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INTERPRETATION OF SOIL GEOCHEMICAL DATA FROM RAINBOW PROSPECT, NIFTY, WA

M. Cornelius

CRC LEME OPEN FILE REPORT 181

February 2008

(CRC LEME Restricted Report 184R / CSIRO EM Report 1034R, 2002
2nd Impression 2008)

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PREFACE

This soil survey was recommended as part of a pilot study that M. Cornelius of CSIRO completed for Straits Resources Ltd in November 2002. Its objective is to assess the use of soil sampling at Straits Resources' Rainbow Prospect, in particular, size fractions and element suites.

Results show that the <53 µm and the 850-2000 µm fractions of residual/semi residual soils overlying bedrock mineralization are the most strongly enriched in Cu and Pb; the <53 µm fraction is also enriched in some pathfinder elements. Copper shows a single peak (width 500 m >300 ppm Cu, maximum 1280 ppm Cu), whereas Pb has peaks either side of the Cu anomaly. Other pathfinder elements are associated with both Cu and Pb, and, hence, show three peaks. As only 15 samples were taken along the orientation line, the presence of three anomalies gives a somewhat erratic appearance and it is only their correlation with the Cu and Pb peaks that indicates a relationship between the pathfinders and the three mineralized units.

For further regional work, the use of the <53 µm fraction is recommended; material can be obtained from erosional areas with residual soil as well as from areas dominated by aeolian sand. The critical elements for target delineation work at the Rainbow Prospect are Cu and Pb; Fe, Mn and Zn are also important. In new areas, outside the Rainbow Prospect area, it is recommended to use the full suite of 47 elements (ALS method ME-MS61) for an initial survey before reducing the suite to the most critical elements.

Matthias Cornelius
Project Leader

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ABSTRACT

As part of a pilot study on geochemistry for base metal exploration at Nifty (Cornelius, 2002), the regolith-landform setting at the Bloodwood and Rainbow prospects was appraised during short field visits and recommendations made for an soil geochemical orientation survey. Such a survey was completed at Rainbow Prospect by B. Hooper of Straits Resources shortly after. Fifteen samples were taken across strike of the mineralization that had been intersected from 4 m depth by percussion drilling (30 m @0.3% Cu in two holes). The sample intervals are 40-100 m, samples were taken from 100 mm depth.

Five samples were sieved into eight size fractions by ALS Laboratories (>2000, 850-2000 µm, 600-850 µm, 425-600 µm, 250-425 µm, 125-250 µm, 53-125 µm, < 53 µm) in order to compare their grainsize distributions. The fractions, most dominated by aeolian material, are 125-425 µm. Geochemical analyses were done for the 850-2000 µm, 600-850 µm, 53-125 µm and <53 µm fractions by ICP-MS and AES for 47 elements following a 4-acid digest (ALS Laboratories, Perth, method ME-MS61). The strongest anomaly to background contrast was in the 850-2000 µm and <53 µm fractions and the remaining 10 samples were analyzed for 47 elements in these two size fractions.

Results show a strong Cu anomaly in soil above the bedrock mineralization in both the 850-2000 µm and the <53 µm fractions (480 ppm and 1280 ppm respectively). Either side of the Cu anomaly, Pb peaks at 300-500 ppm. Other trace and main elements are associated with all three peaks (Al, Be, Fe, Ga, K, Li, Mg, P, Ta, Tl, U, V and Zn).

It is recommended that Cu and Pb be used to delineate the regolith expression of bedrock mineralization at Rainbow Prospect and to also analyze for Fe, Mn and Zn. In other areas, use of the full element suite (47) is recommended for first stage sampling to identify all anomalous elements.

The most suitable grainsize fraction is <53 µm, because it yields sufficient sample material both in erosional as well as depositional (aeolian cover) areas, and shows a very good anomaly to background contrast for the target element(s). Coarser material (850-2000 µm) gives equally good results in erosional terrain, such as Rainbow, but will not yield sufficient sample material in areas with dominantly aeolian cover. It also fails to show subtle anomalies in other trace elements over all mineralized bedrock units and this may be of significance in other exploration areas.

1. Introduction

1.1 General project outline

This report summarizes the results of a soil orientation survey by Straits Resources at their Rainbow prospect, undertaken subsequently to a pilot study on the geochemistry for base metal exploration at Nifty by CRC LEME/CSIRO (Cornelius, 2002).

1.2 Location and site characteristics

The Nifty mine is located 450 km east of Port Hedland (Figure 1) in the Proterozoic Paterson orogen of Western Australia (Williams and Myers, 1990) on the Paterson Range 1:250 000 geological sheet (Chin et al., 1982), and is centred on $121^0$34'E and $21^0$39'S. The climate is arid, with an average annual rainfall of approximately 250 mm. Rainfall is erratic and the heaviest falls are associated with cyclones and thunderstorms between November and March. The average maximum temperature is about 25^0C in winter and in summer it is about 40^0C. The vegetation is mainly spinifex, low scrubs and scattered medium size trees, mainly eucalypts, mulga and ti-tree.

The Nifty mine lies at the western edge of the Great Sandy Desert. The near mine area is dominated by WNW trending sand dunes that are approximately 50-100 m wide, up to 15 m high, several kilometres long and up to several hundred metres apart. Most dunes are stabilized by grass and a few medium-size trees. The dune swales are mostly sandy but some have been swept clean, exposing saprolite, ferricrete or indurated transported gravel and sand. Surface lag varies according to the landform; in erosional areas, for example, it comprises lithic, ferruginous, saprolitic materials. In sand-covered terrain, lag generally is ferruginous (granules, pisoliths, nodules) with some minor lithic fragments.

Rainbow Prospect is located approximately 20 km N of the Nifty mine site. It was identified by lag sampling and drilling showed intervals of up to 40 m @ 0.3% Cu from 4 m depth. The prospect is dominated by WNW trending, 10-15 m high sand dunes. In swales, thin residual soil with some aeolian sand, covers saprock and saprolite subcrop.

1.3 Objectives

The objective of the orientation study was to

(i) investigate the use of soil sampling in dominantly erosional terrain at Rainbow prospect as a targeting tool for drilling and

(ii) assess soil sampling as a regional exploration technique in sand covered areas.

1.4 Sampling and analysis

Straits Resources took 15 samples (Appendix I) along an approximately 1 km long N-S traverse (Figure 1) across an erosional window between sand dunes. Five samples, including one from a sand dune and another one marginal to it, were sieved into 8 fractions (>2000 µm, 850-2000 µm, 600-850 µm, 425-600 µm, 250-425 µm, 125-250 µm, 53-125 µm, <53 µm) to determine suitable grain size intervals. Results show, 86% of the sand dune material is between 125-425 µm in size (Figure 2).

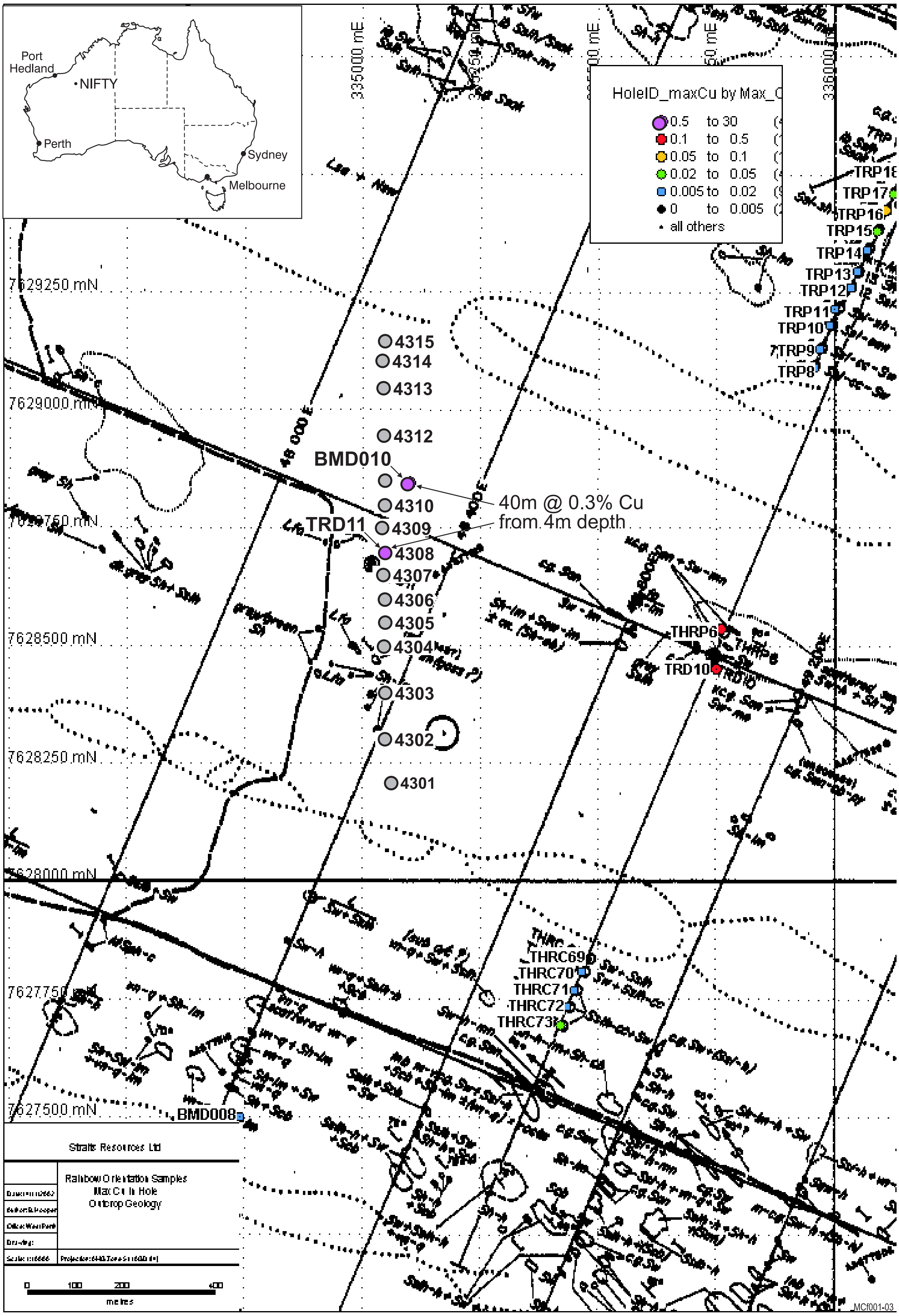

Figure 1. Rainbow Prospect with sample locations (4301-4315), drill results and geology (after Straits Resources).

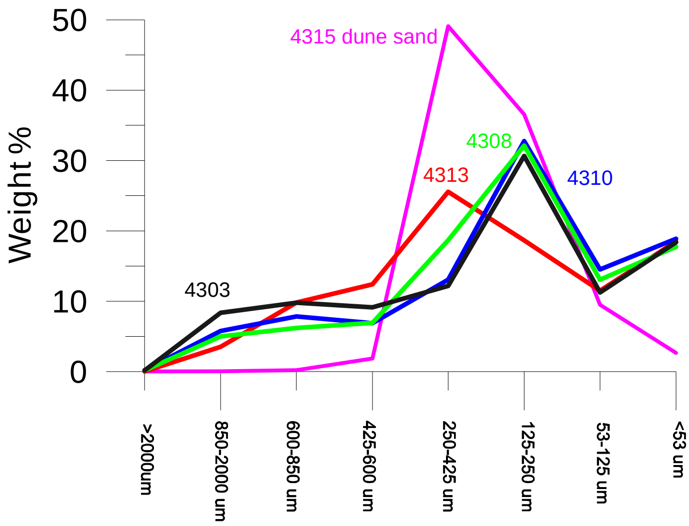

Figure 2. Grain size distribution in five samples from the soil traverse

Geochemical analyses by four-acid digest (nitric, perchloric, hydrofluoric, hydrochloric), followed by ICP-MS and ICP-AES analysis for 47 elements (Table 1), were done on the two fractions smaller (<53 µm, 53-125 µm) and two fractions larger (600-850 µm, 850-2000 µm) than the main dune sand population. Results showed the maximum anomaly to background contrast is in the <53 µm and the 850-2000 µm fractions (Figure). These fractions were analyzed for the remaining 10 samples, although instructions to ALS had been to analyze all 15 samples in a single batch to avoid batch effects. For further interpretation, both batches have been combined, reanalysis of all samples by ALS will be done but results could not be included in this report.

2. Results

Element concentrations in the <53 µm and the 850-2000 µm fractions along the soil traverse are shown in Figure 3 (Appendix 5).

In the <53 µm fraction (Figure 4), Cu concentrations show three peaks, a primary one (1200 ppm) in the center of the traverse (C) and two secondary peaks (400 ppm) on either side (B and D). Lead concentrations only show two small peaks; one (A) approximately 150 m S of the secondary Cu peak (B), the other at the same location as the secondary Cu peak (D).

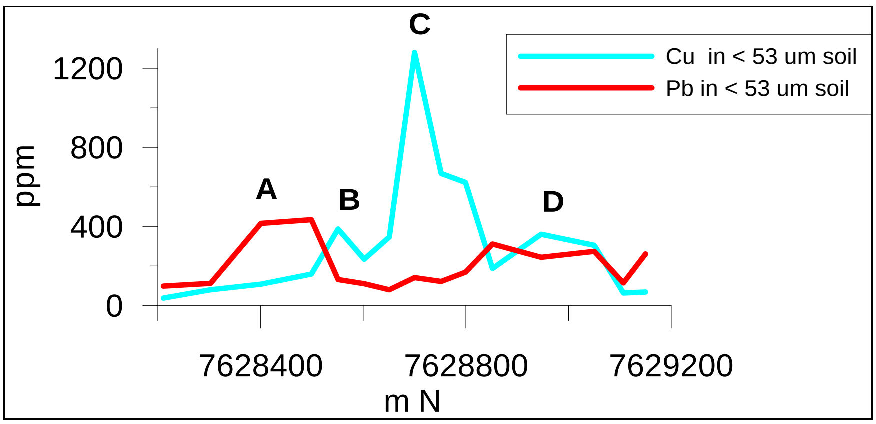

Figure 4. Copper and Pb concentrations in the <53 µm soil fraction.

In the 850-2000 µm fraction (Figure 5), Cu shows a primary peak (C) (450 ppm) and one secondary peak (B) (200 ppm). Lead shows two peaks, A and D. Peak A is similar in concentration and shape to peak A in the <53 µm fraction, peak D, however, is a strong single point anomaly (500 ppm).

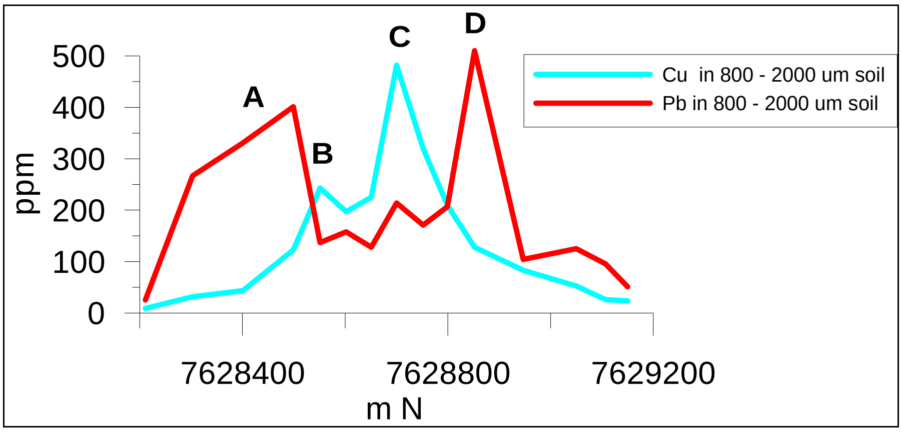

Figure 5. Copper and Pb concentrations in the 800-2000 µm soil fraction.

The combination of the Cu and Pb concentration patterns along the traverse shows broadly three anomalous zones with peaks A and B combined into one. All other elements appear to lack any anomalies or patterns and due to the relatively small number of sample points, there is a potential risk of over interpreting the data. However, if the three-peak pattern is superimposed on other elements, some, e.g., Al, Be, Fe, Ga, K, Li, Mg, P, Ta, Tl, U and V appear to be similar.

3. Interpretation

Both the <53 µm and the 850-2000 µm soil fractions show that main Cu anomaly in the centre of the traverse correlates well with drill results by Straits Resources. The fine fraction also shows two secondary peaks on either side of the main anomaly, that may correspond to other mineralized units in the sequence; these units are also enriched in Pb, whereas the main Cu anomaly is low in Pb. Other elements appear to be anomalous in all three mineralized units without showing strong enrichment in any. This zonation into Cu-rich and Pb-rich units with accompanying anomalous trace elements is similar to that seen at Nifty and indicates primary mineralization rather than patterns related to regolith processes.

Although the main Cu and Pb peaks are shown by both fractions, the <53 µm fraction appears to show better resolution for the secondary peaks for Cu and some trace elements, e.g., Ta, P and Li. It is therefore more suitable for outlining drill targets on a prospect scale. Another advantage of the fine fraction is that it can be obtained from most sites, including those that have a very high component of aeolian material. This will facilitate a uniform data set and correlation across different areas and prospects.

For further soil sampling at Rainbow, the analytical suite could be reduced to Cu, Pb, Zn, Fe and Mn only. Other elements will not significantly add to the target definition in this particular area. However, all prospects and exploration areas should initially be tested along one or two representative traverses using a multi element package such as the 47 elements suite above. This will ensure detection of any type of mineralization, base metal or other, and enable vectoring towards mineralization in greenfields areas.

4. Recommendations

- Use <53 µm soil fraction for testing Rainbow prospect and outlining drill targets.
- Reduce the analytical suite to Cu, Pb, Zn, Fe and Mn.
- In new areas, commence with a multi-element package (e.g., 47 elements, see above) and reduce to critical elements following an orientation survey.
- Carry out further testing to establish signature of mineralization in areas of aeolian sand cover. Indications from this survey are that the < 53 µm fraction may be suitable for testing areas of thin sand cover due to the dominance of residual material in the fine fraction. In coarser soil fractions, transported material may dilute the primary signature.

5. Acknowledgements

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Sample preparation and analyses were by ALS Chemex, Malaga.

T. Naughton prepared the figures and H. Hink formatted the manuscript, which was reviewed by C.R.M. Butt. All this assistance is gratefully acknowledged.

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7. Appendix

Appendix 1. Sample locations and descriptions (From Straits Resources Ltd)
Appendix 2. Sieving results for five samples
Appendix 3. Chemical analyses of five samples and four different size fractions.
Appendix 4. Chemical analyses of 15 orientation samples and two size fractions.
Appendix 5. Figure 3. Element concentrations in the <53 µm and the 850-2000 µm soil fractions.

Rainbow Orientation Soil Sampling

SampNo.	Easting	Northing	Sample Loc Comments	Sample Type Comments
4301	335,064	7,628,211	30m n of sand dune, close to scree	80% sand, 20% fine pisoliths with cutans.
4302	335,052	7,628,303	Subcrop all around	Fragments of rock, fine red sand and shale, occ f qz pebbles, red oxides
4303	335,051	7,628,401	Flat area, no subcrop.	Numerous rock fragments, pisoliths,occ qz, red sst fraction,
4304	335,050	7,628,499	Centre of plain	Significant pisoliths, minor small rock frags, red sst,
4305	335,051	7,628,551	Subcrop all around	Signif large rock frags, freq pisoliths, fine sst, minor aeolian
4306	335,052	7,628,602	Centre of plain	Consid pisoliths, hard compacted, cemented surface, rock fragments
4307	335,046	7,628,651	Centre of plain, near ant hills	Consid pisoliths with cutanes, red sst frags
4308	335,053	7,628,700	Centre of plain, subcrop, 10m S of d	Consid rock frags, sltst, sst, qz frags,
4309	335,045	7,628,752	Centre of plain, subcrop, 5m N of ro:	Large rock frags, qz pebbles, sltst, sst
4310	335,051	7,628,799	Pisolite and Qz float	pisoliths, qtz fragments, inc aeolian sand
4311	335,051	7,628,852	Nearing dune, ant hills	Minor rock frags, pisol, qz pebbles,
4312	335,047	7,628,947	Dune slope	Sandy, small qz pebbles, occ pisoliths, aeolian, charcoal from fire
4313	335,047	7,629,050	Dune slope, nr ant hill	sandy, Fine silts, rare pisolite, qz frags
4314	335,045	7,629,107	Edge sand Dune	Aeolian sand, minor pisoliths
4315	335,050	7,629,150	Nr Top Sand Dune	All Aeolian sand

All samples taken from 100 mm depth, >2 mm sieved to remove coarse material.

Appendix 1. Sample locations and descriptions (from Straits Resources Ltd)

Sample no		>2000 um	2000-850 u	850-600 um	600-425 um	425-250 um	250-125 um	125-53 um	<53 um	Total
SOO4315	Weight in grams	0.2	0.4	2.2	18.1	474.5	353.4	91.9	25.8	966.5
SOO4313		0.2	39.1	108.9	137.5	283	206.8	127.2	204.8	1107.5
SOO4310		2.4	61.3	83.1	72.9	138.6	347.2	153.8	200.2	1059.5
SOO4308		1.6	52.5	65.2	73	196.1	336.9	137.2	186.3	1048.8
SOO4303		1.7	86.8	101.9	95.1	126.4	317.9	116.7	190.9	1037.4
SOO4315	Weight in percent	0.02	0.04	0.23	1.87	49.09	36.56	9.51	2.67	100.00
SOO4313		0.02	3.53	9.83	12.42	25.55	18.67	11.49	18.49	100.00
SOO4310		0.23	5.79	7.84	6.88	13.08	32.77	14.52	18.90	100.00
SOO4308		0.15	5.01	6.22	6.96	18.70	32.12	13.08	17.76	100.00
SOO4303		0.16	8.37	9.82	9.17	12.18	30.64	11.25	18.40	100.00

Appendix 2. Sieving results for five samples

Sample number	Size fraction	Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ga	Ge
		ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
		ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
4303	850-2000 um	0.51	3.13	22.7	521	1.79	0.24	0.03	0.2	33.5	9.5	215	1.44	43.6	5.25	10.7	0.025
4308	850-2000 um	1.21	4.35	29.8	915	2.29	0.27	0.02	0.19	85.7	14.7	254	2.35	482	6.88	16.5	0.025
4310	850-2000 um	1.08	3.55	22.6	617	1.65	0.17	-0.01	0.06	58.4	8.5	206	2.03	210	4.98	13.1	0.025
4313	850-2000 um	0.36	1.75	6.7	308	0.74	0.14	0.01	0.01	24.6	4.9	220	1.02	52.8	2.3	6.21	0.025
4315	850-2000 um	0.44	1.38	4.2	285	0.49	0.1	0.2	0.01	14.7	2.4	66	1.1	23.6	2.63	4.68	0.025
4303	600-850 um	0.38	2.13	9.6	384	0.76	0.12	0.01	0.03	23	4.2	151	1.06	25.4	1.9	7.28	0.025
4308	600-850 um	1.13	3.12	12.4	637	1.54	0.12	-0.01	0.01	46.1	6.2	110	1.78	198	2.76	10.9	0.025
4310	600-850 um	0.92	2.37	8.1	454	0.7	0.08	-0.01	0.01	28	3.8	127	1.39	104	1.87	7.85	0.025
4313	600-850 um	0.29	1.38	2	255	0.32	0.07	-0.01	0.01	12.4	1.8	110	0.66	21.8	0.82	3.96	0.025
4315	600-850 um	0.23	0.87	3.5	134	0.36	0.04	-0.01	0.01	6.37	0.7	24	0.46	14.4	0.59	2.42	0.025
4303	53-125 um	0.27	2.02	5.9	197	0.5	0.12	-0.01	0.01	18.4	2.3	32	1.01	20.3	1.13	5.98	0.025
4308	53-125 um	0.52	2.29	4.1	216	0.77	0.13	0.01	0.01	23.4	2.8	30	1.11	121	1.29	6.37	0.025
4310	53-125 um	0.48	2.24	4.6	193	0.65	0.13	-0.01	0.01	16.5	2.7	29	1.22	84.1	1.2	6.82	0.025
4313	53-125 um	0.28	1.83	2.6	197	0.46	0.12	0.02	0.01	12.6	2.1	29	0.92	31.7	0.93	5.55	0.025
4315	53-125 um	0.28	1.44	3.1	164	0.3	0.1	-0.01	0.01	11.4	1.2	30	0.65	15.9	0.8	3.87	0.025
4303	<53 um	0.48	12.99	22.9	529	4.09	0.41	0.12	0.34	22.3	17.7	109	4.33	108	5.56	27.3	0.07
4308	<53 um	0.68	13.5	22.7	634	3.61	0.44	0.12	0.23	36.9	20.8	123	4.72	1280	6.38	31	0.06
4310	<53 um	0.57	11.37	23.5	569	3.22	0.4	0.15	0.21	46.2	19.7	115	5.98	622	5.77	30.2	0.025
4313	<53 um	0.6	10.12	13.8	595	3.54	0.41	0.2	0.28	41.2	15.7	116	5.29	305	5.1	23.8	0.025
4315	<53 um	0.43	10.52	63.9	340	1.96	0.66	0.41	0.27	41.2	16.6	227	3.95	67.6	5.35	21	0.025

Appendix 3. Chemical analyses of 5 samples and 4 different size fractions.

Sample number	Size fraction	Hf	In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Rb	Re	S
		ppm	ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%
		ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
4303	850-2000 um	2.1	0.036	1.59	16.3	10.9	0.19	1660	1.68	0.06	4	72.6	154	331	53	0.004	0.005
4308	850-2000 um	2.9	0.062	1.87	23.3	13.5	0.3	2690	2.05	0.08	9	25	167	214	75.5	0.001	0.005
4310	850-2000 um	2.2	0.047	1.7	18.6	9.5	0.22	1370	1.43	0.07	7.2	20.7	121	207	63.8	0.001	0.005
4313	850-2000 um	1.2	0.018	0.88	10.1	4.2	0.09	556	1.08	0.05	3.1	11.7	82	125	28.6	0.001	0.005
4315	850-2000 um	0.9	0.02	1.14	10	2.3	0.07	168	0.73	0.04	3.5	11.6	178	51.1	34.5	0.002	0.01
4303	600-850 um	1.3	0.021	1.51	11.6	5.7	0.09	452	0.85	0.05	4.1	13	75	105	45.4	0.001	0.005
4308	600-850 um	1.7	0.03	1.85	16.8	7.4	0.15	825	1.02	0.08	6.1	16.4	91	95.5	58.7	0.001	0.005
4310	600-850 um	1.3	0.019	1.65	11.3	4.6	0.1	432	1	0.05	4.5	11.1	57	69.8	49.1	0.001	0.005
4313	600-850 um	0.7	0.009	1.13	6.5	2.2	0.04	152	0.56	0.04	3	6	41	53.9	29.5	0.001	0.005
4315	600-850 um	0.5	0.006	0.68	4.5	1.5	0.02	38	0.29	0.02	2.5	4.9	23	20.5	19.6	0.001	0.005
4303	53-125 um	2.2	0.016	0.85	11.1	7.1	0.04	131	0.4	0.09	6.5	10	46	53.1	37.6	0.001	0.005
4308	53-125 um	2.3	0.021	0.92	14.3	8.5	0.06	206	0.45	0.08	8.5	9.5	70	27.1	44	0.001	0.005
4310	53-125 um	2	0.018	0.92	9.9	8.3	0.06	169	0.44	0.07	6.6	10.5	63	30.2	46.2	0.002	0.005
4313	53-125 um	2	0.017	0.88	8.1	6.3	0.04	99	0.36	0.09	7.1	8.5	66	38.8	41.6	0.001	0.005
4315	53-125 um	1.7	0.012	0.77	7.4	3.7	0.02	63	0.39	0.05	6.4	6.8	38	20.8	33.2	0.001	0.005
4303	<53 um	4.5	0.088	1.56	11.5	47.9	0.49	1310	1.61	0.13	16.1	43.1	403	416	68.5	0.002	0.03
4308	<53 um	5.4	0.085	1.7	20.4	46.9	0.61	1690	1.79	0.13	20.3	49.8	346	141	80.2	0.001	0.03
4310	<53 um	5.2	0.085	1.22	24.7	42.8	0.49	1430	1.65	0.12	19.2	46.6	350	169	79.2	0.001	0.02
4313	<53 um	5.1	0.086	1.79	25.1	41	0.67	1140	1.8	0.14	17.8	38.4	421	274	99.9	0.003	0.02
4315	<53 um	5	0.086	1.16	23.2	32.9	0.48	817	5.52	0.21	16.2	63.5	420	261	78.2	0.002	0.07

Appendix 3. Chemical analyses of 5 samples and 4 different size fractions.

Sample number	Size fraction	Sb ppm ME-MS61	Se ppm ME-MS61	Sn ppm ME-MS61	Sr ppm ME-MS61	Ta ppm ME-MS61	Te ppm ME-MS61	Th ppm ME-MS61	Ti % ME-MS61	Tl ppm ME-MS61	U ppm ME-MS61	V ppm ME-MS61	W ppm ME-MS61	Y ppm ME-MS61	Zn ppm ME-MS61	Zr ppm ME-MS61
4303	850-2000 um	0.91	0.5	1.9	8.6	0.41	0.06	8.4	0.1	0.69	1.3	99	0.6	5.8	127	62.8
4308	850-2000 um	0.86	0.5	2.8	11.4	0.81	0.07	13	0.2	1.07	2	154	0.9	10.2	93	106
4310	850-2000 um	0.65	0.5	2.3	9.2	0.67	0.07	10.8	0.17	0.8	1.5	114	0.7	7.3	57	83.7
4313	850-2000 um	0.34	0.5	1.1	5.5	0.31	0.025	5	0.07	0.38	0.8	42	0.6	4	26	39.4
4315	850-2000 um	0.33	0.5	0.8	26.6	0.29	0.025	4.2	0.07	0.26	0.6	48	0.4	2.8	47	31.6
4303	600-850 um	0.38	0.5	1.2	5.6	0.39	0.025	5.2	0.07	0.46	0.9	37	0.4	4.1	46	44.4
4308	600-850 um	0.44	0.5	1.6	7.9	0.57	0.025	7	0.12	0.69	1.1	59	0.5	6.2	43	63.5
4310	600-850 um	0.3	0.5	1.2	6.2	0.46	0.025	5.4	0.09	0.5	0.9	40	0.5	4.2	26	45.4
4313	600-850 um	0.12	0.5	0.7	3.8	0.26	0.025	2.9	0.05	0.26	0.6	17	0.3	2.6	14	26.1
4315	600-850 um	0.12	0.5	0.6	3.6	0.16	0.025	2	0.03	0.15	0.4	12	0.2	1.7	12	17.7
4303	53-125 um	0.25	0.5	1.3	10	0.6	0.025	5.7	0.22	0.28	0.9	27	0.4	4.8	23	76.4
4308	53-125 um	0.24	0.5	1.4	11	0.74	0.025	7	0.25	0.33	1.1	31	0.5	6	20	85.2
4310	53-125 um	0.22	0.5	1.5	12	0.61	0.025	5.4	0.2	0.32	0.9	29	0.4	5.2	15	68.6
4313	53-125 um	0.2	0.5	1.2	10.8	0.67	0.025	5	0.21	0.27	0.8	24	0.4	4.7	15	73.1
4315	53-125 um	0.18	0.5	1	8.1	0.53	0.025	4.4	0.21	0.24	0.7	20	0.4	2.9	17	61.2
4303	<53 um	0.93	1	6.2	36.6	1.88	0.07	10.8	0.52	1.09	3.6	131	2	8.2	223	194
4308	<53 um	0.75	1	6.9	39	2.09	0.07	12.2	0.61	1.17	4	144	2	12.5	154	211
4310	<53 um	0.73	1	6.7	41.8	1.88	0.09	14.7	0.59	1.09	3.5	137	1.9	13.9	119	201
4313	<53 um	0.57	1	7	36.4	1.86	0.05	14.7	0.53	1.1	3.7	124	2	17.3	117	194
4315	<53 um	1.34	1	11.6	52.5	1.72	0.09	15.9	0.55	0.75	2.7	122	6	15.8	169	202

Appendix 3. Chemical analyses of 5 samples and 4 different size fractions.

Sample number		Ag	Al	As	Ba	Be	Bi	Ca	Cd	Ce	Co	Cr	Cs	Cu	Fe	Ga	Ge	Hf
		ppm	%	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm
		ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
4301	<53 um	0.04	4.99	8.2	386	1.25	0.26	0.07	0.38	93.9	6.5	60	2.12	37.9	2.96	12	0.2	6.7
4302	<53 um	0.09	7.52	13.2	465	2.32	0.31	0.1	0.52	174	15.1	68	3.54	79.8	4.22	17.4	0.31	7
4303	<53 um	0.48	12.99	22.9	529	4.09	0.41	0.12	0.34	22.3	17.7	109	4.33	108	5.56	27.3	0.07	4.5
4304	<53 um	0.08	8.31	13.5	533	1.99	0.32	0.13	0.4	156	14.2	76	3.52	159	4.51	18.2	0.29	6.6
4305	<53 um	0.04	9.91	16	597	2.57	0.37	0.1	0.31	249	21.7	73	4.79	387	4.85	23	0.37	6.4
4306	<53 um	0.02	7.15	12.4	478	1.88	0.32	0.08	0.29	185	15.9	63	3.49	234	4.01	17.5	0.28	6.9
4307	<53 um	-0.02	7.16	11.6	512	2.02	0.3	0.13	0.32	146	12.1	66	3.14	347	3.99	16.8	0.29	7.3
4308	<53 um	0.68	13.5	22.7	634	3.61	0.44	0.12	0.23	36.9	20.8	123	4.72	1280	6.38	31	0.06	5.4
4309	<53 um	0.19	10.29	18	559	2.86	0.44	0.13	0.36	262	15.9	80	6.12	668	5.19	22.4	0.43	7.5
4310	<53 um	0.57	11.37	23.5	569	3.22	0.4	0.15	0.21	46.2	19.7	115	5.98	622	5.77	30.2	0.025	5.2
4311	<53 um	-0.02	6.86	13.8	484	1.89	0.27	0.12	0.33	131	12.2	64	3.08	187	3.72	15.8	0.25	6.8
4312	<53 um	0.05	8.7	12	551	2.67	0.32	0.18	0.41	178	16.3	73	4.2	360	4.05	20.8	0.33	6.3
4313	<53 um	0.6	10.12	13.8	595	3.54	0.41	0.2	0.28	41.2	15.7	116	5.29	305	5.1	23.8	0.025	5.1
4314	<53 um	0.05	4.29	5.9	334	1.15	0.23	0.09	0.25	77.2	7.4	53	1.72	63.2	2.74	11.3	0.17	6.5
4315	<53 um	0.43	10.52	63.9	340	1.96	0.66	0.41	0.27	41.2	16.6	227	3.95	67.6	5.35	21	0.025	5
4301	850-2000 um	-0.02	1.64	3.1	159	0.38	0.08	0.02	0.08	10.7	4.5	115	0.59	9.1	1.16	4.47	-0.05	2.5
4302	850-2000 um	-0.02	3.21	29.4	565	1.64	0.17	0.04	0.71	65.8	20.4	153	1.22	31.9	5.74	11.2	0.13	2.5
4303	850-2000 um	0.51	3.13	22.7	521	1.79	0.24	0.03	0.2	33.5	9.5	215	1.44	43.6	5.25	10.7	0.025	2.1
4304	850-2000 um	0.1	3.91	21.7	592	1.33	0.21	0.05	0.22	39.7	9.8	141	1.45	123	5.59	13.1	0.13	2.8
4305	850-2000 um	0.24	4.27	28.2	571	1.78	0.29	0.03	0.18	48.6	12.7	161	1.58	243	6.53	14.8	0.15	3.1
4306	850-2000 um	0.31	4.02	23.6	574	1.51	0.23	0.07	0.17	57.9	11.4	164	1.43	197	6.25	14.1	0.15	3.3
4307	850-2000 um	0.58	3.85	22.5	613	1.49	0.22	0.04	0.21	48.1	9.7	163	1.57	225	6.39	14.6	0.16	3
4308	850-2000 um	1.21	4.35	29.8	915	2.29	0.27	0.02	0.19	85.7	14.7	254	2.35	482	6.88	16.5	0.025	2.9
4309	850-2000 um	1.04	4.06	16.4	659	1.58	0.21	0.03	0.21	52.5	10.2	138	1.69	320	4.59	12.7	0.13	3.1
4310	850-2000 um	1.08	3.55	22.6	617	1.65	0.17	-0.01	0.06	58.4	8.5	206	2.03	210	4.98	13.1	0.025	2.2
4311	850-2000 um	0.72	3.4	27.9	584	1.23	0.16	0.04	0.18	37.2	7.9	113	1.33	128	4.36	11	0.12	2.3
4312	850-2000 um	0.41	2.55	5.7	363	0.8	0.09	0.01	0.1	19.3	3.7	108	0.95	83.4	2.23	7.45	0.1	1.5
4313	850-2000 um	0.36	1.75	6.7	308	0.74	0.14	0.01	0.01	24.6	4.9	220	1.02	52.8	2.3	6.21	0.025	1.2
4314	850-2000 um	0.12	1.81	7.8	263	0.54	0.21	0.02	0.1	19.3	4.9	208	0.63	26.1	3.81	6.29	0.11	1.5
4315	850-2000 um	0.44	1.38	4.2	285	0.49	0.1	0.2	0.01	14.7	2.4	66	1.1	23.6	2.63	4.68	0.025	0.9

Appendix 4. Chemical analyses of 15 orientation soil samples (2 size fractions)

Sample number		In	K	La	Li	Mg	Mn	Mo	Na	Nb	Ni	P	Pb	Rb	Re	S	Sb	Se
		ppm	%	ppm	ppm	%	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	%	ppm	ppm
		ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61
4301	<53 um	0.05	0.94	62.8	18.3	0.2	445	0.68	0.14	13.7	18.7	154	98	43.7	-0.002	0.01	0.28	-1
4302	<53 um	0.07	1.21	121	27.2	0.34	1280	1.09	0.17	15	30.7	238	112	80.6	-0.002	0.01	0.4	1
4303	<53 um	0.088	1.56	11.5	47.9	0.49	1310	1.61	0.13	16.1	43.1	403	416	68.5	0.002	0.03	0.93	1
4304	<53 um	0.072	1.07	115	30.2	0.29	1150	1.06	0.15	15.1	28.8	266	434	75.9	-0.002	0.02	0.46	1
4305	<53 um	0.088	1.25	173	37.3	0.33	1570	1.43	0.11	16.5	39.1	235	131	126	-0.002	0.01	0.45	2
4306	<53 um	0.068	0.95	112	27.9	0.22	1360	1.19	0.12	15.6	27.8	187	111	76.6	-0.002	-0.01	0.33	2
4307	<53 um	0.063	1.04	109	27.8	0.27	921	1.05	0.14	17.8	29.2	192	79.2	72.2	-0.002	-0.01	0.3	2
4308	<53 um	0.085	1.7	20.4	46.9	0.61	1690	1.79	0.13	20.3	49.8	346	141	80.2	0.001	0.03	0.75	1
4309	<53 um	0.089	1.31	184	38	0.46	1250	1.26	0.12	20.2	36.8	250	121	179	-0.002	0.01	0.42	2
4310	<53 um	0.085	1.22	24.7	42.8	0.49	1430	1.65	0.12	19.2	46.6	350	169	79.2	0.001	0.02	0.73	1
4311	<53 um	0.066	1.26	94.4	23.2	0.31	1010	0.89	0.2	14.5	26	217	311	75.4	-0.002	-0.01	0.34	1
4312	<53 um	0.083	1.47	146	32.9	0.42	1270	1.12	0.15	16.6	33.4	314	244	127	-0.002	0.01	0.33	2
4313	<53 um	0.086	1.79	25.1	41	0.67	1140	1.8	0.14	17.8	38.4	421	274	99.9	0.003	0.02	0.57	1
4314	<53 um	0.047	0.88	49.8	17.4	0.16	462	0.69	0.15	13.1	17.8	163	115	40.3	-0.002	-0.01	0.2	1
4315	<53 um	0.086	1.16	23.2	32.9	0.48	817	5.52	0.21	16.2	63.5	420	261	78.2	0.002	0.07	1.34	1
4301	850-2000 um	0.016	0.76	7	5.5	0.05	116	0.7	0.04	6	7.1	45	25.4	27.2	-0.002	-0.01	0.16	-1
4302	850-2000 um	0.05	1.05	16	15.6	0.19	3290	1.77	0.06	5.2	32.1	217	267	37	-0.002	-0.01	0.72	-1
4303	850-2000 um	0.036	1.59	16.3	10.9	0.19	1660	1.68	0.06	4	72.6	154	331	53	0.004	0.005	0.91	0.5
4304	850-2000 um	0.055	1.49	16.8	11.6	0.23	1320	1.34	0.06	6.8	18.7	133	401	50	-0.002	-0.01	0.62	-1
4305	850-2000 um	0.068	1.12	16.4	15.1	0.2	1270	1.71	0.06	7.6	21.4	127	137	46	-0.002	-0.01	0.69	-1
4306	850-2000 um	0.06	1.07	16.8	13.8	0.18	1410	1.83	0.06	8	21.7	145	158	41.5	-0.002	-0.01	0.63	1
4307	850-2000 um	0.057	1.29	16.7	11.7	0.22	1330	1.68	0.06	8.6	21.5	126	128	46.2	-0.002	-0.01	0.73	-1
4308	850-2000 um	0.062	1.87	23.3	13.5	0.3	2690	2.05	0.08	9	25	167	214	75.5	0.001	0.005	0.86	0.5
4309	850-2000 um	0.052	1.66	19.5	13.7	0.25	1330	1.12	0.09	9.4	19.4	115	171	59.7	-0.002	-0.01	0.41	-1
4310	850-2000 um	0.047	1.7	18.6	9.5	0.22	1370	1.43	0.07	7.2	20.7	121	207	63.8	0.001	0.005	0.65	0.5
4311	850-2000 um	0.041	1.62	14.5	8.7	0.22	1670	2.43	0.08	5.8	16.8	141	510	50.9	-0.002	-0.01	0.63	-1
4312	850-2000 um	0.025	1.02	11.8	6.8	0.13	333	1	0.06	4.4	9.6	95	104	30.2	-0.002	-0.01	0.18	-1
4313	850-2000 um	0.018	0.88	10.1	4.2	0.09	556	1.08	0.05	3.1	11.7	82	125	28.6	0.001	0.005	0.34	0.5
4314	850-2000 um	0.025	0.85	7.9	4.2	0.1	539	1.08	0.03	3.5	10.2	67	95.5	23.6	-0.002	-0.01	0.3	-1
4315	850-2000 um	0.02	1.14	10	2.3	0.07	168	0.73	0.04	3.5	11.6	178	51.1	34.5	0.002	0.01	0.33	0.5

Appendix 4. Chemical analyses of 15 orientation soil samples (2 size fractions)

Sample number		Sn	Sr	Ta	Te	Th	Ti	Tl	U	V	W	Y	Zn	Zr	Ta	Be
		ppm	ppm	ppm	ppm	ppm	%	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm	ppm
		ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	ME-MS61	*500	*250
4301	<53 um	2.7	35.5	1.35	-0.05	20.1	0.55	0.55	2.5	73	1.2	24.4	92	226	675	312.5
4302	<53 um	3.7	48.4	1.49	-0.05	28.5	0.52	0.78	2.9	91	1.4	43.4	180	212	745	580
4303	<53 um	6.2	36.6	1.88	0.07	10.8	0.52	1.09	3.6	131	2	8.2	223	194	940	1022.5
4304	<53 um	3.6	47.2	1.29	-0.05	27.8	0.55	0.74	3	99	1.5	41	141	214	645	497.5
4305	<53 um	4.1	68.8	1.3	-0.05	37.7	0.54	0.9	3.2	108	1.7	57.8	71	195	650	642.5
4306	<53 um	3.5	50.3	1.45	-0.05	29.3	0.54	0.8	3	92	1.4	40.2	47	198	725	470
4307	<53 um	3.5	46.3	1.49	0.05	25.4	0.58	0.73	3.2	90	1.5	39	67	224	745	505
4308	<53 um	6.9	39	2.09	0.07	12.2	0.61	1.17	4	144	2	12.5	154	211	1045	902.5
4309	<53 um	4.3	68.3	1.94	0.05	43.7	0.62	0.88	3.5	112	1.7	67.1	86	228	970	715
4310	<53 um	6.7	41.8	1.88	0.09	14.7	0.59	1.09	3.5	137	1.9	13.9	119	201	940	805
4311	<53 um	3.3	47.1	1.27	-0.05	22.3	0.53	0.68	2.9	86	1.3	35.9	62	213	635	472.5
4312	<53 um	4.1	60.3	1.49	0.06	27.8	0.51	0.88	3.3	97	1.6	53.3	69	184	745	667.5
4313	<53 um	7	36.4	1.86	0.05	14.7	0.53	1.1	3.7	124	2	17.3	117	194	930	885
4314	<53 um	2.5	32.4	1.19	-0.05	17.6	0.51	0.49	2.3	70	1	20.9	45	209	595	287.5
4315	<53 um	11.6	52.5	1.72	0.09	15.9	0.55	0.75	2.7	122	6	15.8	169	202	860	490
															0	0
4301	850-2000 um	1	7.7	0.49	-0.05	3.7	0.14	0.24	0.6	23	0.7	5.1	21	68.4	245	95
4302	850-2000 um	1.9	11.6	0.41	0.06	7.9	0.13	0.84	1.1	94	0.8	7.2	197	81.3	205	410
4303	850-2000 um	1.9	8.6	0.41	0.06	8.4	0.1	0.69	1.3	99	0.6	5.8	127	62.8	205	447.5
4304	850-2000 um	2.3	11.3	0.51	0.07	8.4	0.16	0.71	1	117	0.8	6.6	96	89.1	255	332.5
4305	850-2000 um	2.5	15	0.59	0.09	9.4	0.2	0.74	1.3	142	0.9	7.9	50	102	295	445
4306	850-2000 um	2.3	14.4	0.65	0.09	11	0.2	0.78	1.2	140	1	8.2	43	101	325	377.5
4307	850-2000 um	2.4	12.4	0.69	0.1	9.2	0.2	0.77	1.1	139	0.9	7.6	65	96.8	345	372.5
4308	850-2000 um	2.8	11.4	0.81	0.07	13	0.2	1.07	2	154	0.9	10.2	93	106	405	572.5
4309	850-2000 um	2.5	14.1	0.71	0.06	8.1	0.22	0.76	1.1	99	0.9	8.5	60	104	355	395
4310	850-2000 um	2.3	9.2	0.67	0.07	10.8	0.17	0.8	1.5	114	0.7	7.3	57	83.7	335	412.5
4311	850-2000 um	2	10.3	0.44	-0.05	7	0.14	0.66	0.9	91	0.7	6	53	76.1	220	307.5
4312	850-2000 um	1.3	8	0.32	-0.05	4.7	0.11	0.41	0.6	48	0.5	4.7	27	48.1	160	200
4313	850-2000 um	1.1	5.5	0.31	0.025	5	0.07	0.38	0.8	42	0.6	4	26	39.4	155	185
4314	850-2000 um	1	6.3	0.26	-0.05	4.5	0.08	0.29	0.6	63	0.8	5	43	48.8	130	135
4315	850-2000 um	0.8	26.6	0.29	0.025	4.2	0.07	0.26	0.6	48	0.4	2.8	47	31.6	145	122.5

Appendix 4. Chemical analyses of 15 orientation soil samples (2 size fractions)

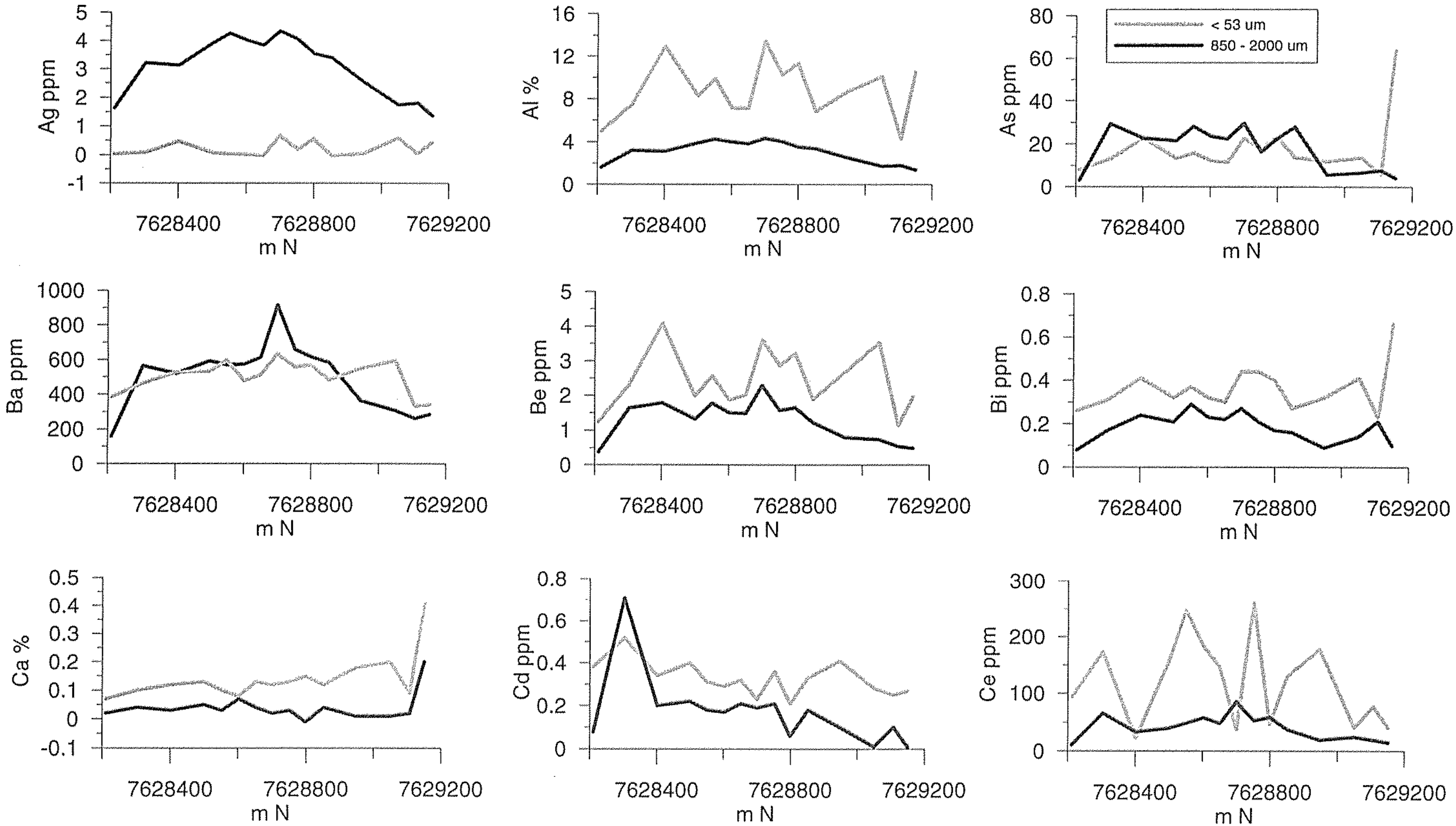

Figure 3a. Element concentrations in the <53 um and the 850-2000 um soil fractions.

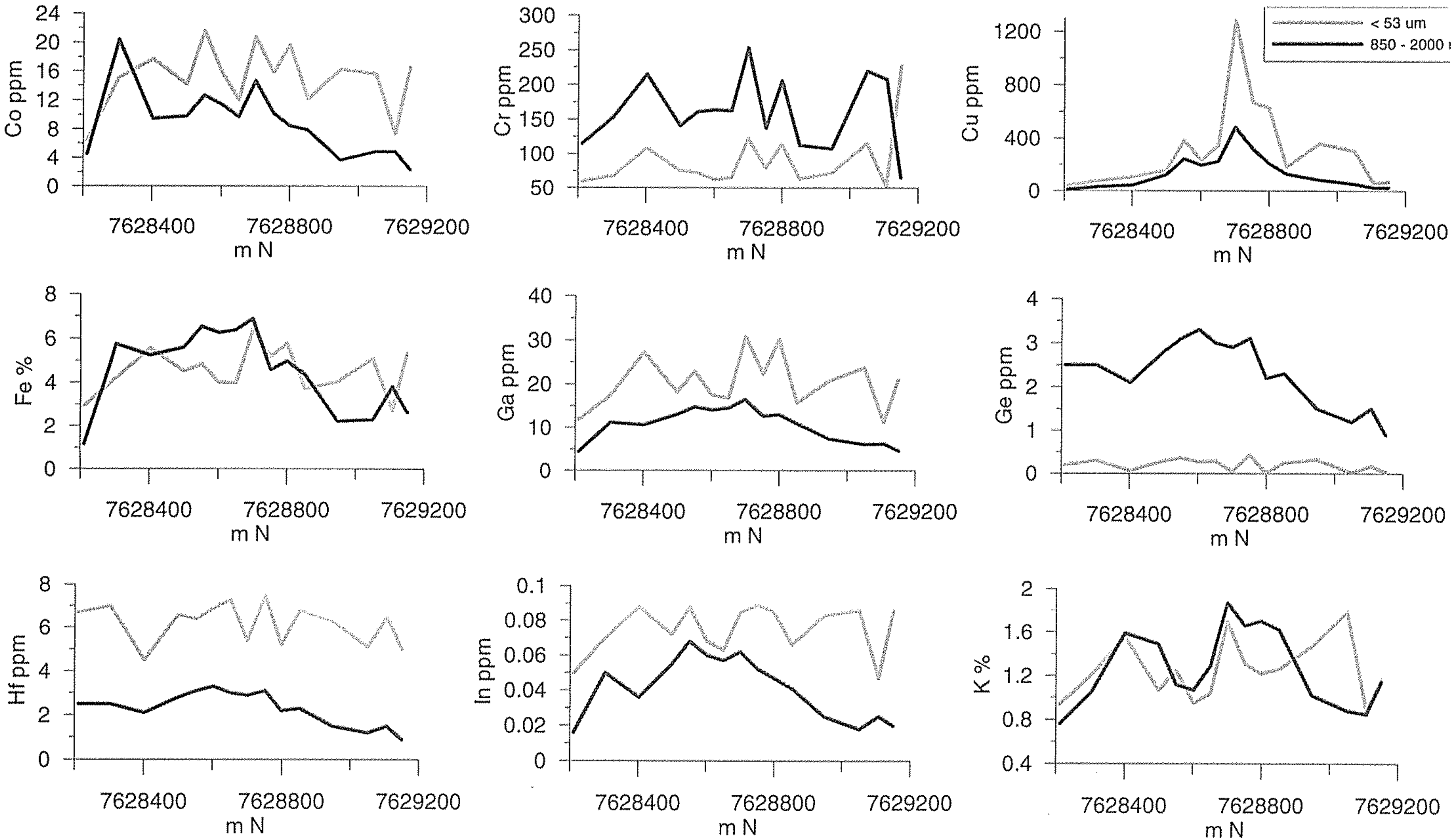

Figure 3b. Element concentrations in the <53 um and the 850-2000 um soil fractions.

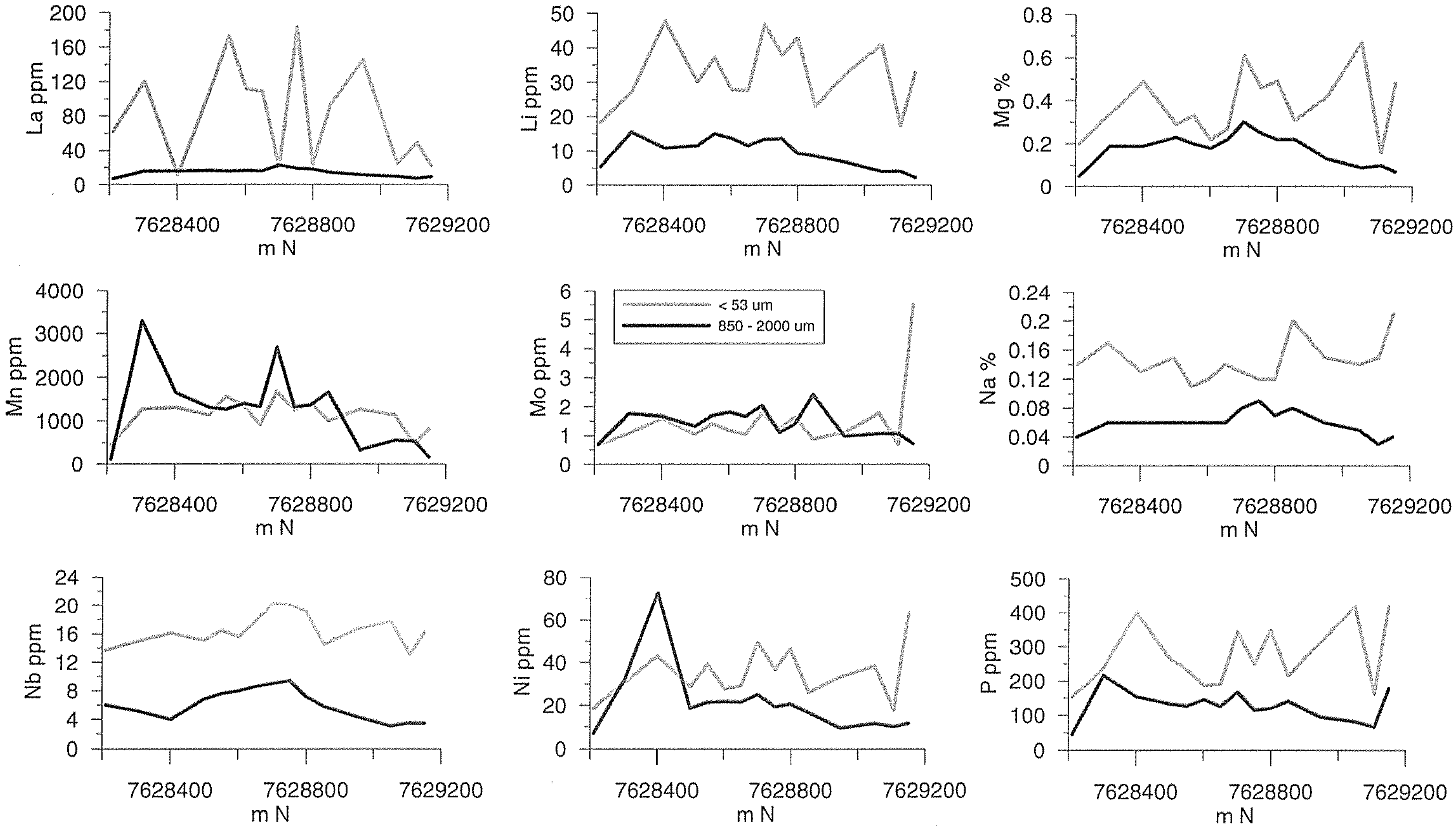

Figure 3c. Element concentrations in the <53 um and the 850-2000 um soil fractions.

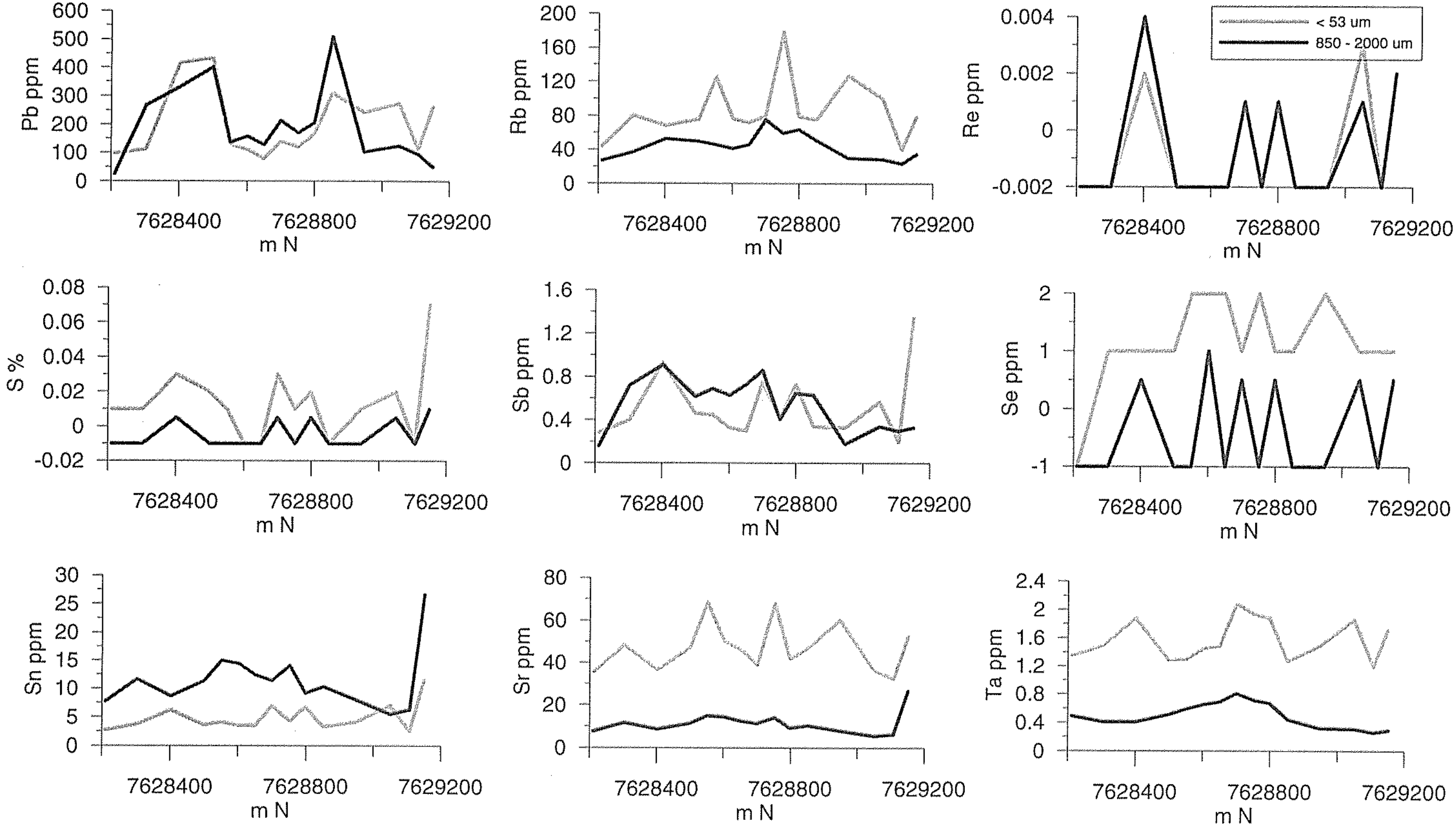

Figure 3d. Element concentrations in the <53 um and the 850-2000 um soil fractions.

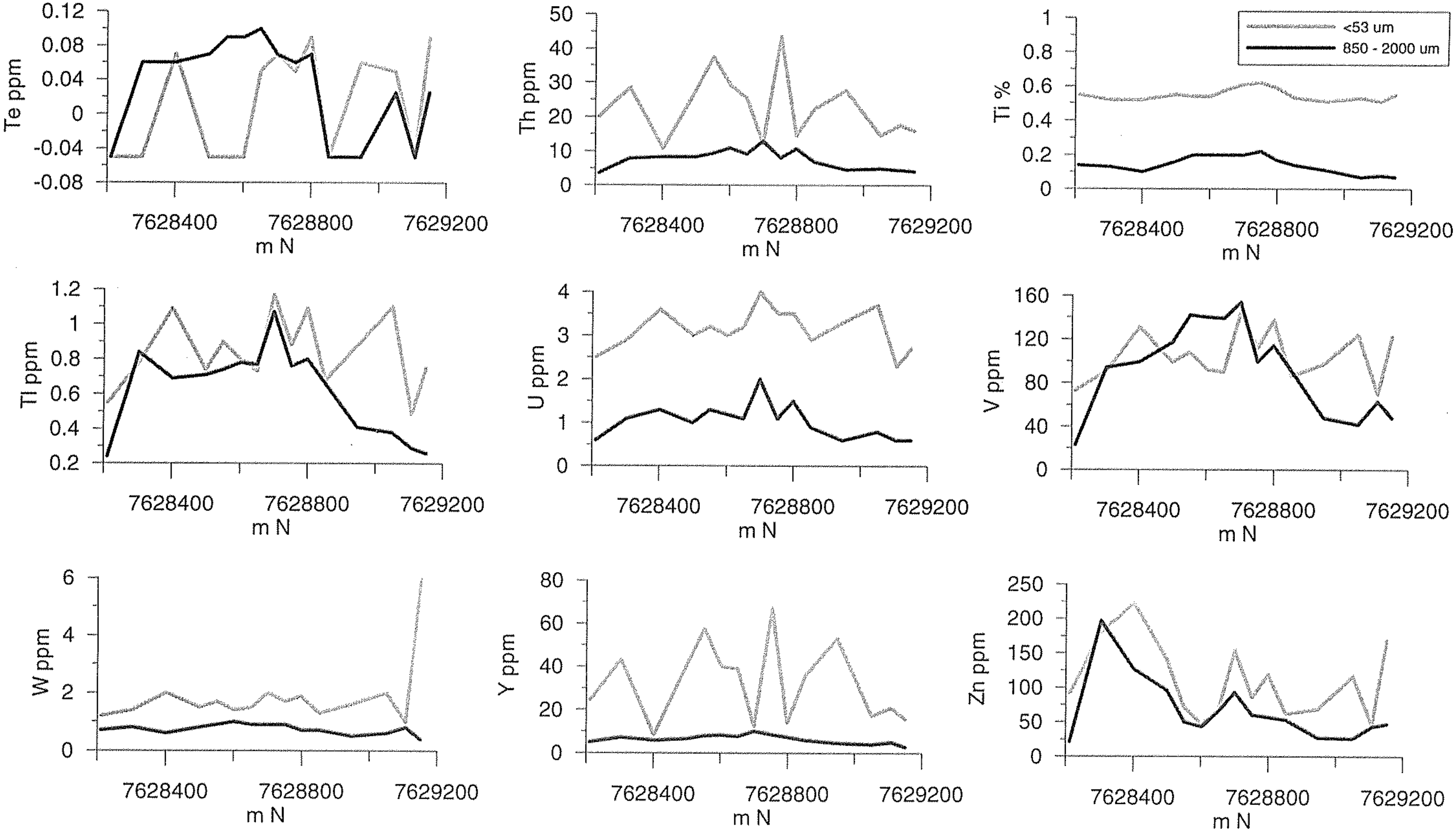

Figure 3e. Element concentrations in the <53 um and the 850-2000 um soil fractions.