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RARE-EARTH-ELEMENT (REE) BEHAVIOUR IN THE STRANGE LAKE INTRUSION, LABRADOR: RESOURCE ESTIMATION USING PREDICTIVE METHODS

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ABSTRACT

This report discusses the testing and assessment of predictive methods that were developed to allow estimation of REE abundances in the Strange Lake Main Zone deposit from other analytical data provided by the 1980s exploration. It also presents an independent resource estimate for this deposit based on the predicted REE data.

*Fifty archived drillcore samples were re-analyzed for the REE and other elements, and used to test predictive methods developed using a previous batch of 100 re-analyzed samples. The method uses linear regression of data for REE and yttrium data from the 1980s. Evaluation of results indicates overestimation of light REE abundances at lower concentrations and underestimation of both light and heavy REE abundances at higher concentrations. The correspondence between predicted and measured values is variably inaccurate at the level of an individual sample, but centralized measures (*e.g.*, mean and median) for the entire dataset compare much better. It appears that overestimation for some samples is counterbalanced by underestimation for others, and the overall results are conservative.*

A second test used comparison of predicted REE abundances for 1980s drillholes in adjacent Québec with the measured results from 'twinned' drillholes completed in 2009 at closely adjacent locations. Some drillhole pairs, notably those with lower grades, compare very well, but others reveal significant differences in the weighted means of predicted and measured data. Such variability is not unexpected and it is, in part, believed to reflect true geological variations and related sampling uncertainties, despite the close proximity of the paired drillholes. However, the overall weighted means for predicted data for 1980s drillholes and measured data for 2009 drillholes are almost identical, suggesting that the method remains valid in the context of resource estimation.

An independent resource calculation was based on 155 drillholes, all located in Labrador. This infers a larger tonnage than the 1980s estimate (66.25 Mt versus *55.8 Mt) but this is counterbalanced by slightly lower average ZrO_2 and Nb_2O_5 grades. The total REE oxide, including yttrium (TREO*) is estimated at about 0.82%. Although the result does not exactly match the earlier estimates, it confirms their general validity. However, any resource estimate for the Main Zone deposit is considered to be minimum, because most drillholes are shallow (<50 m) and terminate in mineralization. Two deeper mineralized holes penetrated to depths of 190 and 281 m, suggesting that the total REE resources are probably much greater than those previously or presently inferred.*

INTRODUCTION

PROJECT OVERVIEW

The *ca.* 1240 Ma Strange Lake Intrusion, located on the Labrador-Québec border some 125 km west of Nain, Labrador (Figure 1; inset), hosts important resources of zirconium (Zr), niobium (Nb), yttrium (Y) and rare-earth elements (REE). Exploration in the late 1970s and 1980s by the Iron Ore Company of Canada (IOC) delineated a deposit in Labrador, now known as the 'Main Zone', estimated to contain resources of some 56 Mt (*e.g.*, Zajac *et al*., 1984; IOC, 1985; Miller, 1986, 1996). Although feasibility studies were completed (IOC, 1985), no development was ever attempted. The Main Zone, and most other prospective areas in Labrador have not benefited from renewed exploration, because they lie within exempt mineral lands (EML) established prior to settlement of aboriginal land claims, during which they became Labrador Inuit Lands. However, the area may yet be reopened to exploration and development, and these potential resources thus retain considerable interest.

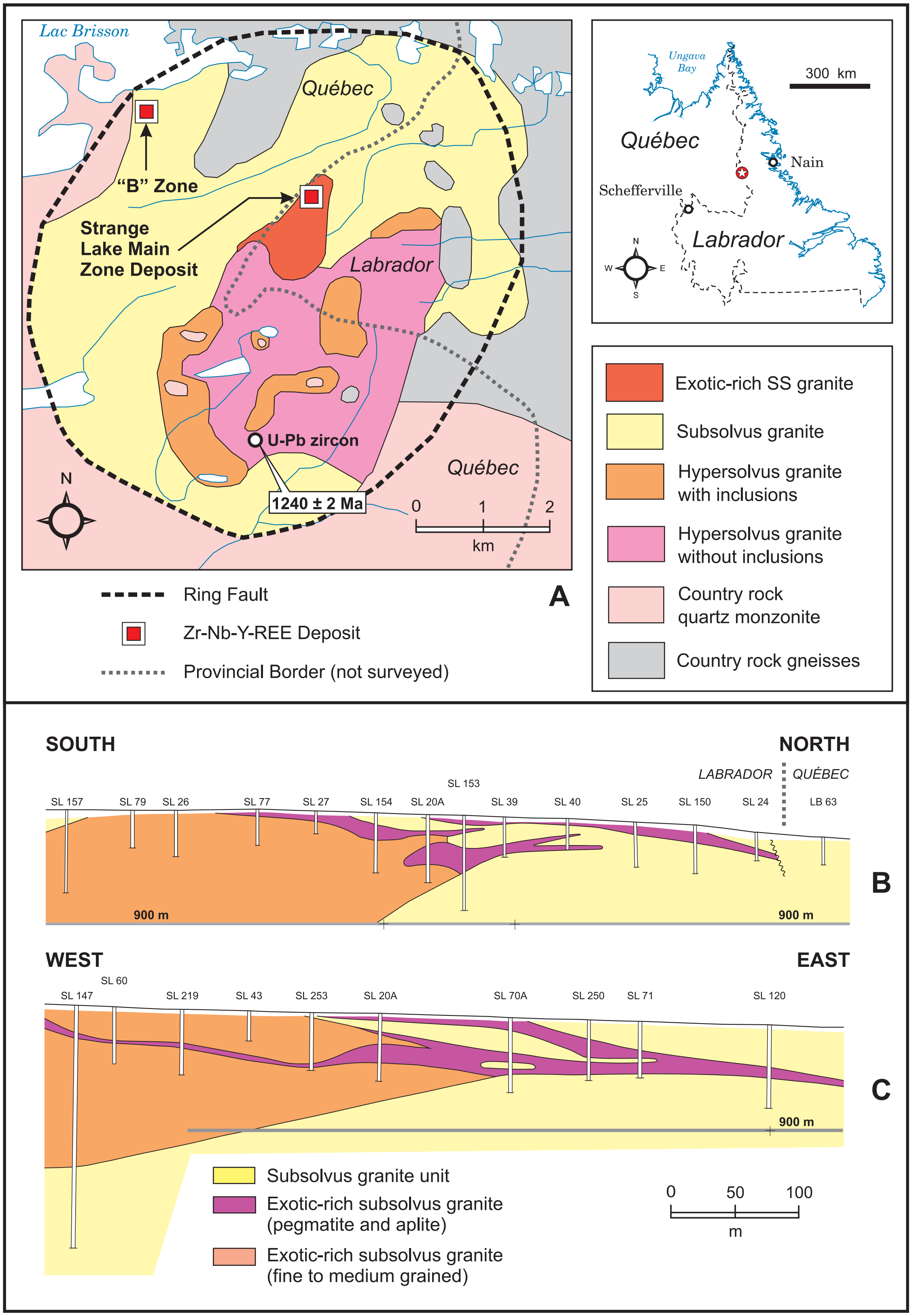

Figure 1. *Simplified geological map of the Strange Lake Intrusion, after Miller (1986) and Miller* et al. *(1997), and generalized cross-sections through the Strange Lake Main Zone deposit. Inset map shows the location of the area on the Québec-Labrador border.*

Recent exploration in Québec, at a site first identified in the 1980s, has delineated a similar large deposit now known as the 'B-Zone' (Ramsey *et al*., 2010; Collins and Cashin, 2011). The most recent resource estimate infers some 278 Mt of low-grade material, within which a smaller high-grade zone (~20 Mt) is now targeted for development. The current exploration emphasis is toward the REE and Y, rather than Zr and Nb; in the 1980s, relatively few samples were analyzed for REE. The REE potential of the Main Zone deposit is thus harder to evaluate.

Kerr and Rafuse (2012) presented the first extensive REE data from the Main Zone deposit, from re-analysis of 100 drillcore pulp samples retrieved from archival storage (termed Batch 1). The objective of their study was to evaluate proxy methods for calculating REE abundances, to develop an estimate of the overall REE resource without the necessity for extensive re-analysis or new drilling. The new REE data are also of interest in the context of geological unit definition and genetic models for the deposits. The REE patterns vary only within narrow limits, and there are predictable relationships between most REE and yttrium (Y) or beryllium (Be).

Regression equations permit estimation of individual elements, using the 1980s data for yttrium as the independent variable. This report presents results from a 'blind test' in which a second batch of archived samples (Batch 2) was re-analyzed, to allow comparison of predicted and measured values, and the assessment of uncertainties. A further test of the methods used data from 2009 drilling by Quest Rare Minerals in adjacent Québec, where 11 drillholes from the 1980s were 'twinned' by holes drilled immediately adjacent to them. A general estimate for the Main Zone REE resource was then derived using the predicted REE data. This resource calculation does not adhere strictly to NI 43-101 criteria for resource estimation, and is a simple block model. Nevertheless, it provides a reasonable starting point for more rigorous evaluation using NI 43-101 protocols.

In this report, the acronym REE generally refers to the elements of the lanthanide series (La, Ce, Pr, Nd, Sm, Eu, Gd, Tb, Dy, Ho, Er, Yb and Lu). The chemically similar element yttrium (Y) is considered part of the REE group, and is now commonly included in exploration results. The terms TREE and TREO refer to total amounts, as elemental or oxide values, respectively. Where accompanied by an asterisk (TREE*, TREO*), these totals include the values for yttrium (Y) or yttrium oxide (Y_2O_3).

REGIONAL GEOLOGICAL SETTING AND MINERALIZATION

The regional settings of the Strange Lake Intrusion and its mineral deposits are described in several reports and papers (*e.g.,* Zajac *et al*., 1984; Miller, 1986, 1996; Miller *et al*., 1997), and in more recent articles by Kerr (2011) and Kerr and Rafuse (2012). The Zr–Y–Nb–REE mineralization at Strange Lake is hosted within the *ca*. 1240 Ma Strange Lake Intrusion, which consists of at least three varieties of peralkaline granite (Figure 1). A geographically restricted unit, considered to represent the most evolved phase of the intrusion, routinely contains 0.5% to 0.8% TREO* (total REE oxides, including yttrium) over wide areas (Miller, 1986; Kerr and Rafuse, 2012). Higher grade material occurs on a more local scale in the form of heterogeneous pegmatite–aplite zones that contain up to several percent TREO*. Such pegmatite–aplite zones are typically discontinuous and variable in texture, and form veins and pods that intrude all other phases of the intrusion. Within the Main Zone, such material appears to be spatially associated with the gently dipping upper contact of the highly evolved granite, against the older unit that sits above it, and adjacent to this contact (Miller, 1996; Figure 1). The most extensive near-surface high-grade areas reside at the north end of the Main Zone in the 'Zone 1 Lens' (Miller, 1996; Figures 1 and 2), which was targeted for small-scale mining by IOC in the 1980s. The B-Zone in Québec consists of numerous pegmatitic sheets and veins intruding an older inclusion-rich granite, and includes similar near-surface high-grade pods (Collins and Cashin, 2011). Although the Main Zone and B-Zone deposits are physically discrete, they are similar in many respects. The resource estimates for both deposits are composite, because both represent mixtures of low-grade enriched granites and higher grade pegmatite–aplite zones (IOC, 1985; Ramsey *et al*., 2010).

Mineralogical studies of the Zone 1 Lens (IOC, 1985) suggested that most of the REE are hosted by the rare minerals gerenite ($(Ca, Na)_2(Y, REE)_3Si_6O_{18}\ 2H_2O$), kainosite ($Ca_2\ (Y, Ce)_2Si_3O_{12}(CO_2,H_2O)$) and gadolinite ($Be_2(Ca, Y, REE, Fe)_3Si_2O_{10}$). Gerenite (Jambor *et al.*, 1998) occurs only at Strange Lake. Zirconium is hosted largely by gittinsite ($CaZrSi_2O_7$), and Nb is hosted largely by pyrochlore ($(Na, Ca)_2Nb_2O_6\ (OH, F)$). Mineralogical analysis of a bulk sample from the B-Zone yielded broadly similar results (Collins and Cashin, 2011). It is not known if this REE deportment applies to other types of mineralization, such as the lower grade disseminated mineralization hosted by homogeneous granites. The presence of the Ca-bearing minerals such as kainosite, gerenite and gittinsite is important from a metallurgical perspective as these are more amenable to acid-leach processing than most other common REE- and Zr-bearing silicates (Zajac *et al.*, 1984). However, as pointed out by Kerr and Rafuse (2012), whole-rock REE patterns cannot easily be accounted for by the analyses of gerenite, kainosite and gadolinite reported by Jambor *et al.* (1998), suggesting that other REE-bearing minerals must be present.

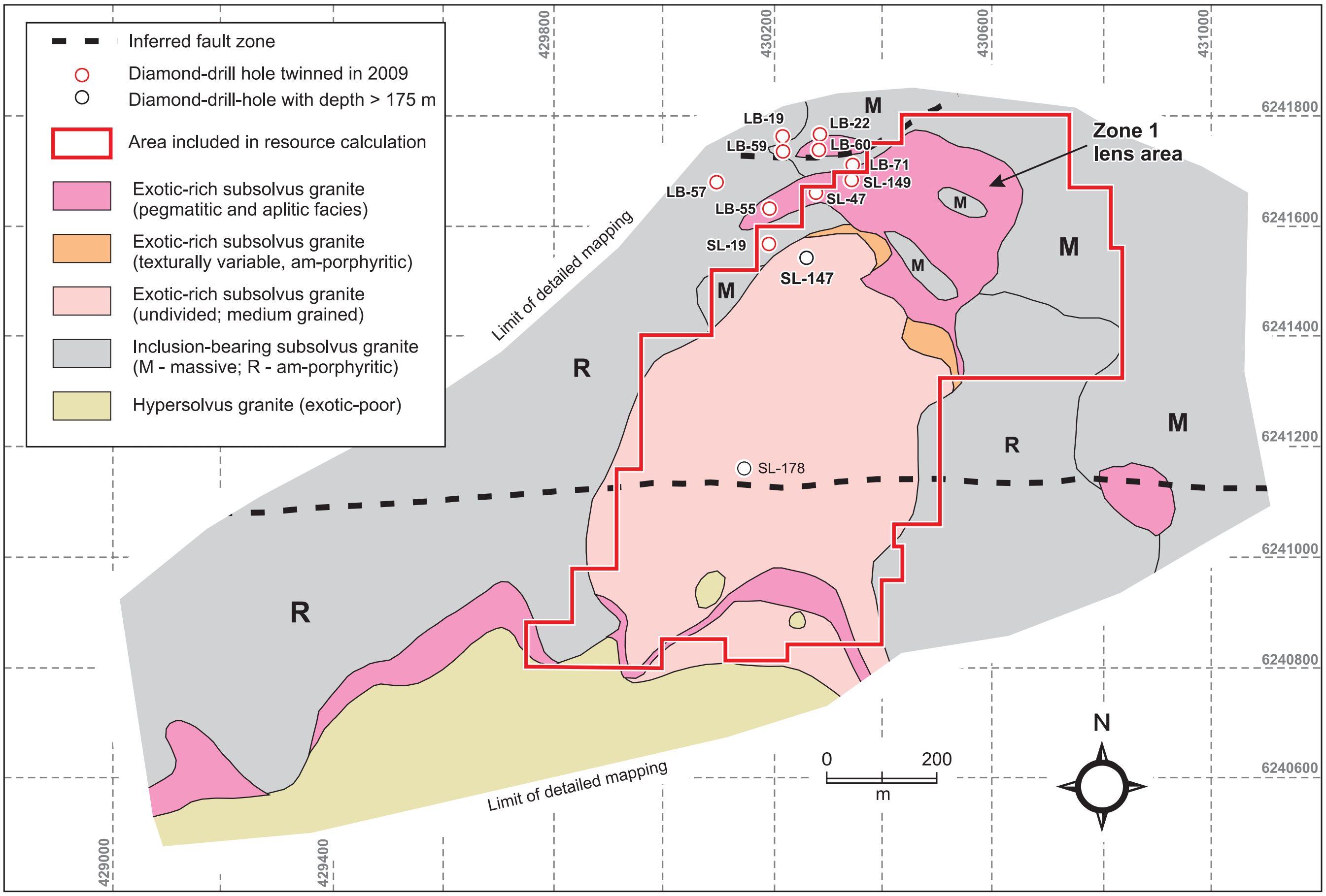

Figure 2. *Geological map of the central part of the Strange Lake Intrusion, including the Zone 1 Lens. The locations of deep drillholes SL-147 and SL-178 are indicated, as are the locations of 1980s holes twinned by Quest Rare Minerals in 2009. The surface extent of the area included in resource calculations is indicated by the red line. Geological information after IOC (1985). In legend: am - amphibole.*

The Strange Lake Intrusion, and contained deposits, are relatively enriched in 'heavy' REE (HREE, specifically Eu, Gd, Tb, Dy, Ho, Er, Tm, Yb and Lu), which are rarer and more valuable than the 'light' REE (LREE, specifically La, Ce, Pr, Nd, Sm). The estimated bulk REE balance for reanalyzed samples from the Main Zone (Kerr and Rafuse, 2012) comprises 52% LREE, 22% HREE and 26% Y (at about 0.87% TREO*), and the disclosed REE resource from the B-Zone in Québec (Ramsey *et al.*, 2010) comprises 56% LREE, 16% HREE and 28% Y (at about 1.1% TREO*). The reasons for the slight differences in REE balance between the two deposits remain unclear, although there is more evidence for hydrothermal alteration in the host granites at the B-Zone compared to the Main Zone.

SAMPLING AND RARE-EARTH ELEMENT ANALYSIS

The first set of 100 archived samples (Batch 1) was reanalyzed in 2010, and discussed by Kerr and Rafuse (2012). A second batch of samples (Batch 2) was analyzed for REE and other elements in 2011. Fifty samples were selected from a single large packing crate containing archived material from drillcores sampled by IOC in the early 1980s. The final selection of the samples was based on the locations of drillholes and the Y, Nb, Be and Zr data from IOC assessment reports, in the interest of having both wide geographic representation and a wide grade spectrum. Samples were processed at the Activation Laboratories Ltd. facility in Goose Bay, Labrador, and then analyzed in Ancaster, Ontario, for major elements, trace elements, Y and REE. The processing and analysis by inductively-coupled plasma mass-spectrometry (ICPMS) essentially duplicate the methods currently used in REE exploration. All data from Labrador are contained within an Open-File release that will follow this report (A. Kerr, unpublished data, 2013). Including samples from the first batch ('Batch 1'; Kerr and Rafuse, 2012), 150 new REE analyses are now available, but these still represent only slightly more than 5% of the total collection of drillcore samples retained from 1980s exploration.

This is an extremely valuable resource for further assessment of the deposit.

Information on the analytical methods employed in the 1980s is limited, but Zr, Y, Nb and Be were obtained using X-Ray fluorescence (XRF) methods at an internal IOC laboratory (IOC, 1985). These data are not reported as assay certificates, but listed in tables within assessment reports. Although some samples were analyzed for 'total REE oxides' at more than one external laboratory, assessment reports suggest that REE contents were to a large extent calculated from from Y concentrations, in a manner similar to that developed here. The basis for calculation came from a small number of REE analyses completed using the now-obsolete thin-film XRF method at Memorial University. However, some calculations are stated to have been based on external analyses of Ce by XRF. Estimates of precision for Y and Nb were quoted at ± 5%, and for Zr at ± 10% (IOC, 1985); however, the estimates for Y and Nb were quoted at abundances of 1% oxide, and those for Zr at 10% oxide, so precision may have been worse at the lower concentrations typical of many samples.

GEOCHEMISTRY

CORRELATIONS OF 1980s AND 2011 DATASETS

Kerr and Rafuse (2012) discussed the results from Batch 1 analyses. The analytical data from Batch 2 were initially compared to results for Y, Nb, Zr and Be obtained from the same samples in the 1980s. With the exception of Be, for which only 37 out of 50 samples were previously analyzed, data are complete for all elements. Scatter plots (Figure 3) illustrate the relationships between old and new data, and can be compared with equivalent plots from Batch 1 (Kerr and Rafuse, 2012, their Figure 3). The two datasets exhibit excellent correlation for all elements, with R^2 values (*see* Kerr and Rafuse, 2012) of 0.95 (Y), 0.94 (Be), 0.89 (Zr) and 0.88 (Nb). Aside from Zr (which has better correlation in Batch 2), these results are essentially identical to the correlations reported by Kerr and Rafuse (2012). However, such correlation does not imply that the values actually correspond, as data arrays are variably displaced from a reference line that indicates exact equivalence (Figure 3). The 2011 values for Y and Zr are lower than their counterparts from the 1980s (Figure 3a, b), but the reverse situation applies for Be (Figure 3d); the Nb data array sits closest to the reference line of equivalence (Figure 3c). These findings duplicate those reported by Kerr and Rafuse (2012), although regression of the 2011 data for yttrium against 1980s data provides a slightly steeper slope (0.89 *vs* 0.82) and a larger negative Y-axis intercept (-243 *vs* + 15). In practice, this difference has only a minimal impact on results; the yttrium data from 2011 are some 18% lower than those from the 1980s, as indicated by the first batch of analyses. Assuming that the 2010 and 2011 ICP-MS analyses are more accurate than 1980s XRF data (which cannot be verified), this implies that older data for Y and Zr may require some correction if used in resource estimation.

ASSESSMENT OF PREDICTIVE METHODS USING LINEAR REGRESSION

Summary of Principles

Kerr and Rafuse (2012) found that most REE had poor correlations with either Zr or Nb, but that some (notably the 'heavy' members, Eu to Lu) showed strong correlations with Y or Be. In general, the strongest correlations for all elements were with yttrium. These observations provide the basis for prediction of element abundances from the 1980s yttrium data, using linear regression analysis. However, the relationships appear not to be strictly linear, as regression equations differed when a small number of higher grade surface samples were included with the larger drillcore database. The greatest disparity was shown by the light REE, notably La, Ce, Pr and Nd. To address this problem, discrete equations were suggested for samples having Y values above or below an arbitrary dividing point of 4000 ppm (0.5% Y_2O_3). Kerr and Rafuse (2012) also investigated a two-stage procedure in which two 'anchor' elements (Sm and Dy) are first calculated from the Y data, with which they are best correlated, and the remaining elements then predicted on the basis of their regression against Sm (for La, Ce, Pr and Nd) or Dy (for Eu, Gd, Tb, Ho, Er, Yb and Lu). This method was referred to as the 'indirect' method, as opposed to the direct prediction from the yttrium data. As in the case of the direct method, discrete regression equations were derived for high- and low-grade samples. The results of all these methods were found to be essentially identical for all heavy REE, but the indirect low-grade method predicted lower light REE values than the direct method, which better matched the results of limited initial testing.

Assessment of regression methods continued since the work of Kerr and Rafuse (2012), and included log-transformation of the data, on the basis that the frequency distributions for all lanthanide elements are positively skewed (*i.e.*, the median values of the data are significantly less than the midpoint of the data range). S. Amor (personal communication, 2011) suggested that this step was appropriate prior to regression. Regression of log-transformed data seems to reduce the influence of higher grade samples, and removes the need for discrete regression equations for different grade categories, simplifying the prediction process. Kerr and Rafuse (2012) also concluded that the indirect method provided no significant advantage, and it is not used in this study. Table 1 summarizes the suggested regression equa-

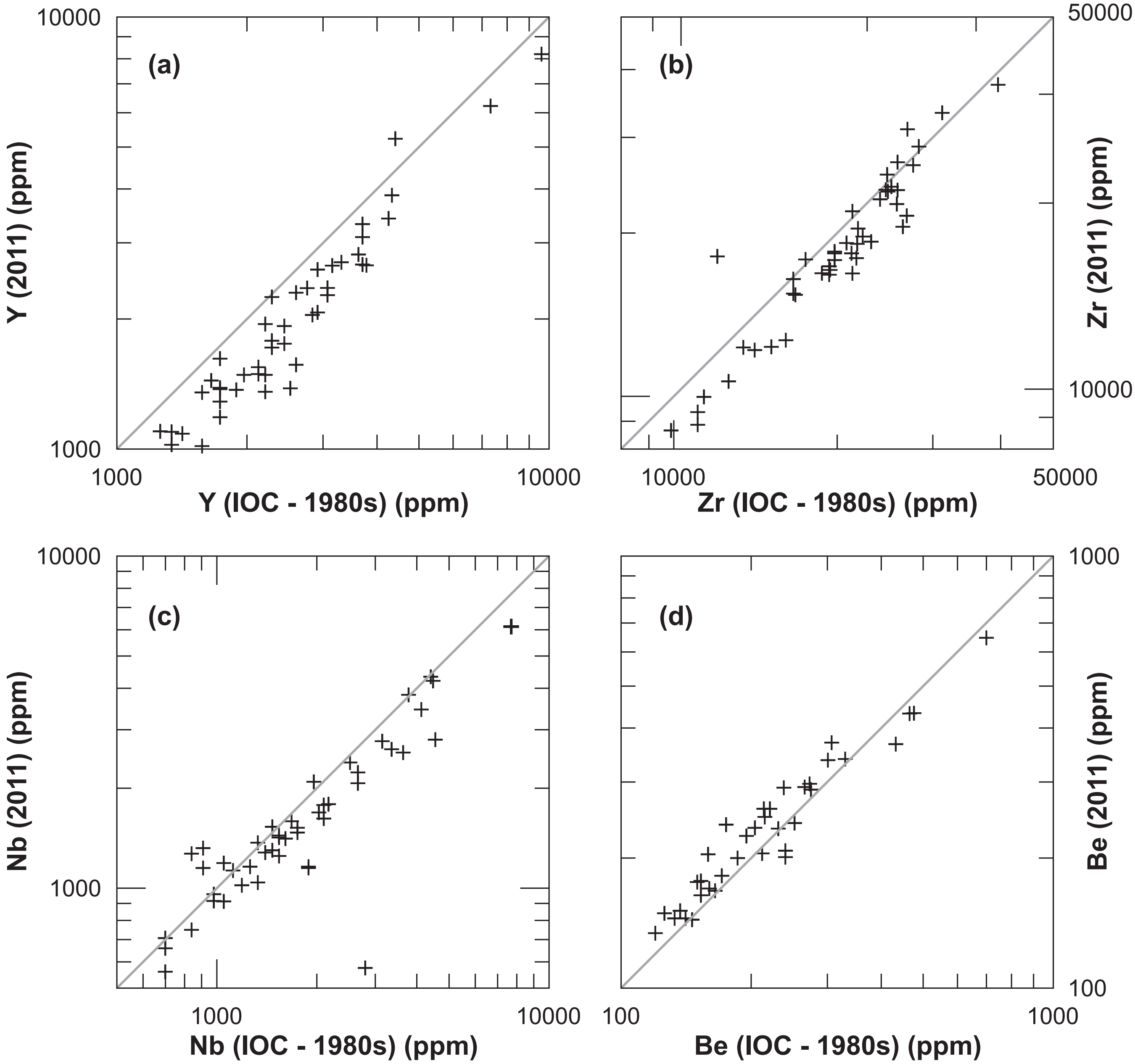

Figure 3. *Scatter plots showing the correlation and correspondence of data for (a) Y, (b) Zr, (c) Nb and (d) Be for analyses completed in the 1980s by IOC, and new analyses completed in 2011.*

tions from log-transformed data, linking the REE to the 1980s yttrium data. These form the basis for prediction of REE data discussed elsewhere in this report. The slopes and intercepts are logarithmic (base 10) values, such that calculation of predicted REE abundances follows the expression:

$$\text{Log}_{10}\ \text{REE (predicted)} = \text{M} * \text{Log}_{10}\ [\text{Yttrium}] + \text{C}$$
(equation 1)

where 'yttrium' is the measured value from 1980s exploration, M is the slope, and C is the constant Y-axis intercept. The predicted data value is obtained by reconversion from logarithmic values (*i.e.*, $10^{\text{Log REE (predicted)}}$). Note that the 1980s yttrium data are reported in weight percent oxide to two decimal places, and their conversion to ppm for calculation purposes thus has an inherent uncertainty of ± 100 ppm. This is of little significance at higher values (>2000 ppm Y or 0.25% Y_2O_3) but has more impact at lower concentrations, where it could introduce an additional 10% uncertainty.

The regression equations for heavy lanthanide elements (Gd to Lu) have the highest degree of correlation (R^2 = 0.53

Table 1. Regression parameters and statistics used for the prediction of lanthanide element abundances from IOC yttrium data. Note the general correlation between R^2 values and the difference in ionic radius of individual REE compared to that of yttrium (0.9)

Element	Ionic Radius (Å)	Slope [M]	Intercept [C]	R^2 Value
La	1.03	0.21474	2.12024	0.09
Ce	1.02	0.29330	2.22949	0.17
Pr	0.99	0.26770	1.35000	0.13
Nd	0.98	0.22343	2.02676	0.09
Sm	0.96	0.40630	0.84835	0.29
Eu	0.95	0.50097	-0.68794	0.44
Gd	0.94	0.51412	0.49884	0.52
Tb	0.92	0.66450	-0.64629	0.74
Dy	0.91	0.75045	-0.05121	0.82
Ho	0.90	0.81393	-0.88943	0.83
Er	0.89	0.87716	-0.57709	0.80
Tm	0.88	0.93444	-1.56479	0.75
Yb	0.87	0.96100	-0.82177	0.68
Lu	0.86	0.97523	-1.67446	0.63

NOTE: Regression equations of the form:

REE (predicted) = $10^{M * \log10(Y) + C}$

to 0.83) and hence the greatest reliability. The regressions for the light lanthanide elements have poorer correlation (R^2 < 0.5) with the worst results for La and Nd. There is a general relationship between the values of R^2 and the difference in the ionic radii of individual REE and Y (Table 1; Figure 4). The strongest correlation is between yttrium and holmium (Ho), which have almost identical ionic radii (0.9 Å), and correlations generally weaken systematically where REE ionic radii are greater or smaller. Such patterns likely indicate the ease of substitution of individual REE for Y in the host minerals, and confirm that such correlations have valid geological causes.

Correlation of Predicted and Measured Results

The equations listed in Table 1 were used to predict REE concentrations for Batch 2, using the 1980s data for Y_2O_3 as a starting point. Scatter plots are used to compare predicted values with the new measured values for the same samples (Figure 5). Cerium and Nd are used to represent the light REE (Figure 5a, b), and Dy and Yb to represent the heavy REE (Figure 5c, d). Investigations of the other elements suggest that these patterns are suitably representative, and they indicate two types of relationship.

The correlation of predicted and observed values for Dy and Yb is excellent (R^2 of 0.95 and 0.64, respectively), and these data arrays cluster around a reference line indicating equivalence (Figure 5c, d). The linearity of data is most evident for Dy, consistent with the very strong Dy–Y correlations noted from the first batch of samples, although there is some underestimation at higher values. Such patterns typify most of the heavy REE, but more scatter is observed for Yb and Lu, consistent with their smaller ionic radii compared to that of Y (Figure 4). The overall data ranges for predicted and observed values for heavy lanthanide elements are also

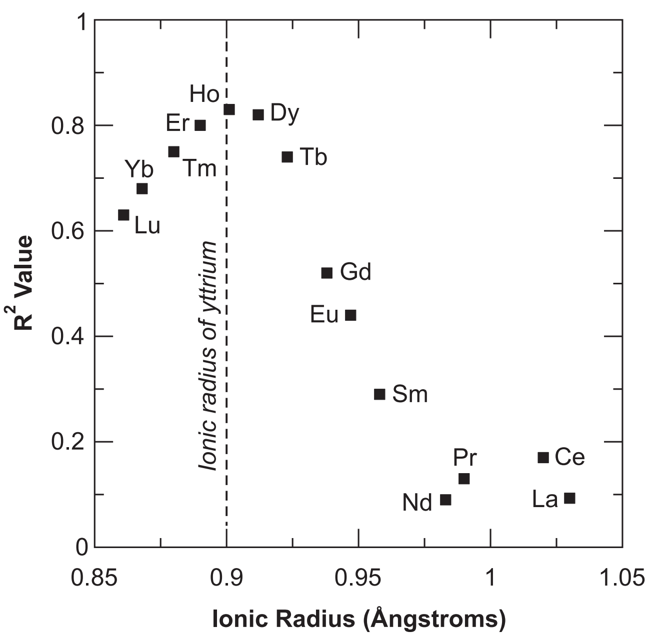

Figure 4. *Relationship between the R^2 value of linear regression analysis against yttrium and the ionic radii of individual REE.*

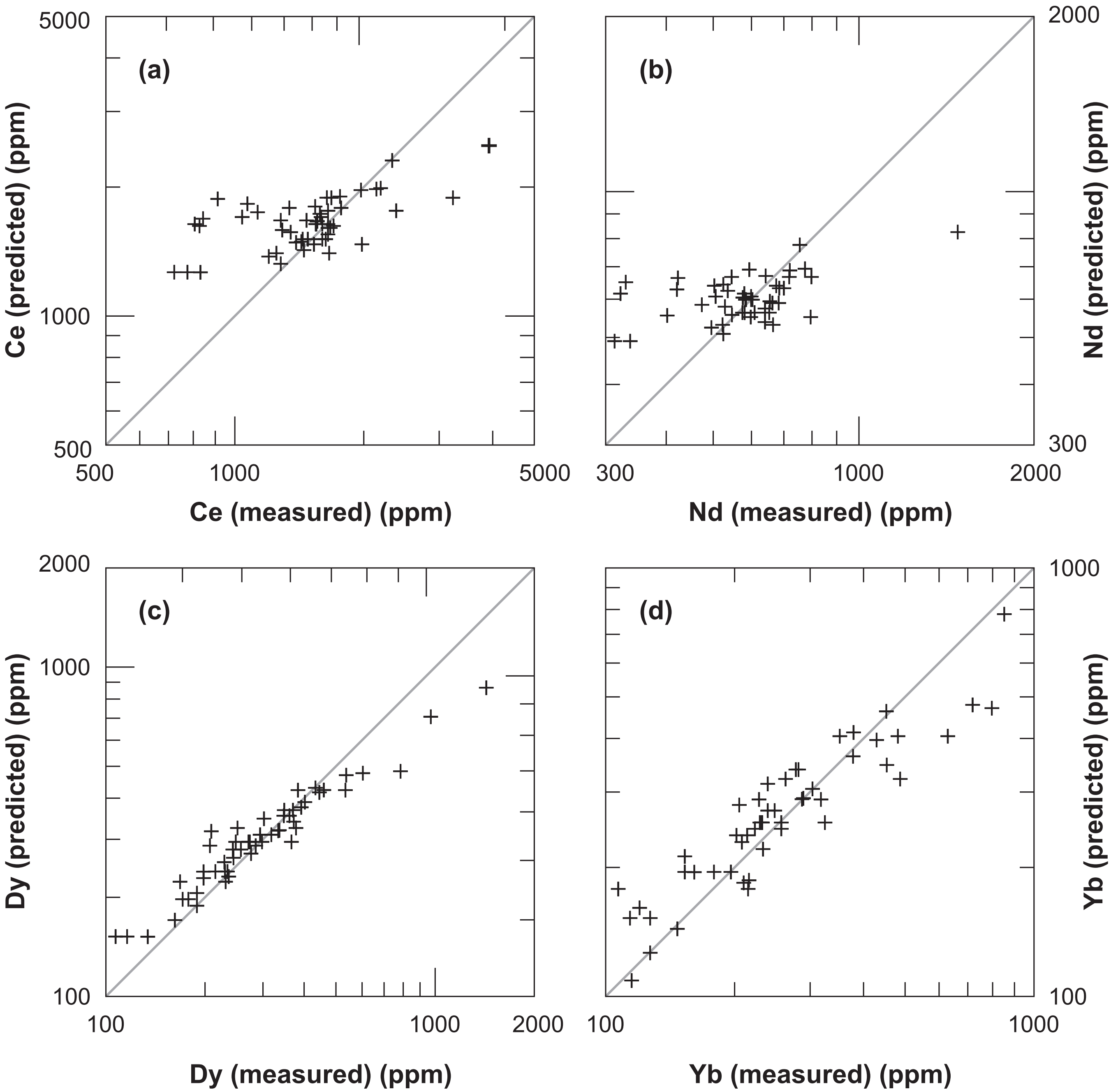

Figure 5. *Scatter plots showing the correlation and correspondence of predicted and measured data for the second batch of 50 samples. (a) Cerium and (b) Nd are provided as examples of light lanthanide elements; (c) Dy and (d) Yb are provided as examples of heavy lanthanide elements.*

closely similar. In contrast, data arrays for the light REE Ce and Nd trend obliquely across the reference line of equivalence, indicating that predictions are overestimates at low concentrations, and underestimates at high concentrations (Figure 5a, b). The overall data range for predicted values is also only about half as much as for the observed values, but most of the data cluster around the reference line between 1000 and 3000 ppm (for Ce) and between 500 and 900 ppm (for Nd). The correlations of predicted and observed values for Ce and Nd are also poorer (R^2 of 0.28 for both). Below about 1000 ppm Ce, predicted values may be as much as double the measured values (Figure 5a), and a similar tendency is seen below about 400 ppm Nd (Figure 5b). A tendency toward the overestimation of LREE at lower concentrations was also noted in initial testing (Kerr and Rafuse, 2012), and is apparently not entirely removed by log-transformation prior to regression. The indirect regression method noted previously was also tested with reference to the 2011 results, but it did not offer any significant improvement, although it does enlarge the data range for the predicted values somewhat.

The results of this simple test suggest that prediction of heavy REE concentrations seems to be reliable at all but the highest concentrations, but confirm that prediction of the light REE at low concentrations is problematic. There may also be a tendency to underestimate light REE concentrations at higher values, but there are less data in this range upon which to base conclusions.

Assessment of Prediction Discrepancy

It is important that the accuracy and reliability of predictions be quantified, as these uncertainties will persist and likely propagate if such data are used as input for resource calculations (*see* below). The simplest measure is a parameter here termed *Prediction Discrepancy*, (PD_X) which is given by:

$$PD_X\,(\%) = 100 * (X_P - X_M) \;/\; ((X_P + X_M) / 2) \quad \text{(equation 2)}$$

where X_P is the predicted value and X_M is the measured value for the sample. This expression is analogous to that used to estimate analytical precision (as ± %) values using analyses of duplicate or replicate samples. In that context, the result is converted to an absolute number, but in the context of this study it is important to know if the prediction is an overestimate or an underestimate. Positive values of PD_X indicate overestimation, whereas negative values indicate underestimation. Table 2 summarizes this information for all of the samples in Batch 2.

As implied by the relationships in Figure 5, there is for some elements a predictable relationship between PD_X and the concentrations measured in 2011, as illustrated in Figure 6. For the light REE (*e.g.*, Ce, Nd), there is a strong inverse relationship, such that PD_X is positive at lower concentrations and variably negative at high concentrations (Figure 6a, b). The overestimation at low concentrations is more obvious than the underestimation at higher values, but there are less data in the higher range. The patterns for heavy REE Dy and Yb show less variation in PD_X with their measured values, although there remains some indication of mild overestimation at lower concentrations, and mild underestimation at higher values (Figure 6c, d).

Knowledge of this relationship between PD_X and the true concentrations theoretically allows correction of predicted values, but this is not useful in a real situation because only the predicted values are known. Nevertheless, such relationships need to be assessed, to assess the relative frequency and severity of overestimation or underestimation. In the cases of Dy and Yb, and other heavy lanthanides, individual PD_X values are both positive and negative, so in a sufficiently large dataset, overestimation and underestimation will tend to cancel each other out wherever a central measure (mean or median) is derived. Calculating the mean and median values of PD_X from the entire dataset provides a simple evaluation of how accurate the equivalent statistics from predicted values should be; Table 2 (Part 1) shows that for all REE except Tb, mean or median PD_X is weakly positive, indicating that prediction tends to overestimate values. In most cases, the median values for PD_X are smaller than the mean values, suggesting that this statistic may actually provide a better estimate. However, it is important to understand that this method of assessing prediction discrepancy provides a measure of the mean or median reliability of an *individual* (*i.e.*, sample-level) prediction. There is a slightly different method that can be used to assess the precision of mean or median estimates from predicted REE data, which is probably more relevant to the objectives of this study. It is discussed in more detail in the next section.

PREDICTION OF CENTRAL MEASURES AND OTHER BULK PARAMETERS

The objective of this study is to assess methods that can be used in bulk resource estimation, and there is no assumption or requirement that these can also provide accurate prediction of REE values at an individual sample level. The conclusion that sample-level predictions will be variably unreliable does not come as any surprise. The wider objective is to find a way to derive *central measures* of composition such as weighted mean grades for a drillhole or a bulk resource calculation. In this context, it is the *bulk parameters* of the orebody that matter most, not the individual details of the hundreds of assays used in such computation.

Table 2 (Part 2) also lists the mean and median of measured REE abundances for the entire dataset, and the mean and median of the predicted values for each element. As would be expected, the mean and median values for predictions differ from those for observations, but the match is very close for many of the heavy REE. These centralized values can be used as input for equation 2, and the resulting value is termed PD_{XMEAN} or $PD_{XMEDIAN}$, as appropriate. For example, the mean PD_X value for Nd is 9.3% (based on all of the individual values), but the PD_{XMEAN} mean value is given by ((598.6 - 583)/ 586.3)*100, which yields a significantly better value of 4.8%.

In general, the PD_{XMEAN} and $PD_{XMEDIAN}$ values listed in Table 2 (Part 2) are smaller positive or negative values than those derived from averaging the PD_X values of individual records, and they indicate a better match between predicted

Table 2. Part 1: Summary of prediction discrepancy for individual REE elements based on individual comparisons of predicted and measured values. Part 2: Mean and median values for predicted and measured data, and the prediction discrepancy values calculated using these values as input for calculation

Element		**Y(IOC)**	**Y**	**La**	**Ce**	**Pr**	**Nd**	**Sm**	**Eu**	**Gd**	**Tb**	**Dy**	**Ho**	**Er**	**Tm**	**Yb**	**Lu**
Part 1: Prediction Discrepancy Values																	
Best Positive PD_X	%			1.2	1.0	0.5	1.4	0.2	0.6	0.3	0.5	0.7	0.7	1.2	1.4	0.3	0.5
Worst Positive PD_X	%			73.3	69.2	70.2	77.5	74.7	67.0	57.4	43.5	41.1	42.6	46.6	43.0	56.9	83.9
Best Negative PD_X	%			-0.1	-0.2	-0.3	-0.1	-1.5	-0.8	-1.1	-0.5	-0.2	-0.5	-0.4	-0.3	-0.4	0.0
Worst Negative PD_X	%			-73.2	-52.4	-55.5	-63.4	-63.2	-54.0	-59.8	-61.6	-49.1	-42.1	-38.8	-47.0	-51.4	-48.0
Mean of PD_X	%			8.9	11.1	8.6	9.3	9.8	6.9	4.3	-1.6	2.4	7.1	8.9	2.3	4.5	12.2
Median of PD_X	%			2.8	6.0	1.3	1.7	5.3	1.2	0.3	-3.2	3.2	9.0	10.9	5.1	8.8	16.6
Part 2: Summary of Predicted and Measured Values																	
Mean REE Values																	
Measured			2112.4	677.1	1556.9	172.4	576.0	159.0	10.0	176.5	44.8	336.1	76.9	254.8	43.6	289.4	42.1
Predicted		2627.6	2154.7	700.6	1664.3	179.8	604.6	167.7	10.3	175.0	41.1	319.5	76.8	260.8	42.4	289.9	45.6
Median REE Values																	
Measured			1735.0	657.0	1545.0	175.0	583.0	157.0	9.7	165.0	37.8	273.5	60.9	206.0	35.4	232.0	34.3
Predicted		2283.0	1872.1	694.1	1638.9	177.4	598.6	163.3	9.9	168.1	38.5	294.6	69.8	233.8	37.5	254.5	39.9
PD_{XMEAN}	%			3.4	6.7	4.2	4.8	5.3	2.8	-0.8	-8.6	-5.0	-0.1	2.3	-2.9	0.2	8.1
$PD_{XMEDIAN}$	%			5.5	5.9	1.4	2.6	3.9	2.1	1.8	2.0	7.4	13.8	12.6	5.8	9.3	15.1

Notes
PD_X represents the percentage difference between predicted and measured values compared to their mean value
Predicted values for yttrium represent an 18% reduction from IOC values

and measured values of bulk parameters. Essentially, the overestimation for some samples is counterbalanced by underestimation of other samples. Given that the analytical precision for most of the REE by ICP-MS methods is probably ± 5%, and there is a similar inherent uncertainty in the 1980s Y_2O_3 data used as a basis for estimation, this provides encouragement as to the overall reliability of resource estimates calculated using predicted data.

However, a caveat! The mean values listed in Table 2 represent *arithmetic* means, in which each result is accorded equal weight. This is different from the approach used in resource estimation, in which results are weighted according either to their perceived reliability, the amount of material that they are considered to represent, or both factors. In such a *weighted* estimation, the amount of material represented by higher grade analyses is typically a small part of the larger entity, and has a proportionally lesser impact on the result. Lower grade material is typically dominant in terms of total amount, but much of the lowest grade category would likely be excluded from resource calculations, because it will not meet the lower grade limit (cut-off grade) for inclusion in the resource.

Figure 7 illustrates the correspondence between the mean predicted REE concentrations and measured values for samples re-analyzed in 2011, using both raw analytical data (Figure 7a) and the more familiar chondrite-normalized method (Figure 7b). The two lines for the raw un-normalized data are so close as to be indistinguishable, except for the low-abundance elements Eu, Tb and Lu. The underestimation of Tb and overestimation of Lu would have negligible effects upon overall grade, as they are generally present only as a few tens of ppm. The chondrite-normalized plot accentuates differences by virtue of scaling changes, but the match remains extremely close, especially for the heavy REE elements. The yttrium values are also extremely close, if the 1980s data are corrected on the basis of the 18% difference noted in Figure 3. The predictions do not exactly match observations, and this is to be expected. However, the PD_{XMEAN} or $PD_{XMEDIAN}$ values listed in Table 2 (Part 2) provide an empirical method by which a predicted bulk composition can be adjusted to more

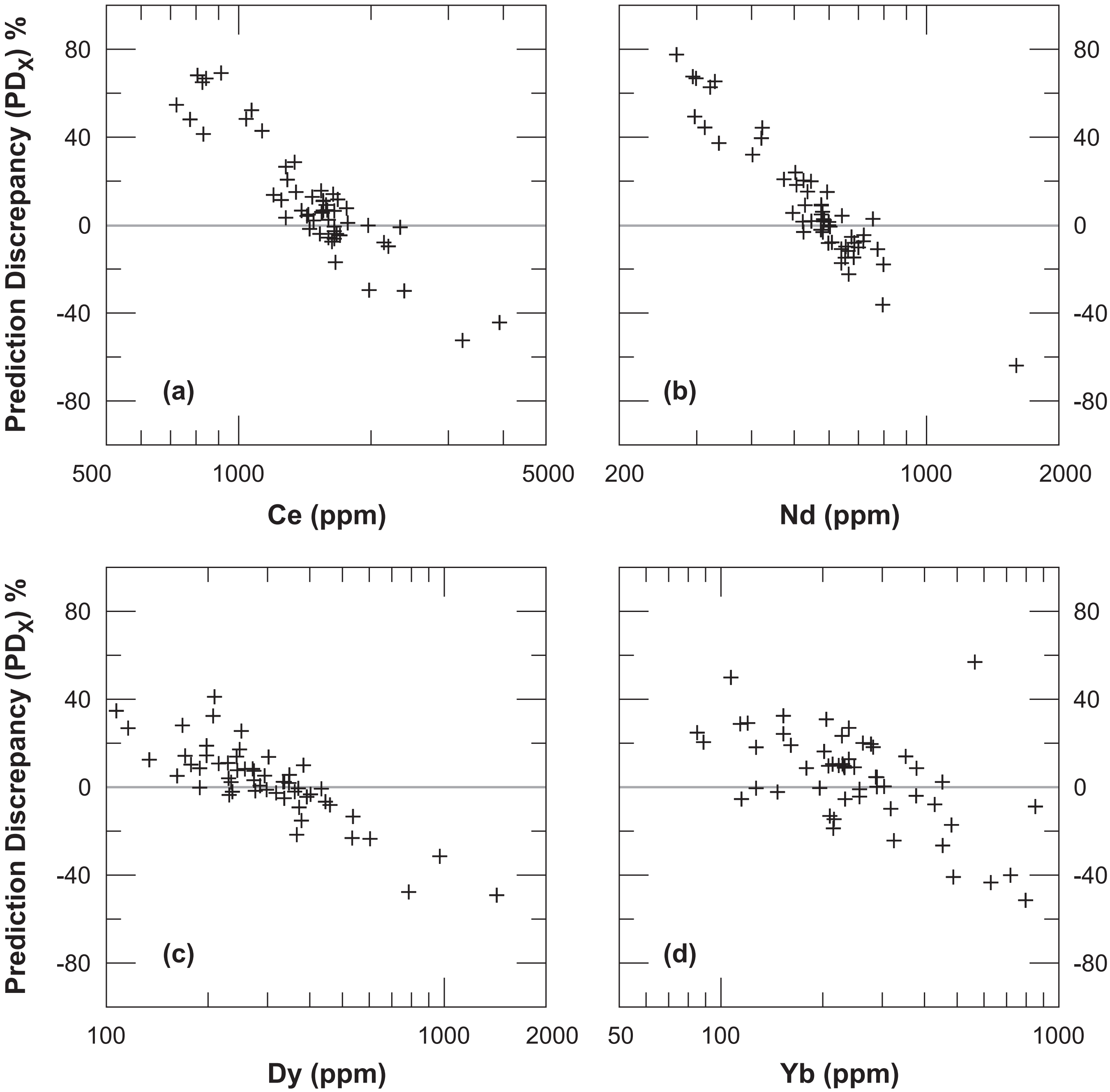

Figure 6. *Scatter plots showing the relationship between the prediction discrepancy and measured values for (a) Ce, (b) Nd, (c) Dy and (d) Yb. The prediction discrepancy is the difference between predicted and measured values, expressed as a percentage of their mean value;* see *text for further discussion.*

closely approach observed values. This is far simpler than attempting to correct such data within the calculation process.

ASSESSMENT OF 'TWINNED HOLES' FROM THE ZONE 1 LENS IN QUÉBEC

A second test of the methods involved comparison of predicted REE concentrations for holes drilled in the 1980s with those measured from closely adjacent ('twinned') drillholes completed in 2009. These results come from the extension of the Zone 1 Lens in adjacent Québec, where Quest Rare Minerals Ltd. drilled 30 holes in 2009 (Figure 2), but the results apply to the Main Zone as well. Eleven of the 2009 drillholes were sited within 11 m of drillholes completed by IOC in the 1980s, and were deliberately intended

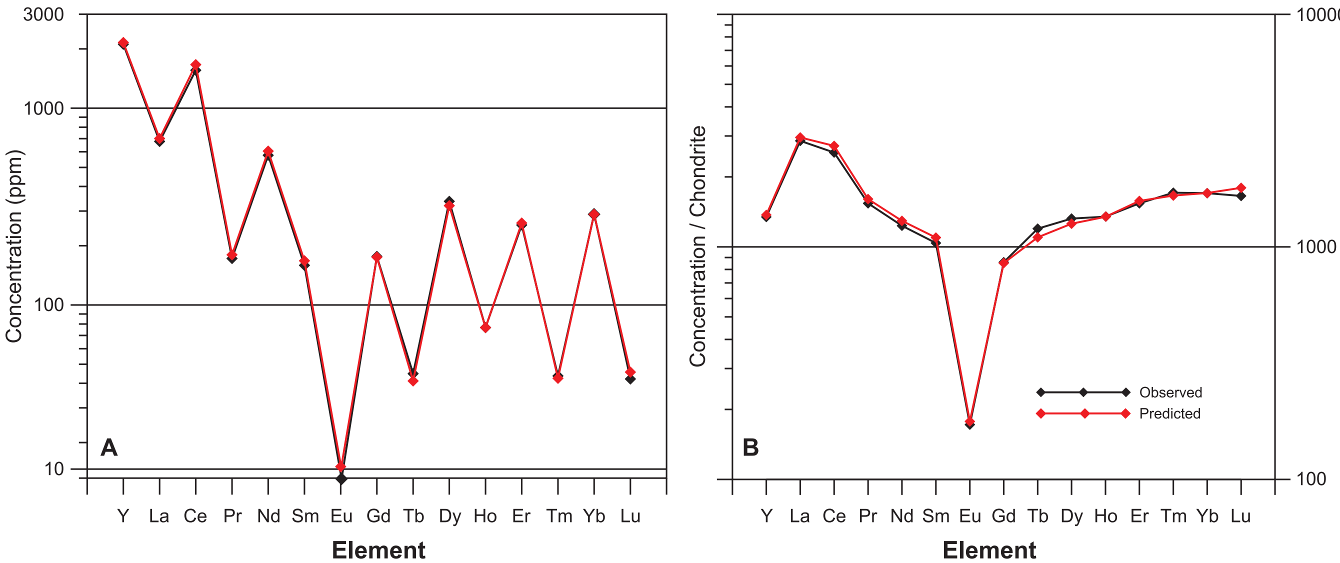

Figure 7. *Comparison of the mean REE profiles for predicted and measured data for the second batch of 50 samples. (a) untransformed data, in ppm; (b) chondrite-normalized REE profile, using chondritic values of Taylor and McLennan (1985).*

to test the reliability of earlier results. The holes are all short, and vertical, so they remain closely equivalent throughout their lengths. Given the proximity, it is reasonable to expect that the rock types and grades encountered over equivalent depths in the 1980s and in 2009 should correspond well, although this is not guaranteed (*see* below). The data from exploration in Québec are now in the public domain (Collins and Cashin, 2010), and were kindly made available to the author in digital form by Quest Rare Minerals Ltd. The data from the 1980s holes are contained within several IOC assessment reports including Miller (1984) for adjacent Quebec. Of the 11 pairs, only 10 could be assessed, as data from one of the 1980s drillholes is missing from the IOC reports. In most cases, the IOC drillholes were located in Québec (LB-series), but others are actually located in Labrador according to topographic map data (SL-series). This reflects the inherent uncertainty in the location of the border.

In contrast to the first type of test, in which the old and the new data represent *exactly* the same sample material, testing using twinned drillholes introduces some additional sources of variation. The most obvious are geological factors, such as true differences in rock type or grade, or in the thickness of the mineralized units. The drillholes are all vertical, and the mineralized pegmatite–aplite zones are gently dipping to flat (Miller, 1996), but this does not preclude marked changes in thickness or local attitude from hole to hole. A second factor that must be considered relates to sampling errors; the 1980s data are from AQ drillcore (~2.5 cm diameter), whereas the 2009 data are from NQ drillcore (~5 cm diameter). Thus, the effective volume of an analyzed interval for a given length is about 4 times larger for the 2009 results. This would have limited impact in finer grained, homogeneous rocks, but it could be significant in coarse-grained pegmatites. Examination of 1980s drillcore in the Goose Bay core-storage library suggests that core recovery was generally very poor in pegmatitic intervals, so the effective differences due to sample size may be even larger. The most significant source of uncertainty relates to the style of mineralization, in which discontinuous high-grade pegmatite and aplite zones occur within low-grade subsolvus granite. Examination of REE patterns from the first batch of 100 analyses indicated that pegmatite and aplites show the most variation, in that many are relatively depleted in light REE and enriched in heavy REE, whereas others show the opposite pattern (Kerr and Rafuse, 2012). The REE patterns for these rocks are thus intrinsically more difficult to predict on the basis of yttrium data. Collectively, these factors imply that the prediction discrepancy (PD_{XMEAN}) for twinned drillholes should be significantly worse than for the first test where the samples correspond directly, and this is borne out by the results (Table 3).

Table 3 (Part 1) compares the weighted means of predicted values for ten drillholes from the 1980s to the weighted means of measured analyses for the adjacent 2009 drillholes. In all cases, weighting was on the basis of interval lengths. The total lengths used from the 2009 holes were selected to correspond as closely as possible to the final depths of the generally shorter drillholes from the 1980s. The deeper sections of the 2009 drillholes were excluded, although some actually contained good grades of mineralization. Table 3 also lists the PD_{XMEAN} values that assess the correspondence between predicted values for 1980s drillholes and measured values for 2009 holes. Table 3 (Part 1) also lists the weighted means for Y, Zr, and Nb, which are measured values for both 1980s and 2009 exploration. These latter values are important, as large differences (seen in some cases for Zr and Nb) likely indicate real geological differences between materials intersected by the two holes.

The results from twinned drillholes are variable. The weighted means for predictions and measurements for some pairs compare well, having PD_{XMEAN} values that range between +10% and -10% for most elements (*e.g.*, LB-22/SL-09-004 and LB-60/SL-09-003). For other drillholes, notably those with short lengths or higher overall REE contents, the PD_{XMEAN} values indicate greater divergence between predicted and observed values, particularly for the less-abundant heavy REE, such as Tb, Tm and Lu. In general, the worst results are for paired drillholes where there are also significant differences between 1980s and 2009 results for Y, Zr and Nb (*e.g.*, SL-19/SL-09-006, SL-47/SL-09-012 and LB-55/SL-09-013). This suggests (but does not prove) that there could be real geological differences between these paired drillholes, despite their proximity to one another. In general, the best results are for the heavy REE.

Once again, it must be remembered that the purpose of this investigation is to assess methods for resource estimation. Thus, Table 3 (Part 2) also lists the arithmetic and weighted means for predicted and measured data for the 1980s and 2009 drillholes, with weighting on the basis of their total lengths. This is exactly the type of calculation that would be involved in calculation of grade for a resource estimate based on these drillholes. Viewed from this perspective, there is a much better match between the weighted means, with PD_{XMEAN} values sitting within ± 5% for most light REE (aside from Nd and Eu) and within ± 15% for most heavy REE (aside from Yb and Lu). Note also that the worst prediction discrepancy values mostly come from the least abundant elements. The weighted mean of predicted total REE content from 1980s drillholes is only about 2% lower than the weighted mean from the adjacent 2009 holes, and the predicted yttrium content is only about 5% lower. In view of the possibility that there may be real geological differences between adjacent holes, this correspondence of the central measures is extremely good. These results, which constitute an independent test of the regression equations in Table 1, are not radically worse than those derived for the first test, in which predicted and measured values came from exactly the same samples (Table 2).

RESOURCE ESTIMATES FOR THE MAIN ZONE DEPOSIT

DATABASE AND PREVIOUS WORK

In total, 266 drillholes were completed in Labrador within the Strange Lake Intrusion, and an additional 113 holes were completed on the Québec side of the border (IOC, 1985). Some of these represent regional exploration holes in outlying areas, but most lie within a 4 km^2 area centred on the Main Zone (Figure 2). Within this area, the highest density of drillholes is in and around the Zone 1 Lens. Drillholes are not arranged on a regular grid, but there are several 'fences' of holes oriented in both north–south and east–west orientations. In the Zone 1 Lens area, holes are typically separated by less than 50 m, but in the larger area of exotic-rich subsolvus granite to the southwest, they may be hundreds of metres apart. Virtually all drillholes at Strange Lake were vertical, and most are short (<60 m). The large database for Labrador is now compiled into digital format. In the main area of mineralization, all intervals were assayed for Zr, Y, and Nb, and most were assayed for Be. Other elements such as U, Th, Ce, Sn and Pb were also analyzed for some holes. 'Total Rare Earth Oxides' are reported for many samples, but it is not clear how many of these determinations represent actual measurements and how many are estimates derived either from Y_2O_3 or Ce analyses.

The methods used for calculation of 'reserves' in the 1980s are not fully outlined in available documents, and no tabular listing for the block model used to calculate the volume of mineralization is available. The overall estimate for the Main Zone derived in the feasibility study was 55.8 million metric tonnes at 2.99% ZrO_2, 0.38% Y_2O_3, 0.29% Nb_2O_5 and 0.08% BeO; the REE oxide content (excluding Y) was estimated at 0.54% (IOC, 1985; Table 4). Higher grade estimates for specific parts of the Zone 1 Lens were derived as part of preliminary mining plans, but the tonnages to which these apply remain unclear. The resource calculation described below was completed independently from first principles; Figure 2 shows the outline of the area included in the calculation. A map, since provided by S. Zajac (personal communication, 2012), shows that IOC also used mostly rectangular blocks constructed around drillholes, and these are similar to, but not exactly the same, as those used in this estimate.

RESOURCE CALCULATION METHODS

As pointed out in the Introduction, such calculations do not meet the criteria in NI 43-101. Resource calculation for the Main Zone is simple, because all the holes are vertical, and most were assayed in their entirety. The exotic-rich subsolvus granite (in the southwest part of the area) is a homogeneous rock type containing disseminated mineralization, but the Zone 1 Lens area includes more variable and sporadic pegmatite–aplite zones. There is greater uncertainty of grade continuity in this latter area, as indicated in part by the results from some of the twinned drillholes in adjacent Québec. The resource calculation was conducted using the following sequential steps:

Table 3. Part 1: Comparison of weighted means for predicted REE abundances based on 1980s drillholes with weighted means for measured values for 2009 drillholes completed at closely adjacent locations in the Zone 1 Lens area of the Strange Lake Main Zone deposit. The 2009 data were provided by Quest Rare Minerals (see Collins and Cashin, 2011). Part 2: Comparisons of the weighted mean values for all 1980s holes (predicted data) and weighted mean values for all 2009 holes (measured data); this represents the type of calculation involved in using such data to calculate grades for a resource estimate

Hole	Length	Zr	Nb	Y	Y (corr)	La	Ce	Pr	Nd	Sm	Eu
Part 1: Weighted Means for Predicted Data (LB-, SL- series holes from 1980s) and Measured Data (SL-09 series drilled in 2009)											
SL-149	10.7	14655.5	6033.2	7055.3	5785.4	853.6	2185.5	230.4	742.6	245.9	16.5
SL-09-001	9.0	15319.6	4084.0	5347.7	5347.0	1060.1	2569.0	276.6	952.1	309.7	21.4
PD $_{XMEAN}$ (%)		-4.4	38.5	27.5	7.9	-21.6	-16.1	-18.2	-24.7	-23.0	-25.8
LB-71	10.8	19576.5	5840.7	6034.9	4948.6	834.8	2118.0	224.0	725.6	234.8	15.6
SL-09-002	11.0	20902.6	4758.4	6318.5	6318.5	1055.1	2437.1	246.3	824.7	281.7	20.5
PD $_{XMEAN}$ (%)		-6.6	20.4	-4.6	-24.3	-23.3	-14.0	-9.5	-12.8	-18.2	-27.2
LB-60	31.1	12257.0	2241.6	3116.4	2555.5	716.8	1719.3	185.2	619.2	175.9	10.9
SL-09-003	28.4	11113.5	1860.6	2482.6	2482.6	671.2	1574.2	178.4	601.1	169.1	11.0
PD $_{XMEAN}$ (%)		9.8	18.6	22.6	2.9	6.6	8.8	3.7	3.0	4.0	-0.5
LB-22	30.2	13213.7	1229.9	1833.3	1503.3	653.7	1512.2	164.8	562.5	146.5	8.7
SL-09-004	28.4	11503.0	1252.0	1737.0	1737.0	636.6	1464.7	164.9	575.0	150.5	9.2
PD $_{XMEAN}$ (%)		13.8	-1.8	5.4	-14.4	2.7	3.2	0.0	-2.2	-2.7	-6.2
SL-19	13.4	10808.4	1064.8	1088.0	892.1	591.8	1318.0	145.4	507.0	120.7	6.8
SL-09-006	12.0	14683.8	1623.9	2110.8	2110.8	608.5	1421.2	171.1	608.3	172.9	11.0
PD $_{XMEAN}$ (%)		-30.4	-41.6	-64.0	-81.2	-2.8	-7.5	-16.2	-18.2	-35.5	-47.1
LB-59	31.7	11753.8	1029.3	1821.4	1493.6	661.2	1533.6	167.0	569.1	148.9	8.8
SL-09-008	32.0	11441.4	945.8	1397.1	1397.1	685.1	1565.6	188.9	762.6	176.9	11.3
PD $_{XMEAN}$ (%)		2.7	8.5	26.4	6.7	-3.5	-2.1	-12.3	-29.1	-17.2	-25.1
LB-19	17.1	12862.9	1209.6	1370.6	1123.9	621.8	1410.2	154.7	533.8	132.6	7.6
SL-09-009	18.0	11790.7	1075.4	1407.7	1407.7	658.9	1506.7	179.8	716.9	172.8	11.3
PD $_{XMEAN}$ (%)		8.7	11.7	-2.7	-22.4	-5.8	-6.6	-15.0	-29.3	-26.3	-39.0
SL-47	14.6	13263.5	2677.3	1446.2	1185.8	734.1	1771.7	190.4	634.6	182.4	11.4
SL-09-012	14.0	15353.0	2541.8	1775.4	1775.4	725.6	1702.3	181.7	653.5	181.0	11.7
PD $_{XMEAN}$ (%)		-14.6	5.2	-20.4	-39.8	1.2	4.0	4.7	-2.9	0.8	-3.1
LB-55	22.35	14079.6	1517.0	2356.9	1932.6	692.8	1636.2	177.1	597.5	163.2	9.9
SL-09-013	22.0	8974.3	1070.6	1476.0	1476.0	690.2	1500.9	174.4	601.2	150.9	9.1
PD $_{XMEAN}$ (%)		44.3	34.5	46.0	26.8		0.4	8.6	1.6	-0.6	7.9
LB-57	27.13	11610.3	1088.1	1779.0	1458.7	657.1	1520.9	165.7	565.4	147.3	8.7
SL-09-014	27.33	10208.0	1054.2	1294.6	1294.6	707.3	1481.2	170.2	581.8	140.6	8.3
PD $_{XMEAN}$ (%)		12.9	3.2	31.5	11.9	-7.4	2.6	-2.7	-2.9	4.6	5.2
Part 2: Mean Values for all 10 Pairs of Drillholes											
Arithmetic Means											
1980s prediction	13408.1	2913.3	2270.0	1861.4		698.4	1661.8	179.4	602.7	168.4	10.4
2009 measured	13129.0	2611.4	1950.0	1950.1		749.8	1722.3	193.2	687.7	190.6	12.5
PD $_{XMEAN}$ (%)	2.1	10.9	15.2	-4.7		-7.1	-3.6	-7.4	-13.2	-12.4	-18.4
Weighted Means (weighting by total length)											
1980s prediction	12957.7	2528.9	1849.1	1516.2		685.1	1616.2	175.0	590.7	161.5	9.8
2009 measured	12150.8	2158.4	1602.1	1602.1		712.6	1621.9	184.6	662.6	175.7	11.3
PD $_{XMEAN}$ (%)	6.4	15.8	14.3	-5.5		-3.9	-0.4	-5.3	-11.5	-8.4	-13.8

NOTES

The data for SL-09 series holes come from Quest Rare Minerals Inc., now in the public domain (assessment report of Collins and Cashin, 2011)

Y (corr) represents correction of 1980s Y values by -18%, in accordance with observation from reanalysis of both batch 1 and batch 2 samples

TREO* denotes total rare-earth-element oxides, including yttrium oxide, expressed as weight percent. All other entries are ppm element

Table 3. *(Continued)*

Hole	Gd	Tb	Dy	Ho	Er	Tm	Yb	Lu	TREE	TREO*%
Part 1: Weighted Means for Predicted Data (LB-, SL- series holes from 1980s) and Measured Data (SL-09 series drilled in 2009)										
SL-149	285.7	78.1	663.1	170.1	616.7	106.3	747.7	119.5	7061.7	1.56
SL-09-001	394.8	110.9	781.4	180.3	533.3	90.5	522.3	62.3	7864.7	1.60
PD $_{XMEAN}$ (%)	-32.1	-34.7	-16.4	-5.8	14.5	16.1	35.5	62.8	-10.8	-2.4
LB-71	268.6	71.6	598.4	151.6	542.3	92.3	645.4	102.8	6625.7	1.40
SL-09-002	382.1	120.8	922.8	227.0	707.0	124.4	752.9	94.5	8197.0	1.76
PD $_{XMEAN}$ (%)	-34.9	-51.2	-42.7	-39.9	-26.4	-29.6	-15.4	8.4	-21.2	-22.6
LB-60	186.7	45.0	356.4	86.9	299.6	49.4	340.2	53.8	4845.3	0.89
SL-09-003	197.4	52.6	378.1	89.6	268.7	46.5	280.8	35.0	4553.8	0.85
PD $_{XMEAN}$ (%)	-5.5	-15.6	-5.9	-3.1	10.8	6.1	19.1	42.2	6.2	5.0
LB-22	147.2	32.7	246.0	57.7	191.1	30.4	205.5	32.2	3991.1	0.66
SL-09-004	166.7	39.6	273.0	63.7	198.7	35.3	225.5	29.5	4033.0	0.69
PD $_{XMEAN}$ (%)	-12.4	-19.2	-10.4	-10.0	-3.9	-15.2	-9.3	8.6	-1.0	-5.1
SL-19	114.8	23.5	168.8	38.2	122.0	18.7	124.8	19.4	3320.0	0.50
SL-09-006	194.1	51.2	356.7	82.9	253.5	44.3	271.8	34.4	4281.7	0.77
PD $_{XMEAN}$ (%)	-51.4	-74.0	-71.5	-73.9	-70.0	-81.1	-74.1	-56.0	-25.3	-42.1
LB-59	149.6	33.1	248.6	58.1	191.8	30.3	204.9	32.0	4037.1	0.66
SL-09-008	209.8	34.1	222.3	49.0	144.9	24.6	152.1	19.7	4246.8	0.67
PD $_{XMEAN}$ (%)	-33.5	-3.0	11.2	17.0	27.9	20.8	29.6	47.9	-5.1	-1.8
LB-19	129.2	27.4	200.7	46.1	149.4	23.2	155.9	24.3	3617.0	0.57
SL-09-009	212.9	35.5	231.1	50.0	143.3	23.6	141.5	17.8	4102.1	0.66
PD $_{XMEAN}$ (%)	-48.9	-25.6	-14.1	-8.1	4.1	-1.6	9.6	30.7	-12.6	-15.2
SL-47	194.0	46.6	367.3	89.0	304.7	49.8	341.9	53.9	4971.9	0.73
SL-09-012	212.7	56.2	395.2	93.7	290.7	49.9	306.2	39.1	3969.8	0.69
PD $_{XMEAN}$ (%)	-9.2	-18.6	-7.3	-5.1	4.7	-0.1	11.0	31.7	22.4	6.0
LB-55	168.5	38.8	298.4	71.0	238.9	38.4	261.8	41.1	4433.8	0.76
SL-09-013	151.5	36.0	242.5	55.6	169.2	29.1	178.7	22.9	4012.2	0.66
PD $_{XMEAN}$ (%)	10.6	7.4	20.7	24.4	34.2	27.8	37.7	56.7	10.0	15.1
LB-57	147.6	32.6	243.9	57.0	187.7	29.7	200.2	31.3	3995.1	0.65
SL-09-014	140.3	31.0	200.9	44.9	133.1	22.5	140.4	18.6	3821.1	0.61
PD $_{XMEAN}$ (%)	5.0	5.0	19.4	23.6	34.1	27.3	35.1	50.7	4.5	6.5
Part 2: Mean Values for all 10 Pairs of Drillholes										
Arithmetic Means										
1980s prediction	177.3	42.4	334.6	81.4	280.3	46.2	318.1	50.3	4651.6	0.78
2009 measured	226.2	56.8	400.4	93.7	284.2	49.1	297.2	37.4	4908.2	0.82
PD $_{XMEAN}$ (%)	-24.2	-29.0	-17.9	-14.0	-1.4	-6.1	6.8	29.4	-5.4	-5.2
Weighted Means (weighting by total length)										
1980s prediction	167.5	39.1	304.3	73.2	249.2	40.6	278.3	43.8	4434.4	0.71
2009 measured	203.4	48.1	334.4	77.7	235.2	40.6	247.8	31.5	4522.9	0.73
PD $_{XMEAN}$ (%)	-19.3	-20.5	-9.4	-5.9	5.8	0.0	11.6	32.9	-2.0	-2.9

1. All drillhole locations in the central area were superimposed upon a UTM grid, and rectangular 'areas of influence' were drawn manually around each drillhole. The objective was to keep these areas as small as possible, and centred upon the drillholes. A line approximately along UTM northing coordinate 6241400 forms a convenient boundary (Figure 2). The Zone 1 Lens lies north of this line, and has a higher drillhole density. The areas of influence for individual holes in this northern sector are relatively small, ranging from 25 x 25 m (625 m^2) to around 80 x 80 m (6400 m^2), although not all are square. South of 6241400, drillholes are more widely spaced and their areas of influence range up to 100 x 100 m (10 000 m^2). In both the northern and southern sectors, this grid-based approach left a small number of areas of a similar size range that remain unrepresented by approximately central drillholes; the treatment of these is discussed below.

2. The REE data for all these drillholes were calculated using the regression expressions listed in Table 1, with the IOC Y_2O_3 data as the starting point. All calculations provided elemental data expressed as ppm, rather than weight % oxide values. The IOC data for ZrO_2, Nb_2O_5 and BeO were likewise converted, and added to the database. The weighted means for Y, Zr, Nb, Be and individual REE were then calculated for each hole, with weighting on the basis of interval length. The assay results were not capped.

3. Areas that were not defined by central drillholes, but surrounded by mineralized drillholes, were assigned grades, based on the arithmetic mean of the weighted means from surrounding holes. In a similar manner, they were assigned a depth value based on the arithmetic mean of the depths (excluding overburden) of the surrounding holes.

4. The volume of mineralized material characterized by each hole was calculated from the area of influence and the depth of drilling, to define a simple rectangular block, typically of tabular shape, as the holes are generally short. The overburden section at the top of each hole was excluded. If the lower section of a drillhole was not assayed (this was unusual), the vertical dimension of the block was defined as the maximum assay depth. In a few cases, the upper section of a hole was not assayed, in which case it was assumed to be barren, but still included in the weighted mean for the hole as dilution. In this initial calculation, no specific cut-off grade for yttrium was used, and all material defined by individual holes was retained within the estimate. Only 5 drillholes have depths in excess of 100 m, and most drillholes penetrated to less than 50 m; the average depth is about 43 m. No attempt was made to calculate overburden volumes or stripping ratios.

5. The individual volumes defined in Step 4 were added to calculate the total volume of mineralized material, and tonnage was calculated using an assumed density of 2.72, based on the measured density of 80 drillcores (2.72 ± 0.07) reported by Ramsey *et al.* (2010) in their resource estimate for the Strange Lake B-Zone deposit.

6. The weighted mean grade for the total resource was then calculated from the weighted means for all individual blocks, with the final weighting according to their tonnage.

SUMMARY OF RESULTS

The results of resource calculations are summarized in Table 4. In total, 155 drillholes were included, and 18 undefined blocks within this area were modelled as described above. The LB-series holes, located on the Québec side of the Zone 1 Lens, were not included in calculation. Summary information (IOC, 1985) indicates that mineralization on the Québec side of the border is a thin sheet-like zone near the surface, so this should have limited effect upon the final estimate. The final tonnage estimate (66.25 million metric tonnes) is about 20% larger than that derived by IOC (55.8 million metric tonnes) but the overall grade is slightly lower at 2.8% ZrO_2 (2.01% Zr), 0.31% Y_2O_3 (0.24% Y), 0.25% Nb_2O_5 (0.17% Nb) and 0.52% total REE oxides (0.44% TREE). No calculation was attempted for Be, as many holes lack data for this element. The overall REE oxide content, including Y (TREO*), is 0.82%. However, it is suspected that the 1980s Y_2O_3 data are themselves overestimates, and if these are corrected appropriately, the mean Y_2O_3 content diminishes to 0.25% and the estimated TREO* becomes 0.77%. The PD_X values listed in Table 2 imply that some of the light REE may be slightly overestimated, but some of the heavy REE underestimated. The average values for individual REE (expressed as ppm element for convenience) are also listed in Table 4; these are not corrected using the parameters from Table 2.

The resource calculation confirms, in general, the previous estimates by IOC, and the higher tonnage and lower average grade are consistent with the inclusion of lower grade material that likely fell below the cut-off employed by IOC, which was based on the *in-situ* dollar per tonne value applicable to potential ore at that time (1985). Information on the vertical dimensions of resource blocks used by IOC remains unavailable, and it is also possible that they excluded some material on the basis of mining feasibility.

ADDITIONAL POTENTIAL RESOURCES AT DEPTH

The 1980s exploration work was almost entirely directed at the definition of near-surface, high-grade reserves, and most drillholes completed were very short, having an average length of about 43 m. Many drillholes were actually shorter than this, and only 6 drillholes exceeded 100 m in

Table 4. A summary of results from resource calculations by IOC in the 1980s, and completed independently in this study

Part 1: Estimates from Exploration in the 1980s

Category	high-grade	medium-grade	low-grade	Total
Tonnage (millions, metric)	14	20	21.8	55.8
ZrO_2 (%)	3.35	3.03	2.73	2.99
Nb_2O_5 (%)	0.41	0.27	0.23	0.29
Y_2O_3 (%)	0.54	0.35	0.31	0.38
BeO (%)	0.11	0.07	0.06	0.08
Total REO (%)	n/a	n/a	n/a	0.54

Part 2: Estimates from this study (Tonnage Estimate 66.25 Million Metric Tonnes)

Element	Method	ppm	wt%	wt% oxide
Zirconium (Zr)	measured	20614.3	2.0614	2.7829
Niobium (Nb)	measured	1713.7	0.1714	0.2451
Yttrium (Y)	measured	2404.1	0.2404	0.3053
Lanthanum (La)	predicted	683.4	0.0683	0.0800
Cerium (Ce)	predicted	1616.9	0.1617	0.1892
Praseodymium (Pr)	predicted	174.9	0.0175	0.0205
Neodymium (Nd)	predicted	589.5	0.0589	0.0690
Samarium (Sm)	predicted	161.9	0.0162	0.0189
Europium (Eu)	predicted	9.9	0.0010	0.0012
Gadolinium (Gd)	predicted	167.8	0.0168	0.0196
Terbium (Tb)	predicted	38.9	0.0039	0.0046
Dysprosium (Dy)	predicted	300.5	0.0301	0.0352
Holmium (Ho)	predicted	71.8	0.0072	0.0084
Erbium (Er)	predicted	242.2	0.0242	0.0283
Thulium [Tm]	predicted	39.1	0.0039	0.0046
Ytterbium (Yb)	predicted	266.8	0.0267	0.0312
Lutetium (Lu)	predicted	41.9	0.0042	0.0049
Total REE (Y excluded)		4405.6	0.4406	0.5155
Total REE + Y		6809.7	0.6810	0.8208

NOTE: The IOC tonnage/grade estimates are derived from the Feasibility Study (IOC, 1985)
Slightly different figures may appear in other assessment reports and documents

depth. The deepest were holes SL-147 and SL-178 (Figure 2), which penetrated to about 190 m and 281 m, respectively (Figure 8). Most other drillholes in the southwestern part of the Main Zone deposit terminated in mineralized granites. Some drillholes in the Zone 1 Lens terminated in weakly mineralized granites, but the 2009 drilling completed by Quest Rare Minerals in adjacent Québec indicates that additional high-grade pegmatites occur at greater depth (Collins and Cashin, 2011). It is therefore appropriate to consider the potential for additional resources at depth in the Main Zone deposit.

Hole SL-178 is mineralized throughout most of its length, and intersected the lower contact of the exotic-rich subsolvus granite against older (?) hypersolvus granite, at a depth of 225 m. The geochemical profile for this hole, including REE predicted in this study, is indicated in Figure 8A. As noted previously by Miller (1985), the Zr grades remain relatively constant throughout, until the lower contact is reached, but there is a trend toward lower Y and Nb values at depth, and lower predicted REE values (Figure 8A). Nevertheless, REE values remain at interesting levels as far as the contact zone at 225 m. There is little sign of any

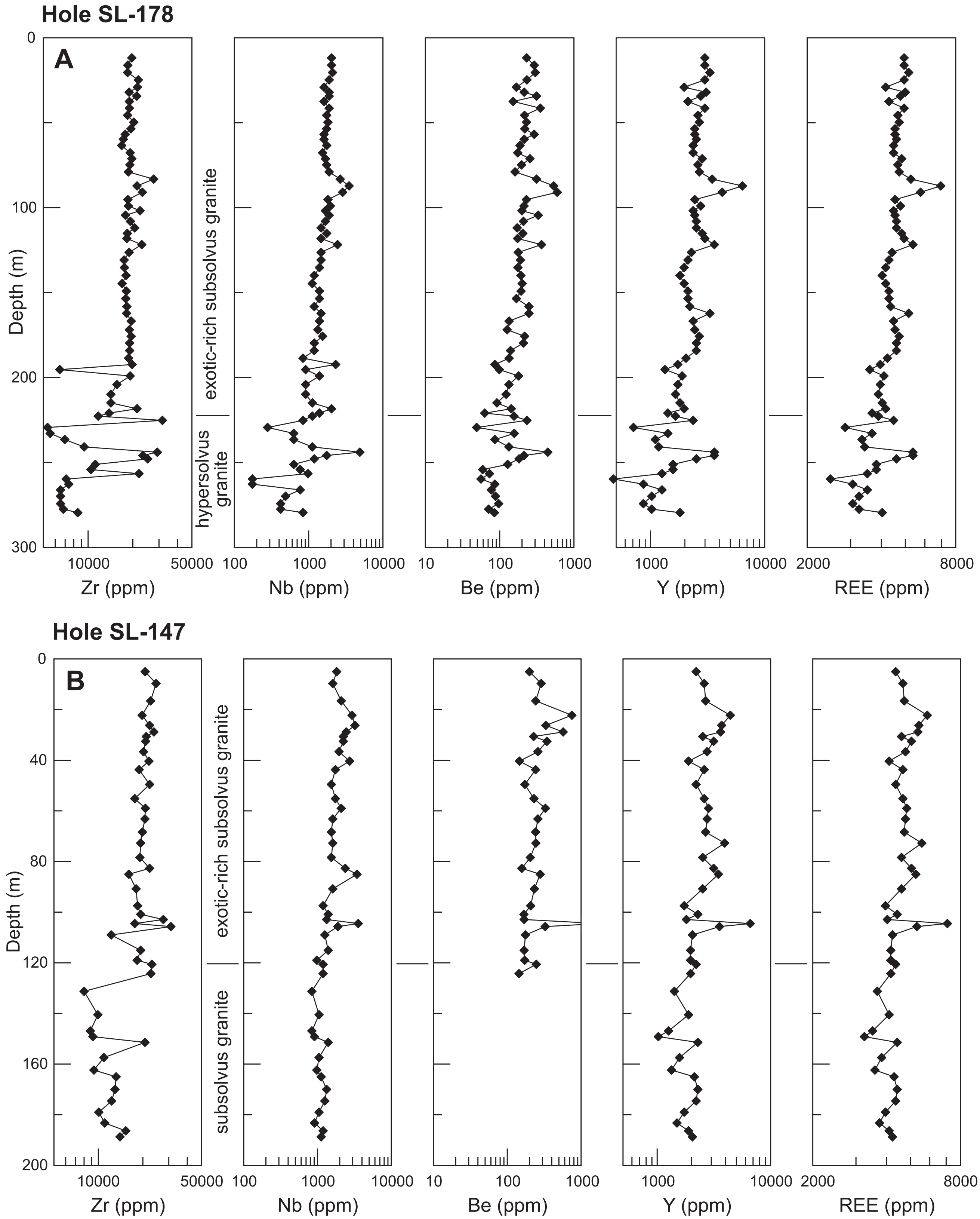

Figure 8. *The variation of Zr, Nb, Be, Y and calculated total REE (TREE) with depth in two deep drillholes from Strange Lake. (A) hole SL-178; (B) hole SL-147. The data come from IOC analyses reported by Miller (1985) and in earlier assessment reports.*

similar decline in Y or Nb values in drillhole SL-147, located just a few hundred metres to the north (Figure 8B), although this is also interpreted to intercept a lower contact zone at about 120 m. Both drillholes contain a pegmatitic and aplitic high-grade interval at a depth of approximately 100 m, and this is about 11 m thick in SL-178 (Figure 8A). The location of this zone is below the maximum penetration depth of most other drillholes in the southwestern part of the Main Zone deposit.

Information from two drillholes alone is obviously inadequate for inferring the quantity of any potential deep mineral resource at Strange Lake, and there is no guarantee that any such material could feasibly be mined. Nevertheless, these data indicate that mineralization is potentially widespread below the extent of previous drilling, and is not uniformly of low grade. Depending on the exact subsurface geometry of the exotic-rich subsolvus granite unit, and on the possible presence of deeper pegmatite–aplite zones, the total resources could be as much as an order of magnitude greater than those indicated by shallow drilling.

DISCUSSION AND CONCLUSIONS

Results from Kerr and Rafuse (2012) and this study indicate that prediction of REE abundances from 1980s yttrium data represents a valid approach to assessing the potential REE resource at the Strange Lake Main Zone deposit. This approach avoids additional drilling at great expense, and also the lesser but still significant expense of re-analyzing all of the archived drillcore samples. The predictive method will not always give accurate estimates at an individual sample level, but there is good correspondence between predicted and measured values for weighted means of individual drillholes or groups of drillholes. The accuracy, when centralized measures such as these are calculated, seems acceptable, especially given the inherent uncertainties of analytical methods.

There appears to be a tendency toward overestimation of values for the light REE elements (at low concentrations), and underestimation of values for most REE at higher grades. This is not necessarily a problem for resource estimation as these effects will, to some extent, counteract each other. In general, the prediction discrepancy for the more valuable heavy REE is better than for the less valuable light REE, and the greatest uncertainties are for the less abundant elements, which make the smallest contribution to the overall grade of the resource.

Examination of results from twinned 1980s and 2009 drillholes from the Québec side of the Zone 1 Lens suggests that predictions may significantly underestimate or overestimate grade on the level of individual drillhole pairs. However, there are indications that some of this variability reflects geological factors such as different units or unit thicknesses, and also the intrinsic variability in the REE patterns of pegmatites and aplites that host much of the mineralization in this area. These complications are not unexpected. Nevertheless, the overall weighted means for predicted data from the 1980s drillholes and measured results from 2009 correspond extremely well.

An independent resource calculation for the Main Zone deposit, using the predicted REE data, provides broadly similar results to those obtained in the 1980s (IOC, 1985), but gives a higher tonnage estimate. This is, to some extent, counterbalanced by lower calculated grades, which likely reflects the inclusion of material excluded by IOC, either on the basis of grade or depth. Drilling completed in the 1980s was shallow (typically <50 m depth), but the few deeper holes imply that mineralization is continuous to depths at least locally exceeding 200 m, and that high-grade pegmatite zones still exist in places below the exploration limits of shallow 1980s drilling. Thus, the total resources of REE (and other elements) at Strange Lake are likely much greater than defined by previous or current estimates.

Ultimately, clearer definition of reserves and resources in the Main Zone deposit to NI 43-101 standards, including any potential deep speculative resources, and further assessment of mining and processing feasibility, must depend on additional drilling. This is particularly so for the higher grade Zone 1 Lens area, because there are indications of greater geological and geochemical variablity in areas richer in pegmatites and aplites. Deeper drilling is also required to better understand the subsurface geometry of mineralized granite unit(s) elsewhere in the deposit. In the interim, a selective re-analysis program of archived core samples would provide more sophisticated resource estimates that might more closely adhere to NI 43-101 protocols. The initial step in this process is to sort and organize archived samples such that individual drillholes can be re-analyzed in their entirety. Given that over 3000 archived samples are presently stored in Goose Bay, this is not a trivial task. The obvious priorities are holes from the higher grade Zone 1 Lens, including the original material from drillholes completed in the 1980s on the Québec side of the Zone 1 Lens that were later replicated by the 2009 Quest drillholes. This information could be very important in assessing the role of geological factors in lateral variability and continuity of mineralization. On a wider scale, re-analysis of other holes would permit greater confidence in resource estimation, and could highlight geographic and/or depth variations in grade and geochemistry that may be important in terms of economic assessment and geological modelling.

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