

# Analysis of Rock Samples from the New Laboratory

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*In Progress, Additional Data Will Be Added As It Becomes Available*

## Abstract

Several rock samples have been taken from various locations in the new underground laboratory and are being analysed for K, U and Th content using a Ge detector located at the University of Guelph. In addition, accelerated shotcrete and concrete samples were also analysed to determine their background. An elemental analysis was carried out on two of the rock samples, the accelerated shotcrete and concrete samples by Geoscience Laboratories and Testmark Laboratories (Subcontracted to Petrolabs), these results are also presented. In addition, historical data from SNO during its excavations are shown so that the reader can compare the current and historical measurements of K, U and Th concentration levels in rock and shotcrete.

## 1 Introduction

The rock located around the underground laboratory is the principle source of dust that enters the lab, apart from construction materials which are brought into the lab. It is therefore very important that the levels of K, U and Th are well known for the particular rock in which the laboratory is situated, so that measures can be taken to reduce the dust entering the lab as much as possible. If very high levels of U and Th are detected in the rock walls in particular places in the laboratory then that may determine where some experiments can be located depending on the experiment's requirements, especially for radon as radon and its daughters are decay products of U and Th.

Several rock samples will be taken from each area of the new lab, where possible two samples will be collected from each room. These samples will be analysed using a Ge detector located at the University of Guelph and through the ICP-MS, ICP-AES and WD-XRF methods by Geoscience Laboratories and using gamma-ray spectroscopy by Petrolabs who were subcontracted by Testmark Laboratories. Further details of each of these methods are described in detail below. Due to the observed higher levels of U and Th in the shotcrete and concrete as compared to the rock, additional details about the shotcrete and concrete composition are given. Historical measurements of K, U and Th during the construction of the SNO cavern are shown so that the reader can compare current measurements with the historical measurements.

## 2 Rock Sample Locations

There were 13 rock samples taken from the Ladder lab area on October 5, 2005. The samples were taken from various locations, but generally two samples were taken from each room where possible. Complete excavations of this area was not completed at that time. The sample locations can be observed in figure 1. In addition, a sample of accelerated shotcrete (sample 15) and a sample of concrete (sample 14) were retrieved for analysis. These samples came from random large bags that were stored in the SNO drifts. For comparison with the new shotcrete, a cured shotcrete sample (sample 16) was taken from the existing SNO entrance. On January 16, 2006 a sample of shotcrete was obtained from the entrance to the existing SNO laboratory. On January 23, 2006, five additional rock samples were obtained, one sample from the ladder area and 4 samples from the cube hall area (rooms 134 and 125). On March 7, 2006, two rock samples were obtained from the ladder room area from the lower part of the wall in room 127. On May 25, 2006 three rock samples were obtained from the cube hall and two rock samples were obtained from the utility hall as well a sample of accelerated shotcrete was obtained which was manufactured on April 6, 2006. On November 17, 2006, eight rock samples were collected from the cube hall and one sample each of shotcrete and concrete were obtained. The sample locations can be observed in figures 1 and 2. In addition, samples of the shotcrete and concrete ingredients were obtained from King Packaged Materials Company, the supplier of SNOLAB's concrete and shotcrete, for analysis of the individual components.

## 3 Ge Detector Analysis Results

Thorium, uranium and potassium are frequently determined in various materials by directly counting the  $\gamma$ -ray emission from these materials with a shielded  $\gamma$ -ray detector. The University of Guelph has an ultra low background high purity Ge (ULB) detector which was initially used to search for neutrinoless double beta decay of  $^{76}\text{Ge}$ . The detector contains a single crystal with volume  $208\text{ cm}^3$  and is custom made using low radioactivity components. The crystal has  $4\pi$  shielding of 6 mm Hg and 15 cm low background Pb and is a basement laboratory below one meter of concrete. The detector's internal background has been very well determined by running the system 305 meters underground in a salt mine. A thorough description of the apparatus is given in [1, 2].

The cavity inside the shield can hold up to one-litre samples in an inverted beaker geometry (Marinelli beaker) surrounding the cryostat end-cap. Generally, samples are crushed or broken into pieces to fill the acrylic Marinelli beaker used, and MnO powder filling a beaker of the same size is used as the calibration standard. The following  $\gamma$ -rays are used to determine elemental concentrations: in the Th series, the  $\gamma$ -rays are at 583, 911 and 2614 keV; in  $^{238}\text{U}$  series, the  $\gamma$ -rays are at 609, 1001 and 1764 keV and in  $^{40}\text{K}$  the  $\gamma$ -ray energy is 1461 keV.

A second high purity Ge detector has also been used to allow two rock samples to be measured simultaneously to speed up the measurements. This detector is a LOAX, high purity Ge detector, manufactured by EG&G Ortec. The LOAX detector detects only the

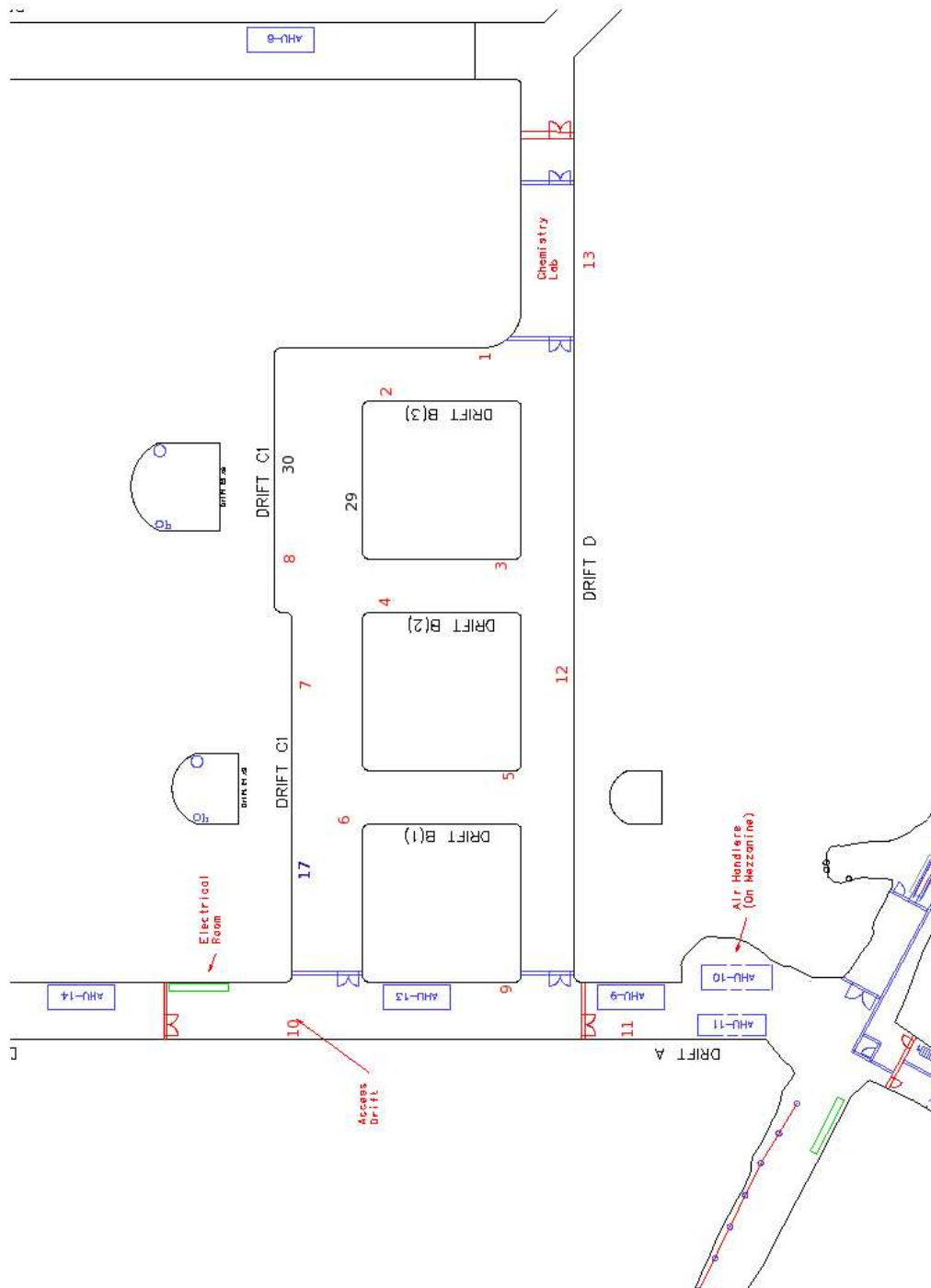


Figure 1: The locations of each of the 14 rock samples in the ladder lab area are shown with the red (first 13 samples), blue (sample 17) and black (sample 29 and 30) numbers.

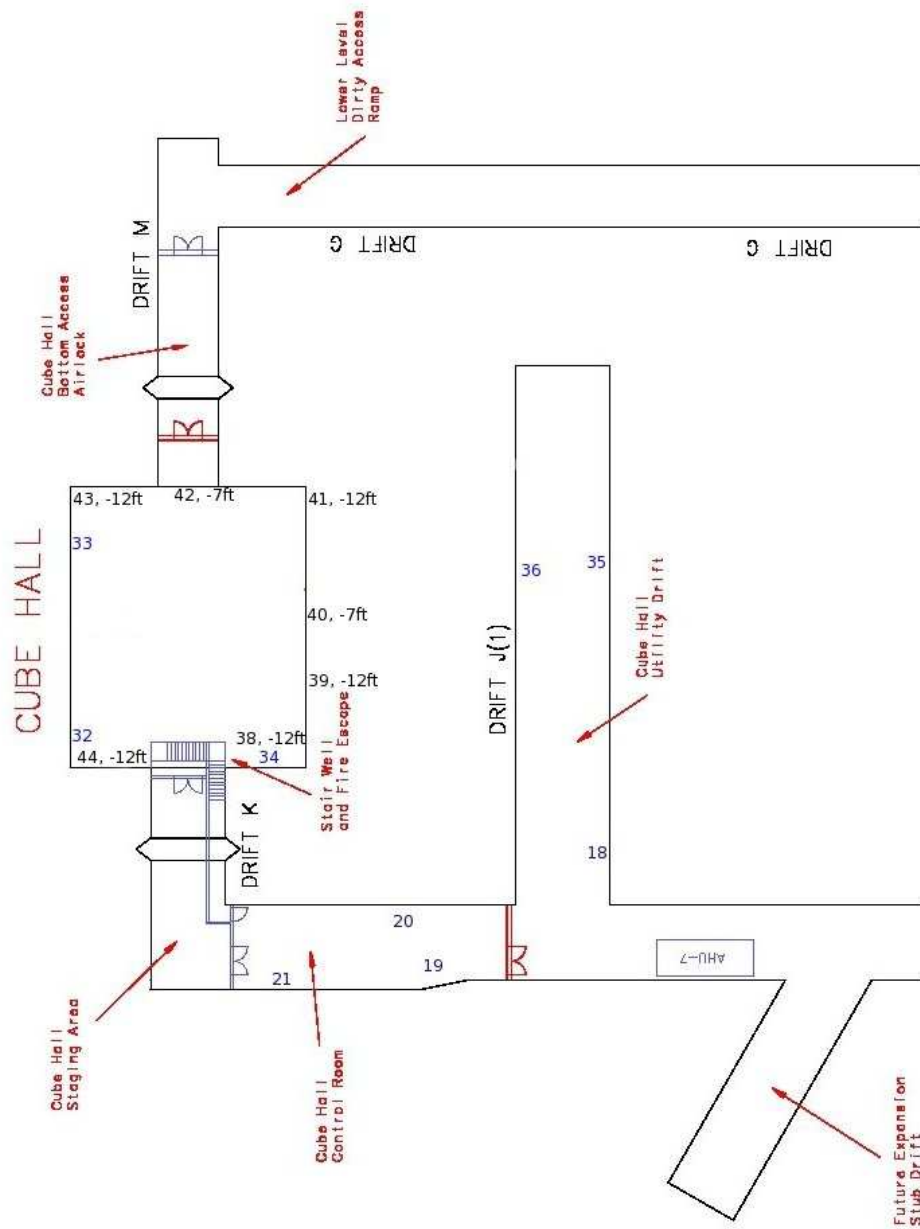


Figure 2: The locations of each of the 10 rock samples in the cube hall area are shown with the blue numbers.

low energy  $\gamma$ -rays and does not detect the 2614 keV  $\gamma$ -ray from Th. However, the LOAX detector has better resolution at all detectable energies as compared to the ULB detector.

The results for K, U and Th for each rock or shotcrete sample are shown in table 1. Note that any of the characteristic gamma rays from any of the progeny may be used for the concentration determination of uranium and thorium. In addition, unlike thorium which is mono-isotopic, uranium consists of two primary isotopes which are known to show variations in their relative abundances;  $^{235}\text{U}$  may be enhanced or depleted for many reasons in synthetic materials and even in natural materials. The concentrations determined by gamma-ray spectrometry are reported as natural U consisting of 99.275%  $^{238}\text{U}$  and 0.72%  $^{235}\text{U}$ .

Because of the differences in the chemical properties of the progeny, they may or may not be in secular equilibrium with the parent uranium and thorium in natural materials. It is almost always certain that the radioactive equilibrium is disturbed by anthropogenic processes. In this sense, the concentrations determined by gamma-ray spectrometry are reported as equilibrium equivalent values of Uranium and Thorium with respect to the radioactive progeny employed in the measurement.

## 4 Elemental Analysis Results

Two rock samples (samples 8 and 11) and a sample of concrete and accelerated shotcrete were analysed by Geoscience Laboratories using several methods depending on the elements to be determined. To determine the concentration of trace elements, the Inductively Coupled Plasma Mass Spectrometry (ICP-MS) method was utilized. This is a type of mass spectrometry that is highly sensitive and capable of simultaneous analysis of a range of metals at the part per million (ppm) level. It is based on coupling together an inductively coupled plasma as an ion source with a mass spectrometer as a method of detecting the ions. The concentration of a sample is determined through calibration with elemental standards to ensure the integrity of the measurement.

Table 2 shows the results of the ICP-MS analyses for the 4 samples. The two rock samples were taken at points far from one another so that any variation in the local rock could be observed. The detection limit is shown for each element along with the detected concentrations of each element for the four samples. The largest detected element using the ICP-MS procedure is Ti which has a level of approximately 2900 ppm. Other elements of interest are U and Th, giving 1.20 ppm and 5.5 ppm, respectively.

To determine concentrations of Al, Ca, Fe, K, Mg, Mn and Na, the Inductively Coupled Plasma - Atomic Emission Spectrometer (ICP-AES) method was used. ICP-AES is used for the chemical analysis of aqueous solutions of rock and other materials. A spectrometer is used to search for each wavelength emitted by the sample, which is used to determine the elemental concentrations. This method has some limitations, as not all elements are dissolved through the digestion procedure, some elements such as Si are evaporated and the method has low sensitivity to most elements. However, ICP-AES can easily search for elements of large concentrations such as those listed above in this paragraph. The results of these large concentration elements are shown in table 3.

Rock Sample	K (%)	<sup>226</sup> Ra Uranium (ppm)	<sup>228</sup> Th Thorium (ppm)
1 – Rock, Drift B3 (Rm 130), Front Right	1.12 ± 0.04	1.06 ± 0.05	5.83 ± 0.19
2 – Rock, Drift B3 (Rm 130), Rear Left	1.13 ± 0.04	1.01 ± 0.04	5.14 ± 0.20
3 – Rock, Drift B2 (Rm 129), Front Right	1.02 ± 0.02	1.25 ± 0.08	5.45 ± 0.49
4 – Rock, Drift B2 (Rm 129), Rear Left	1.03 ± 0.01	1.16 ± 0.15	5.19 ± 0.39
5 – Rock, Drift B1 (Rm 128), Front Right	1.08 ± 0.04	1.02 ± 0.03	5.72 ± 0.16
6 – Rock, Drift B1 (Rm 128), Rear Left	1.07 ± 0.03	1.03 ± 0.04	5.72 ± 0.42
7 – Rock, Drift C (Rm 126), NW across from B1	0.80 ± 0.03	0.91 ± 0.01	4.96 ± 0.18
8 – Rock, Drift C (Rm 127), NE across from B2	1.09 ± 0.01	1.24 ± 0.16	5.44 ± 0.37
9 – Rock, Drift F (Rm 124), Front Right	0.93 ± 0.01	1.05 ± 0.11	4.51 ± 0.36
10 – Rock, Drift F (Rm 124), Across from Drift C	1.18 ± 0.04	1.02 ± 0.04	5.83 ± 0.12
11 – Rock, Drift A, South Left Wall	1.06 ± 0.03	1.09 ± 0.03	5.72 ± 0.05
12 – Rock, Drift D (Rm 131), SW between B1 and B2	1.18 ± 0.04	1.05 ± 0.05	6.12 ± 0.01
13 – Rock, Drift D (Rm 132), Chemistry Lab	0.92 ± 0.04	0.92 ± 0.04	4.51 ± 0.08
14 – Concrete March 8, 2005 (Batch 45019)	1.75 ± 0.05	2.41 ± 0.03	15.38 ± 0.40
15 – Accelerated Shotcrete March 8, 2005 (Batch 25017)	1.78 ± 0.05	2.46 ± 0.09	15.24 ± 0.14
16 – Shotcrete (cured, SNO entrance)	1.39 ± 0.07	2.50 ± 0.10	6.33 ± 0.30
17 – Rock, Drift C (Rm 125), N across from B1	1.00 ± 0.03	0.98 ± 0.07	5.40 ± 0.16
18 – Rock, Drift J (Rm 134), S close to Drift F	1.05 ± 0.03	1.30 ± 0.10	6.50 ± 0.14
19 – Rock, Drift F (Rm 135), W across from Drift J	0.92 ± 0.01	1.51 ± 0.16	6.63 ± 0.48
20 – Rock, Drift F (Rm 135), E near to Drift J	0.95 ± 0.03	1.26 ± 0.04	5.87 ± 0.62
21 – Rock, Drift F (Rm 135), W across from Drift J	0.73 ± 0.03	1.13 ± 0.01	5.49 ± 0.03
22 – Concrete sand from King Shotcrete	2.02 ± 0.05	1.76 ± 0.04	14.60 ± 0.05
23 – Filter (shotcrete) sand from King Shotcrete	2.18 ± 0.06	1.76 ± 0.04	16.69 ± 0.05
24 – 1/4" (concrete) rock from King Shotcrete	2.57 ± 0.07	2.18 ± 0.02	27.50 ± 0.75
25 – 3/8" (shotcrete) rock from King Shotcrete	2.49 ± 0.03	2.51 ± 0.05	26.86 ± 0.84
26 – High-early cement (accelerated shotcrete) from King Shotcrete	0.42 ± 0.02	3.27 ± 0.08	5.59 ± 0.06
27 – Portland cement (concrete & non- accelerated shotcrete) from King Shotcrete	0.40 ± 0.02	3.28 ± 0.04	5.42 ± 0.17
28 – Silica fume (accelerated and non- accelerated shotcrete) from King Shotcrete	0.44 ± 0.02	0.39 ± 0.04	0.23 ± 0.09
29 – Rock, Drift C (Rm 127) Wall between B2 and B3, lower elevation	1.09 ± 0.03	1.06 ± 0.07	5.50 ± 0.08
30 – Rock, Drift C (Rm 127) Wall across from B3, lower elevation	1.08 ± 0.03	1.11 ± 0.07	5.94 ± 0.14
31 – MS-D1 Synthetic Fibre Shotcrete from King	1.70 ± 0.05	2.43 ± 0.03	13.58 ± 0.14
32 – Rock, Cube Hall, Left side, Drift Level	0.99 ± 0.03	1.17 ± 0.02	5.65 ± 0.12
33 – Rock, Cube Hall, Left side, Drift Level	0.81 ± 0.03	1.04 ± 0.04	5.22 ± 0.16
34 – Rock, Cube Hall, Right side, Drift Level	0.81 ± 0.03	1.14 ± 0.02	5.44 ± 0.12
35 – Rock, Utility Hall, Right side	0.83 ± 0.03	1.06 ± 0.06	5.13 ± 0.05
36 – Rock, Utility Hall, Left side	1.10 ± 0.04	1.22 ± 0.03	6.12 ± 0.09
37 – Accelerated Shotcrete, April 6, 2006	1.85 ± 0.05	2.40 ± 0.08	16.69 ± 0.11
Overall Average Rock Concentration Levels	1.00 ± 0.13	1.11 ± 0.13	5.56 ± 0.52
Ladder Lab Concentration Levels	1.05 ± 0.10	1.06 ± 0.10	5.44 ± 0.47
Cube Hall Concentration Levels	0.87 ± 0.10	1.11 ± 0.07	5.44 ± 0.22
Cube Hall Utility Area Concentration Levels	0.93 ± 0.14	1.25 ± 0.16	5.96 ± 0.58

Table 1: Part 1: The Gamma-ray spectrometry results for each rock, shotcrete or concrete sample. The last rows shows the average K, U and Th concentration levels for only the rock samples and for some specific areas of the lab expansion.

The amount of Si in the rock was determined through wavelength dispersive X-Ray fluorescence (XRF). The samples were first run for loss on ignition (LOI) and then fused with a borate flux to produce a glass bead. These results are shown in table 3. The amount of dissolved C, H and O in the rock was determined by Petrolabs (subcontracted by Testmark Laboratories) using gamma-ray spectroscopy and are shown in the last three lines of the table.

## 5 Shotcrete and Concrete Details

After observing the relatively high levels of K, U and Th in the shotcrete and concrete samples it was decided to analyze the components of the shotcrete and concrete to determine if one particular component is causing the observed higher quantities of K, U and Th as compared to the rock samples. The components are listed in table 1 as samples 23 to 28. The accelerated shotcrete, Creighton Mix 25017 (trade name MS-D3 Accelerated Shotcrete), has the following composition:

- Silica fume: 4.9 – 11.05 %
- High-early cement: 15 – 25 %
- Filter sand:  $\sim 20$  %
- 3/8" aggregate:  $\sim 50$  %

The non-accelerated shotcrete (trade name MS-D1 Shotcrete) has the following composition:

- Silica fume: 4.9 – 11.05 %
- Portland cement: 15 – 25 %
- Filter sand:  $\sim 20$  %
- 3/8" aggregate:  $\sim 50$  %

The non-accelerated fibre shotcrete (trade name MS-D1 Synthetic Fibre Shotcrete) has the following composition:

- Silica fume: 4.9 – 11.05 %
- Portland cement: 15 – 25 %
- Filter sand:  $\sim 20$  %
- 3/8" aggregate:  $\sim 50$  %
- synthetic polyfibres

Element	Detection Limit (ppm)	Rock Sample 8 (ppm)	Rock Sample 11 (ppm)	Shotcrete Sample 15 (ppm)	Concrete Sample 14 (ppm)
Ti	10	2830	2900	1970	2070
Li	0.6	17.8	16.6	14.3	14.3
Be	0.3	1.01	1.05	1.65	1.60
Sc	0.5	20.2	21.1	9.18	9.50
V	2	144	148	79.0	81.1
Cr	6	>400	>400	112	140
Co	0.1	46.8	50.3	10.9	11.2
Ni	1	158	251	34.8	36.4
Cu	2	82.2	>140	24.6	26.3
Zn	3	93.9	86.4	98.2	80.4
Ga	0.2	14.1	15.2	15.4	14.8
Rb	0.09	38.2	41.2	83.0	76.2
Sr	1	320	326	263	268
Y	0.04	16.2	17.2	13.2	13.1
Zr	1	52.7	28.0	96.4	92.8
Nb	0.1	3.69	5.56	6.17	6.12
Mo	0.08	1.23	1.13	2.04	2.02
Cd	1	N.D.	N.D.	N.D.	N.D.
Sn	0.2	1.00	0.98	1.19	1.12
Sb	0.05	0.11	0.11	0.19	0.16
Cs	0.01	1.82	1.40	1.19	1.17
Ba	0.8	424	465	584	564
La	0.05	26.3	24.8	30.3	28.0
Ce	0.1	52.7	49.8	58.3	51.8
Pr	0.01	6.25	5.87	6.42	5.90
Nd	0.04	23.1	22.0	21.8	20.0
Sm	0.02	4.08	3.96	3.60	3.41
Eu	0.006	1.02	1.09	0.81	0.78
Gd	0.01	3.58	3.64	2.96	2.80
Tb	0.005	0.52	0.52	0.43	0.41
Dy	0.01	2.81	2.90	2.20	2.14
Ho	0.004	0.61	0.64	0.45	0.45
Er	0.008	1.64	1.70	1.17	1.16
Tm	0.002	0.24	0.25	0.18	0.17
Yb	0.02	1.63	1.73	1.15	1.10
Lu	0.003	0.25	0.26	0.17	0.16
Hf	0.01	1.64	1.52	2.85	2.71
Ta	0.04	0.27	0.36	0.48	0.47
W	0.03	0.24	0.31	0.50	0.51
Hg	n/a	N.D.	N.D.	N.D.	N.D.
Tl	0.01	0.26	0.27	0.44	0.40
Pb	0.6	10.2	10.6	13.5	13.9
Th	0.02	5.54	5.19	14.9	13.1
U	0.005	1.21	1.14	2.56	2.38
Total		~5088.3	~5095.3	3582.7	3662.0

Table 2: The ICP-MS results for each measured element in ppm. Note that N.D. is used if the element was not detected.



Element	Detection Limit (ppm)	Rock Sample 8 (%)	Rock Sample 11 (%)	Shotcrete (%)	Concrete (%)
Al	100	6.01	6.43	6.04	5.86
Ca	90	3.43	3.80	9.54	10.10
Fe	200	6.37	6.68	2.54	2.61
K	30	0.97	1.02	1.76	1.61
Mg	60	6.06	—	1.18	1.22
Mn	1	0.10	0.10	0.37	0.39
Na	200	1.72	1.73	2.25	2.14
Si	—	26.9	26.7	27.9	27.6
H	—	0.05	0.01	0.04	0.04
C	—	0.03	0.01	0.04	0.04
O	—	47.8	47.0	48.0	48.0

Table 3: The ICP-AES results for Al, Ca, Fe, K, Mg, Mn and Na. The WD-XRF results for silicon and the gamma-ray spectroscopy results for H, C and O.

The concrete, Creighton Mix 45017 (trade name PC-35 Mining Concrete) has the following composition:

- Silica fume: 4.9 – 11.05 %
- Portland cement: 10 – 25 %
- Concrete sand: 20 – 30 %
- 1/4" aggregate: ~50 %

Silica fume is a byproduct of producing silicon metal or ferrosilicon alloys and is used in concrete as it is a very reactive pozzolan and gives the concrete (or shotcrete) higher strength. The raw materials of silica fume are quartz, coal and wood chips and it is primarily  $\text{SiO}_2$ , the particles are 1/100th the size of cement particles thus filling the voids that remain from the sand and aggregate. The high-early cement has an additional component as compared to the Portland cement to help speed up the curing process of the shotcrete. The results of the analysis of the individual components are shown in table 1. The results indicate that the high Th levels are attributable to the aggregate and sand components used to manufacture the shotcrete and concrete. The two types of cement have higher U levels but their Th levels are comparable to the rock samples from the SNOLAB excavation area. The Silica Fume has low levels both U and Th, but it is only a small component in the shotcrete and concrete mixtures.

Combining the approximate ratios from above with the results shown in table 1, the accelerated shotcrete has K, U, and Th levels of  $\sim 1.81\%$ ,  $\sim 2.30$  ppm and  $\sim 18.3$  ppm, respectively. The concrete has K, U, and Th levels of  $\sim 1.81\%$ ,  $\sim 2.14$  ppm and  $\sim 17.8$  ppm, respectively. The expected approximate levels of K, U, and Th in the non-accelerated shotcrete are  $\sim 1.81\%$ ,  $\sim 2.30$  ppm and  $\sim 18.9$  ppm, respectively. These numbers are very approximate as the exact ratio of ingredients can vary somewhat from batch to batch, but they do agree with the results shown in tables 1 and 2 for the shotcrete and concrete samples previously measured.

Norite Rock Samples				
Date	K (%)	$^{235}\text{U}$ (ppm)	$^{238}\text{Th}$ (ppm)	Notes
91/10/31	$1.261 \pm 0.004$	$1.134 \pm 0.015$	$5.848 \pm 0.055$	dome
91/11/05	$1.031 \pm 0.006$	$0.996 \pm 0.089$	$4.775 \pm 0.089$	dome
91/10/30	$1.232 \pm 0.008$	$0.990 \pm 0.030$	$5.181 \pm 0.112$	dome
91/11/09	$1.285 \pm 0.007$	$1.492 \pm 0.031$	$6.470 \pm 0.112$	ramp

Research Station (4600 Foot Level) Rock (Granite) and Shotcrete Samples				
Date	K (%)	$^{235}\text{U}$ (ppm)	$^{238}\text{Th}$ (ppm)	Notes
91/11/14	$1.651 \pm 0.008$	$3.188 \pm 0.330$	$19.175 \pm 0.174$	rock
91/11/10	$1.337 \pm 0.008$	$2.053 \pm 0.094$	$5.976 \pm 0.116$	shotcrete

Other Samples				
Date	K (%)	$^{235}\text{U}$ (ppm)	$^{238}\text{Th}$ (ppm)	Notes
91/07/24	$0.938 \pm 0.005$	$1.812 \pm 0.100$	$7.473 \pm 0.200$	backfill

Table 4: Historical measurements of the K, U and Th concentrations taken during the construction of the SNO detector using a Ge detector [3].

## 6 Historical SNO Data

Several rock and and shotcrete samples were measured for K, U and Th concentration levels during the construction of the SNO detector. E.D. Hallman and D.L. Cuff described in the SNO technical report SNO-STR-91-082 some of these measurements [3]. They used large 4 kg rock samples from three representative sections of the SNO cavity dome walls in October 1991. A fourth sample from the wall at the base of the ramp was also obtained. Each sample was counted for 24 hours using a three crystal Ge detector located at Laurentian University at that time. The results of these measurements are shown in the top part of table 4.

In addition, a sample of rock and a sample of shotcrete were collected from the 4600 foot level of Creighton Mine. At this level the rock is granite, therefore differences are expected as compared to the norite rock samples collected from the 6800 foot level at the SNO laboratory. These results are shown in the middle part of table 4. A typical backfill sample was collected from the 6800 foot level of Creighton Mine and these results are shown in the bottom part of table 4.

A second SNO technical note, SNO-STR-94-015, by A.R. Smith [4] describes several measurements of K, U and Th concentration levels for various depths of the SNO cavity using a NaI(Tl) scintillation detector and gamma-spectrometric analysis. The average values of K, U and Th concentrations are shown in table 5 for the two methods.

## 7 Summary

Several rock, shotcrete, and concrete samples (including the components of the shotcrete and concrete) were analysed for K, U and Th concentrations. The results are shown in

Method	K (%)	$^{235}\text{U}$ (ppm)	$^{238}\text{Th}$ (ppm)
NaI(Tl)	$1.032 \pm 0.0094$	$1.10 \pm 0.09$	$5.10 \pm 0.48$
Gamma spectrometry	1.02	1.14	4.90

Table 5: Historical measurements of the K, U and Th concentrations taken during the construction of the SNO detector using a NaI(Tl) scintillation detector and gamma spectrometry [4].

Element	Rock Sample 8		Rock Sample 11	
	Ge Detector	ICP-MS or ICP-AES	Ge Detector	ICP-MS or ICP-AES
K (%)	$1.09 \pm 0.01$	0.97	$1.06 \pm 0.03$	1.02
U (ppm)	$1.24 \pm 0.16$	1.21	$1.09 \pm 0.03$	1.14
TH (ppm)	$5.44 \pm 0.37$	5.54	$5.72 \pm 0.05$	5.19

Element	Shotcrete Sample 15		Concrete Sample 14	
	Ge Detector	ICP-MS or ICP-AES	Ge Detector	ICP-MS or ICP-AES
K (%)	$1.78 \pm 0.05$	1.76	$1.75 \pm 0.05$	1.61
U (ppm)	$2.46 \pm 0.09$	2.56	$2.41 \pm 0.03$	2.38
TH (ppm)	$15.24 \pm 0.14$	14.9	$15.38 \pm 0.40$	13.1

Table 6: A comparison of the K, U and Th levels between the Ge detector and the ICP-MS or ICP-AES methods for rock samples 8 and 11, shotcrete sample 15 and concrete sample 14.

the tables presented previously in this note. The average K, U, and Th levels in the rock samples from the lab are  $(1.00 \pm 0.13)\%$ ,  $(1.11 \pm 0.13)$  ppm and  $(5.56 \pm 0.52)$  ppm, respectively. The current measurements of the rock samples also agree very well with the measurements recorded during the construction phase of the SNO laboratory for norite rock.

Two rock samples (samples 8 and 11), shotcrete sample 15 and concrete sample 14 were analysed with both the Ge detector and the ICP-MS or ICP-AES methods, a comparison of the results between the two types of methods are shown in table 6. In most cases there was good agreement between the two types of analysis methods. The shotcrete and concrete samples had higher K, U and Th levels than the rock samples so an analysis of the individual components of the shotcrete and concrete samples was done. These results showed that the higher K, Th and U levels were due to the high levels of these elements in the aggregate and sand used to make the various types of shotcrete.

## References

- [1] H.L. Malm, M.M. Watt, I. Bostock, J.L. Campbell, P. Jagam and J.J. Simpson, Nucl. Inst. and Meth. A223 (1984) 420.
- [2] P. Jagam, J.J. Simpson, J.L. Campbell, B.C. Robertson, and H.L. Malm, Nucl. Inst. and Meth. A239 (1985) 214.

- [3] E.D. Hallman and D.L. Cuff, SNO Technical Report, SNO-STR-91-082.
- [4] Alan R. Smith, SNO Technical Report, SNO-STR-94-015.