

Handheld ED-XRF Instruments as a Quantitative Tool for Field or Lab Assessments of Metals in Rocks or Soil Contamination Studies

#### **Overview**

In a time when data collection and analytics are required to be easy and almost instant, portable handheld energy dispersive x-ray fluorescence (ED-XRF) instruments have become an efficient tool for remote field and laboratory analysis of metals, metalloids and some non-metal elements in rock and soil samples. Incorporating XRF into a field program provides the flexibility of rapid, in-situ, elemental measurements and the ability to immediately delineate contamination hot spots. By refining the areal extent of contamination in the field, a detailed and precise sampling approach can be developed right away in order to obtain material for high precision laboratory analysis using other geochemical approaches such as mass spectrometry techniques in the laboratory. It is important to note that portable XRF geochemistry is not intended to replace traditional high-resolution geochemical methods but it provides a means for more direct and focused sampling, saving time and money when evaluating small and large field sites.

The use of portable ED-XRF instruments is well established and is used across many industries including pharmaceuticals, materials, agriculture, mining, petroleum and environmental testing. For results to be meaningful and quantitative, XRF data from handheld devices must be calibrated to full scale wavelength dispersive XRF (WD-XRF) or inductively coupled plasma optical emission spectroscopy (ICP-OES) outputs. For the purposes of this study, ED-XRF data was compared and calibrated against ICP-OES and WD-XRF analyses.

A series of 20 unprocessed soil samples were analyzed using ICP-OES, WD-XRF and ED-XRF, on an as received basis with a total of 28 elements being measured and compared. For elements not analyzed with the ICP-OES, WD-XRF was used to calibrate the ED-XRF output. Results are provided for 13 elements between ICP-OES and calibrated ED-XRF data and 15 elements between WD-XRF and ED-XRF. Between ICP-OES and ED-XRF, eight of the 13 comparisons show a goodness of fit greater than 0.9. Between WD-XRF and ED-XRF, 11 of the 15 comparisons show a goodness of fit greater than 0.9. While there is a high degree of repeatability, some elements such as Sn and Co show lower correlation factors which highlights the need for laboratory validation testing to further refine and delineate calibrations of these elements for ED-XRF applications.

# Background

Traditional environmental testing or rock or soil metal contaminations involves acid soluble extractions and the use of ICP-OES techniques for measurement. An alternative, faster and less laborious method using energy dispersive x-ray fluorescence (ED-XRF) or handheld XRF has become more frequently used in recent years due to advancements in new designs and improved detector technology. Recent guidelines from the British Columbia Ministry of Environment and Climate Change Strategy in "Soil Sampling and Investigations", now allow the use of ED-XRF as a testing methodology.

ED-XRF is a fast and efficient method that takes on the order of 2 to 3 minutes after preparation to analyze a sample. In order to effectively utilize ED-XRF technology as a quantitative tool, the instrument must be calibrated properly for materials targeted for analysis. Calibrations of ED-XRF instruments are based on other geochemical analytical instruments with high-precision and internal standards to provide data comparisons with the ED-XRF signal counts. The underlying principle behind all XRF applications is an x-ray source which excites electrons within the orbitals of an atom. Based on the elements, electrons from the K, L, or M orbitals are knocked off and an electron from an outer orbital moves in to fill the hole created. As the electrons change orbitals, a unique energy is emitted, which is specific to each element (Figure 1).

There are two main differences between WD-XRF and ED-XRF methodologies. First, the energy of the WD-XRF system is considerably higher which allows for better detection limits, particularly with light elements like sodium. Secondly, WD-XRF systems use internal crystals which diffract the x-rays directly to the detector. By changing the angle of the crystal, specific wavelengths are targeted resulting in a higher degree of resolution. ED-XRF instruments are much simpler (Figure 2) and collect a broad spectrum of emission x-rays.

In order to calibrate ED-XRF data, lab data from WD-XRF/ ICP-OES is compared against the ED-XRF spectral intensities for a range of elements typically found in contaminated soils. Where possible, elemental concentrations should cover a wide range which allows for a better correlation fit and a more versatile calibration. For soils with anomalous elemental compounds or concentrations, a specific calibration should be built. In this study, the empirical coefficient model proposed by Lucas-Tooth and Price (1961) is used for calibration of ED-XRF concentrations.







Figure 2: Schematic of handheld ED-XRF unit (ThermoFisher).

# Samples

For the purposes of this study, 20 samples were collected and analyzed using ICP-OES, WD-XRF and ED-XRF techniques. The samples were first dried in a standard laboratory oven at 60oC for a period of 24 hours to remove bulk moisture. High-temperature drying (>60oC) will cause significant changes to cations, especially potassium, and will cause loss of volatile metals and organic compounds. Drying soils at 60oC +/- 2oC avoids these problems. The samples were then split using a riffle splitter into representative portions. ICP-OES samples were prepared by digestion in a nitric acid and hydrochloric acid matrix. Testing was completed using a Perkin Elmer Optima 7300. WD-XRF samples were ground to a powder of less than 50 µm in a tungsten carbide mill and then pressed into a pellet for trace elemental analysis. The samples were run on a Bruker S8 Tiger instrument. ED-XRF samples were ground to a powder, loaded into sample cups with a 4 µm prolene film and run on a Bruker Tracer IV-SD instrument.

## Results

Good comparisons are observed between the different instrument outputs when comparing metal concentrations. Comparisons between ED-XRF and ICP-OES shows that the majority of elements have a strong fit with a correlation coefficient >0.9. Increasing the size of the dataset would increase the strength in correlation due to enhanced refinements. For elements not analyzed by ICP-OES methods, ED-XRF was compared to WD-XRF where the majority of elements have a correlation coefficient >0.9. For elements that did not have strong correlations, the limiting factor is typically samples with a low concentration range which creates a cluster effect with several anomalous data points. For this study, twenty samples were analyzed and compared, however, larger datasets often markedly improve calibrations for these elements. Further studies will target a population of >100 samples. Table 1 provides the full dataset and comparison values. Figure 3 to Figure 6 provide plots of ED-XRF results to both ICP-OES and WD-XRF with examples of strong and weak correlations.

Element	t Sc (ppm)		Cs (ppm)		Ba (ppm)		Ti (	ï (%)		opm)	Ce (ppm)		V (ppm)		Cr (ppm)		Mn (%)		Fe (%)		Co	(ppm)	n) Ni (ppm)		Cu (ppm)		Zn (ppm)	
Data Source	WDXRF	EDXRF	WDXRF	EDXRF	ICP	EDXRF	WDXRF	EDXRF	WDXRF	EDXRF \	NDXRF	EDXRF	ICP	EDXRF	ICP	EDXRF	WDXRF	EDXRF	WDXRF	EDXRF	ICP	EDXRF	ICP	EDXRF	ICP	EDXRF	ICP	EDXRF
Sample ID																												
207	9	11	. 12	10	627	559	0.37	0.38	49	48	120	121	23.3	26	12.3	12	0.02	0.02	3.06	2.98	9	8	41	L 40	11.1	11	. 12	5 111
208	7	10	4	10	342	346	0.32	0.36	38	47	93	112	18.2	19	10.3	9	0.02	0.01	2.34	2.46	6.4	1 4	19.8	3 29	11.3	7	6	9 84
226	12	11	. 10	8	144	64	0.4	0.36	59	45	117	107	27.6	20	13	11	0.02	0.01	0.99	1.13	2.7	7 2	24.8	3 16	15.1	17	6	1 42
255	4	4	2	3	51.3	87	0.14	0.17	40	45	89	95	17	21	9	9	0.02	0.03	1.15	1.03	11.8	3 13	53	54	19.5	20	17	2 173
258	14	14	11	10	240	314	0.49	0.45	52	53	143	144	40	42	21.4	25	0.02	0.01	4.62	4.79	34	1 25	65	61	26	27	19	6 166
262	14	14	10	8	180	182	0.49	0.51	51	49	130	127	36.1	47	18.9	22	0.02	0.02	1.49	1.65	93	3 6	40.1	40	21.2	21	11	0 113
268	7	F	3	3	55.3	44	0.21	0.18	41	45	96	93	14.4	12	7 0	9	0.04	0.04	1.43	1 53	17.1	22	93.4	1 93	14.1	14	27	3 273
200	16	12	9	9	221	276	0.21	0.10		50	126	129	41.7	21	20	19	0.04	0.02	2.45	2.55	27.5	11	46.1	41	10	19	17	0 01
2/3	10	11	9	10	100	206	0.44	0.43	40	47	114	120	91.7	27	0.7	10	0.04	0.03	2.04	2 10	27		40.3	41	13	10	12	7 22
205	13	12	10	10	213	200	0.36	0.4	43	47	120	110	24.0	40	3.7	10	0.01	0.01	2.22	2.13	0.3		1.0		5.4		-	7 22
200	15	12	10	10	215	245	0.40	0.41	44	47	120	110	50.5	40	12	15	0.01	0.01	3	2.77	1.5	4	3.4	5 S	0.1	3	1	5 12
290	13	13	8	9	1/5	1/8	3 0.41	0.49	59	53	245	233	64.5	64	23.4	23	0.01	0.01	7.95	7.99	2.8	3 4	1.1	14	15.8	1/	3	5 45
291	12	12	10	g	299	312	0.43	0.45	53	50	125	133	42.8	45	16.1	19	0.01	0.01	3.8	3.8/	1.6	0 0	3.6	6	10.3	11	2	0 22
329	1/	18	10	10	168	191	0.56	0.54	49	51	126	113	102	101	34.9	36	0.02	0.02	3.36	3.35	17.1	1 15	43.5	44	28.1	. 27	13	8 141
332	15	15	7	10	326	264	1 0.5	0.52	47	52	122	141	70.5	60	32.9	27	0.03	0.03	4.06	4.16	11	1 14	29.7	45	25.8	26	9	9 117
372	15	16	8	10	265	355	0.58	0.56	48	51	113	135	76.4	76	32.6	31	0.01	0.01	3.3	3.36	5.4	1 9	14.7	15	22.8	24	8	8 87
384	16	17	12	8	226	223	0.55	0.55	54	51	145	128	90.8	86	32.7	30	0.02	0.01	3.37	3.4	18	3 18	51.1	57	25.9	25	16	9 169
404	16	16	7	8	729	700	0.52	0.53	45	47	94	92	71.9	84	33.3	35	0.02	0.02	3.35	3.27	9.9	12	25.6	27	25.7	27	10	9 112
408	14	14	14	12	186	188	3 0.46	0.46	55	53	117	128	76.9	64	33.7	30	0.02	0.02	3.39	3.25	17.2	2 20	50.8	67	28	28	14	3 141
423	17	17	13	11	207	140	0.57	0.55	54	52	128	133	102	98	33.4	33	0.02	0.02	3.21	3.21	18.8	3 15	43.9	40	25	26	13	8 136
452	19	15	9	10	351	328	3 0.52	0.5	43	52	120	152	43.3	58	33.5	25	0.02	0.01	4.48	4.31	7	7 12	22.5	23	31	29	8	0 79
Element	Ga (i	oom)	As (	(mac	Pb (	ppm)	Th (c	opm)	Rb (i	(mac	U (r	(mac	Sr (	ppm)	Y (	(mac	Zr (p	iom)	Nb (	(mag	Mo	(ppm)	Cd	(ppm)	Sn (	(maa	Sb	(ppm)
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Element Data Source Sample ID	Ga ( WDXRF	ppm) EDXRF	As ( ICP	opm) EDXRF	Pb ( ICP	ppm) EDXRF	Th (p WDXRF	ppm) EDXRF	Rb (j WDXRF	opm) EDXRF I	U (p CP	opm) EDXRF	Sr ( WDXRF	ppm) EDXRF	Y ( WDXRF	opm) EDXRF	Zr (p WDXRF	pm) EDXRF	Nb ( WDXRF	ppm) EDXRF	Mo ICP	(ppm) EDXRF	Cd ICP	(ppm) EDXRF	Sn ( ICP	ppm) EDXRF	Sb ICP	(ppm) EDXRF
Element Data Source Sample ID 207	Ga (j WDXRF 11	ppm) EDXRF 11	As (j ICP 16	opm) EDXRF	Pb ( ICP 8.5	ppm) EDXRF 11	Th (p WDXRF	ppm) EDXRF 13	Rb (j WDXRF 76	opm) EDXRF I 76	U (p CP 1.7	opm) EDXRF 1	Sr ( WDXRF 129	ppm) EDXRF 130	Y ( WDXRF	opm) EDXRF 32	Zr (p WDXRF 201	pm) EDXRF 193	Nb ( WDXRF 10	ppm) EDXRF 11	Mo ICP	(ppm) EDXRF	Cd ICP <0.5	(ppm) EDXRF	Sn ( ICP <0.5	ppm) EDXRF	Sb ICP 0.	(ppm) EDXRF
Element Data Source Sample ID 207 208	Ga ( WDXRF 11 9	ppm) EDXRF 11	As (j ICP 16	opm) EDXRF 6 2	Pb ( ICP 8.5	ppm) EDXRF 11	Th (p WDXRF	ppm) EDXRF 13	Rb (j WDXRF 76	opm) EDXRF I 76 62	U (p CP 1.7	opm) EDXRF 1	Sr ( WDXRF 129 107	ppm) EDXRF 130	Y ( WDXRF 32	opm) EDXRF 32	Zr (p WDXRF 201 194	pm) EDXRF 193	Nb ( WDXRF 10	ppm) EDXRF 11	Mo ICP	(ppm) EDXRF	Cd ICP <0.5	(ppm) EDXRF 0	Sn ( ICP <0.5	ppm) EDXRF 1	Sb ICP 0.	(ppm) EDXRF 6 0
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Element Data Source Sample ID 207 208 226 255 258 262 268 268 279 392	Ga ( WDXRF 11 9 11 6 15 15 6 14 12	ppm) EDXRF 11 11 11 12 16 15 15 15 11	As () ICP 16 11.9 1.2 2.5 2.3 2.3 1.6 5.2 9.6	opm) EDXRF 2 4 2 4 1 1 1 4 9	Pb ( ICP 9 10 4.8 16.1 11.1 3.8 4.4 14.4	ppm) EDXRF 9 8 6 17 11 6 13 13	Th (p WDXRF	ppm) EDXRF 13 13 11 8 17 15 9 14	Rb (j WDXRF 76 59 68 31 111 96 30 86 81	20000000000000000000000000000000000000	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7	Dpm) EDXRF 1 0 1 1 2 2 2 2 1	Sr ( WDXRF 129 107 120 112 155 131 86 112 106	ppm) EDXRF 130 111 120 112 156 130 86 111 101	Y ( WDXRF 32 16 18 6 34 27 10 26 26 13	DDDM) EDXRF 32 12 17 6 32 28 11 25 12	Zr (p WDXRF 201 194 170 63 169 210 59 198 210	pm) EDXRF 193 190 180 63 178 214 62 188 309	Nb ( WDXRF 10 9 11 4 15 14 5 13 13	ppm) EDXRF 11 10 10 4 15 15 6 12 11	Mo ICP 1.4 0.8 0.7 0.8 2.3 1.4 1.1 1.4	(ppm) EDXRF	Cd ICP <0.5 <0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF 1 0 1 1 1 1 1 1 1 1 1	Sb ICP 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 226 255 258 262 268 262 268 269 279 283 299	Ga ( WDXRF 11 9 11 6 15 15 6 14 14	ppm) EDXRF 11 11 11 11 11 11 11 11 11 11 11 11 11	As () ICP 16 11.9 2.5 2.3 2.3 1.6 5.2 9.6	opm) EDXRF 6 2 4 4 2 4 4 1 1 1 4 8 8	Pb ( ICP 9 10 4.8 16.1 11.1 3.8 14.4 13.7 0.9	ppm) EDXRF 9 8 6 117 11 6 13 13 10 10	Th (p WDXRF	ppm) EDXRF 13 13 13 11 8 17 15 9 14 14 14	Rb (j WDXRF 76 59 68 31 111 96 30 86 86 81 00	20000000000000000000000000000000000000	U (p CP 1.7 1.3 1.6 2.2 1.8 1.1 1.7 (0.5	Dpm) EDXRF 1 1 1 2 2 2 2 1 1	Sr ( WDXRF 129 107 120 112 155 131 86 112 106	ppm) EDXRF 130 111 120 112 156 130 86 111 101	Y ( WDXRF 32 16 18 6 34 27 10 26 26 12	20000000000000000000000000000000000000	Zr (p WDXRF 201 194 170 63 169 210 59 198 210	pm) EDXRF 193 190 180 63 178 214 62 188 209	Nb ( WDXRF 10 9 11 4 15 14 5 13 13 12	ppm) EDXRF 11 10 10 4 15 15 6 12 12 11	Mo ICP 1.4 0.5 2.3 1.4 1.1 4 (0.5	(ppm) EDXRF 1 1 3 1 7 1 3 1 3 2 4 1 1 4 2 0 0	Cd ICP <0.5 <0.5 0.6 0.5 0.5 2.1 0.7 <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF 1 0 1 1 1 1 1 1 1 1 1 1	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 6 0 0
Element Data Source Sample ID 207 208 226 255 258 268 268 268 279 283 285	Ga ( WDXRF 11 6 15 15 6 14 14 12 14	ppm) [EDXRF 11 11 13 16 15 16 15 15 16 15 15 12 12 12 12 12 12 12 12 12 12 12 12 12	As () ICP 16 11.9 2.5 2.3 2.3 1.6 5.2 9.6 3.8 8 1.0 2.3	opm) EDXRF 6 2 4 4 1 1 1 1 4 8 2 2	Pb ( ICP 9 10 4.8 16.1 11.1 13.8 14.4 13.7 9.8	ppm) EDXRF 9 8 6 177 111 111 6 6 13 10 10	Th (r WDXRF	ppm) EDXRF 13 13 11 8 177 15 9 14 14 14	Rb (p WDXRF 766 599 688 311 1111 966 300 866 811 900	2000 DDXRF I EDXRF I 76 62 72 25 107 97 97 38 85 77 4 83 4 85 77 4 83 4 85 77 83 8 85 77 83 8 8 8 8 8 8 8 8 8 8 8 8 8	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5	ppm) EDXRF 1 0 1 1 2 2 2 2 1 1 1 1	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83	ppm) EDXRF 130 111 120 112 156 130 86 111 101 83	Y ( WDXRF 322 16 18 6 344 277 10 26 27 10 26 27 10 26 12 13	2000 DDXRF EDXRF 122 177 6 322 288 111 255 133 14	Zr (p WDXRF 201 194 170 63 169 210 59 198 210 179	pm) EDXRF 193 190 180 63 1788 214 62 188 209 201	Nb ( WDXRF 10 9 111 4 15 14 5 13 12 12 12	ppm) EDXRF 11 10 10 10 4 4 15 15 6 6 12 11 11 2	Mo ICP 1.4 0.8 2.3 1.4 1.1 1.4 4.0.5 0.6	(ppm) EDXRF 1 1 3 1 7 1 8 1 1 1 8 2 1 1 1 1 4 2 0 0 5 1 1	Cd ICP <0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5 0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF 1 0 1 1 1 1 1 1 1 1 1 1 1 0	5b ICP 0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 226 255 258 262 268 262 268 279 283 285 285 290	Ga ( WDXRF 11 9 11 6 15 15 6 6 14 4 12 14 12	ppm) EDXRF 111 111 112 113 113 115 113 111 112 122 122	As (r ICP 119 12 2.5 2.3 2.3 1.6 5.2 9.6 3.8 122	2pm) EDXRF 6 2 4 4 2 4 4 1 1 1 1 4 8 8 2 2 122	Pb ( ICP 9 100 4.8 16.1 11.1 3.8 14.4 4 13.7 9.8 15.9	ppm) EDXRF 111 9 8 6 6 177 111 111 6 133 100 10 10	Th (r WDXRF 13 13 13 12 13 13 12 13 13 14 15 15 15 15 15 15 14 14 15 14 14 15 14 14 15 14 14 15 14 14 14 14 14 14 14 14 14 14 14 14 14	ppm) EDXRF 13 13 11 8 17 15 9 14 14 14 14	Rb (y WDXRF 76 59 68 31 1111 96 30 86 86 81 90 90	ppm) EDXRF   62 72 25 107 97 38 85 77 48 85 77 48 85	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 50.5 50.5 0.8	ppm) EDXRF 1 1 1 1 2 2 2 2 1 1 1 1 1 1	Sr ( WDXRF 129 107 120 112 155 131 131 86 112 106 83 308	ppm) EDXRF 130 1111 1200 112 156 130 86 1111 1011 83 308	Y ( WDXRF 32 16 18 6 4 34 27 10 20 20 10 11 13 15	2000 2000 2000 2000 2000 2000 2000 200	Zr (p WDXRF 201 194 170 63 169 210 59 198 210 179 163	pm) EDXRF 193 1900 63 178 214 62 188 209 201 165	Nb ( WDXRF 10 9 9 111 4 4 5 133 12 12 12 12	ppm) EDXRF 11 100 100 4 4 155 6 6 122 111 12 2 2	Mo ICP 1.4 0.8 0.7 0.8 0.8 0.8 1.4 1.1 1.4 <0.5 0.6 0.8	(ppm) EDXRF 1 1 8 1 7 1 8 1 7 1 8 1 8 1 8 1 1 1 1 1 1 1 1 1 8 1 7 1 8 1 7 1 8 1 7 1 8 1 7 1 8 1 7 1 8 1 7 1 8 1 8 1 7 1 8 1 8 1 7 1 8 1 8 1 7 1 8	Cd ICP <0.5 0.5 0.5 0.9 2.1 0.7 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <	ppm) EDXRF 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Sb ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 226 255 258 262 268 262 268 279 283 285 290 291	Ga ( WDXRF 111 9 111 6 155 155 15 6 144 12 14 12 14 12	ppm) EDXRF 111 111 111 112 112 112 112 112 112 11	As (r ICP 119 125 23 23 23 23 16 52 23 23 23 23 23 23 23 23 23 23 23 23 23	2pm) EDXRF 6 2 4 4 2 4 4 1 1 1 1 4 8 8 2 2 122 36	Pb ( ICP 9 100 4.8 161.1 111.1 3.8 14.4 13.7 9.8 15.9 15.9	ppm) EDXRF 111 9 8 6 177 111 111 111 111 111 111 111 111 1	Th (r WDXRF	ppm) EDXRF 13 13 13 13 11 8 17 15 9 9 14 14 14 25 16	Rb (y WDXRF 766 599 688 311 1111 960 300 866 811 900 922 888	2000 DDD DDD DDDD DDDDD DDDDDDDDDDDDDDD	U (r CP 1.7 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5 0.5 0.5	2000) EDXRF	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 105	ppm) EDXRF 130 111 120 156 130 86 111 101 83 308 308 105	Y ( WDXRF 32 16 18 6 4 34 27 10 26 26 12 10 13 15 14	2000 Depm) EDXRF 32 12 17 6 32 28 32 28 11 25 13 3 14 4 4 3 14	2r (p WDXRF 201 194 170 63 169 210 59 198 210 179 163 189	pm) EDXRF 193 190 63 178 214 62 188 209 201 165 193	Nb ( WDXRF 10 9 11 14 5 14 5 13 12 12 12 12 11 11	ppm) EDXRF 11 10 10 10 4 15 5 15 6 6 12 11 12 12 12	Mo ICP 1.4 0.8 0.7 0.8 1.4 1.1 1.4 <0.5 0.6 0.8 0.8 0.7	(ppm) EDXRF 1 1 1 1 1 1 1 1 1 2 1 1 1 2 1 1 1 2 1 1 1 2 1 1 1 2 1 1 1 1	Cd ICP <0.5 0.5 0.5 2.1 0.7 <0.5 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <	ppm) EDXRF	Sb ICP 0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 226 255 258 262 268 279 283 285 285 285 290 291 329	Ga (j WDXRF 111 9 11 15 15 15 6 14 14 12 14 12 14 12 13 20	ppm) EDXRF 111 111 111 112 16 19 19 8 8 133 111 12 122 122 122 122	As (r ICP 16 11.9 2.5 2.3 2.3 1.6 5.2 2.9 6. 3.8 122 37.8 8 122 129	2pm) EDXRF 6 2 2 4 4 2 4 1 1 1 1 1 1 1 1 2 2 1 222 3 6 6 2 3 3 6 2 3 2 3	Pb ( ICP 9 10 4.8 16.1 11.1 11.1 3.8 14.4 13.7 9.8 15.9 13.2 13.2 13.2	ppm) EDXRF 9 8 6 177 111 6 13 13 10 10 10 10 10 13 3 19	Th (p WDXRF 1 13 1 13 1 13 1 13 1 13 1 13 1 13 1 1	ppm) EDXRF 13 13 11 8 17 15 9 9 14 14 14 14 25 16 6 17	Rb (j)   WDXRF   766   599   668   311   916   300   866   811   900   922   888   145	ppm)   EDXRF   	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5 0.8 0.5 1.6	20000000000000000000000000000000000000	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 83 308 105 152	ppm) EDXRF 130 111 120 112 156 130 866 1111 101 83 308 308 105 155	Y ( WDXRF 322 166 188 6 344 277 100 266 122 120 131 159 144 299	2000 2000 2000 2000 2000 2000 2000 200	2r (p WDXRF 201 194 170 63 169 210 59 198 210 179 163 189 203	pm) EDXRF 193 190 180 63 178 2214 62 188 209 201 1655 1933 209	Nb ( WDXRF 10 9 9 11 4 4 5 5 13 12 12 12 11 11 11	ppm) EDXRF 11 10 10 4 15 15 6 6 12 11 11 12 12 12 20 20	Mo ICP 1.4. 0.8. 0.7. 0.7. 0.7. 0.7. 0.7. 0.7. 0.7	(ppm) EDXRF	Cd   ICP   <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 6 0 0 6 0 0 6 1 1 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 226 255 258 262 268 268 268 268 268 269 279 283 285 290 290 291 329 332	Ga (r WDXRF 11 9 11 6 15 15 15 6 14 4 12 14 12 13 200 17	ppm) EDXRF 11 11 11 11 11 12 16 15 16 15 16 11 11 12 12 12 12 12 12 12 12 12 12 12	As (r ICP 16 11.9 2.25 2.3 2.3 2.3 1.6 5.22 9.6 3.8 122 37.8 19 12.1	2pm) EDXRF 6 2 4 4 2 4 4 1 1 1 4 8 2 2 122 366 23 3 6 23 11	Pb ( ICP 9 100 4.8.5 16.1 11.1 3.8 16.1 11.1 13.7 9.8 15.9 13.2 18.8 18.5	ppm) EDXRF 9 8 6 6 177 11 11 6 13 10 10 10 10 10 13 19 9 8 8	Th (p WDXRF	ppm) EDXRF 13 13 13 11 8 17 15 9 14 14 14 14 25 16 17 18	Rb (r) WDXRF 76 59 68 31 111 96 30 86 81 90 90 92 88 81 45 5 109	2000 Sppm) EDXRF 1 F05 C2 76 62 72 25 107 97 38 85 77 4 97 97 38 85 77 4 99 90 4 92 90 4 90 4 92 90 4 90 8 8 9 9 9 9 9 9 9 9 9 9 9 9 9	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5 0.8 0.5 1.6 2.9	ppm) EDXRF 1 0 1 1 1 2 2 2 2 1 1 1 1 1 1 1 1 2 2 2 2	Sr ( WDXRF 129 107 120 112 155 155 131 86 112 106 83 308 105 152 101	ppm) EDXRF 130 111 120 112 156 130 86 111 101 101 83 308 308 105 155 105	Y ( WDXRF 32 16 18 6 6 34 27 10 26 12 10 13 13 15 14 29 24	2ppm) EDXRF 322 122 177 6 322 288 111 255 133 144 13 166 311 222	2r (p WDXRF 2011 194 170 63 369 210 59 198 210 179 163 189 203 189	pm) EDXRF 193 1900 180 63 178 214 62 218 209 201 165 1933 209 201	Nb ( WDXRF 10 9 9 11 4 4 5 13 12 12 12 12 11 11 11 19 9 9	ppm) EDXRF 11 10 10 4 4 15 15 6 6 12 11 11 12 12 12 12 20 0 15	Mo ICP 1.4 0.8 0.3 0.8 2.3 1.4 1.4 1.1 1.4 <0.5 0.6 0.8 0.7 0.6 0.7 0.6 2.3	(ppm) EDXRF 1 1 1 1 1 1 1 1 1 1 1 2 1 1 1 2 1 1 2 0 0 5 1 1 8 1 1 7 1 1 5 1 1 8 2 2 2	Cd   ICP   <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <	ppm) EDXRF	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 6 0 6 1 0 0 6 1 0
Element Data Source Sample ID 226 255 258 262 262 268 279 283 285 290 290 291 329 332 372	Ga (j WDXRF 11 9 11 6 15 15 6 14 12 14 12 14 12 13 20 17 18	ppm) EDXRF 11 11 11 15 16 16 15 15 15 11 11 12 12 12 12 12 12 12 12 12 12 12	As (p ICP 16 11.9 2.5 2.3 1.6 5.2 9.6 3.8 122 3.7.8 19 121 6.9	2pm) EDXRF 6 2 4 4 1 1 1 1 1 2 2 36 36 23 3111 6	Pb ( ICP 100 4.8 16.1 11.1 11.1 13.8 14.4 13.7 9.8 15.9 13.2 13.2 13.2 13.2 14.5	ppm) EDXRF 111 9 8 6 6 133 130 100 16 133 139 19 18 8 8 17	Th (p WDXRF 13 13 8 122 8 8 7 17 15 5 9 8 14 0 15 0 14 0 15 0 14 6 26 6 14 0 17 8 17 7 16	ppm) EDXRF 13 13 11 8 17 15 9 14 14 14 14 25 16 16 17 7 18 8 17	Rb (r)   WDXRF   76   59   68   311   1111   96   300   86   81   90   92   88   145   109   120	2pm)   EDXRF   76 62 72 25 107 97 38 8 85 777 4 83 6 92 90 90 90 90 90 144 108 119	U (r CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 c0.5 c0.5 c0.5 c0.5 c0.5 c0.5 c0.5 c0.5	2ppm) EDXRF 1 0 1 1 2 2 2 2 2 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 105 152 101 100	ppm) EDXRF 130 111 120 112 156 130 866 1111 101 105 105 105 105 102	Y ( WDXRF 32 16 18 6 344 27 10 26 27 10 26 12 13 13 15 14 29 244 22 2	2000) EDXRF 322 122 177 6 322 288 111 255 133 144 133 16 311 222 188	Zr (pp WDXRF 201 194 170 63 169 210 59 198 210 179 163 198 203 198 203	ppm) EDXRF 193 190 180 63 1788 214 62 214 62 214 62 209 201 165 193 209 201 201 201	Nb ( WDXRF 10 9 111 4 15 14 5 13 12 12 112 11 11 11 11 11 11 15 5 18	ppm) EDXRF 11 10 10 4 4 15 6 6 12 12 12 12 12 20 20 5 5 17	Mo ICP 1.4 0.8 0.7 0.8 2.2:2 1.4 1.4 1.1 1.4 50.5 0.6 0.8 0.0 0.8 0.0 0.8 0.7 1.4 1.4 1.4 1.4 50.5	(ppm) EDXRF 1 1 1 1 3 1 1 1 3 2 1 1 1 2 2 1 1 1 1 2 2 1 1 1 1 2 2 1 1 1 1	Cd   ICP   <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 6 0 6 0 6 1 0 0 6 1 0 0 0 6 0 0 0 6 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 208 226 255 258 262 268 279 283 285 290 283 285 290 291 329 3322 3322 3322	Ga () WDXRF 11 9 111 6 15 15 16 14 12 14 12 13 20 20 17 18 18	ppm) EDXRF 111 111 111 111 111 111 112 112 112 11	As (p ICP 11.9 1.2 2.5 2.3 1.6 5.2 9.6 37.8 19 12.1 12.1 1.2 9.6 9.6 9.2 3.2 1.2 1.5 1.5 1.5 1.5 1.5 1.5 1.5 1.5	ppm) EDXRF 6 2 4 4 4 1 1 1 1 4 4 8 8 2 2 3 6 2 3 3 6 2 3 5 2 3 6 2 2 3 6 2 2 3 6 2 3 6 2 3 6 2 2 3 6 2 2 4 4 5 2 2 4 4 5 2 2 4 4 5 2 2 4 4 5 2 2 4 4 5 5 5 5	Pb ( ICP 100 100 4.8.5 16.1 11.1 13.8 14.4 13.7 9.8 15.9 13.2 18.8 18.5 14.5 14.5 19.5	ppm) EDXRF 111 9 8 6 6 133 10 10 10 10 10 10 10 10 10 10 10 10 10	Th (p WDXRF 13 13 13 12 5 5 8 12 15 5 9 9 14 15 5 9 8 14 15 5 9 8 14 14 5 14 15 17 14 14 15 17 17 16 14 12 17 17 17 14 14 14 14 14 14 14 14 14 14 14 14 14	ppm) EDXRF 13 13 13 11 8 17 15 9 14 4 14 14 14 14 14 14 17 17 18 8 177 18	Rb (r)   76   59   68   311   1111   96   30   866   81   90   92   88   145   109   1200   130	2000 2000 2000 2000 2000 2000 2000 200	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 60.5 60.5 60.5 60.5 1.6 2.9 2.2 9 2.2 1.9	Dpm) EDXRF 1 0 1 1 2 2 2 2 1 1 1 1 1 1 1 1 1 2 2 2 2	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 105 152 101 100 101 100	ppm) EDXRF 130 111 120 112 156 130 86 131 101 101 83 308 105 155 105 102 102	Y ( WDXRF 322 166 18 6 6 34 26 26 26 26 26 26 122 13 155 144 222 24 224 31	2000 EDXRF 322 122 177 6 322 288 111 255 133 144 133 146 311 222 88 300 300	Zr (p WDXRF 201 194 170 63 169 210 59 198 210 179 163 189 203 198 2203 203	pm) EDXRF 193 190 180 63 178 214 62 188 209 201 1655 193 209 201 201 201 201 201	Nb ( WDXRF 10 9 111 4 4 5 5 133 2 2 2 12 12 111 111 111 111 111 111	ppm) EDXRF 111 100 100 44 155 155 66 122 111 111 122 122 122 122 127 177 18	Mo   ICP   1.4   0.8   0.7   1.4   0.8   0.5   0.6   0.8   0.7   1.4   <0.5	(ppm) EDXRF 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Cd   iCP   <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 6 0 6 1 6 1 0 0 6 1 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 207 208 2266 255 258 262 279 288 279 283 285 290 201 322 329 322 332 329 332 334 404	Ga ( WDXRF 91 11 9 11 6 15 15 6 14 12 14 12 14 12 13 200 17 7 18 8 16	ppm) EDXRF 111 111 112 125 166 195 8 131 111 122 142 142 212 177 155 168 166 166 166 167 167 177 177 177 177 177	As (p 16 11.9 1.2 2.5 2.3 1.6 5.2 9.66 3.8 122 37.8 19 12.1 6.9 12.1 12.1 12.1 12.1 12.1 12.1 12.1 12.1 12.1 12.1 12.1 12.5 13.2 14.1 14.9 14.2	2000) EDXRF 6 2 4 4 2 4 4 1 1 1 1 1 2 2 3 6 2 2 3 6 2 2 2 2 2 2 2 2 2 2 2 2	Pb ( ICP 100 100 4.8 16.1 11.1 11.1 11.1 3.8 14.4 13.7 9.8 15.9 13.2 18.8 18.5 14.5 14.5 22.4	ppm) EDXRF 11 9 8 8 6 6 6 17 11 11 10 10 10 10 10 10 10 10 10 10 10	Th (p WDXRF 133 133 122 127 177 127 127 127 127 127 127 127	ppm) EDXRF 13 13 11 15 9 9 14 14 14 14 25 16 17 18 17 18 17 18	Rb (p WDXRF 76 59 688 311 1111 966 300 866 811 900 92 888 1455 109 1200 1300 1117	2000 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	U (p CP 1.7 1.3 1.6 2.2 1.8 1.1 1.7 c0.5 c0.5 c0.5 c0.5 1.6 2.9 2.2 1.9 2.2 1.9 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2.2 2	ppm) EDXRF 1 0 1 1 2 2 2 2 2 1 1 1 1 1 1 1 1 1 2 2 2 2 2 2 2 2 2 2 2 2 2	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 105 152 100 100 161 155	ppm) EDXRF 130 111 120 130 86 110 83 308 105 105 105 102 102 102	Y ( WDXRF 32 16 18 6 6 27 10 10 26 12 13 15 15 14 29 24 24 22 24 24 22 24 24 22 24 24 24 24	2000 EDXRF 222 177 6 322 288 111 225 133 144 133 14 311 222 188 300 225	Zr (pp WDXRF 201 194 170 63 169 210 59 198 210 179 163 189 203 198 223 201 202	pm) EDXRF 193 190 180 63 178 214 62 188 209 201 165 193 209 201 201 201 201 201 201	Nb ( WDXRF 10 9 111 4 4 5 5 133 12 12 12 12 12 12 12 11 11 11 11 11 11	ppm) EDXRF 11 10 10 4 4 5 5 6 6 12 11 12 20 20 0 15 15 17 7 18	Mo ICP 1.4 0.8 0.7 0.7 0.8 2.3 1.4 4 1.1 1.1 1.4 <0.5 0.6 0.7 0.7 0.8 0.7 1.7 1.7	(ppm) EDXRF 1 1 1 8 1 1 8 1 1 8 1 1 8 1 1 8 1 1 1 1 1 1 2 1 0 0 5 1 1 7 1 1 8 2 1 1 7 1 1 7 1 1 7 1 1 7 1 1	Cd ICP <0.5 0.5 0.5 0.5 2.1 0.7 0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5	ppm) EDXRF	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample (D 2007 2026 2262 255 2588 262 262 262 262 262 262 262 263 263 265 263 265 263 263 263 263 263 263 263 263 263 263	Ga () WDXRF 111 9 111 6 15 15 6 14 14 12 14 14 12 13 20 17 7 18 18 16 6 17	ppm) EDXRF 11 11 11 15 5 16 15 15 16 11 12 12 12 12 12 12 12 12 12 12 12 12	As (p ICP 11.9 2.5 2.3 2.3 1.6 5.2 2.3 2.3 1.6 3.8 1.5 2.3 2.3 2.3 1.6 3.8 1.5 2.3 2.3 2.3 1.6 1.5 2.5 2.3 2.3 1.6 1.9 6.9 9.6 3.8 1.9 2.3 1.9 1.9 2.5 5.5 1.9 2.5 5.5 1.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 2.5 5.5 5	ppm) EDXRF 6 2 4 4 2 2 4 4 1 1 1 1 1 1 2 2 366 223 1111 6 6 226 2177 9 9	Pb ( ICP 9 100 4.8 16:1. 11:1 13.7 9.8 15:9 13.2 13.2 13.2 13.2 14:5 14:5 14:5 14:5 22:4 40.9	ppm) EDXRF 11 9 8 8 6 6 6 7 77 11 11 6 13 10 0 10 10 10 10 13 10 10 10 19 19 19 19 21 17 7 7 11 10 10 10 10 10 10 10 10 10 10 10 10	Th (p WDXRF 13) 133 133 133 133 133 133 133 133 133	ppm) EDXRF 13 11 11 8 177 15 5 9 14 14 14 14 14 14 14 15 16 17 18 177 15 5	Rb (p WDXRF 599 688 311 1111 966 300 866 811 900 922 88 81 455 109 1200 1300 1177	2000) EDXRF 1 EDXRF 1 76 62 72 25 107 97 38 83 5 83 5 97 90 4 144 108 119 133 113	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5 0.5 0.5 1.6 2.9 2.2 1.9 2.2 1.9 2.2 2 2 2 2 2	Dpm) EDXRF	Sr ( WDXRF 129 107 120 112 155 131 86 112 106 83 308 105 152 101 100 161 155 125	ppm) EDXRF 130 1111 120 1566 130 86 1111 101 101 105 105 105 105 105 105 10	Y ( WDXRF 32 16 18 6 4 34 34 27 10 10 26 26 13 3 15 1 5 24 22 2 22 23 31 12 24 24 24 24	2pm) EDXRF 32 12 177 6 32 28 111 25 13 14 4 13 16 31 22 2 18 30 25 25 25	Zr (p WDXRF 201 1944 170 63 169 210 59 210 179 198 2210 179 198 203 189 203 203 201 202 202 180	pm) EDXRF 193 1900 633 178 214 62 188 209 2011 1655 193 209 2011 2011 2011 2011 2011 2011 2011	Nb ( WDXRF 10 99 111 44 55 133 122 12 11 111 111 119 155 188 188 177 15	ppm) EDXRF 11 100 100 4 4 55 15 6 6 122 11 11 12 12 12 20 5 5 17 7 15 17 17	Mo   ICP   1.4   0.8.0   0.7.1   1.4   0.5   0.6.0   0.8   0.7   0.8   0.8   0.7   0.7   0.8   0.7   0.7   0.8   0.7   0.7   1.7   1.7	(ppm) EDXRF 1 1 1 1 1 2 1 1 1 2 1 1 1 2 1 1 1 2 1 0 0 5 1 1 1 2 1 1 2 1 2 1 1 1 2 1 1 2 1 1 2 1 1 7 1 1 1 3 2 1 1 1 7 1 1 1 3 2 1 1 1 7 1 1 1 7 1 1 1 7 1 1 1 1	Cd ICP <0.5 0.6 0.6 0.5 0.5 0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.	(ppm) EDXRF 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0	Sn ( ICP <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.6 <0.7 <0.6 <0.6 <0.7 <0.6 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <0.7 <	ppm) EDXRF 1 0 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1 1	Sb   ICP   <0.5	(ppm) EDXRF 6 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0 0
Element Data Source Sample ID 2007 2026 2255 255 255 262 268 262 268 2799 283 285 290 290 291 329 3322 3324 3344 404 408 403	Ga () WDXRF 9 111 9 111 6 155 155 15 15 15 15 15 15 15 15 15 15 1	ppm) EDXRF 111 117 116 115 16 117 12 12 12 12 12 12 12 12 12 12 12 12 12	As (µ ICP 160 11.9 1.2 2.5 2.3 2.3 1.6 5.2 9.6 3.88 122 3.7.8 125 2.2.3 2.2.3 1.2.1 1.5.5 2.2.3 2.3.3 2.	ppm) EDXRF 2 4 4 1 1 1 1 4 8 8 2 2 3 6 2 3 6 2 3 6 2 3 6 2 3 6 1 9 9 19	Pb ( ICP 9 100 4.8.5 16.1 11.1 11.1 13.7 9.8 15.9 13.2 13.2 13.2 13.2 13.2 13.2 14.5 19.5 2.2.4 40.9 18.6	ppm) EDXRF 111 9 8 6 6 177 111 6 6 133 100 100 16 133 19 9 19 19 212 17 7 9 9 9 8 8 8 7 7 7 9 9 8 8 8 7 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 9 9 8 8 8 7 7 9 9 8 8 8 7 7 9 8 8 8 7 7 7 177 111 11 9 8 8 8 7 7 7 177 111 111 10 9 8 8 8 7 7 7 117 111 111 111 111 111 111	Th (p)   WDXRF   133   133   133   133   133   133   133   133   133   133   131   133   133   134   155   9   141   152   141   152   141   152   141   152   141   152   141   152   141   152   141   152   141   152   141   152   141   152   153   154   155   157   161   170	ppm) EDXRF 13 11 18 8 17 15 9 9 14 14 14 14 14 14 14 14 14 17 7 18 17 7 18 17 7 15 17	Rb (p WDXRF 76 59 68 31 1111 96 30 30 30 88 81 111 90 90 90 90 92 88 88 145 109 9120 130 01310 137 117 117	2000)   EDXRF     EDXRF     76 622 72 25 107 97 38 85 777 4 38 4 92 90 4 108 119 113 123 118	U (p CP 1.7 1 1.3 1.6 2.2 1.8 1.1 1.7 0.5 0.5 0.5 0.5 0.5 0.5 1.6 2.9 2.2 1.9 2.2 1.9 2.2 1.9 1.9 2.2 1.9 1.9 2.2 1.9 1.9 2.2 1.9 1.9 1.9 1.9 1.9 1.9 1.9 1.9 1.9 1.9	Depm) EDXRF 1 0 1 1 1 2 2 2 2 2 1 1 1 1 1 1 1 1 1 2	Sr ( WDXRF 129 107 120 112 155 155 131 86 112 106 105 152 100 100 161 155 1252 119	ppm) EDXRF 130 111 120 156 130 86 111 101 105 105 105 105 102 105 102 105 102 105 102 102 105 102 102 105 102 105 105 105 105 105 105 105 105 105 105	Y ( WDXRF 322 160 181 6 34 277 100 260 260 270 102 122 122 133 153 144 225 244 222 244 222 331	2000 EDXRF 32 177 6 32 288 111 225 33 31 44 13 166 311 222 188 300 25 25 300	Zr (p WDXRF 1944 1700 63 169 2100 599 1988 2100 1799 1633 189 2003 1988 2203 2001 2002 1800 2007	pm) EDXRF 193 190 1800 63 178 2144 62 201 201 165 193 209 201 201 201 201 201 201 201 201 201 201	Nb (   WDXRF   10   9   111   4   55   133   122   122   121   111   119   15   18   18   18   18   18   19	ppm) EDXRF 11 10 10 4 15 6 6 12 11 11 12 20 12 20 15 177 18 8 177 15 9 19	Mo   ICP   0.8   0.7   1.4   1.1   1.4   0.5   0.6   2.3   1.4   1.4   1.4   0.7   0.6   0.7   0.7   1.7   <0.5	(ppm) EDXRF 1 1 1 8 1 7 1 8 2 1 1 1 1 8 2 2 1 1 1 1 1 1 2 2 1 1 1 1 2 2 1 1 1 7 1 1 1 7 1 1 7 1 7 2 2 2 2 2 2	Cd ICP <0.5 0.5 0.5 0.5 0.5 0.5 0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 <0.5 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Table 1: Comparison of WD-XRF (top) and ICP-OES (bottom) to ED-XRF data.











Figure 5: WD-XRF to ED-XRF data comparisons with weak correlation coefficients.



**Figure 6:** ICP-OES to ED-XRF data comparisons with weak correlation coefficients. Note that Pb has an outlier that significantly skews the correlation.

# Samples

The potential of using portable ED-XRF testing as a field and screening tool for measuring trace metal concentrations on contaminated soil sites was evaluated for this study. Portable XRF analysis provides a quick, easy and nondestructive approach that is cost effective. The intent of the ED-XRF field methodology is to facilitate efficient delineation of contaminated zones vertically and laterally, allowing for focused sampling in order to obtained the most critical samples for laboratory verification and high-precision metal contamination data using other methods (ICP-OES, etc). The test program evaluated the correlation and strength of fit for elemental analyses when comparing geochemical metal data of different methods such as XRF and ICP-OES. The use of ED-XRF testing as a rapid test tool is incumbent upon the development of a robust calibration. Without proper calibration, datasets lose the accuracy and reliability required for onsite assessments. Through the stringent development of a metals calibration, results show that there is a strong correlation between ED-XRF and ICP-OES methodologies for most elements and would provide an effective tool for field testing.

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