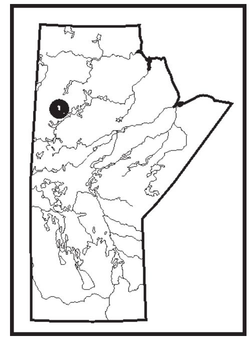
GS-8 Enzyme Leach℠ and Terrasol Leach℠ studies of soils at the MacLellan Au-Ag deposit, Lynn Lake, Manitoba (NTS 64C15)

by G.H. Gale, P. Pawliw[1] and G.T. Hill[2]



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Summary

Data from geochemical studies at the MacLellan Au-Ag deposit illustrate that there is no one 'best' sample medium or sample depth for Enzyme Leach℠ and Terrasol Leach℠ soil surveys to identify mineralization similar to that found in the Rainbow zone. Various metals, including Eu, give anomalies at different soil horizons, and it appears that element patterns are just as important or more important in identifying the anomaly source, which can be within the till, at the bedrock surface or buried under considerable thicknesses of rock (Clark et al., 1990). However, this study, as well as many others conducted in glacial environments, suggests that relatively shallow sample depths of 10–20 cm yield fairly consistent, high-contrast results above subcropping mineralization (e.g., Clark, 1993; Clark et al., 1990; Hamilton et al., 2004a, b). Nonetheless, it is important to develop a three-dimensional (3-D) understanding of soil geochemistry above mineral deposits so that selective extraction results can be put into this spatial context. In this area, and in many other areas underlain by glacial till, it is not possible to find the same sampling medium at a specific sample depth. Consequently, the indications of the strength of an electrochemical cell may be of greater assistance in selecting drill targets than the identification of individual 'high metal' sites. Additional samples collected across this mineral zone will provide a 3-D view of metal distribution in the upper portions of this relatively homogeneous sample medium.

Introduction

The behaviour of rare earth elements (REE) in association with massive sulphide deposits indicates that Eu can be used as a vector to massive sulphide mineralization in exhalite units that contain trace amounts of base metals (Gale, et al., 1997; Gale et al., 1999; Gale 2003). This study is part of a project designed to investigate the distribution of Eu in the soil and vegetation overlying Au and base-metal deposits, specifically to determine the behaviour of the REE in soils and vegetation over known Au mineralization. This part of the project provides a 3-D view of the distribution of elements within a relatively homogeneous overburden that consists predominantly of fine- to medium-grained sand. The presence or absence of Eu anomalies in association with base- and precious-metal anomalies could be of assistance in exploration in the Lynn Lake area, where overburden cover is extensive along features such as the Agassiz Metallotect (Fedikow, 1986).

Core samples collected from a drillhole that intersected the Rainbow zone (Figure GS-8-1) were analyzed for major and trace elements. Soil samples were collected at different depths below the surface along a profile across the Rainbow zone at the MacLellan mine. The outer bark of spruce trees over 10 cm in diameter was collected adjacent to the soil sample sites (Gale, 2003). Three sites (Mac 31, Mac 32 and Mac 33) adjacent to the surface projection of the Rainbow zone were selected for detailed profiling by the second author and sampled at 5 cm intervals to a depth of 100 cm. Additional soil samples were collected over the Rainbow, Main and Nisku zones during the 2004 field season. This paper reports the results of Enzyme Leach℠ and Terrasol Leach℠ analyses of soils collected from the three 1 m deep pits.

Geological setting of the MacLellan deposit

The MacLellan deposit, consisting of the Rainbow, Main and Nisku Au-Ag±Zn±Pb zones, and other known precious metal deposits occur within the Agassiz Metallotect, a regional feature that encompasses a distinctive stratigraphic unit (Fedikow and Gale, 1982; Fedikow, 1986). The Agassiz Metallotect includes a sequence of dominantly sedimentary rocks with both clastic and chemical components, and minor mafic volcanic and volcaniclastic rocks (Fedikow, 1986). Although sheared and faulted, mineralization at the MacLellan mine is essentially stratabound. The hostrocks to the mineralization occupy a 10–20 m thick layer of sedimentary and volcanic rocks that has been followed for approximately 1.5 km along strike within the much thicker Agassiz sequence of sedimentary and volcanic rocks (Fedikow, 1986). The sedimentary hostrocks include siltstone, magnetite-bearing siliceous siltstone, biotitic sulphidic

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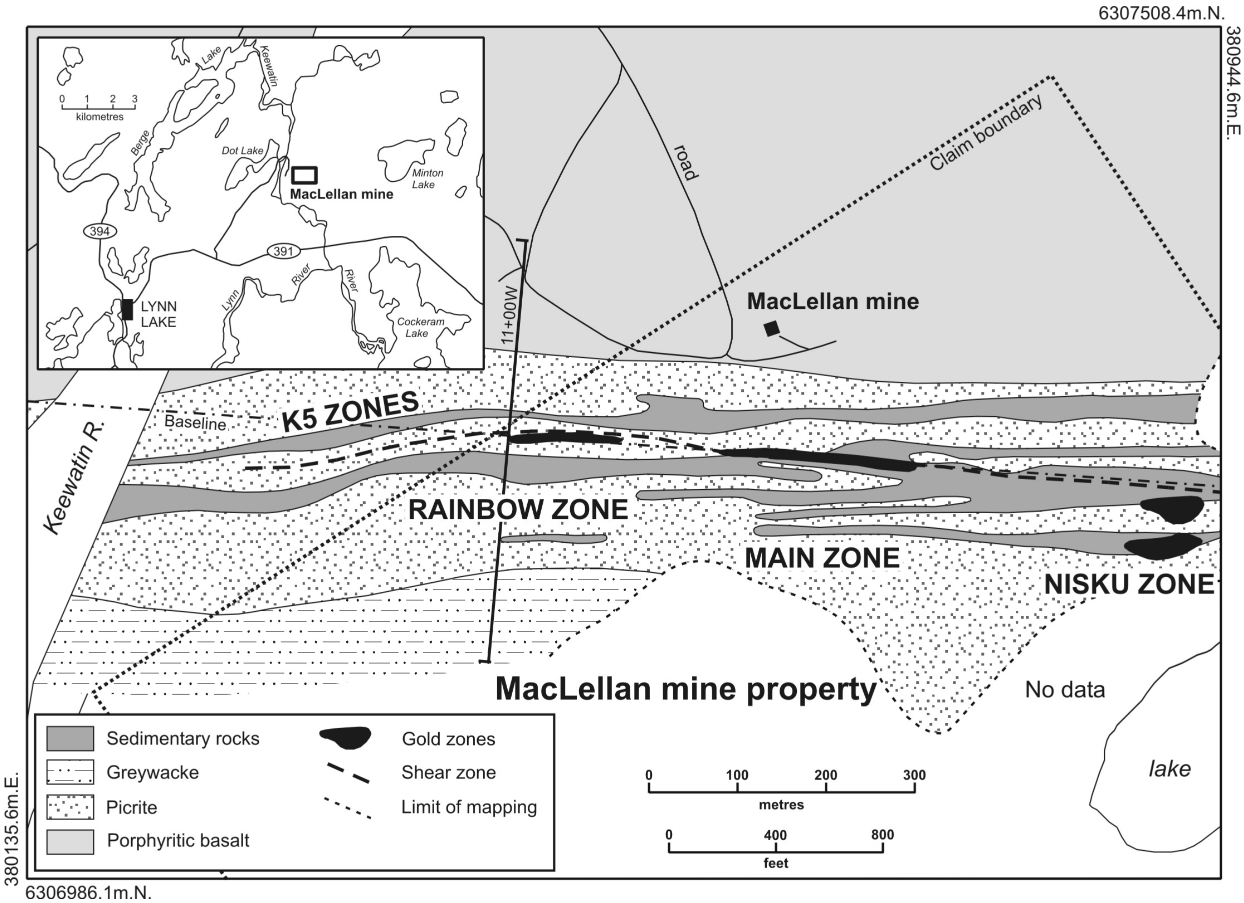

Figure GS-8-1: *Location of the Rainbow zone, MacLellan mine, Lynn Lake.*

siltstone, oxide-facies iron formation with chert and magnetite laminae, and silicate-facies iron formation consisting of chlorite-garnet-actinolite with Fe and base-metal sulphides (Fedikow, 1986; Ferreira and Baldwin, 1997). Rhythmically layered pyrite and pyrrhotite occur in the sulphide-facies iron formation. The volcanic rocks are 1–3 m thick massive basalt and derived tuff or tuffaceous sedimentary rocks. These rocks have high Mg, Ni and Cr, and are geochemically distinct from the sedimentary rocks (Fedikow, 1986). Locally, the basaltic rocks are silicified and carbonatized. Although commonly referred to as picrite (Fox and Johnston, 1980), the basalt does not appear to have any olivine or the chemical composition of picrite (P. Theyer, pers. comm., 2004). Medium- to coarse-grained amphibole-rich rocks in this sequence mineralogically and geochemically resemble metamorphosed Mg-rich alteration lenses in the footwall alteration zones associated with volcanogenic massive sulphide deposits.

Samples of chemical and clastic sedimentary rocks and basalt from drillhole 8326 show a wide variation in both major and trace elements. The SiO_2 contents vary from 43 to 72% and MgO contents vary from 1.4 to 15.5%. The samples have europium deviation (Eu^d)[3] values that vary from –1 to +447%, but there is no correlation between the Eu^d and mineralization or rock type. The highest Eu^d value occurs in a 'chert-like' rock with 3.7% Na_2O and 4.5% K_2O, but there is no correlation with Au content.

Partial leach analyses

Partial leach analyses act selectively on different portions of the soil constituents and strip varying amounts of amorphous and crystalline oxide coatings, primarily those of Fe and Mn, from the same samples. Trace elements contained within these coatings are released into solution, together with water-soluble components, and other components are released through hydrolysis. Elemental concentrations vary not only laterally, but also vertically (at different

[3] $Eu^d = (Eu/(Sm_n/2 + Gd_n/2) - 1) \times 100$, where $_n$ is the chondrite-normalized value

soil depths) and in different soil horizons within glacial overburden (Hamilton et al., 2004a, b). Studies in various terrains have determined that the ideal sample depth or soil type varies from place to place — there are indications that the ideal depth may vary over time. Tables GS-8-1 and -2 show the relative concentrations for elements from the same samples using the weak extraction method of Enzyme Leach^{SM} and the stronger Terrasol Leach^{SM} for three test pits (Mac 31, Mac 32, Mac 33) at the Rainbow Au zone; each sample represents a 5 cm depth interval.

Enzyme Leach^{SM}

The locations of sample pits Mac 31, Mac 32 and Mac 33 are shown on Figure GS-8-2, together with the position of the Agassiz sequence and the surface projection of the underlying mineralization. On Figure GS-8-3, the sample locations are shown in relation to the projected surface position of both the Rainbow ore zone and two thinner hangingwall mineralized zones. Data for selected elements are presented in Table GS-8-1. The complete Enzyme Leach^{SM} database for all samples from the three sites is available in Data Repository item 2004003.[4]

Selected element profiles for the 1 m deep pits at sites Mac 31, Mac 32 and Mac 33 are illustrated in Figures GS-8-4 and -5; the Enzyme Leach^{SM} data are normalized to the first quartile (lower 25% of the data) and the results are plotted as BB (= 'times background'). All of the profiles show a marked variation from top to bottom. The profile for Au at site Mac 31 is not only >50 BB in the top 10 cm of the soil profile, but Au is detectable to a depth of 45 cm. In the other two pits, none of the B-horizon soil samples shows a Au response. The sample medium at site Mac 31 is quite similar to that at the other two sites, so the difference in Au responses cannot be attributed to selective collection by A, B or C soil types (cf. Clark, 1993). The Mac 31 site is closer to or directly overlies the mineralized zone, as indicated by projection of drillhole information to the subsurface (Figures GS-8-2, -3). At site Mac 32, only the top 5 cm of the A horizon has a Au response; it is considered to be considerably closer to the subsurface projection of the mineralized zone than Mac 33 (Figure GS-8-2). This indicates that Au forms an apical anomaly and that there is limited dispersion of Au away from the immediate vicinity of the mineralized zone.

Arsenic responses are strong at site Mac 31, the strongest being in the A-horizon samples. The Ae- and B-horizon samples show weak responses that can still be used to identify the mineralized zone. Tellurium and rubidium are anomalously higher in the A-horizon at site Mac 31 relative to the other two sites; in addition, the responses for both elements extend deeper at site Mac 31 and are independent of soil type (Figure GS-8-4b).

Manganese responses in the upper portions of the soil profile are highest in the top 5 cm of organic-rich material, but do not discriminate between sites Mac 31 and Mac 33. Manganese response is much lower (<10 BB) in the lower part of the A, Ae and B soil horizons, and much higher (100–200 BB) in the lower part of the C horizon (Figure GS-8-5) at sites Mac 31 and Mac 32. In contrast, the lower part of the C horizon at site Mac 33 has <25 BB Mn, but the lower part of the A, Ae B horizons, and the upper part of the C horizon all have <5 BB Mn. The patterns for Zr, Y and REE are similar to those for Mn (Table GS-8-2).

Base-metal responses (Figure GS-8-4c) are strong at site Mac 31, with BB values >200 for Zn in the top 5 cm of the A soil horizon. Strong responses for Zn, Pb and Cd in the top 10 cm of the profile suggest that the A-horizon anomaly will be dispersed over a much larger area than the mineralized zone and may not identify a specific exploration target. Base metals in the 10–20 cm depth interval at site Mac 31 are anomalous in comparison to Mac 32 and Mac 33.

Both positive and negative Eu^d values are present at all three sites, and the distribution and size of the europium deviation (Eu^d) differs both vertically and laterally. Site Mac 31 has positive Eu^d values in all samples down to a depth of 60 cm and shows deviations of up to 300% in both A- and B-horizon samples (Figure GS-8-4a). The uppermost parts of the A-horizon soils at sites Mac 32 and Mac 33 have negative Eu^d values, and the extent of the Eu^d is considerably less at comparable sample depths than at site Mac 33, which is closer to the mineralized zone. This is probably a response to the presence of reduced chemical species such as H_2, reduced or methylated metals and/or hydrocarbons rising above the mineralized zone. This type of environment would allow Eu^{2+} to form and migrate from the reduced body into the upper parts of the soil zone until oxidized by the atmosphere. Oxidation is probably also responsible for the fixing of many other metals that have migrated to the upper part of the soil profile as volatile species.

Oxygen availability from the atmosphere may be a key reaction component for fixing metals, and this is probably controlled primarily by sample depth in specific media. A constant sampling depth can be used in this area to identify Rainbow zone–type mineralization (cf. Hamilton et al., 2003, 2004a). Samples collected at the 10–25 cm depth interval

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[4] MGS Data Repository item 2004003, containing the data or other information sources used to compile this report, is available on-line to download free of charge at www2.gov.mb.ca/itm-cat/freedownloads.htm, or on request from minesinfo@gov.mb.ca or Mineral Resources Library, Manitoba Industry, Economic Development and Mines, 360–1395 Ellice Avenue, Winnipeg, MB R3G 3P2, Canada.

Table GS-8-1: Selected element data for Enzyme Leach[SM] analyses at sites Mac 31, Mac 32 and Mac 33, Rainbow zone, McLellan mine. All data in ppb. Blank cells in table indicate 'below detection limit'. Complete Enzyme Leach[SM] analyses and UTM coordinates are available in Data Repository item 2004003.

Sample no.	West	North	Soil	Depth (cm)	Eu[d]	S.Q. Cl	As	Mo	Sb	W	Au	Th	Co	Ni	Cu	Zn	Pb	Cd	Sn	Tl	Sm	Eu	Gd	Mn	Rb	Sr	Cs	Ba
42-03-Mac 31A	1025	0	Ao	0	29	63200	220	258	41	259	0.143	16	25	131	66	552	8	7.9	0.9	1.0	0.6	0.2	0.5	1400	537	2175	2.7	883
42-03-Mac 31B	1025	0	Ao	5	204	53800	297	252	43	293	0.121	11	11	68	19	242	10	3.7	0.3	0.8	0.2	0.2	0.2	223	354	2400	1.6	1029
42-03-Mac 31C	1025	0	Ao	10	306	48000	190	159	44	122	0.068	6	11	47	24	102	3	1.8		0.6	0.1	0.2	0.2	38	183	2375	1.3	1060
42-03-Mac 31D	1025	0	Ao/A1	15	164	33400	34	72	11	10	0.027	4	8	16	3	18		0.6		0.3	0.1	0.1	0.1	17	49	1315	0.5	518
42-03-Mac 31E	1025	0	A2/Ae	20	93	26200	9	10	1		0.016	0	2	15				0.3		0.0	0.1	0.0	0.0	20	6	420	0.0	202
42-03-Mac 31F	1025	0	B	25	48	25800	4	8	1		0.015	1	3	19	2	11	0			0.1	0.2	0.1	0.2	35	16	400	0.1	322
42-03-Mac 31G	1025	0	B	30	63	26400	3	6	1		0.017	1	3	19	2	10	0	0.2		0.2	0.2	0.1	0.2	23	25	403	0.4	440
42-03-Mac 31H	1025	0	B	35	135	24600	1	6	0	1	0.017	0	3	10	2			0.2		0.2	0.2	0.1	0.2	15	31	377	0.4	634
42-03-Mac 31I	1025	0	B	40	294	23300	1	5	0	2	0.014	0	3	8	2					0.1	0.2	0.2	0.1	13	35	291	0.3	1255
42-03-Mac 31J	1025	0	C	45	90	23600	1	4	0	2		1	4	9	3					0.1	0.6	0.3	0.5	33	41	298	0.1	1610
42-03-Mac 31K	1025	0	C	50	76	23600	2	5	0	4		2	22	7	2					0.0	0.5	0.3	0.4	428	33	224	0.0	1310
42-03-Mac 31L	1025	0	C	55	18	20400	2	5	0	3		2	43	6	3					0.0	0.8	0.3	0.5	887	19	177	0.0	1120
42-03-Mac 31M	1025	0	C	60	-0	23900	3	7	0			4	29	8	10			0.2		0.0	1.5	0.4	1.1	594	17	227		1400
42-03-Mac 31N	1025	0	C	65	-21	24400	4	8	0			4	31	12	16			0.2		0.0	2.5	0.6	1.9	671	11	213		1290
42-03-Mac 31O	1025	0	C	70	-39	23100	5	11	0			6	104	19	23			0.5		0.0	4.2	0.7	3.1	2210	9	226	0.0	1310
42-03-Mac 31P	1025	0	C	75	-44	23100	6	15	0			6	147	22	25			0.7		0.0	6.4	1.0	4.6	3040	6	215		1310
42-03-Mac 31Q	1025	0	C	80	-47	25400	7	14	0			6	152	24	31		0	0.6		0.0	7.8	1.2	5.5	2430	5	225		1310
42-03-Mac 31R	1025	0	C	85	-48	23600	8	16	0			7	168	28	38		0	0.6		0.0	9.8	1.4	6.3	2710	5	218	0.0	1330
42-03-Mac 31S	1025	0	C	90	-45	23100	7	21	0			6	209	33	38		0	0.6		0.0	9.5	1.5	6.3	3530	5	199		1220
42-03-Mac 31T	1025	0	C	95	-45	21400	7	17	0			5	206	27	38		0	0.6		0.0	8.7	1.3	5.6	2550	5	165		1070
42-03-Mac 31T REP	1025	0	C	95	-43	23600	7	19	0	1		4	241	31	43		0	0.7		0.0	8.4	1.4	5.8	2800	5	179		1250
42-03-Mac 32A	1080	0	Ao	0	-42	44600	180	123	21	125	0.027	12	21	69	13	64	1	2.1		0.3	3.1	0.5	1.8	231	242	1540	0.4	555
42-03-Mac 32B	1080	0	Ao	5	-24	28000	152	33	9	10		6	15	36	4	9	0	0.5		0.2	1.0	0.2	0.8	21	53	924	0.2	469
42-03-Mac 32C	1080	0	A1/A2	10	12	26200	17	5	1			1	5	28	1	6	0	0.2		0.1	0.5	0.2	0.4	17	21	421	0.2	490
42-03-Mac 32D	1080	0	B	15	38	25400	6	4	1			1	6	30	1	13	0			0.2	0.5	0.2	0.4	16	33	474	0.3	953
42-03-Mac 32E	1080	0	B	20	31	23200	3	3	1			1	8	25	1			0.2		0.2	0.7	0.3	0.6	12	47	605	0.5	1150
42-03-Mac 32F	1080	0	B	25	37	24200	2	3	0	2		1	5	14	1					0.2	0.6	0.3	0.5	7	43	595	0.7	1130
42-03-Mac 32G	1080	0	B	30	84	24200	1	4	0	3		1	4	9	1	88		0.2		0.2	0.6	0.3	0.5	8	48	503	0.5	1450
42-03-Mac 32H	1080	0	B	35	69	21700	1	5	0	3		1	4	8	1					0.2	0.9	0.4	0.7	10	53	447	0.5	2130
42-03-Mac 32I	1080	0	C	40	90	22300	2	4	0	4		1	3	5	2					0.1	0.8	0.4	0.6	18	45	252	0.3	2420
42-03-Mac 32J	1080	0	C	45	26	24900	2	5	0	3		2	4	6	5					0.1	1.7	0.6	1.3	57	31	183	0.2	2530

Table GS-8-1: Selected element data for Enzyme Leach[SM] analyses at sites Mac 31, Mac 32 and Mac 33, Rainbow zone, McLellan mine. All data in ppb. Blank cells in table indicate 'below detection limit'. Complete Enzyme Leach[SM] analyses and UTM coordinates are available in Data Repository item 2004003. *(continued)*

Sample no.	West	North	Soil	Depth (cm)	Eu^d	S.Q. Cl	As	Mo	Sb	W	Au	Th	Co	Ni	Cu	Zn	Pb	Cd	Sn	Tl	Sm	Eu	Gd	Mn	Rb	Sr	Cs	Ba
42-03-Mac 32K	1080	0	C	50	14	21500	2	5	0	5		2	2	5	4					0.0	1.2	0.4	0.9	65	10	122	0.0	1550
42-03-Mac 32L	1080	0	C	55	-24	23500	3	5	0	4		2	7	8	8					0.0	1.9	0.4	1.5	138	6	118		1380
42-03-Mac 32M	1080	0	C	60	-36	21000	6	8	0			5	33	15	20		0	0.2		0.0	5.9	1.1	4.2	749	5	152		1950
42-03-Mac 32N	1080	0	C	65	-36	25000	7	12	0			6	53	23	36		0	0.4		0.0	8.5	1.5	5.5	1190	3	173		1870
42-03-Mac 32O	1080	0	C	70	-36	23800	9	16	0			5	95	37	69		0	0.3		0.0	8.1	1.5	5.4	1920	3	189		1820
42-03-Mac 32P	1080	0	C	75	-39	23200	9	18	0	1		4	109	44	68		0	0.4		0.0	7.4	1.3	4.9	2410	3	179		1830
42-03-Mac 32Q	1080	0	C	80	-35	23800	9	21	0			4	121	33	59		0	0.4		0.0	5.8	1.1	4.0	2640	3	176		1770
42-03-Mac 32R	1080	0	C	85	-31	24200	9	18	0			2	114	32	53		0	0.4		0.0	4.1	0.8	2.8	2170	3	185		1660
42-03-Mac 32S	1080	0	C	90	-23	24100	9	14	0			1	114	28	49	9	0	0.8		0.0	3.2	0.7	2.3	2410	4	172	0.0	1580
42-03-Mac 32T	1080	0	C	95	-23	23500	9	15	0			1	137	33	64	11	0	1.2		0.0	2.7	0.6	2.0	2660	4	174	0.0	1500
42-03-Mac 33A	1100	130	Ao	0	-18	33400	127	61	35	39		8	36	74	21	244	3	6.3		0.5	1.5	0.4	1.3	1175	155	1360	0.2	715
42-03-Mac 33B	1100	130	A1	5	18	24800	31	30	16	2		2	34	42	1	66	0	4.1	0.7	0.2	0.3	0.1	0.2	99	25	591	0.0	385
42-03-Mac 33C	1100	130	A2	10	60	20800	3	12	3			1	9	30	2	15	1	0.5	1.5	0.2	0.6	0.3	0.4	21	31	248	0.4	928
42-03-Mac 33D	1100	130	A2	15	54	20300	2	7	1	0		1	4	23	4	13	0	0.4	0.6	0.2	1.1	0.5	0.8	15	49	188	1.0	1460
42-03-Mac 33E	1100	130	A2	20	21	19800	2	5	1	0		2	3	16	4		0		0.5	0.2	1.4	0.5	1.1	10	53	174	1.1	1640
42-03-Mac 33F	1100	130	A2	25	17	21800	1	4	1	0		2	3	16	4				0.2	0.2	1.4	0.5	1.1	10	58	177	1.0	1390
42-03-Mac 33G	1100	130	B	30	7	20400	1	4	1	1		2	4	20	5					0.2	1.6	0.5	1.3	8	60	169	0.9	1330
42-03-Mac 33H	1100	130	B	35	8	22300	1	4	0	2		3	4	17	6					0.2	1.9	0.6	1.6	7	58	149	0.6	1860
42-03-Mac 33I	1100	130	B	40	-7	22300	1	4	0	2		3	5	18	6			0.1		0.2	2.8	0.8	2.2	14	57	190	0.6	1960
42-03-Mac 33J	1100	130	B	45	-14	20600	1	4	0	2		4	4	14	6			0.2		0.2	3.5	0.9	2.9	12	54	202	0.4	2220
42-03-Mac 33K	1100	130	B	50	-18	22100	1	5	0	3		3	4	8	7			0.1		0.2	3.8	0.9	2.9	27	49	184	0.3	1900
42-03-Mac 33L	1100	130	B	55	-23	21500	1	4	0	3		3	5	6	8			0.3		0.2	3.5	0.8	2.7	67	41	163	0.2	1660
42-03-Mac 33M	1100	130	C	60	-29	20500	1	3	0	3		3	4	4	8					0.1	3.7	0.8	2.5	65	22	149	0.1	1240
42-03-Mac 33N	1100	130	C	65	-27	20800	2	3	0	4		2	3	4	9					0.1	4.1	0.8	2.6	45	10	146	0.0	1140
42-03-Mac 33O	1100	130	C	70	-30	20100	2	2	1	4		2	4	6	12					0.0	3.9	0.8	2.7	75	3	133		1020
42-03-Mac 33P	1100	130	C	75	-35	22500	3	6	1	4		2	9	22	19			0.2		0.0	4.0	0.8	3.0	270	4	200	0.0	968
42-03-Mac 33Q	1100	130	C	80	-32	24200	5	6	1	1		2	10	14	27			0.3		0.0	5.5	1.0	3.5	229	3	234		1310
42-03-Mac 33R	1100	130	C	85	-31	24100	6	6	1	1		2	9	16	39			0.2		0.0	5.1	1.0	3.4	245	3	285		1300
42-03-Mac 33S	1100	130	C	90	-28	22800	6	7	0	1		1	13	14	30	13		0.2		0.0	3.6	0.7	2.4	305	3	307		1140
42-03-Mac 33S REP	1100	130	C	90	-31	20200	6	7	0	1		1	15	14	33		0	0.3		0.0	3.4	0.7	2.3	345	3	320		1280
42-03-Mac 33T	1100	130	C	95	-30	25500	7	7	0	0		1	17	18	42			0.2		0.0	3.1	0.6	2.1	346	3	314	0.0	1120

Abbreviations: S.Q., semiquantitative; $Eu^d = (Eu_n/(Sm_n/2 + Gd_n/2) - 1) \times 100$

Table GS-8-2: Selected Terrasol Leach^{SM} data for samples from sites Mac 31, Mac 32 and Mac 33, Rainbow zone, McLellan mine. Concentrations in ppb. Westing and northing are referenced to the MacLellan mine grid. Complete Terrasol Leach^{SM} analyses and UTM coordinates are available in Data Repository item 2004003.

Sample ID:	West	North	Soil	Depth (cm)	S.Q. Cl	As	Mo	Sb	W	Au	Th	Co	Ni	Cu	Zn	Pb	Cd	Sn	Tl	Sm	Eu	Gd	Mn	Rb	Sr	Cs
42-03-Mac 31A	1025	0	Ao	0	44600	730	1140	60	758	0.234	142	628	5810	776	16000	1590	153	16	0.25	151	30	143	11300	1230	25600	23
42-03-Mac 31B	1025	0	Ao	5	40300	1050	1830	81	1140	0.375	156	623	7190	327	13100	1000	133	5	0.25	184	42	174	3630	901	41600	13
42-03-Mac 31C	1025	0	Ao	10	39500	614	1410	90	502	0.265	152	628	5820	153	7890	544	77	5	0.25	239	53	223	1090	557	47100	11
42-03-Mac 31D	1025	0	Ao/A1	15		157	352	25	39		306	377	1900	20	1960	122	21	5	0.25	290	60	283	302	124	25300	5
42-03-Mac 31E	1025	0	A2/Ae	20		85	13	3	5	0.132	112	29	273	70	173	133	11	5	0.25	71	16	72	98	30	2750	3
42-03-Mac 31F	1025	0	B	25		97	24	3	5	0.101	158	26	266	144	191	314	11	11	2.27	121	23	116	134	62	1750	7
42-03-Mac 31G	1025	0	B	30		80	23	3	5		148	20	219	136	161	262	13	5	6.29	115	20	104	92	69	1440	12
42-03-Mac 31H	1025	0	B	35		42	27	2	5		146	20	116	114	129	124	7	5	6.22	98	20	87	90	87	1250	12
42-03-Mac 31I	1025	0	B	40		22	10	1	5		91	19	78	77	90	52	10	5	0.657	57	12	51	148	97	822	9
42-03-Mac 31J	1025	0	C	45		19	6	1	5	0.146	70	29	49	77	60	46	13	5	0.25	43	9	40	464	114	747	5
42-03-Mac 31K	1025	0	C	50		15	6	1	5	0.167	64	117	36	58	84	64	21	33	0.25	34	6	33	1880	90	660	2
42-03-Mac 31L	1025	0	C	55		16	10	1	5	0.539	68	222	48	60	56	61	19	31	0.25	47	8	42	3790	53	634	2
42-03-Mac 31M	1025	0	C	60		18	11	1	5	0.269	103	140	51	150	71	72	14	5	0.25	82	13	76	2460	47	747	1
42-03-Mac 31N	1025	0	C	65		28	13	1	5	0.178	117	126	76	203	71	89	9	5	0.25	142	21	126	2140	32	751	2
42-03-Mac 32A	1080	0	Ao	0	37000	1130	442	43	198	0.416	252	534	3680	329	2920	746	57	51	0.25	358	69	325	2460	697	21500	9
42-03-Mac 32B	1080	0	Ao	5		1190	79	24	28	0.141	674	297	1580	175	725	178	17	18	0.25	685	130	611	130	171	10700	7
42-03-Mac 32C	1080	0	A1/A2	10		188	8	4	5		143	25	274	122	104	203	13	13	0.25	128	24	116	48	69	1610	8
42-03-Mac 32D	1080	0	B	15		96	5	2	5		146	27	197	200	167	298	9	18	1.31	146	27	125	38	81	1330	13
42-03-Mac 32E	1080	0	B	20		70	7	2	5		197	40	245	241	118	259	10	5	4.49	247	46	210	42	106	1960	15
42-03-Mac 32F	1080	0	B	25		50	5	1	5		198	33	156	237	120	147	8	5	7.43	241	45	208	25	112	2060	15
42-03-Mac 32G	1080	0	B	30		31	12	1	5		134	22	78	138	137	81	9	5	7.16	149	27	121	62	121	1390	13
42-03-Mac 32H	1080	0	B	35		24	9	1	5	0.136	109	24	55	102	100	48	6	5	4.25	102	20	88	158	132	1080	12
42-03-Mac 32I	1080	0	C	40		16	1	1	5	0.105	62	20	40	57	29	28	11	5	0.25	55	10	42	301	105	552	8
42-03-Mac 32J	1080	0	C	45		16	8	1	5		66	30	50	62	64	33	11	5	0.25	59	11	47	587	89	535	6
42-03-Mac 32K	1080	0	C	50		13	7	1	5	0.257	58	41	47	66	45	35	17	5	0.25	61	11	54	695	37	560	2
42-03-Mac 32L	1080	0	C	55		21	6	1	5	0.417	75	88	92	130	75	51	12	32	0.25	139	21	111	1200	23	530	2
42-03-Mac 32M	1080	0	C	60		43	11	1	5		124	138	100	269	87	84	10	5	0.25	465	64	326	2230	19	591	1
42-03-Mac 32N	1080	0	C	65		39	12	1	5	0.216	105	203	129	385	88	78	4	5	0.25	575	87	459	3490	14	602	1
42-03-Mac 32O	1080	0	C	70		42	14	1	5	0.2395	105	301	165	563	103	94	11	5	0.25	584	86	468	4870	12	610	1
42-03-Mac 33A	1100	130	Ao	0		1020	186	122	109	0.266	402	618	2560	689	5660	824	117	32	0.25	535	113	478	9600	649	15000	7

Table GS-8-2: Selected Terrasol Leach^{SM} data for samples from sites Mac 31, Mac 32 and Mac 33, Rainbow zone, McLellan mine. Concentrations in ppb. Westing and northing are referenced to the MacLellan mine grid. Complete Terrasol Leach^{SM} analyses and UTM coordinates are available in Data Repository item 2004003. *(continued)*

Sample ID:	West	North	Soil	Depth (cm)	S.Q. Cl	As	Mo	Sb	W	Au	Th	Co	Ni	Cu	Zn	Pb	Cd	Sn	Tl	Sm	Eu	Gd	Mn	Rb	Sr	Cs
42-03-Mac 33B	1100	130	A1	5		597	63	72	20	0.119	359	284	738	270	1070	376	46	15	0.25	281	60	249	582	199	5020	3
42-03-Mac 33C	1100	130	A2	10		91	12	7	5		120	34	187	101	179	249	9	11	2.59	89	19	77	66	91	739	12
42-03-Mac 33D	1100	130	A2	15		62	7	3	5		177	15	170	119	122	208	5	11	5.89	149	31	120	51	124	503	22
42-03-Mac 33E	1100	130	A2	20		43	4	2	5		172	13	89	120	83	152	7	5	6.27	151	30	121	56	143	451	21
42-03-Mac 33F	1100	130	A2	25		47	8	1	5		217	14	113	172	82	139	7	5	7.76	184	38	148	37	159	503	19
42-03-Mac 33G	1100	130	B	30		50	9	1	5		235	15	126	204	59	120	5	5	5.81	213	40	162	36	145	462	16
42-03-Mac 33H	1100	130	B	35		36	17	1	5		226	24	81	182	59	80	2	5	4.41	204	39	157	89	166	411	14
42-03-Mac 33I	1100	130	B	40		20	12	1	5		180	21	75	143	62	59	4	5	0.25	199	34	148	100	156	447	15
42-03-Mac 33J	1100	130	B	45		25	9	1	5		161	22	93	132	31	61	8	5	0.25	238	41	190	181	141	474	12
42-03-Mac 33K	1100	130	B	50		18	6	1	5		107	23	59	109	28	36	4	5	0.25	209	33	156	223	124	422	9
42-03-Mac 33L	1100	130	B	55		14	3	1	5		77	33	57	89	51	23	7	5	0.25	162	26	118	470	106	427	6
42-03-Mac 33M	1100	130	C	60		12	1	1	5		63	24	47	95	45	24	11	5	0.25	142	22	105	349	64	503	3
42-03-Mac 33N	1100	130	C	65		12	1	1	5	0.102	62	29	30	93	32	20	11	5	0.25	154	24	104	372	29	512	1
42-03-Mac 33O	1100	130	C	70		13	1	1	5	0.198	68	39	41	132	76	25	6	5	0.25	165	25	128	533	11	542	1

Abbreviations: S.Q., semiquantitative

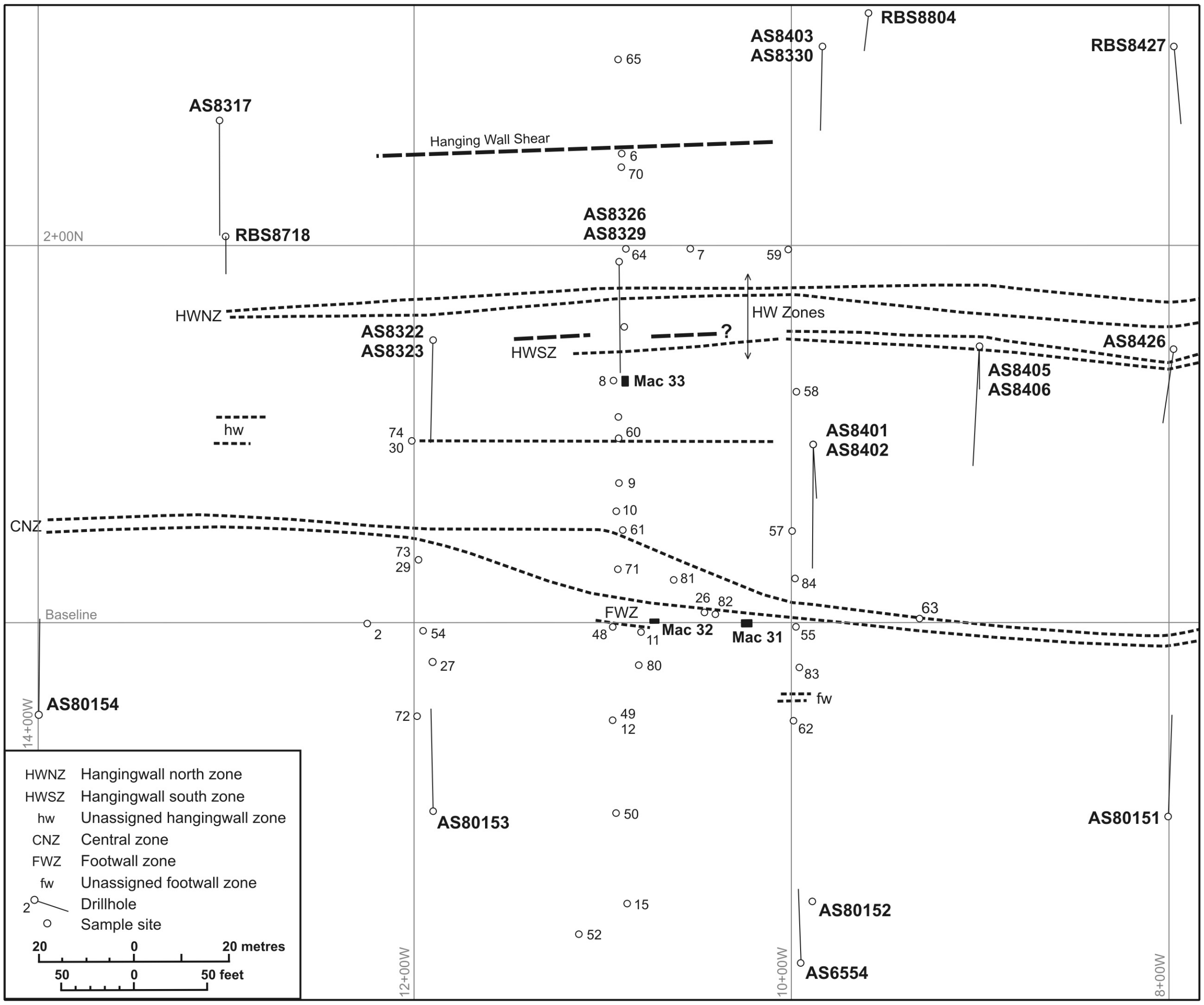

Figure GS-8-2: *Location of sample sites and three 1 m deep pits at the Rainbow zone, McLellan mine. Geological information provided by Black Hawk Mining Ltd.*

distinguish the Rainbow zone from site Mac 33. However, Au responses in the uppermost part of the A horizon extend beyond the responses in the B-horizon samples and appear to provide a larger target anomaly. Therefore, it may be preferable to collect A-horizon samples, instead of using shorter sampling intervals, in areas where the exploration target is a narrow vein. Figure GS-8-4 suggests that Au and base-metal responses may be independent of Mn responses (cf. Clark, 1992). This, in turn, suggests that normalization of Enzyme Leach^{SM} responses to a constant Mn content may not be advisable.

Terrasol Leach^{SM}

Portions of the same samples were analyzed by the Terrasol Leach^{SM} method; selected elements are presented in Table GS-8-2. Although the Terrasol Leach^{SM} is a stronger partial extraction, the relative distributions of most elements in the three pits are similar to those of the Enzyme Leach^{SM} data (cf. Figures GS-8-4 and -5). Manganese values are higher in the upper organic-rich samples and near background in the vicinity of the interface between B- and C-horizon samples. The Mn pattern present in Mac 33 is opposite to that seen in the Enzyme Leach^{SM} data, where the higher values are in the C horizon and not the B horizon (cf. Figure GS-8-4); this suggests that amorphous Mn-oxides are more abundant in the C horizon, although crystalline Mn-oxide may be more concentrated in the B horizon in Mac 33. The Eu^d values are negative for all Terrasol Leach^{SM} samples, and the data cannot be used to discriminate underlying mineralization.

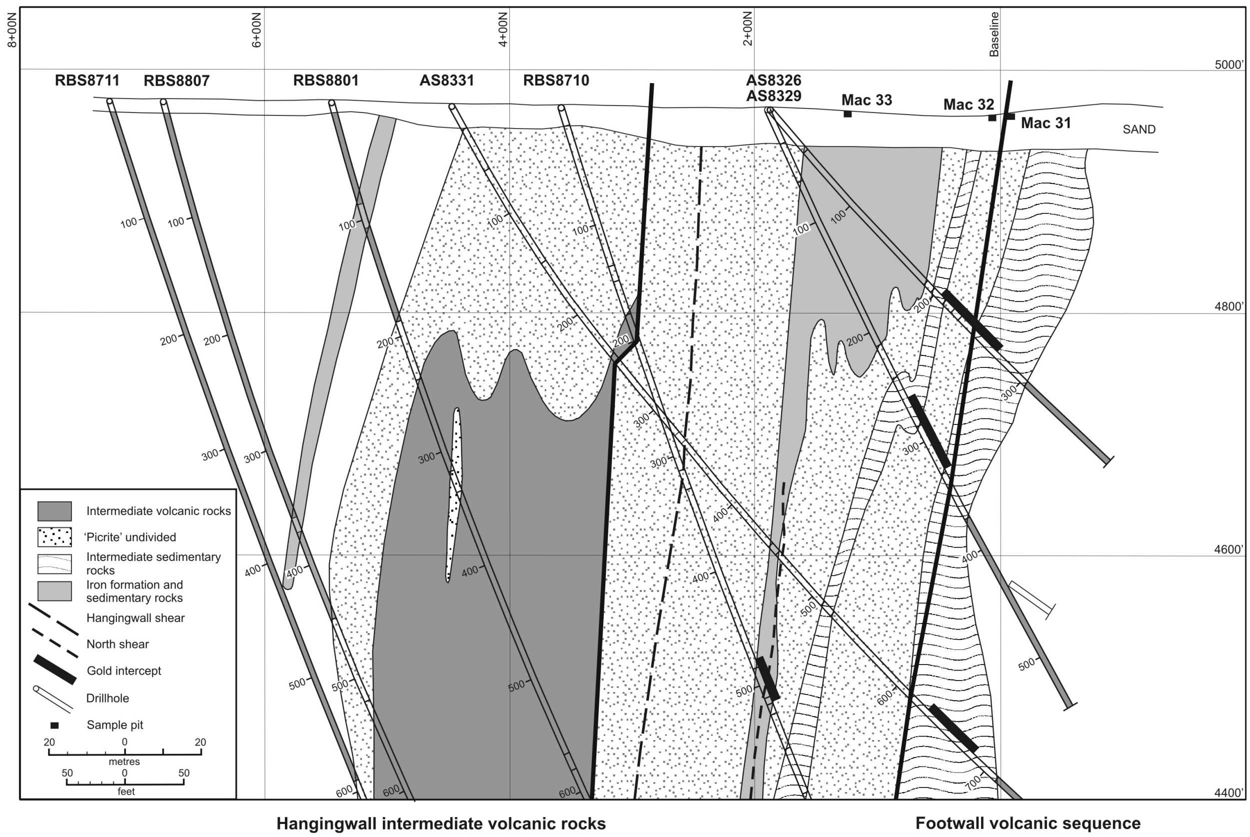

Figure GS-8-3: *Geological cross-section along section 11+00 west through the Rainbow zone, McLellan mine. Location of sample pits projected onto section (cf. Figure GS-8-2).*

Economic considerations

This study shows that both the Enzyme Leach^{SM} and Terrasol Leach^{SM} partial extraction methods are effective in detecting buried mineralization at the MacLellan mine. There is a distinctive Eu^d positive anomaly associated with the Rainbow zone mineralization and within soils that overlie the mineralized zone. It is proposed that the REE data will be of assistance in discriminating 'false' anomalies derived from metals in transported overburden from anomalies derived from oxidation of a buried, reduced, mineralized body in the bedrock, because transported metals in glacial till and their metal anomalies should not be associated with positive Eu^d anomalies.

Acknowledgments

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Figure GS-8-4: *Vertical profiles of Enzyme Leach[SM] element responses in three pits at the Rainbow zone, McLellan mine:* ***a)*** *Eu[d], As, Au;* ***b)*** *Tl, Mn, Rb; and* ***c)*** *Zn, Pb, Cd. Each sample represents a continuous 5 cm depth interval. Background is set at the first quartile and BB = 'times background'. Complete analytical data are available in Data Repository item 2004003.*

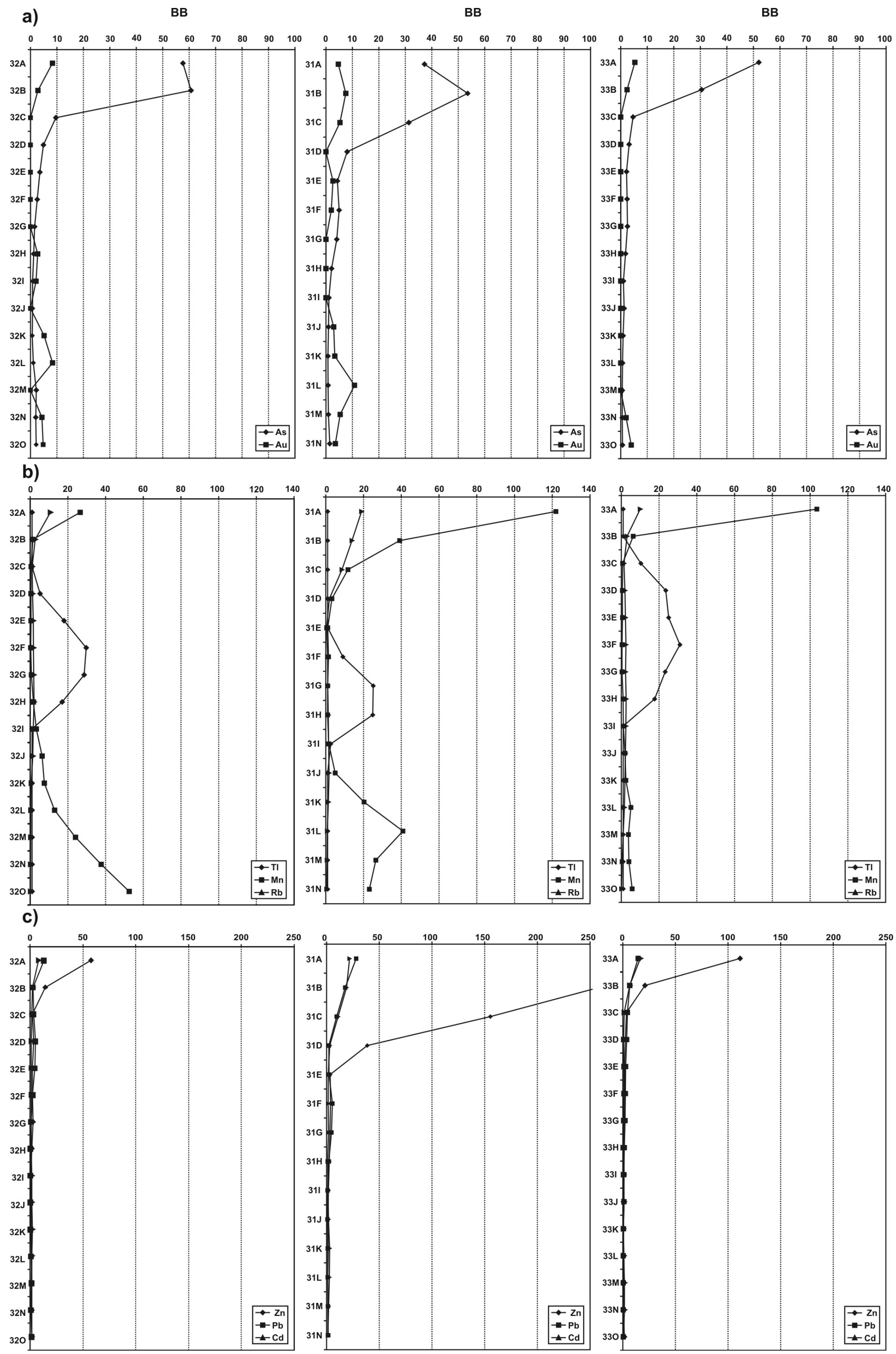

Figure GS-8-5: *Vertical profiles of Terrasol Leach[SM] element responses in three pits at the Rainbow zone, McLellan mine:* ***a)*** *As, Au;* ***b)*** *Tl, Mn, Rb; and* ***c)*** *Zn, Pb, Cd. The samples are duplicates of those used in the Enzyme Leach[SM] study. Background is set at the first quartile and BB = 'times background'. Complete analytical data are available in Data Repository item 2004003.*

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