the coming years. *(Source: various public sources)*

19.6.2 Macronutrient Fertilizer Elements: Magnesium, Potassium Sulfate

Overall fertilizer demand in the United States is approximately twenty million tons annually. USDA data indicates that potash (potassium) makes up some five million tons of this total.

Mixed Potassium-magnesium fertilizer is widely sold at a concentration of 22% potassium, 11% magnesium and 22% sulfur. This fertilizer is easily used in a starter fertilizer for corn or as a Mg source when there is no desire to increase soil pH. *(Sources: USDA and other various public sources)*

19.6.3 Micronutrient Fertilizer Elements: Iron, Manganese Sulfate

Micronutrients is the term given to a group of metal sulfates that include iron and manganese. They are applied to targeted crops and regions. This sector is rapidly growing worldwide. *(Source: various public sources)*

19.6.4 Sodium Sulfate

Sodium sulfate has many applications in many industries, among which detergent and cleaning agents are the most popular. The glass industry, cellulose and paper industry, textile and leather industry are also important end markets. Other industries, such as feed and pharmaceutical, only comprise a small share of total consumption.

The sodium sulfate industry is dominated by China. China is both the largest producer as well as the largest consumer. In 2017, China produced 12,581.7 K MT sodium sulfate, which comprises roughly 79.2% of production market share in the world. China is the world's largest exporting country. *(Source, various public sources)*

Nearly all of the above commodities are now being produced in China and imported in to the US market. Wholesale prices for these commodities are taken to be the FOB China price Transportation costs and duties are not considered in the pricing, although they are probably significant for these bulk, low value products, so there may be a pricing advantage available to Round Top.

19.7 RISKS AND UNCERTAINTIES

19.7.1 Pilot Plant Testing

There are assumptions within this chapter that each of the named products can be produced and sold separately at market rates. While leach test work indicates that these products report to the PLS, and technology exists to separate the various end products, full pilot plant testing has not been completed to demonstrate the practicality of the process at an industrial scale, nor to demonstrate the ultimate purity and marketability of the end products.

Gustavson recommends that Pilot plant testing be completed as soon as possible to demonstrate the leach kinetics and the refining process on an industrial scale to confirm the practicality of the process and the marketability of the products.

19.7.2 Price Variability

The Rare Earth Elements market has demonstrated significant price volatility over the past decade. Pricing is significantly affected by Chinese supply and may become affected in the mid-term by additional REE production coming on line. Round Top alone may produce sufficient quantities of certain of the heavy REEs to affect overall supply and demand conditions to impact market pricing for these commodities.

Pricing for industrial sulfates and Tech Metals is generally governed by individual offtake agreements and contracts, which can be significantly influenced by transportation and handling costs. There are currently no contracts in place for these products for Round Top. As such, actual pricing may vary from the assumptions set forth herein.

Gustavson recommends that a more complete market analysis be produced as part of a Pre-Feasibility or Feasibility Study for the project, including securing offtake contracts when applicable.

19.8 OPPORTUNITIES

Rare Earth elements have been designated as strategic materials by the current US administration (See Appendix F.) and there is considerable interest in the US defense industry to secure a reliable domestic supply. This may provide a price advantage to Round Top as the mine enters production but has not been considered in the pricing models for the current study.

There are several additional rare earth elements which are present at Round Top and which are demonstrated to report to the PLS, but for which no value is assigned in the current model. Development of reliable markets or offtake agreements for these products could add incremental revenue for the project.

19.9 CONTRACT SALES

USA Rare Earth will need to develop sufficient product samples from bench scale and subsequent pilot scale tests of REE material for sale in order to be in a position to enter into memorandum of understanding (MOU) or letter of intent (LOI) agreements with intended end users prior to advancing beyond pre-feasibility

19.10 MARKET ANALYSIS

Because none of the products produced from the Round Top Operation are exchange-traded commodities, a significant part of the subsequent feasibility study will be researching the nuances of these markets and the securing of offtake contracts. Concern over secure domestic supply will likely be a significant factor in these negotiations, particularly with defense related industries.

Another significant part of the forthcoming feasibility work should be promoting research into the uses of the "rare" heavy rare earth elements that are abundantly present in the Round Top deposit.

20 ENVIRONMENTAL STUDIES, PERMITTING AND SOCIAL OR COMMUNITY IMPACT

20.1 ENVIRONMENTAL

20.1.1 Preliminary Evaluation of Potential Environmental Impacts

At this stage of project planning, the anticipated environmental impacts can be categorized into the following main categories:

- Potential impacts to the environment resulting from the storage of mine waste including:
  - Additional potential that the waste may be considered hazardous, and
  - Additional potential that the waste may contain naturally occurring radioactive material,
- Potential impacts to water quality resulting from mine operations and the storage of mine waste;
- Potential impacts to air quality resulting from particulate matter and emissions;
- Site reclamation following completion of mining activities;
- Potential impacts to known and/or unknown archeological or cultural artifacts; and
- Potential impacts to threatened, endangered, or sensitive species of vegetation and/or wildlife.

These broad categories will be thoroughly analyzed through the environmental impact analysis process, which will occur with oversight and review by federal, state, and local regulatory agencies. The following section on permitting will provide a summary of the major federal and state environmental permits that may be applicable to the Round Top Project. Permitting will be reviewed in greater detail as part of the pre-feasibility study.

20.1.2 Currently Held Permits for Exploration Activities

All exploration drilling has been complete and TMRC does not currently hold any exploration permits. If bulk samples are needed, then TMRC will obtain the necessary permits from the GLO. For all future geotech drilling, the permits will need to be obtained through the GLO. The GLO is the only agency that TMRC will need to deal with to obtain exploration permits.

20.1.3 Expected Future Permits

The permitting process will most likely occur cooperatively and concurrently with the applicable state and federal agencies. Steps needed to obtain state and federal permission to operate this Project will be refined as the project details develop. The following paragraphs will highlight the main areas of consideration, as well as a brief description of the permits which may be required. It is currently understood from discussions with the Texas agencies, that the main areas of concern will be waste handling and storage, water quality and management, and air quality. Also, permitting efforts will likely have to consider the project's potential impacts to environmental considerations like wildlife, vegetation, and cultural resources.

Texas Commission on Environmental Quality (TCEQ) does not have a sector specifically charged with hard rock mining, nor does it require an operating permit specific to mining. Because Texas has a very limited hard rock mining industry, TMRC has an opportunity to work collaboratively with the agencies to walk through the permitting process in an efficient and comprehensive manner.

The largest permitting issues will be for the leach facility and air quality permit for the Project. In addition, protection of water resources will also be an important factor, as it is with any mining project. TMRC will have to be pro-active in their approach to ensure statutory boundaries are maintained and demonstrate that the proposed Project, and all associated plans and mitigations, will meet or exceed regulatory requirements.

20.1.4 Current Permitting Efforts

TMRC has initiated preliminary discussions with TCEQ concerning the permitting process. TMRC also has engaged a team of experienced advisors and is developing its strategy for the permitting process.

20.2 PERMIT REQUIREMENTS

20.2.1 List of Permits and Registrations

Table 20-1 includes major federal and state environmental permits that may be applicable to construction and operation of the Project

Table 20-1 Preliminary Permit Summary

Media	Permit	Agency	When Required
Air	New Source Review Permit to Construct	State TCEQ	Must be obtained prior to the start of construction.
	Title V Federal Operating Permit	US EPA	Application for permit must be filed prior to operating
Water	Construction Storm Water General Permit	State TCEQ	In advance of commencement of construction
	Industrial Storm Water Multi-Sector General Permit (MSGP)	State TCEQ	Prior to start of operation
	Public Water System Authorization	State TCEQ	Approval must be obtained prior to use of non-municipal water as drinking water source
	Water Rights Permit	State TCEQ	Must be obtained prior to using surface water
Operations	Petroleum Storage	TCEQ	Prior to storage of petroleum products on site
	Explosives permit	US Bureau of Alcohol, Tobacco, Firearms, and Explosives	Required prior to storage and use of explosives
Waste	Hazardous or Industrial Waste Management, Waste Streams, and Waste Management Units Registration	State TCEQ	Registration number must be obtained prior to engaging in regulated activity
	EPA ID Number for Hazardous Waste Activity Hazardous Waste Permit RCRA	U.S. EPA through the State TCEQ	ID number must be obtained prior to engaging in regulated activity
	Hazardous Waste Permit (including financial assurance)	State TCEQ	Must be obtained prior to commencement of hazardous waste treatment, storage, or disposal activities.
	Radioactive Material License	State TCEQ	Must be obtained prior to possession of materials containing NORM waste, as defined by THSC 401.003(26)

401 Permit, Certification of Texas State Water Quality Standards

The proposed operation will be a zero discharge operation so it is unlikely that this permit will be needed. If so, TCEQ will also be required to provide certification that the discharges from the project area meets state water quality standards, also known as the 401 certification. To make this determination, detailed technical information will be needed for things such as avoidance of or minimization of impacts to WUS, characterization of waste material, design aspects of the processing plant and tailings storage facility, as well as an understanding of the hydrogeologic setting of the impoundment site. Because of the size and scope of the Round Top Project, it's likely that the joint federal and state review required to issue 401 and 404 permits will be the most likely means of initiating the NEPA (EA or EIS development) process.

Texas Pollution Discharge Elimination Permit

If there are plans to discharge industrial waste waters into jurisdictional waters, TMRC will be required to obtain an Individual Industrial Waste Water Permit from the TCEQ and the Texas Pollution Discharge Elimination System (TPDES). The TDPES permit will require that industrial waste water meets the State's water quality standards prior to entering jurisdictional waters, which may require water treatment before discharging. At this point, a discharge is not anticipated for the Round Top Project.

Industrial and Hazardous Waste Permit

If the waste that is to be stored at tailings facility is classified as hazardous materials, an Industrial and Hazardous Waste Permit (IHW) will be required from the TCEQ. As mentioned earlier, the Bevill Amendment of the RCRA excludes certain mine wastes as being categorized as hazardous that result after the beneficiation process TMRC will most likely go through an extensive review of the anticipated waste material in order to properly identify and categorize the waste material that will be produced. The tailings produced from the flotation circuit, which is the vast majority of the waste generated, will likely be Bevill excluded as discussed earlier.

Radioactive Waste Handling and Storage Permit

If the waste material is considered radioactive, TMRC may have to obtain a Radioactive Materials License from TCEQ. This license is required for a variety of reasons such as having an operation that recovers source material that contains uranium or having an operation that disposes of waste that has naturally occurring low-levels of radioactive material. Naturally Occurring Radioactive Material (NORM) is material that naturally contains one or more radioactive isotopes, called radionuclides. If the waste material generated by the Round Top Project is categorized as containing NORM, proper handling procedures will need to be followed to store the waste. Typically, the NORM is in very low concentrations of a high volume of mining waste material. TCEQ has jurisdiction over the disposal of most NORM wastes, but the Texas Department of State Health Services may also be consulted to address potential concerns to human health.

Industrial Multi-Sector General Permit

The Round Top Project will also be required to obtain coverage for discharging stormwater from the mine site via the TCEQ's Industrial Multi-Sector General Permit (MSGP). The process for obtaining this permit dictates that the company will follow best management practices needed to ensure that any stormwater discharging from the mine site has not come into contact with any industrial or hazardous materials and will not diminish the water quality of the surrounding environment. The arid environmental lends to a simple design of holding precipitation run-off and evaporating it versus having a discharge from a non-point source.

Air Quality - Federal Operating Permit

Because the Round Top Project will be using a variety of equipment that will have fossil fuel, particulate matter, and other regulated emissions at the site, an Air Operating Permit will be required. This permit will not only provide an inventory of the types of equipment to be used but will ensure that the equipment is operating under Best Available Control Technology (BACT) in order to comply with the protections of the Clean Air Act. TMRC will work with TCEQ's Air

Protection Division to obtain a Federal Operating Permit (FOP). Air modeling will be required for point sources and fugitive dust emissions generated from the Round Top Project. The model will have to demonstrate compliance with ambient air quality standards.

The air program can be broken into two categories, major and minor source classification. Once a major source determination has been completed, which is based on the total amount of point source emissions, it could drive a Potentially Significant Deterioration (PSD) program. It is likely the project can avoid the PSD approach for the first major operating phase but that should be determined. The PSD process adds a few more steps and action levels to the air quality permitting effort.

Currently, Hudspeth County, Texas meets the national ambient air quality standards for criteria monitored by the EPA. In order to obtain the FOP, TMRC will have to monitor the baseline air quality area near the project site and assess the potential impact of project emissions to the area. Several months of data collection may be required.

Petroleum Storage Tank Regulation

The project site will most likely have to provide space to store a variety of fuels at the site for equipment use. The TCEQ has procedural requirements for the storage, handling, and reporting of fuel or other petroleum substances. The Round Top Project will be required to register their fuel storage tanks with the state's Petroleum Storage Tank Registration Program.

Water Rights

As mentioned above, due to the historical aspects of land grant rules and adoption of English law, Texas holds a very old approach to appropriation of surface water rights and ground water rights. Under Texas law, groundwater is a possession right held by the land owner. Water can be freely pumped for private use or sale for any purpose. This simplifies the water rights issue and TMRC is actively assessing available water sources and has identified several sources that could be obtained.

Private Wells as Public Systems

There is a possibility that the project may have to follow the state rules that govern Public Water Systems, since the Round Top Project will most likely have to acquire water from a privately owned well to provide water to mine employees. If water is obtained from a private well that does not have sanitary control over their facility, and that water is supplied to at least 25 or more people for longer than six months a year, the system would be considered a Non-Transient Non-Community Water Supply (NTNC). TCEQ has rules and guidance for public water systems to ensure that potable water meets state standards.

20.3 OTHER ENVIRONMENTAL CONCERNS

Because the Round Top Project will most likely go through a joint federal and state environmental analysis review, a variety of environmental concerns will need to be addressed to prepare the NEPA document. The project's anticipated effects to concerns such as threatened, endangered, or sensitive species of vegetation and wildlife will need to be reviewed. Potential effects to cultural or tribal interests may also be reviewed. Other environmental concerns may include topics like impacts to recreational use, scenery, or sound.

TMRC will have to develop baseline data collection programs to support preparation of applications and provide characterization of the environmental conditions at the project site. The collection of baseline data may have to span several seasons to collect natural variability that may occur for specific species or conditions.

The Mine closure and reclamation capital for the project has not been estimated. A value of $10 million bond has been included at the initiation of the project in the economic analysis as a representative cost. The cost was estimated based on similar environmental liabilities associated with mines of this size and life span.

21 CAPITAL AND OPERATING COSTS

This PEA, including the mine plan, is preliminary in nature and includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves and there is no certainty that the results of this PEA, including this mine plan, will be realized. Mineral resources that are not mineral reserves have no demonstrated economic viability.

Capital and operating costs for both the mine and processing facilities were developed based on factored and built up estimating techniques, benchmarking and conceptual scheduled production/equipment hours where available. These costs and requirements were determined from a variety of sources which include, estimates from vendors, Gustavson's, RDi'sand TMRC's personnel experience and cost estimates, InfoMine USA Mine and Mill Equipment Cost Estimators Guide. The qualified persons have reviewed these costs and concluded they are reasonable for inclusion in this PEA. Capital and operating costs are to be within +/- 50% at a Preliminary Economic Assessment level of accuracy and operating costs are typically within +/- 35 %. Gustavson has included a 25% contingency on all capital costs and 20% contingency on all operating costs.

21.1 CAPITAL COST ESTIMATE

For this study, the first 20 years of the project were used. Due to the size of the resource, it is assumed that mining will continue past the first 20 years that were analyzed. Total capital costs for this study are US$602.4 million, which includes initial capital costs of US$350.4 million and sustaining capital costs of the 20-year plan of US$252 million. The initial and sustaining capital costs are presented in Table 21-1.

Table 21-1 Capital Cost Estimate for 20KT/day Operation

Area	***Initial Capital ($x1000)***	***Sustaining Capital ($x1000)***
Mining Capital	NA*	NA*
Process Capital	$ 201,300	$ 175,600
Infrastructure	$ 25,200	$ 10,100
Pre-Production & Environmental	$ 27,850	$ 15,900
Mine Development	$ 8,350	$ -
Subtotal	$ 262,700	$ 201,600
Indirects, EPCM	*$ 22,000*	
Contingency (25%)	*$ 65,700*	*$ 50,400*
Total	$ 350,400	$ 252,000

*Because the project is planned as a contract mining operation, Mining capital is included as part of mining operating cost.

21.1.1 Mine Equipment Capital Costs

This PEA assumes contract mining, and thus the mine equipment capital is included as a portion of the mine operating cost. This section describes the inputs to the capital recovery portion of the mine operating costs. The 20-year mine equipment capital costs are estimated at $46.6 million. Initial mine equipment is estimated at $22.6 million and sustaining mine equipment is $24 million, which includes a contingency of 25%. The sustaining equipment capital is the cost of equipment replacement at the end of the service life without consideration of the salvage value. A summary of the mine capital costs is shown in Table 21-2 and a list of the initial mining equipment is shown in Table 21-3.

Table 21-2 Mine Equipment Capital Expenditures

Description	LoM Capital (x1000)	Initial Capital (x1000)	Sustaining Capital (x1000)
Production Equip	$30,439	$15,112	$15,327
Support & Misc Equip	$6,874	$2,977	$3,897
Subtotal Capital	**$37,313**	**$18,089**	**$19,224**
Contingency (25%)	$9,328	$4,522	$4,806
Total Mine Equipment Capital	**$46,641**	**$22,611**	**$24,030**

Table 21-3 Initial Mine Equipment

Model (Cat Equivalent)	Unit	Cost Capital (x1000)	# of Units	Initial Capital (x1000)
Cat 992K	Wheel loader	$2,200	2	$4,400
Cat 777	Haul Truck*	$1,103	8	$8,824
Cat D9	Dozer	$1,136	1	$1,136
Cat 14M	Motorgrader	$473	1	$473
Cat 972K	Wheel Loader	$317	1	$317
Sandvik D50KS	Blasthole Drill	$837	2	$1,674
	Powder Truck	$214	1	$214
	Crane	$395	1	$395
	Fork Lift	$46	1	$46
	Mechanics Trucks	$86	2	$172
	Pickups	$46	4	$184
	Water Truck	$253	1	$253
Total				**$18,089**
	Contingency	30%		$4,522
Grand Total				**$22,611**

21.1.2 Mine Development Capital

The mine development capital costs are US$8.35 million. This is for development of roads, mine buildings, and mine development. Contingency is estimated at 25%. The contingency is also shown on the project wide capital cost table (Table 21-1), which shows subtotals for each area and total indirects and contingency. The mine development capital costs are presented in Table 21-4 Mine Development Capital Expenditures below.

Table 21-4 Mine Development Capital Expenditures

Description	Initial Capital (x1000)
Haul Roads/Site Work	$ 5,000
Mine Development Stripping	$ 1,000
Shop	$ 900
Electrical	$ 850
Engineering	$ 600
Mine Development	**$ 8,350**
Contingency (25%)	$ 2,100
Total	$ 10,450

21.1.3 Process Capital Costs

Crushing Plant, Conveying and stacking, Acid Handling and similar Equipment costs were estimated from experience with similar sized operations and the "InfoMine Mining Cost Service" estimating guide. Heap leach pad capital cost was derived from the Mine Cost Service estimating guide figures for a 30 million tonne heap leach pad.

Detailed capital costs for the REE extraction plant and U/Th separation plant were provided by K-Tech. Capital costs for a second CIC/CIX plant for secondary metals, a membrane plant for Lithium Carbonate Extraction, and a Chemical plant for Industrial Sulfate production were also estimated by K-Tech.

Indirect costs are estimated by a 25% factor based on direct costs, except where indirect costs had already been included in the initial estimates. Contingency was estimated as 30% of Total Constructed Costs.

The 20-year process capital costs are estimated at $486.8 million. Initial process capital is estimated at $267.3 million. The initial capital is for building of the crushing plant, overland conveyors, initial heap leach facility, and for the processing plant. Sustaining capital is $219.5 million for the 20-year project. The sustaining capital includes expansion of the leach pad and the irrigation system for the leach pads. The process capital costs are presented in Table 21-5 Plant Capital Costs below.

Table 21-5 Process Plant Capital Expenditures

Area	Initial Capital (x1000)	Sustaining Capital (x1000)
Crushing Plant	$ 16,500	$ 33,000
Leach Pads & Ponds	$ 18,000	$ 72,000
Conveying & Stacking	$ 6,400	$ 6,400
Acid Handling	$ 4,500	$ 1,800
Irrigation System	$ 3,400	$ 1,400
Process Solution Management	$ 5,000	$ 2,000
Water System	$ 2,900	$ 1,200
REE Plant	$ 39,600	$ 15,800
U/Th Plant	$ 9,000	$ 3,600
CIX-CIC processing	$ 20,000	$ 8,000
Membrane Recovery	$ 45,000	$ 18,000
Sulfate Chemical Plant	$ 25,000	$ 10,000
Acid Recovery	$ 6,000	$ 2,400
Subtotal, Process	$ 201,300	$ 175,600
Indirects, EPCM	$ 15,700	
Contingency (25%)	$ 50,300	$ 43,900
Total	$ 267,300	$ 219,500

21.1.1 Infrastructure Capital Costs

Capital costs for major infrastructure were estimated from experience with similar sized operations and the "InfoMine Mining Cost Service" estimating guide, as listed in Table 21-6. Indirect costs are estimated at 25% of directs. Contingency is estimated at 25%.

Table 21-6 Infrastructure Capital

Area	Initial Capital (x1000)	Sustaining Capital (x1000)
Rail Head	$ 15,200	$ 6,100
Power, Transportation	$ 5,000	$ 2,000
Buildings	$ 5,000	$ 2,000
Subtotal, Infrastructure	$ 25,200	$ 10,100
Indirects, EPCM	$ 6,300	
Contingency (25%)	$ 6,300	$ 2,500
Total	$ 37,800	$ 12,600

21.1.2 Preproduction and Environmental Capital Costs

20-year owner costs and environmental are $54.75 million. These costs include a $10 million reclamation bond. Environmental baseline studies, permitting, pre-production corporate costs, and the complete budget through feasibility study listed in Table 26-1 in section 26. The preproduction and environmental capital costs include a 25% contingency and are presented in Table 21-6 Preproduction Capital Expenditures below.

Table 21-7 Preproduction Capital and Environmental Expenditures

Area	***Initial Capital (x1000)***	***Sustaining Capital (x1000)***
Reclamation Bond	$ 10,000	$ (10,000)
Owners Costs	$ 600	
Permitting	$ 500	
Plan of Operations, Environmental	$ 2,500	
Budget through Feasibility (Table 26-1)	$ 13,250	
Environmental Closure Costs		$ 24,400
Corporate Services	$ 1,000	$ 1,500
Subtotal	$ 27,850	$ 15,900
Contingency (25%)	*$ 7,000*	*$ 4,000*
Total	$ 34,850	$ 19,900

21.2 BASIS OF ESTIMATE

Initial capital costs for the Round Top Project PEA were estimated based on the following:

- Crushing, grinding, screening, and leaching estimates based on factored estimated for actual costs from similar size gold and copper leaching facilities.
- Infrastructure estimated from experience with similar sized operations and the “InfoMine Mining Cost Service” estimating guide.
- The REE and U/Th plant costs are derived from an estimate presented by K-Technologies Inc based on their experience in REE and U/Th processing.
- Costs for process plants for CIC-CIX, Membranes plant for production of Lithium Carbonate and chemical process facilities are estimated by K-Tech.
- Indirect costs were estimated by a 25% factor based on all direct costs, except for the items where project indirects had been included in the capital cost estimates. Contingency was estimated as 25% of Total Constructed Costs.
- Various aspects of the Round Top Project were cross-checke based on published information by InfoMine USA, Februaryr 2019 Electronic Edition.

- Pre-Production Capital Costs are principally the project budget through feasibility detailed in section 26, reclamation bond, and environmental permitting costs.

Sustaining capital costs for the Round Top PEA are estimated as follows:

- Crusher sustaining capital was estimated at 10% of initial capital cost annually, principally for replacement of jaws, liners and similar items.
- Heap leach sustaining capital is based on the assumption that the initial leach pad has 30-million-ton capacity. Thus, the sustaining capital budget envisions adding a similarly sized leach pad each 4 years.
- Conveyor sustaining capital is estimated as 20% of initial capital every 4 years to allow for conveyor expansions with each leach pad expansion.
- The remaining sustaining capital items are estimated at 2% of initial capital expense annually.
- Environmental costs equal to 20% of heap leach pad construction costs are included in years 5, 9, 13 and 17 of the project. An additional $10 million environmental closure cost is estimated at year 20, offset by the release of the reclamation bond in year 21.

21.3 OPERATING COST ESTIMATE

21.3.1 Project Cost and Basis

Operating costs were developed based on benchmarking and conceptual scheduled production/equipment hours where available. These costs and requirements were determined from a variety of sources which include, estimates from vendors, Gustavson's, RDi's,and TMRC's personnel's experience and cost estimates, InfoMine USA Mine and Mill Equipment Cost Estimators Guide. The qualified person has reviewed these costs and concluded they are reasonable for inclusion in this PEA.

The operating cost estimate for the Heap Leach and other processing facilities were based primarily on experience with previous estimates for facilities of similar size and complexity. The accuracy of the component costs is within the separate benchmarked operating costs, manpower requirements, power and reagent costs listed in the various applicable sections of the Mine Cost Service estimating guide.

Because the mining operation is executed on a contract basis, certain technical services costs, including salaries for both process technical services and mine technical services, are assigned as G&A in the project operating costs. This avoids double-counting of these costs in the mine and overall project areas.

Project operating costs an average $15.61/t-processed. Gustavson estimated the mining costs based on the 20,000 TPD mine plan discussed in Section 16 at $2.67/t plus contingency. Operating costs for the project include labor, power, fuel, maintenance, supplies, parts, and material. A 20% contingency was included in the operating costs of the project. The Project operating cost summary is presented in Table 21-7 Operating Expenditures Summary.

Table 21-8 Operating Expenditures Summary

Item	Cost ($/Tonne)
Mining*	$ 2.67
Crushing & Conveying	$ 0.91
Heap Leach	$ 3.55
Recovery	$ 3.96
Rail Systems	$ 0.23
G&A	$ 1.78
Sub Total	$ 13.11
Contingency (20%)*	$ 2.50
Total	$ 15.61

*Note, 20% contingency is applied to direct mine operating costs only, not to capital recovery or contractor profit.

21.3.2 Processing Costs

Processing cost consists of Crushing and Conveying, Heap Leach, and Recovery of Products. Cost breakdowns by area for each are presented below:

Table 21-9 Crushing and Conveying Operating Cost per Tonne

Area	Cost ($/Tonne)
Labor	$ 0.21
Maintenance	$ 0.09
Power	$ 0.38
Wear Parts	$ 0.23
Subtotal	$ 0.91
Contingency (20%)	$ 0.18
Total	$ 1.09

Crushing and conveying and heap leach operating costs were estimated by RDi and are inclusive of all costs including labor and power costs. Breakdown by line items are provided in Table 21-9 and Table 21-10

Table 21-10 Heap Leach Cost per Tonne

Area	Cost ($/Tonne)
Labor	$ 0.16
Maintenance	$ 0.12
Power	$ 0.05
Water	$ 0.10
Reagents	$ 3.13
Subtotal	$ 3.55
Contingency (20%)	$ 0.71
Total	$ 4.26

Operating costs for the various individual recovery process plants were estimated by K-tech based on their previous experience with similar operations. Labor costs were estimated by RDi based on the equipment proposed by K-tech. Recovery operating costs are detailed in Table 21-11.

Table 21-11 Recovery Process Operating Costs per Tonne

Area	Cost ($/Tonne)
REE CIX	$ 0.82
U/Th Plant	$ 0.17
CIX 2	$ 0.62
Li Membrane	$ 0.62
Chemical	$ 0.62
Solutions / Acid Recovery	$ 0.05
Process Labor	$ 0.98
Laboratory	$ 0.10
Subtotal	$ 3.96
Contingency (20%)	$ 0.79
Total	$ 4.76

21.3.3 Project Manpower

Personnel requirements and wages were estimated based on bench marks with similar sized Gold and Copper concentrators. It was estimated direct TMRC hourly staff will be around 170 personnel.

The processing plant and mining operations will operate 24 hours per day with three 8-hour shifts.

Table 21-12 Plant Manpower

Area	*No.*	*Hourly Rate*	*Annual Cost*
Crushing			
Operators	8	$ 30	$ 698,880
Conveying/Stacker	4	$ 30	$ 349,440
Helpers	8	$ 20	$ 465,920
Heap Leach/PLS Ponds			
Operators	4	$ 30	$ 349,440
Helpers	4	$ 20	$ 232,960
Construction	4	$ 30	$ 349,440
Helpers for Construction	4	$ 20	$ 232,960
REE/U/Th Plant			
Operators	8	$ 30	$ 698,880
Helpers	8	$ 20	$ 465,920
Lithium/Sulfate Products			
Operators	20	$ 30	$ 1,747,200
Helpers	16	$ 20	$ 931,840
Acid Management			
Operators	4	$ 30	$ 349,440
Helpers	4	$ 20	$ 232,960
Solution Management			
Operators	4	$ 30	$ 349,440
Helpers	4	$ 20	$ 232,960
Maintenance			
Mechanical	5	$ 30	$ 436,800
Electricians	5	$ 30	$ 436,800
Helpers	10	$ 20	$ 582,400
Product Shipment			
Technicians	6	$ 30	$ 524,160
Rail Head Operations			
Truck Drivers	2	$ 25	$ 145,600
Dry Product Loading Operations	2	$ 20	$ 116,480
Aluminum Sulfate Operations	2	$ 20	$ 116,480
Loader Operator	2	$ 25	$ 145,600
Swithch Engine Driver	1	$ 40	$ 116,480
Switchman	1	$ 20	$ 58,240
Support and Shops			
Mechanical	5	$ 30	$ 436,800
Sr. Electrician	5	$ 30	$ 436,800
Helper	10	$ 20	$ 582,400
Analytical Laboratory			
Jr. Chemists	3	$ 25	$ 218,400
Technicians	6	$ 25	$ 436,800
Total			**$ 12,477,920**
$/Tonne			**$ 1.71**

21.3.4 Mine Operating Costs

The LoM project mining costs average $2.67/t-RoM plus contingency. This includes allowances for contractor profit and for recapture of mining equipment capital. Table 21-13 presents cost detail by functional area.

Table 21-13 Mine Operating Expenditures

Description	LoM (x$1000)	$Tonne RoM
Production		
Drilling & Blasting	$ 121,540	$ 0.83
Loading & Hauling	$ 114,471	$ 0.78
SubTotal Production	$ 236,011	$ 1.62
Mine G&A		
Mine Support	$ 50,814	$ 0.35
Mine Administrative	$ 11,995	$ 0.08
SubTotal G&A	$ 62,809	$ 0.43
Direct Operating Expenditures	$ 298,820	$ 2.05
Contractor Expenses		
Capital Recovery	$ 46,641	$ 0.32
Contractor Profit 15%	$ 44,823	$ 0.31
SubTotal Mining Opex	$ 390,284	$ 2.67
Contingency at 20% of Direct*	$ 59,764	$ 0.41
Total Mining Opex	$ 450,048	$ 3.08

- Contingency is applied to Direct Operating Expenditures, not Capital Recovery or Contractor Profit. Capital recovery already includes 25% contingency on the equipment costs.

The mine operating costs are based on the Mine Operating Schedule shown in table 21-9 and the Mining Productivities shown in Table 21-14.

Table 21-14 Mine Operating Schedules

Description	Value	Units
Surface Mine		
Max Daily RoM Production	20,000	Tonnes/day
AssumedAnnual RoM Production	7,300	ktonnes/yr
Total LoM Production	146,000	ktonnes
Operating Days per year	365	d/yr
Operating Shifts per Day	3	sh/d
Operating Hours per Shift	8	hr/sh
Operating Efficiency	80	%
Mechanical Efficiency	80	%

Table 21-15 Mining Productivities

Description	Basis	Units	Production Mining
Drill	per ea drill	tonne/hr	1,400
Blast	per ea expl ldr	tonne/hr	1,400
Load	per ea loader	tonne/hr	1,100
Haul	per ea truck	tonne/hr	Variable

Mine operating costs are estimated by Gustavson. The mining cost is derived from the required equipment production hours, based on mining productivities and annual mine tonnages.

Mine salaried and hourly labor staffing is presented in Table 21-11 Mining Salary Labor Rates.

21.3.1 General and Administration Operating Costs

General and Administrative costs for this project include salaried management and technical staff and hourly secretarial and security staff who cross functional areas. Manpower costs include 40% load and are detailed in Table 21-17. Also included are allowances for mobile equipment to support the operation, Labor Transport to provide bussing for hourly labor to El Paso and other regional population centers, an allowance for product marketing costs, and environmental allowance of $1.75 million per year, and a general G&A allocation of $3.5 million per year. Cost assumptions are listed in Table 21-16.

Table 21-16 General and Administrative costs (includes Technical Services)

Item	Cost ($/Tonne)
Labor, Includes Technical Services	$ 0.54
Facilities Maintenance	$ 0.04
Mobile Equipment	$ 0.10
Labor Transport	$ 0.10
Marketing	$ 0.25
Environmental	$ 0.25
Other G&A: Insurance, Safety, Security, Etc.	$ 0.50
Sub Total	$ 1.78
Contingency (20%)	$ 0.36
Total	$ 2.14

Table 21-17 G&A Manpower

Department	No.	Salary	Annual Cost
Management			
General Manger	1	$ 150,000	$ 210,000
Mining Engineer	1	$ 80,000	$ 112,000
Geologist	1	$ 80,000	$ 112,000
Process Manager	1	$ 100,000	$ 140,000
Metallurgist	3	$ 100,000	$ 420,000
Environmental Engineer	1	$ 95,000	$ 133,000
HR Manager	1	$ 80,000	$ 112,000
Marketing Manager	1	$ 80,000	$ 112,000
Accounting Manager	1	$ 80,000	$ 112,000
Maintenance Manager	1	$ 100,000	$ 140,000
Hourly Staff			
Secretary	1	$ 20	$ 58,240
Receptionist	1	$ 20	$ 58,240
Accounting Clerks	2	$ 25	$ 145,600
Store/Warehouse	2	$ 25	$ 145,600
Helpers	4	$ 20	$ 232,960
Security	4	$ 20	$ 232,960
Total			**$ 2,476,600**
$/Tonne			**$ 0.34**

Table 21-18 Processing Operating Schedule

Description	Value	Units
Leach + Separation		
Max Daily RoM Production	20,000	mtpd
Max Annual RoM Production	7,300	ktonnes/yr
Total RoM Production	146,000	ktonnes
Operating Days per year	365	d/yr
Operating Shifts per Day	3	sh/d
Operating Hours per Shift	8	hr/sh
Operating Efficiency	100.0	%
Mechanical Efficiency	92.0	%

21.3.2 General and Administration Costs

General and administrative costs include general management, safety, accounting, environmental, purchasing, sales, and plant management, insurance etc. at $0.50 per tonne.

21.3.1 Operating Cost Summary

A table of operating costs by classification are included as Table 21-19.

Table 21-19: Operating Cost by Classification

Item	Cost ($/Tonne)
Mining*	$ 2.67
Process Labor	$ 2.05
Reagents	$ 4.83
Water	$ 0.10
Power	$ 1.00
Maintenance Supplies (at 3% of Capex)	$ 0.93
Crusher Wear Parts (at 10% of Capex)	$ 0.23
Mobile Equipment	$ 0.10
Labor Transportation	$ 0.10
Laboratory	$ 0.10
Marketing	$ 0.25
Environmental	$ 0.25
G & A	$ 0.50
Sub Total	$ 13.11
Contingency (20%)*	$ 2.50
Total	$ 15.61
*Mining contingency is applied to direct operating costs only, not Contractor profit or Capital recovery.	

22 Economic Analysis

Economic analysis of the Round Top project is conducted on a PEA basis, using metals pricing, capital and operating cost, and recovery parameters discussed in previous sections of this report. The reader is cautioned that this is not a pre-feasibility or feasibility study and reserves have not yet been delineated for the Project. While the underlying economic assumptions are believed to be reasonable, additional information may change operating cost, capital cost, or metallurgical recovery parameters and this would have an impact on the analysis. These results are prepared on a pre-tax, unleveraged annual basis. All costs are in Q4 2019 US constant dollars.

22.1 MODEL PARAMETERS

The indicative economic model was prepared on an unleveraged, pre-tax basis and the results are presented in this section. Key criteria used in the analysis are discussed in detail throughout this report. Assumptions are summarized in the Table 22-1 below.

Table 22-1 Economic Assumptions

Description	Value	Comments
Project Equity	100%	100% project equity
Working Capital Requirement	30%	% of cash costs
Discount Rate	10.00%	
CapEx - Contingency Total	25.0%	
Mine Equipment	25.0%	Included in Mining Opex
Mine Development	25.0%	
Process Equipment	25.0%	
Preproduction Costs	25.0%	
OpEx - Contingency Total	20%	
Mining	20%	
Process	20%	
G&A	20%	

The estimated resource contains sufficient material to operate for well over 20 years. Gustavson has defined an initial pit and mining plan which addresses the first 22 years of production, the first 20 years of which is the basis of this presentation. An annual schedule was produced based on this mining plan, which yields tonnage and grade of resource mined.

9% of the resource within the 22-year mine plan is inferred resource, inferred resources cannot be included in mineral reserves. The resource model is extremely consistent in grade, so there is relatively low risk to the overall mining schedule. However, a small number of resource delineation drill holes might be useful to reclassify inferred resource as measured and indicated prior to the PFS in order to allow for all the relevant material to be considered as reserves.

22.2 METALS CONSIDERED IN THE CASH FLOW ANALYSIS.

Run of mine material from Round Top contains a number of rare earth elements, as well as additional minerals of interest. A total of 27 materials (16 rare earth and related, 6 technology metals, 6 industrial sulfates, plus tin and niobium) are contained in the rhyolite and are extracted in the acid leaching process. The pricing structure and markets for these materials are discussed at length in section 19. Tin and Niobium are not considered in the economic model because a process for recovery of these elements has not been described.

The current economic analysis focuses on 20 products which are the principal value drivers for the project. Some of the remaining elements are produced in relatively small quantities, have relatively low unit values, or have poorly defined markets, and these elements are ignored in the analysis. Pricing assumptions for the products are shown in Table 22-2. Items listed as – are not considered it the economic analysis.

Table 22-2: Products considered in Economic Analysis

	Product	Base Case Price Assumption	
Rare Earth Oxides (&Relatives)	Yttrium Oxide	$ 3.60	$/Kg
	Praseodymium Oxide	$ 54.50	$/Kg
	Neodymium Oxide	$ 44.00	$/Kg
	Samarium Oxide	$ 1.83	$/Kg
	Europium Oxide	$ -	$/Kg
	Gadolinium Oxide	$ -	$/Kg
	Terbium Oxide	$ 575.50	$/Kg
	Dysprosium Oxide	$ 270.50	$/Kg
	Thulium Oxide	$ -	$/Kg
	Ytterbium Oxide	$ -	$/Kg
	Lutetium Oxide	$ 618.63	$/Kg
	Scandium Oxide	$ 1,040.76	$/Kg
Tech Metals	Uranium Oxide	$ 56.10	$/Kg
	Thorium Oxide	$ -	$/Kg
	Lithium Carbonate	$ 13.75	$/Kg
	Zirconium Oxide	$ 15.12	$/Kg
	Hafnium Oxide	$ 864.00	$/Kg
	Beryllium Hydroxide	$ 220.00	$/Kg
	Gallium Oxide	$ 162.00	$/Kg
Sulfates	Aluminum Sulfate	$ 0.21	$/Kg
	Iron Sulfate	$ 0.10	$/Kg
	Magnesium Sulfate	$ 0.13	$/Kg
	Manganese Sulfate	$ 1.19	$/Kg
	Potassium Sulfate	$ 0.43	$/Kg
	Sodium Sulfate	$ 0.20	$/Kg

It is assumed that the final rare earth oxide will be a saleable product and therefore will not be sent to a smelter for further refining. All oxides are to be sold at the plant and will not incur additional shipping charges.

For technology metals and industrial sulfates, price comparisons are FOB China. It is therefore assumed that transportation costs from Round Top will be at or lower than comparable shipping costs from the comparable price structure.

An allowance has been made in G&A operating costs to cover marketing costs for the various materials.

22.3 PROJECT ECONOMICS: BASE CASE

The indicative economic analysis results are shown in Table 22-4 Economic Analysis Summary. The analysis is based on June and July 2019 spot prices as discussed in section 19. The analysis indicates a NPV $_{10\%}$ of US$1.56 million (pre-tax) with an IRR of 70%. With a positive initial cash flow in Year 1, payback will be in 1.4 years. The following provides the basis for the Gustavson LoM plan and economics:

- Initial Mine life of 20 years
- LoM mill recoveries vary by metal and shown in Table 22-2;
- Operating costs $15.61/t-RoM;
- Capital costs of $ 602.4 million, with initial capital costs of $350.4 million and sustaining capital over the LoM of $252 million;
- Initial reclamation bond of S10.0 million (incl. in initial capital);
- A $24.4 million environmental closure cost allowance, and
- No salvage value provisions at end of life (EOL).

22.3.1 Business Factors

No research has been conducted to date on the local labor markets. Through observation it is apparent that a significant proportion of the staff to manage and operate the mine will be imported from El Paso, Arizona and New Mexico.

The Round Top project is sensitive to the pricing of the various products. However, the range of products produced should provide significant diversification to the mine. Also, the declaration of Rare Earth Elements as a critical strategic resource may help Round Top develop markets in the US.

22.4 ROYALTIES

This study assumes that Round Top will be assessed a 6.25% royalty on total product revenue.

22.5 CONTRACTS

The qualified person does not know of any contracts or agreements that TMRC has that would adversely affect any information presented in this study.

22.6 INDICATIVE ECONOMICS, BASE CASE

The economic analysis uses the prices discussed in in Section 19-6 of this PEA.

Table 22-3 : Indicative Economics

Gross Revenue	**$(000)**	**$8,440,103**	
Refining & Transport	$(000)	$0	
Royalty	**$(000)**	**$8,440,103**	
Texas State Royalty	$(000)	($529,706)	
Gross Income	**$(000)**	**$7,910,396**	
Operating Costs			
Mining	$(000)	$298,821	
Process	$(000)	$1,246,840	
G&A	$(000)	$274,292	
Subtotal Operating Costs	**$(000)**	**$1,819,953**	
Contingency	$(000)	$363,991	
Total Operating Costs	**$(000)**	**$2,275,407**	
Operating Margin	**$(000)**	**$5,916,849**	
Capital			
Mine Equipment	$(000)	$0	
Mine Development	$(000)	$8,350	
Process Equipment	$(000)	$392,860	
Preproduction Costs	$(000)	$87,030	
Subtotal Capital	**$(000)**	**$488,240**	
Contingency	$(000)	$125,388	
Total Capital	**$(000)**	**$613,628**	
Income Tax	$(000)	$0	Pretax Model
Interest Expense	$(000)	$0	100% Equity Model
Cash Flow	**$(000)**	**$5,021,361**	
Present Value	10%	**$1,564,904**	
IRR	%	70%	
Payback	Years	1.4	

Table 22-4 Operating Margins, Base Case

	Base Case
Average Annual Revenue ($/yr)	395.5 million
Average Revenue Per ($/T)	$ 54.18
Average Operating Cost ($/T)	$ 15.61
Average Operating Margin ($/T)	$ 38.58
Operating Margin	71%
Pre-Tax Project NPV 10%	$ 1.56 billion
IRR	70%
Payback (years)	1.4

22.7 SENSITIVITY ANALYSIS

Sensitivity analysis was performed on the capital costs, operating costs, and revenue. Sensitivities were conducted on the above three criteria in 5% increments up to +/- 25%. Figures 22-1 and 22-2 below shows the results of this study affect the NPV the IRR.

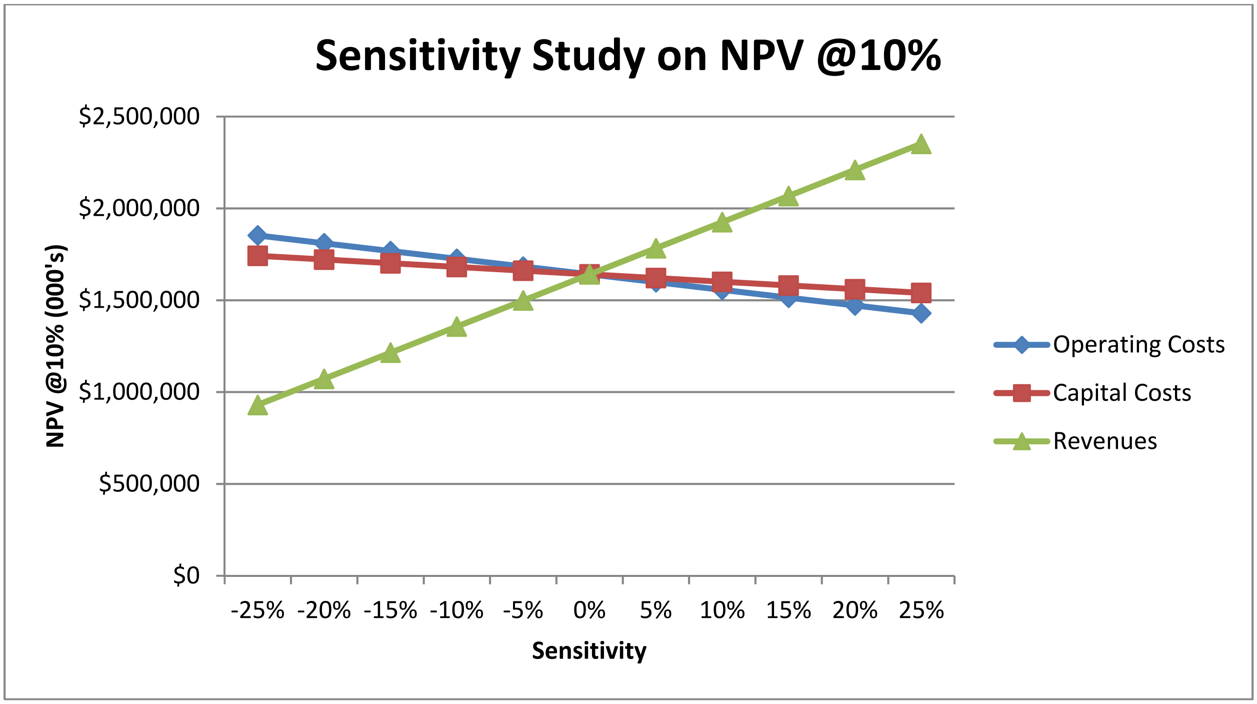


Figure 22-1 Sensitivity on NPV

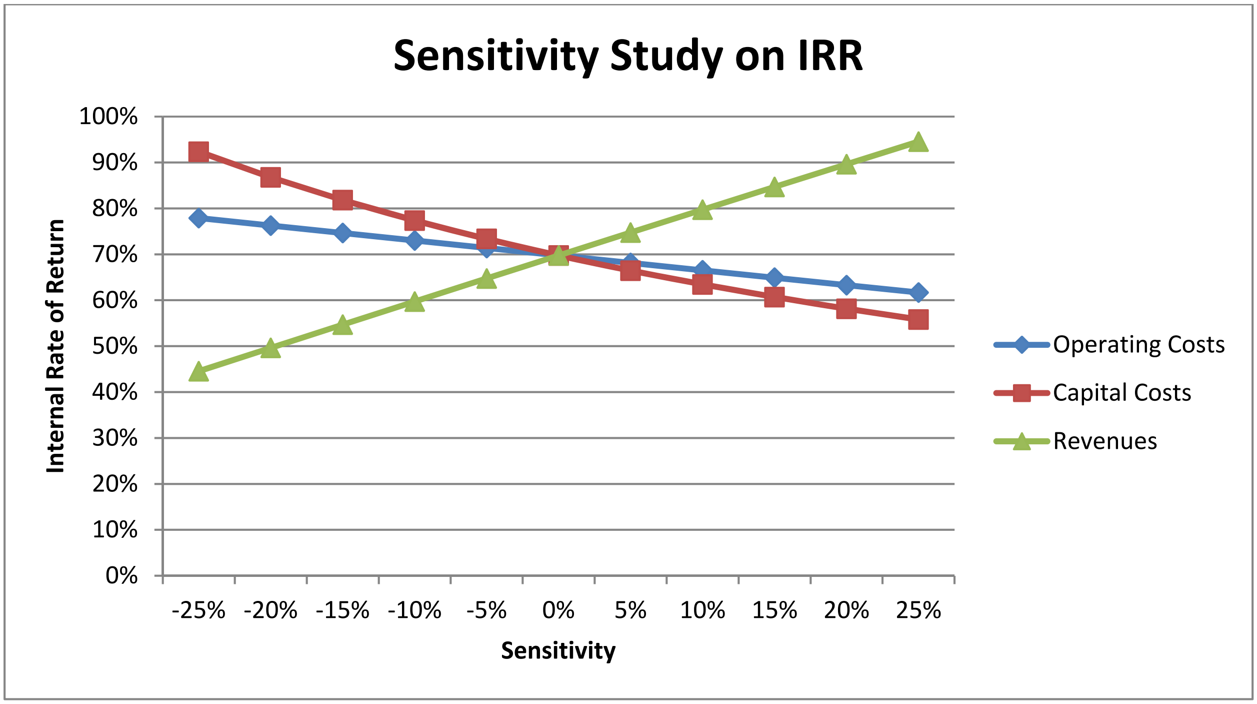


Figure 22-2 Sensitivity on IRR

As can be seen from the figures above, the Round Top project is most sensitive to the price of metals.

22.8 ALTERNATIVE CASES/ SENSITIVITY MODELS

22.8.1 Alternative Case: Rare Earths Price Reduction

Pricing of rare earth metals may be sensitive to supply. Round Top may produce enough Yttrium and Lutitium to impact the worldwide price of these metals. Accordingly, a sensitivity model has been produced to understand the impact of a 50% reduction in prices for these two products.

22.8.2 Alternative Case: Reduced Lithium Price

Lithium Carbonate may have exposure to medium term price volatility because of additional mine supply coming on line over the next 5-10 years. Accordingly, a sensitivity was run reducing average Lithium pricing from $13.35 to $9 per kg.

22.8.1 Alternative Case: Increased Lithium Extraction

Preliminary Test work indicates that Lithium extraction to the PLS is sensitive to acid strength. It is considered possible that up to 30% additional lithium could be made available to the PLS, with a corresponding increase in production. A sensitivity model has been produced to understand the impact of this change

22.8.2 Alternative Case: 2 year Delayed Start

Discounted Cash Flows and internal rates of return are significantly sensitive to the start date of a project. The base case for this project assumes a 2-year pre-production period for completion of process test work and design, environmental baseline studies, and construction of the process plants. This alternative case looks at the impact on NPV and IRR based on a 4-year pre-production period rather than 2 years.

22.8.3 Alternative Case: Conservative Case

The conservative case takes the three principal sensitivities, reduction in pricing for Lithium Carbonate, reduction in pricing for Yttrium and Lutitium, and also extends the pre-production period from 2 years to 4 years. The project remains quite robust in this condition, producing 947 million in discounted cash flows (10% discount) and a 40% IRR.

Table 22-5 Alternative Economics Case Studies

	Reduced Lu / Yt Revenue	Reduced Li Price	Enhanced Li Extraction	2 year Delayed Start	2-year delayed start, price reduced case
Average Revenue ($/yr)	379.1 million	351.7 million	434.9 million	395.5 million	335.3 million
Average Revenue Per ($/T)	$ 51.94	$ 48.18	$ 59.57	$ 54.18	$ 45.58
Average Operating Cost ($/T)	$ 15.61	$ 15.61	$ 15.61	$ 15.61	$ 15.61
Average Operating Margin ($/T)	$ 36.33	$ 32.57	$ 43.96	$ 38.57	$ 29.97
Operating Margin	70%	68%	74%	71%	66%
Pre-Tax Project NPV 10% ($)	1.45 billion	1.26 billion	1.70 billion	1.29 billion	947 million
IRR	65%	59%	80%	54%	40%
Payback (years)	1.5	1.7	1.2	1.4	1.8

23 ADJACENT PROPERTIES

At the time of this report, and to the qualified persons' knowledge, there are no known adjacent properties that host REE deposits.

24 OTHER RELEVANT DATA AND INFORMATION

To the qualified persons' knowledge, there is no other relevant data or information that is not already disclosed in this PEA.

25 INTERPRETATIONs AND CONCLUSIONS

The Round Top Project is an Eocene-aged peralkaline rhyolite-hosted REE deposit with a high ratio of HREEs to LREEs. The rhyolite body is a mushroom-shaped laccolith, slightly elongated northwest-southeast and dipping gently to the southwest.

The REEs are primarily contained in the minerals yttrofluorite and bastnaesite, which are very fine-grained and disseminated throughout the rhyolite mainly in microfractures, voids and coatings on predominantly alkali feldspar phenocrysts. There are different levels of alteration within the rhyolite, although analysis shows that the REE grades do not vary significantly with the rhyolite color or alteration. However, the recoveries or the strength and amount of solution required may vary with rhyolite type.

The resource model suggests the deposit contains an estimated measured and indicated resource of 364 million metric tons of mineralized rhyolite, with additional inferred resources of 735 million tons.

Side hill open pit mining methods are proposed with on-site processing facilities employing acid heap leach extraction and a multi-step CIX/ CIC and membrane technologies to produce various end products. Heap leach extractions have been demonstrated by bench scale test work, and recovery of REE and principal co-products is based on well-defined industrial processes, although they have not necessarily been proven using leach solutions form Round Top materials.

A preliminary mine plan suggests that part of the resource, containing an estimated 160 million metric tons of material, can be mined and processed according to the assumptions in this report. This material is sufficient for 22 years of mine production at a nominal 20,000 tonnes per day.

The PEA assumes a processing rate of 20,000 metric tons of rhyolite per day or 7.3 million tons per year and analyzes the first 20 years of the mine life. The Base Case NPV at a 10% discount rate is estimated to be $1.56 billion with 70% internal rate of return. The life-of- mine capital costs are projected to be $602.4 million. Details are contained in Table 22-3. Sensitivity cases demonstrate that the project is economically robust under a range of current product pricing and processing assumptions.

It is the qualified persons' opinion that the resource and economic model described in this report is suitable for preliminary economic evaluation, and assessment of the potential project viability for determination of advancement of the Project. The PEA results justify advancing the Project to a pre-feasibility study.

This PEA, including the mine plan, is preliminary in nature and includes inferred mineral resources that are considered too speculative geologically to have the economic considerations applied to them that would enable them to be categorized as mineral reserves. No mineral resources defined in this PEA have been converted to reserves. Mineral resources that are not mineral reserves have no demonstrated economic viability. There is no certainty that the results of this PEA, including the mine plan, will be realized.

Principal risks to developing Round Top include the price and demand for REOs and to Lithium and Sulfate co-products, and finalization of the process flow sheet, process recoveries, and associated capital and operating costs parameters. Although the Round Top deposit is a low grade deposit, it is relatively insensitive to both operating and capital costs.

It may be beneficial for TMRC to enter into memorandum of understanding (MOU) or letter of intent (LOI) agreements with intended end users prior to advancing beyond feasibility. The major focus of the MOU/LOI's will be toward the sale of potential CREEs that will be in demand in the future. Although the Roskill market study shows a solid projected demand accompanying the increasing use of electronics, securing these agreements in advance will provide a measure of protection to the Project revenue.

26 RECOMMENDATIONS

26.1 GENERAL RECOMMENDATIONS

- The project warrants advancement to the feasibility stage based on the results of the PEA.
- Geotechnical and hydrological drilling and study of the proposed leach area and processing plant.
- Bench scale test work to advance metallurgical understanding of the project, followed by pilot heap leach and chemical plant to confirm the continuous operation of the process and generate final Capex and Opex figures for process.
- Conversion of resources to reserves

26.2 GEOLOGY AND RESOURCE ESTIMATION

- The deposit shows extremely consistent mineralization throughout the rhyolite material. The more densely drilled portion of the resource volume is sufficient to support in excess of 20 years of mine life. Accordingly, additional exploration drilling is not recommended at this time, except that if new drillholes are needed for geotechnical determinations, material from these holes could be assayed and that information added to the database.
- There is an outstanding question with regard to Hafnium and Zirconium assays which needs to be addressed. The current chemical analysis appears to be depleted in these two elements. The 2013 analysis provides values that compare well with the values from the column leach tests, thus these values have been used in the estimate. The difference may be gravimetric segregation of the samples over time. This should be reviewed.

26.3 METALLURGY AND PROCESS DESIGN

To advance the metallurgical and processing understanding of the project, the following bench test work and studies are recommended:

- Optimization of the heap leach process parameters (crush size, acid concentration, leach time PLS concentration, etc.) for optimum extraction of all products (REEs, U/Th, Aluminum Sulfate, Lithium and other sulfates.
- Optimization of the REE separation from impurities and other products (Phase 1), including resins, PLS concentration, etc.
- Optimization of separation of REEs in different groups (Phase 2) followed by separation of individual REE products (Phase 3).

- Develop and optimize process for production of lithium product (carbonate or hydroxide) aluminum sulfate and other sulfate products.
- Process for production of hafnium and zirconium products should be developed and optimized, as these materials have been demonstrated to report to the PLS and show significant economic potential.

Following the confirmation of the process in bench scale testing, run geometallurgical tests with different feed materials (predominantly red-pink vs. grey rhyolite).

Design and implement a 5,000 to 10,000 tonne heap leach test facility and chemical pilot plant to confirm the process flowsheet on a continuous basis and generate data for refining CAPEX and OPEX estimates to a feasibility level.

26.4 GEOTECHNICAL EXPLORATION

A full geotechnical and hydrological study should be completed for the Round Top Project. Condemnation holes should be drilled and test pits excavated in the areas for the proposed facility and leach site.

26.5 ENVIRONMENTAL STUDIES AND MINE PLANNING

As stated in Section 20, monitoring as part of an environmental baseline study may require monitoring over several months or seasons in order to collect representative data. As such, it is recommended that a scope of an environmental baseline study should be determined followed by monitoring.

26.6 MARKET STUDY FOR FEASIBILITY

An updated market study should be generated, informed by the results of pilot plant test work. This should include identification of specific market partners for the various products at the purity levels produced by the pilot plant, as well as letters of intent or formal offtake agreements when possible.

26.7 FEASIBILITY STUDY

The above recommended work should culminate in the completion of a feasibility study. The qualified persons' recommend continuing development, including various studies needed to advance the project, proceeding through to completion of a feasibility study at a cost of $16.5 million as outlined below. A pilot plant is included in the metallurgical budget. The budget is presented in Table 26-1 below.

Table 26-1 Proposed Budget through Feasibility Stage

Task	**Budget**
Geotechnical Studies	$400,000
Environmental Studies	$2,000,000
Metallurgy & Process Design	
Bench Scale Testing & Optimization	$2,000,000
Pilot Plant	$2,000,000
Metallurgy and Process Engineering	$500,000
Heap Leach Contractor Design	$400,000
Ground Water Wells / Hydrology	$500,000
Power Evaluation / Power Line Upgrade	$1,500,000
Pre-Feasibility Study	$500,000
Feasibility Study	$1,200,000
Subtotal	$11,000,000
Project personnel	$1,450,000
General and Administrative (project only)	$800,000
Subtotal	$13,250,000
Contingency 25%	$3,300,000
Total (with contingency)	**$16,550,000**

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28 Certificate of Author Forms

DONALD E. HULSE

Principal Mining Engineer

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CERTIFICATE of AUTHOR

I, Donald E. Hulse do hereby certify that:

1. I am currently employed as Principal Mining Engineer by Gustavson Associates, LLC at:

    274 Union Boulevard
    Suite 450
    Lakewood, Colorado 80228

2. I am a graduate of the Colorado School of Mines with a Bachelor of Science in Mining Engineering (1982) and have practiced my profession continuously since 1983.
3. I am a registered Professional Engineer, in good standing in the State of Colorado (35269), and a registered member in good standing of the Society of Mining Metallurgy & Exploration (1533190RM).
4. I have worked as a mining engineer for a total of 36 years since my graduation from university; as an employee of a major mining company, a major engineering company, and as a consulting engineer. I have estimated mineral resources in precious metals, base metals, and industrial minerals in a variety of geologic settings. I have planned and operated surface mines in the US, Chile and Mexico, including cost estimation, cutoff grade determination, and equipment productivities.
5. I have read the definition of "qualified person" set out in National Instrument 43-101 Standard of Disclosure for Mineral Projects ("**NI 43-101**") and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.
6. I am responsible for the preparation of the technical report titled "NI 43-101 Preliminary Economic Assessment on the Round Top Project Sierra Blanca, Texas" dated August 16, 2019 with an effective date of July 1, 2019 (the "**PEA**"). I am specifically responsible for Sections 1 through 6, 14,15, 16, and 18 and for the overall content of the report. I conducted a site visit on September 18, 2013 for one day.

7. I have had prior involvement with the property that is the subject of the PEA. I was responsible for the preparation of the technical report titled "NI 43-101 Preliminary Economic Assessment on the Round Top Project Sierra Blanca, Texas" dated June 22, 2012 with an effective date of May 15, 2012. I was specifically responsible for Sections 1 through 6, 15, 16, and 18 through 27. I was also responsible for the preparation of the technical report titled "NI 43-101 Preliminary Economic Assessment on the Round Top Project Sierra Blanca, Texas" dated December 20, 2013 with an effective date of November 30, 2013. I was specifically responsible for Sections 1 through 6, 15, 16, and 18 through 27.
8. I am independent of Texas Mineral Resources Corp. and of USA Rare Earth LLC applying all of the tests in Section 1.5 of NI 43-101.
9. I have read National Instrument 43-101 and Form 43-101, and the PEA has been prepared in compliance with that instrument and form.
10. As of the effective date of this PEA, to the best of my knowledge, information and belief, the PEA contains all scientific and technical information that is required to be disclosed to make the PEA not misleading.

Dated this 10th day of August 2019.

/s/ Donald E. Hulse
Signature of Qualified Person

Donald E. Hulse
Print name of Qualified Person

Thomas C. Matthews, MMSA QP

Principal Resource Geologist

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CERTIFICATE of AUTHOR

I, Thomas C. Matthews, do hereby certify that:

1. I am currently employed as Principal Resource Geologist by Gustavson Associates, LLC at:

   274 Union Boulevard
   Suite 450
   Lakewood, Colorado 80228

2. I graduated with a Bachelor's of Science degree in Geology from University of Rochester in 1994. I have practiced my profession continuously since 1995.
3. I am a Qualified Professional (QP) Member of the Mining and Metallurgical Society of America (01455QP) with special expertise in Geology and Ore Reserves.
4. I have worked as a geologist for a total of 24 years since my graduation from university, as an employee of an exploration company, a mining company, and as a consultant. My relevant experience includes exploration, geologic modeling, and resource estimation, reserves definition in feasibility studies, ore control systems, and mine-model reconciliation for a variety of mineral systems.
5. I have read the definition of "qualified person" set out in National Instrument 43-101 (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

6. I am responsible for the Sections 7-12, 19, and 22 through 26. of the report entitled "NI 43-101 Preliminary Economic Assessment, Round Top Project, Sierra Blanca, Texas", dated August 10, 2019 with an effective date of July 1, 2019 (the "**PEA**"). I visited the property on July 9, 2019.
7. I have not had prior involvement with the Round Top property that is the subject of the PEA.
8. I am independent of Texas Mineral Resources Corp. and of USA Rare Earth LLC applying all of the tests in Section 1.5 of NI 43-101.
9. I have read NI 43-101 and Form 43-101, and the PEA has been prepared in compliance with that instrument and form.
10. As of the effective date of this PEA, to the best of my knowledge, information and belief, the PEA contains all scientific and technical information that is required to be disclosed to make the PEA not misleading.

Dated this 16th day of August 2019.

/s/ Thomas C Matthews
Signature of Qualified Person

Thomas C. Matthews
Print name of Qualified Person

Deepak Malhotra, Ph.D.
President
Resource Development, Inc. (RDi)
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CERTIFICATE of AUTHOR

I, Deepak Malhotra, PhD do hereby certify that:

1. I am President of:

   Resource Development, Inc. (RDi)
   11475 W. I-70 Frontage Road North
   Wheat Ridge, CO, USA, 80033

2. I graduated with a degree in Master of Science from Colorado School of Mines in 1973. In addition, I have obtained a PhD in Mineral Economics from Colorado School of Mines in 1977.

3. I am a registered member of the Society of Mining, Metallurgy and Exploration, Inc. (SME), member No. 2006420RM.

4. I have worked as a mineral processing engineer and mineral economist for a total of 40 years since my graduation from university. I have experience in similar project types inclusive of those in the Western United States.

5. I have read the definition of "qualified person" set out in National Instrument 43-101 (NI 43-101) and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.

6. I am responsible for the preparation of Sections 13, 17 and the process costs portion of Section 20of the Technical Report titled "NI 43-101 Preliminary Economic Assessment of the Round Top Project, Sierra Blanca, Texas," dated August 16, 2019 with an effective date of July 1, 2019 relating to the Round Top Project. I visited the subject property on July 9, 2019.

7. I have had prior involvement with the Round Top property that is the subject of the PEA. I was responsible for the preparation of Sections 13 and 17 of the Technical Report titled "NI 43-101 Preliminary Economic Assessment of the Round Top Project, Sierra Blanca, Texas," dated June 22, 2012 with an effective date of May 15, 2012 relating to the Round Top Rare Earth Project. I was also responsible for the preparation of Sections 13 and 17 of the Technical Report titled "NI 43-101 Preliminary Economic Assessment of the Round Top Project, Sierra Blanca, Texas," dated December 20, 2013 with an effective date of November 30, 2013 relating to the Round Top Rare Earth Project.

8. I am independent of the issuers applying all of the tests in section 1.5 of National Instrument 43-101.

9. I have read NI 43-101 and Form 43-101F1, and the PEA has been prepared in compliance with that instrument and form.

10. As of the effective date of this PEA, to the best of my knowledge, information and belief, the PEA contains all scientific and technical information that is required to be disclosed to make the PEA not misleading.

Dated this 16 day of August 2019.

/s/ *Deepak Malhotra*
Signature of Qualified Person

Deepak Malhotra .
Print name of Qualified Person

Christopher Emanuel, PE, SME-RM

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CERTIFICATE of AUTHOR

I, Christopher Emanuel, PE do hereby certify that:

1. I am currently employed as Principal Mining Engineer by Gustavson Associates, LLC at:

   274 Union Boulevard
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   Lakewood, Colorado 80228

2. I am a graduate of the Colorado School of Mines with a Bachelor of Science in Mining Engineering (2005) and have practiced my profession continuously since 2005.
3. I am a registered member in good standing of the Society of Mining Metallurgy & Exploration (04151007RM).
4. I have worked as a mining engineer for a total of 13 years since my graduation from university; as an employee of a mining company, a mine services contractor, and a mining consulting firm. I have planned surface and underground mines in the United States and Mexico, including cost estimation, pit designs, and equipment productivities.
5. I have read the definition of "qualified person" set out in National Instrument 43-101 Standard of Disclosure for Mineral Projects ("**NI 43-101**") and certify that by reason of my education, affiliation with a professional association (as defined in NI 43-101) and past relevant work experience, I fulfill the requirements to be a "qualified person" for the purposes of NI 43-101.
6. I am responsible for the preparation of the technical report titled "NI 43-101 Preliminary Economic Assessment on the Round Top Project Sierra Blanca, Texas" dated August 16, 2019 with an effective date of July 1, 2019 (the "**PEA**"). I am specifically responsible for Sections 16, the mining costs portion of section 20, and section 22.

7. I have not had prior involvement with the property that is the subject of the PEA.
8. I am independent of Texas Mineral Resources Corp. and of USA Rare Earth LLC applying all of the tests in Section 1.5 of NI 43-101.
9. I have read National Instrument 43-101 and Form 43-101, and the PEA has been prepared in compliance with that instrument and form.
10. As of the effective date of this PEA, to the best of my knowledge, information and belief, the PEA contains all scientific and technical information that is required to be disclosed to make the PEA not misleading.

Dated this 16th day of August 2019.

/s/ Christopher Emanuel
Signature of Qualified Person

Christopher Emanuel
Print name of Qualified Person

29 APPENDIX A: DRILL HOLE COLLARS

BHID	DEPTH	XCOLLAR	YCOLLAR	ZCOLLAR
1	350	689556.81	10466919.44	5093.22
2	150	690434.65	10467187.66	5067.04
3	350	688349.71	10466584.84	4893.23
5	300	689205.26	10466674.04	5098.07
201	600	688115.33	10463752.37	4567.38
202	80	691434.31	10467060.46	5088.24
203	142	691250.74	10467076.9	5110.53
204	352	691054.83	10467079.38	5110.35
205	232	690930.65	10466946.17	5134
206	183	690753.9	10467059.73	5116.4
207	122	690565.33	10467187.51	5075.07
208	152	690376.99	10467150.01	5065.64
209	203	690320.38	10467024.68	5069.05
211	250	690265.63	10466800.11	5074.73
212	110	690185.05	10466998.35	4999.42
213	195	690143.41	10466894.15	5010.33
214	210	690023.04	10466911.51	5029.07
215	215	689840.65	10466989.13	5039.89
216	220	689762.99	10467018.66	5041.54
217	200	689638.05	10467085.56	5022.11
218	210	689154.02	10466910.23	4984.91
219	220	689363.86	10467013.75	5007.66
220	140	688955.39	10466931.32	4923.75
221	160	688692.21	10466879.07	4904.57
222	220	688535.57	10466761.94	4888.95
223	140	688780.41	10466923.53	4900.21
224	160	688865.79	10466956.69	4902.99
226	216	688572.26	10466938.35	4864.42
227	180	690302.71	10467149.31	5042.54
228	300	689237.03	10466692	5106.23
229	360	689400.23	10466812.3	5119.93
230	360	689790.07	10466813.24	5132.26
231	320	690345.63	10466652.37	5138.12
232	280	690135.59	10466652.52	5130.85
233	360	690458.51	10466825.48	5175.1
234	280	690514.81	10467006.65	5138.84
235	380	690894.39	10466713.13	5240.96
236	320	691049.67	10466832.74	5205.35

BHID	DEPTH	XCOLLAR	YCOLLAR	ZCOLLAR
237	260	691415.26	10466881.84	5199.33
238	300	690726.09	10466904.62	5191.83
239	360	689043.73	10466615.93	5104.21
240	360	688330.96	10466574.12	4891.64
241	410	688193.68	10466438.97	4885.5
242	580	688508.57	10466330.85	5055.41
243	445	688689.87	10466456.74	5062.45
244	312.5	688814.51	10466590.64	5066.77
245	290	689410	10466881	5092.51
246	385	689617.18	10466907.7	5100.82
247	165	688354.84	10467049.24	4786.98
248	205	688322.44	10466864.73	4779.02
249	165	688140.78	10466762.88	4766.31
250	205	688008.47	10466627.93	4767.6
251	325	687933.73	10466412.7	4763.28
252	345	687875.76	10466247.77	4756.22
253	445	688474.89	10466462.76	4984.46
254	400	688638.05	10466626.39	4975.5
255	265	688786.06	10466752.06	4978.14
256	285	688971.73	10466800.98	4988.28
259	465	688409.45	10466516.99	4943.26
260	365	688486.18	10466545.32	4949.79
261	305	688439.61	10466646.23	4891.21
262	305	688045.15	10466706.3	4758.95
263	165	688251.91	10466791.99	4779.71
264	245	688115.26	10466584.66	4813.36
265	245	688205.19	10466652.64	4823.72
266	205	688293	10466699.1	4829.53
267	180	688374.1	10466743.81	4828.03
268	405	689146.54	10466617.91	5106.93
269	525	688616.62	10466395.27	5062.39
270	190	690491.1	10467128.47	5089.69
271	280	690380.54	10466930.62	5113.44
280	405	689166.92	10466502.57	5187.8
281	395	689258.48	10466552.1	5172.47
282	265	692975.79	10465089.79	5106.57
283	265	692795.58	10465182.63	5104.61
284	265	692928.19	10464890.93	5131.52
285	285	692995.06	10464727	5107.79
286	265	693125.39	10464559.37	5109.55

BHID	DEPTH	XCOLLAR	YCOLLAR	ZCOLLAR
287	305	693105.94	10464351.06	5122.8
288	125	688102.85	10466850.2	4729.44
289	100	688031.05	10466826.45	4724.55
290	60	687947.61	10466824.62	4707.23
291	100	687878.82	10466747	4707.6
292	125	688184.88	10466881.07	4731.64
293	255	688275	10466545.66	4883.03
294	330	690770.11	10466850.32	5208.15
295	400	690586.77	10466852.57	5213.66
296	405	690519.41	10466667.46	5237.68
308	267.5	688241.67	10466675.14	4826.57
309	120	689484.39	10467183.87	4946.34
310	120	689408.68	10467142.27	4958.91
311	140	689303.65	10467089.07	4962.73
312	120	689219.07	10467045.42	4953.08
313	100	689135.18	10466997.67	4940
314	145	689071.07	10466936.97	4937.74
315	260	689058.86	10466843.2	4974.65
316	580	688559.54	10466363.92	5058.56
317	382.5	689300.46	10466755.94	5102.69
318	252.5	689063.19	10466711.95	5038.55
319	400	688965.11	10466709.79	5034.95
320	320	689128.82	10466716.28	5043.46
321	260	689220.41	10466828.06	5039.8
322	240	689299.97	10466896	5048.32
323	260	689380.97	10466946.08	5048.74
324	435	689472.62	10466986.58	5045.13
325	220	690413.8	10467046.17	5098.13
336	645	690344.8	10462565.55	4682.32
337	460	687842	10465480	4652.703
RT 401	260	690385.13	10461090.18	4524.13
RT 402	240	690532.55	10461474.71	4554.5
RT 403	570	690587.44	10463216.28	4798.06
RT 404	560	690346.92	10462579.85	4684.14
RT 405	400	691697.16	10461555.25	4587.22
RT 406	415	691546.05	10461175.89	4551.58
RT 407	385	691113.4	10460798.42	4514.68
RT 408	385	691122.75	10460574.37	4502.44
RT 409	375	692055.47	10459214.82	4500.52
RT 410	400	690725.1	10459943.8	4475.37

BHID	DEPTH	XCOLLAR	YCOLLAR	ZCOLLAR
RT 411	435	689835.54	10459936.09	4463.7
RT 412	480	688718.33	10460541.39	4450.56
RT 413	400	688528.6	10461265.01	4468.18
RT 414	400	687764.5	10461245.37	4435.94
RT 415	520	687491.35	10462243.99	4439.29
RT 416	90	687783.5	10462232.93	4456.33
RT 417	500	687832.95	10462785.14	4488.58
RT 418	500	686520.47	10461799.42	4398.57
RT 419	500	685756	10463023.13	4376.1
RT 420A	760	688786.43	10464401.42	4845.13
RT 421	740	689337.86	10464089.9	4897.85
RT 422	420	687840.68	10465497.31	4650.22
RT 423	580	687766.03	10464749.55	4594.82
RT 424	300	685965.86	10464317.67	4376.05
RT 425	380	687499.79	10465526.68	4546.75
RT 426	340	687233.15	10466152.72	4513.32
RT 427	700	688513.04	10466735.11	4886.05
RT 428	370	688149.5	10466390.22	4879.65
RT 429	300	688322.72	10466583.41	4884.54
RT 430	115	688838.05	10466974.61	4891.21
RT 431	50	689532.36	10467219.55	4935.479
RT 432	95	689330.55	10467104.99	4962.52
RT 433	75	689112.01	10466971.04	4941.84
RT 434	180	688911.09	10466796.56	4983.19
RT 435	230	688759.51	10466737.51	4978.95
RT 436	440	688397.25	10466449.9	4966.49
RT 437	135	689913.44	10466964.45	5032.04
RT 438	165	690453.05	10467106.36	5091.35
RT 439	360	690243.47	10466591.65	5146.38
RT 440	300	689606.81	10466872.38	5118.9
RT 441	360	689217.05	10466702.17	5094.43
RT 442	270	688885.26	10466609.88	5079.88
RT 443	260	688647.87	10466429.93	5056.86
RT 444	560	688403.32	10466232.93	5040.34
RT 445	205	691521.21	10466839.75	5191.83
RT 446	230	691227.2	10466945.8	5190
RT 447	315	691012.63	10466763.1	5210
RT 448	230	690690.57	10466948.8	5177
RT 449	550	688879.7	10466061.1	5260
RT 450	675	688667.5	10466163.6	5200

BHID	DEPTH	XCOLLAR	YCOLLAR	ZCOLLAR
RT 451	440	689482.323	10466629	5240
RT 452A	475	690772.446	10466641.44	5307.996
RT 452A-60	570	690773.994	10466640.25	5308.002
RT 452A-70	495	690773.242	10466640.82	5308.002
RT 453	600	690655.311	10466299.7	5360
RT 454	615	690370.3	10466118.3	5396.066
RT 455	305	690762.09	10466213.61	5431.594
RT 456	800	690000.679	10465965.91	5561.63
RT 457	720	689720.86	10466088.05	5527.125
RT 458	460	690541.37	10466380.98	5284.831
RT 459	830	691502.69	10466017.55	5626.948
RT 460-45	400	689706.86	10466088.05	5527.125
RT 460-55	300	689708.86	10466088.05	5527.125
RT 460-80	720	689708.86	10466088.05	5527.125
RT 461	1180	690985.41	10465415.86	5722.594
RT 462	640	690444.42	10465664.5	5667.948
RT 462A	1020	690460.4	10465661.97	5669.952
RT 463-45	820	689725.86	10466093.05	5527.125
RT 463-60	530	689726.86	10466095.05	5527.125
RT 464	780	691195.26	10465733.49	5688.993
RT 465	1020	691346.56	10465634.82	5690.727
RT 467	960	690963.92	10465715.52	5689.12
RT 466-60	470	689715.86	10466093.05	5527.125
RT 468	260	693110.112	10464355.9	5121.37
RT 469	855	689871.67	10465613.17	5440.16
RT 470	765	692090	10464694.9	5472.707
RT 471	725	691683.36	10465034.47	5479.47
RT 472	965	691463.17	10465262.13	5538.16
RT 474	585	691057.51	10463382.69	4811.02
RT 475	520	689409.14	10462816.94	4564.02
RT 476	665	690256.13	10463725.31	4803.42
RT 477	375	692025.8	10463159.7	4759.11
RT 478	435	692462.46	10462620.9	4738.25
RT 479	1000	693062.4	10464222.99	5051.31
RT 480	600	692900.35	10466092.24	4972.38
RTC 459	279	691507.69	10466012.55	5626.95
RTC 461	1024.5	690985.41	10465425.86	5722.59

30 APPENDIX B: HAZEN MINERALOGY REPORT

This letter report provides Hazen Research, Inc.'s summary of a mineralogical evaluation, using QEMSCAN technology, of a whole ore sample (HRI 53333-1), a rougher tails sample from flotation Test 3641-108, and a H_2SO_4 acid bake–water leach residue (Test 5, 3553-27-7). The whole ore sample was provided by Texas Rare Earth Resources (TMRC), reportedly from their Round Top Mountain Project in Hudspeth County, Texas. The flotation tails and leach residue samples were produced in laboratory experiments conducted at Hazen using the sample provided by TMRC. The main objectives of the study were to:

1. Identify the minerals that contain the rare earth elements (REE) in the ore, in particular the high revenue-generating elements yttrium and dysprosium.
2. Identify the mode of occurrence of REE-bearing minerals that are lost to the flotation tails.
3. Characterize the residual REE minerals in the leach residue.

The samples analyzed by QEMSCAN are described in more detail in later sections. The main results are as follows:

1. An yttrium-rich fluorite is the main carrier of yttrium and dysprosium.
2. The yttrium-rich fluorite is fine-grained (up to 40 µm but usually less than 10 µm).
3. Yttrium-rich fluorite levels appear to be slightly reduced in the flotation rougher tails when compared with the head.
4. Yttrium-rich fluorite levels in the leach residue are considerably lower than in the head. Residual yttrium-rich fluorite is locked in silicate gangue.
5. Zircon and iron-rich biotite in the residue show evidence of leaching.

Simple Description and Preparation

<u>Whole Ore (HRI 53333-1)</u>

The whole ore sample is a composite and was assigned the Hazen internal reference number 53333-1 on receipt from TMRC. A portion of the composite was ground to 100% passing 1.7 mm (10 mesh) for mineral processing. A representative split was then submitted for QEMSCAN analysis. The split was screened at 38 µm and one polished section of each of the size fractions was prepared and analyzed. More than 90% of the mass was contained in the plus 38 µm fraction. The data presented here are the combined results from both size fractions. The yttrium concentration is 211 ppm, dysprosium is 29 ppm, zirconium is 0.107%, and thorium is 16 ppm; total TREE + Y is 0.05%. The analytical work was conducted by Activation Laboratories (Actlabs) (Ancaster, Ontario). Yttrium and zirconium were analyzed by inductively coupled plasma (ICP) spectroscopy; dysprosium, all other REE, and thorium were analyzed by ICP–mass spectrometry.

Flotation Rougher Tails

The rougher tails from flotation Test 3641-108 (repeat of Mountain States R&D International, Inc. (Vail, Arizona) Test 17 conditions with a 20 min grind) were mounted in a polished section without screening. The measured 80% passing size (P_{80}) at that grind was 85 µm. The rougher tails represent about 88% of the total sample mass. About 55% of the total yttrium and 56% of the total dysprosium reported to the rougher tails. The reagent schedule and dosages are shown in the data sheet (enclosed).

Acid Bake–Water Leach (ABWL, Test 5, 3553-27-7)

Whole ore, ground for 20 min with a P_{80} of about 70 µm, was acid baked (H_2SO_4) and water leached. Inductively coupled plasma analyses indicated a high extraction of yttrium, about 94%. The residue of this ABWL was mounted as a polished section and analyzed by QEMSCAN. The residual yttrium is 13 ppm, dysprosium is 2.1 ppm, zirconium is 0.08%, and thorium is 35 ppm; TREE + Y is 0.004%, which is more than an order of magnitude lower than in the head sample.

Mineral Abundance Results

Based on Actlabs data, the head sample contains 0.05% TREE + Y. At the low levels of elements of interest in the Round Top ore, it must be noted that the mineralogical results presented here may not be entirely representative of the whole ore. There are very few occurrences of the minerals of interest in the exposed plane of a single polished section. For this reason, the data presented here should be regarded as indications for the mode of occurrence of the REE-bearing minerals in the ore. The results of the mineral abundance analyses of the three samples are summarized in Table 1. The minerals identified in the ore and the flotation rougher tails are described in the Whole Ore section. Additional phases formed during the ABWL process are described in the ABWL section.

Table 30-1. Mineral Abundances

Sample	Composite	Rougher Tails	ABWL Residue
ID	**53333-1**	**3641-108**	**3553-27-7**
Mineral	**Analysis, mass %**		
Yttrofluorite	0.06	0.04	0.003
Zircon	0.27	0.18	0.34
Zircon(Hf)	0.04	0.03	0.08
Th Mineral	0.07	0.04	0.03
Bastnäsite or Cerite	0.01	0.01	0.0002
Columbite	0.09	0.09	0.02
Xenotime-(Y, Yb)	0.002	0.002	0.00002
Monazite	0.0004	0.0002	0
Quartz	27.6	26.8	31.3
K-Feldspar	30.8	29.7	29.2
Na-Feldspar	30.7	32.0	33.6
Mica and Chlorite	2.5	4.9	3.1
Fe-Rich Biotite	2.4	2.9	0.9
Fluorite	0.7	0.07	0.0005
Carbonate	0.2	0.02	0.001
Fe Oxide and Fe Hydroxide	0.9	0.7	0.4
Pb–Nb–Ta Oxide	0.01	0.01	0.001
Cryolite	1.8	1.1	0.04
Gearksutite	0.2	0.04	0.0002
Thomsenolite	0.0001	0	0
Ralstonite	0.1	0.04	0.0003
Mn–Zn–Pb Oxide or Hydroxide	0.08	0.01	0.0001
Sn-Bearing Minerals	0.03	0.05	0.02
Miscellaneous	0.9	0.4	0.1
Unidentified	0.5	0.7	0.4
Si-S Phase	nd	nd	0.4
Al Sulfate	nd	nd	0.01
Total	**100**	**100**	**100**

nd = not detected

Whole Ore

In general, REE minerals and REE-bearing minerals occur intimately intergrown with each other or with gangue and are very fine-grained, making the identification of minerals and chemical compositions difficult.

An yttrium-rich fluorite (here called yttrofluorite) is the main REE mineral in the ore. Its concentration was determined to be less than 0.1%. Yttrofluorite occurs up to 30 µm in size but is usually less than 10 µm. It is mainly intergrown with feldspar, and to a lesser degree with quartz and mica. It also occurs as liberated grains. When yttrofluorite is intergrown with gangue, it usually shows some surface exposure. Small inclusions of yttrofluorite in thorite, which is usually locked in zircon, were also observed. Figures 1 and 2 show examples of yttrofluorite intergrown with gangue. The chemical composition of yttrofluorite is variable. It contains mainly the heavy rare earth elements ytterbium, dysprosium, and erbium, but can also contain low levels of gadolinium, samarium, cerium, and neodymium. Calcium levels are variable and show an inverse correlation with yttrium. Occasionally, yttrofluorite shows some alteration at the edges, with increased iron and reduced yttrium compared with the center of the particle. Possibly, invasive iron-rich fluids led to the changes. Ultratrace amounts of an yttrium mineral that contains light rare earth elements (LREE) only was also observed. This phase was grouped under yttrofluorite.

Ultratraces of an ytterbium-bearing xenotime ($(Y,Yb)PO_4$), locked in gangue, were observed and were less than 5 µm in size. This xenotime also contains erbium and dysprosium, and minor gadolinium, neodymium, samarium, and thorium. Erbium levels appear to be higher than those of dysprosium.

Trace levels of bastnäsite ($(Ce,La)(CO_3)F$) or cerite (with a general formula of $Ce_9Fe(SiO_4)_6[(SiO_3)(OH)](OH)_3$), or both, were observed, with a maximum observed size of 15 µm. This mineral, or minerals, probably contains the major portion of the LREE in the ore. Bastnäsite or cerite may also contain low levels of yttrium, thorium, uranium, calcium, and lead.

Monazite ($(Ce,La,Nd,Th)PO_4$) may be present as well.

The measured concentration of zircon was about 0.3%. Zircon usually contains measureable concentrations of hafnium. These can be relatively high, and zircon that contains elevated hafnium concentrations (estimated at greater than 10%) was distinguished from zircon with less hafnium. Zircon grains up to 100 µm were observed. It is very common for zircon to include a thorium mineral (probably thorite) as very fine inclusions (Figure 3). Zircon may also include fine inclusions of an yttrium-rich mineral (probably yttrofluorite). Zircon also occurs with no or very few inclusions of thorite (Figure 4).

Thorite ($ThSiO_4$) is probably the main thorium- und uranium-bearing mineral. Because of the thorium-containing minerals being so fine-grained, it cannot be excluded that other thorium minerals are present as well. Yttrium, ytterbium, erbium, uranium, and iron were observed in thorite. The x-ray signals may have originated from submicroscopic inclusions of other minerals. Thorite up to 30 µm in size was observed (Figure 4).

Columbite-(Fe,Mn) up to about 80 µm in size appears to be the main niobium mineral in the ore. Columbite contains manganese, iron, and tantalum. Niobium and tantalum are also observed in lead-rich niobium–tantalum oxide or hydroxide and in a tin-rich niobium–tantalum–iron–manganese oxide (probably foordite). Tin was also observed as tin oxide (cassiterite).

Iron oxide (mainly magnetite that is oxidized to hematite to a large degree) and iron-rich biotite are the main iron-bearing minerals. It is estimated that magnetite and hematite contain about

60% of the iron in the sample. The remainder is mainly present as iron-rich mica. The concentrations of iron oxide and iron-rich mica are about 1 and 2.5%, respectively. Mica (probably muscovite) and chlorite minerals were also observed. Their combined concentration was measured at 2.5%

Quartz, Na-feldspar (albite) and K-feldspar are the main gangue minerals. They are usually intergrown with each other. At the grind size studied, quartz is not well liberated.

Carbonate (calcite) concentrations were measured at 0.2%. The main fluorine-bearing minerals are cryolite (Na_2AlF_6), fluorite (CaF_2), gearksutite ($CaAl(OH,F)_5 \cdot (H_2O)$)), and ralstonite ($Na_xMg_xAl_{2-x}(F,OH)_6 \cdot (H_2O)$)). Traces of thomsenolite ($NaCaAlF_6 \cdot (H_2O)$ may also be present. Liberated cryolite, up to 450 µm in size, was observed. It also occurs intergrown with silicate gangue. Gearksutite occurs as liberated grains and intergrown with fluorite.

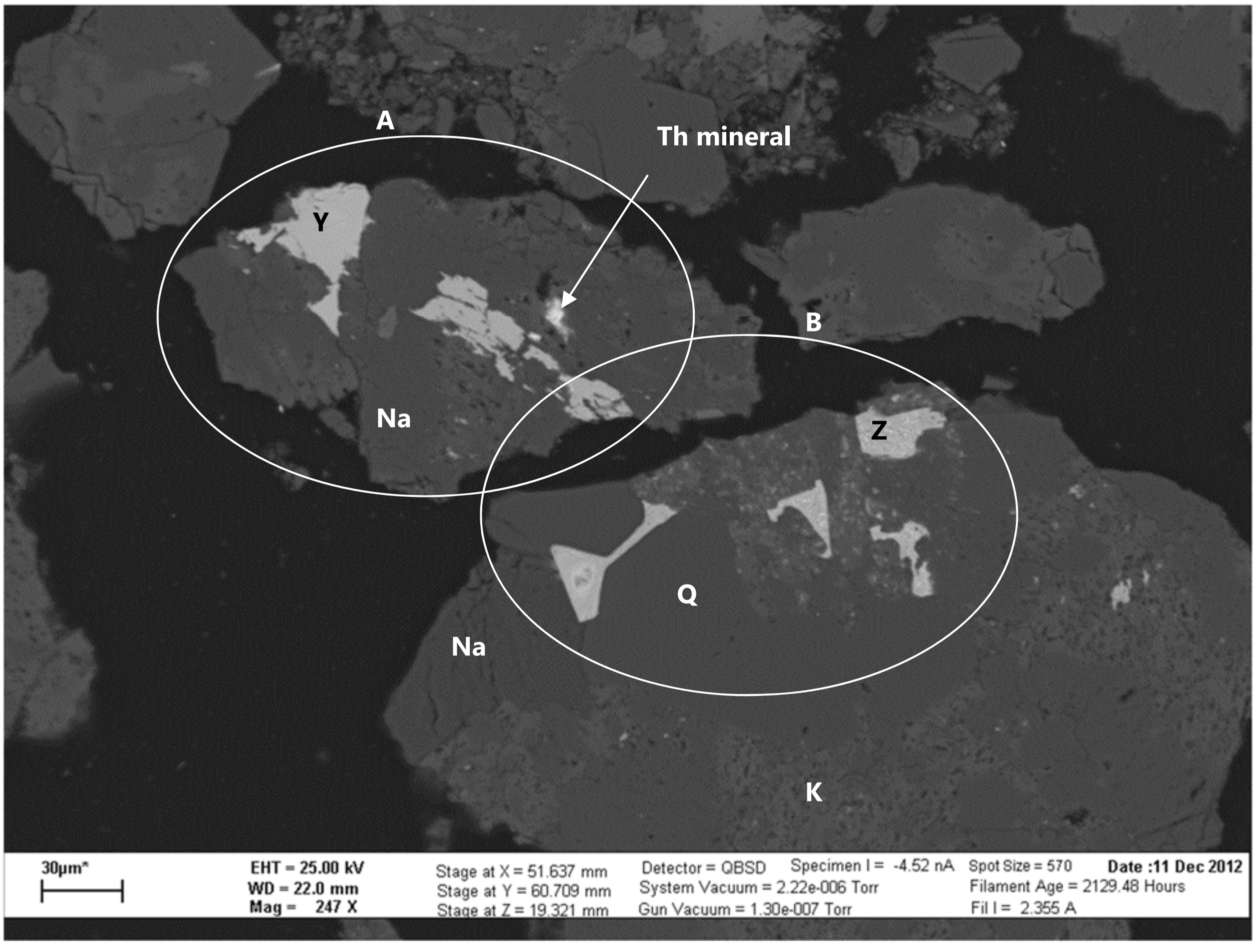


Figure 30-1. Backscattered Electron (BSE) Image of Gangue Particles Containing Yttrofluorite (Y) and Zircon (Z) in Head Sample

The scale bar on the bottom left-hand side is 30 µm. Brighter particles in circle A are mainly yttrofluorite and particles in circle B are mainly zircon. The gangue minerals are mainly albite (Na–feldspar, Na), K–feldspar (K), and quartz (Q). At high magnification, very small inclusions in zircon of a thorium mineral (probably thorite) in circle B are visible. Slightly larger thorite is also observed in circle A. The brighter specks surrounding zircon in circle B are probably small inclusions of iron-rich mica and iron oxide or both.

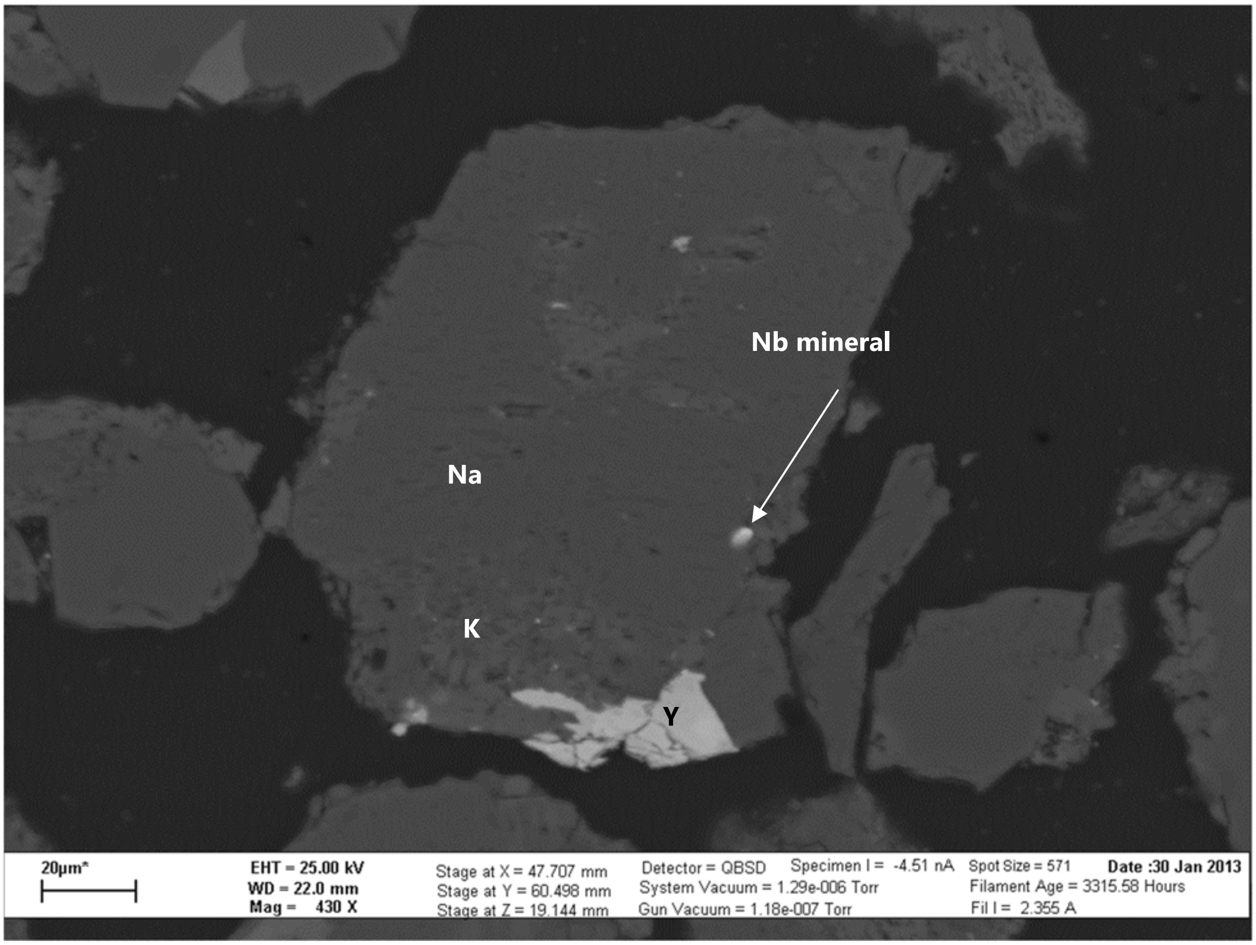


Figure 30-2. BSE Image of Gangue Particle Containing Yttrofluorite (Y) in Head Sample

The scale bar is 20 µm. Yttrofluorite is exposed at the surface of the gangue particle that contains mainly albite (Na) and K–feldspar (K).

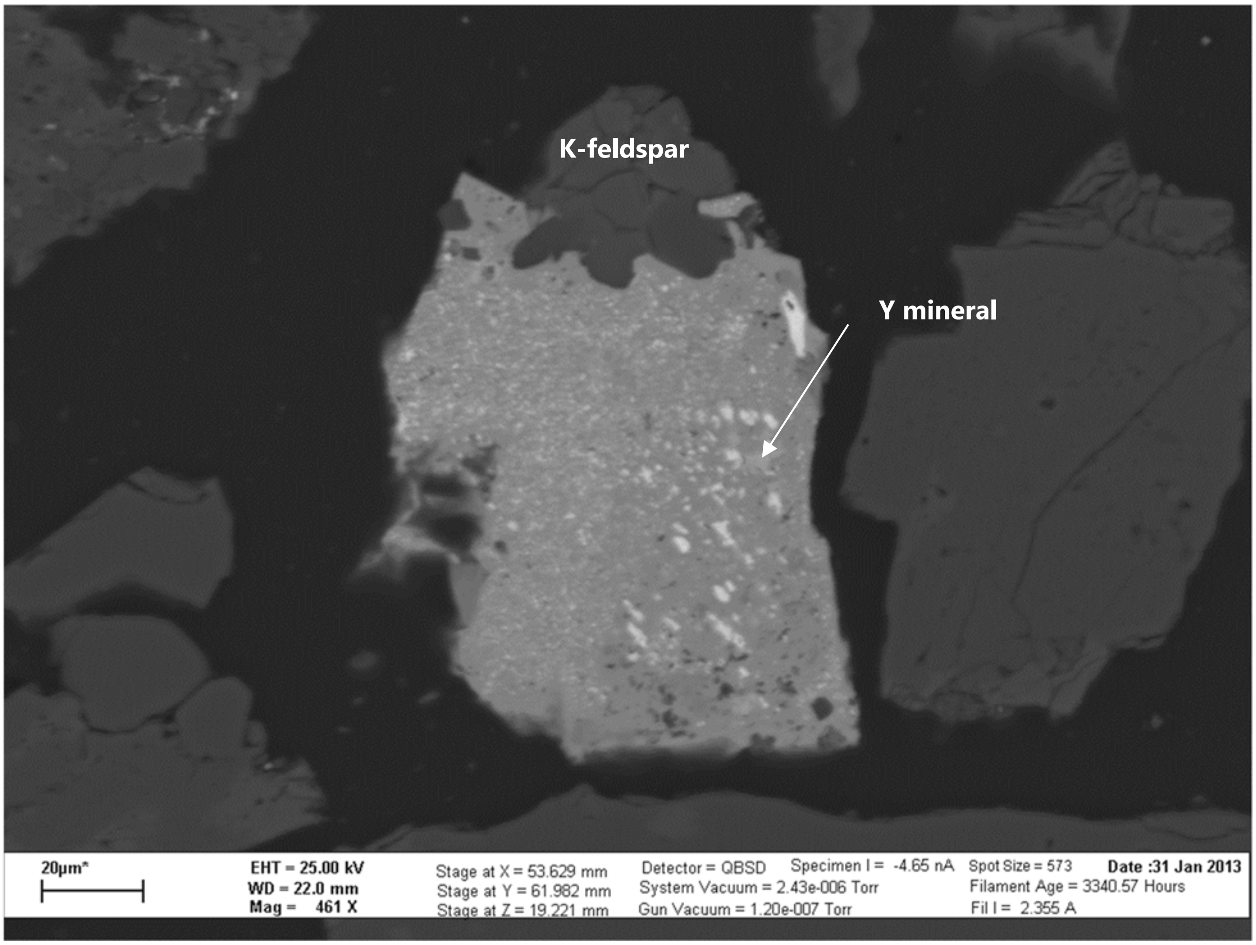


Figure 30-3. BSE Zircon with Thorite Inclusions in Head Sample

The zircon particle contains many fine inclusions of thorite (light gray). Also observed, but not very common, are inclusions of yttrium-rich grains (probably yttrofluorite, slightly brighter than zircon).

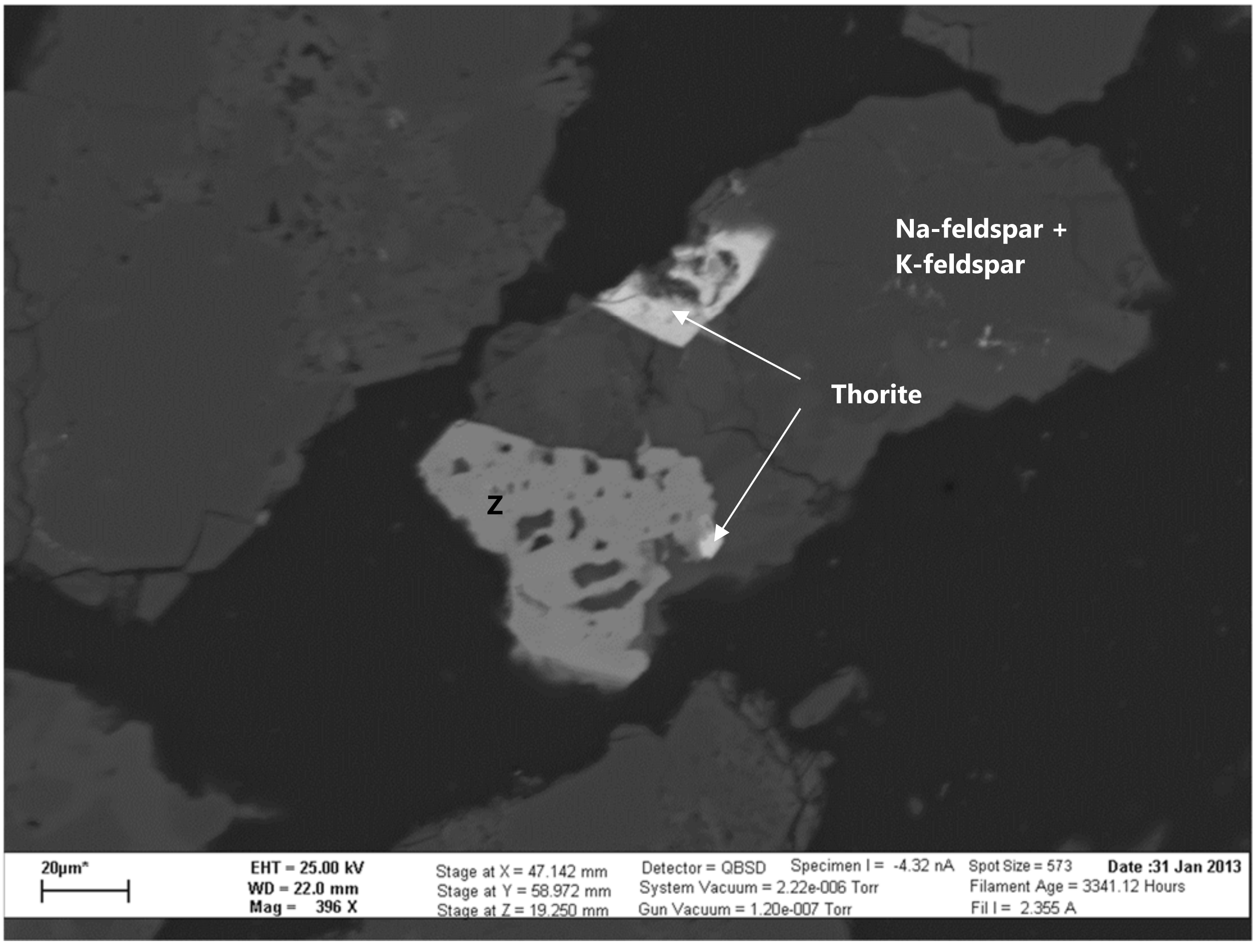


Figure 30-4. BSE Image of Zircon in Head Sample

Thorite is associated with the zircon and intergrown with feldspar.

Rougher Tails

The results of the mineral abundance analysis of the rougher tails are presented in Table 1. The tails represent 88% of the total mass of the feed to the flotation test. The concentrations of mica and chlorite and iron-rich biotite are higher in the tails when compared with the whole ore sample, and zircon and fluoride minerals show lower levels than in the head. The measured concentration of yttrofluorite at 0.04% is slightly lower in the tails than in the head (0.06%). At this low level, it is not possible to evaluate if yttrofluorite floated under the conditions used or if the observed variation is statistical variance. The chemical analyses of the flotation products show that 55% of the total yttrium and fluorine, each, occur in the rougher tails. Therefore, the observed variation of the yttrofluorite concentration in the whole ore sample and rougher tails is probably statistical variance.

Yttrofluorite in the tails was up to 40 µm in size and is generally intergrown with silicate gangue, but often exposed at the surface of the composite gangue particles. Occasionally, yttrofluorite was also observed as liberated grains.

ABWL Residue

Chemical analyses of the feed and residue indicate an yttrium extraction of 94%. The measured levels of yttrofluorite in the residue were 0.003% compared with 0.06% in the leach feed. Residual yttrofluorite occurs locked in silicate gangue and occasionally in zircon. Figure 5 shows an example of residual yttrofluorite in iron-rich biotite.

The measured concentration of zircon in the residue is similar to that of the head sample. Zircon grains exhibit signs of leaching at the edges (Figure 6). This is also supported by the lower zirconium level in the residue (0.08 versus 0.11%) measured by ICP analysis in the head sample. The residual layer at the edge of zircon contains mainly silica and some sulfur. Layers with a similar chemical composition were also observed at the edges of iron-rich biotite (Figure 7). When observed at the edge of biotite, this layer also contains potassium. Although the measured concentration of iron oxide in the residue is less than the concentration in the whole ore (0.4 versus 0.9%), the remaining iron oxide showed no obvious evidence of leaching. These observations are considered evidence that the iron in the leach liquor may originate mainly from some leaching of biotite.

A phase with a similar composition (silicon–sulfur) was also observed between clusters of particles (Figure 8). It is believed that some of the silicon–sulfur–potassium phase, observed next to biotite, may also be a gel-like, silica-rich precipitate. The total measured concentration of the silicon–sulfur phase, which may also contain potassium, was 0.4%. To shed more light on whether this phase is a residual layer or a precipitate, or both, would require more work.

An aluminum sulfate precipitate (probably alunogen ($Al_2(SO_4)_3 \cdot 17(H_2O)$)) was also observed (0.01%).

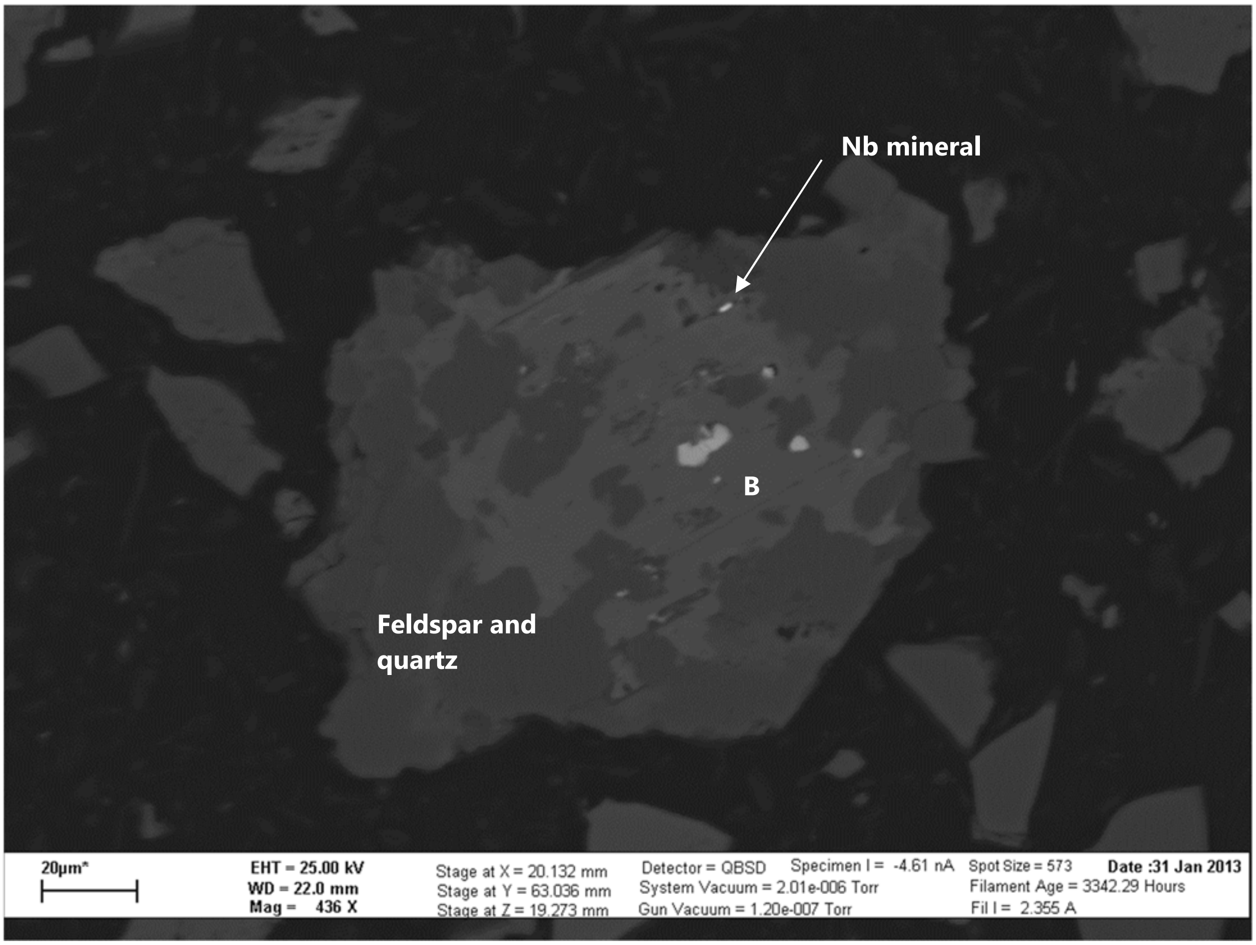


Figure 30-5. BSE Image of Yttrofluorite (light inclusions) in Iron-Rich Biotite (B) in ABWL Residue

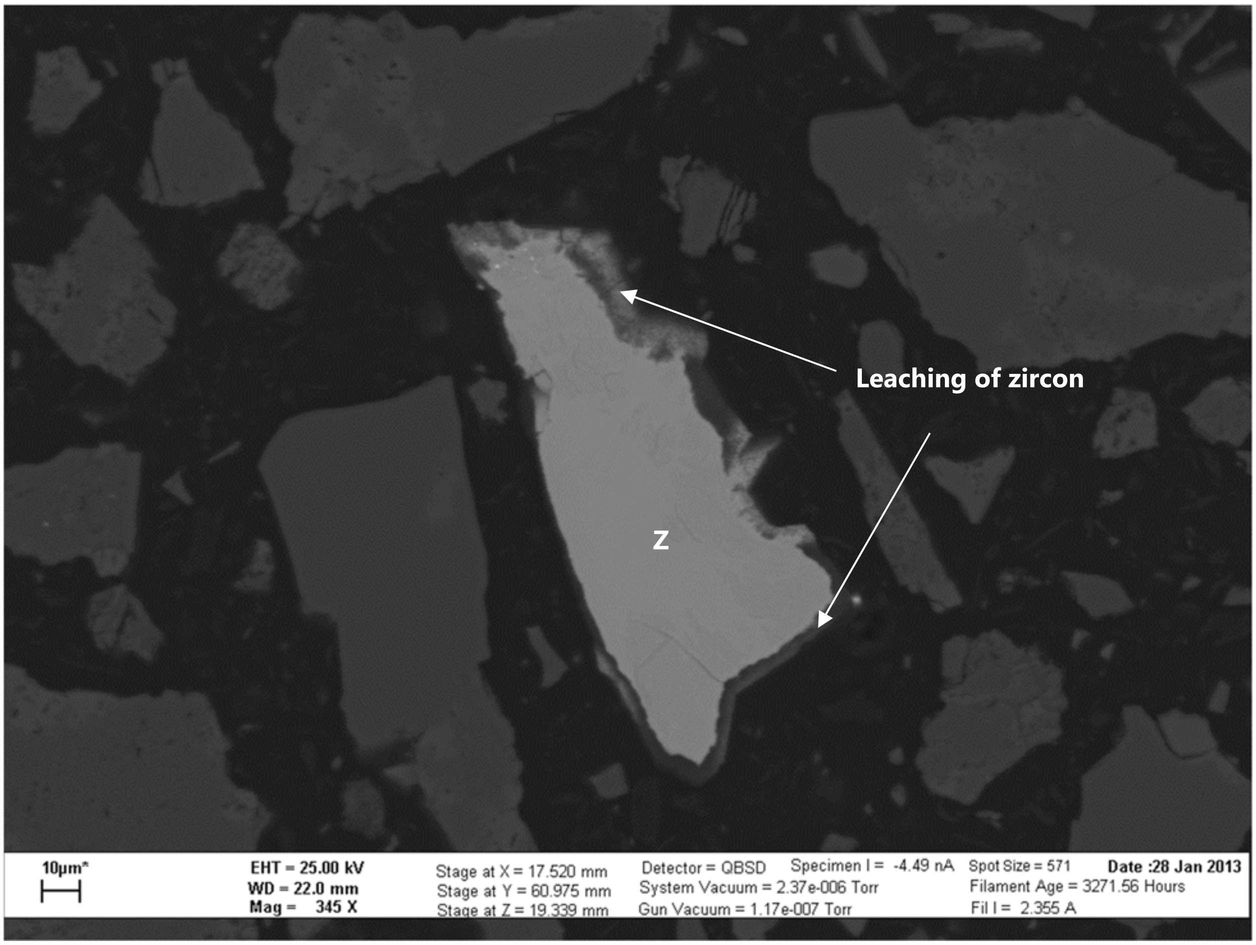


Figure 30-6. BSE Image of Zircon (Z) with Apparent Leaching at the Edges in ABWL Residue

The length of the scale bar is 10 µm. This zircon grain shows evidence of leaching at the edges. The leached rim is about 5 µm thick and chemically consists of silicon oxide and some sulfur.

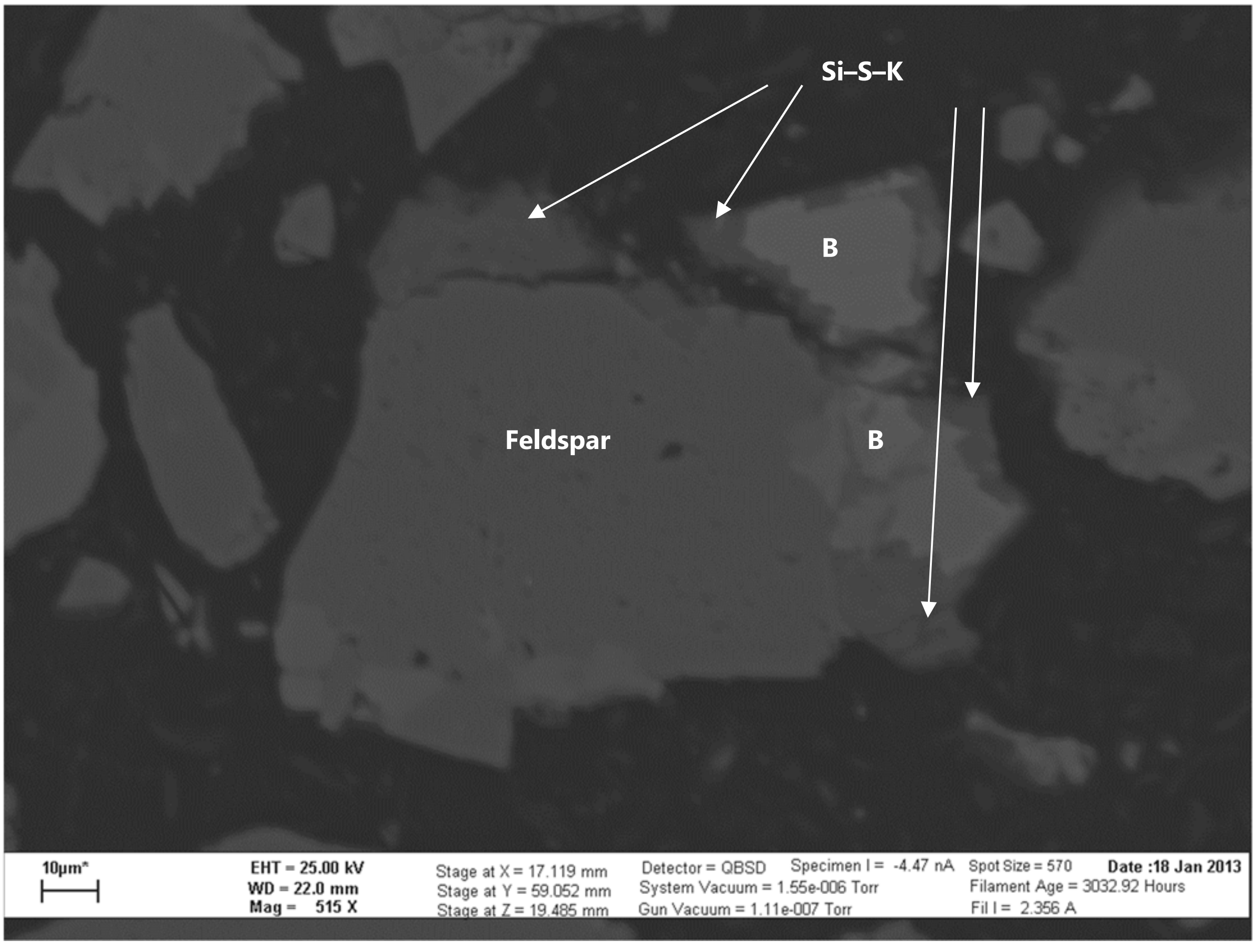


Figure 30-7. BSE Image Showing Evidence of Leaching around Iron-Rich Biotite (B) in ABWL Residue

The areas at the edge of the biotite where leaching is evident are marked with arrows. The phase is silicon-rich and also contains sulfur and potassium (Si–S–K).

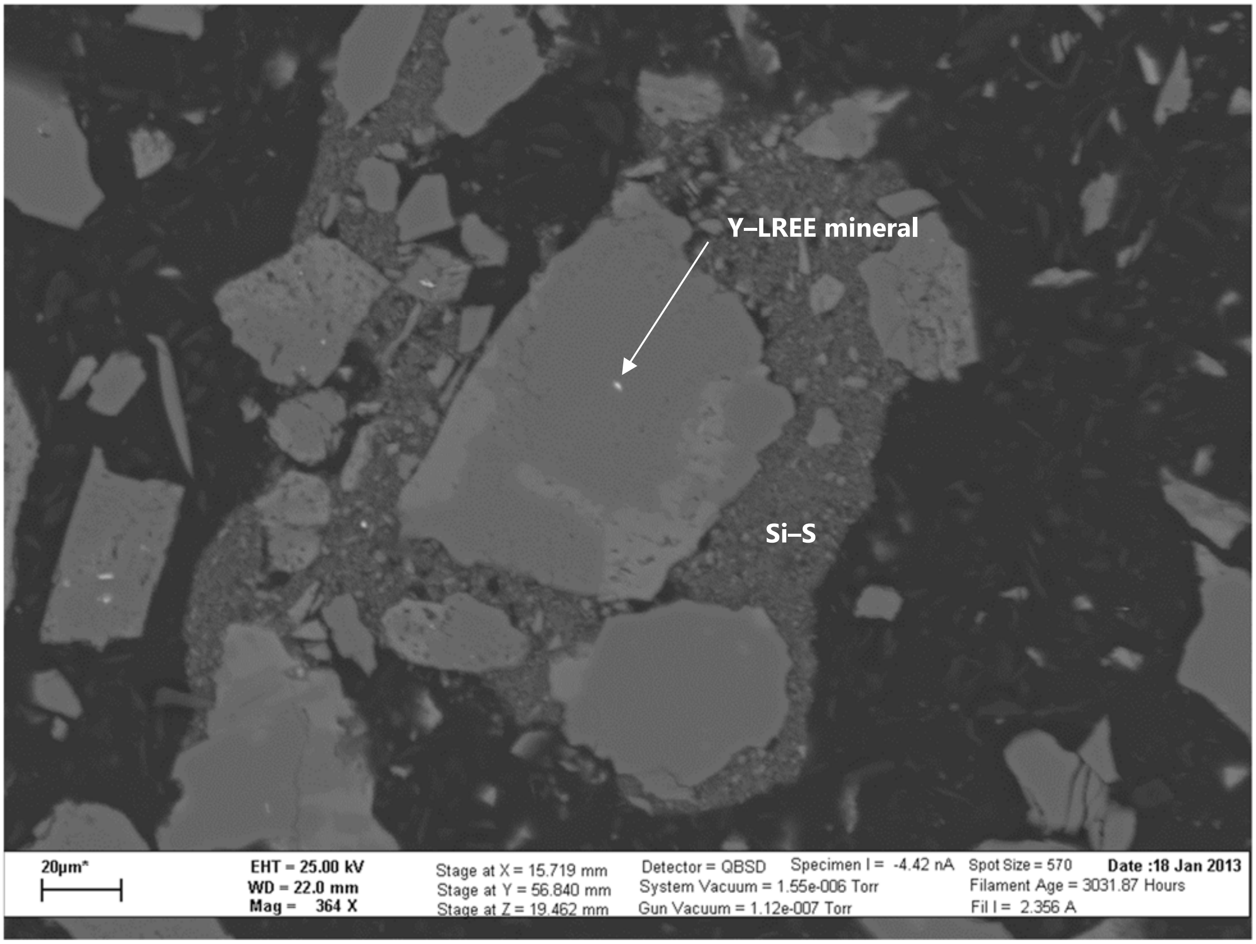
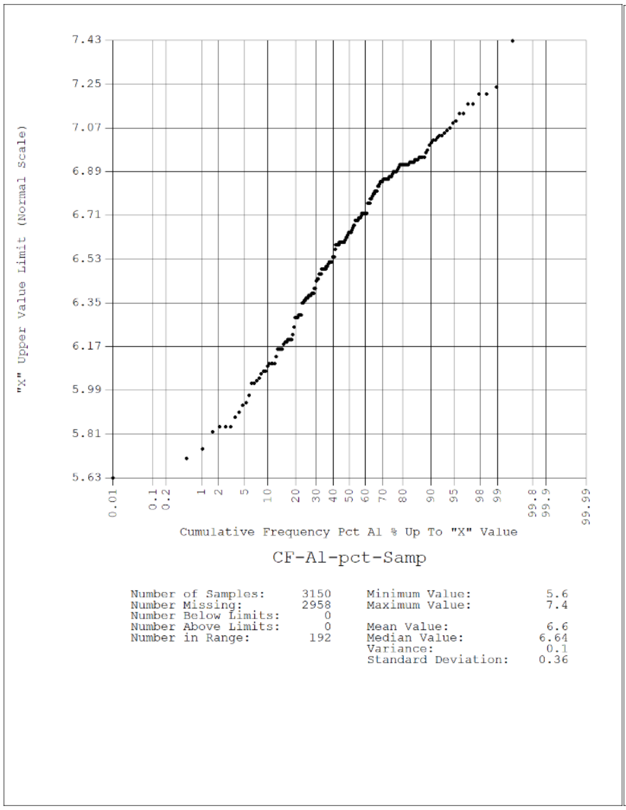
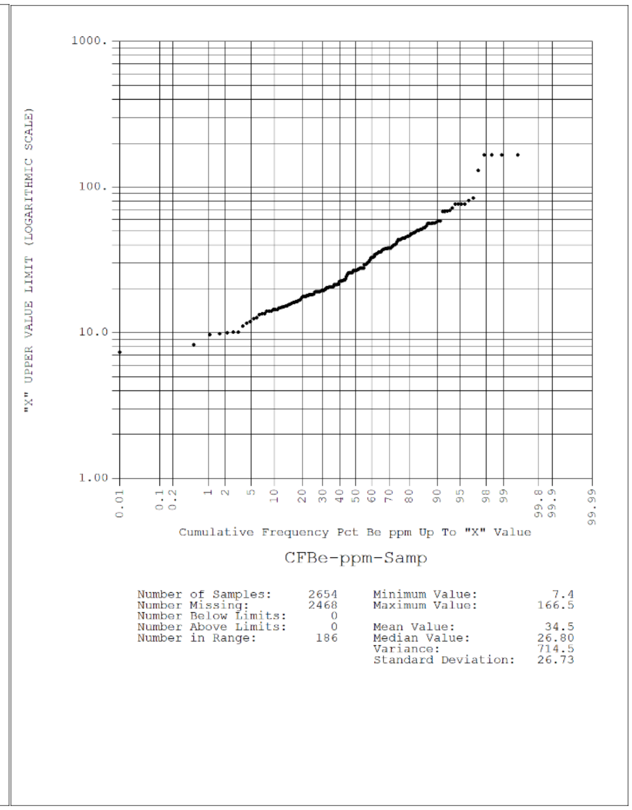


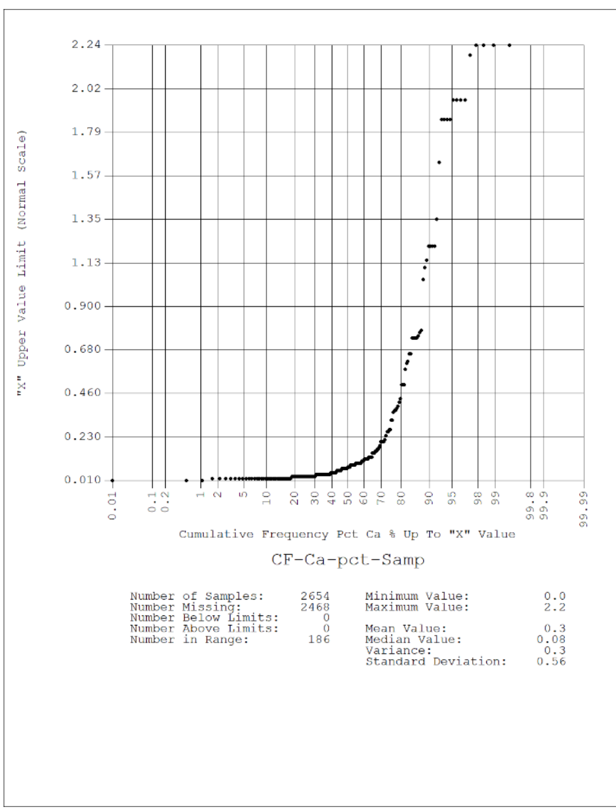
Figure 30-8. BSE Image of Gangue Particles that Appear to be Cemented by a Si–S Phase in ABWL Residue

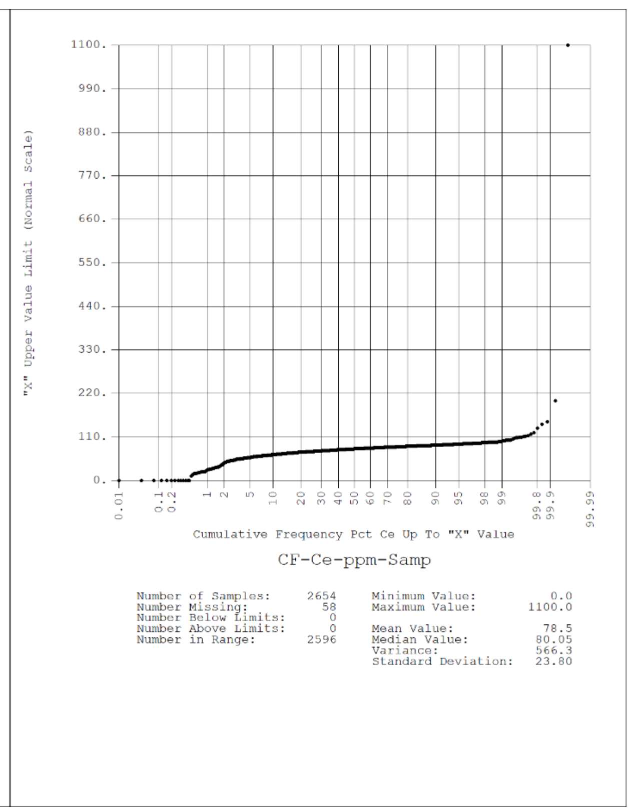
A Si–S phase appears to cement larger gangue particles and also encloses very fine-grained particles. The silica-rich phase appears to be a precipitate rather than a residual phase after removal of ions.

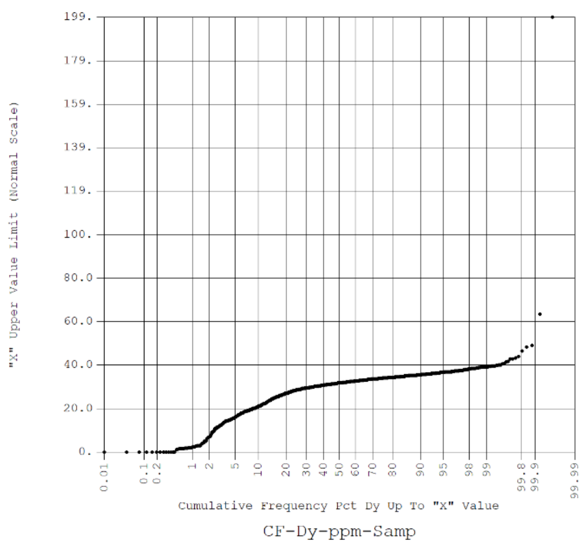
31 APPENDIX C: SAMPLE CUMULATIVE FREQUENCY PLOTS



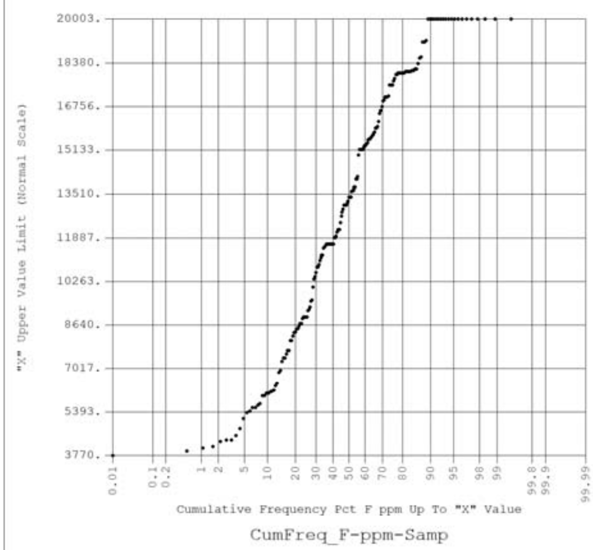




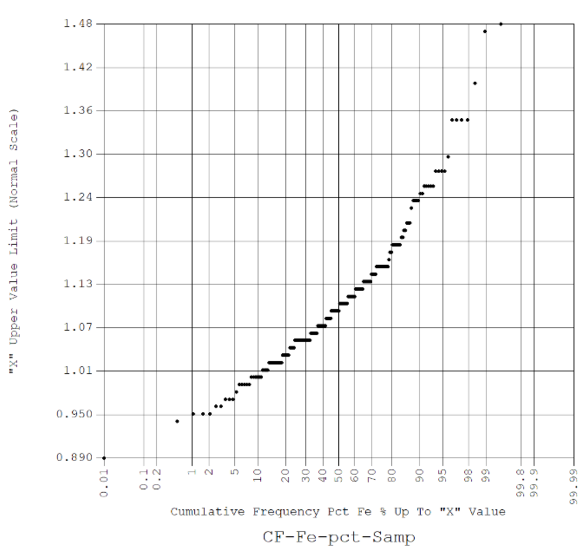




Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	58	Maximum Value:	199.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	29.9
Number in Range:	2596	Median Value:	31.70
		Variance:	56.2
		Standard Deviation:	7.49



Number of Samples:	2654	Minimum Value:	3770.0
Number Missing:	2468	Maximum Value:	20001.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	13121.3
Number in Range:	186	Median Value:	13325.00
		Variance:	22989204.0
		Standard Deviation:	4794.71



Number of Samples:	3150	Minimum Value:	0.9
Number Missing:	2958	Maximum Value:	1.5
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	1.1
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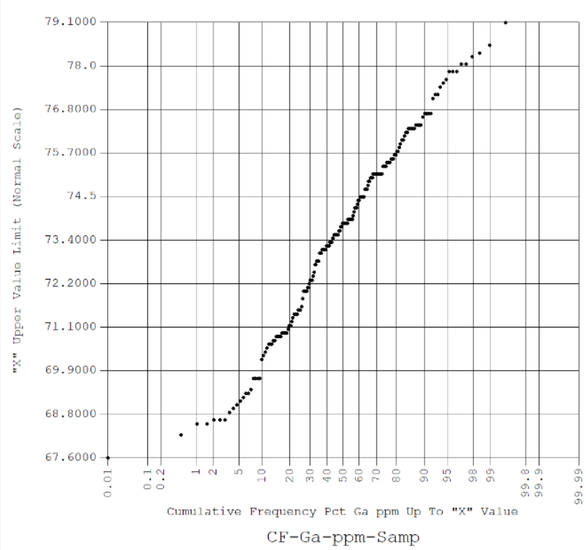
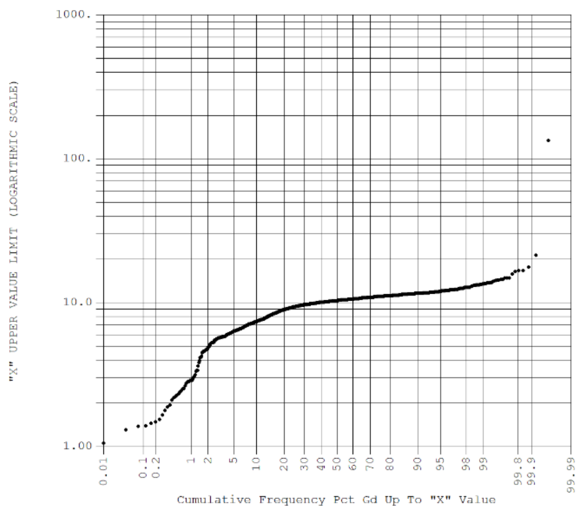
		Variance:	0.0
		Standard Deviation:	0.10

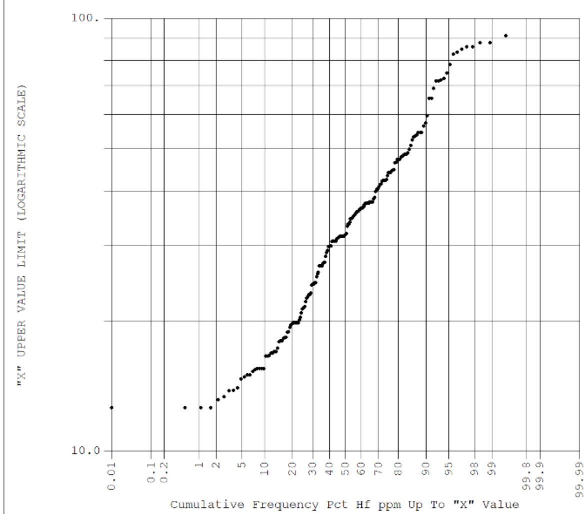


Number of Samples:	3150	Minimum Value:	67.6
Number Missing:	2958	Maximum Value:	79.1
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	73.5
Number in Range:	192	Median Value:	73.80
		Variance:	6.3
		Standard Deviation:	2.50



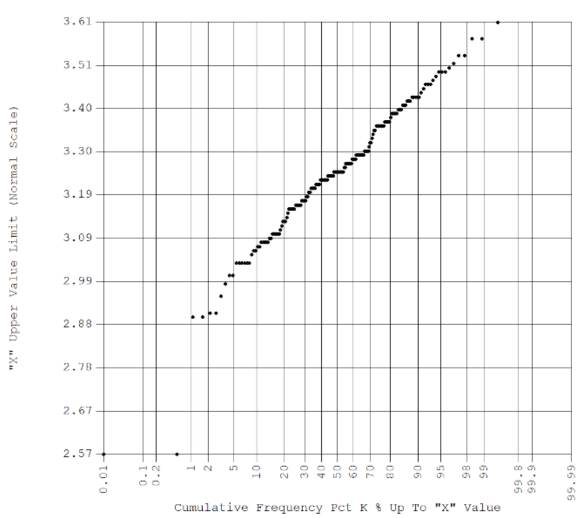
CF-Gd-ppm-Samp

Number of Samples:	2654	Minimum Value:	1.1
Number Missing:	58	Maximum Value:	134.0
Number Below Limits:	13		
Number Above Limits:	0	Mean Value:	10.0
Number in Range:	2583	Median Value:	10.35
		Variance:	9.4
		Standard Deviation:	3.07



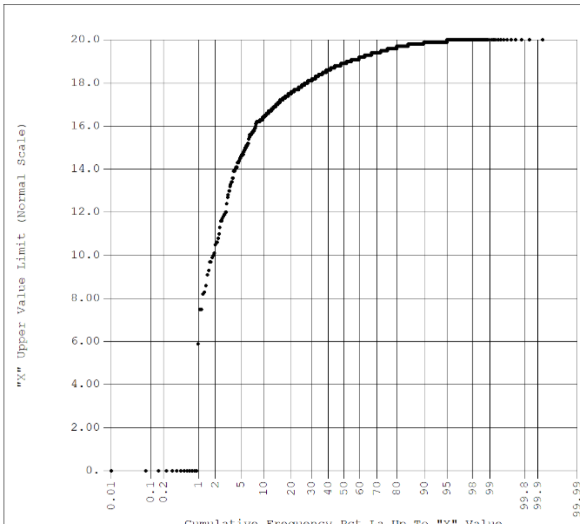
CF-Hf-ppm-Samp

Number of Samples:	2654	Minimum Value:	12.6
Number Missing:	2468	Maximum Value:	91.3
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	35.5
Number in Range:	186	Median Value:	31.60
		Variance:	320.9
		Standard Deviation:	17.91



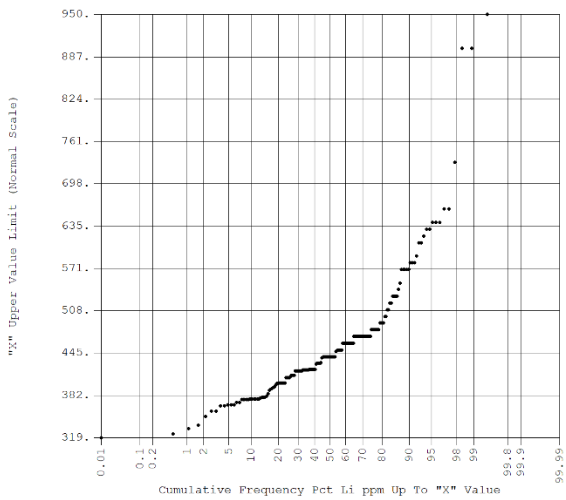
CF-K-pct-Samp

Number of Samples:	2654	Minimum Value:	2.6
Number Missing:	2468	Maximum Value:	3.6
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	3.2
Number in Range:	186	Median Value:	3.25
		Variance:	0.0
		Standard Deviation:	0.16



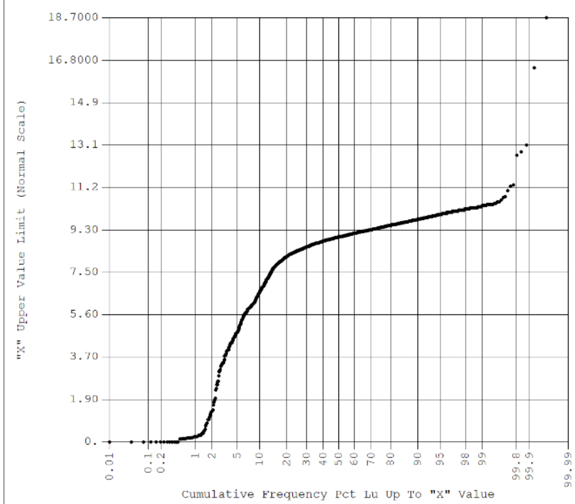
CF-La-ppm-Samp

Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	58	Maximum Value:	20.0
Number Below Limits:	0		
Number Above Limits:	1291	Mean Value:	18.2
Number in Range:	1305	Median Value:	18.90
		Variance:	6.5
		Standard Deviation:	2.56



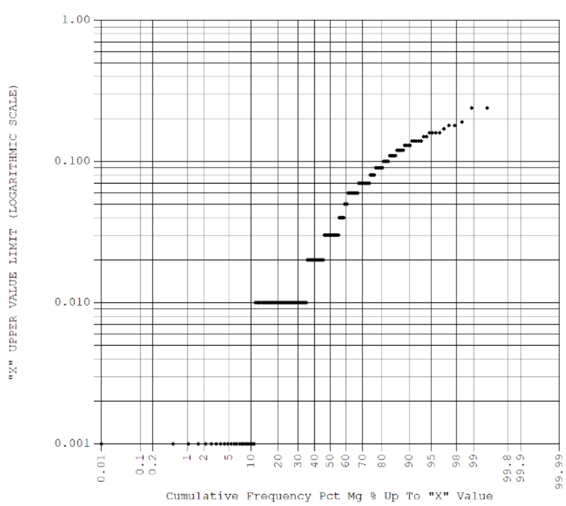
CF-Li-ppm-Samp

Number of Samples:	2654	Minimum Value:	319.0
Number Missing:	2468	Maximum Value:	950.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	459.8
Number in Range:	186	Median Value:	440.00
		Variance:	8537.5
		Standard Deviation:	92.40



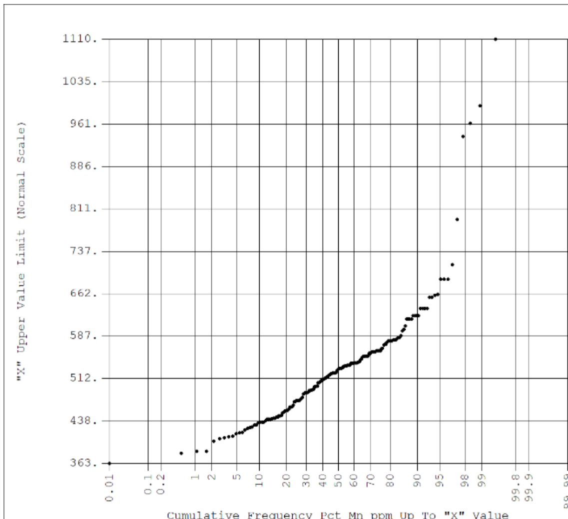
CF-Lu-ppm-Samp

Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	58	Maximum Value:	18.6
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	8.5
Number in Range:	2596	Median Value:	9.01
		Variance:	3.2
		Standard Deviation:	1.78



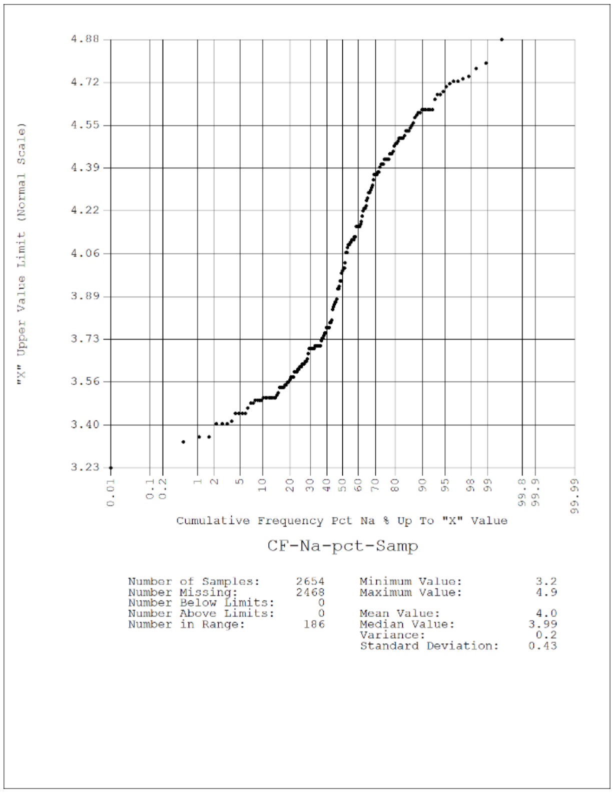
CF-Mg-pct-Samp

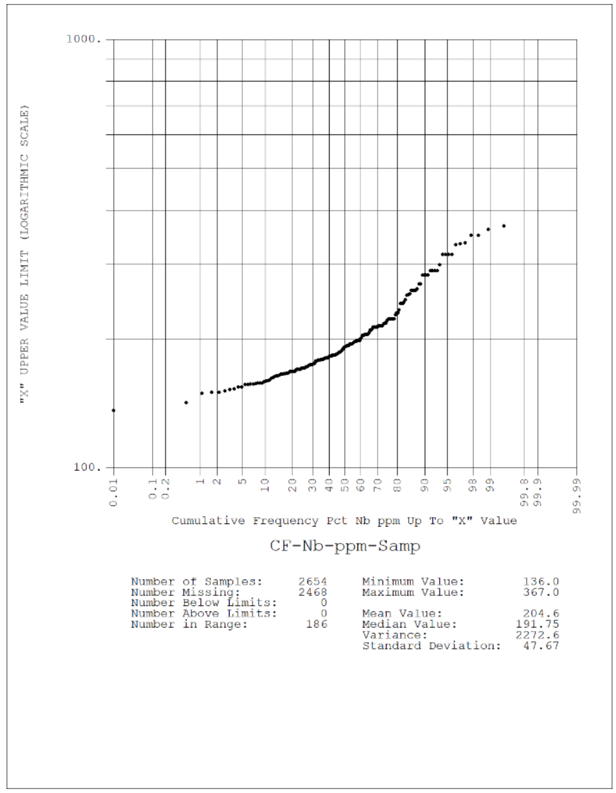
Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	2468	Maximum Value:	0.2
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	0.1
Number in Range:	186	Median Value:	0.03
		Variance:	0.0
		Standard Deviation:	0.05

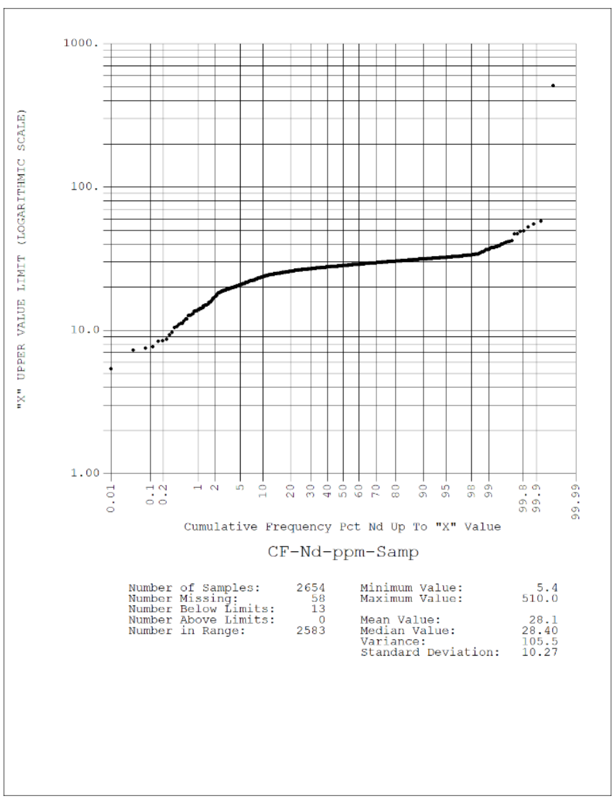


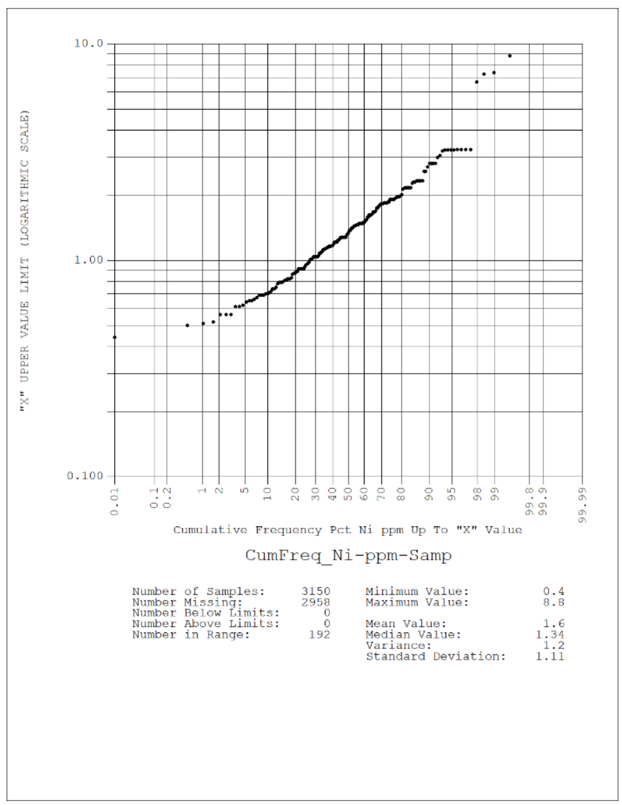
CF-Mn-ppm-Samp

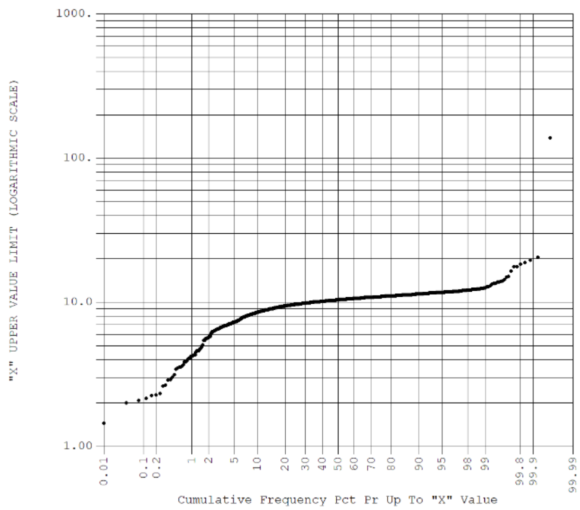
Number of Samples:	2654	Minimum Value:	363.0
Number Missing:	2468	Maximum Value:	1110.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	532.5
Number in Range:	186	Median Value:	528.00
		Variance:	9894.7
		Standard Deviation:	99.47


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Na % Up To "X" Value
CF-Na-pct-Samp
Number of Samples: 2654
Number Missing: 2468
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 186
Minimum Value: 3.2
Maximum Value: 4.9
Mean Value: 4.0
Median Value: 3.99
Variance: 0.2
Standard Deviation: 0.43


"X" UPPER VALUE LIMIT (LOGARITHMIC SCALE)
Cumulative Frequency Pct Nb ppm Up To "X" Value
CF-Nb-ppm-Samp
Number of Samples: 2654
Number Missing: 2468
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 186
Minimum Value: 136.0
Maximum Value: 367.0
Mean Value: 204.6
Median Value: 191.75
Variance: 2272.6
Standard Deviation: 47.67

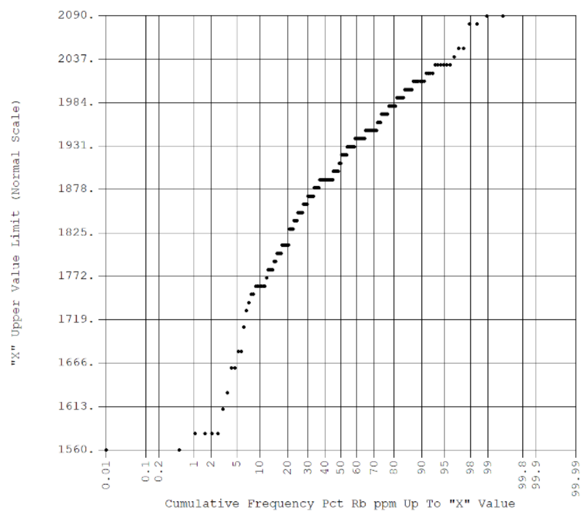

"X" UPPER VALUE LIMIT (LOGARITHMIC SCALE)
Cumulative Frequency Pct Nd Up To "X" Value
CF-Nd-ppm-Samp
Number of Samples: 2654
Number Missing: 58
Number Below Limits: 13
Number Above Limits: 0
Number in Range: 2583
Minimum Value: 5.4
Maximum Value: 510.0
Mean Value: 28.1
Median Value: 28.40
Variance: 105.5
Standard Deviation: 10.27


"X" UPPER VALUE LIMIT (LOGARITHMIC SCALE)
Cumulative Frequency Pct Ni ppm Up To "X" Value
CumFreq_Ni-ppm-Samp
Number of Samples: 3150
Number Missing: 2958
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 192
Minimum Value: 0.4
Maximum Value: 8.8
Mean Value: 1.6
Median Value: 1.34
Variance: 1.2
Standard Deviation: 1.11



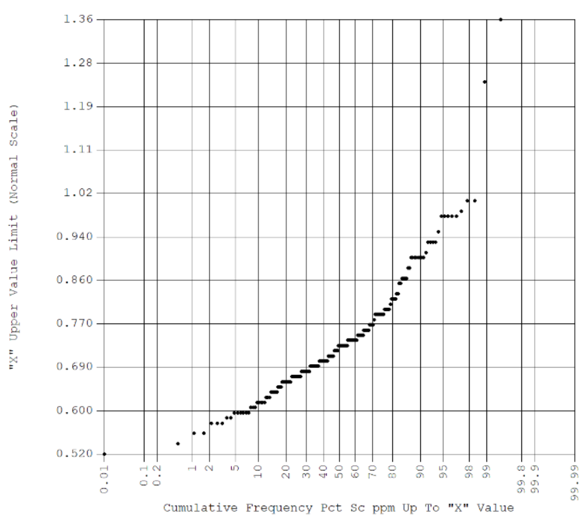
CF-Pr-ppm-Samp

Number of Samples:	2654	Minimum Value:	1.5
Number Missing:	58	Maximum Value:	138.0
Number Below Limits:	13		
Number Above Limits:	0	Mean Value:	10.2
Number in Range:	2583	Median Value:	10.40
		Variance:	8.6
		Standard Deviation:	2.93



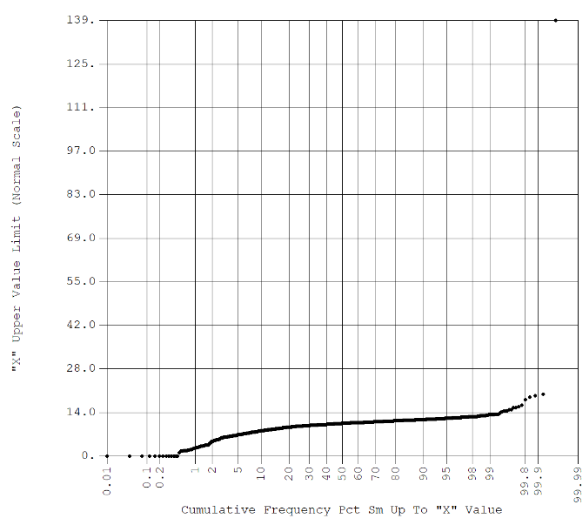
CumFreq_Rb-ppm-Samp

Number of Samples:	3150	Minimum Value:	1560.0
Number Missing:	2958	Maximum Value:	2090.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	1894.2
Number in Range:	192	Median Value:	1910.00
		Variance:	11617.1
		Standard Deviation:	107.78



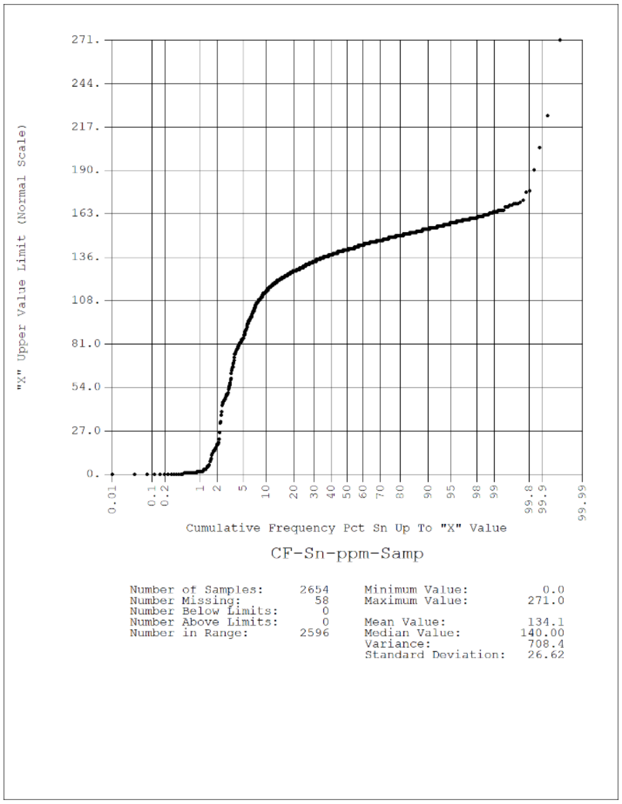
CF-Sc-ppm-Samp

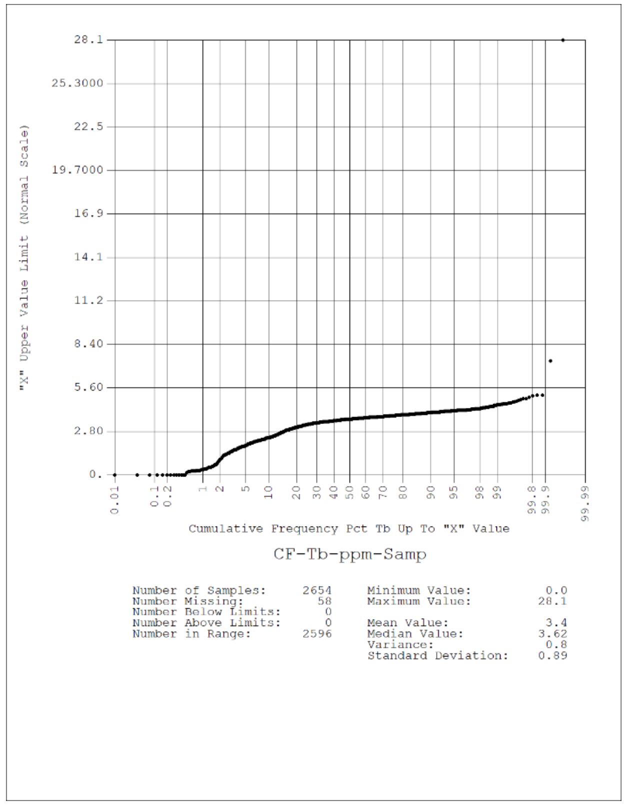
Number of Samples:	2654	Minimum Value:	0.5
Number Missing:	2468	Maximum Value:	1.4
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	0.7
Number in Range:	186	Median Value:	0.73
		Variance:	0.0
		Standard Deviation:	0.12

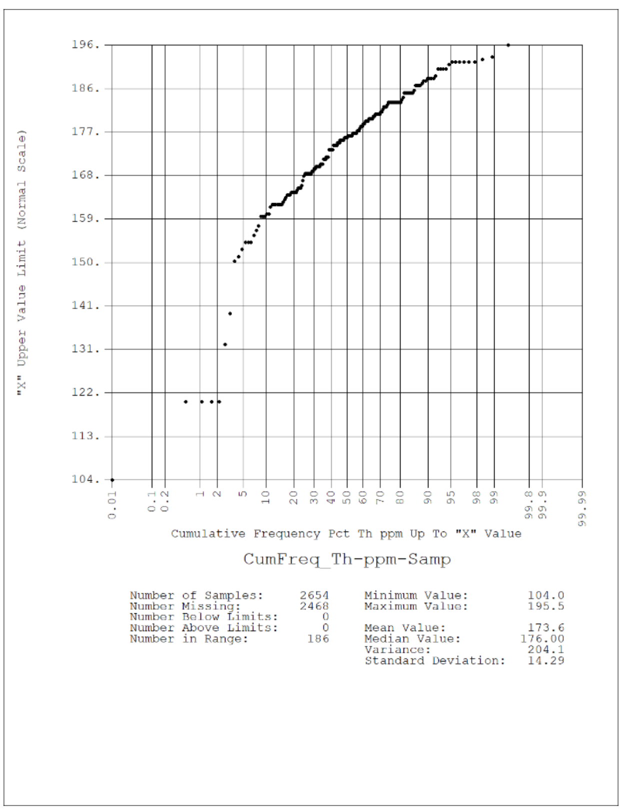


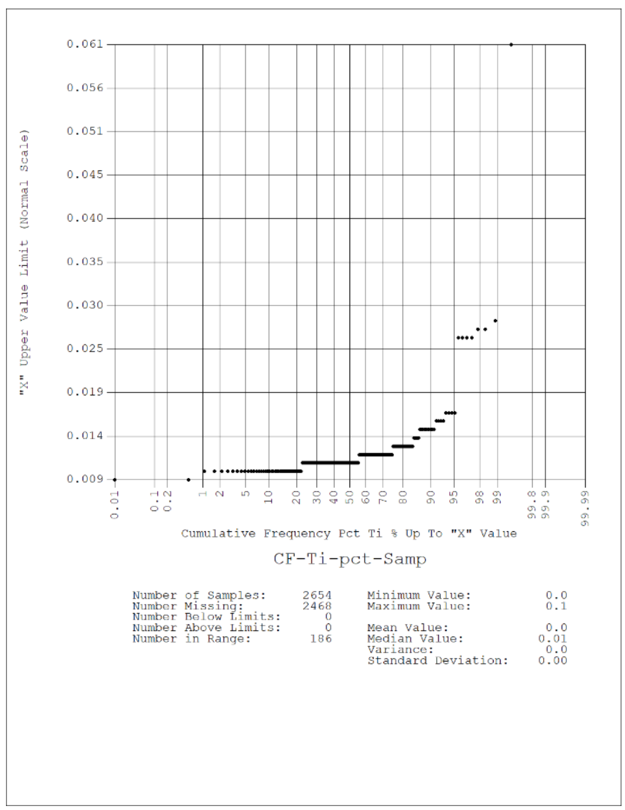
CF-Sm-ppm-Samp

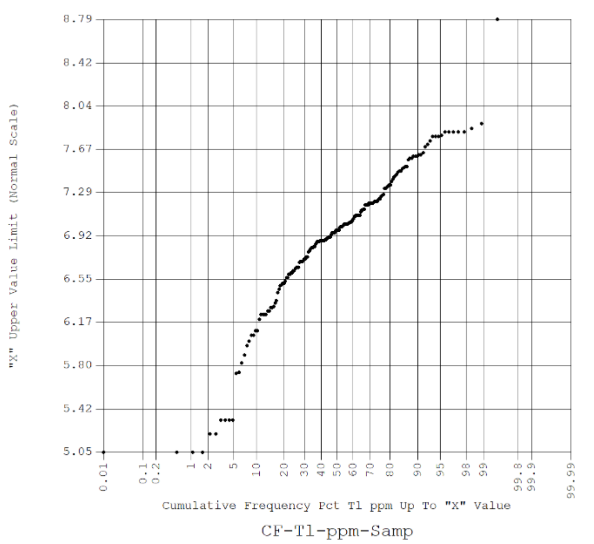
Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	58	Maximum Value:	138.5
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	10.1
Number in Range:	2596	Median Value:	10.40
		Variance:	9.7
		Standard Deviation:	3.12


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Sn Up To "X" Value
CF-Sn-ppm-Samp
Number of Samples: 2654
Number Missing: 58
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 2596
Minimum Value: 0.0
Maximum Value: 271.0
Mean Value: 134.1
Median Value: 140.00
Variance: 708.4
Standard Deviation: 26.62

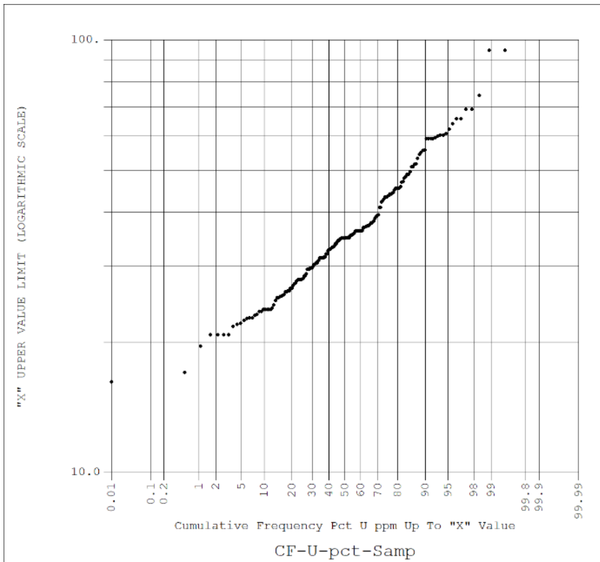

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Tb Up To "X" Value
CF-Tb-ppm-Samp
Number of Samples: 2654
Number Missing: 58
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 2596
Minimum Value: 0.0
Maximum Value: 28.1
Mean Value: 3.4
Median Value: 3.62
Variance: 0.8
Standard Deviation: 0.89


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Th ppm Up To "X" Value
CumFreq_Th-ppm-Samp
Number of Samples: 2654
Number Missing: 2468
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 186
Minimum Value: 104.0
Maximum Value: 195.5
Mean Value: 173.6
Median Value: 176.00
Variance: 204.1
Standard Deviation: 14.29

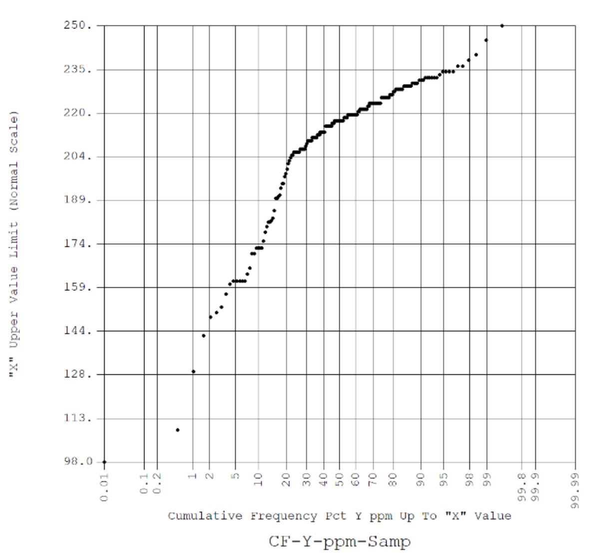

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Ti % Up To "X" Value
CF-Ti-pct-Samp
Number of Samples: 2654
Number Missing: 2468
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 186
Minimum Value: 0.0
Maximum Value: 0.1
Mean Value: 0.0
Median Value: 0.01
Variance: 0.0
Standard Deviation: 0.00



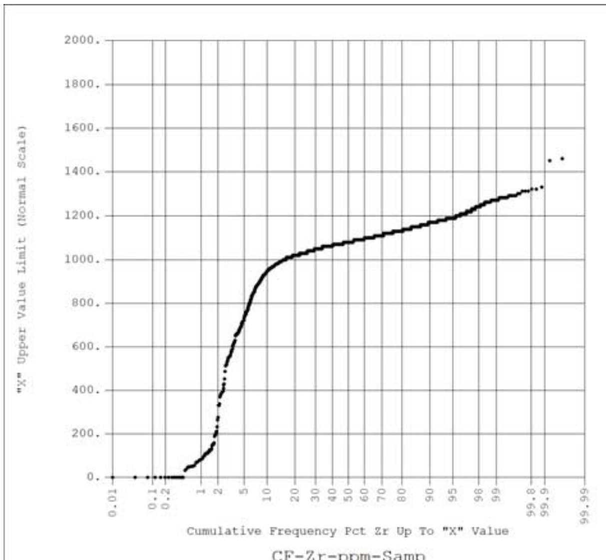
Number of Samples:	2654	Minimum Value:	5.1
Number Missing:	2468	Maximum Value:	8.8
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	6.9
Number in Range:	186	Median Value:	6.97
		Variance:	0.4
		Standard Deviation:	0.63



Number of Samples:	2654	Minimum Value:	16.2
Number Missing:	2468	Maximum Value:	94.7
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	37.2
Number in Range:	186	Median Value:	34.80
		Variance:	170.5
		Standard Deviation:	13.06

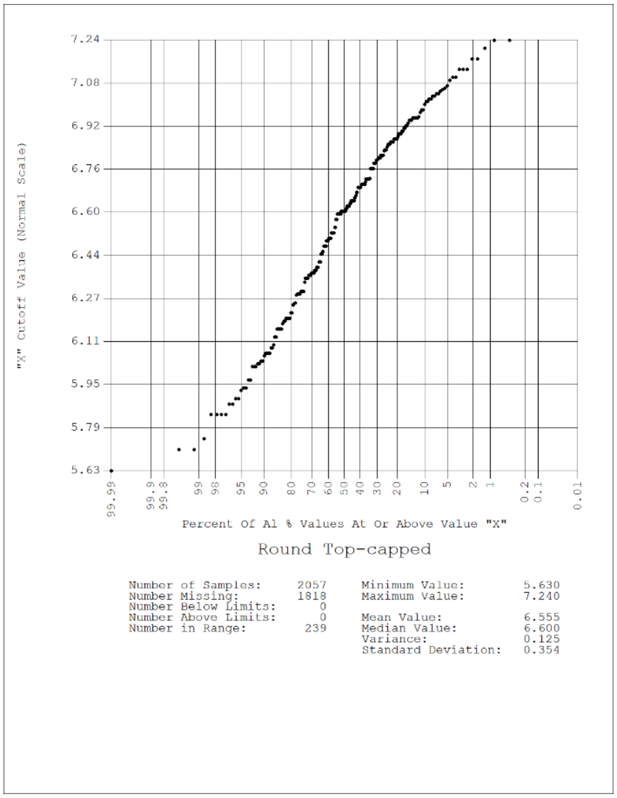


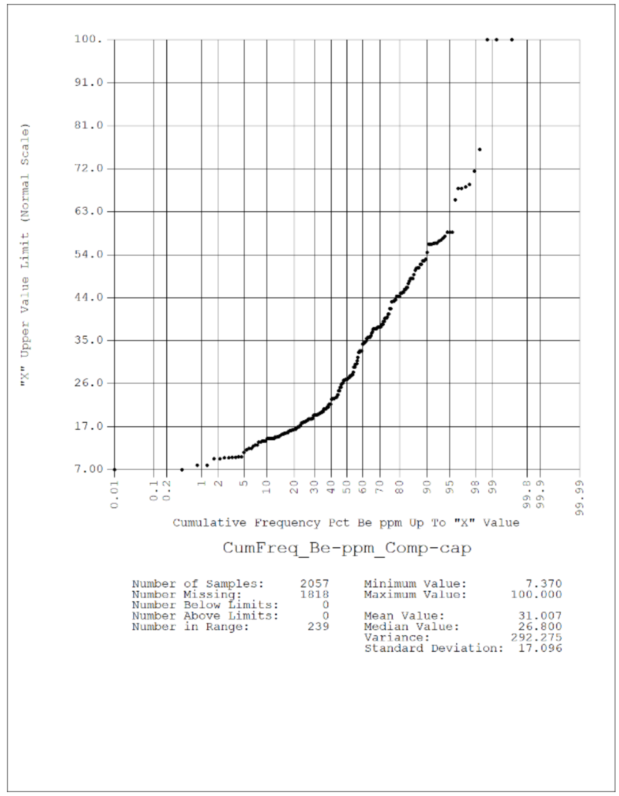
Number of Samples:	3150	Minimum Value:	97.9
Number Missing:	2958	Maximum Value:	250.0
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	209.7
Number in Range:	192	Median Value:	217.00
		Variance:	588.2
		Standard Deviation:	24.25

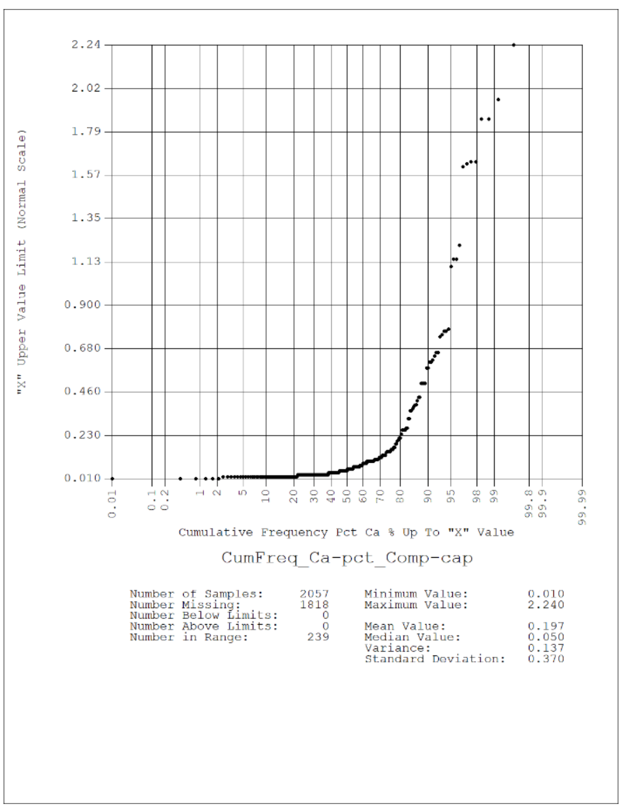


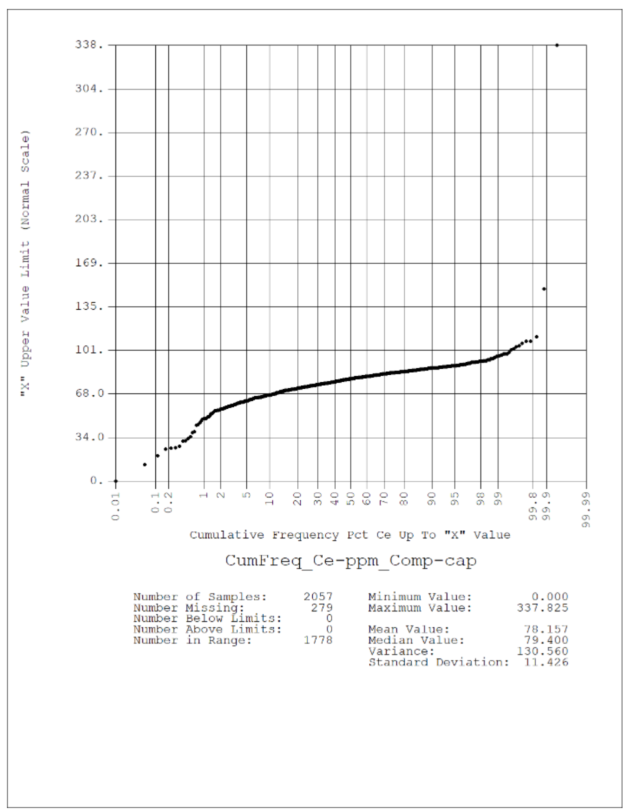
Number of Samples:	2654	Minimum Value:	0.0
Number Missing:	58	Maximum Value:	1460.0
Number Below Limits:	0		
Number Above Limits:	2	Mean Value:	1045.1
Number in Range:	2594	Median Value:	1080.00
		Variance:	32750.7
		Standard Deviation:	180.97

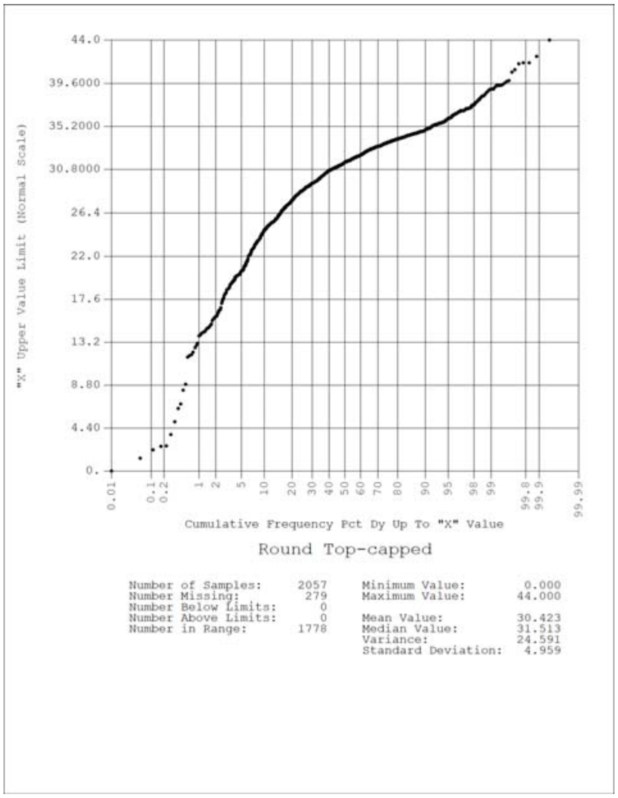
32 APPENDIX D: CAP-COMPOSITE CUM. FREQUENCY PLOTS

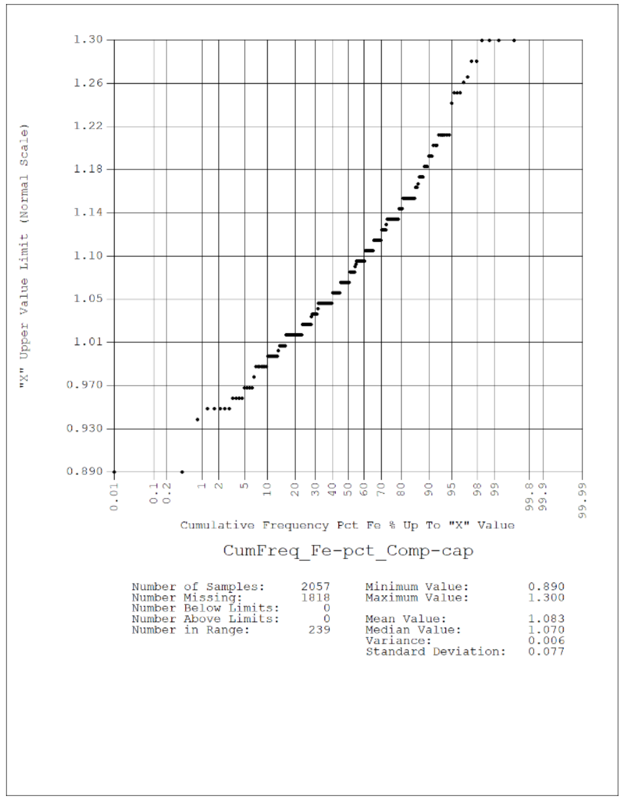


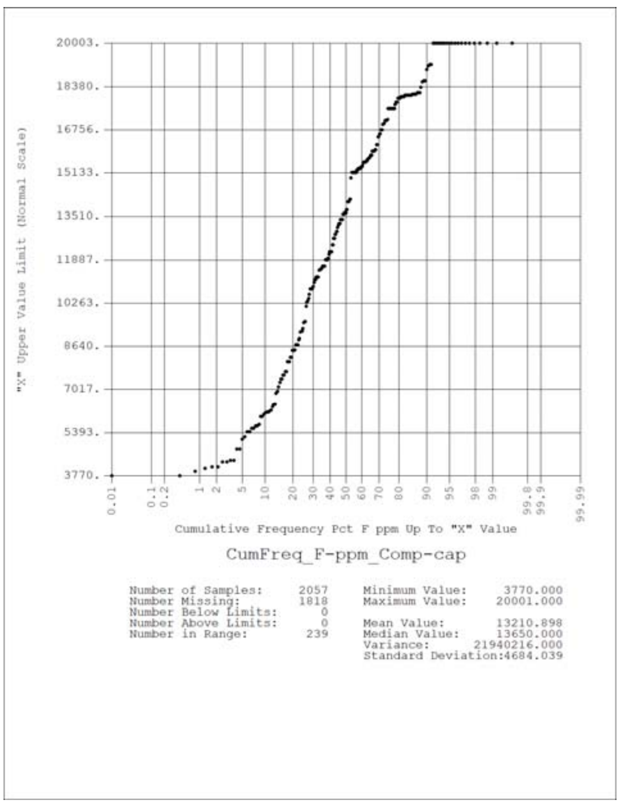


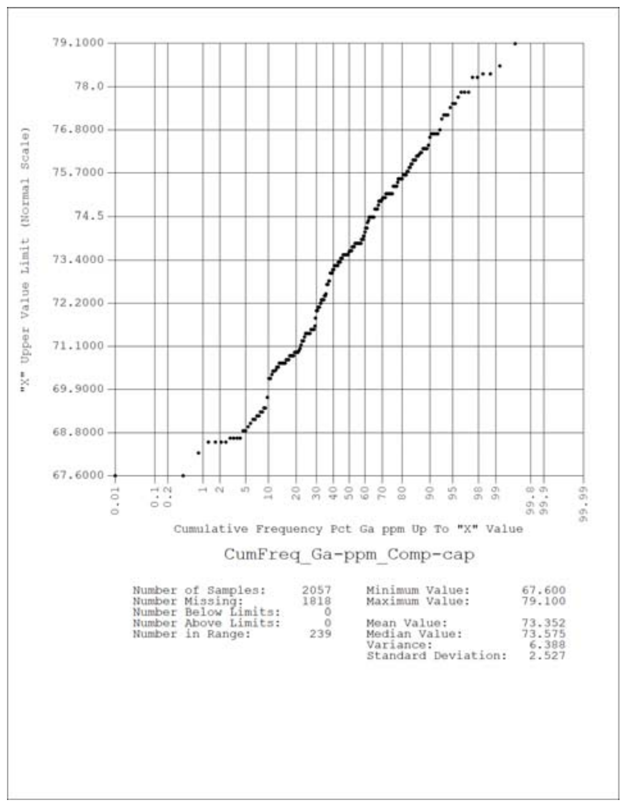












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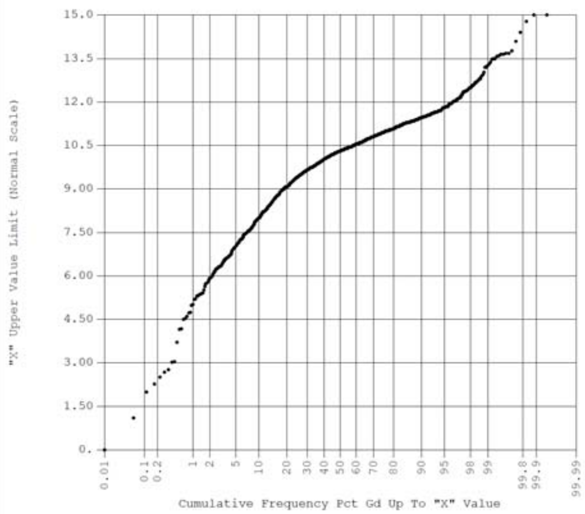
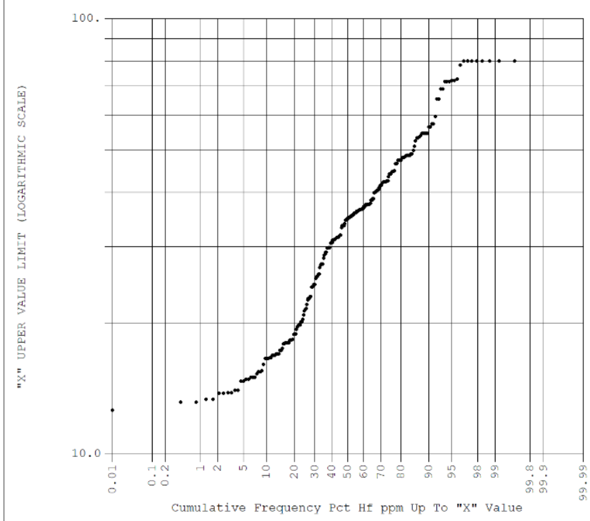


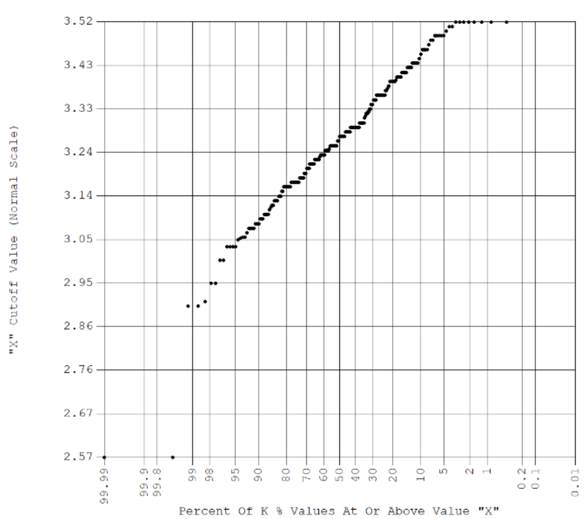
CumFreq_Gd-ppm_Comp-cap

Number of Samples:	2057	Minimum Value:	0.000
Number Missing:	279	Maximum Value:	15.000
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	10.005
Number in Range:	1778	Median Value:	10.311
		Variance:	2.396
		Standard Deviation:	1.548



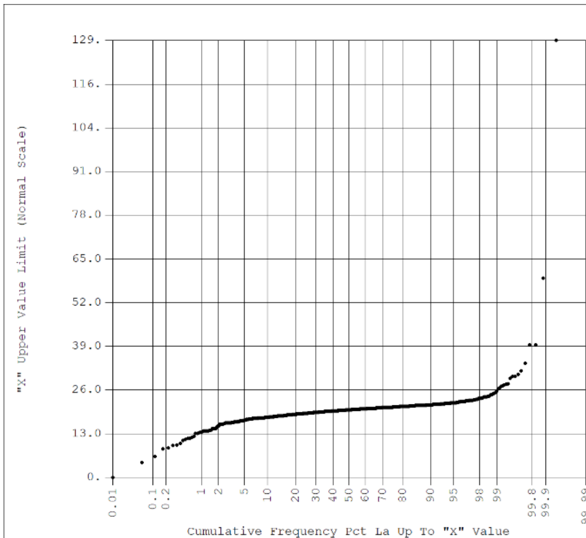
Round Top-capped

Number of Samples:	2057	Minimum Value:	12.600
Number Missing:	1818	Maximum Value:	80.000
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	35.406
Number in Range:	239	Median Value:	34.600
		Variance:	273.219
		Standard Deviation:	16.529



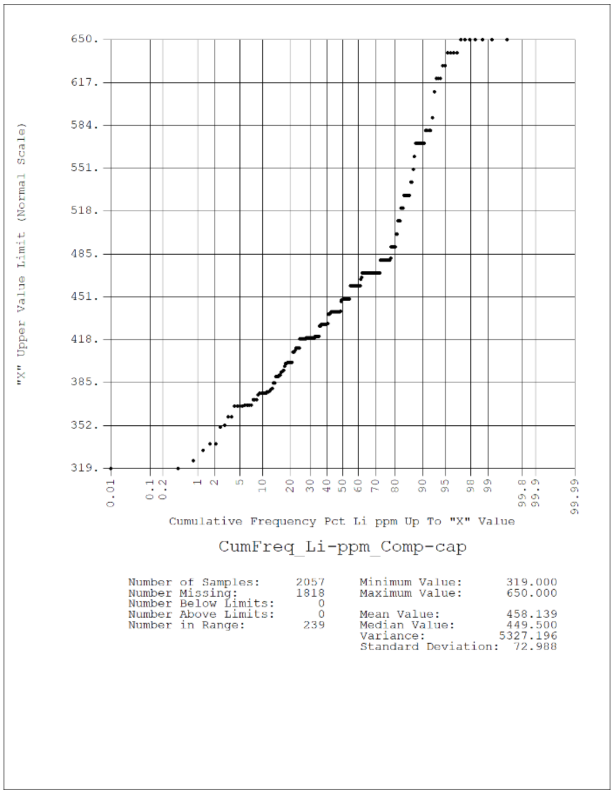
Round Top-capped

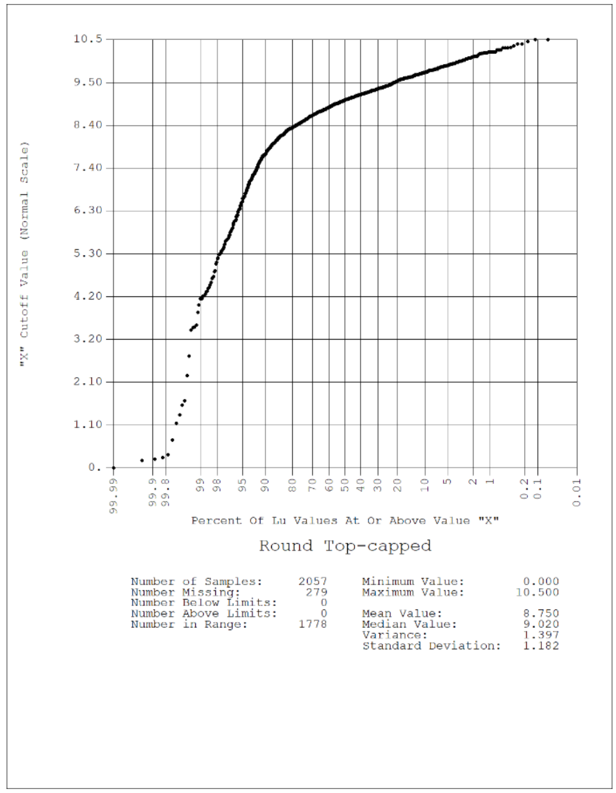
Number of Samples:	2057	Minimum Value:	2.570
Number Missing:	1818	Maximum Value:	3.520
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	3.260
Number in Range:	239	Median Value:	3.270
		Variance:	0.022
		Standard Deviation:	0.148

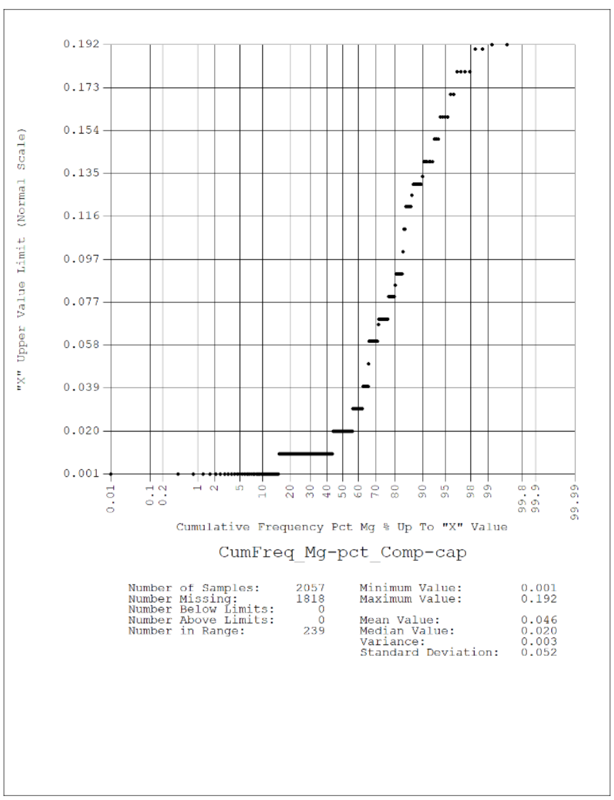


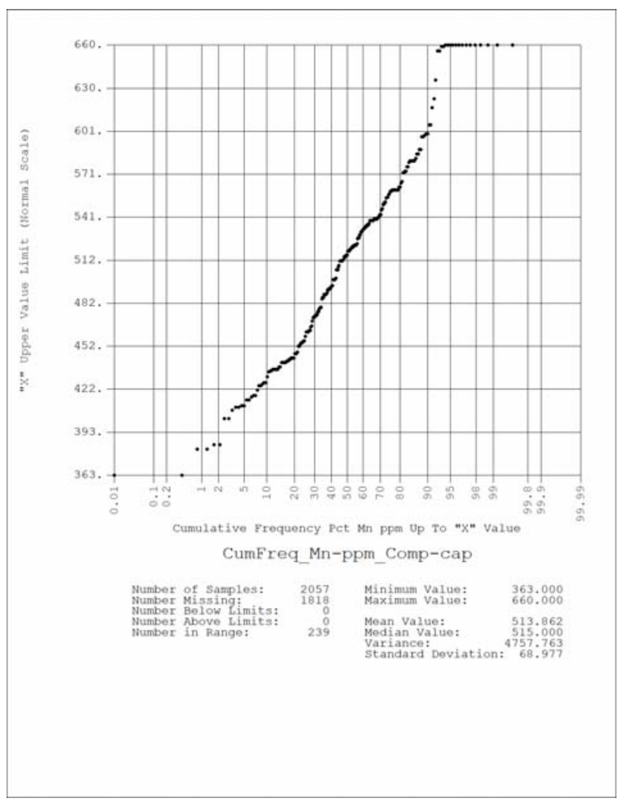
CumFreq_La-ppm_Comp-cap

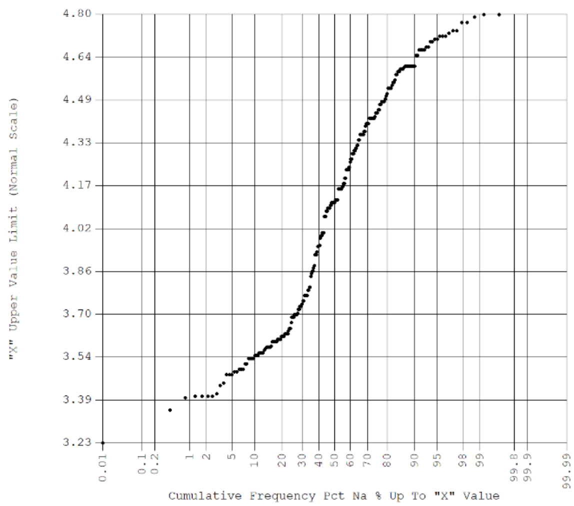
Number of Samples:	2057	Minimum Value:	0.000
Number Missing:	279	Maximum Value:	129.425
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	19.930
Number in Range:	1778	Median Value:	20.000
		Variance:	12.045
		Standard Deviation:	3.471


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Li ppm Up To "X" Value
CumFreq_Li-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 319.000
Maximum Value: 650.000
Mean Value: 458.139
Median Value: 449.500
Variance: 5327.196
Standard Deviation: 72.988


"X" Cutoff Value (Normal Scale)
Percent Of Lu Values At Or Above Value "X"
Round Top-capped
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 10.500
Mean Value: 8.750
Median Value: 9.020
Variance: 1.397
Standard Deviation: 1.182

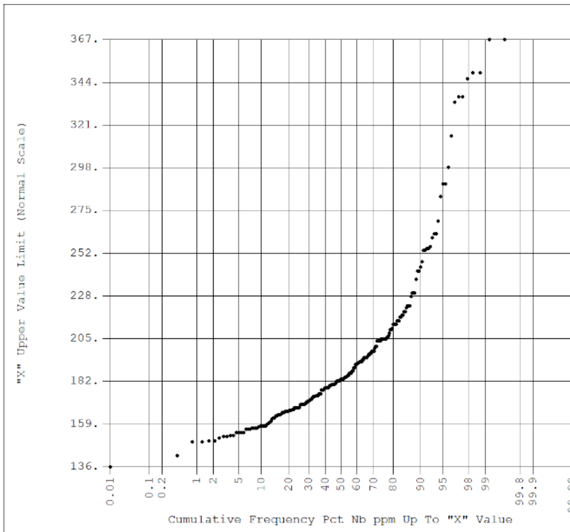

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Mg % Up To "X" Value
CumFreq_Mg-pct_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 0.001
Maximum Value: 0.192
Mean Value: 0.046
Median Value: 0.020
Variance: 0.003
Standard Deviation: 0.052


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Mn ppm Up To "X" Value
CumFreq_Mn-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 363.000
Maximum Value: 660.000
Mean Value: 513.862
Median Value: 515.000
Variance: 4757.763
Standard Deviation: 68.977



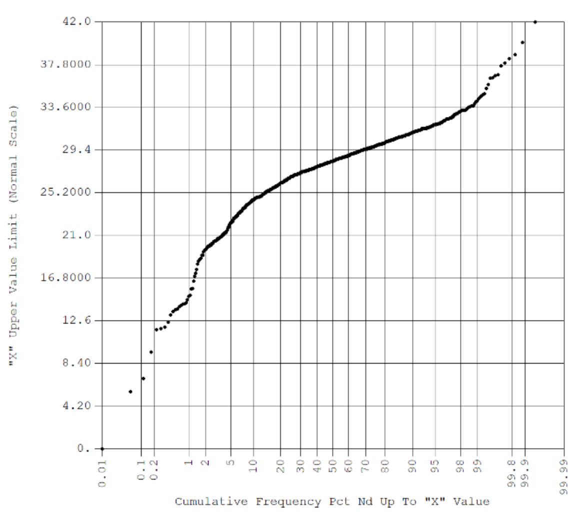
CumFreq_Na-pct_Comp-cap

Number of Samples:	2057	Minimum Value:	3.230
Number Missing:	1818	Maximum Value:	4.800
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	4.084
Number in Range:	239	Median Value:	4.110
		Variance:	0.174
		Standard Deviation:	0.418



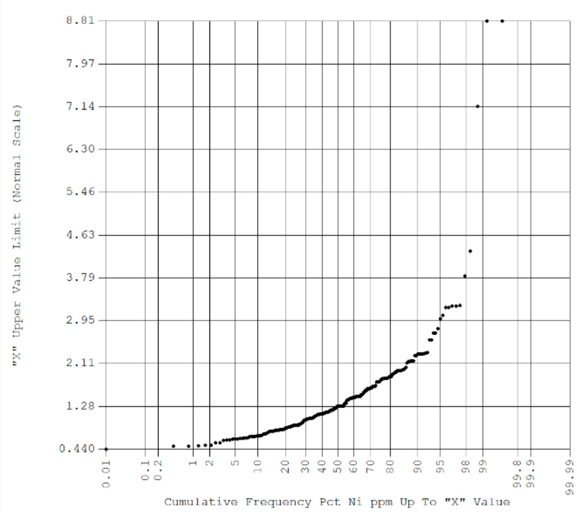
CumFreq_Nb-ppm_Comp-cap

Number of Samples:	2057	Minimum Value:	136.000
Number Missing:	1818	Maximum Value:	367.000
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	194.262
Number in Range:	239	Median Value:	183.500
		Variance:	1696.470
		Standard Deviation:	41.188



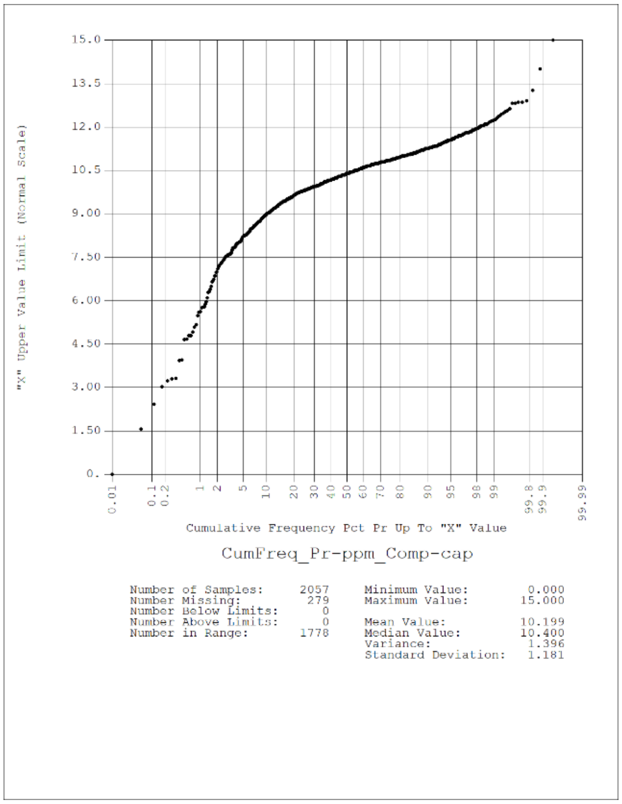
CumFreq_Nd-ppm_Comp-cap

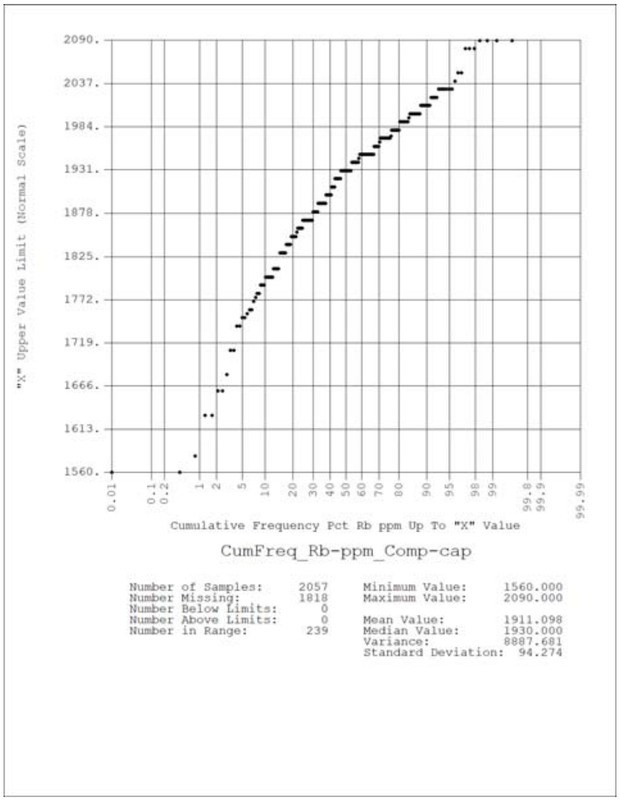
Number of Samples:	2057	Minimum Value:	0.000
Number Missing:	279	Maximum Value:	42.000
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	27.927
Number in Range:	1778	Median Value:	28.325
		Variance:	10.883
		Standard Deviation:	3.299

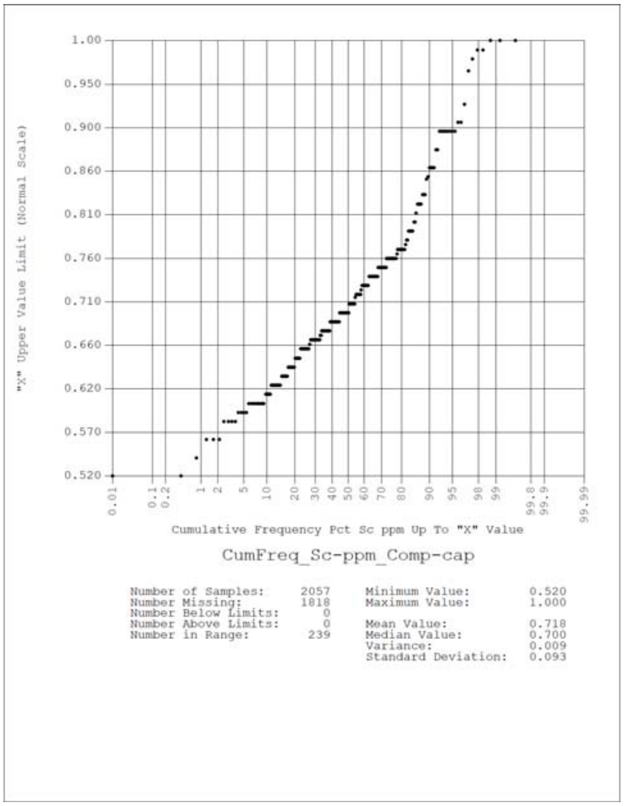


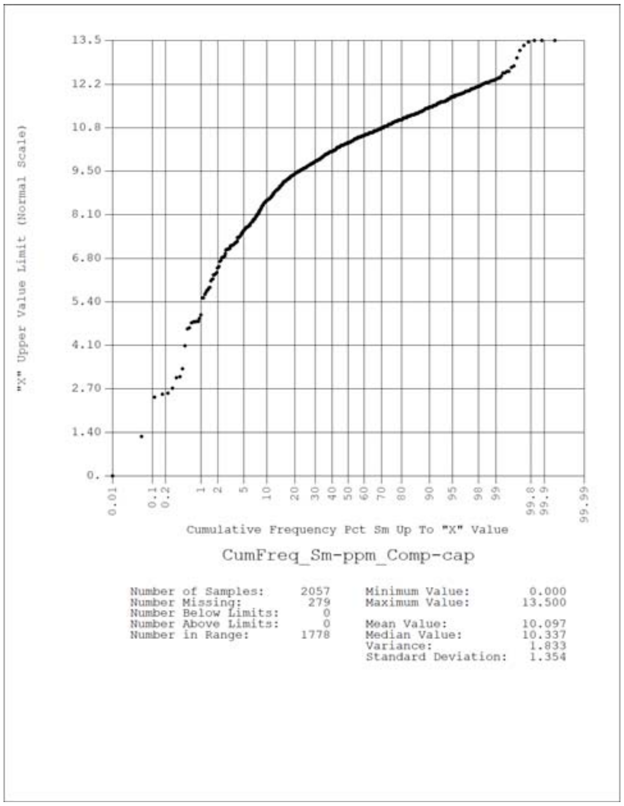
CumFreq_Ni-ppm_Comp-cap

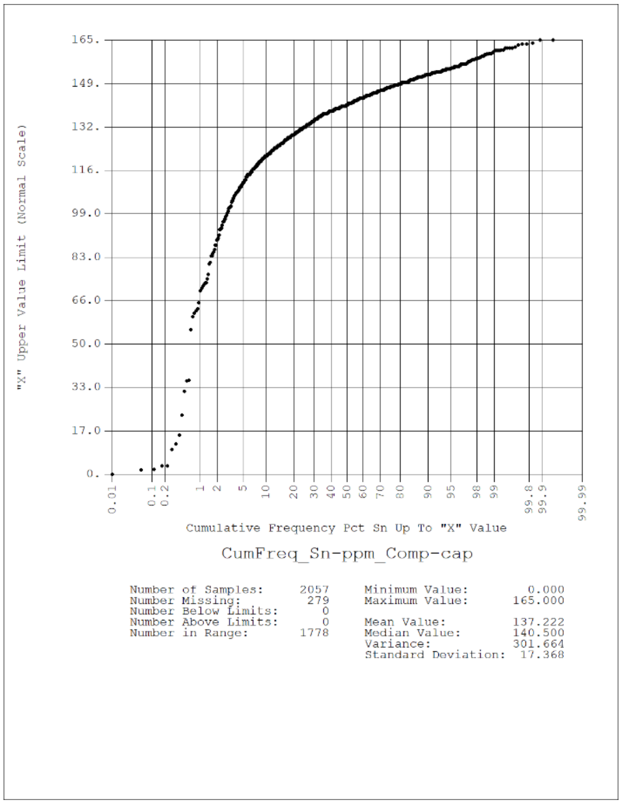
Number of Samples:	2057	Minimum Value:	0.440
Number Missing:	1818	Maximum Value:	8.810
Number Below Limits:	0		
Number Above Limits:	0	Mean Value:	1.477
Number in Range:	239	Median Value:	1.280
		Variance:	1.005
		Standard Deviation:	1.003

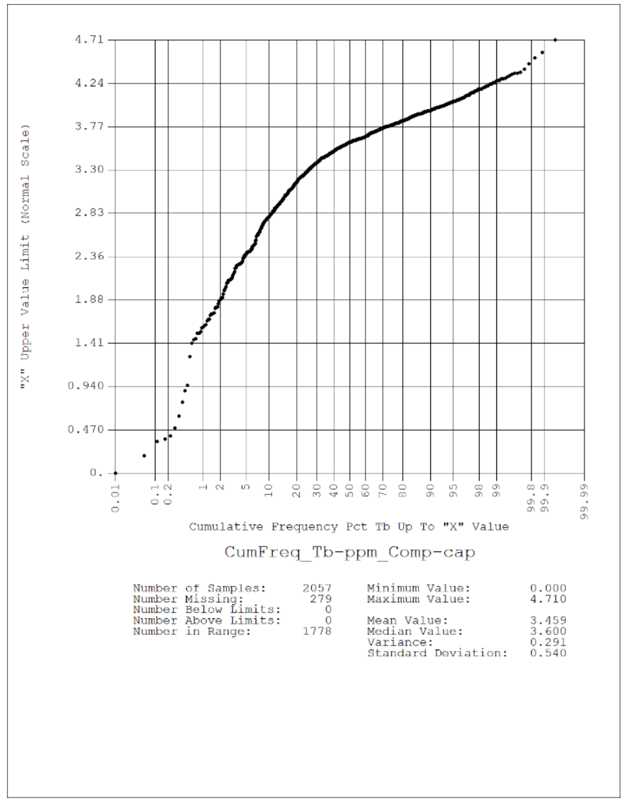

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Pr Up To "X" Value
CumFreq_Pr-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 15.000
Mean Value: 10.199
Median Value: 10.400
Variance: 1.396
Standard Deviation: 1.181

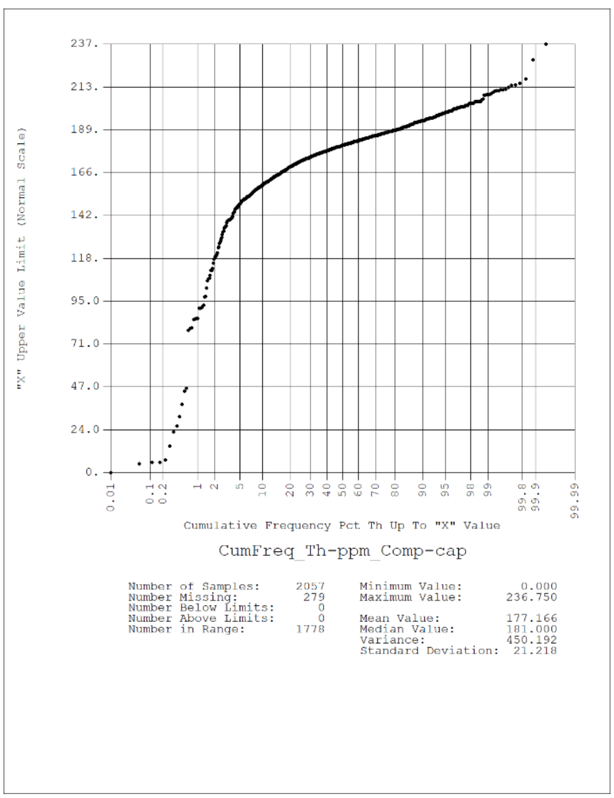

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Rb ppm Up To "X" Value
CumFreq_Rb-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 1560.000
Maximum Value: 2090.000
Mean Value: 1911.098
Median Value: 1930.000
Variance: 8887.681
Standard Deviation: 94.274

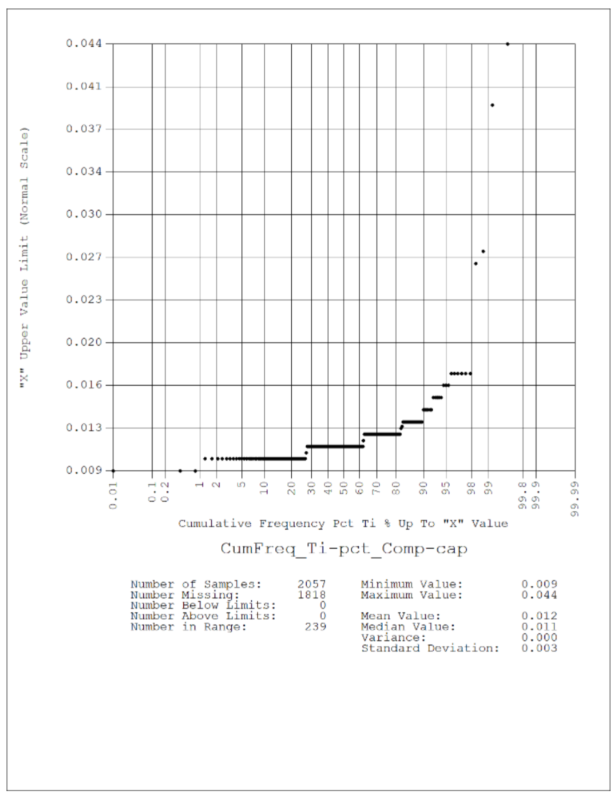

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Sc ppm Up To "X" Value
CumFreq_Sc-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 0.520
Maximum Value: 1.000
Mean Value: 0.718
Median Value: 0.700
Variance: 0.009
Standard Deviation: 0.093

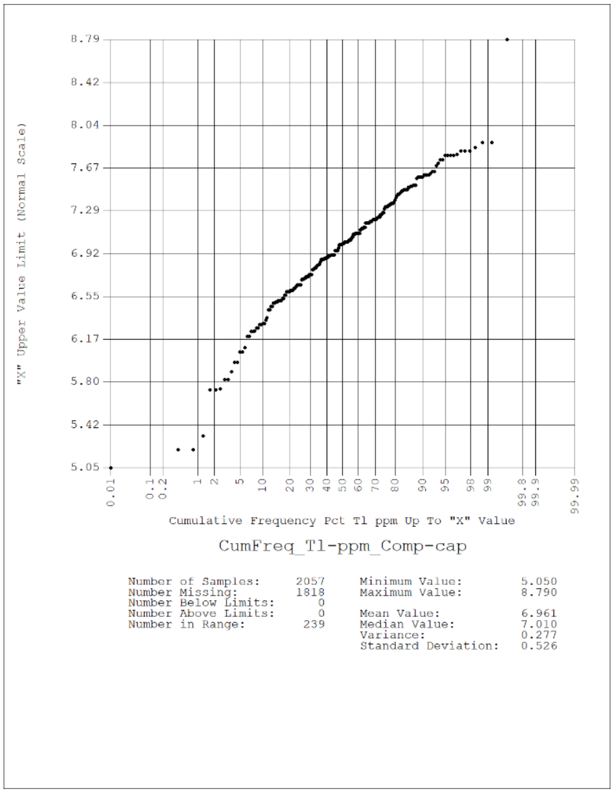

"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Sm Up To "X" Value
CumFreq_Sm-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 13.500
Mean Value: 10.097
Median Value: 10.337
Variance: 1.833
Standard Deviation: 1.354

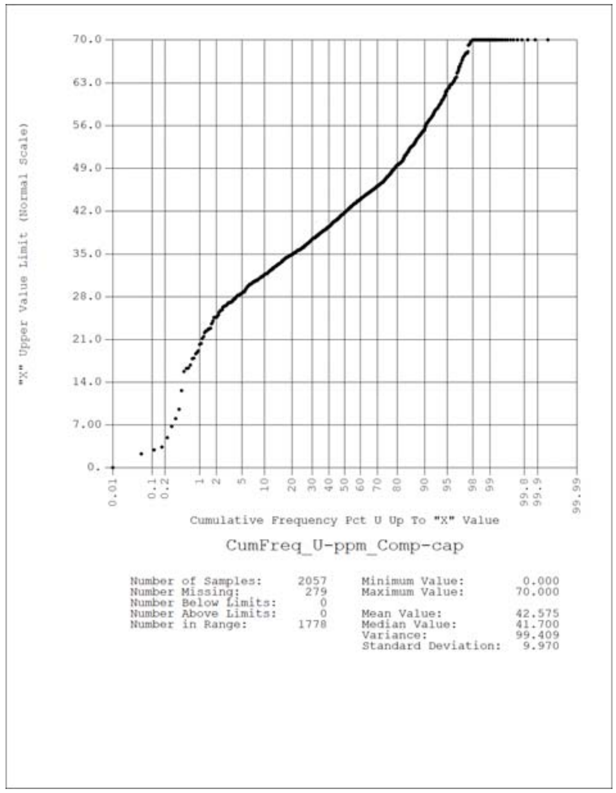

"X" Upper Value Limit (Normal Scale)
165.
149.
132.
116.
99.0
83.0
66.0
50.0
33.0
17.0
0.
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
Cumulative Frequency Pct Sn Up To "X" Value
CumFreq_Sn-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 165.000
Mean Value: 137.222
Median Value: 140.500
Variance: 301.664
Standard Deviation: 17.368

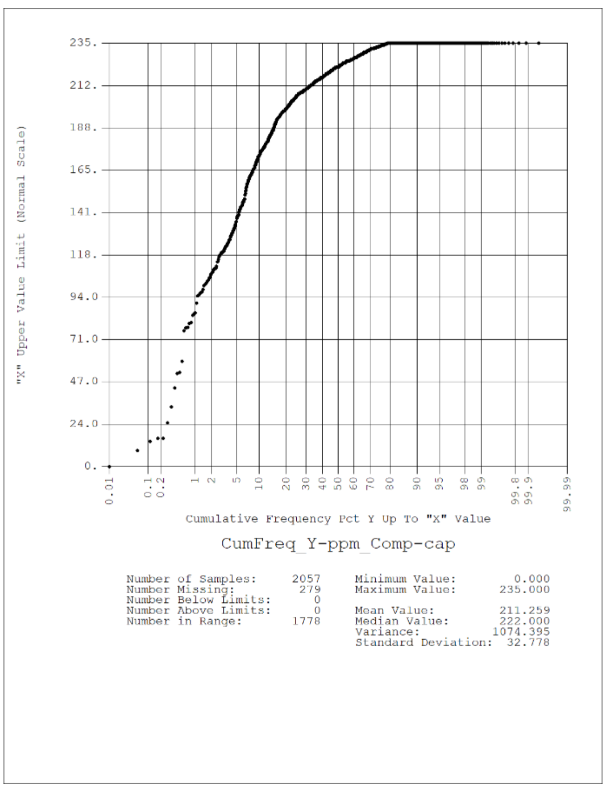

"X" Upper Value Limit (Normal Scale)
4.71
4.24
3.77
3.30
2.83
2.36
1.88
1.41
0.940
0.470
0.
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
Cumulative Frequency Pct Tb Up To "X" Value
CumFreq_Tb-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 4.710
Mean Value: 3.459
Median Value: 3.600
Variance: 0.291
Standard Deviation: 0.540

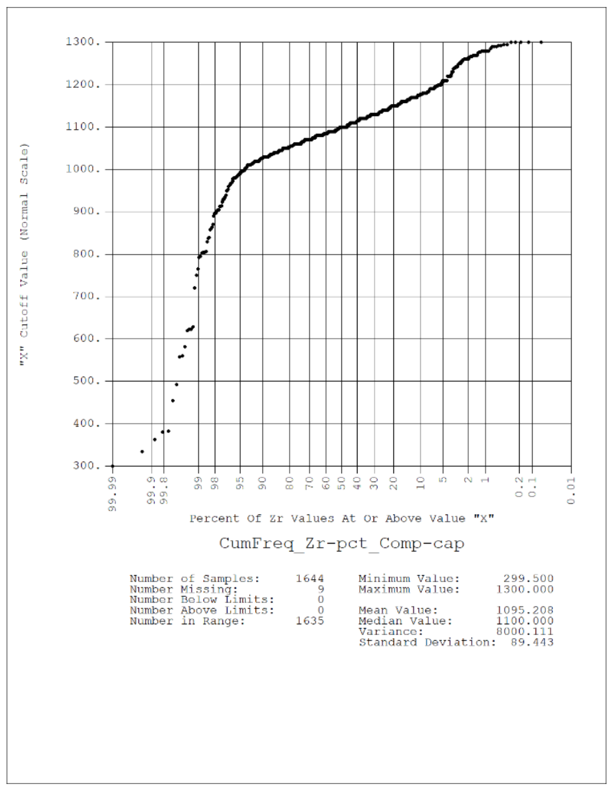

"X" Upper Value Limit (Normal Scale)
237.
213.
189.
166.
142.
118.
95.0
71.0
47.0
24.0
0.
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
Cumulative Frequency Pct Th Up To "X" Value
CumFreq_Th-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 236.750
Mean Value: 177.166
Median Value: 181.000
Variance: 450.192
Standard Deviation: 21.218


"X" Upper Value Limit (Normal Scale)
0.044
0.041
0.037
0.034
0.030
0.027
0.023
0.020
0.016
0.013
0.009
0.01 0.1 0.2 1 2 5 10 20 30 40 50 60 70 80 90 95 98 99 99.8 99.9 99.99
Cumulative Frequency Pct Ti % Up To "X" Value
CumFreq_Ti-pct_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 0.009
Maximum Value: 0.044
Mean Value: 0.012
Median Value: 0.011
Variance: 0.000
Standard Deviation: 0.003


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Tl ppm Up To "X" Value
CumFreq_Tl-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 1818
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 239
Minimum Value: 5.050
Maximum Value: 8.790
Mean Value: 6.961
Median Value: 7.010
Variance: 0.277
Standard Deviation: 0.526


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct U Up To "X" Value
CumFreq_U-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 70.000
Mean Value: 42.575
Median Value: 41.700
Variance: 99.409
Standard Deviation: 9.970


"X" Upper Value Limit (Normal Scale)
Cumulative Frequency Pct Y Up To "X" Value
CumFreq_Y-ppm_Comp-cap
Number of Samples: 2057
Number Missing: 279
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1778
Minimum Value: 0.000
Maximum Value: 235.000
Mean Value: 211.259
Median Value: 222.000
Variance: 1074.395
Standard Deviation: 32.778


"X" Cutoff Value (Normal Scale)
Percent of Zr Values At or Above Value "X"
CumFreq_Zr-pct_Comp-cap
Number of Samples: 1644
Number Missing: 9
Number Below Limits: 0
Number Above Limits: 0
Number in Range: 1635
Minimum Value: 299.500
Maximum Value: 1300.000
Mean Value: 1095.208
Median Value: 1100.000
Variance: 8000.111
Standard Deviation: 89.443

33 APPENDIX E: HISTORY OF DEVELOPMENT OF ION EXCHANGE TECHNOLOGY

Ion Exchange

A major effort to obtain better separation methods was undertaken in the mid 1940's as part of the Manhattan Project, the crash program undertaken by the U.S. government during WW II to develop the atom bomb. Atomic weapons are made from uranium and plutonium, which are part of another group of elements similar to the lanthanide REEs, called the actinide series. The chemical and metallurgical properties of the elements making up the actinide series are quite similar to the lanthanide series. Since the rare earth elements found in nature are not radioactive and their toxicities are relative low, they presented an ideal surrogate to assess methods for separating the actinides.

Use of the rare earths as the surrogate therefore permitted a wide range of tests to be conducted to perfect separation techniques that could then be applied to the actinides. This resulted in far fewer experiments being required using the radioactive and in some cases highly toxic, actinide elements.

A number of methodologies were tested and in 1947 researchers at both the Oak Ridge National Laboratory in Tennessee and the Ames Laboratory in Iowa published results indicating that ION EXCHANGE (IX) techniques offered the best way to separate the rare earths. The earlier IX techniques were batch operations and were similar in concept to the now familiar home water softeners.

Ion exchange has become a mainstay of chemical processing and over the intervening years many specialized types of these resins have been developed by a number of domestic and international producers, e.g. Dow, Rohm&Haas; Purolite; Lanxess; and others.

The two most commonly used resin types are anion resins that attract negatively charged ions, and cation resins that attract positively charges ions. Rare earth elements are among the highest positively charged metal ions, thus are strongly attracted to strong cation resins at the expense of the lesser charged ions. These rare earth element ions will displace lesser attracted ions from the resin, thus it is possible to extract rare earths from a solution of low rare earth concentrations and higher impurity concentrations.

In the case of rare earths extraction using cation exchange reins, the loaded resin is regenerated with an acid solution, e.g. sulfuric acid, which will return the resin sites to a hydrogen (H^+) form. The H^+ form resin is then ready for reuse.

In the case of ion exchange, the chemistry for the extraction of the rare earths from an acidic solution is well established and indeed was used extensively in the mid-1940's through early 1950's. The main difference today is that with the advent of continuous ion exchange systems (circa 1983), the entire ion exchange process, i.e. loading, washing, regeneration, and the like, can be carried out in an uninterrupted fashion which has had profound impacts on the operational capabilities and resulting economics associated with the ion exchange approach.

Ion Chromatography

Because of the almost identical chemical characteristics of the rare earth elements, in order to separate them the simple batch IX procedures had to be modified. The technique, referred to as ion chromatography (IC) was developed to carry out the actual separation of the rare earths from each other. Ion chromatography is an established chemical separation technique that is extensively used in the analytical chemistry sector as well as demanding applications in arenas such as biologicals, food separations, high purity hydrometallurgical separations, and the like.

In the past, the IC approaches were typically applied to systems which had relatively small flow rates and generally had higher valued products. With the advent of continuous ion chromatography (CIC), the processing arenas where such technology can be applied have been significantly increased.

In the IC application, the resin bed is only partially loaded near its top with rare earths, which permits fresh resin to be available during the regeneration step. The partially loaded resin is then regenerated with specially selected solutions (referred to as complexing agents) that slightly change the behavior of each rare earth element, thus allowing them to be separated within the resin system.

As the regeneration travels down through the resin bed, the rare earths, now having slightly different affinities for the resin in the presence of the complexing solution, move down through the resin bed at different velocities. As they travel down through the column, the rare earths will initially tend to separate as groups, e.g. light, mids, and heavies. With sufficient length, the rare earths within each group will further separate into individual species which can then be collected as the regeneration solution exits the IC column.

Several types of complexing agents were discovered during the earlier development work. Some allow the heavy rare earth ions to exit the IC unit first, while others allow the lightest to exit first. By calibrating the columns and reagents, extremely pure separations of the individual elements can be made.

Thus, IC was the initial method used to separate and purify larger quantities of rare earth elements. IC was developed in the mid 1940's primarily by Oak Ridge National Laboratories and the Ames Laboratories in support of the U.S. nuclear development program. With the batch IC approach, kilogram quantities of purified rare earths could be produced.

The net result was development of a system using batch IC to carry out individual REE separations at a larger scale than could be achieved by fractional crystallization. While the IC approach allowed the production of very high purity products, 99.999% or more, it was somewhat cumbersome and required a fairly extensive liquid handling support system to enable proper operation.

Even with this limitation, however, batch IC is still used for the production of the higher valued very high purity rare earths. In many cases, even though the volumes are small the price associated with the higher purities has justified this approach. Products with purities in excess of 99.9999+% have been produced with this methodology.

Continuous Ion Exchange and Ion Chromatography

While capable of producing higher purity products than SX, fixed bed IX -- owing to its difficulty of operation in more complex process systems and low volume capacity when used in the chromatographic mode of operation -- was not suited to large, commercial production of materials such as rare earths. For IX to be competitive with SX, the process would have to be simplified and be able to process the higher volumes necessary in commercial applications and ideally would be continuous in nature.

In the early 1980's what is now called continuous ion exchange (CIX) was developed. The heart of the system was a specially designed liquid distributor unit, or hub, that had a minimal number of moving parts. The distributor was synchronized with a rotating table (carrousel) on which the resin columns were placed. During operation, all process streams were continuously fed to and discharged from the single CIX system.

As a result of on-going equipment system refinements, the latest CIX design is embodied in the so-called "fixed bed-rotating valve" concept. In this design the resin beds are fixed and a fluid distributor is used that incorporates a rotating assembly to direct fluids to the appropriate column locations on a continuous basis. The feeds and discharges from the unit remain at fixed locations. This configuration removed any constraints on the size and volume of the system. The same techniques and system design were rapidly applied to CIC.

The tolerance of this system to variations in ionic concentration of feed and flow rates led to acceptance of the process in a variety of commercial process arenas.

CIX/CIC processing is extensively used in industries such as:

- Food and pharmaceutical
- Hydrometallurgical
- Chemical processing
- Water and waste water treatment
- Oil processing
- Petrochemical

Potential Relevance and Contribution to the Rare Earth Industry

A common question relative to the CIX and CIC-type systems is why haven't they been used in the rare earths industries before now? Keep in mind that the CIX approach was not invented until 1983 and for the most part was in the initial application development phases well into the mid-1980's.

The answer is that by the late 1980's the rare earth industry had largely established itself in China using the existing SX process. Labor costs, economic considerations and environmental regulation were not factors. Given the state-owned element of many Chinese REE producers, market concepts of profit were not essential considerations. From that time until 2009 there was no attempt to develop new production outside of China and there was little incentive to innovate.

34 APPENDIX F: MEMORANDUM FOR THE SECRETARY OF DEFENSE

Federal Register / Vol. 84, No. 143 / Thursday, July 25, 2019 / Presidential Documents 35969

Presidential Documents

Presidential Determination No. 2019–17 of July 22, 2019

Presidential Determination Pursuant to Section 303 of the Defense Production Act of 1950, as Amended

Memorandum for the Secretary of Defense

By the authority vested in me as President by the Constitution and the laws of the United States of America, including section 303 of the Defense Production Act of 1950, as amended (the "Act") (50 U.S.C. 4533), I hereby determine, pursuant to section 303(a)(5) of the Act, that the domestic production capability for separation and processing of Light Rare Earth Elements is essential to the national defense.

Without Presidential action under section 303 of the Act, United States industry cannot reasonably be expected to provide the production capability for separation and processing of Light Rare Earth Elements adequately and in a timely manner. Further, purchases, purchase commitments, or other action pursuant to section 303 of the Act are the most cost-effective, expedient, and practical alternative method for meeting the need for this critical capability.

You are authorized and directed to publish this memorandum in the *Federal Register*.

THE WHITE HOUSE,
Washington, July 22, 2019

[FR Doc. 2019–15998
Filed 7–24–19; 11:15 am]
Billing code 5001–06–P