ISSN: 2690 - 0688

Research article

Journal of Humanities and Social Sciences

Distribution of arsenic in fresh and weathered rocks in Sri Lanka

Upali de Silva Jayawardena

Department of Civil Engineering, Faculty of Engineering University of Peradeniya, Peradeniya

***Corresponding author**

Upali de Silva Jayawardena, Department of Civil Engineering, Faculty of Engineering University of Peradeniya, Peradeniya

Submitted: 21 Mar 2022; **Accepted:** 25 Mar 2022; **Published:** 23 Jun 2022

Citation: *U.de S. Jayawardena Peradeniya (2022) Distribution of arsenic in fresh and weathered rocks in Sri Lanka J Huma Soci Scie, 5(2): 144-165.*

Abstract

This study was carried out to determine the distribution of arsenic, which may slowly harm human health, in the weathered rocks of different parent rocks in the country. 293 samples were collected from different crystalline rocks and in-situ weathered formations above the particular parent rock in 50 localities. Selected minor elements (including arsenic) were analysed by X-ray fluorescence spectrometry on RIGAKU KG-X system (Japan). The results indicated that the maximum arsenic amount in fresh rock is 12 and 48 ppm in completely weathered rocks. About 86.9% of fresh rocks showed less than 5 ppm of arsenic, while 89.8% of their weathered grades showed the arsenic concentration to be less than 10 ppm. The average arsenic in all fresh rock samples was 3.5ppm (lowest); it was 7.6 ppm (highest) in residual soils. This is the normal condition of arsenic distribution worldwide. Under this condition, the arsenic concentration in natural groundwater in the residual soil areas should be below the acceptable limit. Therefore, the amount of arsenic released from parent rocks and their weathered products due to natural geological processes is very low in Sri Lanka.

Keywords: Arsenic, Parent Rocks, Weathered Rocks, X-Ray Fluorescence, Sri Lanka

Introduction

Many patients with chronic kidney disease of unknown etiology (CKDu) were reported from rural Sri Lanka, especially from North Central Province (NCP) after 1993. CKDu has gradually emerged as a major health problem in the Dry Zone of Sri Lanka for last two decades (Fig.1). Arsenic (in drinking groundwater) has already been identified as one of the major etiological factors for the disease also mentioned that they arrived at this conclusion despite a lack of scientific evidence on the occurrence of arsenic in bedrock and other natural environments in Sri Lanka [1]. Therefore, a study on the distribution of arsenic in the parent rocks and their weathered materials are very important.

The authors carried out a geochemical study (via XRF) to find out the variation of major and minor elements for fresh rocks and differently graded weathered materials of major parent rocks of Sri Lanka [2,3]. Concentrations of major elements were used for their studies but minor element concentrations were noted to be further scientific studies. After the recognition of the CKDu problem in rural areas of Sri Lanka, the authors decided to do an analysis on the occurrence and distribution of arsenic (one of the minor element detected) in fresh and weathered materials to describe its natural concentration in the country. The objective of this paper is to provide scientific evidence on the distribution of arsenic concentration in different parent rocks and their weathered forms in Sri Lanka. To identify the effect of external sources to groundwater quality, some knowledge and understanding on the concentration of elements in parent and weathered rocks is necessary. These findings may be a source for scientists who research arsenic in groundwater in Sri Lankan soil and create solutions to reduce the spread of CKDu.

Literature Review

General geography and geology of Sri Lanka

Sri Lanka is an Island in the Indian Ocean. The total land area measures 65,610 square kilometres. Physiographically, Sri Lanka consists as a central mountainous mass or central highland surrounded by a low, flat plain on all sides that extend to the sea. The Island can be divided into three main morphological regions as coastal lowlands (less than 305 m MSL), uplands (305–915m MSL) and highlands (915–2420m MSL) [4]. Most of the rivers start from this central highland and flow in a radial pattern towards the sea. Sri Lanka is considered to have a humid tropical climate.

Geologically, 90% of Sri Lanka is made up of high-grade metamorphic rocks from the Precambrian age. These rocks have been formed under the granulite and amphibolite facies of regional metamorphism and re-metamorphism. Also, it is believed that the major types of metamorphosed sedimentary rocks from the Precambrian age consist of Quartzite, gneisses (different mineral combinations), migmatite, marble, dolomite, amphibolite and charnockite/charnockitic gneiss. However, the original nature before metamorphism of charnockite/charnockitic gneiss

is uncertain [5]. The remaining rocks are sedimentary rocks of predominantly Miocene age (limestone) in the northwest (and sandstone in very few places in the southeast) with some Jurassic sediments (shale and sandstone) preserved in small faulted basins (Fig. 2). There are recent sedimentary formations, which have been identified as Pleistocene and iron oxide deposits in a few locations. There are plutonic-type igneous formations (about 1% of the country) but no evidence for volcanic igneous formations such as solidified lava flows and volcanic dust deposits has been found [5]. Pegmatite, granites, apatite rich carbonatite, vein quarts, dolerite, copper-magnetite body and serpentinite bodies are the plutonic igneous intrusions. In addition, there are a few small magnetite iron ore deposits in several places within the crystalline complex.

The land surface of Sri Lanka has been subjected to a prolonged period of weathering and erosion under different climatic conditions. The secondary formations arising from weathering such as clay minerals (mainly kaolinite and halloysite) and lateritic soil are found throughout the Island; laterite (goethite, gibbsite, boehmite, diaspore) is found mainly in the southwestern part of the country. In a few locations, some iron ore (hematite, limonite, and goethite) minerals occur as surface deposits. Recent deposits include both residual and alluvial formations. Residual deposits include deep weathered zones or soils that can be found in the central hill country and in the intermediate slopes. These deposits are not uniform in character and contain fragments of un-decomposed rocks [6,7]. The weathering is not uniform in any place in the country and the thickness changes drastically from place to place. There are thick alluvial deposits, flood plain deposits, and small deltas in the coastal lowland areas near to the sea and wind-blown dune sand and silt deposits along the coastal zones.

General distribution of arsenic in parent rocks, weathered rocks, and soils

Arsenic in rocks

The concentration of arsenic in the rocks of the lithosphere varies with the abundance of arsenic-carrying minerals. These minerals may contain arsenic at concentrations reaching 6000 mg/kg. Smedley and Kinniburgh and Takeshi describe the concentration of arsenic in different parent rocks and minerals in the earth crust [8,9]

Table 1. Arsenic concentrations in different rocks (Takeshi, 1988 and Smedley and Kinniburgh, 2002)

Rock type		Range, ppm	Mean, ppm
Igneous rocks	Ultra basic rocks	0.03-15.8	1.5
	Basic extrusive	0.18-11.3	2.3
	Basic intrusive	0.06-28.0	1.5
	Intermediate extrusive	0.5-5.8	2.7
	Intermediate intrusive	0.09-13.4	1.03
	Acid extrusive	3.2-5.4	4.3
	Acid intrusive	0.18-15.0	1.29
Sedimentary rocks	Recent sediments	1-13,000	14.1
	Ocean sediments	0.4-455	33.7
	Shale, argillite	0.3-500	14.5
	Sandstone, arkose, conglomerate	0.6-120	4.1
	Limestone, dolomite	0.1-20.1	2.6
	Iron rich sediments	1-2900	-
	Gypsum	0.1-10	3.5
	Phosporite	3.4-100	14.6
Metamorphic rocks	Sedimentary origin quartzite	2.2-7.6	5.5
	Regional metamorphism gneiss	0.5-4.1	1.5
	Amphibolite, greenstone	0.4-45	6.3
	Contact metamorphism rocks	0.7-11	5.9

Arsenic in natural soils

The rocks are gradually transforming into loose or dense soils during the process of weathering. It passes various stages before it ultimately is reduced to products of residual soils. The rocks in this weathering stage can be grouped on the degree of weathering either chemically, physically or any other explanation [10] . These processes of chemical weathering alter the parent minerals and create secondary minerals, iron oxides and hydroxides, and some other formations in different chemical compositions that keep some ions within the new products and release others to either surface or groundwater.

Soils near arseniferous deposits worldwide may range from 20 to 2400 ppm. In general, heavy metals in ore deposits are dispersed in soils or weathered zones of rocks mainly by the action of water. The arsenic concentration tends to increase during the weathering process with the lowest concentration in the un-weathered rock and the highest in soils. Arsenic concentra-

tion range in normal soils varies from 0.1 to 55 ppm with an average of 7.2 ppm. It may vary in different soil horizons such as A, B, and C . The soils formed from different rock types in Japan are given in Table 2. It shows that the soils formed from sedimentary rocks have higher arsenic concentrations than igneous and metamorphic rocks. Arsenic concentrations in soils are not clearly correlated with soil character or clay content and not clearly identified the chemical forms of arsenic in soils. However, arsenic is generally enriched in the B horizon of most normal soils.

The average concentration of arsenic in unconsolidated sediments such as sand, clay, silt, and gravel etc. do not show much higher values. But the ranges may be different as in alluvial Arsenic concentrations in different rocks [8]

sediments (3–10 ppm), lake sediments (0.9–44 ppm), glacial till (1.9–170 ppm) and aeoline deposits (5.4–18 ppm), etc. Arsenic in placer deposits may be much higher in some localities if there are considerable amounts of sulfide minerals such as pyrite [8]. The arsenic content in recent and old alluvial sediments in Bangladesh is much higher than the normal concentration due to the occurrence of arsenic-enriched pyrites at different levels below the ground surface [11].

Table 2: Arsenic concentrations in different soils. (Takeshi, 1988)

Soil	Range, ppm	Mean, ppm
Soils worldwide	0.1-55	7.2
Soils formed from different rocks		
From igneous rocks		
extrusive	8-31.9	20
intrusive	13.9-16.9	15.4
From sedimentary rocks		
volcanic ash	20.3-31.6	24.8
clastic rocks	14-51.3	25.6
From metamorphic rocks	10.9—25.8	16.9
Arsenic minerals in Sri Lankan rocks and soils		

Arsenic minerals in Sri Lankan rocks and soils

No records of the occurrence of minerals that contain arsenic include arsenopyrite (FeAsS), realgar (AsS), orpiment (As2S3), and arsenolite (As2O3) in the parent rocks, especially in the plutonic igneous origin rocks (1%) in Sri Lanka currently exist. However, there are many accessory minerals in crystalline rocks (metamorphic and igneous rocks) such as sulphide-group metallic minerals; namely pyrite (FeS2), chalcopyrite (CuFeS2), pyrrohotite (Fe5S6), Molybdenum (MoS2) and Galena (PbS). These minerals occur as minor accessory minerals in the crystalline rocks. Magnetite, ilmenite, rutile, zircon, apatite, sphene and graphite are the other accessory minerals in Sri Lankan rocks. The magnetite in iron ore deposits is associated with these sulfide minerals. Higher arsenic content may be higher in these small magnetic iron ore deposits but only in few localities. The sedimentary rocks (nearly 10%) in the NW and north are mainly limestone. In some localities, the limestone is covered by ferruginous gravels and red earth [3]. There are Jurassic age sedimentary rocks, namely shale and sandstone in two locations. Those are also very small deposits. Graphite, mica, feldspar, apatite (carbonatite rock), limestone, marble and dolomite, river sand, mineral sand and gems are the major mining sites in Sri Lanka. Except for apatite (carbonatite), others are not arsenic-releasing mines or metal-extracting mines. There are several hot water springs in the eastern part of the country. All hot springs occur in the flat terrains in the Dry Zone of Sri Lanka (Figure.1). The reasons for the increase in water temperature have not been identified clearly yet [12,13] .There are no very clear deposits of chemical sediments around these hot springs. Ferruginous gravel deposits and red earth deposits are the major quaternary sediments above the limestone bed along the northwest coastal zone (Figure.2).

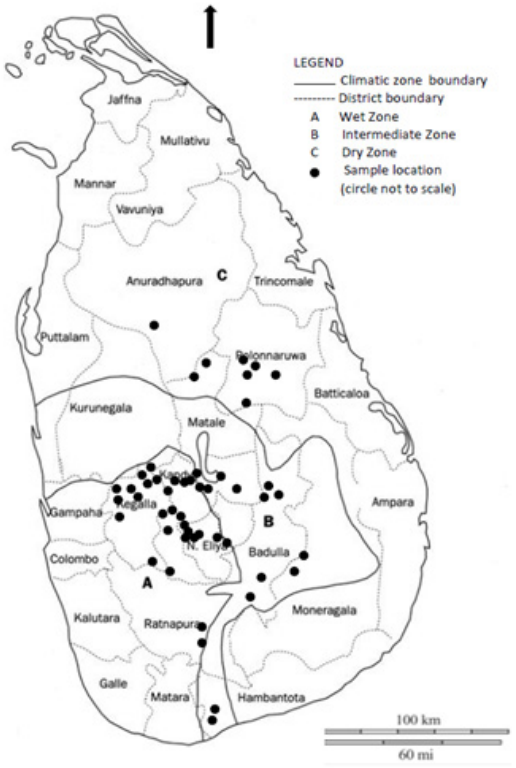

Figure 1: Different climatic boundaries of Sri Lanka (NARESA,1991). The black dots indicate the locations of samples collected for laboratory tests.

Figure 2: Subdivisions of the geology of Sri Lanka (Cooray, 1994)

Method of Study

Sample Collection

Limestone is the major sedimentary rock in the country but there are no good weathering profiles in this carbonate rocky terrain. Hence, it is not selected for the investigation. The distribution of igneous rocks (carbonatite, granite, dolerite, vein quartz and pegmatite) is about 1% or less in the total land of Sri Lanka. Only carbonatite (apatite rock) was selected to collect samples for this investigation. Samples were collected from metamorphic rocks (about 90% of the country) and their weathered grades in different localities. Most of samples were collected from the hilly region where the thick weathering profiles can be seen. A few samples were collected from some other locations, which are nearly flat with isolated hills and uneven terrains.

Representative locations were selected to collect samples from different rock types for testing. 49 out of 50 locations show metamorphic rock types and the other shows an igneous rock. Charnockite/charnockitic gneiss, garnet sillimanite gneiss, hornblende biotite gneiss, migmatite, biotite gneiss, and quartzite are the major metamorphic rocks types in Sri Lanka. Pink granitic / microcline gneiss, calc gneiss, and amphibolite are not the major rock types but samples were collected. Carbonatite (apatite rock) was the only igneous rock. Before obtaining the samples, the exposed surfaces were cleared to avoid the mixing of other materials. Fresh, irregular samples, similar to the same size were obtained from rock quarries and outcrops. Generally, the sample block size was approximately 10 × 10 × 10 cm3. The degree of weathering of rocks was identified according to the standard field methods [10] . Weathered samples were collected from in-situ weathered formations above the particular parent rock at the same place or an adjacent place very close to the fresh rock. The samples represented their grade of weathering according to the field classification. The weathering grades are slightly weathered (SW), moderately weathered (MW), highly weathered (HW), completely weathered (CW), and residual soil (RS). CW samples and residual soils were collected in polyethylene bags and each bag was sealed and numbered to indicate the field itself.

Table 3: Total number of samples collected from different rock types and different grades of weathering

Rock Type	Climatic Zone	Number of Locations	FR	SW	MW	HW	CW	RS
Ch/ChGn	WET	15	15	15	15	15	15	15
	DRY	8	8	8	8	8	8	8
HbBtGn*	WET	8	8	8	8	8	8	8
	DRY	5	5	5	5	5	5	5
GtSilGn	WET	8	4	5	8	8	8	8
Pink GrGn	DRY	1	1	1	1	1	1	1
Calc Gneiss	WET	2	2	2	2	2	2	2
Amphibolite	WET	1	1	1	1	1	1	1
Quartzite	WET	1	1	1	1	1	1	1
Apatite rock	DRY	1	1	1	1	1	1	1
All Rocks	Both	50	46	47	50	50	50	50
TOTAL		50			**293 Samples**			

Ch/ChGn= Charnockite/ Charnockitic gneiss, HbBtGn*= Hornblende biotite gneiss (*including Migmatite and garnet bearing biotite gneiss), GtSilGn= Garnet sillimanite gneiss,), PinkGrGn= Pink Granitic Gneiss, Apatite rock = Carbonatite Fresh Rock (FR), Slightly Weathered (SW), Moderately Weathered (MW), Highly Weathered (HW), Completely Weathered (CW), Residual Soil (RS).

The uppermost materials (about 1 m below surface level) were not considered as residual soils, but were treated as transported surface materials. Black soils near the residual soil level were also rejected assuming that the soils were mixed with organic materials. The localities of the 50 sampling points are shown in Figure. 1. The sample collection was carried out in two stages. The total number of samples collected was 293 (Table 3).

Preparation Of Samples

About 10 grams of each sample were pulverized by employing a sample vibration mill (HEIKO, Model No T1-100). Every attempt was made to avoid contamination of the powdered material. After preparation, the powder sample was inserted into a separate small polythene bag and sealed. This powdered sample of the particular specimen was used for its entire dry analysis.

X-Ray Fluorescence Analysis

Before X-ray fluorescence analysis, a small part of each powdered sample was used to find out the H_2O (+) and H_2O (-) using ignition loss method. Major elements and selected minor elements were analysed by X-ray fluorescence (XRF) spectrometry on a RIX 3100 system (KG-X system), manufactured by RIGAKU Denki Kogyo Company Limited, Japan at the Department of Earth Resources Engineering of Kyushu University, Japan, (Jayawardena and Izawa, 1993), (Jayawardena, 2000). The major elements are SiO_2, TiO_2, Al_2O_3, Fe_2O_3, MnO, MgO, CaO, Na_2O, K_2O and P_2O_5. The minor elements are S, Cl, F, Cr, Ni, Zn, As, Zr, Pb, Ga, Rb, Y, Ca, Sr, Ba, Co, and Nb. The detection limits of the calibrated XRF spectrometry are in parts per million (ppm).

Results and Method of Analysis

The total results of all minor elements are given in the Annexure 1 as a Supplementary Table. Arsenic (As) is one of the selected minor elements. The results obtained after the testing can be summarized in different ways. Table 4 shows the maximum and minimum concentrations of arsenic in different rock types and their weathering grades without considering the climatic zones as Dry or Wet. Rather than indicating the concentrated amount for each individual sample, it is better to divide into two different ranges to explain its distribution. Generally, the average arsenic concentration in metamorphic rocks is 5 ppm [8] .

Accordingly, the number of fresh rock samples less than 5 ppm arsenic and more than 5 ppm arsenic were found and is given in Table 5a as a percentage. Takeshi [9] found that the minimum arsenic content in soils formed from weathered metamorphic rocks was 10.9 ppm (Table 2). Therefore, for this study, 10 ppm of arsenic in weathered rocks and residual soils was considered as the upper limit. The number of weathered rocks and soil samples that show 10 ppm or less than 10 ppm of arsenic concentration is given in Table 5b.

Table 4: Arsenic concentrations as ppm in different fresh rocks and their weathering grades and total summary

Rock Type	Climatic Zone (Fig.2)		As concentration (ppm) in different fresh and weathered rocks					
			FR	SW	MW	HW	CW	RS
Charnockite/ Charnockitic gneiss	Both Zones	Minimum	0	0	0	1	2	1
		Maximum	12	18	17	46	18	27
Hornblende Biotite Gneiss		Minimum	0	0	0	0	0	0
		Maximum	7	13	13	9	5	24
Garnet Sillimanite Gneiss		Minimum	0	2	0	2	0	3
		Maximum	6	9	9	14	48	31
Some other rock types		Minimum	0	1	0	1	3	3
		Maximum	7	9	9	9	10	10
Summary	Both Zones	Minimum	0	0	0	0	0	0
		Maximum	12	18	17	46	48	31

Table 5a. Summary of Arsenic concentration more than 5ppm (>5ppm) or less than 5ppm (5ppm >) in fresh rock as percentage

Arsenic concentration	Number of fresh rock samples which show Arsenic concentration less than 5ppm				
	Charnockite/ Charnockitic Gneiss	Hornblende Biotite Gneiss	Garnet Sillimanite Gneiss	Other rock types	ALL (total)
Less than 5ppm	20	12	3	5	40
More than 5ppm	3	1	1	1	06
Total Samples	23	13	4	6	46
Percentage of samples Less than 5ppm	86.9	92.3	75.0	83.3	86.9
Percentage of samples More than 5ppm	13.1	7.7	25.0	6.7	13.1

Table 5b. Summary of Arsenic concentration more than 10ppm (>10ppm) or less than 10ppm (10ppm>) in weathered rocks and residual soils as percentage

Weathering Grade	Number of weathered rock/soil samples which show Arsenic concentration less than 10ppm				
	Charnockite/ Charnockitic Gneiss	Hornblende Biotite Gneiss	Garnet Sillimanite Gneiss	Other rock types	ALL (total)
Slightly Weathered	20	11	5	6	42
Moderately Weathered	21	12	8	6	47
Highly Weathered	21	13	7	6	47
Completely Weathered	21	13	6	6	46
Residual Soil	16	12	6	6	40
No. of Samples less than 10 ppm	99	61	32	30	222
Total Samples	115	65	37	30	247
% of samples Less than 10ppm	86.0	93.8	86.5	100.0	89.8
% of samples More than 10ppm	14.0	6.2	13.5	0.0	1.2

The results indicate that there are no arsenic in 6 fresh rock samples and 19 weathered rock samples (total 25). There is no meaning to calculate an average value using zero ppm. Therefore to calculate the average, 1.0 ppm arsenic concentration was used instead of zero ppm of those 25 samples. Insert Table 6 shows the total arsenic values in each sample and the average values after adding 1 ppm instead of zero ppm.

Discussion

Previous Results By Others

There may be some investigations under various objectives carried out by different scientists and organizations for agricultural soils and stream sediments from shallow depths. Those samples are not residual soils related to the parent rock and hence cannot be considered as natural residual earth material. Therefore, the arsenic concentrations in those samples carried out by previous researchers are not related to the original fresh rock. The results from the present investigation indicate the distribution of arsenic that is related to the parent rocks and their weathered grades only.

Arsenic Content In General

Table 6 shows the distribution of arsenic amount of 293 samples analysed by XRF spectrometry in different ways. The results for different rock types given in Table 4 show the maximum and minimum amount of arsenic concentration in fresh and weathered rocks in Sri Lanka. Accordingly, the highest arsenic amount (48 ppm) was found from one completely weathered (CW) rock sample of garnet sillimanite gneiss. The overall results indicate that the average arsenic concentration in fresh rocks is 3.5 ppm and 7.6 ppm in residual soils. The average in total weathered rocks is 5.2 ppm (Table 6). This is similar (or less than) to the average arsenic concentration in metamorphic rocks from other countries [8,9]. With the continuation of weathering processess, rocks convert into soil and the composition of soil may vary with the number of clay minerals and other altered primary minerals. The average results indicate that the arsenic concentration increases slightly with the increase of weathering and the formation of soil. This increase of arsenic in soils may be due to

Table 6. As concentrations in total 293 samples and average values after added 1 ppm for zero values.

Sample Location No	FR	SW	Mw	Hw	CW	RS
1	5	7	6	4	9	27
2	8	9	10	9	9	13
3	4	5	8	9	10	10
4	12	12	11	9	8	1
5	5	18	17	11	8	10
6	1	5	2	0	3	2
7	2	4	1	2	0	1
8	1	0	1	3	0	1
9	5	1	4	5	3	2
10	2	4	4	8	6	7
11	3	2	10	2	8	9
12	7	8	8	7	9	20

13	1	2	2	1	1	1
14	4	1	2	2	4	18
15	4	4	5	6	9	11
16	0	11	10	46	13	9
17	5	6	6	10	8	12
18	4	1	1	1	5	2
19	1	0	1	1	2	2
20	5	2	5	1	4	8
21	3	5	5	4	4	4
22	0	0	0	0	10	14
23	9	0	0	0	16	2
24	1	2	5	8	48	31
25	3	1	1	3	1	3
26	2	1	2	2	2	3
27	0	0	0	0	24	13
28	1	4	3	3	8	8
29	2	2	1	2	3	2
30	7	6	7	2	5	8
31	3	2	6	2	10	8
32	5	2	2	3	1	5
33	2	3	1	3	2	2
34	3	4	6	8	13	7
35	3	12	13	9	5	7
36	2	3	1	2	3	2
37	5	4	4	3	6	8
38	0	9	0	0	25	6
39	4	6	6	8	4	3
40	7	3	11	5	7	16
41	*	2	7	3	5	7
42	*	*	5	3	4	9
43	*	*	6	2	6	1
44	*	*	5	8	0	0
45	5	3	3	2	3	2
46	2	1	2	5	6	10
47	3	1	4	5	5	9
48	0	1	2	1	3	3
49	0	9	9	10	10	18
50	7	4	0	7	10	5
Added for zero ppm	6	5	5	5	3	1
Average separately	3.5	4.1	4.7	5.1	7.4	7.6
Average	Fresh Rock 3.5 ppm		Weathered Rocks 5.2 ppm			
*Samples were not collected						
(a) absorption by clay minerals and other secondary minerals; (b) altered primary minerals such as ferrous and ferric oxides, aluminium oxide, goethite, limonite and bauxite, laterite, etc.; (c) concentration of non-solubility in groundwater; and (d) movement of fine sediments with the groundwater from one place to another.						

Arsenic Content In Fresh Rocks

In general, the average arsenic concentration in metamorphic rocks is 5ppm [8]. Considering that fact Table 5a was made to show the percentages of distribution of arsenic 5 ppm or less than 5ppm (5ppm >) in fresh rocks of this study. 86.9% of charnockite (20 of 23 samples), 92.3% of hornblende biotite gneiss (12 of 13 samples), 75 % of garnet sillimanite gneiss (3 of 4 samples) and 83.3% of other rock types (5 of 6 samples including apatite rock) show the arsenic concentration is less than 5ppm. 86.9% of the total samples (40 of 46 samples) show less than 5ppm arsenic content (Table 5a). These results indicate that metamorphic rocks of Sri Lanka cannot be the source rocks for the distribution of arsenic in the Island.

Arsenic Content In Weathered Rocks

Table 2 indicates that the arsenic distribution in residual soils formed from metamorphic rocks in Japan. It varies from 10.9 to 25.8ppm and the average is 16.9ppm. In Sri Lanka, the maximum is 31ppm but the average is 5.2ppm (Table 6). It is less than the minimum amount of the soils in Japan. Table 5b shows a summary of the variation of arsenic content in natural weathered rock materials and residual soils. To classify the arsenic content, 10 ppm of arsenic in a sample was considered as the upper limit in soils. The percentage of arsenic content less than or equal to 10 ppm in different weathered rock samples is different but as an average for the total weathered samples including residual soils is 89.8%. It is clear that only a few samples of weathered rocks and soils have arsenic more than 10 ppm. This analysis does not indicate whether the arsenic content in Sri Lankan soils is soluble or non-soluble. However, the average arsenic content in fresh rocks is 3.5ppm and is 7.6ppm in residual soil (Table 6). This shows that the arsenic content in fresh rocks is concentrated in residual soils and is increased by weathering due to its non-soluble behaviour.

Garnet sillimanite gneiss is a fast weathering metamorphic rock in Sri Lanka. Generally, unlike other rock types, very fresh rock samples of garnet sillimanite gneiss cannot be seen at the surface but such samples that experienced weathering are available in wet zones within the country. The highest arsenic concentration (48ppm) was found in completely weathered (CW) rocks of garnet sillimanite gneiss (Table 4). Recent investigations carried out by Dissanayake and Chandrajith found that the arsenic content in river sediments in Sri Lanka is less than 7 ppm. Therefore, it can be assumed that the arsenic concentration in alluvial deposits also is similar to the recent measurements due to the same parent rock condition [14].

The arsenic content in fresh apatite mineral is 7 ppm and increases up to 10 ppm in highly weathered grades (Annexure 1). Jayasumana et al. claim that the range of arsenic in apatite is from 3.4 to 21.8 ppm. The average arsenic content in other intrusive rocks may be less than 5 ppm [15].

Conclusion

The results indicate that the maximum arsenic amount in fresh rock is 12 ppm and 48 ppm in completely weathered rocks. 86.9% of the samples (total 46 samples) from different fresh rock types show less than 5 ppm arsenic content. 89.8% of their weathering grades (total of 247 samples) showed that the arsenic concentration is less than 10 ppm. The average arsenic in all fresh rock samples is 3.5 ppm (lowest average) and is 7.6 ppm (highest average) in residual soils. This is the normal condition of arsenic distribution worldwide; under this condition, the arsenic concentration in natural groundwater in the residual soil areas should be below the acceptable limit. Therefore, the amount of arsenic released from parent rocks and their weathered products due to natural geological processes is very low in Sri Lanka [16,17].

Acknowledgements

The author gratefully acknowledges the financial support provided by the Asian Development Bank through the Science & Technology Personal Development Project to carry out higher studies at the Department of Earth Resources Engineering (previously Mining Department), Kyushu University, Fukuoka, Japan. Also the author sincerely thanks to Prof. E. Izawa, Prof. K Watanabe and technical staff of the Department of Earth Resources Engineering for their invaluable help to carry out this project.

Declarations

funding

I received a scholarship from the Asian Development Bank through the Science & Technology Personal Development Project for my studies at the Earth Resources Engineering Department, University of Kyushu, Fukuoka, Japan in 1999.

Conflicts Of Interest/Competing Interests

Not applicable

Availability Of Data And Material

All data used for this analysis and preparation of manuscript are the results of my laboratory experiments at the University of Kyushu, Fukuoka, Japan. Samples were collected from various localities in Sri Lanka before my arrival to Japan. All data have been attached as a supplementary Table. These data has not been published previously in any local or international journals.

Code Availability

Not applicable

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Annexure 1 Supplementary Table

Arsenic content in all samples, ppm

	FR	SW	Mw	Hw	CW	RS
1	5	7	6	4	9	27
2	8	9	10	9	9	13
3	4	5	8	9	10	10
4	12	12	11	9	8	1
5	5	18	17	11	8	10
6	1	5	2	0	3	2
7	2	4	1	2	0	1
8	1	0	1	3	0	1
9	5	1	4	5	3	2
10	2	4	4	8	6	7
11	3	2	10	2	8	9
12	7	8	8	7	9	20
13	1	2	2	1	1	1
14	4	1	2	2	4	18
15	4	4	5	6	9	11
16	0	11	10	46	13	9
17	5	6	6	10	8	12
18	4	1	1	1	5	2
19	1	0	1	1	2	2
20	5	2	5	1	4	8
21	3	5	5	4	4	4
22	0	0	0	0	10	14
23	9	0	0	0	16	2
24	1	2	5	8	48	31
25	3	1	1	3	1	3
26	2	1	2	2	2	3

27	0	0	0	0	24	13
28	1	4	3	3	8	8
29	2	2	1	2	3	2
30	7	6	7	2	5	8
31	3	2	6	2	10	8
32	5	2	2	3	1	5
33	2	3	1	3	2	2
34	3	4	6	8	13	7
35	3	12	13	9	5	7
36	2	3	1	2	3	2
37	5	4	4	3	6	8
38	0	9	0	0	25	6
39	4	6	6	8	4	3
40	7	3	11	5	7	16
41	0	2	7	3	5	7
42	0	0	5	3	4	9
43	0	0	6	2	6	1
44	0	0	5	8	0	0
45	5	3	3	2	3	2
46	2	1	2	5	6	10
47	3	1	4	5	5	9
48	0	1	2	1	3	3
49	0	9	9	10	10	18
50	7	4	0	7	10	5

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: WATAWALA

Sample	**Weath-ering**	**Minor Elements as ppm**															
No 1	**Grade**	**S**	**Cl**	**F**	**Cr**	**Ni**	**Zn**	**As**	**Zr**	**Pb**	**Ga**	**Rb**	**Y**	**Cu**	**Sr**	**Ba**	**Co**	**Nb**
1--1	FR	4	0	90	8	4	19	5	76	43	14	83	22	3	235	740	3	0
1--2	SW	8	0	97	25	15	28	7	95	57	15	130	28	5	240	741	3	1
1--3	MW	9	0	152	27	15	27	6	95	54	17	129	27	6	237	718	2	2
1--4	HW	6	43	239	11	6	77	4	142	36	19	65	17	5	187	360	9	4
1--5	CW	19	2	0	21	15	21	9	195	82	17	237	50	12	167	620	4	2
1--6	RS	155	14	0	133	50	40	27	195	626	52	5	13	87	11	152	46	17

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: GINIGATHHENA

Sample	**Weath-ering**	**Minor Elements as ppm**															
No 2	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
2--1	FR	8	14	58	23	13	52	8	282	75	16	263	52	3	163	990	5	5
2--2	SW	82	0	0	13	21	37	9	150	90	15	252	53	35	173	652	3	1
2--3	MW	71	0	28	11	31	187	10	167	77	16	242	54	58	162	666	3	0
2--4	HW	20	1	139	15	14	20	9	175	72	17	212	44	11	150	542	3	2
2--5	CW	82	1	98	18	34	189	9	173	82	18	252	56	57	166	640	3	0
2--6	RS	48	17	718	112	43	34	13	183	119	29	60	29	32	7	131	10	6

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: HATTON

Sample	Weath-ering	Minor Elements as ppm															
No 3	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
3--1	FR	8	0	5	20	13	17	4	59	41	14	72	17	4	227	611	2	0
3--2	SW	25	15	128	203	69	101	5	74	43	20	41	67	27	108	229	24	6
3--3	MW	25	6	414	29	13	31	8	289	72	18	195	40	5	187	857	4	4
3--4	HW	22	3	7	49	17	45	9	143	78	18	186	43	27	161	611	10	1
3--5	CW	20	14	0	23	14	29	10	269	80	18	268	55	4	142	976	6	4
3--6	RS	23	18	45	32	15	33	10	274	86	17	287	60	6	152	995	6	4

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS (with Garnet)
Location: GINIGATHHENA

Sample	Weath-ering	Minor Elements as ppm															
No 4	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
4--1	FR	10	2	139	23	27	44	12	224	112	19	274	62	13	274	1925	6	6
4--2	SW	6	0	37	20	14	12	12	35	99	18	252	59	5	257	1931	2	0
4--3	MW	4	0	44	16	14	13	11	33	110	18	258	63	8	279	2040	2	0
4--4	HW	18	24	298	54	44	87	9	248	58	22	189	52	18	193	1192	11	8
4--5	CW	14	19	448	57	41	81	8	233	54	19	175	49	16	182	1118	11	8
4--6	RS	162	8	0	414	79	34	1	76	0	29	1	36	197	1	79	54	4

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: HANTANA

Sample	Weath-ering	Minor Elements as ppm															
No 5	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
5--1	FR	22	6	582	222	60	69	5	124	50	16	163	45	11	238	765	10	4
5--2	SW	4	0	25	17	13	17	18	66	174	15	294	55	5	326	1872	3	0
5--3	MW	5	0	26	16	14	17	17	66	178	17	295	55	6	327	1654	3	0
5--4	HW	6	0	131	16	14	5	11	45	111	15	271	51	5	218	1344	2	0
5--5	CW	31	11	404	24	18	23	8	143	85	22	175	34	8	125	748	5	2
5--6	RS	109	9	0	61	16	21	10	161	56	19	128	25	11	56	441	17	1

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: KANDAKETIYA

Sample	Weath-ering	Minor Elements as ppm															
No 6	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
6--1	FR	9	0	0	46	15	72	1	54	11	17	12	20	23	232	212	19	0
6--2	SW	6	0	91	21	12	32	5	148	49	20	255	68	3	42	257	2	7
6--3	MW	15	1	290	53	17	50	2	789	18	27	270	228	148	50	605	8	34
6--4	HW	3	0	78	21	11	5	0	251	0	2	1	7	3	3	33	3	2
6--5	CW	74	0	30	26	15	52	3	769	25	21	251	211	23	72	1017	8	24
6--6	RS	7	3	13	26	18	55	2	612	13	27	34	101	11	72	140	7	19

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: RANDENIGALA

Sample	Weath-ering	Minor Elements as ppm															
No 7	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
7--1	FR	13	27	352	88	24	81	2	59	16	14	20	21	27	154	158	25	1
7--2	SW	6	12	277	40	21	55	4	241	42	14	101	30	19	389	1356	8	2
7--3	MW	18	15	0	379	29	91	1	68	7	20	1	34	3	44	273	29	2
7--4	HW	23	15	0	277	33	82	2	57	8	20	2	23	10	46	347	21	1
7--5	CW	3	0	76	42	12	4	0	266	0	3	1	5	3	2	30	2	3
7--6	RS	12	30	3573	895	42	116	1	44	7	15	14	8	44	84	217	29	1

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: RANTABE AREA

Sample	Weath-ering	Minor Elements as ppm															
No 8	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
8--1	FR	102	22	248	601	26	58	1	33	2	10	1	9	43	152	0	20	0
8--2	SW	91	9	0	97	17	77	0	88	8	15	1	19	46	192	42	22	0
8--3	MW	7	15	885	95	39	85	1	243	12	21	485	135	32	49	706	16	11
8--4	HW	11	0	15	17	14	39	3	1013	26	22	254	191	8	59	939	6	31
8--5	CW	17	12	0	260	33	78	0	52	8	17	2	20	10	42	278	19	1
8--6	RS	9	33	87	18	13	27	1	142	9	14	35	8	3	439	543	4	0

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: ELAHERA

Sample	Weath-ering	Minor Elements as ppm															
No 9	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
9--1	FR	70	13	191	50	24	51	5	276	46	17	107	36	21	947	2275	11	0
9--2	SW	7	0	64	24	13	4	1	247	14	2	42	14	3	36	369	1	3
9--3	MW	52	6	61	26	25	27	4	249	46	14	125	45	23	667	3533	7	0
9--4	HW	54	7	64	27	24	28	5	254	45	12	129	44	24	678	3491	8	0
9--5	CW	203	1	301	45	14	45	3	711	17	24	249	159	75	47	464	5	49
9--6	RS	6	63	131	31	13	35	2	80	16	16	7	8	4	472	348	4	0

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: RANWALA, KEGALLE

Sample	Weath-ering	Minor Elements as ppm															
No 10	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
10--1	FR	6	2	0	71	29	145	2	226	4	10	2	29	7	97	76	16	5
10--2	SW	25	9	205	33	24	27	4	136	44	18	116	28	20	303	550	6	5
10--3	MW	15	20	369	47	41	153	4	49	36	29	112	74	2	227	515	24	10
10--4	HW	25	43	310	125	83	90	8	84	71	39	107	82	34	63	423	17	9
10--5	CW	36	28	194	62	30	33	6	82	52	22	134	41	17	157	686	9	2
10--6	RS	34	15	147	132	38	52	7	45	50	26	33	74	43	20	209	18	4

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: DANOVITA

Sample	Weath-ering	Minor Elements as ppm															
No 11	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
11--1	FR	9	9	508	43	41	106	3	33	26	17	79	38	2	271	183	22	4
11--2	SW	135	2	6	23	34	123	2	138	6	22	35	49	44	86	208	25	8
11--3	MW	25	22	350	50	40	99	10	141	101	22	69	50	65	93	647	130	3
11--4	HW	15	3	395	32	21	59	2	157	14	16	27	26	22	145	676	10	2
11--5	CW	57	5	130	30	20	137	8	338	67	19	248	137	5	189	969	8	9
11--6	RS	7	5	123	31	23	46	9	372	86	21	298	376	4	281	1506	4	12

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: RADAWADUNNA

Sample	Weath-ering	Minor Elements as ppm															
No 12	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
12--1	FR	51	11	30	32	16	84	7	325	79	18	245	79	4	164	756	10	10
12--2	SW	55	4	100	30	19	136	8	333	67	20	242	143	5	187	900	8	9
12--3	MW	8	3	112	27	21	44	8	362	75	20	283	360	4	268	1477	3	12
12--4	HW	17	8	166	18	65	69	7	166	63	21	74	88	65	162	693	4	3
12--5	CW	23	12	135	40	49	62	9	363	80	33	72	130	74	135	483	5	16
12--6	RS	22	14	179	66	51	53	20	84	201	36	8	124	57	5	512	11	9

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: GIRITALE

Sample	Weath-ering	Minor Elements as ppm															
No 13	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
13--1	FR	8	38	105	23	15	42	1	101	10	15	17	7	3	469	441	6	0
13--2	SW	11	16	47	19	14	38	2	81	14	15	11	3	6	445	424	5	0
13--3	MW	5	63	92	36	14	35	2	85	13	16	7	9	6	500	368	5	0
13--4	HW	14	80	144	16	13	48	1	113	20	15	35	8	7	532	466	4	0
13--5	CW	8	33	28	18	13	27	1	146	13	15	37	10	3	448	547	5	0
13--6	RS	17	20	48	234	100	101	1	149	14	20	8	31	111	126	398	42	3

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: POLONNARUWA

Sample	Weath-ering	Minor Elements as ppm															
No 14	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
14--1	FR	52	19	164	43	21	97	4	379	31	17	64	49	22	315	1205	16	11
14--2	SW	14	59	174	40	22	75	1	135	12	18	33	26	4	347	645	11	0
14--3	MW	11	16	54	20	13	37	2	80	16	14	11	5	6	443	395	5	0
14--4	HW	12	21	37	29	17	80	2	155	20	17	25	15	6	397	763	10	1
14--5	CW	16	27	0	43	23	71	4	375	33	19	68	48	16	244	1492	20	13
14--6	RS	25	11	0	48	22	29	18	115	141	14	189	39	23	205	1186	36	0

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: AMITIRIGALA

Sample	Weath-ering	Minor Elements as ppm																
No 15	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
15--1	FR	20	18	271	36	18	108	4	133	39	15	80	33	12	477	1398	11	4
15--2	SW	35	5	234	28	16	103	4	200	39	19	88	29	21	646	1102	10	2
15--3	MW	12	7	30	20	14	57	5	139	57	17	147	31	27	586	1676	5	0
15--4	HW	33	8	271	31	17	74	6	199	56	19	105	36	26	234	1395	8	0
15--5	CW	13	7	99	17	16	27	9	217	88	14	226	41	7	441	2794	5	0
15--6	RS	17	11	0	156	47	237	11	368	104	29	30	552	109	35	383	15	45

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: RATNAPURA

Sample	Weath-ering	Minor Elements as ppm																
No 16	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
16--1	FR	98	8	288	203	155	78	0	33	6	13	5	15	85	84	38	31	0
16--2	SW	5	0	0	20	14	10	11	138	109	15	350	65	3	152	614	3	1
16--3	MW	6	0	0	15	16	12	10	102	101	14	318	59	4	142	622	2	2
16--4	HW	161	9	0	1331	112	11	46	73	459	33	1	1	102	0	56	39	1
16--5	CW	141	6	0	445	45	19	13	185	51	30	12	5	45	8	63	32	4
16--6	RS	88	8	0	101	35	56	9	458	46	31	14	25	66	11	107	25	6

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: SURIYAKANDE

Sample	Weath-ering	Minor Elements as ppm																
No 17	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
17--1	FR	11	0	38	18	21	101	5	1177	39	16	168	96	11	85	707	8	9
17--2	SW	19	23	203	19	22	141	6	781	63	23	309	247	35	80	852	10	27
17--3	MW	3	0	0	14	18	124	6	808	63	23	338	184	5	68	896	6	24
17--4	HW	21	13	0	25	19	95	10	719	84	26	375	147	34	85	953	10	24
17--5	CW	35	9	150	69	33	66	8	251	62	23	72	24	35	150	875	14	6
17--6	RS	106	6	0	136	35	52	12	253	55	23	14	13	88	8	40	33	6

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: MULGIRIGALA

Sample	Weath-ering	Minor Elements as ppm																
No 18	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
18--1	FR	59	5	249	69	32	58	4	145	43	16	100	28	29	865	1339	8	0
18--2	SW	7	1	0	240	53	92	1	33	5	14	2	8	30	244	178	27	0
18--3	MW	14	4	78	30	22	73	1	22	4	18	2	17	76	161	305	30	0
18--4	HW	18	10	0	590	195	80	1	46	2	19	7	17	63	122	201	30	0
18--5	CW	18	11	0	366	49	34	5	28	49	22	11	11	104	24	376	54	2
18--6	RS	18	11	3	57	22	30	2	138	8	17	4	7	27	94	60	9	1

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: NONAGAMA JUNCTION

Sample	Weath-ering	Minor Elements as ppm															
No 19	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
19--1	FR	7	8	0	124	44	119	1	93	0	19	1	38	43	128	77	30	2
19--2	SW	7	4	0	206	41	129	0	108	5	19	0	62	55	117	74	36	4
19--3	MW	29	27	0	185	91	99	1	146	10	26	1	59	86	124	104	43	4
19--4	HW	16	11	0	171	123	142	1	141	6	23	1	66	68	55	174	47	5
19--5	CW	39	10	0	458	124	71	2	149	10	25	3	65	104	16	122	75	5
19--6	RS	35	12	0	385	128	82	2	274	14	19	6	46	72	38	93	32	7

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: ELLA

Sample	Weath-ering	Minor Elements as ppm															
No 20	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
20--1	FR	9	0	0	17	13	21	5	136	50	13	153	29	6	412	1168	3	0
20--2	SW	3	0	101	236	14	14	2	55	23	5	57	11	10	165	1421	1	0
20--3	MW	5	0	3	20	18	16	5	144	44	13	205	36	29	499	1406	3	0
20--4	HW	11	32	85	242	120	101	1	39	8	17	3	17	7	69	67	29	1
20--5	CW	4	0	0	20	16	17	4	115	42	13	167	29	26	473	1144	2	0
20--6	RS	20	48	71	140	53	70	8	162	60	28	166	68	28	185	965	15	3

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: DEMODARA

Sample	Weath-ering	Minor Elements as ppm															
No 21	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
21--1	FR	41	1	294	77	38	54	3	162	27	15	66	18	16	794	1046	7	0
21--2	SW	33	1	14	44	23	30	5	256	47	15	92	22	50	1094	2133	6	0
21--3	MW	32	0	56	45	23	31	5	260	54	14	95	21	50	1108	2114	6	0
21--4	HW	8	0	4	55	41	64	4	255	30	19	23	12	36	808	614	10	0
21--5	CW	8	2	35	79	35	58	4	198	47	20	93	24	44	1063	1774	10	0
21--6	RS	18	6	199	100	48	70	4	210	39	17	90	28	54	861	1522	14	0

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS (with garnet)
Location: BANDARAWELA

Sample	Weath-ering	Minor Elements as ppm															
No 22	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
22--1	FR	167	114	361	80	35	44	0	273	53	7	266	62	17	154	1619	23	22
22--2	SW	576	211	192	64	35	31	0	565	35	5	249	21	107	476	5307	11	0
22--3	MW	232	87	33	15	65	79	0	277	17	11	32	217	16	10	98	19	82
22--4	HW	231	73	28	15	81	71	0	225	17	31	18	147	35	26	611	36	58
22--5	CW	163	57	69	23	210	71	10	337	18	25	19	38	128	66	1350	21	19
22--6	RS	20	15	103	131	59	152	14	287	102	47	32	54	84	42	544	29	14

Rock Type: CHARNOCKITE/CHARNOCKITIC GNEISS
Location: NUWARAELIYA

Sample	Weath-ering	Minor Elements as ppm																
No 23	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
23--1	FR	279	76	21	17	27	114	9	353	17	16	97	39	18	260	3575	11	36
23--2	SW	217	61	111	13	58	118	0	413	62	12	122	51	27	150	1462	23	27
23--3	MW	282	87	124	15	28	43	0	218	56	0	0	4	8	11	53	26	16
23--4	HW	494	100	61	31	13	38	0	271	0	0	0	11	25	0	141	6	24
23--5	CW	551	169	160	54	127	218	16	31	46	16	28	18	0	10	37	3	1
23--6	RS	27	137	4	125	67	90	2	48	21	21	17	24	61	118	166	33	5

Rock Type: HORNBLENDE BIOTITE GNEISS
Location: TENNEKUMBURA

Sample	Weath-ering	Minor Elements as ppm																
No 24	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
24--1	FR	374	41	0	75	34	100	1	74	3	19	14	22	87	556	418	28	0
24--2	SW	371	41	0	70	34	98	2	747	15	23	14	22	85	550	369	29	0
24--3	MW	10	8	11	70	22	67	5	43	7	14	2	13	28	165	102	24	0
24--4	HW	7	0	388	24	15	36	8	331	81	16	197	43	13	663	1647	4	1
24--5	CW	23	11	160	54	51	65	48	404	87	38	76	139	76	145	518	5	17
24--6	RS	23	17	286	78	34	75	31	288	25	19	150	107	25	55	417	13	8

Rock Type: HORNBLENDE BIOTITE GNEISS
Location: TENNEKUMBURA

Sample	Weath-ering	Minor Elements as ppm																
No 25	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
25--1	FR	38	8	124	128	46	109	3	156	8	18	31	35	22	199	336	25	7
25--2	SW	19	148	0	41	57	134	1	180	13	20	13	45	53	195	375	35	8
25--3	MW	22	149	0	43	58	131	1	183	2	20	11	46	53	195	362	34	7
25--4	HW	27	209	0	50	62	136	3	150	37	22	24	43	70	188	400	33	6
25--5	CW	29	34	0	43	62	135	1	205	8	28	8	75	168	27	417	38	10
25--6	RS	41	14	6	41	20	46	3	123	22	9	105	39	4	177	659	7	5

Rock Type: HORNBLENDE BIOTITE GNEISS
Location: NAWALAPITIYA

Sample	Weath-ering	Minor Elements as ppm																
No 26	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
26--1	FR	154	49	60	132	52	73	2	191	12	19	17	31	69	486	368	21	4
26--2	SW	8	15	362	274	157	127	1	27	13	13	6	14	3	57	64	28	0
26--3	MW	18	18	0	149	46	128	2	77	31	17	29	32	12	351	316	30	1
26--4	HW	11	7	36	22	21	75	2	67	29	20	34	46	21	584	338	15	2
26--5	CW	6	0	132	17	10	34	2	98	21	11	105	34	4	180	715	3	2
26--6	RS	6	0	147	19	11	21	3	131	20	11	99	20	7	324	1423	3	0

Rock Type: HORNBLENDE BIOTITE GNEISS
Location: Kandy Dangolla

Sample	Weath-ering	Minor Elements as ppm																
No 27	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
27--1	FR	171	426	21	17	27	76	0	159	0	0	0	26	28	133	215	33	5
27--2	SW	138	326	26	15	168	131	0	105	0	47	0	17	73	21	100	29	18
27--3	MW	175	440	0	33	89	88	0	87	0	38	0	117	70	0	99	28	36
27--4	HW	110	471	0	20	75	85	0	82	16	20	0	89	74	0	0	50	32
27--5	CW	207	53	0	66	24	45	24	55	0	15	0	18	76	8	94	38	18
27--6	RS	14	8	0	17	16	48	13	625	132	23	226	211	5	131	1261	9	20

Rock Type: MIGMATITE / HORNBLENDE BIOTITE GNEISS
Location: DAULAGALA

Sample	Weath-ering	Minor Elements as ppm																
No 28	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
28--1	FR	87	139	0	42	55	129	1	162	7	19	11	39	101	236	368	31	6
28--2	SW	79	8	0	134	69	110	4	159	31	18	81	41	40	596	595	24	2
28--3	MW	154	7	10	26	17	70	3	211	18	19	108	30	247	522	926	14	3
28--4	HW	15	16	163	37	18	97	3	158	32	19	28	28	85	515	400	14	5
28--5	CW	9	3	89	27	24	46	8	194	76	13	181	117	7	175	1372	10	4
28--6	RS	9	5	61	31	24	47	8	198	77	14	184	122	8	179	1419	11	3

Rock Type: MIGMATITE/ HORNBLENDE BIOTITE GNEISS
Location: GADALADENIYA

Sample	Weath-ering	Minor Elements as ppm																
No 29	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
29--1	FR	42	55	102	72	26	69	2	157	19	16	39	34	16	313	685	14	3
29--2	SW	65	29	442	156	102	161	2	26	9	15	6	16	65	55	94	33	0
29--3	MW	69	30	377	156	103	164	1	26	14	14	8	16	63	57	99	33	0
29--4	HW	148	8	0	33	15	88	2	353	20	18	82	49	186	459	927	18	9
29--5	CW	18	15	296	42	20	97	3	155	25	18	73	35	2	787	1242	17	2
29--6	RS	16	9	0	69	23	21	2	92	8	15	3	7	29	35	23	10	1

Rock Type: MIGMATITE/ HORNBLENDE BIOTITE GNEISS
Location: DAMBULLA

Sample	Weath-ering	Minor Elements as ppm																
No 30	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
30--1	FR	11	0	254	19	13	37	7	184	61	17	238	60	4	151	748	4	9
30--2	SW	26	0	319	17	17	56	6	227	54	16	187	58	10	162	670	6	10
30--3	MW	9	0	231	20	15	55	7	239	59	18	216	63	6	172	1015	7	12
30--4	HW	13	0	261	22	15	59	2	123	16	14	65	32	7	260	428	6	3
30--5	CW	3	0	51	12	12	8	5	56	55	13	158	37	3	179	744	2	0
30--6	RS	34	6	266	24	14	54	8	367	65	16	207	59	7	145	827	5	10

Rock Type: BIOTITE GNEISS/ HORNBLENDE BIOTITE GNEISS
Location: DANOVITA

Sample	Weath-ering	Minor Elements as ppm																
No 31	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
31--1	FR	8	0	351	70	19	27	3	197	17	9	173	42	2	62	830	6	3
31--2	SW	30	36	450	56	37	90	2	79	12	18	122	72	42	27	354	16	3
31--3	MW	26	6	129	45	25	61	6	219	60	16	277	77	25	122	1145	12	4
31--4	HW	22	29	322	52	37	84	2	75	15	17	115	68	39	25	337	16	3
31--5	CW	83	0	124	15	35	192	10	175	86	16	256	57	59	169	693	3	0
31--6	RS	8	3	112	27	21	44	8	362	75	20	283	360	4	268	1477	3	12

Rock Type: BIOTITE GNEISS/ HORNBLENDE BIOTITE GNEISS
Location: ADIKARIGAMA

Sample	Weath-ering	Minor Elements as ppm																
No 32	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
32--1	FR	14	0	170	71	28	49	5	361	41	13	176	60	22	160	764	9	4
32--2	SW	11	0	199	69	35	70	2	501	14	13	137	45	14	125	238	9	5
32--3	MW	10	0	236	63	34	67	2	494	16	12	136	45	13	124	307	9	6
32--4	HW	9	0	48	29	17	21	3	200	20	4	103	23	99	70	448	3	1
32--5	CW	8	0	84	32	14	15	1	146	13	5	74	21	8	49	440	4	1
32--6	RS	24	8	120	25	17	32	5	100	48	15	61	23	121	90	217	6	2

Rock Type: BIOTITE GNEISS/ HORNBLENDE BIOTITE GNEISS
Location: MULKIRIGALA

Sample	Weath-ering	Minor Elements as ppm																
No 33	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
33--1	FR	16	0	138	16	12	46	2	113	22	14	106	39	8	204	759	4	3
33--2	SW	9	0	218	18	12	26	3	116	20	10	97	20	8	307	1401	4	0
33--3	MW	11	0	368	19	16	63	1	126	11	15	66	33	5	271	426	8	3
33--4	HW	17	4	199	25	21	28	3	77	24	13	104	26	18	132	577	6	0
33--5	CW	9	0	157	16	13	29	2	118	25	12	99	20	6	311	1469	4	0
33--6	RS	7	0	169	18	12	50	2	120	27	15	135	43	6	176	674	5	8

Rock Type: BIOTITE GNEISS/ HORNBLENDE BIOTITE GNEISS
Location: GIRITALE

Sample	Weath-ering	Minor Elements as ppm																
No 34	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
34--1	FR	18	123	177	25	13	72	3	103	20	25	94	18	7	920	953	7	0
34--2	SW	24	11	385	25	17	58	4	205	45	17	128	32	27	364	1038	7	3
34--3	MW	13	4	184	22	14	49	6	140	54	17	116	29	31	360	1115	6	0
34--4	HW	6	2	67	19	13	22	8	163	73	13	206	40	4	206	747	3	0
34--5	CW	124	68	106	15	34	94	13	154	10	41	74	22	17	30	924	29	14
34--6	Laterite	32	22	103	131	37	49	7	45	45	28	31	70	41	19	219	19	4

Rock Type: GARNET BIOTITE GNEISS / HORNBLENDE BIOTITE GNEISS
Location: Dangolla Kandy

Sample	Weath-ering	Minor Elements as ppm																
No 35	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
35--1	FR	2476	123	499	28	69	47	3	186	27	16	48	16	145	168	717	35	31
35--2	SW	263	90	537	115	49	44	12	272	29	17	9	18	179	75	467	20	32
35--3	MW	281	94	71	308	59	45	13	255	21	40	0	24	63	21	0	20	45
35--4	HW	225	137	80	273	78	56	9	132	16	21	0	16	67	27	245	12	5
35--5	CW	261	105	32	53	50	70	5	142	17	17	0	8	74	10	102	12	21
35--6	RS	290	146	400	203	30	51	7	54	16	5	0	17	54	0	50	28	18

Rock Type: GARNET BIOTITE GNEISS/ HORNBLENDE BIOTITE GNEISS
Location: Kandy Peradeniya

Sample	Weath-ering	Minor Elements as ppm																
No 36	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
36--1	FR	42	2	361	80	37	56	3	162	31	16	66	18	17	798	1111	8	0
36--2	SW	125	120	184	192	18	39	160	972	17	95	90	38	48	32	319	12	49
36--3	MW	23	12	152	18	64	100	5	72	39	19	39	66	25	105	229	24	7
36--4	HW	174	109	111	13	47	144	4	169	38	18	10	10	84	5	214	31	32
36--5	CW	315	93	135	40	36	62	45	429	17	38	6	17	151	17	53	31	47
36--6	RS	99	105	100	30	38	43	10	234	34	6	5	17	57	47	428	29	11

Rock Type: GARNET SILLIMANITE GNEISS
Location: GELIOYA

Sample	Weath-ering	Minor Elements as ppm																
No 37	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
37--1	FR	191	2	25	80	14	61	5	272	41	15	52	63	241	91	1796	20	4
37--2	SW	194	3	0	83	15	62	4	270	36	12	53	64	263	90	1665	22	4
37--3	MW	117	1	82	71	22	40	4	177	38	12	15	34	24	84	91	8	1
37--4	HW	117	1	51	76	21	40	3	184	36	13	16	35	24	87	97	8	1
37--5	CW	21	1	0	100	21	45	6	187	42	23	154	65	26	136	919	14	9
37--6	RS	16	11	1400	43	21	14	8	78	66	26	206	199	12	262	1359	6	0

Rock Type: GARNET SILLIMANITE GNEISS
Location: KANDY

Sample	Weath-ering	Minor Elements as ppm																
No 38	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
38--1	FR	358	34	150	90	96	43	0	141	10	12	109	34	57	163	1704	28	27
38--2	SW	193	55	160	67	58	48	9	363	0	22	23	26	41	25	325	22	39
38--3	MW	194	59	56	78	61	38	0	155	42	19	12	14	56	8	102	34	61
38--4	HW	361	65	45	45	42	46	0	245	20	26	13	11	58	8	70	19	33
38--5	CW	267	77	67	45	166	54	25	162	42	14	6	17	70	12	483	38	20
38--6	RS	162	552	70	56	98	55	6	180	304	0	6	19	65	16	1837	60	31

Rock Type: GARNET GRAPHITE SILLIMANITE GNEISS
Location: BELIHULOYA

Sample	Weath-ering	Minor Elements as ppm																
No 39	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
39--1	FR	496	2	251	118	46	93	4	159	29	25	13	25	27	178	172	15	4
39--2	SW	582	5	51	135	52	103	6	235	62	17	165	66	41	188	1277	18	8
39--3	MW	1620	3	32	125	97	97	6	192	45	21	129	34	117	167	714	21	2
39--4	HW	457	8	43	128	36	81	8	188	73	22	73	50	50	242	623	16	12
39--5	CW	723	4	10	145	52	100	4	190	31	22	76	48	50	118	586	20	10
39--6	RS	321	5	10	148	25	101	3	136	35	26	85	51	48	88	731	15	7

Rock Type: GARNET SILLIMANITE GNEISS
Location: HATTON

Sample	Weath-ering	Minor Elements as ppm																
No 40	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
40--1	FR	351	0	124	114	51	86	7	208	71	27	168	53	32	98	654	13	14
40--2	SW	247	8	40	220	25	29	3	87	33	93	1	1	37	2	24	7	5
40--3	MW	255	10	57	130	66	146	11	162	99	29	7	6	145	12	175	30	9
40--4	HW	1643	0	55	118	94	98	5	187	42	21	124	34	116	164	680	22	1
40--5	CW	457	0	40	123	38	78	7	182	73	21	72	48	47	234	617	15	11
40--6	RS	141	76	32	100	283	41	16	260	17	64	0	44	80	42	200	0	36

Rock Type: GARNET SILLIMANITE GNEISS
Location: DANOVITA (Samples were not collected)**

Sample	Weath-ering	Minor Elements as ppm																
No 41	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
	FR**																	
41--1	SW	44	2	333	62	21	99	2	126	16	17	115	65	5	92	355	19	8
41--2	MW	101	2	12	31	18	56	7	209	63	16	286	82	28	129	1043	8	6
41--3	HW	78	0	0	165	42	142	3	149	25	20	81	47	23	172	619	27	4
41--4	CW	435	16	165	148	61	117	5	242	38	27	44	27	108	11	236	21	12
41--5	RS	15	0	0	83	15	32	7	142	51	19	196	84	13	151	1177	11	5

Rock Type: GARNET SILLIMANITE GNEISS
Location: WATAWALA (Samples were not collected)**

Sample	Weath-ering	Minor Elements as ppm																
No 42	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
	FR**																	
	SW **																	
42--1	MW	1720	0	234	232	186	83	5	820	30	17	40	126	395	288	680	45	4
42--2	HW	140	2	165	206	37	95	3	192	41	38	55	47	72	74	530	19	12
42--3	CW	142	7	152	143	43	94	4	166	36	24	39	41	36	37	255	16	8
42--4	RS	168	135		34	71	72	9	225	32	27	17	10	65	15	186	11	50

Rock Type: GARNET SILLIMANITE GNEISS
Location: MADAMPE (Samples were not collected)**

Sample	Weath-ering	Minor Elements as ppm																
No 43	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
	FR**																	
	SW**																	
43--1	MW	35	7	147	159	75	79	6	244	58	31	77	27	19	19	312	13	11
43--2	HW	23	20	66	55	74	95	2	331	10	17	4	175	27	3	134	14	6
43--3	CW	119	44	57	55	64	97	6	168	37	18	125	26	23	80	1202	12	39
43--4	RS	61	40	60	52	93	217	1	54	13	16	10	37	102	31	82	40	2

Rock Type: GARNET SILLIMANITE GNEISS
Location: RATNAPURA (Samples were not collected)**

Sample	Weath-ering	Minor Elements as ppm																
No 44	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
	FR**																	
	SW**																	
44--1	MW	38	8	150	202	77	184	5	155	28	35	93	128	66	56	532	20	12
44--2	HW	82	8	138	189	69	59	8	300	71	36	14	16	41	11	58	16	14
44--3	CW	145	108	48	158	73	29	0	29	192	0	41	10	8	18	217	8	13
44--4	RS	186	132	56	72	36	55	0	185	188	0	33	32	52	11	215	26	34

Rock Type: PINK GRANITIC GNEISS (MICROCLINE GNEISS)
Location: HABARANA

Sample	Weath-ering	Minor Elements as ppm																
No 45	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
45--1	FR	5	0	65	23	19	24	5	107	46	15	196	42	6	164	1094	4	1
45--2	SW	5	2	83	43	19	30	3	295	25	8	108	33	4	73	383	5	3
45--3	MW	12	0	186	58	27	45	3	316	18	12	104	52	9	40	432	7	5
45--4	HW	6	1	145	58	24	42	2	346	15	15	77	36	2	59	241	7	5
45--5	CW	31	5	40	49	21	40	3	334	18	12	81	29	15	62	407	8	4
45--6	RS	15	80	45	56	12	48	2	112	20	14	33	7	7	56	442	4	0

Rock Type: CALC GNEISS
Location: UTHUWANKANDE

Sample	Weath-ering	Minor Elements as ppm																
No 46	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
46--1	FR	223	136	76	30	16	37	2	149	23	6	4	16	3	166	14	4	1
46--2	SW	133	8	35	34	18	47	1	132	4	6	4	27	2	95	33	4	2
46--3	MW	108	8	0	32	19	46	2	110	15	7	18	15	1	96	201	4	4
46--4	HW	4	0	41	12	12	22	5	168	55	14	220	50	2	251	1913	4	1
46--5	CW	6	0	78	14	12	18	6	159	60	15	214	44	5	222	2104	4	2
46--6	RS	8	2	0	124	37	73	10	388	83	15	237	94	7	318	1336	13	17

Rock Type: CALC GNEISS
Location: UTHUWANKANDE

Sample	Weath-ering	Minor Elements as ppm																
No 47	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
47--1	FR	202	136	70	40	28	32	3	150	23	7	3	18	4	170	18	4	2
47--2	SW	135	9	108	32	19	46	1	133	10	6	4	27	1	96	38	4	2
47--3	MW	115	10	10	34	18	54	4	121	20	8	20	16	2	90	220	4	3
47--4	HW	120	2	34	16	12	28	5	160	60	15	190	45	2	250	1890	5	2
47--5	CW	56	2	60	12	10	22	5	160	48	16	210	42	6	240	2100	5	2
47--6	RS	11	4	0	125	39	77	9	411	90	13	252	100	7	336	1433	13	17

Rock Type: AMPHIBOLITE
Location: GINIGATHHENA

Sample	Weath-ering	Minor Elements as ppm																
No 48	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
48--1	FR	94	3	80	188	80	116	0	62	0	18	2	21	70	147	27	32	0
48--2	SW	62	41	489	114	96	219	1	55	14	17	9	37	103	31	98	39	1
48--3	MW	14	30	125	160	83	256	2	200	18	14	7	30	96	54	119	38	2
48--4	HW	17	30	91	162	83	248	1	193	7	15	8	28	94	54	107	36	1
48--5	CW	23	11	0	370	134	339	3	47	23	25	6	47	44	4	467	43	1
48--6	RS	30	8	0	100	232	372	3	59	23	28	8	123	237	6	367	54	4

Rock Type: QUARTZITE
Location: PERADENIYA

Sample	Weath-ering	Minor Elements as ppm																
No 49	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
49--1	FR	109	67	12	2	17	13	0	95	0	1	18	0	22	10	0	0	0
49--2	SW	122	610	10	1	35	25	9	111	17	2	52	35	22	37	192	0	5
49--3	MW	98	47	15	2	17	12	9	136	37	2	152	13	34	37	211	14	25
49--4	HW	100	67	12	2	15	10	10	140	40	1	142	17	30	156	234	12	23
49--5	CW	110	70	5	1	25	30	10	150	38	1	100	35	38	200	560	12	28
49--6	RS	113	91	3	3	38	59	18	271	33	2	23	55	35	2076	1922	9	34

Rock Type: APATITE PHOPHATE ROCK (Carbonatite)
Location: EPPAWELA

Sample	Weath-ering	Minor Elements as ppm																
No 50	Grade	S	Cl	F	Cr	Ni	Zn	As	Zr	Pb	Ga	Rb	Y	Cu	Sr	Ba	Co	Nb
50--1	FR	166	10373	415	4	0	54	7	44	0	8	0	28	23	1200	192	0	0
50--2	SW	128	5271	412	2	0	53	4	49	14	4	0	26	20	660	132	0	19
50--3	MW	140	1105	330	2	16	67	0	3	0	0	0	40	70	348	0	17	19
50--4	HW	191	9406	287	1	5	54	7	252	0	8	0	77	37	1493	132	0	14
50--5	CW	165	5949	300	3	32	118	10	319	0	12	0	46	191	2926	622	8	20
50--6	RS	145	41	120	2	31	35	5	157	16	29	45	39	29	586	411	11	16