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terrane, western Yukon: GEM 2 Cordillera project**

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**2016**

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doi:10.4095/299484

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**Recommended citation**

Milidragovic, D., Ryan, J.J., Zagorevski, A., and Piercey, S.J., 2016. Geochemistry of Permian rocks of the Yukon-Tanana terrane, western Yukon: GEM 2 Cordillera project; Geological Survey of Canada, Open File 8170, 21 p., doi:10.4095/299484

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# Geochemistry of Permian rocks of the Yukon-Tanana terrane, western Yukon: GEM-2 Cordillera project

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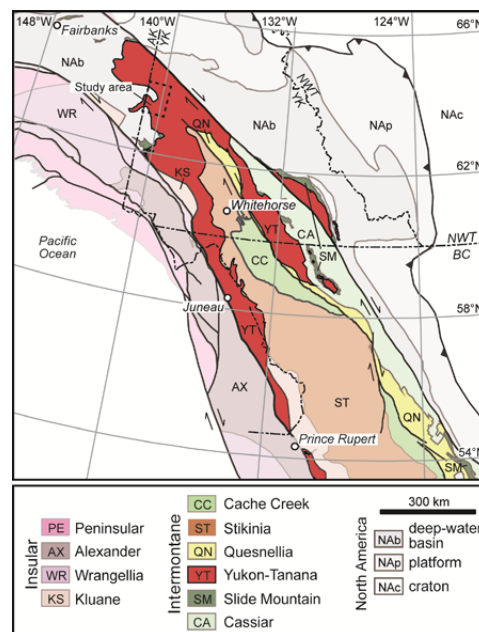
## Foreword

Geochemical data, presented in this open file release, have been collected over the past fifteen years as part of regional mapping projects conducted under the auspices of the Geological Survey of Canada's Ancient Pacific Margin (NATMAP) and Geo-mapping for Energy and Minerals (GEM) programs. The data include major and trace element analyses for over 100 samples of Permian age rocks.

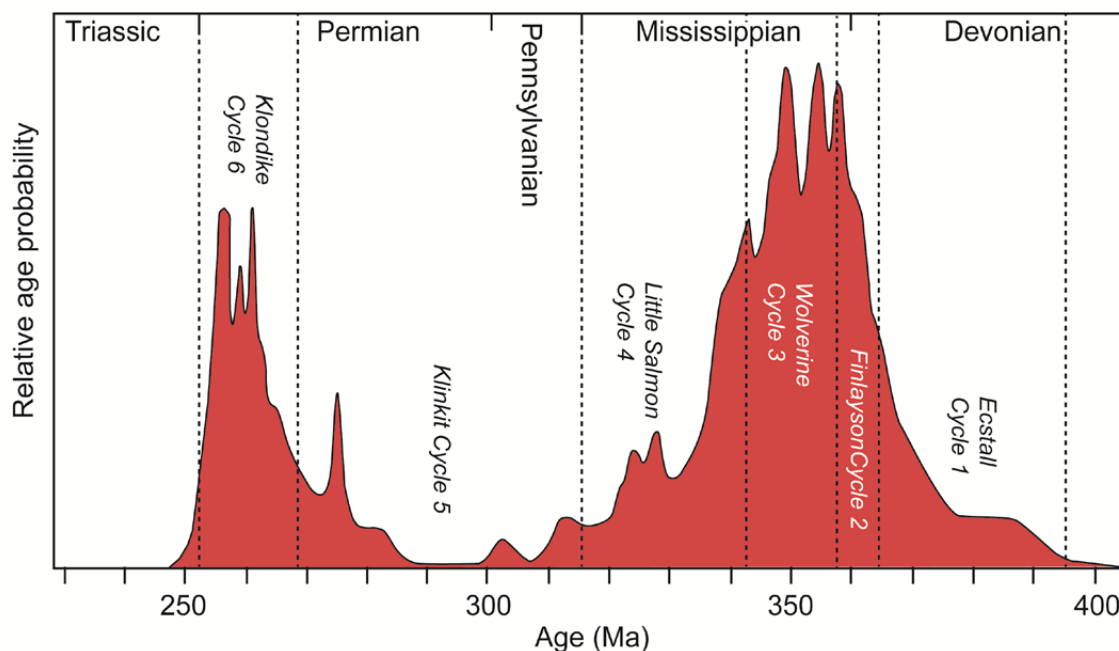
## Introduction

The Yukon-Tanana terrane is a composite, peri-cratonic terrane of Devonian-Triassic age (Nelson et al., 2006; 2013), exposed from eastern Alaska to northwestern British Columbia (Fig. 1). The Paleozoic evolution of the Yukon-Tanana terrane has been subdivided into six tectonomagmatic cycles (Fig. 2), which affected this large rifted fragment of Laurentia's western margin (Nelson et al., 2006). The geochemical data in this report belong to rocks of the Permian age Klondike assemblage formed during Cycle 6, although some may belong to rocks of the earlier Cycle 5 (Klinkit). Klinkit cycle rocks formed during ca. 314-269 Ma (Pennsylvanian-Early Permian) arc and back-arc volcanism and related sedimentation. Klondike cycle rocks are interpreted to have formed from ca. 265-254 Ma in an arc setting, during westward-dipping subduction of Slide Mountain ocean

crust and re-accretion of the Yukon-Tanana terrane to the North American western margin (Nelson et al., 2006).



**Figure 1.** Terranes of the northern Cordillera modified from Nelson et al., 2013).



**Figure 2.** Geochronological frequency diagram for Devonian to Permian magmatism and high pressure metamorphism in the Yukon-Tanana terrane (n=147), modified from Nelson et al. (2006). The Paleozoic tectonic evolution of the Yukon-Tanana terrane is subdivided into six cycles. Data presented in this report are for rocks of Cycle 6.

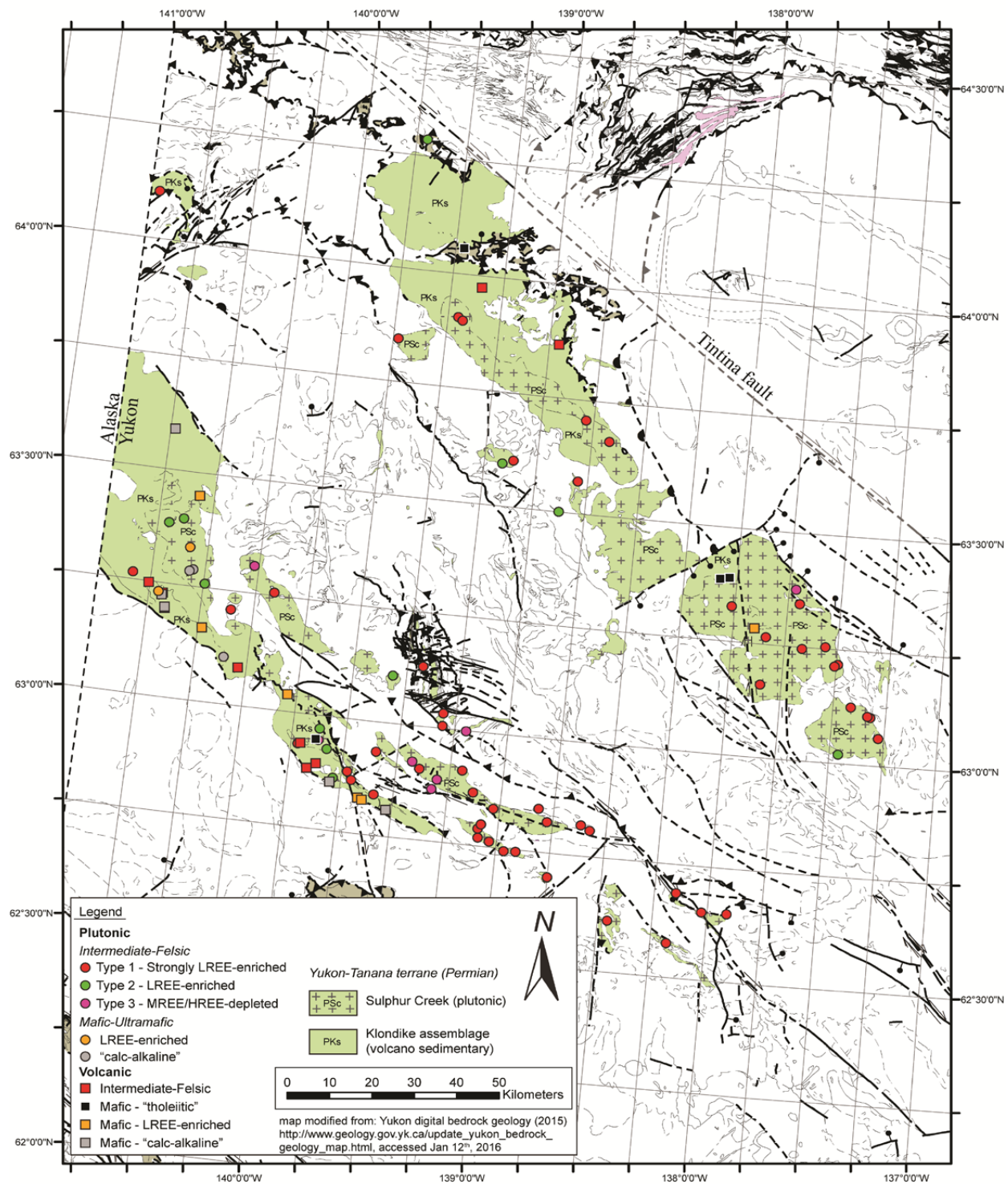
## Methodology and data quality

Data included in this report are a result of a multi-year effort by the Geological Survey of Canada and the Yukon Geological Survey to understand the geological history, architecture, and mineral potential of the Yukon-Tanana terrane in western Yukon. The data were acquired between 2002 and 2015; over the course of this period four laboratories were used for geochemical analyses. Samples collected during the NATMAP project (2002 to 2003) were analyzed at the University of Western Ontario (London, ON) and at the Ontario Geoscience Laboratories (Sudbury, ON). During 2009 and 2010, samples were analyzed by Activation Laboratories Ltd. (Ancaster, ON). In 2011, samples were analyzed by ACME Analytical Laboratories (Vancouver, BC). Samples, collected during 2014 and 2015 campaigns were analyzed by Bureau Veritas Commodities Canada Ltd. (Vancouver, BC), which acquired ACME

Analytical Laboratories in 2011. A selection of archived samples that were previously not analyzed, were analyzed in 2015 at Bureau Veritas. Isotopic data included in this report were acquired at the University of British Columbia's Pacific Institute for Isotopic and Geochemical Research (PCIIGR, Vancouver, BC).

### *Data acquired at Laurentian University*

Major element analyses were performed using X-ray fluorescence (XRF) on fused discs at the University of Western Ontario (UWO). Trace element concentrations were determined using XRF on pressed pellets at UWO, and by inductively coupled plasma–emission spectrometry (ICP-ES) and inductively coupled plasma–mass spectrometry (ICP-MS) at the Ontario Geoscience Laboratories. Analyses of 4 duplicate samples suggest absolute errors in major element measurements are <0.4 wt. %, which in most cases is  $\leq 2\%$  relative.



**Figure 3.** Map of the extent of Permian rocks of the Yukon-Tanana terrane in western Yukon, and location of geochemical samples listed in this report.

At concentrations approaching the limit of quantification (3.3 x limit of detection) the relative uncertainty in measurement of major elements is  $\leq 20\%$ . A review of data acquired at Laurentian University during the period 2002-2003 is available from MacDonald et al. (2005).

#### *Data acquired at Activation Laboratories*

Samples analyzed at Activation Laboratories (Ancaster, Ontario) were crushed and processed using lithium metaborate/tetraborate fusion and nitric acid dissolution. Analyses were performed by ICP-ES and ICP-MS (4Lithores analytical package). At a 95% confidence level, the uncertainty in measurement of major elements exceeding their limit of quantification is  $\leq 3\%$  relative. The less abundant major elements ( $\text{TiO}_2$  and  $\text{P}_2\text{O}_5$ ) are exceptions, with relative uncertainties of  $\leq 10\%$  and  $\leq 15\%$ , respectively. The uncertainty in measurement of most trace elements is  $\leq 15\%$  relative, at a 95% confidence level.

#### *Data acquired at ACME Laboratories*

Samples analyzed at ACME Analytical Laboratories (Vancouver, BC) were crushed and processed using lithium metaborate/tetraborate fusion and dilute nitric acid dissolution. Major element and trace element analyses were performed by ICP-OES and ICP-MS, respectively (analytical package 4A-4B). At a 95% confidence level, the uncertainty in measurement of most major elements exceeding their limit of quantification is  $\leq 10\%$  relative. The relative uncertainty in measurement of  $\text{TiO}_2$  and  $\text{MgO}$  is  $\leq 20\%$ , whereas the relative uncertainty in measurement of  $\text{MnO}$  and  $\text{P}_2\text{O}_5$  is  $\leq 25\%$ , and  $\leq 65\%$ , respectively. The uncertainty in measurement of most trace elements is 10-25% relative, at a 95% confidence level. Notably, the relative uncertainties in the

concentration of Th and U are  $\leq 40\%$  and  $\leq 150\%$ , respectively.

#### *Data acquired at Bureau Veritas*

Samples analyzed at Bureau Veritas Minerals Laboratories (Vancouver, BC) were crushed and processed using lithium metaborate/tetraborate fusion and dilute nitric acid dissolution. Major element concentrations were determined using ICP-OES; the concentrations of trace elements were measured using ICP-MS (analytical package LF200). Trace metals were leached using aqua regia and analyzed using ICP-MS (analytical package AQ200). The uncertainty in measurement of most major elements, at a 95% confidence level is  $\leq 5\%$ , although at concentrations approaching the limit of quantification the relative uncertainties may be as high as 25-60%. The average relative uncertainty, at a 95% confidence level, for the less abundant  $\text{MnO}$  and  $\text{P}_2\text{O}_5$  is 10-20%. The average uncertainty in measurement of most trace elements is 5-15% relative, at a 95% confidence level. However, the relative uncertainty in quoted measurements is  $\leq 70\%$  near the limit of quantification.

## **Results**

Analyzed samples are inferred to be of Permian age and part of the Klondike assemblage, composed of either the Sulphur Creek plutonic suite (Tables 1-3), or the metavolcanic Klondike schist (Tables 4 and 5). A small subset of mafic plutonic rocks (Table 6) has not been classified.

The Sulphur Creek plutonic suite includes tonalite, granodiorite and granite, which may be further subdivided into: 1) the strongly-light rare earth element (LREE) enriched suite, 2) the LREE-enriched suite, and 3) the heavy REE (HREE) and middle REE (MREE)-depleted suite (Fig 4). The intermediate to felsic volcanic rocks ( $\text{SiO}_2 > 60$  wt.%; Fig. 5) of the Klondike

schist are largely indistinguishable from the strongly LREE-enriched plutonic rocks in terms of their incompatible trace element geochemistry.

Basaltic to andesitic ( $\text{SiO}_2 \leq 60$  wt. %) members of the Klondike schist display important variations in immobile trace element geochemistry. On the basis of the trace element profiles, the mafic members of the Klondike schist may be classified as follows: 1) tholeiitic metavolcanic rocks with relatively flat REE and high field strength element (HFSE) profiles, 2) LREE-enriched metavolcanic rocks lacking significant HFSE depletion, and 3) calc-alkaline" metavolcanic rocks, characterized by LREE-enrichment and depletion in HFSE, primarily Nb, Ta, and Ti.

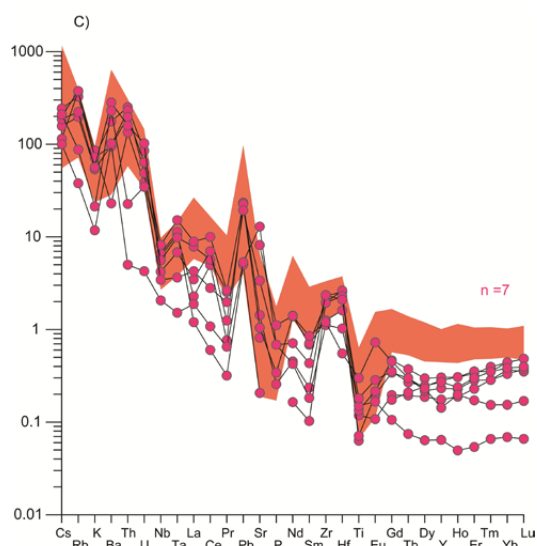
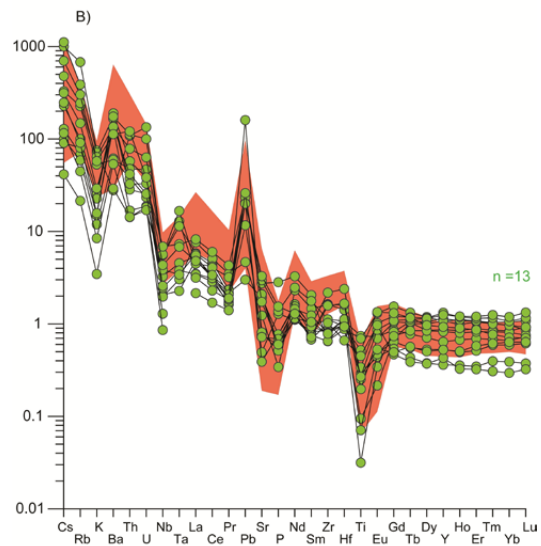
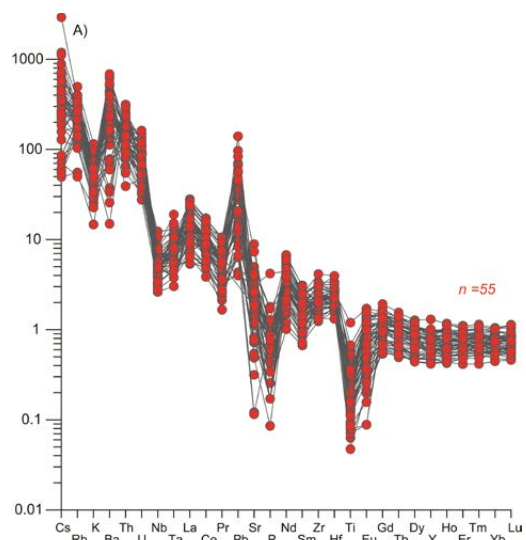
## Discussion

The Permian Klondike assemblage is one of the defining elements of Yukon-Tanana terrane, and is generally accepted (e.g. Nelson et al., 2006) as having formed in an arc setting, during westward-dipping subduction of Slide Mountain ocean crust and re-accretion of the Yukon-Tanana terrane to the North American western margin. The known extent of Klondike

assemblage rocks has increased significantly over the last decade, through new mapping and geochronology. Regional datasets are improved enough to warrant re-evaluation of existing tectonic models. It is striking that there is a close spatial relationship between numerous mineral deposits across Yukon-Tanana terrane and rocks of the Klondike assemblage; however, there has not been a genetic link established to date.

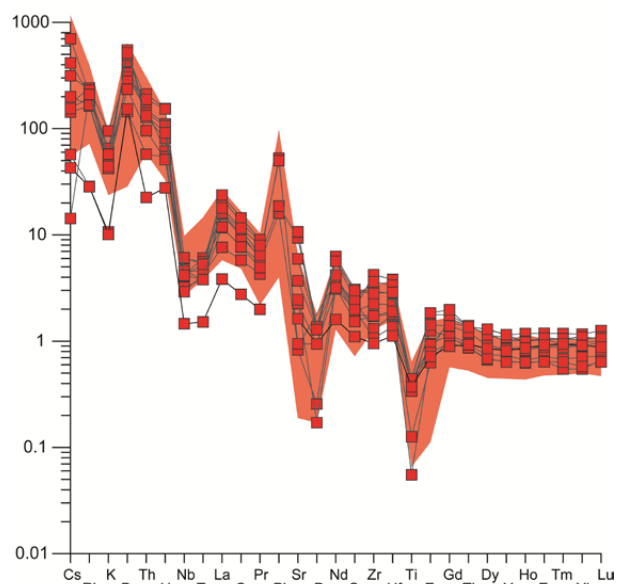
Geochemical investigation of the Permian plutonic and volcanic rocks, presented herein, indicates that while the suite is relatively homogeneous on the regional scale, important geochemical differences exist. These differences need to be investigated further to constrain the petrogenesis and tectonic setting of the Permian igneous suites and, perhaps ultimately, their relationship to younger mineralization. Future work will combine the geochemical data presented in this report, with isotopic (Sm-Nd and Lu-Hf) and geochronological (U-Pb and Ar-Ar) data to place new constraints on the timing and petrological processes involved in the evolution of the Yukon-Tanana terrane during the Permian Klondike cycle.



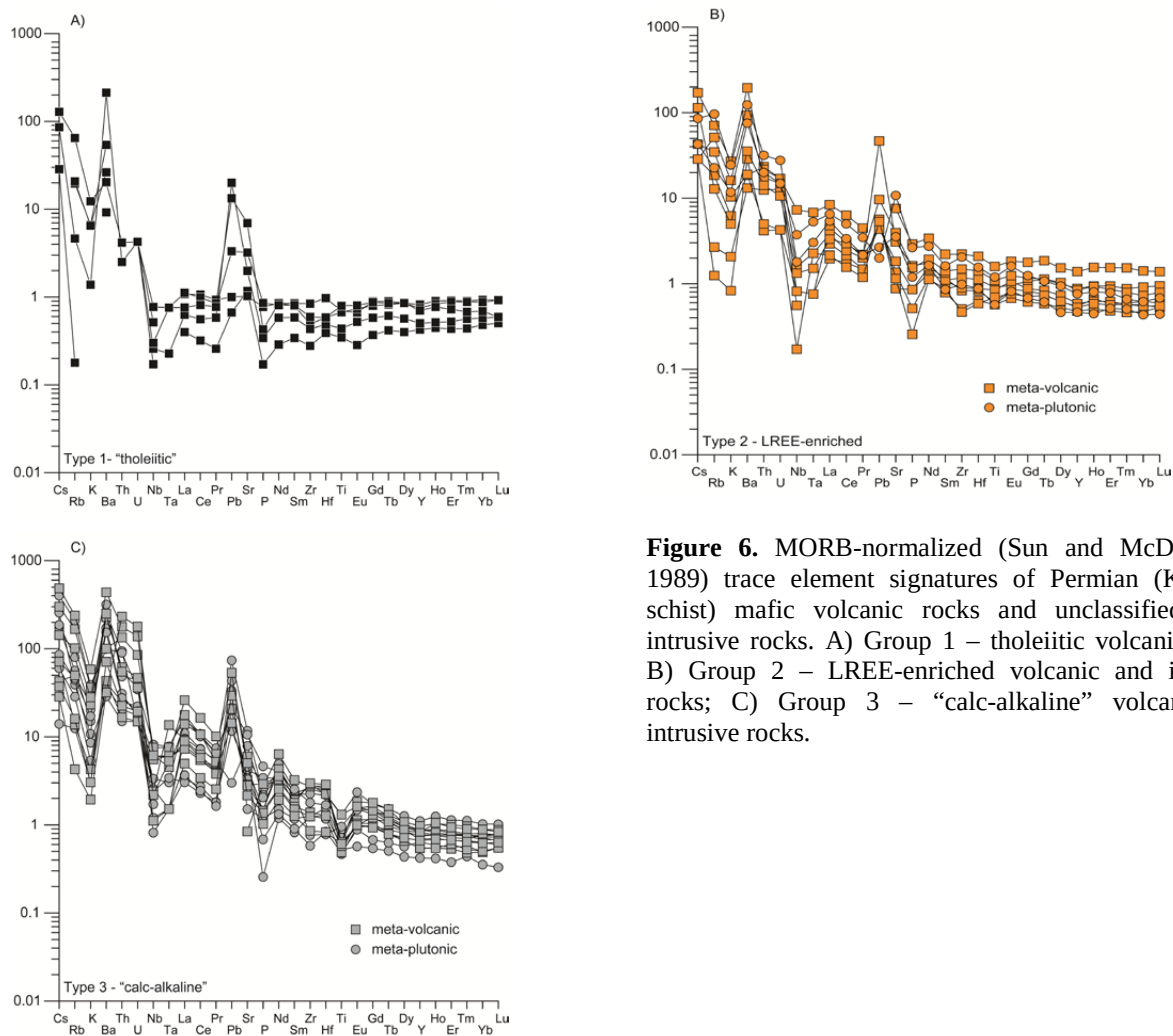


**Figure 4.** MORB-normalized (Sun and McDonough, 1989) trace element signatures of Permian (Sulphur Creek suite) plutonic rocks. A) Strongly LREE-enriched; B) LREE-enriched; C) MREE-depleted. The red field in B) and C) is the 95% confidence envelope for the strongly LREE-enriched plutonic rocks.





**Figure 5.** MORB-normalized (Sun and McDonough, 1989) trace element signatures of Permian (Klondike schist) intermediate to felsic volcanic rocks.



**Figure 6.** MORB-normalized (Sun and McDonough, 1989) trace element signatures of Permian (Klondike schist) mafic volcanic rocks and unclassified mafic intrusive rocks. A) Group 1 – tholeiitic volcanic rocks; B) Group 2 – LREE-enriched volcanic and intrusive rocks; C) Group 3 – “calc-alkaline” volcanic and intrusive rocks.

**TABLE 1.** Major and trace element compositions of the Permian Sulphur Creek plutonic suite (Strongly LREE-enriched)

| Sample #                       | 00GGA-034A <sup>a</sup> | 00GGA-069A <sup>a</sup> | 00GGA-072A1 <sup>d</sup> | 00GGA-075A <sup>a</sup> | 00GGA-106A <sup>a</sup> | 00RAY-044A <sup>a</sup> | 00RAY-073 <sup>a</sup> | 00RAY-202A <sup>a</sup> | 01RAY-310A1 <sup>d</sup> | 02RAY-288A1 <sup>d</sup> | 02RAY-304A <sup>a</sup> | 02RAYG-275A2 <sup>d</sup> | 03GGA-264A1 <sup>a</sup> |
|--------------------------------|-------------------------|-------------------------|--------------------------|-------------------------|-------------------------|-------------------------|------------------------|-------------------------|--------------------------|--------------------------|-------------------------|---------------------------|--------------------------|
| Easting                        | 585784                  | 609447                  | 615504                   | 609396                  | 575980                  | 585501                  | 585720                 | 579217                  | 562682                   | 615501                   | 515565                  | 532401                    | 542008                   |
| Northing                       | 6987398                 | 7066242                 | 7061828                  | 7051161                 | 7087425                 | 6990521                 | 6987404                | 7001350                 | 7080325                  | 7061838                  | 7010992                 | 7009112                   | 7014569                  |
| Major elements (wt.%)          |                         |                         |                          |                         |                         |                         |                        |                         |                          |                          |                         |                           |                          |
| SiO <sub>2</sub>               | 74.70                   | 73.31                   | 75.03                    | 69.76                   | 74.20                   | 74.13                   | 74.97                  | 75.15                   | 70.68                    | 73.66                    | 65.51                   | 71.09                     | 67.24                    |
| TiO <sub>2</sub>               | 0.20                    | 0.45                    | 0.19                     | 0.41                    | 0.41                    | 0.25                    | 0.18                   | 0.14                    | 0.27                     | 0.19                     | 0.47                    | 0.30                      | 0.66                     |
| Al <sub>2</sub> O <sub>3</sub> | 12.94                   | 11.49                   | 13.25                    | 14.34                   | 12.38                   | 13.14                   | 12.98                  | 13.25                   | 14.80                    | 13.32                    | 16.21                   | 14.80                     | 15.01                    |
| Fe <sub>2</sub> O <sub>3</sub> | 2.29                    | 3.25                    | 2.32                     | 3.36                    | 3.03                    | 2.28                    | 1.88                   | 1.97                    | 3.05                     | 2.23                     | 3.47                    | 2.63                      | 4.79                     |
| MnO                            | 0.04                    | 0.07                    | 0.04                     | 0.06                    | 0.03                    | 0.03                    | 0.03                   | 0.01                    | 0.06                     | 0.04                     | 0.12                    | 0.04                      | 0.08                     |
| MgO                            | 0.27                    | 1.09                    | 0.62                     | 0.97                    | 1.40                    | 0.35                    | 0.23                   | 0.12                    | 0.68                     | 0.54                     | 1.80                    | 0.53                      | 1.58                     |
| CaO                            | 1.19                    | 1.75                    | 1.51                     | 2.56                    | 0.13                    | 1.22                    | 0.99                   | 0.28                    | 2.10                     | 1.34                     | 2.92                    | 1.47                      | 1.66                     |
| Na <sub>2</sub> O              | 3.20                    | 1.78                    | 2.86                     | 2.80                    | <0.01                   | 2.91                    | 2.79                   | 3.79                    | 2.55                     | 2.39                     | 2.63                    | 2.42                      | 5.63                     |
| K <sub>2</sub> O               | 4.41                    | 3.63                    | 2.45                     | 4.56                    | 5.35                    | 4.66                    | 5.17                   | 3.96                    | 4.41                     | 3.25                     | 4.09                    | 4.60                      | 1.64                     |
| P <sub>2</sub> O <sub>5</sub>  | 0.04                    | 0.09                    | 0.04                     | 0.10                    | 0.10                    | 0.05                    | 0.02                   | 0.02                    | 0.10                     | 0.02                     | 0.10                    | 0.07                      | 0.20                     |
| LOI                            | 0.50                    | 2.7                     | 1.15                     | 0.7                     | 2.70                    | 0.70                    | 0.50                   | 1.00                    | 0.79                     | 2.03                     | 2.00                    | 1.00                      | 1.30                     |
| Total                          | 99.78                   | 99.65                   | 99.47                    | 99.67                   | 99.73                   | 99.74                   | 99.75                  | 99.67                   | 99.50                    | 99.01                    | 99.37                   | 98.95                     | 99.77                    |
| Trace elements (ppm)           |                         |                         |                          |                         |                         |                         |                        |                         |                          |                          |                         |                           |                          |
| Ni                             | <20                     | <20                     | <3                       | <20                     | <20                     | <20                     | <20                    | <20                     | 12                       | <4                       | <20                     | 7                         | <20                      |
| Cr                             | -                       | -                       | 6                        | -                       | -                       | -                       | -                      | -                       | <4                       | -                        | -                       | 7                         | -                        |
| Co                             | 2                       | 4.2                     | <2                       | 5.4                     | 2.8                     | 2                       | 1.6                    | 0.7                     | <3                       | <3                       | 2.4                     | <2                        | 6.2                      |
| V                              | 19                      | 30                      | 20                       | 30                      | 27                      | 10                      | <8                     | 9                       | 35                       | 25                       | 45                      | 28                        | 74                       |
| S                              | <500                    | <500                    | -                        | <500                    | <500                    | <500                    | <500                   | <500                    | -                        | 335                      | <500                    | 103                       | <500                     |
| Sc                             | 5                       | 9                       | 7                        | 8                       | 7                       | 6                       | 4                      | 3                       | 6                        | 6.59                     | 6                       | 4.98                      | 14                       |
| Cu                             | 1.2                     | 6.5                     | <2                       | 1.8                     | 6.9                     | 2.9                     | 2.2                    | 2                       | <2                       | -                        | 6.8                     | -                         | 4.3                      |
| Pb                             | 6.2                     | 13.8                    | <3                       | 4.1                     | 2                       | 3.6                     | 5.9                    | 1.9                     | 17                       | -                        | 17.3                    | -                         | 1.2                      |
| Zn                             | 38                      | 25                      | 37                       | 52                      | 20                      | 39                      | 38                     | 10                      | 60                       | 35                       | 14                      | 45                        | 61                       |
| As                             | 1.1                     | 1.1                     | 3                        | <0.5                    | 2.7                     | <0.5                    | 0.7                    | <0.5                    | 3                        | -                        | <0.5                    | -                         | 0.9                      |
| Mo                             | 0.1                     | 0.2                     | -                        | 0.4                     | 0.1                     | 0.1                     | 0.2                    | 1.2                     | -                        | -                        | 0.2                     | -                         | 0.1                      |
| W                              | <0.5                    | 6                       | -                        | 2.7                     | 3.3                     | <0.5                    | <0.5                   | 2                       | -                        | 17                       | 1.9                     | -                         | <0.5                     |
| Cd                             | <0.1                    | 0.1                     | -                        | <0.1                    | 0.2                     | <0.1                    | <0.1                   | <0.1                    | -                        | -                        | <0.1                    | 7                         | <0.1                     |
| Sn                             | 1                       | 2                       | -                        | 1                       | 2                       | 1                       | 1                      | 1                       | -                        | -                        | 2                       | -                         | <1                       |
| Nb                             | 7.9                     | 11.3                    | 13                       | 11                      | 10                      | 7.9                     | 6.6                    | 13.5                    | 17.9                     | 14.1                     | 14.9                    | 12.2                      | 7.1                      |
| Ta                             | 0.6                     | 0.7                     | 1.05                     | 0.7                     | 0.6                     | 0.6                     | 0.5                    | 1                       | 0.76                     | 0.97                     | 0.8                     | 0.75                      | 2                        |
| Zr                             | 149.6                   | 155.8                   | 178                      | 167.1                   | 145.2                   | 157.3                   | 133.4                  | 160.5                   | 147                      | 172                      | 305.9                   | 183                       | 130.3                    |
| Hf                             | 4.7                     | 4.5                     | 4.73                     | 4.7                     | 3.8                     | 4.7                     | 4.2                    | 4.5                     | 4.9                      | 4.35                     | 8.1                     | 5.56                      | 3.7                      |
| Y                              | 21.7                    | 28.3                    | 23                       | 21.4                    | 18.9                    | 11.7                    | 16.6                   | 14.5                    | 14                       | 21                       | 25                      | 13                        | 22.5                     |
| Ga                             | 16.3                    | 13.5                    | 13                       | 16.5                    | 14.8                    | 15.2                    | 13.9                   | 15.9                    | 17                       | 13                       | 16.1                    | 15                        | 13.6                     |
| Cs                             | 1.7                     | 0.6                     | 0.38                     | 3.1                     | 1.1                     | 2.9                     | 5                      | 1.1                     | >5.00                    | 0.43                     | 1.9                     | 2.45                      | 0.5                      |
| Sr                             | 69.3                    | 46.8                    | 168                      | 236.8                   | 10.4                    | 106.6                   | 126.8                  | 118.4                   | 363                      | 140                      | 659.2                   | 178                       | 388.8                    |
| Rb                             | 148.6                   | 121.2                   | 79                       | 158.6                   | 186.8                   | 140.1                   | 154.2                  | 99.6                    | 175                      | 94                       | 118.2                   | 153                       | 27.9                     |
| Ba                             | 1467                    | 2507                    | 3400                     | 2113                    | 1850                    | 1890                    | 1667                   | 2552                    | 1874                     | 4306                     | 3883                    | 2518                      | 1036                     |
| Be                             | 5                       | <1                      | N.D.                     | <1                      | <1                      | 2                       | 4                      | 3                       | -                        | 1.54                     | 3                       | 1.31                      | <1                       |
| Li                             | -                       | -                       | 10                       | -                       | -                       | -                       | -                      | -                       | 42                       | 9                        | -                       | -                         | -                        |
| Th                             | 13.7                    | 11                      | 17                       | 16.7                    | 12                      | 13.9                    | 14.6                   | 9.9                     | 17.39                    | 16.1                     | 21.3                    | 20.62                     | 4.7                      |
| U                              | 3.2                     | 2.5                     | 5.54                     | 4                       | 1.8                     | 3.2                     | 2.7                    | 1.6                     | 4.1                      | 4.85                     | 7.6                     | 4.16                      | 2.2                      |
| La                             | 22.9                    | 34.4                    | 42.04                    | 36.5                    | 15.9                    | 17.6                    | 39.4                   | 17.6                    | 40.65                    | 34.29                    | 60.7                    | 33.43                     | 17.1                     |
| Ce                             | 66.7                    | 62.4                    | 77.96                    | 94.2                    | 43.6                    | 76.6                    | 77.1                   | 36.6                    | 71.94                    | 69.11                    | 119.2                   | 73.34                     | 37.7                     |
| Pr                             | 4.77                    | 7.38                    | 9.8                      | 7.02                    | 3.64                    | 3.47                    | 8.36                   | 3.34                    | 8.45                     | 8.17                     | 12.17                   | 7.18                      | 4.43                     |
| Nd                             | 15.6                    | 28.6                    | 34.3                     | 24.7                    | 13.2                    | 11.7                    | 32.6                   | 12.3                    | 29.52                    | 29.65                    | 44                      | 24.75                     | 18.9                     |
| Sm                             | 3.08                    | 5.17                    | 6.57                     | 4.72                    | 2.45                    | 1.9                     | 5.02                   | 2.36                    | 5.78                     | 5.99                     | 6.46                    | 4.75                      | 3.76                     |
| Eu                             | 0.37                    | 1.01                    | 1.21                     | 1.03                    | 0.4                     | 0.26                    | 0.4                    | 0.27                    | 1.31                     | 1.63                     | 1.49                    | 1.17                      | 1.02                     |
| Gd                             | 3.51                    | 4.93                    | 5.75                     | 4.57                    | 2.5                     | 2.07                    | 4.21                   | 1.98                    | 5.02                     | 5.36                     | 5.34                    | 4.37                      | 3.74                     |
| Tb                             | 0.63                    | 0.75                    | 0.94                     | 0.68                    | 0.44                    | 0.35                    | 0.58                   | 0.36                    | 0.7                      | 0.89                     | 0.79                    | 0.74                      | 0.6                      |
| Dy                             | 4.02                    | 4.52                    | 5.29                     | 4.04                    | 2.8                     | 2.01                    | 3.22                   | 2.13                    | 3.85                     | 5.51                     | 4.36                    | 4.36                      | 3.68                     |
| Ho                             | 0.82                    | 0.91                    | 1.13                     | 0.79                    | 0.63                    | 0.44                    | 0.64                   | 0.51                    | 0.73                     | 1.18                     | 0.83                    | 0.93                      | 0.86                     |
| Er                             | 2.35                    | 2.71                    | 3.18                     | 2.28                    | 2.14                    | 1.42                    | 1.87                   | 1.61                    | 1.86                     | 3.28                     | 2.53                    | 2.55                      | 2.42                     |
| Tm                             | 0.39                    | 0.36                    | 0.49                     | 0.32                    | 0.28                    | 0.22                    | 0.3                    | 0.25                    | 0.26                     | 0.52                     | 0.41                    | 0.39                      | 0.37                     |
| Yb                             | 2.23                    | 2.42                    | 3.12                     | 2.09                    | 1.94                    | 1.62                    | 1.95                   | 1.88                    | 1.62                     | 3.19                     | 2.48                    | 2.49                      | 2.56                     |
| Lu                             | 0.34                    | 0.36                    | 0.506                    | 0.33                    | 0.26                    | 0.24                    | 0.31                   | 0.27                    | 0.249                    | 0.515                    | 0.42                    | 0.378                     | 0.39                     |

**TABLE 1.** cont.

| Sample #                       | 03GGA-<br>383A1 <sup>a</sup> | 03RAY-<br>006A1 <sup>d</sup> | 03RAY-<br>269A <sup>a</sup> | 09RAYEK-<br>027A1 <sup>a</sup> | 09RAYJR-<br>102A1 <sup>a</sup> | 09RAYJR-<br>105A1 <sup>a</sup> | 09RAYJR-<br>175A03 <sup>c</sup> | 09RAYJR-<br>177A1 <sup>a</sup> | 09RAYJR-<br>178A03 <sup>c</sup> | 09RAYJR-<br>179A03 <sup>c</sup> | 09RAYJR-<br>186A1 <sup>a</sup> | 09RAYMC<br>-016A1 <sup>a</sup> | 09RAYRS-<br>014A1 <sup>a</sup> |
|--------------------------------|------------------------------|------------------------------|-----------------------------|--------------------------------|--------------------------------|--------------------------------|---------------------------------|--------------------------------|---------------------------------|---------------------------------|--------------------------------|--------------------------------|--------------------------------|
| Easting                        | 508222                       | 593671                       | 577216                      | 374817                         | 371615                         | 365165                         | 647512                          | 373965                         | 356537                          | 382824                          | 378049                         | 382171                         | 384977                         |
| Northing                       | 7015335                      | 7054203                      | 7086628                     | 7012221                        | 7016580                        | 7026804                        | 647512                          | 7011907                        | 7006830                         | 6999632                         | 7001985                        | 6999772                        | 6994537                        |
| Major elements (wt.%)          |                              |                              |                             |                                |                                |                                |                                 |                                |                                 |                                 |                                |                                |                                |
| SiO <sub>2</sub>               | 75.20                        | 75.24                        | 74.37                       | 72.32                          | 71.25                          | 66.55                          | 74.33                           | 75.71                          | 74.89                           | 68.91                           | 71.32                          | 68.76                          | 65.80                          |
| TiO <sub>2</sub>               | 0.11                         | 0.23                         | 0.17                        | 0.46                           | 0.48                           | 0.36                           | 0.37                            | 0.24                           | 0.20                            | 0.42                            | 0.34                           | 0.45                           | 0.63                           |
| Al <sub>2</sub> O <sub>3</sub> | 12.01                        | 13.58                        | 13.90                       | 13.73                          | 13.73                          | 14.92                          | 13.17                           | 12.89                          | 12.49                           | 15.34                           | 14.31                          | 14.90                          | 15.23                          |
| Fe <sub>2</sub> O <sub>3</sub> | 1.65                         | 3.06                         | 2.16                        | 3.71                           | 3.76                           | 5.21                           | 2.63                            | 2.63                           | 1.85                            | 3.77                            | 3.30                           | 3.95                           | 5.68                           |
| MnO                            | 0.02                         | 0.05                         | 0.02                        | 0.03                           | 0.03                           | 0.10                           | 0.04                            | 0.02                           | 0.02                            | 0.08                            | 0.06                           | 0.07                           | 0.08                           |
| MgO                            | 0.13                         | 0.51                         | 0.65                        | 1.06                           | 1.38                           | 1.65                           | 0.67                            | 0.57                           | 0.29                            | 1.38                            | 0.68                           | 1.00                           | 1.28                           |
| CaO                            | 0.86                         | 2.32                         | 0.04                        | 0.45                           | 1.35                           | 4.53                           | 2.39                            | 0.49                           | 0.71                            | 4.39                            | 2.47                           | 3.16                           | 3.53                           |
| Na <sub>2</sub> O              | 1.92                         | 3.81                         | 2.43                        | 3.19                           | 3.95                           | 2.85                           | 3.27                            | 3.02                           | 3.93                            | 3.10                            | 2.66                           | 2.76                           | 2.35                           |
| K <sub>2</sub> O               | 7.00                         | 1.06                         | 4.25                        | 2.59                           | 3.00                           | 2.60                           | 2.14                            | 2.35                           | 3.67                            | 2.79                            | 4.27                           | 3.92                           | 3.70                           |
| P <sub>2</sub> O <sub>5</sub>  | 0.02                         | 0.10                         | 0.02                        | 0.21                           | 0.10                           | 0.09                           | 0.08                            | 0.05                           | 0.02                            | 0.15                            | 0.11                           | 0.14                           | 0.20                           |
| LOI                            | 1.00                         | 0.35                         | 1.60                        | 1.90                           | 0.60                           | 0.90                           | 1.13                            | 1.70                           | 0.57                            | 0.57                            | 0.20                           | 0.60                           | 1.10                           |
| Total                          | 99.88                        | 100.31                       | 99.57                       | 99.63                          | 99.68                          | 99.79                          | 100.20                          | 99.65                          | 98.63                           | 100.90                          | 99.73                          | 99.74                          | 99.56                          |
| Trace elements (ppm)           |                              |                              |                             |                                |                                |                                |                                 |                                |                                 |                                 |                                |                                |                                |
| Ni                             | <20                          | <3                           | <20                         | <20                            | <20                            | <20                            | < 20                            | <20                            | < 20                            | < 20                            | <20                            | <20                            | <20                            |
| Cr                             | -                            | -                            | -                           | -                              | -                              | -                              | 40                              | -                              | 40                              | 20                              | -                              | -                              | -                              |
| Co                             | 0.4                          | <1                           | 1.4                         | 5                              | 4.3                            | 10.6                           | 3                               | 2.1                            | 1                               | 6                               | 3.8                            | 5.9                            | 6.5                            |
| V                              | <8                           | 25                           | <8                          | 39                             | 37                             | 94                             | 26                              | 20                             | 9                               | 57                              | 31                             | 42                             | 59                             |
| S                              | <500                         | 111                          | <500                        | <500                           | <500                           | <500                           | -                               | <500                           | -                               | -                               | <500                           | <500                           | <500                           |
| Sc                             | 3                            | 6.4                          | 4                           | 10                             | 8                              | 12                             | 6                               | 6                              | 3                               | 16                              | 7                              | 8                              | 13                             |
| Cu                             | 2.7                          | -                            | 2.9                         | 9.7                            | 3.3                            | 3.5                            | < 10                            | 9                              | < 10                            | < 10                            | 3.5                            | 8.6                            | 6.7                            |
| Pb                             | 25.1                         | <3                           | 13.8                        | 1.9                            | 3.8                            | 1.3                            | 11                              | 2.5                            | 10                              | 20                              | 12.7                           | 4.3                            | 3.6                            |
| Zn                             | 4                            | 23                           | 5                           | 38                             | 43                             | 46                             | < 30                            | 9                              | < 30                            | 60                              | 65                             | 59                             | 80                             |
| As                             | 0.6                          | 4                            | <0.5                        | 0.7                            | <0.5                           | <0.5                           | < 5                             | <0.5                           | < 5                             | < 5                             | 1                              | 1                              | 0.6                            |
| Mo                             | 0.1                          | -                            | <0.1                        | 0.4                            | <0.1                           | <0.1                           | < 2                             | 0.7                            | < 2                             | < 2                             | 0.1                            | 0.2                            | 0.3                            |
| W                              | 0.7                          | 8                            | 1.8                         | 1                              | 1.2                            | <0.5                           | < 0.5                           | 0.5                            | < 0.5                           | < 0.5                           | <0.5                           | <0.5                           | 0.6                            |
| Cd                             | <0.1                         | -                            | <0.1                        | <0.1                           | <0.1                           | <0.1                           | -                               | <0.1                           | -                               | -                               | 0.1                            | <0.1                           | <0.1                           |
| Sn                             | 2                            | -                            | 3                           | 3                              | 3                              | <1                             | 1                               | 1                              | 6                               | 2                               | 2                              | 2                              | <1                             |
| Nb                             | 18.7                         | 9.4                          | 10.7                        | 10.3                           | 11.7                           | 7.6                            | 8.9                             | 6.6                            | 11.6                            | 13                              | 12.6                           | 13.2                           | 14                             |
| Ta                             | 1.4                          | 0.71                         | 1                           | 1                              | 0.9                            | 0.6                            | 0.99                            | 0.5                            | 1.41                            | 1.09                            | 1.3                            | 1.3                            | 0.5                            |
| Zr                             | 139.3                        | 121.9                        | 159.5                       | 183.4                          | 169                            | 99                             | 159                             | 129.1                          | 175                             | 183                             | 137.1                          | 162.8                          | 220.1                          |
| Hf                             | 4.9                          | 3.9                          | 5.5                         | 4.7                            | 4.8                            | 2.7                            | 3.8                             | 3.5                            | 4.4                             | 4.1                             | 4.2                            | 4.6                            | 5.6                            |
| Y                              | 36.4                         | 23.4                         | 18.7                        | 15.8                           | 20.5                           | 12.1                           | 21.2                            | 17                             | 16.3                            | 27.9                            | 23.3                           | 23.4                           | 19.3                           |
| Ga                             | 15.4                         | 16                           | 16                          | 15.9                           | 14.5                           | 15.1                           | 16                              | 13.2                           | 15                              | 18                              | 17.2                           | 16.9                           | 17.5                           |
| Cs                             | 3.2                          | 0.346                        | 1.1                         | 1.7                            | 4.1                            | 1.3                            | 0.9                             | 0.6                            | 0.5                             | 3.2                             | 4.2                            | 4.7                            | 2.4                            |
| Sr                             | 74.1                         | 135                          | 69.7                        | 67.4                           | 128.5                          | 377.5                          | 244                             | 49                             | 101                             | 350                             | 291.5                          | 328.6                          | 447.4                          |
| Rb                             | 181.2                        | 31                           | 156.3                       | 76.8                           | 72.8                           | 79.7                           | 58                              | 63.6                           | 99                              | 108                             | 184.6                          | 154.9                          | 113.6                          |
| Ba                             | 375                          | 1054                         | 3269                        | 2620                           | 2060                           | 1002                           | 2159                            | 2834                           | 2267                            | 1172                            | 1629                           | 1442                           | 2651                           |
| Be                             | 3                            | 0.52                         | 3                           | <1                             | 2                              | 2                              | 2                               | <1                             | 3                               | 3                               | 5                              | 6                              | 2                              |
| Li                             | -                            | 3                            | -                           | -                              | -                              | -                              | -                               | -                              | -                               | -                               | -                              | -                              | -                              |
| Th                             | 28.3                         | 6.57                         | 20.3                        | 11.2                           | 14.1                           | 9.9                            | 14.3                            | 9.6                            | 21.1                            | 25.2                            | 12.6                           | 14.4                           | 13.8                           |
| U                              | 5.70                         | 1.525                        | 3.50                        | 2.30                           | 4.50                           | 1.30                           | 4.22                            | 2.50                           | 4.22                            | 2.42                            | 2.40                           | 2.30                           | 1.60                           |
| La                             | 65.5                         | 13.66                        | 39.2                        | 19.4                           | 35.8                           | 21.5                           | 66.9                            | 17                             | 33.8                            | 70.1                            | 24.3                           | 27.4                           | 34.5                           |
| Ce                             | 127.4                        | 37.02                        | 40.2                        | 66.1                           | 74.4                           | 38.9                           | 107                             | 36                             | 66.3                            | 129                             | 50.2                           | 62.2                           | 91                             |
| Pr                             | 13.9                         | 3.055                        | 8.04                        | 4.89                           | 7.52                           | 4.05                           | 14.0                            | 4.01                           | 7.16                            | 13.3                            | 5.02                           | 6.33                           | 7.41                           |
| Nd                             | 49.2                         | 10.9                         | 27.0                        | 17.5                           | 29.0                           | 13.5                           | 43.7                            | 14.0                           | 22.2                            | 46.3                            | 18.7                           | 22.4                           | 26.1                           |
| Sm                             | 8.01                         | 2.2                          | 4.08                        | 3.79                           | 5.15                           | 2.35                           | 6.89                            | 2.7                            | 3.79                            | 8.15                            | 3.9                            | 4.53                           | 5.15                           |
| Eu                             | 0.16                         | 0.493                        | 0.58                        | 0.71                           | 0.85                           | 0.69                           | 1.05                            | 0.44                           | 0.333                           | 1.29                            | 0.9                            | 1.12                           | 1.41                           |
| Gd                             | 7.08                         | 2.552                        | 3.67                        | 3.43                           | 4.57                           | 2.17                           | 4.79                            | 2.76                           | 2.81                            | 6.27                            | 3.67                           | 4.21                           | 5.3                            |
| Tb                             | 1.04                         | 0.503                        | 0.61                        | 0.56                           | 0.69                           | 0.36                           | 0.72                            | 0.49                           | 0.47                            | 0.90                            | 0.64                           | 0.69                           | 0.73                           |
| Dy                             | 5.78                         | 3.708                        | 3.52                        | 3.31                           | 3.76                           | 2.01                           | 3.92                            | 3.02                           | 2.94                            | 4.93                            | 3.86                           | 3.76                           | 4.38                           |
| Ho                             | 1.18                         | 0.854                        | 0.68                        | 0.68                           | 0.74                           | 0.44                           | 0.76                            | 0.58                           | 0.62                            | 0.95                            | 0.79                           | 0.75                           | 0.75                           |
| Er                             | 2.99                         | 2.757                        | 2.04                        | 2.03                           | 2.27                           | 1.23                           | 2.13                            | 1.84                           | 1.92                            | 2.67                            | 2.37                           | 2.21                           | 1.98                           |
| Tm                             | 0.47                         | 0.416                        | 0.30                        | 0.30                           | 0.36                           | 0.19                           | 0.327                           | 0.26                           | 0.339                           | 0.391                           | 0.37                           | 0.35                           | 0.28                           |
| Yb                             | 2.84                         | 2.80                         | 2.20                        | 1.89                           | 2.08                           | 1.36                           | 2.06                            | 1.65                           | 2.32                            | 2.47                            | 2.33                           | 2.26                           | 1.9                            |
| Lu                             | 0.43                         | 0.43                         | 0.32                        | 0.28                           | 0.28                           | 0.21                           | 0.312                           | 0.22                           | 0.331                           | 0.348                           | 0.39                           | 0.34                           | 0.24                           |

**TABLE 1.** cont.

| Sample #                       | 09RAYRS-<br>064A1 <sup>a</sup> | 09RAYRS-<br>097A1 <sup>a</sup> | 10RAYJR-<br>048A02 <sup>c</sup> | 10RAYJR-<br>068A01 <sup>a</sup> | 10RAYJR-<br>092A01 <sup>a</sup> | 10RAYJR-<br>103A02 <sup>c</sup> | 10RAYMC<br>-005A02 <sup>c</sup> | 11RAYAZ-<br>133A02 <sup>b</sup> | 11RAYAZ-<br>293A01 <sup>a</sup> | 11RAYAZ-<br>307A02 <sup>b</sup> | 11RAYAZ-<br>309A02 <sup>b</sup> | 11RAYAZ-<br>316A02 <sup>b</sup> | 11RAYAZ-<br>360A02 <sup>b</sup> |
|--------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|
| Easting                        | 649573                         | 357431                         | 350834                          | 645109                          | 615152                          | 606917                          | 652392                          | 564919                          | 591816                          | 597280                          | 613249                          | 610876                          | 645826                          |
| Northing                       | 7025655                        | 7018369                        | 6950041                         | 6941625                         | 6953879                         | 6959044                         | 6950160                         | 6973307                         | 6977201                         | 6963538                         | 6967258                         | 6970255                         | 6953973                         |
| Major elements (wt.%)          |                                |                                |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| SiO <sub>2</sub>               | 57.54                          | 75.39                          | 69.52                           | 68.59                           | 71.05                           | 70.31                           | 72.88                           | 70.96                           | 73.83                           | 73.05                           | 76.64                           | 64.75                           | 73.10                           |
| TiO <sub>2</sub>               | 1.52                           | 0.12                           | 0.39                            | 0.53                            | 0.30                            | 0.38                            | 0.20                            | 0.2                             | 0.20                            | 0.31                            | 0.06                            | 0.85                            | 0.39                            |
| Al <sub>2</sub> O <sub>3</sub> | 15.21                          | 12.83                          | 14.50                           | 14.85                           | 14.56                           | 14.11                           | 13.66                           | 14.53                           | 13.40                           | 13.22                           | 12.53                           | 14.76                           | 12.84                           |
| Fe <sub>2</sub> O <sub>3</sub> | 10.47                          | 1.87                           | 3.36                            | 3.83                            | 2.86                            | 2.63                            | 1.77                            | 2.78                            | 2.05                            | 1.82                            | 1.18                            | 5.57                            | 2.48                            |
| MnO                            | 0.20                           | 0.03                           | 0.06                            | 0.05                            | 0.05                            | 0.04                            | 0.01                            | 0.08                            | 0.04                            | 0.02                            | 0.04                            | 0.07                            | 0.02                            |
| MgO                            | 2.41                           | 0.10                           | 0.99                            | 1.17                            | 0.85                            | 1.04                            | 0.60                            | 0.56                            | 0.47                            | 0.77                            | 0.11                            | 2.11                            | 0.92                            |
| CaO                            | 5.66                           | 1.23                           | 1.90                            | 2.64                            | 2.07                            | 1.96                            | 1.23                            | 1.68                            | 1.67                            | 1.02                            | 0.46                            | 5.85                            | 1.32                            |
| Na <sub>2</sub> O              | 1.54                           | 2.72                           | 3.24                            | 2.68                            | 3.06                            | 3.12                            | 3.55                            | 4.19                            | 3.14                            | 3.05                            | 3.05                            | 1.01                            | 2.41                            |
| K <sub>2</sub> O               | 3.41                           | 4.86                           | 3.96                            | 4.13                            | 4.14                            | 4.43                            | 4.26                            | 3.9                             | 4.70                            | 5.55                            | 4.66                            | 2.39                            | 4.72                            |
| P <sub>2</sub> O <sub>5</sub>  | 0.49                           | 0.02                           | 0.09                            | 0.11                            | 0.07                            | 0.09                            | 0.04                            | 0.07                            | 0.04                            | 0.15                            | 0.01                            | 0.09                            | 0.09                            |
| LOI                            | 1.20                           | 0.50                           | 1.01                            | 1.00                            | 0.80                            | 0.62                            | 1.75                            | 0.70                            | 0.30                            | 0.80                            | 0.70                            | 2.00                            | 1.10                            |
| Total                          | 99.60                          | 99.65                          | 99.01                           | 99.54                           | 99.81                           | 98.73                           | 99.94                           | 99.62                           | 99.84                           | 99.76                           | 99.44                           | 99.50                           | 99.43                           |
| Trace elements (ppm)           |                                |                                |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                                 |
| Ni                             | <20                            | <20                            | < 20                            | <20                             | <20                             | < 20                            | < 20                            | <20                             | <20                             | 32                              | 24                              | 32                              | <20                             |
| Cr                             | -                              | -                              | 40                              | -                               | -                               | 70                              | 50                              | -                               | -                               | -                               | -                               | -                               | -                               |
| Co                             | 14.2                           | 0.5                            | 6                               | 6.1                             | 4.5                             | 4                               | 4                               | 2.9                             | 2.7                             | 2.3                             | 0.6                             | 7.6                             | 4.2                             |
| V                              | 166                            | <8                             | 34                              | 42                              | 29                              | 28                              | 10                              | 9                               | 14                              | 19                              | <8                              | 85                              | 23                              |
| S                              | <500                           | <500                           | -                               | <500                            | <500                            | -                               | -                               | -                               | <500                            | -                               | -                               | -                               | -                               |
| Sc                             | 22                             | 6                              | 6                               | 8                               | 5                               | 6                               | 3                               | 2                               | 2                               | 4                               | <1                              | 12                              | 5                               |
| Cu                             | 3.1                            | 3.5                            | < 10                            | 17.6                            | 1.3                             | < 10                            | 20                              | -                               | 6.1                             | -                               | -                               | -                               | -                               |
| Pb                             | 1.2                            | 9.4                            | 29                              | 4.3                             | 9                               | 42                              | 21                              | -                               | 8.3                             | -                               | -                               | -                               | -                               |
| Zn                             | 85                             | 25                             | 40                              | 43                              | 38                              | 50                              | 80                              | -                               | 35                              | -                               | -                               | -                               | -                               |
| As                             | <0.5                           | 1.4                            | < 5                             | 1.4                             | 2.5                             | < 5                             | < 5                             | -                               | 1                               | -                               | -                               | -                               | -                               |
| Mo                             | 0.1                            | 0.2                            | < 2                             | 0.2                             | 0.2                             | < 2                             | < 2                             | -                               | 0.2                             | -                               | -                               | -                               | -                               |
| W                              | 2.6                            | 0.8                            | 1                               | <0.5                            | <0.5                            | < 0.5                           | 1.9                             | 0.9                             | <0.5                            | 1.2                             | <0.5                            | <0.5                            | <0.5                            |
| Cd                             | <0.1                           | 0.1                            | -                               | <0.1                            | <0.1                            | -                               | -                               | -                               | <0.1                            | -                               | -                               | -                               | -                               |
| Sn                             | 3                              | 13                             | 5                               | <1                              | <1                              | 6                               | 2                               | 5                               | 6                               | 2                               | 2                               | 3                               | 4                               |
| Nb                             | 15.7                           | 12.6                           | 10.4                            | 6.1                             | 8.8                             | 10                              | 11.8                            | 11                              | 13.8                            | 16.1                            | 14.7                            | 14.8                            | 10.8                            |
| Ta                             | 0.8                            | 1.3                            | 1.22                            | 0.4                             | 1                               | 1.18                            | 1.28                            | 0.9                             | 1.2                             | 1.5                             | 1.1                             | 1.1                             | 1.2                             |
| Zr                             | 241.6                          | 120.2                          | 162                             | 236.9                           | 138.3                           | 137                             | 148                             | 169.8                           | 156.7                           | 177.8                           | 92.7                            | 247.5                           | 165.4                           |
| Hf                             | 5.4                            | 4.4                            | 4.7                             | 6.5                             | 4.3                             | 4.1                             | 4.2                             | 4.4                             | 4.7                             | 5.9                             | 3.8                             | 6.9                             | 5.7                             |
| Y                              | 25.4                           | 26                             | 22.1                            | 19.7                            | 22.6                            | 15.2                            | 19.4                            | 13.4                            | 17.5                            | 14.9                            | 13                              | 27.2                            | 22.2                            |
| Ga                             | 19                             | 16.9                           | 17                              | 18.2                            | 17.1                            | 18                              | 14                              | 16.2                            | 13.6                            | 13.6                            | 13.4                            | 19.2                            | 13.7                            |
| Cs                             | 0.4                            | 1.5                            | 7.8                             | 2.8                             | 6.2                             | 2.8                             | 1.8                             | 1.8                             | 2.6                             | 3.6                             | 1.8                             | 3.4                             | 4.8                             |
| Sr                             | 279.8                          | 137.3                          | 284                             | 328.5                           | 365.6                           | 209                             | 210                             | 295.5                           | 235                             | 159.9                           | 43.9                            | 798.8                           | 169.7                           |
| Rb                             | 94.4                           | 147.4                          | 151                             | 100.4                           | 140.6                           | 150                             | 121                             | 122.2                           | 149.1                           | 187.8                           | 220.1                           | 113.4                           | 162.7                           |
| Ba                             | 2162                           | 2585                           | 961                             | 3222                            | 858                             | 841                             | 1447                            | 2508                            | 708                             | 1167                            | 162                             | 470                             | 1191                            |
| Be                             | 3                              | 3                              | 4                               | 2                               | 5                               | 5                               | 2                               | 5                               | 3                               | 3                               | 4                               | 1                               | <1                              |
| Li                             | -                              | -                              | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                               |
| Th                             | 10.2                           | 13.8                           | 18.8                            | 7.8                             | 15.5                            | 14.6                            | 21.6                            | 20.9                            | 26.1                            | 23.3                            | 35.4                            | 13.4                            | 12.2                            |
| U                              | 3.6                            | 3.5                            | 5.56                            | 6.4                             | 5.8                             | 3.5                             | 7.01                            | 6.5                             | 4.8                             | 3.6                             | 2.7                             | 2.8                             | 3.2                             |
| La                             | 34.5                           | 25.0                           | 43.1                            | 37.3                            | 46.1                            | 31.0                            | 46.8                            | 38.3                            | 55.4                            | 27.8                            | 28.8                            | 36.6                            | 19.3                            |
| Ce                             | 68.9                           | 60.1                           | 76.5                            | 70.2                            | 63.3                            | 64.1                            | 77.3                            | 72.6                            | 102.5                           | 58.0                            | 54.2                            | 78.8                            | 40.2                            |
| Pr                             | 8.27                           | 5.58                           | 8.92                            | 7.45                            | 8.98                            | 6.98                            | 8.01                            | 6.93                            | 10.15                           | 5.17                            | 5.49                            | 8.74                            | 4.80                            |
| Nd                             | 32.5                           | 21.3                           | 31.3                            | 26.0                            | 29.8                            | 24.9                            | 26.3                            | 22.7                            | 31.5                            | 15.5                            | 17.4                            | 35.4                            | 18.1                            |
| Sm                             | 6.17                           | 3.71                           | 5.68                            | 4.42                            | 5.63                            | 4.78                            | 4.20                            | 3.34                            | 5.01                            | 2.85                            | 3.16                            | 6.30                            | 4.12                            |
| Eu                             | 1.75                           | 0.49                           | 0.989                           | 1.25                            | 0.79                            | 0.86                            | 0.747                           | 0.8                             | 0.69                            | 0.49                            | 0.22                            | 1.47                            | 0.52                            |
| Gd                             | 5.82                           | 3.91                           | 4.58                            | 3.87                            | 4.61                            | 3.65                            | 3.42                            | 2.56                            | 3.96                            | 2.26                            | 3.10                            | 5.32                            | 3.61                            |
| Tb                             | 0.91                           | 0.72                           | 0.7                             | 0.64                            | 0.7                             | 0.55                            | 0.52                            | 0.38                            | 0.59                            | 0.42                            | 0.41                            | 0.84                            | 0.65                            |
| Dy                             | 5.1                            | 4.59                           | 4.04                            | 3.5                             | 3.72                            | 3.05                            | 3.16                            | 2.21                            | 3.3                             | 2.45                            | 2.21                            | 4.55                            | 3.85                            |
| Ho                             | 0.95                           | 0.99                           | 0.77                            | 0.65                            | 0.61                            | 0.57                            | 0.65                            | 0.43                            | 0.62                            | 0.54                            | 0.46                            | 0.94                            | 0.75                            |
| Er                             | 2.64                           | 2.69                           | 2.23                            | 2.07                            | 1.97                            | 1.68                            | 2.00                            | 1.42                            | 1.8                             | 1.74                            | 1.46                            | 2.66                            | 2.32                            |
| Tm                             | 0.39                           | 0.43                           | 0.334                           | 0.32                            | 0.3                             | 0.248                           | 0.303                           | 0.22                            | 0.25                            | 0.29                            | 0.24                            | 0.41                            | 0.37                            |
| Yb                             | 2.68                           | 2.90                           | 2.20                            | 2.16                            | 2.05                            | 1.65                            | 2.13                            | 1.73                            | 1.81                            | 1.66                            | 1.75                            | 2.57                            | 2.43                            |
| Lu                             | 0.37                           | 0.4                            | 0.346                           | 0.37                            | 0.27                            | 0.264                           | 0.361                           | 0.27                            | 0.28                            | 0.32                            | 0.25                            | 0.39                            | 0.34                            |

**TABLE 1.** cont.

| Sample #                       | 11RAYAZ-<br>373A02 <sup>b</sup> | 11RAYAZ-<br>382A02 <sup>b</sup> | 11RAYCR-<br>165B <sup>a</sup> | 11RAYJC-<br>127A1 <sup>a</sup> | 11RAYJR-<br>103A1 <sup>a</sup> | 11RAYJR-<br>109A02 <sup>b</sup> | 11RAYJR-<br>238A01 <sup>a</sup> | 11RAYJR-<br>240A01 <sup>a</sup> | 11RAYJR-<br>261A02 <sup>b</sup> | 11RAYJR-<br>261A02 <sup>b</sup> | 11RAYJR-<br>262A01 <sup>a</sup> | 11RAYJR-<br>264A01 <sup>a</sup> | 11RAYTD-<br>040 <sup>a</sup> |
|--------------------------------|---------------------------------|---------------------------------|-------------------------------|--------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|------------------------------|
| Easting                        | 566049                          | 597890                          | 623625                        | 552558                         | 571864                         | 571060                          | 600342                          | 604077                          | 594968                          | 594968                          | 600373                          | 597564                          | 621355                       |
| Northing                       | 6971415                         | 6964632                         | 6966499                       | 6978620                        | 6968583                        | 6979033                         | 6960835                         | 6958781                         | 6972235                         | 6972235                         | 6968820                         | 6961378                         | 6967600                      |
| Major elements (wt.%)          |                                 |                                 |                               |                                |                                |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                              |
| SiO <sub>2</sub>               | 74.36                           | 74.42                           | 74.47                         | 74.83                          | 69.09                          | 76.99                           | 71.37                           | 73.64                           | 76.21                           | 76.06                           | 72.64                           | 71.91                           | 69.45                        |
| TiO <sub>2</sub>               | 0.48                            | 0.22                            | 0.17                          | 0.10                           | 0.73                           | 0.09                            | 0.36                            | 0.25                            | 0.14                            | 0.15                            | 0.16                            | 0.35                            | 0.38                         |
| Al <sub>2</sub> O <sub>3</sub> | 11.94                           | 13.78                           | 13.02                         | 13.25                          | 13.69                          | 12.36                           | 14.11                           | 13.31                           | 12.78                           | 12.88                           | 13.84                           | 14.01                           | 14.64                        |
| Fe <sub>2</sub> O <sub>3</sub> | 3.76                            | 1.59                            | 2.22                          | 1.58                           | 6.06                           | 1.14                            | 3.05                            | 2.46                            | 1.56                            | 1.48                            | 2.52                            | 2.78                            | 3.77                         |
| MnO                            | 0.07                            | 0.03                            | 0.03                          | 0.02                           | 0.07                           | 0.02                            | 0.05                            | 0.04                            | 0.04                            | 0.04                            | 0.04                            | 0.05                            | 0.05                         |
| MgO                            | 1.25                            | 0.57                            | 0.31                          | 0.70                           | 2.34                           | 0.06                            | 1.25                            | 0.55                            | 0.32                            | 0.31                            | 0.37                            | 0.70                            | 0.93                         |
| CaO                            | 2.19                            | 1.93                            | 1.01                          | 0.04                           | 2.57                           | 0.46                            | 0.92                            | 0.51                            | 0.73                            | 0.75                            | 1.48                            | 2.09                            | 2.51                         |
| Na <sub>2</sub> O              | 2.00                            | 4.33                            | 2.70                          | 1.72                           | 2.09                           | 3.50                            | 3.61                            | 2.94                            | 3.93                            | 4.03                            | 2.91                            | 3.03                            | 2.76                         |
| K <sub>2</sub> O               | 2.60                            | 2.56                            | 5.55                          | 6.53                           | 1.85                           | 4.82                            | 4.40                            | 5.49                            | 3.12                            | 3.16                            | 4.76                            | 4.46                            | 4.47                         |
| P <sub>2</sub> O <sub>5</sub>  | 0.14                            | 0.06                            | 0.03                          | <0.01                          | 0.10                           | <0.01                           | 0.08                            | 0.04                            | 0.07                            | 0.02                            | 0.02                            | 0.07                            | 0.08                         |
| LOI                            | 0.90                            | 0.40                            | 0.40                          | 1.10                           | 1.20                           | 0.50                            | 0.60                            | 0.60                            | 0.90                            | 0.90                            | 1.00                            | 0.40                            | 0.70                         |
| Total                          | 99.73                           | 99.90                           | 99.89                         | 99.91                          | 99.81                          | 99.96                           | 99.79                           | 99.82                           | 99.83                           | 99.80                           | 99.77                           | 99.83                           | 99.76                        |
| Trace elements (ppm)           |                                 |                                 |                               |                                |                                |                                 |                                 |                                 |                                 |                                 |                                 |                                 |                              |
| Ni                             | <20                             | <20                             | <20                           | <20                            | 48                             | <20                             | <20                             | <20                             | <20                             | <20                             | <20                             | <20                             | <20                          |
| Cr                             | -                               | -                               | -                             | -                              | -                              | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                            |
| Co                             | 4.5                             | 1.8                             | 1.7                           | 0.3                            | 15.2                           | 0.4                             | 4.9                             | 2.3                             | 1.4                             | 1.7                             | 1.6                             | 3.6                             | 5.4                          |
| V                              | 109                             | 26                              | 11                            | <8                             | 80                             | <8                              | 30                              | 12                              | <8                              | <8                              | 10                              | 19                              | 29                           |
| S                              | -                               | -                               | <500                          | <500                           | <500                           | -                               | <500                            | <500                            | -                               | -                               | <500                            | <500                            | <500                         |
| Sc                             | 9                               | 6                               | 2                             | 1                              | 12                             | <1                              | 6                               | 3                               | 1                               | 2                               | 2                               | 4                               | 5                            |
| Cu                             | -                               | -                               | 3.6                           | 18.8                           | 22.2                           | -                               | 10.3                            | 3.3                             | -                               | -                               | 3.3                             | 1.1                             | 6                            |
| Pb                             | -                               | -                               | 4.6                           | 2.9                            | 5.3                            | -                               | 12.9                            | 10.1                            | -                               | -                               | 11                              | 9.9                             | 6                            |
| Zn                             | -                               | -                               | 25                            | 20                             | 66                             | -                               | 56                              | 40                              | -                               | -                               | 31                              | 41                              | 58                           |
| As                             | -                               | -                               | <0.5                          | 1.2                            | 1.3                            | -                               | 0.5                             | <0.5                            | -                               | -                               | 1.4                             | <0.5                            | <0.5                         |
| Mo                             | -                               | -                               | <0.1                          | 0.2                            | 0.2                            | -                               | 0.4                             | 0.4                             | -                               | -                               | 0.2                             | 0.2                             | 0.5                          |
| W                              | 1                               | 2.3                             | 0.7                           | 1                              | 0.6                            | 0.9                             | 1.4                             | 1.2                             | 1.2                             | 1.3                             | 0.7                             | 1.7                             | <0.5                         |
| Cd                             | -                               | -                               | <0.1                          | 0.1                            | <0.1                           | -                               | <0.1                            | <0.1                            | -                               | -                               | <0.1                            | <0.1                            | <0.1                         |
| Sn                             | 1                               | 4                               | 19.5                          | 2                              | <1                             | 1                               | 3                               | 3                               | 2                               | 2                               | 2                               | 5                               | 2                            |
| Nb                             | 10.5                            | 10.5                            | 2                             | 24.7                           | 12.3                           | 28.6                            | 10.2                            | 10.8                            | 13.7                            | 14.9                            | 11.9                            | 11.7                            | 11.8                         |
| Ta                             | 0.8                             | 1.0                             | 1.8                           | 1.5                            | 0.5                            | 1.7                             | 1.1                             | 1.1                             | 1.4                             | 1.4                             | 1.0                             | 1.1                             | 0.5                          |
| Zr                             | 129.1                           | 114.5                           | 143.3                         | 221.2                          | 210.4                          | 134                             | 171.8                           | 173.8                           | 105                             | 109.2                           | 166.4                           | 164.2                           | 213.4                        |
| Hf                             | 3.6                             | 3.9                             | 4.5                           | 8.1                            | 5.3                            | 4.4                             | 4.7                             | 5.2                             | 3.5                             | 3.2                             | 4.7                             | 4.8                             | 5.4                          |
| Y                              | 19.3                            | 23.5                            | 17.8                          | 28.2                           | 18.4                           | 16.9                            | 20.4                            | 17.7                            | 14.8                            | 16.2                            | 13                              | 21.5                            | 13.7                         |
| Ga                             | 17                              | 18.8                            | 16.5                          | 18.4                           | 16.2                           | 16.8                            | 15.8                            | 13.9                            | 12.7                            | 13                              | 14                              | 15.3                            | 17.1                         |
| Cs                             | 2.1                             | 2.6                             | 2.3                           | 1.3                            | 1.3                            | 20.5                            | 2.6                             | 1.1                             | 0.6                             | 0.6                             | 1.7                             | 5.0                             | 2.1                          |
| Sr                             | 173.5                           | 224.5                           | 154.4                         | 10.9                           | 262.1                          | 28.4                            | 147.8                           | 117.6                           | 164.3                           | 170                             | 161.8                           | 188.2                           | 251.1                        |
| Rb                             | 96.1                            | 94                              | 166.8                         | 223.4                          | 60.2                           | 202.7                           | 132.1                           | 162.6                           | 115.8                           | 114.1                           | 164.3                           | 188.9                           | 134.7                        |
| Ba                             | 1750                            | 411                             | 493                           | 212                            | 442                            | 94                              | 1030                            | 923                             | 438                             | 441                             | 1460                            | 773                             | 1462                         |
| Be                             | 1                               | 2                               | 3                             | 3                              | <1                             | 4                               | 2                               | 2                               | 2                               | 2                               | 3                               | 4                               | 6                            |
| Li                             | -                               | -                               | -                             | -                              | -                              | -                               | -                               | -                               | -                               | -                               | -                               | -                               | -                            |
| Th                             | 10.1                            | 20.7                            | 20.6                          | 27.7                           | 13.8                           | 30.3                            | 18.9                            | 30.9                            | 37.5                            | 37.7                            | 20.7                            | 19.5                            | 17.3                         |
| U                              | 3.9                             | 3.0                             | 5.1                           | 3.3                            | 2.0                            | 3.0                             | 3.8                             | 5.8                             | 2.9                             | 2.8                             | 4.4                             | 5.4                             | 2.6                          |
| La                             | 26.6                            | 30.4                            | 13.4                          | 31.2                           | 38.3                           | 23.5                            | 36                              | 49.2                            | 47                              | 47.5                            | 31.1                            | 36.8                            | 24.1                         |
| Ce                             | 51.7                            | 58.1                            | 41.2                          | 62.9                           | 81.8                           | 56.8                            | 72.8                            | 91.4                            | 72.7                            | 72.2                            | 60.1                            | 75.4                            | 60.2                         |
| Pr                             | 5.9                             | 6.18                            | 2.2                           | 6.94                           | 8.13                           | 5.66                            | 7.1                             | 8.28                            | 6.92                            | 7.26                            | 4.99                            | 7.46                            | 4.16                         |
| Nd                             | 22.2                            | 21.9                            | 7.4                           | 25.6                           | 31.1                           | 19.3                            | 25.1                            | 27.3                            | 21.3                            | 21.7                            | 16.3                            | 27.7                            | 13.9                         |
| Sm                             | 3.99                            | 4.5                             | 1.76                          | 4.96                           | 5.4                            | 4.35                            | 4.42                            | 4.16                            | 3.27                            | 3.36                            | 2.47                            | 4.88                            | 2.7                          |
| Eu                             | 0.86                            | 0.61                            | 0.31                          | 0.09                           | 1.3                            | 0.09                            | 0.70                            | 0.54                            | 0.46                            | 0.49                            | 0.37                            | 0.71                            | 0.91                         |
| Gd                             | 3.53                            | 4.17                            | 2.19                          | 4.77                           | 4.73                           | 3.85                            | 3.83                            | 3.47                            | 2.6                             | 2.63                            | 2.14                            | 4.47                            | 2.77                         |
| Tb                             | 0.64                            | 0.75                            | 0.41                          | 0.77                           | 0.67                           | 0.49                            | 0.58                            | 0.49                            | 0.42                            | 0.46                            | 0.33                            | 0.68                            | 0.43                         |
| Dy                             | 3.23                            | 4.19                            | 2.78                          | 4.65                           | 3.55                           | 3.05                            | 3.38                            | 3.15                            | 2.32                            | 2.36                            | 2.16                            | 4.17                            | 2.47                         |
| Ho                             | 0.73                            | 0.87                            | 0.58                          | 0.97                           | 0.65                           | 0.5                             | 0.67                            | 0.55                            | 0.49                            | 0.54                            | 0.49                            | 0.77                            | 0.54                         |
| Er                             | 2.04                            | 2.61                            | 1.93                          | 2.85                           | 1.87                           | 1.67                            | 2.08                            | 1.74                            | 1.59                            | 1.54                            | 1.41                            | 2.26                            | 1.49                         |
| Tm                             | 0.32                            | 0.39                            | 0.31                          | 0.45                           | 0.28                           | 0.31                            | 0.3                             | 0.26                            | 0.25                            | 0.26                            | 0.25                            | 0.37                            | 0.24                         |
| Yb                             | 2.28                            | 2.43                            | 2.30                          | 3.12                           | 1.92                           | 2.48                            | 1.89                            | 1.72                            | 1.78                            | 1.95                            | 1.75                            | 2.26                            | 1.47                         |
| Lu                             | 0.35                            | 0.39                            | 0.34                          | 0.48                           | 0.28                           | 0.36                            | 0.28                            | 0.25                            | 0.30                            | 0.31                            | 0.31                            | 0.35                            | 0.21                         |

**TABLE 1. cont.**

| Sample #                       | 11RAYWC<br>-135A <sup>a</sup> | 11RAYWC<br>-279A01 <sup>a</sup> | 14RAY-<br>130A01 <sup>a</sup> |
|--------------------------------|-------------------------------|---------------------------------|-------------------------------|
| Easting                        | 581720                        | 630638                          | 502091                        |
| Northing                       | 6976319                       | 6945193                         | 7108675                       |
| Major elements (wt.%)          |                               |                                 |                               |
| SiO <sub>2</sub>               | 76.53                         | 73.56                           | 66.39                         |
| TiO <sub>2</sub>               | 0.08                          | 0.32                            | 0.26                          |
| Al <sub>2</sub> O <sub>3</sub> | 12.17                         | 13.31                           | 15.98                         |
| Fe <sub>2</sub> O <sub>3</sub> | 1.45                          | 2.67                            | 3.86                          |
| MnO                            | <0.01                         | 0.04                            | 0.07                          |
| MgO                            | 0.24                          | 0.40                            | 2.29                          |
| CaO                            | <0.01                         | 0.94                            | 1.41                          |
| Na <sub>2</sub> O              | 0.18                          | 2.88                            | 1.95                          |
| K <sub>2</sub> O               | 8.30                          | 5.09                            | 4.91                          |
| P <sub>2</sub> O <sub>5</sub>  | <0.01                         | 0.05                            | 0.06                          |
| LOI                            | 1.00                          | 0.50                            | 2.20                          |
| Total                          | 99.94                         | 99.78                           | 99.41                         |
| Trace elements (ppm)           |                               |                                 |                               |
| Ni                             | <20                           | <20                             | <20                           |
| Cr                             | -                             | -                               | -                             |
| Co                             | 0.7                           | 1.2                             | 3                             |
| V                              | <8                            | 14                              | 21                            |
| S                              | <500                          | <500                            | -                             |
| Sc                             | <1                            | 6                               | 6                             |
| Cu                             | 1.3                           | 5.3                             | 2.1                           |
| Pb                             | 2.5                           | 9.6                             | 16.7                          |
| Zn                             | 6                             | 27                              | 65                            |
| As                             | 4                             | 1.4                             | <0.1                          |
| Mo                             | <0.1                          | 0.2                             | <0.1                          |
| W                              | 2.6                           | 0.9                             | 1.4                           |
| Cd                             | <0.1                          | 0.2                             | <0.1                          |
| Sn                             | 2                             | 4                               | 3                             |
| Nb                             | 19                            | 9.8                             | 13.9                          |
| Ta                             | 2.5                           | 0.9                             | 1                             |
| Zr                             | 91.8                          | 231.8                           | 228.5                         |
| Hf                             | 3.3                           | 6.5                             | 5.9                           |
| Y                              | 16.9                          | 23.1                            | 27.7                          |
| Ga                             | 13                            | 15.2                            | 23.1                          |
| Cs                             | 1.6                           | 3.5                             | 8.3                           |
| Sr                             | 65                            | 147.2                           | 239.8                         |
| Rb                             | 277.9                         | 168.5                           | 199.4                         |
| Ba                             | 236                           | 1084                            | 4090                          |
| Be                             | <1                            | <1                              | <1                            |
| Li                             | -                             | -                               | -                             |
| Th                             | 34.7                          | 24.1                            | 21.3                          |
| U                              | 3.9                           | 4.0                             | 5.6                           |
| La                             | 16.1                          | 60.7                            | 57.5                          |
| Ce                             | 28.9                          | 112.7                           | 104.9                         |
| Pr                             | 2.80                          | 11.13                           | 11.09                         |
| Nd                             | 8.6                           | 40.5                            | 37.3                          |
| Sm                             | 1.89                          | 6.27                            | 6.66                          |
| Eu                             | 0.2                           | 0.69                            | 1.34                          |
| Gd                             | 2.12                          | 5.32                            | 5.47                          |
| Tb                             | 0.39                          | 0.76                            | 0.84                          |
| Dy                             | 2.47                          | 4.37                            | 4.8                           |
| Ho                             | 0.56                          | 0.92                            | 1.01                          |
| Er                             | 1.66                          | 2.46                            | 2.90                          |
| Tm                             | 0.28                          | 0.39                            | 0.46                          |
| Yb                             | 2.17                          | 2.52                            | 2.93                          |
| Lu                             | 0.32                          | 0.37                            | 0.42                          |

<sup>a</sup>2014-2015 analyses by Bureau Veritas Commodities Canada Ltd.<sup>b</sup>2011 analyses by ACME Analytical Laboratories LTD<sup>c</sup>2009-2010 analyses by Activation Laboratories LTD<sup>d</sup>2000-2003 analyses at Laurentian University

**TABLE 2.** Major and trace element compositions of the Permian Sulphur Creek plutonic suite (Moderately LREE-enriched)

| Sample #                       | 01RAY-<br>108A <sup>a</sup> | 02RAY-<br>099B1 <sup>d</sup> | 02RAY-<br>104A1 <sup>d</sup> | 02RAY-<br>186A1 <sup>d</sup> | 02RAY-<br>201A1 <sup>d</sup> | 03GGAC-<br>002A1 <sup>d</sup> | 03GGAC-<br>137A1 <sup>d</sup> | 09RAYKR-<br>096A1 <sup>a</sup> | 11RAYAZ-<br>207A02 <sup>a</sup> | 11RAYAZ-<br>370A01 <sup>a</sup> | 11RAYCR-<br>109A <sup>a</sup> | 11RAYJR-<br>001A01 <sup>a</sup> | 14RAY-<br>106A01 <sup>a</sup> |
|--------------------------------|-----------------------------|------------------------------|------------------------------|------------------------------|------------------------------|-------------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|-------------------------------|---------------------------------|-------------------------------|
| Easting                        | 572543                      | 521451                       | 525480                       | 518421                       | 515106                       | 591164                        | 605839                        | 375565                         | 559394                          | 561769.39                       | 557141                        | 614952                          | 562967                        |
| Northing                       | 6998067                     | 7017053                      | 7014535                      | 7029790                      | 7028307                      | 7053137                       | 7043179                       | 6990279                        | 6978163                         | 6971402.15                      | 6982937                       | 6953558                         | 7129589                       |
| Major elements (wt.%)          |                             |                              |                              |                              |                              |                               |                               |                                |                                 |                                 |                               |                                 |                               |
| SiO <sub>2</sub>               | 72.27                       | 62.62                        | 62.72                        | 71.92                        | 69.88                        | 58.80                         | 74.38                         | 76.48                          | 74.26                           | 87.60                           | 62.21                         | 72.26                           | 74.82                         |
| TiO <sub>2</sub>               | 0.34                        | 0.57                         | 0.66                         | 0.34                         | 0.43                         | 0.88                          | 0.09                          | 0.04                           | 0.25                            | 0.37                            | 0.94                          | 0.32                            | 0.12                          |
| Al <sub>2</sub> O <sub>3</sub> | 13.68                       | 16.72                        | 15.52                        | 13.22                        | 14.88                        | 17.75                         | 14.43                         | 12.92                          | 12.52                           | 5.25                            | 14.75                         | 13.92                           | 13.14                         |
| Fe <sub>2</sub> O <sub>3</sub> | 2.96                        | 5.86                         | 6.41                         | 3.99                         | 3.79                         | 8.72                          | 1.17                          | 0.97                           | 2.91                            | 2.76                            | 7.86                          | 2.41                            | 1.96                          |
| MnO                            | 0.06                        | 0.11                         | 0.08                         | 0.06                         | 0.07                         | 0.14                          | 0.04                          | 0.03                           | 0.05                            | 0.02                            | 0.14                          | 0.03                            | 0.02                          |
| MgO                            | 0.81                        | 2.14                         | 2.57                         | 0.85                         | 0.92                         | 2.31                          | 0.14                          | 0.11                           | 0.59                            | 0.98                            | 2.53                          | 0.83                            | 0.12                          |
| CaO                            | 1.86                        | 6.58                         | 6.29                         | 3.07                         | 1.94                         | 5.08                          | 1.08                          | 1.22                           | 2.25                            | 0.21                            | 6.95                          | 1.28                            | 0.47                          |
| Na <sub>2</sub> O              | 2.61                        | 1.67                         | 2.87                         | 3.67                         | 2.50                         | 3.25                          | 2.80                          | 3.66                           | 3.71                            | 0.59                            | 1.83                          | 2.82                            | 2.58                          |
| K <sub>2</sub> O               | 4.17                        | 1.14                         | 0.25                         | 0.61                         | 2.11                         | 1.64                          | 4.62                          | 3.83                           | 1.86                            | 0.86                            | 1.08                          | 5.16                            | 5.43                          |
| P <sub>2</sub> O <sub>5</sub>  | 0.07                        | 0.18                         | 0.16                         | 0.06                         | 0.08                         | 0.33                          | 0.06                          | 0.07                           | 0.04                            | 0.09                            | 0.09                          | 0.07                            | 0.15                          |
| LOI                            | 1.00                        | 2.01                         | 1.79                         | 1.08                         | 1.60                         | 0.58                          | 0.74                          | 0.60                           | 1.40                            | 1.20                            | 1.40                          | 0.70                            | 1.10                          |
| Total                          | 99.86                       | 99.60                        | 99.32                        | 98.87                        | 98.20                        | 99.48                         | 99.55                         | 99.93                          | 99.82                           | 99.92                           | 99.76                         | 99.80                           | 99.95                         |
| Trace elements (ppm)           |                             |                              |                              |                              |                              |                               |                               |                                |                                 |                                 |                               |                                 |                               |
| Ni                             | <20                         | <2                           | 13                           | -                            | <2                           | 10                            | 19                            | <20                            | <20                             | 22                              | <20                           | <20                             | <20                           |
| Cr                             | -                           | 24                           | 47                           | <3                           | -                            | -                             | -                             | -                              | -                               | -                               | -                             | -                               | -                             |
| Co                             | 3.5                         | 17                           | 15                           | 5                            | <4                           | 11                            | -3                            | 0.5                            | 3.2                             | 3.7                             | 15.1                          | 2.9                             | 1.1                           |
| V                              | 34                          | 100                          | 151                          | 40                           | 45                           | 35                            | 7                             | <8                             | 30                              | 61                              | 200                           | 19                              | <8                            |
| S                              | <500                        | 350                          | 329                          | 364                          | 144                          | -                             | -                             | <500                           | -                               | <500                            | <500                          | <500                            | -                             |
| Sc                             | 7                           | 12                           | 24                           | 16.79                        | 14.53                        | 13.2                          | 4                             | 2                              | 8                               | 5                               | 30                            | 5                               | 4                             |
| Cu                             | 6.7                         | 32                           | <9                           | -                            | -                            | n.d.                          | n.d.                          | 2                              | 1.4                             | 19.5                            | 13.8                          | 4                               | 5.4                           |
| Pb                             | 7.8                         | 6                            | <4                           | -                            | -                            | 7                             | 48                            | 3.5                            | 1.4                             | 6.2                             | 0.9                           | 7.7                             | 6                             |
| Zn                             | 41                          | 33                           | 42                           | 22                           | 47                           | 90                            | 15                            | 13                             | 19                              | 49                              | 53                            | 38                              | 35                            |
| As                             | 0.8                         | <1                           | 2                            | -                            | -                            | 3                             | 8                             | <0.5                           | <0.5                            | 7.3                             | 1                             | 0.7                             | <0.1                          |
| Mo                             | <0.1                        | -                            | -                            | -                            | -                            | N.D.                          | N.D.                          | <0.1                           | 0.3                             | 0.5                             | 0.5                           | 0.5                             | 0.7                           |
| W                              | <0.5                        | -                            | -                            | 16                           | 12                           | 3                             | 5                             | <0.5                           | <0.5                            | <0.5                            | <0.5                          | 0.9                             | 4.6                           |
| Cd                             | <0.1                        | 11                           | 8                            | 3                            | 3                            | -                             | -                             | <0.1                           | <0.1                            | <0.1                            | <0.1                          | <0.1                            | <0.1                          |
| Sn                             | 3                           | -                            | -                            | -                            | -                            | -                             | -                             | 3                              | 4.6                             | <1                              | <1                            | 4                               | 12                            |
| Nb                             | 10.1                        | 5.9                          | 9.0                          | 2.1                          | 2.5                          | 16                            | 13.1                          | 5.7                            | 2                               | 7.6                             | 4.8                           | 12.9                            | 13                            |
| Ta                             | 0.9                         | -                            | 0.45                         | -                            | -                            | 0.96                          | 2.2                           | 0.5                            | 0.4                             | 0.6                             | 0.3                           | 1.5                             | 1.7                           |
| Zr                             | 116.8                       | 76                           | 83                           | 58                           | 59                           | 48.3                          | 59.8                          | 48                             | 119.4                           | 121                             | 82.8                          | 161.3                           | 62.3                          |
| Hf                             | 3.4                         | 1.36                         | 1.92                         | 2.29                         | 1.99                         | 1.8                           | 2.3                           | 2.1                            | 3.3                             | 2.9                             | 2.2                           | 4.9                             | 2                             |
| Y                              | 14.7                        | 12                           | 26                           | 35                           | 37                           | 30.04                         | 23.08                         | 32                             | 24.2                            | 10.1                            | 17.9                          | 14.8                            | 30.1                          |
| Ga                             | 14.3                        | 17                           | 17                           | 15                           | 16                           | 20                            | 19                            | 10.7                           | 12.7                            | 5.5                             | 15.3                          | 18.1                            | 18.3                          |
| Cs                             | 4.9                         | 1.73                         | 0.29                         | 0.81                         | 2.2                          | 0.634                         | 3.344                         | 2.3                            | 1.6                             | 0.7                             | 0.9                           | 7.8                             | 7                             |
| Sr                             | 156.2                       | 296                          | 267                          | 188                          | 65                           | 247                           | 73                            | 68.2                           | 111.1                           | 35.1                            | 173                           | 189                             | 44.4                          |
| Rb                             | 169.4                       | 51                           | 12                           | 25                           | 83                           | 45                            | 137                           | 126.8                          | 56.2                            | 33                              | 37.9                          | 217                             | 380.1                         |
| Ba                             | 710                         | 852                          | 183                          | 337                          | 822                          | 1102                          | 850                           | 375                            | 1195                            | 388                             | 1044                          | 1098                            | 176                           |
| Be                             | 2                           | -                            | -                            | 0.4                          | 0.73                         | 0.87                          | 2.62                          | <1                             | <1                              | <1                              | <1                            | 3                               | <1                            |
| Li                             | -                           | 8                            | 6                            | 11                           | -                            | -                             | -                             | -                              | -                               | -                               | -                             | -                               | -                             |
| Th                             | 14.5                        | 5.0                          | 1.72                         | 1.71                         | 2.02                         | 3.93                          | 9.41                          | 5.7                            | 6.9                             | 4.5                             | 3.4                           | 13.4                            | 13                            |
| U                              | 1.8                         | 1.2                          | 0.8                          | 0.86                         | 0.88                         | 1.543                         | 2.97                          | 2.2                            | 1.8                             | 1.1                             | 1.2                           | 4.7                             | 6.3                           |
| La                             | 12                          | 13.76                        | 14.23                        | 5.38                         | 7.88                         | 20.54                         | 11.19                         | 8.6                            | 19.1                            | 13.3                            | 12.2                          | 14.5                            | 8.7                           |
| Ce                             | 25.3                        | 23.43                        | 30.52                        | 12.74                        | 17.2                         | 45.07                         | 31.45                         | 21.5                           | 38.1                            | 24.8                            | 23.7                          | 34.2                            | 23.3                          |
| Pr                             | 2.5                         | 2.49                         | 4.22                         | 1.85                         | 2.41                         | 5.664                         | 2.739                         | 2.25                           | 4.6                             | 3.08                            | 2.85                          | 3.1                             | 2.13                          |
| Nd                             | 9.4                         | 9.4                          | 18.04                        | 8.37                         | 10.57                        | 23.88                         | 9.92                          | 8.2                            | 16.9                            | 11.3                            | 11.9                          | 11.5                            | 8.1                           |
| Sm                             | 1.89                        | 1.78                         | 4.66                         | 2.76                         | 3.25                         | 5.4                           | 2.47                          | 1.99                           | 3.85                            | 2.07                            | 2.5                           | 2.52                            | 2.18                          |
| Eu                             | 0.54                        | 0.99                         | 1.37                         | 0.88                         | 1.04                         | 1.332                         | 0.479                         | 0.35                           | 0.71                            | 0.45                            | 0.74                          | 0.49                            | 0.22                          |
| Gd                             | 1.82                        | 1.72                         | 4.81                         | 3.97                         | 4.47                         | 5.685                         | 2.714                         | 3.02                           | 3.85                            | 1.98                            | 3.16                          | 2.36                            | 2.52                          |
| Tb                             | 0.38                        | 0.26                         | 0.78                         | 0.75                         | 0.79                         | 0.889                         | 0.566                         | 0.71                           | 0.69                            | 0.29                            | 0.52                          | 0.37                            | 0.68                          |
| Dy                             | 2.29                        | 1.69                         | 4.4                          | 5.19                         | 5.25                         | 5.411                         | 3.834                         | 4.8                            | 3.88                            | 1.71                            | 3.23                          | 2.4                             | 4.56                          |
| Ho                             | 0.51                        | 0.33                         | 0.91                         | 1.22                         | 1.2                          | 1.12                          | 0.808                         | 1.09                           | 0.86                            | 0.36                            | 0.68                          | 0.5                             | 1.0                           |
| Er                             | 1.72                        | 0.96                         | 2.56                         | 3.57                         | 3.41                         | 3.205                         | 2.437                         | 3.20                           | 2.63                            | 1.03                            | 2.06                          | 1.52                            | 3.11                          |
| Tm                             | 0.28                        | 0.14                         | 0.35                         | 0.57                         | 0.53                         | 0.457                         | 0.374                         | 0.47                           | 0.39                            | 0.18                            | 0.31                          | 0.27                            | 0.46                          |
| Yb                             | 1.94                        | 0.90                         | 2.17                         | 3.63                         | 3.26                         | 2.94                          | 2.47                          | 3.22                           | 2.56                            | 1.19                            | 2.02                          | 1.81                            | 2.95                          |
| Lu                             | 0.29                        | 0.147                        | 0.32                         | 0.605                        | 0.527                        | 0.42                          | 0.344                         | 0.49                           | 0.42                            | 0.17                            | 0.33                          | 0.28                            | 0.39                          |



**TABLE 3.** Major and trace element compositions of the Permian Sulphur Creek plutonic suite (REE-depleted)

| Sample #                       | 02GG-<br>A172A2 <sup>d</sup> | 00RAY-<br>079B <sup>a</sup> | 09RAYJR-<br>106A1 <sup>a</sup> | 11RAYAZ-<br>286A01 <sup>a</sup> | 11RAYAZ-<br>302A02 <sup>b</sup> | 11RAYCR-<br>155A <sup>a</sup> | 11RAYJR-<br>259A01 <sup>a</sup> |
|--------------------------------|------------------------------|-----------------------------|--------------------------------|---------------------------------|---------------------------------|-------------------------------|---------------------------------|
| Easting                        | 536501                       | 591387                      | 364097                         | 579884                          | 585323                          | 557012                        | 586235                          |
| Northing                       | 7020398                      | 6986953                     | 7030362                        | 6977866                         | 6971744                         | 6980163                       | 6974315                         |
| Major elements (wt.%)          |                              |                             |                                |                                 |                                 |                               |                                 |
| SiO <sub>2</sub>               | 64.85                        | 70.48                       | 68.52                          | 74.50                           | 76.27                           | 76.23                         | 73.86                           |
| TiO <sub>2</sub>               | 0.38                         | 0.23                        | 0.19                           | 0.17                            | 0.09                            | 0.08                          | 0.15                            |
| Al <sub>2</sub> O <sub>3</sub> | 17.89                        | 14.98                       | 17.30                          | 13.32                           | 12.28                           | 12.37                         | 13.54                           |
| Fe <sub>2</sub> O <sub>3</sub> | 3.20                         | 3.27                        | 2.06                           | 2.33                            | 1.32                            | 2.00                          | 2.18                            |
| MnO                            | 0.03                         | 0.08                        | 0.04                           | 0.03                            | 0.01                            | 0.02                          | 0.03                            |
| MgO                            | 0.85                         | 0.55                        | 0.62                           | 0.45                            | 1.17                            | 0.54                          | 0.38                            |
| CaO                            | 4.66                         | 1.33                        | 3.88                           | 0.20                            | 0.30                            | 0.04                          | 0.49                            |
| Na <sub>2</sub> O              | 3.70                         | 3.74                        | 5.45                           | 2.87                            | 2.57                            | 1.77                          | 3.44                            |
| K <sub>2</sub> O               | 1.54                         | 4.07                        | 0.85                           | 5.25                            | 3.88                            | 6.17                          | 5.21                            |
| P <sub>2</sub> O <sub>5</sub>  | 0.13                         | 0.08                        | 0.08                           | 0.04                            | <0.01                           | <0.01                         | 0.03                            |
| LOI                            | 1.19                         | 0.90                        | 0.80                           | 0.70                            | 1.70                            | 0.70                          | 0.50                            |
| Total                          | 98.42                        | 99.72                       | 99.77                          | 99.89                           | 99.58                           | 99.96                         | 99.82                           |
| Trace elements (ppm)           |                              |                             |                                |                                 |                                 |                               |                                 |
| Ni                             | <1                           | <20                         | <20                            | <20                             | <20                             | <20                           | <20                             |
| Cr                             | -                            | -                           | -                              | -                               | -                               | -                             | -                               |
| Co                             | <3                           | 3.2                         | 3                              | 1.7                             | 1                               | <0.2                          | 1.3                             |
| V                              | 69                           | 15                          | 29                             | 10                              | <8                              | <8                            | 9                               |
| S                              | -                            | <500                        | <500                           | <500                            | -                               | <500                          | <500                            |
| Sc                             | 3.33                         | 2                           | 1                              | 2                               | 1                               | <1                            | 2                               |
| Cu                             | <0.5                         | 2.6                         | 1.8                            | 1.2                             | -                               | 2                             | 3.6                             |
| Pb                             | -                            | 5.8                         | 1.6                            | 6.8                             | -                               | 1.5                           | 7                               |
| Zn                             | 84                           | 37                          | 28                             | 19                              | -                               | 3                             | 18                              |
| As                             | -                            | 0.7                         | <0.5                           | 1.1                             | -                               | 0.5                           | 1.7                             |
| Mo                             | -                            | 0.2                         | <0.1                           | 0.3                             | -                               | 0.7                           | 0.1                             |
| W                              | -                            | 1.1                         | <0.5                           | 3.3                             | 1.1                             | 2.4                           | 0.8                             |
| Cd                             | 4                            | <0.1                        | <0.1                           | <0.1                            | -                               | <0.1                          | <0.1                            |
| Sn                             | -                            | 1                           | <1                             | 3                               | 3                               | 3                             | 2                               |
| Nb                             | 7.8                          | 9.8                         | 4.8                            | 19.1                            | 13                              | 15.3                          | 14.3                            |
| Ta                             | 0.48                         | 0.9                         | 0.2                            | 2                               | 1.3                             | 1.5                           | 1.4                             |
| Zr                             | 89.4                         | 174.1                       | 82.5                           | 143.6                           | 92.8                            | 144.5                         | 171.2                           |
| Hf                             | 1.13                         | 4.3                         | 2.1                            | 4.7                             | 3.3                             | 5.4                           | 5.2                             |
| Y                              | 4.1                          | 7.6                         | 1.8                            | 8.5                             | 6.5                             | 7.9                           | 4.9                             |
| Ga                             | 24                           | 15.7                        | 15                             | 13.8                            | 10.9                            | 17.4                          | 12.4                            |
| Cs                             | 1.47                         | 1.3                         | 0.7                            | 1.4                             | 1.1                             | 0.8                           | 1.7                             |
| Sr                             | 735                          | 303.2                       | 1161.3                         | 94.1                            | 73.3                            | 18.6                          | 128.6                           |
| Rb                             | 49                           | 125.1                       | 21.2                           | 210.1                           | 110.4                           | 207.8                         | 182.7                           |
| Ba                             | 1449                         | 1778                        | 642                            | 598                             | 613                             | 145                           | 1108                            |
| Be                             | 0.58                         | 4                           | 3                              | 4                               | <1                              | 5                             | 6                               |
| Li                             | 21                           | -                           | -                              | -                               | -                               | -                             | -                               |
| Th                             | 2.72                         | 19.1                        | 0.6                            | 23.7                            | 27.8                            | 16.1                          | 30.2                            |
| U                              | 1.63                         | 4.8                         | 0.2                            | 3                               | 2.3                             | 1.8                           | 4                               |
| La                             | 10.65                        | 8.7                         | 4.7                            | 22.3                            | 19.6                            | 3                             | 5.7                             |
| Ce                             | 21.02                        | 52.4                        | 8.1                            | 74.8                            | 42.7                            | 4.5                           | 37.2                            |
| Pr                             | 2.61                         | 1.65                        | 0.86                           | 3.49                            | 3.35                            | 0.42                          | 1.01                            |
| Nd                             | 10.22                        | 5.2                         | 3.1                            | 10.1                            | 10.3                            | 1.2                           | 3.3                             |
| Sm                             | 2.24                         | 1.14                        | 0.48                           | 1.87                            | 1.8                             | 0.27                          | 0.62                            |
| Eu                             | 0.74                         | 0.29                        | 0.17                           | 0.22                            | 0.2                             | <0.02                         | 0.11                            |
| Gd                             | 1.66                         | 1.3                         | 0.39                           | 1.71                            | 1.26                            | 0.64                          | 0.72                            |
| Tb                             | 0.2                          | 0.18                        | 0.05                           | 0.25                            | 0.2                             | 0.14                          | 0.13                            |
| Dy                             | 1.05                         | 1.12                        | 0.29                           | 1.35                            | 0.99                            | 1.1                           | 0.85                            |
| Ho                             | 0.2                          | 0.24                        | 0.05                           | 0.31                            | 0.23                            | 0.31                          | 0.19                            |
| Er                             | 0.51                         | 0.89                        | 0.16                           | 1.05                            | 0.84                            | 0.99                          | 0.68                            |
| Tm                             | 0.07                         | 0.16                        | 0.03                           | 0.16                            | 0.13                            | 0.18                          | 0.13                            |
| Yb                             | 0.47                         | 1.17                        | 0.21                           | 1.35                            | 1.01                            | 1.34                          | 1.12                            |
| Lu                             | 0.077                        | 0.18                        | 0.03                           | 0.22                            | 0.17                            | 0.22                          | 0.16                            |

**TABLE 4.** Major and trace element compositions of the felsic/intermediate volcanic rocks of the Permian Klondike schist

| Sample #                       | 11RAYJR-<br>266A02 <sup>b</sup> | 11RAYJR-<br>268A02 <sup>b</sup> | 11RAYAZ-<br>368A02 <sup>b</sup> | 11RAYAZ-<br>125A03 <sup>b</sup> | 10RAYJR-<br>098A02 <sup>c</sup> | 03GGA-<br>391A1 <sup>d</sup> | 02RAY-<br>308A1 <sup>a</sup> | 00GGA-<br>103A <sup>a</sup> | 00GGA-<br>064A <sup>a</sup> | 11RAYAZ-<br>278A02 <sup>b</sup> |
|--------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|---------------------------------|------------------------------|------------------------------|-----------------------------|-----------------------------|---------------------------------|
| Easting                        | 535834                          | 515779                          | 557332                          | 555202                          | 553064                          | 512237                       | 532185                       | 580441                      | 600546                      | 573946                          |
| Northing                       | 6995136                         | 7010935                         | 6974394                         | 6972975                         | 6978861                         | 7013117                      | 6997382                      | 7095340                     | 7083918                     | 6966933                         |
| Major elements (wt.%)          |                                 |                                 |                                 |                                 |                                 |                              |                              |                             |                             |                                 |
| SiO <sub>2</sub>               | 63.85                           | 67.59                           | 71.16                           | 66.83                           | 69.05                           | 68.97                        | 61.60                        | 76.18                       | 75.47                       | 68.88                           |
| TiO <sub>2</sub>               | 0.56                            | 0.43                            | 0.51                            | 0.55                            | 0.52                            | 0.44                         | 0.50                         | 0.16                        | 0.07                        | 0.47                            |
| Al <sub>2</sub> O <sub>3</sub> | 16.62                           | 15.58                           | 13.52                           | 16.08                           | 13.17                           | 15.92                        | 16.26                        | 12.45                       | 12.03                       | 13.06                           |
| Fe <sub>2</sub> O <sub>3</sub> | 3.97                            | 2.68                            | 4.00                            | 3.58                            | 4.97                            | 3.28                         | 5.40                         | 1.61                        | 1.59                        | 3.00                            |
| MnO                            | 0.11                            | 0.08                            | 0.05                            | 0.1                             | 0.09                            | 0.05                         | 0.08                         | 0.02                        | 0.02                        | 0.08                            |
| MgO                            | 2.58                            | 2.01                            | 1.41                            | 2.09                            | 0.98                            | 1.02                         | 2.97                         | 0.47                        | 1.29                        | 2.00                            |
| CaO                            | 3.05                            | 2.00                            | 2.44                            | 3.07                            | 4.12                            | 0.65                         | 4.29                         | 0.02                        | 0.36                        | 3.89                            |
| Na <sub>2</sub> O              | 2.73                            | 2.57                            | 2.53                            | 3.05                            | 4.18                            | 4.97                         | 2.43                         | 0.99                        | 2.04                        | 3.57                            |
| K <sub>2</sub> O               | 4.15                            | 4.13                            | 3.18                            | 3.33                            | 0.77                            | 3.70                         | 3.05                         | 6.87                        | 4.7                         | 0.73                            |
| P <sub>2</sub> O <sub>5</sub>  | 0.15                            | 0.15                            | 0.02                            | 0.16                            | 0.11                            | 0.11                         | 0.15                         | 0.03                        | <0.01                       | 0.11                            |
| LOI                            | 1.70                            | 2.30                            | 0.70                            | 0.60                            | 1.88                            | 0.80                         | 2.80                         | 0.90                        | 2.1                         | 3.60                            |
| Total                          | 99.44                           | 99.47                           | 99.52                           | 99.39                           | 99.84                           | 99.91                        | 99.56                        | 99.71                       | 99.63                       | 99.41                           |
| Trace elements (ppm)           |                                 |                                 |                                 |                                 |                                 |                              |                              |                             |                             |                                 |
| Ni                             | <20                             | 36                              | 61                              | <20                             | -                               | -                            | -                            | -                           | -                           | -                               |
| Cr                             | -                               | -                               | -                               | -                               | < 20                            | 14                           | <20                          | <20                         | <20                         | 30                              |
| Co                             | 7.2                             | 2.5                             | 7.7                             | 5.5                             | 20                              | -                            | -                            | -                           | -                           | -                               |
| V                              | 51                              | 28                              | 53                              | 44                              | 7                               | <1                           | 11.7                         | 0.8                         | 0.7                         | 7.9                             |
| S                              | -                               | -                               | -                               | -                               | 75                              | 59                           | 102                          | 10                          | 13                          | 85                              |
| Sc                             | 9                               | 6                               | 12                              | 8                               | -                               | 66                           | <500                         | <500                        | 5400                        | -                               |
| Cu                             | -                               | -                               | -                               | -                               | 17                              | 5.1                          | 14                           | 4                           | 5                           | 18                              |
| Pb                             | -                               | -                               | -                               | -                               | < 10                            | -                            | 26.8                         | 3.4                         | 0.9                         | -                               |
| Zn                             | -                               | -                               | -                               | -                               | < 5                             | 15                           | 5.6                          | 15.8                        | 4.8                         | -                               |
| As                             | -                               | -                               | -                               | -                               | 40                              | 36                           | 60                           | 6                           | 9                           | -                               |
| Mo                             | -                               | -                               | -                               | -                               | < 5                             | 16                           | 2.2                          | 3.1                         | <0.5                        | -                               |
| W                              | 2.1                             | 1.5                             | 0.9                             | 1.1                             | < 2                             | -                            | <0.1                         | 0.2                         | 0.9                         | -                               |
| Cd                             | -                               | -                               | -                               | -                               | < 0.5                           | 3                            | 1.5                          | 0.8                         | 0.9                         | <0.5                            |
| Sn                             | 3                               | 2                               | 2                               | 2                               | -                               | -                            | <0.1                         | <0.1                        | <0.1                        | -                               |
| Nb                             | 9.7                             | 14.2                            | 9.6                             | 10.7                            | 2                               | -                            | 1                            | 2                           | 3                           | 3                               |
| Ta                             | 0.5                             | 0.7                             | 0.7                             | 0.6                             | 6.8                             | 13.9                         | 7.5                          | 9.7                         | 10.7                        | 3.4                             |
| Zr                             | 207.9                           | 267.5                           | 128.3                           | 216.4                           | 0.56                            | 0.74                         | 0.5                          | 0.8                         | 0.5                         | 0.2                             |
| Hf                             | 5.9                             | 6.9                             | 3.9                             | 5.8                             | 79                              | 312.3                        | 166.6                        | 127                         | 96.4                        | 70.4                            |
| Y                              | 32.2                            | 23.7                            | 17.8                            | 30.4                            | 2.8                             | 7.8                          | 4.5                          | 3.7                         | 3.6                         | 2.3                             |
| Ga                             | 16                              | 15.9                            | 14.4                            | 18.1                            | 32                              | 23.95                        | 18.2                         | 20.6                        | 28.2                        | 22.7                            |
| Cs                             | 2.9                             | 2.2                             | 4.9                             | 1.4                             | 15                              | 20                           | 15.4                         | 14.5                        | 16.4                        | 12                              |
| Sr                             | 535.6                           | 333.2                           | 221.8                           | 961.6                           | 0.4                             | 1.081                        | 1                            | 1.2                         | 0.1                         | 0.3                             |
| Rb                             | 117.2                           | 129                             | 119.7                           | 93.5                            | 203                             | 85                           | 843.5                        | 74.4                        | 80.6                        | 146.2                           |
| Ba                             | 3255                            | 3120                            | 1479                            | 3462                            | 16                              | 110                          | 91.5                         | 135.2                       | 119.7                       | 15.9                            |
| Be                             | 3                               | 2                               | 2                               | 3                               | 909                             | 1757                         | 1916                         | 2102                        | 2706                        | 964                             |
| Li                             | -                               | -                               | -                               | -                               | < 1                             | 1.49                         | <1                           | <1                          | 2                           | 1                               |
| Th                             | 15.9                            | 22.5                            | 11.5                            | 16.8                            | -                               | 13                           | -                            | -                           | -                           | -                               |
| U                              | 4.3                             | 7.2                             | 2.4                             | 5                               | 6.88                            | 25.34                        | 18.1                         | 18.5                        | 15.3                        | 2.7                             |
| La                             | 44.8                            | 59.3                            | 29.7                            | 55.8                            | 2.56                            | 7.269                        | 5.2                          | 2.9                         | 3.8                         | 1.3                             |
| Ce                             | 86.9                            | 108.5                           | 57.7                            | 98.2                            | 19.1                            | 40.52                        | 39.5                         | 39.1                        | 29.3                        | 9.6                             |
| Pr                             | 10.51                           | 11.91                           | 6.5                             | 11.44                           | 43.4                            | 84.61                        | 72.2                         | 77.7                        | 58.7                        | 20.7                            |
| Nd                             | 41.3                            | 41.2                            | 23.2                            | 45.7                            | 5.65                            | 8.526                        | 8.18                         | 7.86                        | 7.29                        | 2.63                            |
| Sm                             | 7.85                            | 6.56                            | 4.03                            | 8.08                            | 22.6                            | 30.62                        | 29.3                         | 27.1                        | 26.5                        | 11.7                            |
| Eu                             | 1.88                            | 1.45                            | 0.80                            | 1.81                            | 5.22                            | 5.39                         | 5.01                         | 4.67                        | 6.28                        | 2.90                            |
| Gd                             | 7.27                            | 5.12                            | 3.5                             | 6.48                            | 0.945                           | 0.967                        | 1.28                         | 0.64                        | 0.81                        | 0.73                            |
| Tb                             | 0.91                            | 0.81                            | 0.58                            | 0.94                            | 5.47                            | 4.184                        | 4.06                         | 3.93                        | 6.01                        | 3.29                            |
| Dy                             | 5.89                            | 4.14                            | 3.12                            | 5.19                            | 0.92                            | 0.641                        | 0.58                         | 0.61                        | 0.93                        | 0.62                            |
| Ho                             | 0.99                            | 0.89                            | 0.64                            | 1.01                            | 5.86                            | 3.813                        | 3.04                         | 3.38                        | 5.24                        | 3.89                            |
| Er                             | 3.18                            | 2.60                            | 1.90                            | 3.07                            | 1.19                            | 0.826                        | 0.63                         | 0.67                        | 1.03                        | 0.87                            |
| Tm                             | 0.48                            | 0.40                            | 0.29                            | 0.48                            | 3.52                            | 2.638                        | 1.92                         | 2.12                        | 3.12                        | 2.73                            |
| Yb                             | 3.34                            | 2.76                            | 1.76                            | 3.15                            | 0.537                           | 0.422                        | 0.25                         | 0.31                        | 0.42                        | 0.43                            |
| Lu                             | 0.48                            | 0.44                            | 0.29                            | 0.50                            | 3.55                            | 2.93                         | 1.67                         | 2.15                        | 2.78                        | 2.78                            |

**TABLE 5.** Major and trace element compositions of the mafic volcanic rocks of the Permian Klondike assemblage

| Sample #                       | 09RAYJR-<br>069A1 <sup>a</sup> | 09RAYJR-<br>119A01 <sup>c</sup> | 11RAYCR-<br>156A <sup>a</sup> | 14RAY-<br>077D01 <sup>a</sup> | 14RAY-<br>088A01 <sup>a</sup> | 02RAY-<br>313A1 <sup>a</sup> | 02RAYG-<br>085A1 <sup>a</sup> | 09RAYJR-<br>120A1 <sup>a</sup> | 11RAYAZ-<br>198A01 <sup>a</sup> | 11RAYJR-<br>097B01 <sup>a</sup> | 11RAYJR-<br>267A02 <sup>b</sup> | 14RAY-<br>077A01 <sup>a</sup> |
|--------------------------------|--------------------------------|---------------------------------|-------------------------------|-------------------------------|-------------------------------|------------------------------|-------------------------------|--------------------------------|---------------------------------|---------------------------------|---------------------------------|-------------------------------|
| Type                           | 1                              | 1                               | 1                             | 1                             | 1                             | 2                            | 2                             | 2                              | 2                               | 2                               | 2                               | 2                             |
| Easting                        | 645975                         | 648093                          | 556400                        | 370608                        | 575208                        | 548438                       | 521513                        | 354762                         | 568147                          | 569156                          | 526124                          | 370608                        |
| Northing                       | 7031998                        | 7032438                         | 6980223                       | 6867814                       | 7104211                       | 6990296                      | 7035746                       | 7020495                        | 6967285                         | 6967024                         | 7003815                         | 6867814                       |
| Major elements (wt.%)          |                                |                                 |                               |                               |                               |                              |                               |                                |                                 |                                 |                                 |                               |
| SiO <sub>2</sub>               | 47.07                          | 49.05                           | 59.51                         | 57.26                         | 54.66                         | 47.85                        | 52.46                         | 48.69                          | 47.37                           | 47.23                           | 47.71                           | 54.09                         |
| TiO <sub>2</sub>               | 1.01                           | 0.555                           | 0.85                          | 0.88                          | 0.44                          | 1.39                         | 0.88                          | 1.07                           | 0.77                            | 0.72                            | 2.02                            | 1.15                          |
| Al <sub>2</sub> O <sub>3</sub> | 15.85                          | 15.03                           | 14.32                         | 14.24                         | 15.57                         | 15.47                        | 16.49                         | 15.61                          | 18.19                           | 17.92                           | 15.70                           | 14.13                         |
| Fe <sub>2</sub> O <sub>3</sub> | 9.60                           | 9.97                            | 9.91                          | 10.00                         | 9.19                          | 9.17                         | 12.58                         | 9.94                           | 12.53                           | 12.22                           | 10.97                           | 10.34                         |
| MnO                            | 0.16                           | 0.155                           | 0.11                          | 0.14                          | 0.15                          | 0.16                         | 0.12                          | 0.17                           | 0.23                            | 0.21                            | 0.17                            | 0.36                          |
| MgO                            | 9.04                           | 10.06                           | 4.00                          | 4.54                          | 7.29                          | 7.23                         | 4.28                          | 8.32                           | 5.85                            | 7.19                            | 4.20                            | 5.85                          |
| CaO                            | 11.93                          | 10.33                           | 4.49                          | 3.22                          | 7.52                          | 10.99                        | 2.80                          | 9.41                           | 10.01                           | 10.26                           | 13.82                           | 5.63                          |
| Na <sub>2</sub> O              | 2.10                           | 2.38                            | 2.82                          | 7.16                          | 2.19                          | 3.33                         | 6.55                          | 2.64                           | 1.66                            | 1.42                            | 2.70                            | 6.14                          |
| K <sub>2</sub> O               | 0.47                           | 0.48                            | 0.89                          | 0.10                          | <0.01                         | 0.36                         | 0.75                          | 1.17                           | 1.95                            | 0.15                            | 0.45                            | 0.06                          |
| P <sub>2</sub> O <sub>5</sub>  | 0.10                           | 0.04                            | 0.05                          | 0.09                          | 0.02                          | 0.18                         | 0.03                          | 0.19                           | 0.10                            | 0.06                            | 0.34                            | 0.10                          |
| LOI                            | 2.30                           | 2.47                            | 2.80                          | 2.10                          | 2.80                          | 3.60                         | 2.90                          | 2.40                           | 1.00                            | 2.40                            | 1.60                            | 1.90                          |
| Total                          | 99.74                          | 100.5                           | 99.79                         | 99.72                         | 99.81                         | 99.74                        | 99.84                         | 99.70                          | 99.65                           | 99.76                           | 99.65                           | 99.80                         |
| Trace elements (ppm)           |                                |                                 |                               |                               |                               |                              |                               |                                |                                 |                                 |                                 |                               |
| Ni                             | 91                             | 120                             | <20                           | <20                           | 77                            | 120                          | <20                           | <20                            | <20                             | 26                              | 31                              | 83                            |
| Cr                             | -                              | 390                             | -                             | -                             | -                             | -                            | -                             | -                              | -                               | -                               | -                               | -                             |
| Co                             | 36.2                           | 36                              | 18.2                          | 25.2                          | 32.5                          | 29.9                         | 24.8                          | 34.6                           | 36.9                            | 38                              | 36.8                            | 35.7                          |
| V                              | 224                            | 263                             | 189                           | 219                           | 288                           | 255                          | 302                           | 273                            | 353                             | 380                             | 366                             | 273                           |
| S                              | <500                           | -                               | 800                           | -                             | -                             | <500                         | <500                          | <500                           | <500                            | <500                            | -                               | -                             |
| Sc                             | 34                             | 42                              | 37                            | 27                            | 38                            | 33                           | 44                            | 37                             | 45                              | 44                              | 34                              | 33                            |
| Cu                             | 1.5                            | <10                             | 31.9                          | 7.5                           | 114.3                         | 11.8                         | 44.8                          | 1.6                            | 157                             | 138.7                           | -                               | 87.9                          |
| Pb                             | 1                              | 6                               | 4                             | 0.3                           | 0.2                           | 2.9                          | 1.6                           | 14                             | 1.3                             | 1.6                             | -                               | 1.7                           |
| Zn                             | 25                             | 70                              | 72                            | 24                            | 53                            | 33                           | 76                            | 39                             | 54                              | 51                              | -                               | 71                            |
| As                             | 0.9                            | <5                              | <0.5                          | <0.1                          | <0.1                          | <0.5                         | <0.5                          | <0.5                           | <0.5                            | <0.5                            | -                               | <0.1                          |
| Mo                             | <0.1                           | <2                              | <0.1                          | 1                             | <0.1                          | <0.1                         | 0.1                           | 0.3                            | 0.2                             | 0.2                             | -                               | 0.2                           |
| W                              | <0.5                           | <0.5                            | <0.5                          | <0.5                          | <0.5                          | <0.5                         | <0.5                          | <0.5                           | <0.5                            | <0.5                            | <0.5                            | <0.5                          |
| Cd                             | <0.1                           | -                               | <0.1                          | <0.1                          | <0.1                          | <0.1                         | <0.1                          | 0.1                            | 0.1                             | <0.1                            | -                               | <0.1                          |
| Sn                             | 1                              | 3                               | <1                            | <1                            | <1                            | <1                           | 1                             | 1                              | <1                              | <1                              | 1                               | <1                            |
| Nb                             | 0.7                            | 0.6                             | 1.8                           | 1.2                           | 0.4                           | 3.1                          | 0.4                           | 3.7                            | 1.9                             | 1.3                             | 17                              | 1.9                           |
| Ta                             | 0.1                            | 0.03                            | 0.1                           | <0.1                          | <0.1                          | 0.2                          | 0.3                           | 0.3                            | 0.1                             | <0.1                            | 0.9                             | 0.1                           |
| Zr                             | 43.9                           | 32                              | 36.4                          | 62.1                          | 20.6                          | 110.1                        | 34.5                          | 66.5                           | 61.4                            | 37.5                            | 164.1                           | 86.9                          |
| Hf                             | 1.2                            | 1                               | 1.2                           | 2                             | 0.8                           | 2.9                          | 1.2                           | 1.8                            | 1.7                             | 1.3                             | 4.3                             | 2.3                           |
| Y                              | 19.7                           | 14.1                            | 21                            | 23                            | 11.9                          | 23.6                         | 14.8                          | 16.4                           | 15.2                            | 13.4                            | 38.9                            | 24.7                          |
| Ga                             | 16                             | 12                              | 15.4                          | 14                            | 14.6                          | 15.4                         | 13.4                          | 16.7                           | 16.6                            | 16.1                            | 24.9                            | 15.7                          |
| Cs                             | <0.1                           | < 0.1                           | 0.9                           | 0.6                           | 0.2                           | 0.8                          | 0.3                           | 0.2                            | 1.2                             | <0.1                            | 0.2                             | 0.2                           |
| Sr                             | 288.8                          | 179                             | 624.9                         | 92.2                          | 105.6                         | 355                          | 103.3                         | 276.9                          | 164.6                           | 122.6                           | 683                             | 78.9                          |
| Rb                             | 11.6                           | 11                              | 36.3                          | 2.6                           | 0.1                           | 7.2                          | 19.4                          | 28.8                           | 39.7                            | 1.5                             | 10.4                            | 0.7                           |
| Ba                             | 166                            | 341                             | 128                           | 1337                          | 58                            | 223                          | 120                           | 590                            | 1228                            | 83                              | 117                             | 181                           |
| Be                             | <1                             | < 1                             | <1                            | <1                            | 1                             | <1                           | 2                             | 2                              | <1                              | 1                               | 1                               | 1                             |
| Li                             | -                              | -                               | -                             | -                             | -                             | -                            | -                             | -                              | -                               | -                               | -                               | -                             |
| Th                             | <0.2                           | < 0.05                          | 0.5                           | 0.3                           | <0.2                          | 1.7                          | 0.6                           | 2.1                            | 2.6                             | 1.5                             | 2.8                             | 0.5                           |
| U                              | <0.1                           | 0.2                             | 0.2                           | 0.2                           | 0.2                           | 0.5                          | 0.2                           | 0.7                            | 0.8                             | 0.6                             | 0.8                             | 0.2                           |
| La                             | 1.9                            | 1.57                            | 2.8                           | 2.7                           | 1                             | 8.3                          | 5.4                           | 9.5                            | 11.2                            | 7.3                             | 21                              | 4.9                           |
| Ce                             | 6.1                            | 4.19                            | 7.4                           | 8.0                           | 2.4                           | 22.1                         | 11.7                          | 18.4                           | 22.8                            | 16.1                            | 47.5                            | 13.2                          |
| Pr                             | 1.02                           | 0.77                            | 1.12                          | 1.23                          | 0.34                          | 2.9                          | 1.57                          | 2.65                           | 2.73                            | 1.96                            | 5.91                            | 1.95                          |
| Nd                             | 5.9                            | 4.25                            | 6.2                           | 6.2                           | 2.1                           | 14.1                         | 8.2                           | 12.8                           | 11.5                            | 8.6                             | 24.8                            | 9.7                           |
| Sm                             | 2.13                           | 1.54                            | 2.09                          | 2.23                          | 0.9                           | 3.71                         | 2.31                          | 2.79                           | 3.06                            | 2.07                            | 5.82                            | 2.89                          |
| Eu                             | 0.82                           | 0.532                           | 0.75                          | 0.68                          | 0.29                          | 1.27                         | 0.78                          | 1.09                           | 0.87                            | 0.69                            | 1.87                            | 0.98                          |
| Gd                             | 3.21                           | 2.14                            | 2.93                          | 3.28                          | 1.36                          | 4.29                         | 2.59                          | 3.21                           | 3.04                            | 2.25                            | 6.57                            | 3.94                          |
| Tb                             | 0.57                           | 0.41                            | 0.55                          | 0.60                          | 0.28                          | 0.76                         | 0.49                          | 0.56                           | 0.50                            | 0.39                            | 1.25                            | 0.75                          |
| Dy                             | 3.88                           | 2.59                            | 3.87                          | 3.89                          | 1.82                          | 4.70                         | 2.84                          | 3.32                           | 2.80                            | 2.39                            | 6.98                            | 4.53                          |
| Ho                             | 0.78                           | 0.52                            | 0.84                          | 0.91                          | 0.45                          | 0.94                         | 0.59                          | 0.63                           | 0.67                            | 0.51                            | 1.57                            | 0.95                          |
| Er                             | 2.15                           | 1.56                            | 2.62                          | 2.71                          | 1.29                          | 2.55                         | 1.68                          | 1.84                           | 1.74                            | 1.43                            | 4.59                            | 2.80                          |
| Tm                             | 0.31                           | 0.257                           | 0.40                          | 0.41                          | 0.20                          | 0.36                         | 0.26                          | 0.26                           | 0.27                            | 0.21                            | 0.70                            | 0.40                          |
| Yb                             | 2.10                           | 1.76                            | 2.67                          | 2.83                          | 1.47                          | 2.22                         | 1.67                          | 1.72                           | 1.90                            | 1.44                            | 4.32                            | 2.79                          |
| Lu                             | 0.27                           | 0.269                           | 0.42                          | 0.42                          | 0.23                          | 0.36                         | 0.25                          | 0.24                           | 0.27                            | 0.24                            | 0.63                            | 0.43                          |

**TABLE 5.** cont.

| Sample #                       | 03GGA-412A1 <sup>d</sup> | 03GGA-418A <sup>a</sup> | 03GGA-419A <sup>a</sup> | 11RAYAZ-258A02 <sup>b</sup> | 11RAYAZ-258B02 <sup>b</sup> | 11RAYJR-160A02 <sup>b</sup> | 14RAY-084A1 <sup>a</sup> |
|--------------------------------|--------------------------|-------------------------|-------------------------|-----------------------------|-----------------------------|-----------------------------|--------------------------|
| Type                           | 3                        | 3                       | 3                       | 3                           | 3                           | 3                           | 3                        |
| Easting                        | 515766                   | 516849                  | 516789                  | 561177                      | 561177                      | 575092                      | 513624                   |
| Northing                       | 7010549                  | 7007542                 | 7007853                 | 6970410                     | 6970410                     | 6965178                     | 7051573                  |
| Major elements (wt.%)          |                          |                         |                         |                             |                             |                             |                          |
| SiO <sub>2</sub>               | 48.34                    | 50.72                   | 51.49                   | 59.85                       | 49.26                       | 55.25                       | 50.75                    |
| TiO <sub>2</sub>               | 0.77                     | 0.73                    | 0.73                    | 0.62                        | 1.66                        | 0.81                        | 0.79                     |
| Al <sub>2</sub> O <sub>3</sub> | 19.42                    | 15.76                   | 14.46                   | 17.20                       | 18.41                       | 15.73                       | 14.42                    |
| Fe <sub>2</sub> O <sub>3</sub> | 11.16                    | 8.62                    | 8.74                    | 4.89                        | 8.33                        | 7.21                        | 8.06                     |
| MnO                            | 0.14                     | 0.14                    | 0.14                    | 0.12                        | 0.16                        | 0.10                        | 0.11                     |
| MgO                            | 5.45                     | 7.25                    | 7.62                    | 6.02                        | 6.95                        | 6.35                        | 5.23                     |
| CaO                            | 7.20                     | 5.27                    | 7.31                    | 0.85                        | 4.88                        | 5.40                        | 7.43                     |
| Na <sub>2</sub> O              | 3.26                     | 3.82                    | 3.71                    | 6.68                        | 5.75                        | 3.02                        | 3.30                     |
| K <sub>2</sub> O               | 0.22                     | 2.03                    | 1.68                    | 0.14                        | 0.31                        | 4.22                        | 2.64                     |
| P <sub>2</sub> O <sub>5</sub>  | 0.12                     | 0.16                    | 0.17                    | 0.34                        | 0.34                        | 0.32                        | 0.17                     |
| LOI                            | 3.80                     | 5.1                     | 3.5                     | 3.10                        | 3.30                        | 0.90                        | 6.80                     |
| Total                          | 99.88                    | 99.6                    | 99.61                   | 99.82                       | 99.39                       | 99.37                       | 99.72                    |
| Trace elements (ppm)           |                          |                         |                         |                             |                             |                             |                          |
| Ni                             | 10                       | 50                      | 92                      | <20                         | 66                          | 61                          | 77                       |
| Cr                             | -                        | -                       | -                       | -                           | -                           | -                           | -                        |
| Co                             | 29                       | 27.1                    | 32.5                    | 9.5                         | 34.2                        | 27.4                        | 28.6                     |
| V                              | 334                      | 228                     | 210                     | 105                         | 190                         | 183                         | 116                      |
| S                              | 130                      | <500                    | <500                    | -                           | -                           | -                           | <500                     |
| Sc                             | 25.5                     | 27                      | 29                      | 9                           | 23                          | 24                          | 14                       |
| Cu                             | 67                       | 83.5                    | 58.3                    | -                           | -                           | -                           | 32.5                     |
| Pb                             | 16                       | 8.8                     | 4.3                     | -                           | -                           | -                           | 6.2                      |
| Zn                             | 108                      | 49                      | 42                      | -                           | -                           | -                           | 84                       |
| As                             | 7                        | 5.4                     | 0.9                     | -                           | -                           | -                           | <0.5                     |
| Mo                             | -                        | 0.1                     | 0.1                     | -                           | -                           | -                           | 0.1                      |
| W                              | -                        | 1                       | <0.5                    | 1                           | 0.8                         | 1.1                         | <0.5                     |
| Cd                             | -                        | <0.1                    | <0.1                    | -                           | -                           | -                           | 0.1                      |
| Sn                             | -                        | <1                      | <1                      | <1                          | 2                           | 2                           | 2                        |
| Nb                             | 2.6                      | 5.1                     | 5.6                     | 14.3                        | 12.9                        | 14.1                        | 17.6                     |
| Ta                             | 0.2                      | 0.7                     | 1.8                     | 0.6                         | 0.8                         | 0.8                         | 1                        |
| Zr                             | 63.3                     | 92.1                    | 102.8                   | 220.6                       | 212                         | 201.8                       | 208.4                    |
| Hf                             | 1.7                      | 2.6                     | 2.6                     | 5.9                         | 4.6                         | 5.7                         | 5.3                      |
| Y                              | 18.6                     | 15.3                    | 15.2                    | 22.7                        | 27.2                        | 24.1                        | 21                       |
| Ga                             | 21                       | 15.3                    | 14.2                    | 18                          | 16.8                        | 17.1                        | 16.7                     |
| Cs                             | 0.261                    | 1                       | 0.3                     | 0.2                         | 0.5                         | 3.4                         | 2.1                      |
| Sr                             | 453                      | 194.2                   | 253.1                   | 75.7                        | 258                         | 537.5                       | 294.2                    |
| Rb                             | 9                        | 56.6                    | 27.9                    | 2.4                         | 7.7                         | 133.5                       | 93.6                     |
| Ba                             | 448                      | 1580                    | 1441                    | 201                         | 273                         | 2756                        | 631                      |
| Be                             | 0.25                     | 4                       | <1                      | 3                           | 2                           | 3                           | 2                        |
| Li                             | 23                       | -                       | -                       | -                           | -                           | -                           | -                        |
| Th                             | 2.7                      | 6.6                     | 7.4                     | 27.8                        | 2                           | 21.3                        | 16.1                     |
| U                              | 0.91                     | 1.7                     | 2.2                     | 8.4                         | 0.7                         | 6.5                         | 4                        |
| La                             | 12.44                    | 22.4                    | 23.1                    | 34.8                        | 18.3                        | 65.2                        | 44.2                     |
| Ce                             | 25.67                    | 43.4                    | 47.1                    | 79.9                        | 40.8                        | 123.1                       | 80.4                     |
| Pr                             | 3.36                     | 5.03                    | 5.18                    | 6.86                        | 5.26                        | 13.35                       | 8.42                     |
| Nd                             | 14.02                    | 18.5                    | 19.1                    | 26.0                        | 22.7                        | 46.4                        | 31.3                     |
| Sm                             | 3.32                     | 3.94                    | 4.25                    | 4.69                        | 5.05                        | 8.5                         | 5.15                     |
| Eu                             | 1.02                     | 1.01                    | 1.06                    | 1.16                        | 1.65                        | 1.87                        | 1.01                     |
| Gd                             | 3.44                     | 3.54                    | 3.82                    | 4.27                        | 5.22                        | 6.56                        | 4.51                     |
| Tb                             | 0.53                     | 0.53                    | 0.54                    | 0.73                        | 0.87                        | 1.01                        | 0.65                     |
| Dy                             | 3.24                     | 3.00                    | 3.02                    | 3.99                        | 4.9                         | 4.68                        | 3.85                     |
| Ho                             | 0.69                     | 0.55                    | 0.55                    | 1.07                        | 1.04                        | 0.90                        | 0.77                     |
| Er                             | 2.00                     | 1.80                    | 1.59                    | 2.79                        | 2.98                        | 2.53                        | 2.13                     |
| Tm                             | 0.29                     | 0.24                    | 0.22                    | 0.41                        | 0.44                        | 0.36                        | 0.32                     |
| Yb                             | 1.89                     | 1.54                    | 1.49                    | 2.71                        | 2.71                        | 2.44                        | 2.32                     |
| Lu                             | 0.29                     | 0.25                    | 0.25                    | 0.38                        | 0.40                        | 0.35                        | 0.36                     |

**TABLE 6.** Major and trace element compositions of the Permian mafic plutonic rocks

| Sample #                       | 03GGA-396A1 <sup>a</sup> | 02RAY-302A1 <sup>a</sup> | 02RAY-099A1 <sup>d</sup> | 02RAY-102A2 <sup>d</sup> | 02RAY-308B1 <sup>d</sup> | 03RAYR-036A2 <sup>d</sup> | 02RAY-G274A | 15RAY-JR141C01 <sup>a</sup> | 15RAY-JR043B02 <sup>a</sup> | 15RAY-EW100A01 |
|--------------------------------|--------------------------|--------------------------|--------------------------|--------------------------|--------------------------|---------------------------|-------------|-----------------------------|-----------------------------|----------------|
| Type                           | 2                        | 2                        | 3                        | 3                        | 3                        | 3                         | 3           | 3                           | 3                           | 3              |
| Easting                        | 514791                   | 520972                   | 521451                   | 522424                   | 532185                   | 622732                    | 532109      | 360315                      | 354709                      | 357486         |
| Northing                       | 7011444                  | 7023006                  | 7017053                  | 7017753                  | 6997382                  | 7041763                   | 7009046     | 6882457                     | 6881009                     | 6882703        |
| Major elements (wt.%)          |                          |                          |                          |                          |                          |                           |             |                             |                             |                |
| SiO <sub>2</sub>               | 46.79                    | 57.29                    | 51.74                    | 53.67                    | 47.16                    | 63.39                     | 47.74       | 47.39                       | 50.84                       | 48.17          |
| TiO <sub>2</sub>               | 1.52                     | 0.72                     | 0.61                     | 0.81                     | 1.66                     | 0.59                      | 0.66        | 0.91                        | 0.92                        | 1.21           |
| Al <sub>2</sub> O <sub>3</sub> | 18.29                    | 16.54                    | 17.03                    | 14.06                    | 18.13                    | 11.42                     | 10.02       | 16.49                       | 16.77                       | 17.53          |
| Fe <sub>2</sub> O <sub>3</sub> | 7.93                     | 7.71                     | 8.94                     | 7.44                     | 9.11                     | 9.59                      | 5.63        | 9.12                        | 7.93                        | 11.55          |
| MnO                            | 0.14                     | 0.12                     | 0.15                     | 0.12                     | 0.15                     | 0.34                      | 0.09        | 0.14                        | 0.12                        | 0.20           |
| MgO                            | 6.23                     | 3.87                     | 5.48                     | 7.32                     | 6.37                     | 5.39                      | 12.54       | 9.88                        | 7.48                        | 5.86           |
| CaO                            | 10.7                     | 7.60                     | 10.79                    | 9.50                     | 8.05                     | 5.45                      | 19.77       | 9.45                        | 8.36                        | 10.02          |
| Na <sub>2</sub> O              | 3.55                     | 2.24                     | 1.13                     | 1.94                     | 3.41                     | 1.86                      | 0.31        | 3.05                        | 4.39                        | 2.40           |
| K <sub>2</sub> O               | 0.85                     | 1.77                     | 0.39                     | 2.80                     | 1.24                     | 0.22                      | 0.62        | 1.46                        | 1.09                        | 0.78           |
| P <sub>2</sub> O <sub>5</sub>  | 0.31                     | 0.14                     | 0.08                     | 0.17                     | 0.40                     | 0.14                      | 0.03        | 0.24                        | 0.26                        | 0.54           |
| LOI                            | 3.30                     | 1.70                     | 2.23                     | 0.86                     | 2.57                     | 0.80                      | 2.1         | 1.30                        | 1.30                        | 1.20           |
| Total                          | 99.65                    | 99.75                    | 98.57                    | 98.69                    | 98.25                    | 99.19                     | 99.69       | 99.54                       | 99.49                       | 99.46          |
| Trace elements (ppm)           |                          |                          |                          |                          |                          |                           |             |                             |                             |                |
| Ni                             | 54                       | 20                       | 21                       | 140                      | 85                       | 50                        | 194         | 145                         | 81                          | 23             |
| Cr                             | -                        | -                        | 21                       | 371                      | 133                      | 104                       | -           | -                           | -                           | -              |
| Co                             | 24.6                     | 20.8                     | 34                       | 31                       | 20                       | 17                        | 28.1        | 38.2                        | 29.3                        | 31.4           |
| V                              | 192                      | 200                      | 236                      | 12                       | 179                      | 164                       | 141         | 193                         | 158                         | 356            |
| S                              | <500                     | <500                     | 539                      | 472                      | >400                     | 222                       | <500        | -                           | -                           | -              |
| Sc                             | 33                       | 24                       | 37                       | 17                       | 23.36                    | 15.5                      | 34          | 27                          | 22                          | 30             |
| Cu                             | 58                       | 24.3                     | 27                       | 13                       | 38                       | 305                       | 50          | 48.1                        | 43.9                        | 57.4           |
| Pb                             | 0.6                      | 0.8                      | 6                        | 13                       | -                        | 10                        | 3.5         | 0.9                         | 22.1                        | 6.4            |
| Zn                             | 44                       | 30                       | 69.3                     | 93                       | 75                       | 108                       | 4           | 33                          | 48                          | 35             |
| As                             | 0.5                      | <0.5                     | <1                       | 3                        | -                        | <1                        | 0.5         | 1                           | <0.5                        | 1.5            |
| Mo                             | <0.1                     | 0.1                      | -                        | -                        | -                        | -                         | <0.1        | <0.1                        | 0.1                         | 0.5            |
| W                              | <0.5                     | 1.3                      | -                        | -                        | 18                       | 3                         | 0.8         | <0.5                        | <0.5                        | 0.5            |
| Cd                             | <0.1                     | <0.1                     | 12                       | 11                       | 4                        | -                         | <0.1        | <0.1                        | 0.2                         | <0.1           |
| Sn                             | 1                        | 1                        | -                        | -                        | -                        | -                         | 2           | 3                           | 1                           | <1             |
| Nb                             | 8.7                      | 4.2                      | 4                        | 19                       | 14                       | 5.6                       | 2.8         | 6                           | 7.8                         | 1.9            |
| Ta                             | 0.7                      | 0.4                      | -                        | 1.03                     | 0.78                     | 0.45                      | 0.2         | 0.2                         | 0.4                         | 0.2            |
| Zr                             | 151.9                    | 72.7                     | 43                       | 132                      | 167                      | 93.9                      | 91.9        | 189.4                       | 198.2                       | 56.6           |
| Hf                             | 3.2                      | 1.8                      | 1.72                     | 3.45                     | 4.47                     | 2.4                       | 3.2         | 4.7                         | 5.1                         | 1.6            |
| Y                              | 21.3                     | 13                       | 18                       | 25                       | 31                       | 21.51                     | 11.8        | 23                          | 19.3                        | 23.9           |
| Ga                             | 15.2                     | 16.5                     | 15                       | 20                       | 17                       | 15                        | 11.4        | 20.4                        | 20                          | 18.3           |
| Cs                             | 0.3                      | 0.6                      | 0.42                     | 2.81                     | 0.5                      | 0.10                      | 0.6         | 1.3                         | 1.2                         | 1.8            |
| Sr                             | 970.2                    | 318.7                    | 307                      | 411                      | 382                      | 136                       | 372.2       | 710.6                       | 1052.9                      | 952.3          |
| Rb                             | 12.7                     | 54                       | 16                       | 117                      | 26                       | 7                         | 24.8        | 44.9                        | 31.7                        | 21.9           |
| Ba                             | 475                      | 778                      | 234                      | 625                      | 966                      | 260                       | 181         | 1082                        | 1588                        | 2001           |
| Be                             | 3                        | 3                        | -                        | -                        | 0.79                     | 0.54                      | <1          | 3                           | <1                          | <1             |
| Li                             | -                        | -                        | 8                        | 32                       | 17                       | 6                         | -           | -                           | -                           | -              |
| Th                             | 2.4                      | 3.8                      | 2.45                     | 10.79                    | 3.31                     | 2.99                      | 1.8         | 3.7                         | 11.3                        | 5.8            |
| U                              | 0.7                      | 1.3                      | 0.83                     | 1.62                     | 0.92                     | 1.04                      | 0.7         | 0.8                         | 0.7                         | 2.1            |
| La                             | 16.3                     | 13.5                     | 9.18                     | 39.14                    | 19.5                     | 7.6                       | 8.3         | 23.8                        | 40.5                        | 27.6           |
| Ce                             | 37.5                     | 25.2                     | 18.31                    | 80.94                    | 42.8                     | 17.2                      | 20.5        | 54.3                        | 75.6                        | 55             |
| Pr                             | 4.59                     | 2.86                     | 2.16                     | 9.8                      | 5.86                     | 2.39                      | 2.4         | 7.04                        | 8.54                        | 6.92           |
| Nd                             | 20                       | 12                       | 9.66                     | 35.95                    | 24.85                    | 10.95                     | 8.7         | 29.1                        | 31.9                        | 29.5           |
| Sm                             | 4.26                     | 2.25                     | 2.38                     | 6.67                     | 5.78                     | 3.08                      | 2.16        | 6.16                        | 5.97                        | 6.19           |
| Eu                             | 1.64                     | 0.83                     | 0.9                      | 1.51                     | 2.40                     | 0.97                      | 0.58        | 1.6                         | 1.53                        | 1.6            |
| Gd                             | 4.59                     | 2.5                      | 2.49                     | 5.49                     | 6.27                     | 3.57                      | 1.99        | 5.38                        | 4.90                        | 5.96           |
| Tb                             | 0.72                     | 0.41                     | 0.42                     | 0.8                      | 1.02                     | 0.59                      | 0.34        | 0.75                        | 0.72                        | 0.84           |
| Dy                             | 4.29                     | 2.10                     | 2.58                     | 4.27                     | 5.74                     | 3.70                      | 1.98        | 4.34                        | 3.93                        | 4.44           |
| Ho                             | 0.81                     | 0.45                     | 0.59                     | 0.83                     | 1.26                     | 0.77                      | 0.42        | 0.78                        | 0.71                        | 0.89           |
| Er                             | 2.33                     | 1.53                     | 1.66                     | 2.28                     | 3.37                     | 2.32                      | 1.12        | 2.27                        | 1.98                        | 2.4            |
| Tm                             | 0.3                      | 0.23                     | 0.26                     | 0.35                     | 0.51                     | 0.35                      | 0.20        | 0.34                        | 0.30                        | 0.35           |
| Yb                             | 1.88                     | 1.32                     | 1.52                     | 2.24                     | 3.12                     | 2.29                      | 1.08        | 2.07                        | 1.94                        | 2.19           |
| Lu                             | 0.31                     | 0.20                     | 0.25                     | 0.33                     | 0.46                     | 0.35                      | 0.15        | 0.31                        | 0.27                        | 0.3            |

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