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Kimberlite indicator-mineral survey, lower Hayes River

By
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Cover photo: An approximately 45-m high section on the Gods River exposing, from top to bottom, Sky Pilot till, Long Spruce till with interbedded sand and gravel (wet horizon), Nelson River sediments and Amery till. The section is typical of many sections in the Hudson Bay Lowland and adjacent Superior Province of northeastern Manitoba.

ABSTRACT

Quaternary sections along the lower Hayes River of northeastern Manitoba expose three tills, interglacial sediments and a variety of postglacial sediments, including glaciolacustrine silt and clay, marine silt and clay, and fluvial sand and gravel. The oldest till, Amery till, is attributed variously to southeasterly to southwesterly ice flow, based on pebble-fabric measurements and pebble counts. In two sections, the Amery till is overlain by interglacial Nelson River sediments. Nelson River sediments and Amery till are stratigraphically overlain by Long Spruce till, which was deposited by south-southwesterly ice flow. The youngest till, which is the surface till throughout northeastern Manitoba, is the Sky Pilot till. Sky Pilot till is yellowish brown in colour, being in part derived by the comminution of red Devonian carbonate rocks from Hudson Bay. The pebble fabric of Sky Pilot till indicates southwesterly ice flow.

Only 21 kimberlite indicator minerals (KIMs) were recovered from the 69 till and 2 gravel samples collected in this survey. The 18 Amery till samples produced no KIMs. The 17 Long Spruce till samples contained 14 KIMs, whereas the 34 Sky Pilot till samples contained only 2 KIMs. The two Holocene gravel samples contained 5 KIMs. The distribution of KIMs indicates they are concentrated in the Long Spruce till and derived from unknown source(s) to the north or north-northeast. The source(s) of KIMs may be an unknown bedrock source or an older buried glacial dispersion train. The KIMs in the Sky Pilot till and Holocene gravel samples are believed to have been reworked from the underlying Long Spruce till.

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INTRODUCTION

The Manitoba Geological Survey (MGS) has undertaken multimedia geochemical and kimberlite indicator-mineral surveys across the northern Superior Province over the past six years. These surveys have attracted the attention of numerous major and minor mineral-exploration companies (Fedikow et al., 1997, 1998, 1999, 2000). Although interest in kimberlite indicator minerals has been particularly high, the source(s) of the indicators continues to elude investigators. The Manitoba Geological Survey's kimberlite indicator-mineral surveys, as well as most of those sponsored by the mineral-exploration industry, have been conducted in areas of relatively thin till, and samples have generally been collected from hand-dug pits. However, sampling from hand-dug pits is not a viable technique for mineral-tracing surveys in the Hudson Bay Lowland and adjacent areas of the northern Superior Province, because the overburden is, in places, more than 100 m thick and multiple tills of uncertain provenance subcrop at depth. Prior to extending mineral-tracing and geochemical surveys into the northernmost part of the northern Superior Province and adjacent Hudson Bay Lowland, reverse-circulation drilling or other 'remote' sampling would be necessary to gain a clear understanding of the subsurface stratigraphy and till provenance. Mapping of selected river exposures would greatly enhance the understanding of the Quaternary stratigraphy and till provenance in support of regional mineral exploration, especially for diamonds.

OBJECTIVES

This survey was undertaken, in support of diamond exploration, to outline the Quaternary stratigraphy and determine the provenance of tills in the northern Superior Province and adjacent Hudson Bay Lowland of Manitoba. These objectives are being met by analyzing tills from a number of till sections and using a combination of pebble analysis, matrix geochemistry, textural analysis, kimberlite indicator-mineral analysis and pebble-fabric analysis.

PREVIOUS WORK

Recent work on the Quaternary stratigraphy of the Hudson Bay Lowland of Manitoba by Nielsen et al. (1986), Berger and Nielsen (1990), Dredge et al. (1990) and Roy (1998) focused primarily on the geology along the Nelson River, downstream from the town of Gillam. These studies highlighted the chronostratigraphy of the Quaternary deposits, but only casual consideration was given to the lithostratigraphy of the tills. Nielsen et al. (1986) outlined a stratigraphy comprising four tills and two nonglacial sequences, not including the present interglacial. The three uppermost tills, the Sky Pilot, Long Spruce and Amery, were deposited by ice flowing out of Hudson Bay in a southwesterly direction, whereas the lowest till, the Sundance, was deposited by southeasterly flowing ice originating in the Nunavut region, north of Manitoba. However, limited information is available on the extent and character of the tills in the Gillam area, across the Hudson Bay Lowland and in the adjacent northern Superior Province of Manitoba.

SURFICIAL GEOLOGY

Most of the area south of Hudson Bay and east of the Nelson River has low relief. The study region includes areas underlain by Paleozoic carbonate bedrock and the Fox River greenstone belt, and the area south to the latitude of Brassey Hill (approximately 55º30'N). Thick overburden, permafrost and extensive muskeg dominate this region. The rivers and creeks are commonly incised 30–50 m into the Quaternary sediments that blanket the area as the result of differential isostatic uplift over the last 8000 years (e.g., Nelson, Gods, Hayes, Fox, Stupart and Pennycutaway rivers). Exposures of Precambrian and Paleozoic rock and Quaternary sediments occur almost exclusively along river valleys.

METHODS

Of the numerous sections exposed along the Hayes, Gods, Pennycutaway, Fox, Stupart and other rivers and creeks in the area, seven sections were selected for detailed investigation (Figure 1). These seven sections, situated along the lower Hayes and Stupart rivers, were selected based on the availability of a suitable helicopter-landing site, the nature of the bedrock and Quaternary geology, distance and relative spacing from other sites, and proximity to multimedia surveys in the northern Superior Province. The seven sections ranged in height from 19 to 39 m. Till samples were collected at 2 or 3 m intervals in each of the sections. Two sample types were taken at each sampling interval: an 11 L sample for kimberlite indicator-mineral and pebble analyses and a 2 kg sample for geochemical analysis. Sixty-nine till and two coarse sand samples were collected from the seven sections. Pebble fabrics, consisting of 30 clasts each, were measured at 19 sample intervals. Munsell colour determinations were made at the MGS Rock Preparation Laboratory on wet samples. Correlation and age assignment of the various tills was done in the field using colour, pebble fabric and stratigraphic position of the various units.

The kimberlite indicator minerals were concentrated, picked and analyzed by electron microprobe, by De Beers Canada Exploration Inc., free of charge. In keeping with the usual confidentiality practice of the MGS, the sampling site locations were not revealed to De Beers. Guidelines for kimberlite-indicator classification used in this report are outlined in Thorleifson et al. (1994).

Pebble counts on the 4–8 mm size fraction were conducted at the MGS Rock Preparation Laboratory in Winnipeg. Pebbles were divided into ten separate lithological classes. Red carbonate, brown carbonate and sandstone pebbles were derived from the Hudson Bay Lowland. Greywacke and iron formation (oolitic jasper) pebbles were derived from the Omarolluk and associated formations in eastern Hudson Bay. Red volcanic pebbles were derived from the Dubawnt area in Nunavut, and volcanic, mafic crystalline and granitoid pebbles were derived locally from the Precambrian Shield of northern Manitoba. The origin of quartzite pebbles is uncertain. The percentages of sand, silt and clay were measured at the University of Manitoba Sedimentology Laboratory. Inductively coupled plasma–atomic emission spectroscopy (ICP-AES) analysis on the <2 µm fraction and instrumental neutron-activation analysis (INAA) on

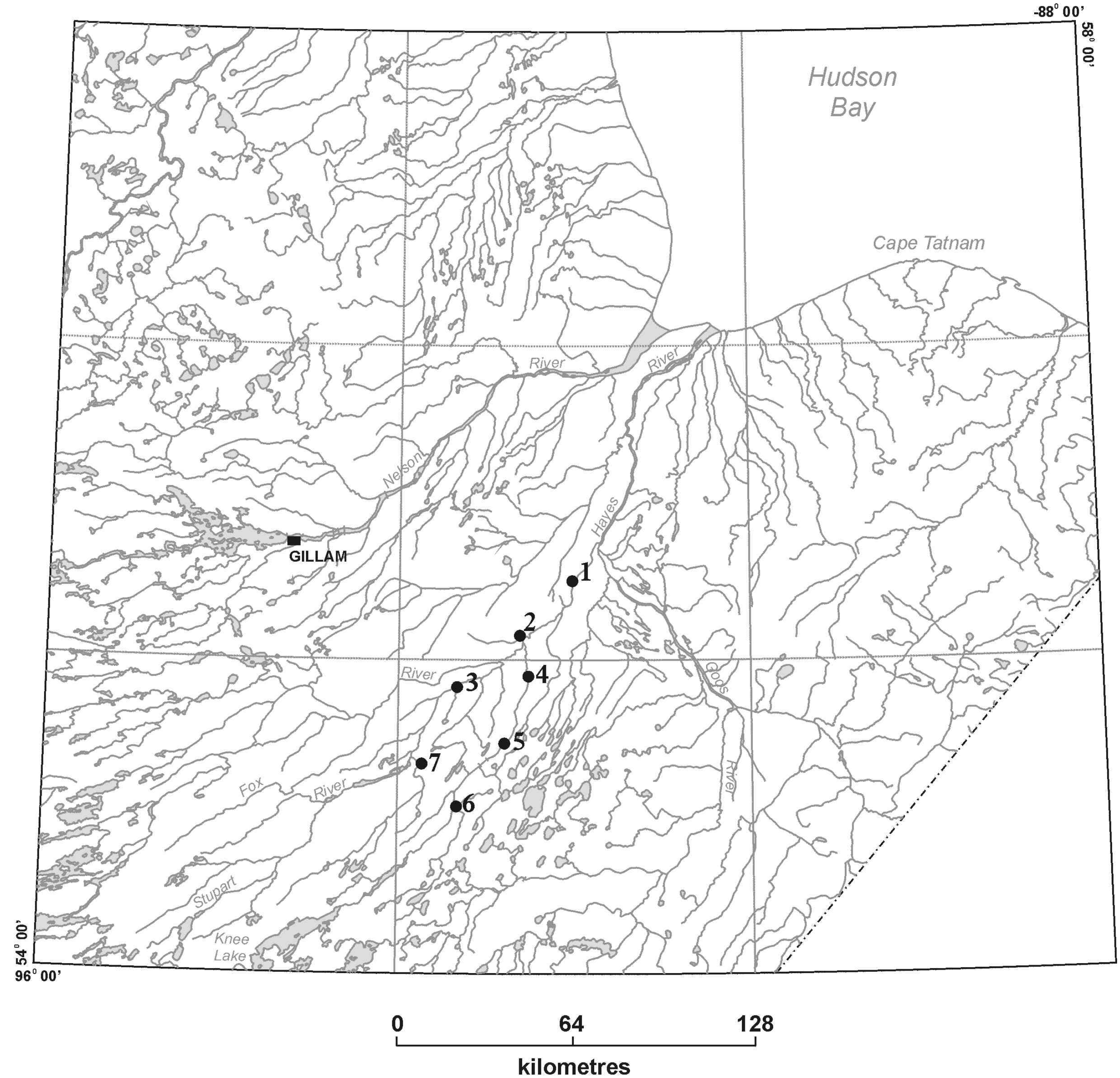

Figure 1: Locations of the seven stratigraphic sections measured along the lower Hayes River in the northern Superior Province and adjacent Hudson Bay Lowland.

the <63 µm fraction were contracted to Bondar-Clegg and Activation Laboratories Ltd., respectively.

Laboratory analyses were used to confirm field correlations, help determine till provenance and accurately define the contacts between the various till units.

BEDROCK GEOLOGY AND SITE DESCRIPTION

Previous work by Fedikow et al. (1997, 1998, 1999, 2000) suggests that kimberlite indicator minerals in the Knee Lake area may originate from unknown source(s) to the northeast. The present investigation was targeted in the area of thick overburden north of Brassey Hill, where tills are not easily sampled from hand-dug pits. An understanding of the till stratigraphy in this area will help determine the direction and proximity to the source of kimberlite minerals in the northern Superior Province and adjacent Hudson Bay Lowland.

Section HR1

Section HR1 is located on the Hayes River, 30 km downstream from its confluence with the Fox River (Figure 1). Ordovician carbonate bedrock of the Red Head Rapids Formation underlies this area, but does not outcrop in the riverbed. The 26 m high Quaternary section is composed almost exclusively of till (Figure 2). The upper 14 m consists of relatively soft, yellowish brown (Munsell colour 10YR 5/4) till. Pebble orientations measured at a depth of 9 m indicate the ice flow was towards the south (185º). In the field, this till was correlated with the Sky Pilot till, based on its colour, fabric and stratigraphic position.

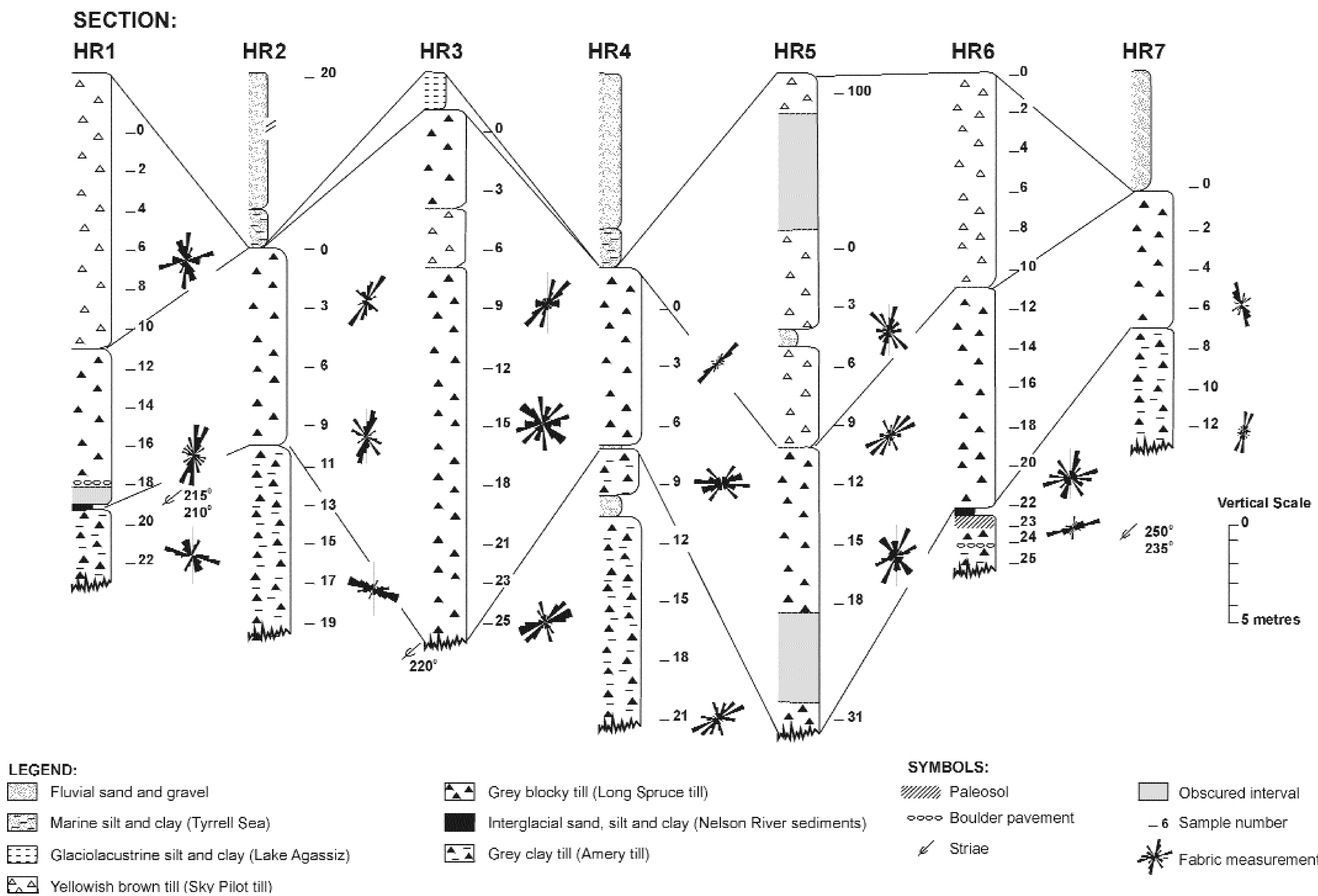

Figure 2: Quaternary stratigraphy and correlation of the seven sections along the lower Hayes River.

Underlying the Sky Pilot till is 7 m of relatively hard, olive-coloured (5Y 4/3) till. At the top of this interval, the olive till is crumbly with no visible oxidation, but gives way to vertically jointed and manganese-stained till towards the bottom. The base of this till rests on a boulder pavement with striations trending 190º, 210º and 215º, consistent with the pebble fabric trending south-southwesterly (200º) measured 1 m above the boulder pavement. An approximately 80 cm thick rusty interval is found 5 m below the top of the olive till. In the field, this till was correlated with the Long Spruce till, based on its colour, fabric and stratigraphic position.

The base of the section comprises poorly exposed 'interglacial' silt capping relatively fine textured, dark olive-grey (5Y 3/2), oxidized till. This 4 m thick till unit is horizontally fissile, with smaller joint blocks than tills outcropping higher in the section. The pebble fabric measured at a depth of 25 m indicates ice flow was towards the southeast (135º). The fabric of this till suggests it should be correlated with the Sundance till, but its stratigraphic position immediately under nonglacial sediments suggests it correlates with the Amery till.

Texture, pebble lithology and geochemistry

A lower percentage of sand and higher percentage of silt differentiate Sky Pilot till from the underlying Long Spruce till (Appendices 1A and 1B). The till at the base of the section has less sand and more clay than the overlying Long Spruce till.

Red carbonate pebbles attain their highest concentrations in the Sky Pilot till and impart the yellowish brown colour to this till. Red volcanic pebbles, from the Dubawnt Formation in Nunavut, increase towards the top, as do Manitoba-derived sandstone and granitoid pebbles. Mafic crystalline and volcanic pebbles derived from the Precambrian terrain of northern Manitoba attain their highest concentrations at the base of the Sky Pilot till, and decrease towards the top. Oolitic jasper (iron formation), from the Sutton Ridge in northern Ontario or eastern Hudson Bay, has its highest concentration in the Long Spruce till. Volcanic and mafic crystalline pebbles increase towards the top of the Long Spruce till, as do locally derived sandstone pebbles. Oolitic jasper, red volcanic and volcanic pebbles are notably absent from the lowest till, and concentrations of sandstone and mafic crystalline pebbles are low. Greywacke from the Omarolluk Formation in eastern Hudson Bay attains its highest concentration at the base of the lowest till, which is not consistent with the pebble fabric indicating southeasterly ice flow. The high concentration of greywacke from the Omarolluk Formation indicates an eastern provenance for this till or reworking of older material derived from the east. Because of the high proportion of greywacke and the stratigraphic position, the lowest till in this section is correlated with the Amery till on the Nelson River.

The <2 μm fraction of Sky Pilot till is slightly depleted in magnesium, strontium and sulphur compared with Long Spruce till (Appendices 2A and 2B). Strontium and calcium decrease towards the top of the Sky Pilot till, whereas zinc, cobalt, iron, barium, chromium, vanadium, potassium and arsenic increase towards the top. Long Spruce till is uniformly high in zinc, chromium, vanadium, magnesium, calcium and strontium. The <2 μm fraction of Amery till is depleted in manganese, sodium, potassium, zirconium, mercury and arsenic, and marginally enriched in barium and titanium, compared to Long Spruce till. The geochemistry of the <2 μm fraction of the Amery till is variable for many elements, suggesting the local bedrock is not far below the bottom of the section. High levels of calcium, magnesium and strontium in the bottom sample support this conclusion.

The <63 μm fraction of Sky Pilot till is enriched in arsenic, cobalt, chromium, iron, nickel, rubidium, scandium, thorium, uranium, lanthanum, cesium, samarium and ytterbium, relative to Long Spruce till (Appendices 3A and 3B). Calcium, cobalt, rubidium and lanthanum decrease in concentration from the bottom to the top of the Sky pilot till, whereas chromium, thorium and ytterbium increase slightly from bottom to top. Barium and bromine decrease from the bottom to the top of the Long Spruce till, whereas most of the other elements show an increase towards the top of the unit. Sample HR1-01-20, collected at the –23 m level in the Amery till, is enriched in cobalt, chromium, iron, sodium, nickel, rubidium, antimony, scandium, thorium, uranium, lanthanum, cesium, neodymium, samarium and ytterbium, compared to the overlying Long Spruce till. Elevated levels of many of these elements at the base of the Long Spruce till are probably due to incorporation of Amery till as the result of overriding.

Section HR2

Section HR2 is located on the Hayes River, approximately 200 m downstream from the confluence with the Fox River (Figure 1). The bedrock is unexposed Precambrian metasedimentary rocks. The upper 20 m of the section comprises Holocene marine silt and clay, and fluvial sand and gravel (Figure 2).

Marine and fluvial sediments overlie 19 m of olive-coloured (5Y 4/3) till. The till is vertically jointed with manganese staining on the joint surfaces. Minor sandy interbeds occur at several intervals in the section. Pebble-fabric measurements at the 23 m and 29 m levels indicate that glacial flow was towards the south-southwest (200º). A third fabric, measured at the 37 m level, shows ice flow towards the east-southeast (110º), indicating that an olive-grey till of different provenance outcrops in the lower part of the section. In the field, these two tills were correlated with the Long Spruce and Amery tills, respectively, and the contact was placed at the 30 m level, based on the sandy texture of the lower till and the differences in the pebble fabrics.

Texture, pebble lithology and geochemistry

The two tills in this section can be differentiated by their fabrics and textures. The Long Spruce till has more clay and less sand than the underlying Amery till (Appendices 1A and 1B). The sand content of the Amery till increases from the bottom of the section towards the top, whereas both silt and clay decrease over the same interval.

Long Spruce till is enriched in pebbles of red volcanic rocks and locally derived volcanic, sandstone, mafic crystalline and granitoid rocks, compared to the underlying Amery till. The proportion of volcanic pebbles in the Long Spruce till increases towards the top of the unit, as do red volcanic, sandstone and granitoid pebbles, but then decreases sharply at the top. Oolitic jasper is highest in the Amery till, but decreases in concentration from the bottom to the top of the unit, as do greywacke and mafic crystalline pebbles. The relatively high concentration of Omarolluk greywacke pebbles in the lower till confirms the correlation with the Amery till. Granitoid pebbles increase slightly through the Amery till, but remain below their concentration in the overlying Long Spruce till.

Long Spruce till shows a marked decrease in zinc, cobalt, iron, manganese, barium, chromium, vanadium, sodium and arsenic in the <2 µm fraction (Appendices 2A and 2B). Magnesium, calcium, zirconium and mercury, on the other hand, show a slight increase towards the top of the Long Spruce till. Zinc, cobalt, manganese, barium, chromium, vanadium and titanium decrease from the bottom to the top of the Amery till, whereas calcium, strontium, sulphur and arsenic increase over the same interval. Magnesium concentration is markedly different between the two till units.

In the <63 µm fraction, arsenic and bromine increase from the bottom to the top of the Long Spruce till (Appendices 3A and 3B). The remaining elements have relatively uniform concentrations throughout the Long Spruce till. Arsenic, barium, cobalt, chromium, iron, nickel, scandium and several of the rare earth elements show marked decreases in concentration from the bottom to the top of the Amery till. Bromine and calcium increase over the same interval.

Section HR3

Section HR3 is situated on the Stupart River, 15 km upstream from the confluence with the Fox River (Figure 1). The bedrock is unexposed Precambrian metasedimentary rock. The upper 2 m of the section is light brown glaciolacustrine silt and clay deposited in Lake Agassiz (Figure 2).

The glaciolacustrine sediment overlies 27 m of predominantly olive-coloured (5Y 4/3) till. The interval from 4 to 7 m is light olive brown (2.5Y 5/4) in colour, but otherwise the section is olive coloured and blocky with vertical jointing and manganese staining. Pebble fabrics measured at the 12, 21 and 28 m levels are weakly developed, but suggest ice flow towards the southwest. In the field, the till exposed in this section was correlated with the Long Spruce till, based on its colour and stratigraphic position.

Texture, pebble lithology and geochemistry

The textural data are variable throughout this section (Appendices 1A and 1B). Sand decreases slightly from the bottom to the top of the section at the expense of clay.

The percentages of red carbonate from the Hudson Bay Lowland, greywacke from eastern Hudson Bay and quartzite of unknown provenance increase slightly in the upper part of the section, whereas brown carbonate and mafic crystalline pebbles decrease.

Cobalt, iron and manganese in the <2 µm fraction increase towards the top of the section (Appendices 2A and 2B). Chromium, vanadium and titanium values are highest in the top two samples, but otherwise the levels of these elements remain constant throughout the section.

In the <63 µm fraction, bromine and calcium decrease slightly from the bottom to the top of the section, whereas barium, cobalt, chromium, iron, nickel, rubidium, scandium, thorium and cesium increase slightly over the same interval (Appendices 3A and 3B).

Section HR4

Section HR4 is situated on the Hayes River, approximately 10 km upstream from the confluence of the Fox and Hayes rivers (Figure 1). The underlying bedrock is unexposed Precambrian metasedimentary rocks similar to those underlying section HR3. The 33 m high section is composed of 10 m of Holocene alluvial sand and gravel and marine silt and clay, capping 23 m of till (Figure 2).

The upper 9 m of till in this section are sandy, pebble-rich and olive coloured (5Y 4/3). A well-developed pebble fabric, measured 13.5 m below the top of the section, indicates that ice flow was towards the southwest (225º). In the field, the upper till in the section was correlated with the Long Spruce till, based on its colour, fabric and stratigraphic position.

The upper till is separated from an underlying till by a number of intercalated fine sand and silt beds up to 1 m thick. The lower till is 14 m thick and fine textured, with relatively few pebbles. It is olive grey (5Y 5/2) in colour. The pebble fabric at the 21 m level suggests ice flow towards the west-northwest (290º), if the dip direction of the pebbles is taken at face value. However, there is little direct evidence in northern Manitoba of ice flow from northwestern Ontario (Thorleifson et al., 1992). Alternatively, the fabric may indicate east-southeasterly (110º) ice flow if there is 180º ambiguity in the direction of pebble dip. The fabric at the 33 m level is poorly developed but suggests a southwesterly ice flow. The lower till in this section is correlated with the Amery till. The fabrics of the Amery till indicate a shift in the ice-flow trajectory from southwesterly at the base to southeasterly near the top, an observation that is consistent with observations in sections 1 and 2.

Texture, pebble lithology and geochemistry

The section exposes two olive-coloured tills. The bottom till, the Amery, has slightly less sand but more silt than the overlying Long Spruce till (Appendices 1A and 1B).

Greywacke concentrations are generally high and increase towards the top of the Amery till, but then decrease sharply in the Long Spruce till. Quartzite concentrations are high at the base of the Amery. Oolitic jasper is almost nonexistent in the Amery till. At the base of the Long Spruce till, the concentration of oolitic jasper is relatively high but falls off towards the top of the section. Volcanic and granitoid pebble concentrations are relatively high at the base of the Amery till but decrease towards the top.

The <2 µm fraction of the Amery till at the base of the section is high in copper, iron, chromium, vanadium, lanthanum, yttrium, titanium and zirconium, but concentrations decrease towards the top of the section (Appendices 2A and 2B). Calcium and strontium concentrations in the Long Spruce till increase towards the top of the Amery till and reach their highest levels in the Long Spruce till.

Numerous elements, including barium, cobalt, chromium, iron, sodium, nickel, rubidium, scandium, thorium, zinc and most of the rare earth elements, are enriched in the <63 µm fraction (Appendices 3A and 3B). Concentrations decrease from the bottom to the top of the section. Bromine concentrations are lowest at the base of the Amery till, but increase towards the top of the Long Spruce till.

Pebble counts and textural and geochemical analyses confirm that the contact between the two tills lies at the 19 m level, as was indicated by the field relations.

Section HR5

Section HR5 is located on the Hayes River, approximately 7.5 km downstream from Whitemud Falls (Figure 1). The Fox River sill underlies this section, but it is not exposed. The 33 m high till section outcrops on the east bank of the river at the mouth of a small tributary of the Hayes River.

The upper 19 m consists of greyish brown (10YR 5/2) till (Figure 2). An approximately 6 m thick interval near the top of the section was obscured due to slumping and could not be sampled. Manganese staining is widespread on joint surfaces. A pebble fabric measured at a depth of 13 m indicates that ice flow was towards the south-southwest (195º), whereas a fabric measured at a depth of 24 m indicates that ice flow was towards the southwest (235º). The difference between the two fabrics suggests a change in the ice-flow trajectory through the intervening 11 m of till deposition. In the field, this till was identified as Sky Pilot till, based on its colour and stratigraphic position.

At a depth of 19 m, the colour of the till changes to grey-brown (2.5Y 5/2) and the relative concentration of pebbles decreases. The interval from 27 to 32 m was almost vertical and too steep to sample. The single pebble fabric measured at the 24 m level is weak, but suggests that ice flow was towards the south (185º). This till is interpreted as Long Spruce till, based on its colour, stratigraphic position and a fabric that suggests south-southwesterly ice flow.

Texture, pebble lithology and geochemistry

The two tills are difficult to separate using texture (Appendices 1A and 1B). Sand concentrations increase slightly from the base to the top of the section, whereas clay decreases slightly. Red carbonate is relatively uniform throughout the section, except for the uppermost sample, which has the highest concentration. Oolitic jasper is high in the uppermost sample of the Long Spruce till and in the lower part of the overlying Sky Pilot till, possibly as the result of incorporation during overriding. The concentration of red volcanic pebbles from Nunavut is high at the base of the Sky Pilot till but decreases rapidly towards the top of the unit. Mafic crystalline rocks are abundant in Long Spruce till, suggesting a local provenance. Concentrations of granitoid rock types are approximately the same in both tills.

The <2 µm fraction of Long Spruce till is slightly enriched in nickel, cobalt, iron, chromium, vanadium, lanthanum, magnesium, lithium and titanium, but depleted in mercury, compared to the overlying Sky Pilot till (Appendices 2A and 2B).

In the <63 µm fraction, the Long Spruce till shows slightly elevated levels of cobalt, chromium, iron, sodium, nickel, rubidium, scandium, thorium, zinc and several of the rare earth elements (Appendices 3A and 3B).

Section HR6

Section HR6 is located on the High Hill River, where it joins the Hayes River on the north side of Brassey Hill (Figure 1). The underlying bedrock is felsic granulite and/or associated granitic rocks. The section is 25 m high and comprises three tills and an interglacial sequence of silt and clay (Figure 2).

The upper 11 m of the section consists of yellowish brown (10YR 5/4) till with relatively small joint blocks and only minor manganese staining. In the field, this till was correlated with the Sky Pilot till, based on colour and stratigraphic position.

The upper till overlies 11 m of olive (5Y 5/3) till. This till is blocky and manganese staining increases towards the bottom of the section, where it becomes intense. The pebble fabric measured at the 20 m level indicates that ice flow was towards the south-southwest (200º). In the field, this till was correlated with the Long Spruce till, based on colour, fabric and stratigraphic position.

An approximately 60 cm thick section of silt and fine sand, with minor organic material, separates the bottom two tills. These nonglacial sediments are tentatively correlated with the Nelson River sediments and assigned a Sangamon Interglacial age. The underlying 2 m of till show evidence of pedogenesis, which further suggests an interglacial age for the overlying nonglacial sediments.

The lowermost till is olive (5Y 5/3) coloured. In the field, it showed a distinct grey-green and variable coloured zone beneath the nonglacial sediments, suggestive of pedogenesis. A boulder pavement at the upper contact of the lower till shows striations orientated towards 250º and 235º, which is consistent with the pebble fabric that indicates ice flow towards the west-southwest (250º). In the field, the bottom till in this section was correlated with the Amery till, based on colour, fabric and stratigraphic position.

Texture, pebble lithology and geochemistry

Sky Pilot, Long Spruce and Amery till outcrop in section HR6. Sky Pilot till has less sand and more clay than the other two tills (Appendices 1A and 1B). Long Spruce till is sandier than the other two tills. The Amery till, at the base of the section, has higher levels of silt and relatively little clay compared to either of the other two tills. Despite the yellow-brown colour of the Sky Pilot till, it has no more red carbonate pebbles than the underlying Long Spruce till. Greywacke pebbles from eastern Hudson Bay are abundant in the Sky Pilot and Amery tills, but relatively scarce in the Long Spruce till. Brown carbonate pebbles increase in abundance, whereas volcanic, sandstone and granitoid pebbles decrease, progressing up through the Long Spruce till. Red volcanic pebbles from the Nunavut region occur near the base of the Long Spruce till. Greywacke and oolitic jasper pebbles of eastern provenance are common, and red volcanic pebbles from Nunavut and locally derived volcanic pebbles are notably absent in the Amery till. The pebble compositions confirm the northerly provenance of the Long Spruce till and northeasterly provenance of the Amery till indicated by pebble-fabric measurements.

The <2 µm fraction of Sky Pilot till has high levels of arsenic and low levels of sulphur, compared to the other tills in this section (Appendices 2A and 2B). Zinc, magnesium, calcium, strontium, potassium and zirconium are elevated in the Long Spruce till. Cobalt is marginally higher, whereas barium, chromium, vanadium, cadmium, potassium and lithium are slightly depleted in the Amery till.

In the <63 µm fraction, calcium is slightly higher and sodium is lower in the Long Spruce till, compared to the other two tills in the section (Appendices 3A and 3B). Iron, chromium, rubidium and several of the rare earth elements are slightly higher in the Sky Pilot till. Many elements in the Amery till show a decrease in concentration towards the top, which may be due to interglacial pedogenesis.

Section HR7

Section HR7 is located 2.5 km northeast of Stupart Lake, on a tributary of the Stupart River (Figure 1). The underlying, unexposed bedrock is undifferentiated granite or granite gneiss.

The 19 m high section exposes 6 m of fluvial sand and gravel overlying 13 m of olive-grey (5Y 5/2), compact, blocky and manganese stained till (Figure 2). The till appears uniform throughout with no obvious geological contacts, although the lower part of the section is finer textured than the upper part. The pebble fabric, 6 m below the contact with the fluvial sediments, indicates ice flow towards the south-southeast (155º), whereas the fabric at the 12 m level, near the bottom of the section, is orientated slightly west of south (190º). The differences in the orientation of the pebble fabrics clearly indicate different ice-flow trajectories. Two tills correlated with the Amery and Long Spruce tills were identified in the field, based on differences in pebble fabrics and texture. However, the position of the contact between the two tills was not identified.

Texture, pebble lithology and geochemistry

The percentages of sand in the six samples from this section are generally low and those of clay are high but variable (Appendices 1A and 1B). The lower three samples are particularly high in clay and low in silt. The same three samples show an increase in red carbonate and are noticeably low in oolitic jasper, volcanic, sandstone and mafic crystalline pebbles, suggesting that these samples are correlated with the Amery till. Brown carbonate pebbles decrease markedly up through the Amery till and increase again up through the overlying Long Spruce till. This is opposite to the behaviour of greywacke pebble concentrations, which increase through the Amery till and decrease in the Long Spruce till. The high concentrations of Omarolluk greywacke pebbles in the lower part of the section confirm its assignment to the Amery till. Concentrations of volcanic, sandstone and mafic crystalline pebbles are all relatively high in the Long Spruce till. The texture and pebble composition indicate that the contact between the two units is at the 13 m level in the section.

In the <2 µm fraction, zinc, cobalt, iron, manganese, barium, chromium, vanadium and titanium increase up through the Amery till (Appendices 2A and 2B). The Amery till has higher concentrations of cobalt, manganese and barium than the overlying Long Spruce till, whereas the Long Spruce till has higher concentrations of sulphur than the Amery till.

In the <63 µm fraction, concentrations of arsenic, barium, cobalt, chromium, iron, rubidium, scandium, thorium and many of the rare earth elements increase, whereas bromine and calcium decrease, up through the Amery till (Appendices 3A and 3B). Arsenic, cobalt, nickel, rubidium, scandium and thorium decrease, while bromine increases, through the Long Spruce till.

STRATIGRAPHIC INTERPRETATION

The seven sections (Figure 2) expose thick till accumulations that are generally capped by glaciolacustrine silt and clay deposits, postglacial marine sediments and, in places, Holocene alluvium. Three distinct tills were identified in the field, based on colour, fabric, texture of the matrix and stratigraphic position. Till fabrics, pebble counts, and textural and geochemical data have confirmed the field observations and helped to more accurately define the contacts between units not visible in the field. A composite stratigraphic section is presented in Figure 3.

The oldest till exposed in the area is olive-grey Amery till. In sections 1 and 6, it underlies nonglacial sediments, interpreted to be Sangamonian interglacial beds. In sections 2, 4 and 7, it underlies Long Spruce till. A tentative correlation with the Amery till on the Nelson River is based on stratigraphic position, fabric and pebble composition. Pebble fabrics measured at six sites indicate that ice flow was initially towards the southwest and then changed towards the south and southeast. Striations on a boulder pavement in section 6 further suggest that ice flow was towards 235–250º, a conclusion supported by the relative abundance of erratics of more easterly provenance. Amery till has not been found in the multimedia surveys in the

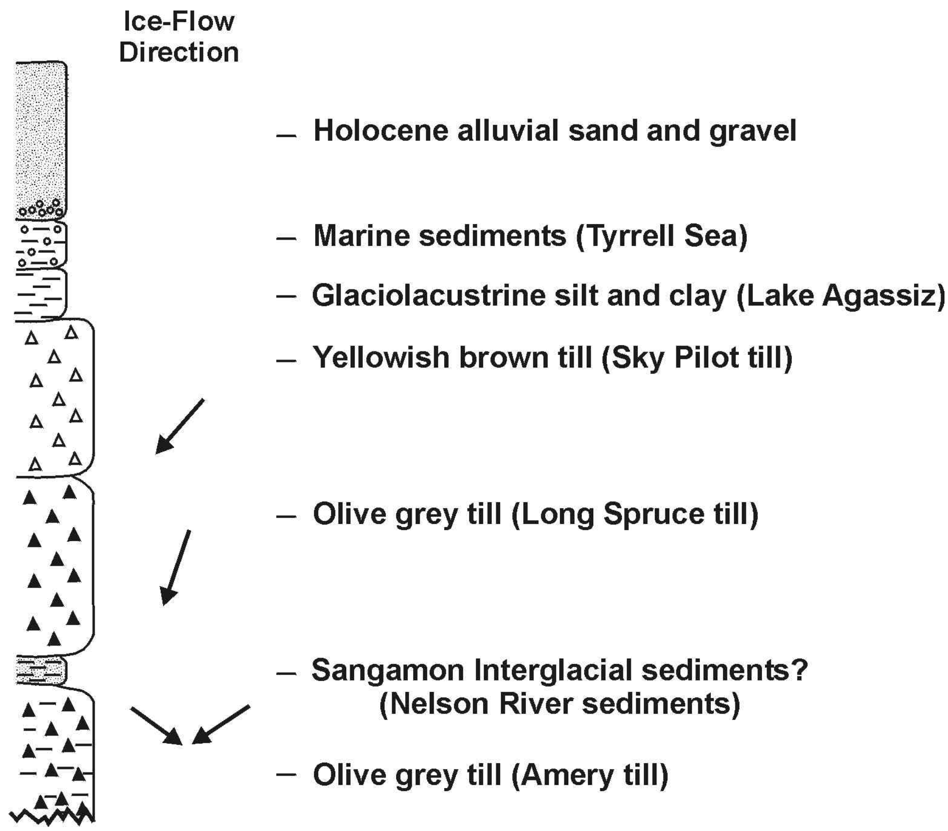

Figure 3: Composite stratigraphic section along the Hayes River, with ice-flow directions and correlation with Quaternary sediments along the Nelson River.

northern Superior Province. Eighteen samples were collected for analysis.

The till stratigraphically overlying the nonglacial Nelson River sediments is olive grey and outcrops in all seven exposures examined. It is a fine-textured till that has not previously been seen in hand-dug pits in the northern Superior Province multimedia surveys, and it is correlated with the Long Spruce till on the Nelson River. Thirty-four samples of Long Spruce till were collected for analysis. Pebble fabrics measured at nine sites record ice flow towards 195º, although there is considerable scatter in the orientations. Striation measurements on a boulder pavement in section 1 indicate ice flow towards 210–215º. Striations measured on bedrock exposed in the Stupart River, not far from section 3 and at approximately the same elevation as the base of the section, record ice flow towards 220º. These striations are not positively correlated with the Long Spruce till. A northerly provenance for this till, as indicated by the fabrics, is supported by the pebble composition.

The uppermost, yellowish brown till is exposed only in sections 1, 5 and 6. This is the surface till throughout the Hudson Bay Lowland and adjacent parts of the northern Superior Province, but it is underrepresented in exposures along the river valleys because of erosion during postglacial valley incision. Similar, fine-textured, yellowish brown till was encountered at a few sites in the Knee Lake area (Fedikow et al., 2002). It is correlated with the Sky Pilot till exposed along the Nelson River. Seventeen samples of Sky Pilot till were collected for analysis. Pebble fabrics measured at three sites indicate that Sky Pilot till was deposited by ice flowing towards 225º, which is consistent with ice flow recorded in the Knee Lake area and elsewhere.

Four sections are capped by glaciolacustrine silt and clay deposited in glacial Lake Agassiz; fossiliferous marine sediments including gravel, sand, silt and clay deposited in the Tyrrell Sea; and/or Holocene alluvial sand and gravel. Two samples of coarse, sandy alluvium were taken for kimberlite indicator-mineral analysis, one from each of sections 2 and 7.

KIMBERLITE INDICATOR-MINERAL SURVEY

A total of 69 till and two gravel samples from the seven sections were submitted for kimberlite indicator-mineral analysis. The distribution of kimberlite indicator minerals in the samples is shown in Figure 4 and the mineral chemistry and classification are given in Appendix 4. The number of indicator minerals recovered was low compared to samples from other parts of the northern Superior Province submitted in previous years (Fedikow et al., 2001). The Holocene gravel sample collected from the top of section 2 contained three Cr-spinel grains and one Mg-ilmenite grain. The single sample of Holocene sand and gravel, from the top of section 7, produced one Cr-spinel grain. From the 17 samples of Sky Pilot till, only two grains were found: a Mg-ilmenite and a Cr-spinel in samples 2 and 6 from section 1. The remaining 14 kimberlite indicator-mineral grains were recovered from 34 samples identified as Long Spruce till, and included two G7, two G9, four

G11 and six Cr-spinel grains. Indicator minerals were not recovered from any of the 18 Amery till samples. Clearly the distribution of indicators is non-random, as the majority of the grains were found in Long Spruce till samples. Indicator minerals recovered from Holocene sand and gravel and Sky Pilot till samples are probably reworked from underlying deposits of Long Spruce till.

Measured fabrics of Long Spruce till suggest that the ice flow was towards 200–215º. This ice-flow direction is, how ever, not very different from that of the overlying Sky Pilot till, which has been measured at 220–247º in the Knee Lake area immediately to the south, or the underlying Amery till, which has a variable fabric ranging between 110º and 250º. Clearly all three tills have a northern or northeastern provenance, so why is the distribution of kimberlite indicator minerals concentrated in the Long Spruce till? Colour, textural, lithological and chemical differences between the Sky Pilot and Long Spruce tills suggest different source areas. The yellowish brown colour of the Sky Pilot till has been shown to be the result of incorporation of yellowish brown Devonian carbonate bedrock from central Hudson Bay (Thorleifson et al., 1993). The origin of the olive-grey colour of the Long Spruce and Amery tills is unknown, but the proportion of Devonian rocks is generally lower than in the other tills, suggesting a different source area(s).

SUMMARY AND CONCLUSIONS

Tills outcropping along river valleys in the Hudson Bay Lowland and adjacent parts of the northern Superior Province have been correlated in the field with tills outcropping along the Nelson River. Correlation in the field was based on texture, colour, fabric and stratigraphic position of the tills. These correlations were subsequently refined and, in some cases, the contacts were moved slightly using the results from textural analysis, pebble counts and geochemical analysis.

Amery, Long Spruce and Sky Pilot tills were identified in the seven sections. Amery till, which is the oldest till identified in the present survey, was present in six sections. The fabrics of the Amery till are variable and suggest a change in the ice-flow trajectory from 110º to 250°. The eighteen samples of Amery till contained no kimberlite indicator minerals.

Amery till is overlain by interglacial deposits in two sections. The interglacial deposits or the Amery till is overlain by Long Spruce till, which outcrops in all seven sections. This till is olive grey in colour and the fabrics suggest a north-north-easterly provenance. The 34 Long Spruce till samples contained 14 kimberlite indicator-mineral grains.

In three sections, Long Spruce till is overlain by yellowish brown Sky Pilot till, which is the surface till throughout the Hudson Bay Lowland and adjacent northern Superior province. The colour of this till is unique, having been derived from the comminution of yellowish brown Devonian rocks subcropping in Hudson Bay. Fabric measurements indicate a northeasterly provenance for Sky Pilot till. Of the 17 samples of Sky Pilot till collected during the present survey, two samples from section 1 each had one kimberlite indicator-mineral grain. These two grains are believed to have been reworked from the underlying Long Spruce till.

Fluvial sand and gravel samples collected near the top of two sections contained five kimberlite indicator-mineral grains. These grains have probably been reworked from Long Spruce till, which underlies the fluvial sediments in both sections.

The distribution of kimberlite indicator minerals in the 69 till samples collected from the seven sections is non-random, with the majority of grains occurring in the Long Spruce till. Long Spruce till is the till that should be sampled to determine the source of kimberlite indicator minerals in the Hudson Bay Lowland and northern Superior Province of Manitoba. Fabric measurements and striations on a boulder pavement indicate that the Long Spruce till ice flow was towards 210–215º.

RECOMMENDATIONS

Although kimberlite indicator minerals in the Hudson Bay Lowland and adjacent parts of northeastern Manitoba appear to be almost completely restricted to Long Spruce till, their concentrations are low compared to the results from surveys in the northern Superior Province. The low concentrations suggest that the present survey area is possibly the distal part of a glacial-dispersion train. Alternatively, the grains may have been reworked from a dispersion train occurring in an older till that may subcrop north of the present survey area. Additional sampling of sections to the north and northeast of the present survey is recommended to determine the origin of the kimberlite indicator minerals. Long Spruce till should not be the exclusive focus of future surveys until it has been determined that kimberlite indicator minerals do not occur in older tills subcropping further to the north.

ACKNOWLEDGMENTS

Chris Bater and Ryan Oger were able and enthusiastic field assistants and we are indebted to them for their hard work and geological insights throughout the summer. I also wish to thank our helicopter pilot, Alain Dejardins (Provincial Helicopters Ltd., Lac du Bonnet) for his considerable skill and good judgment in piloting us safely.

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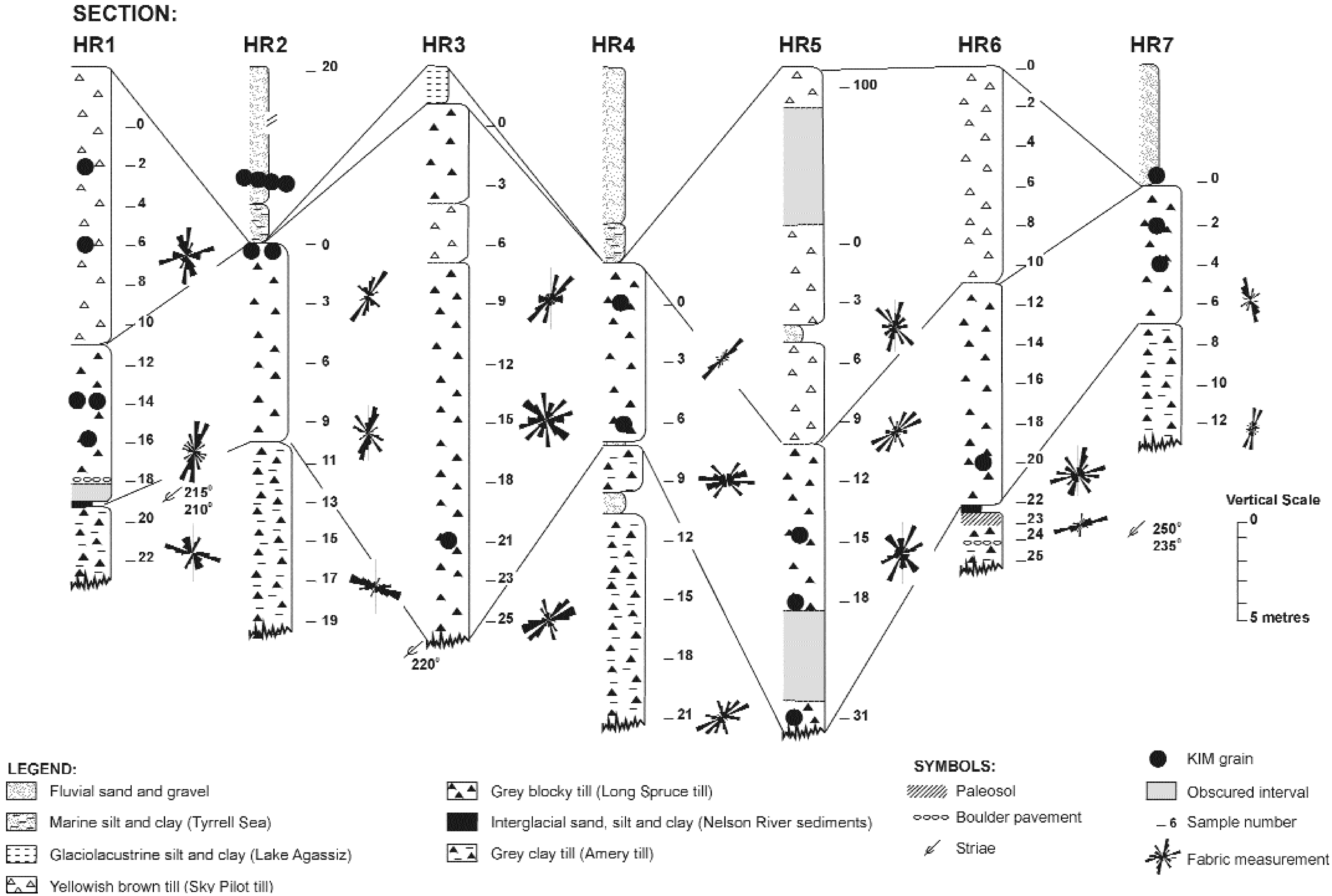

Figure 4: Stratigraphic correlation and distribution of kimberlite indicator minerals in the tills of the lower Hayes River area.

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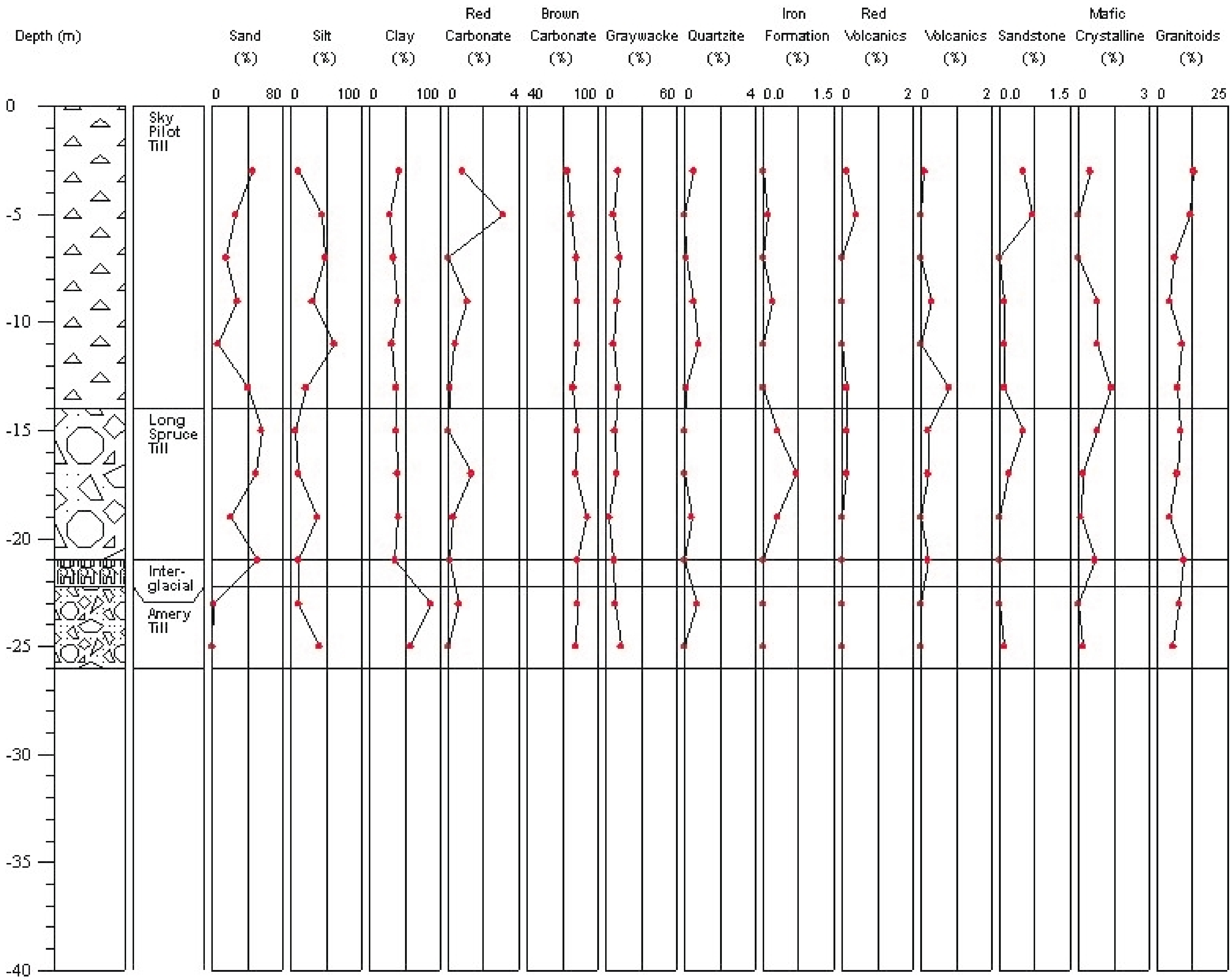
Appendix 1A: Texture and Pebble Count Data. (Shown Graphically)

Section HR1



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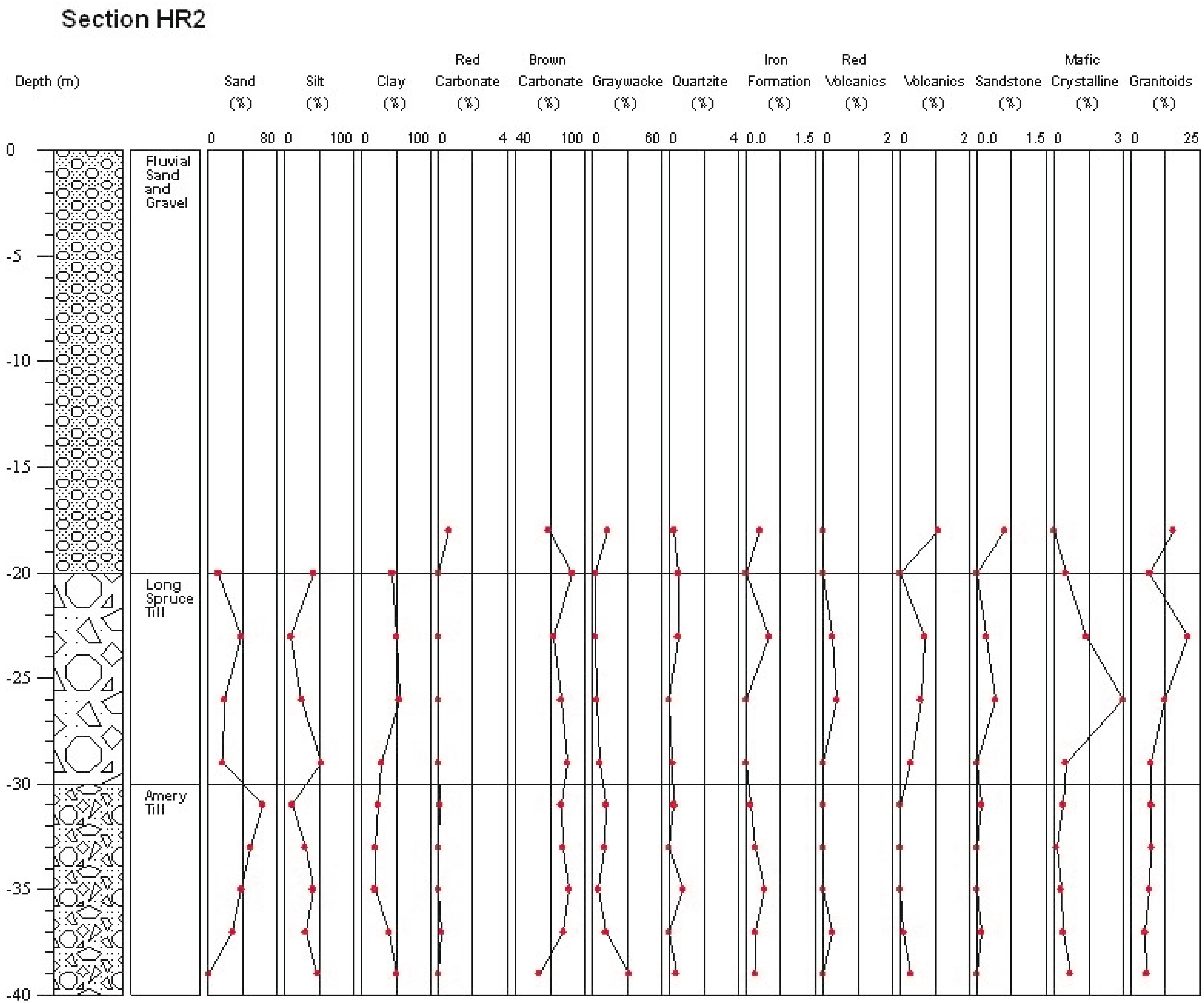

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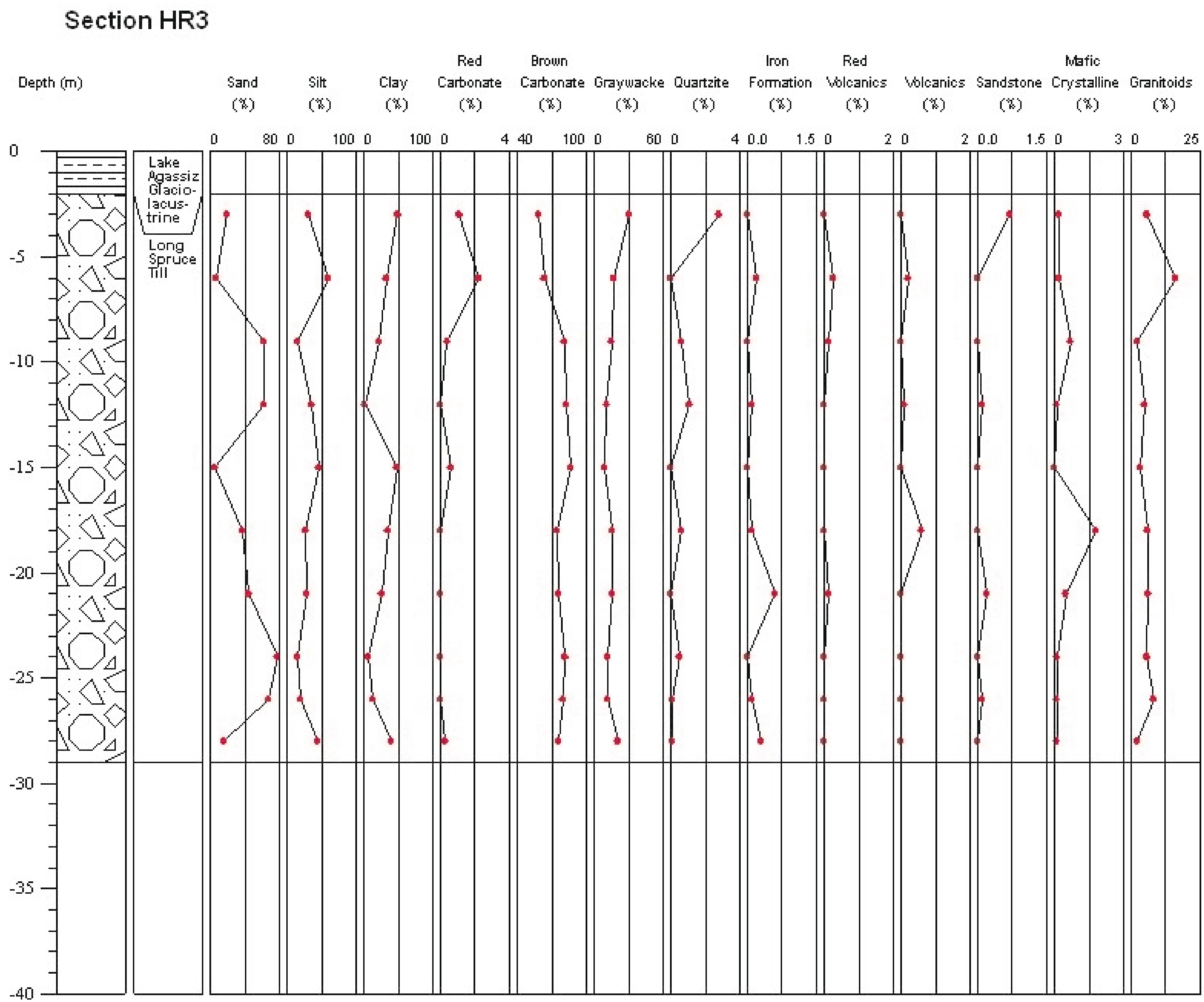
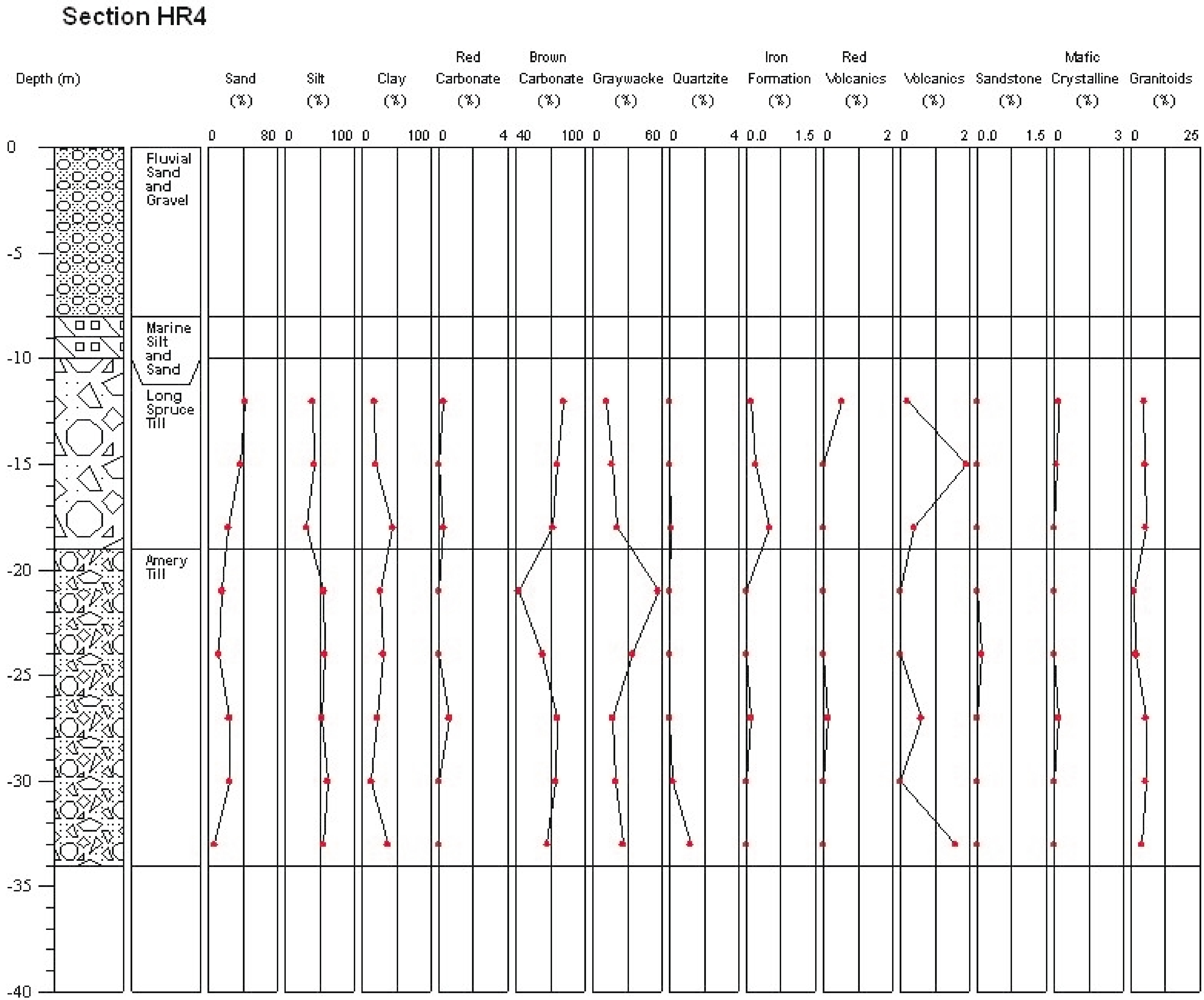
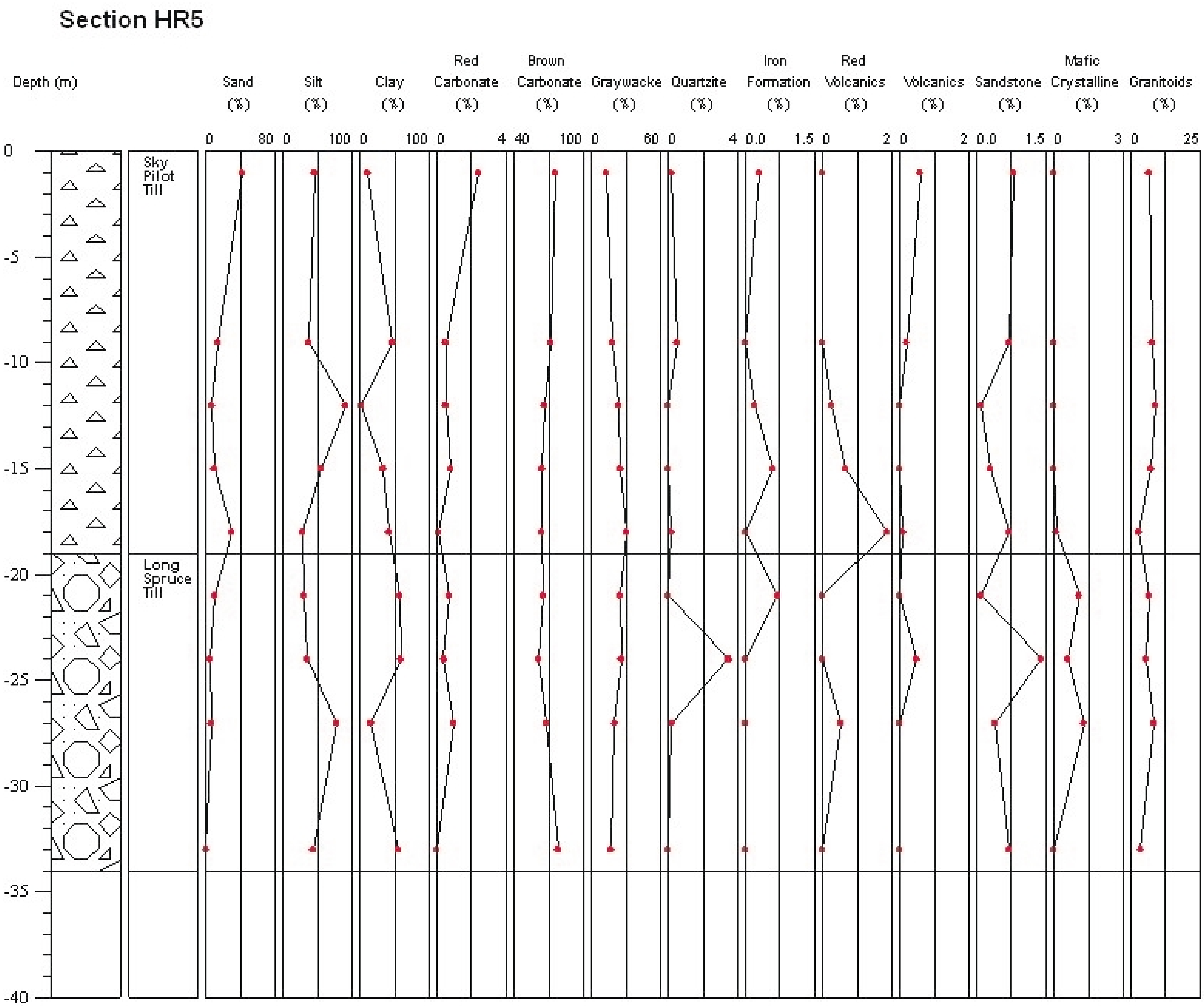


Appendix 1A: Texture and Pebble Count Data. (Shown Graphically) *(continued)*



Appendix 1A: Texture and Pebble Count Data. (Shown Graphically) *(continued)*



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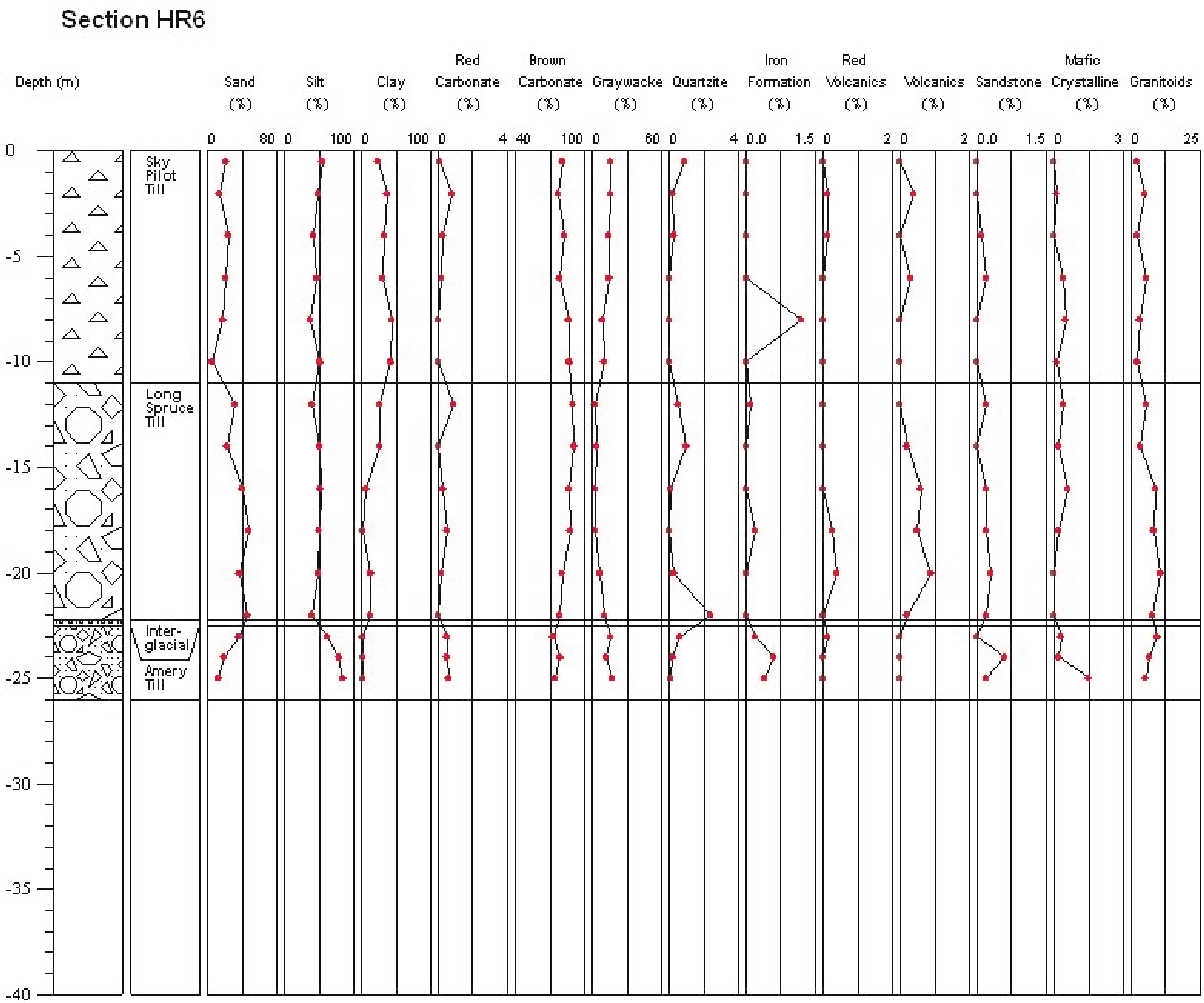

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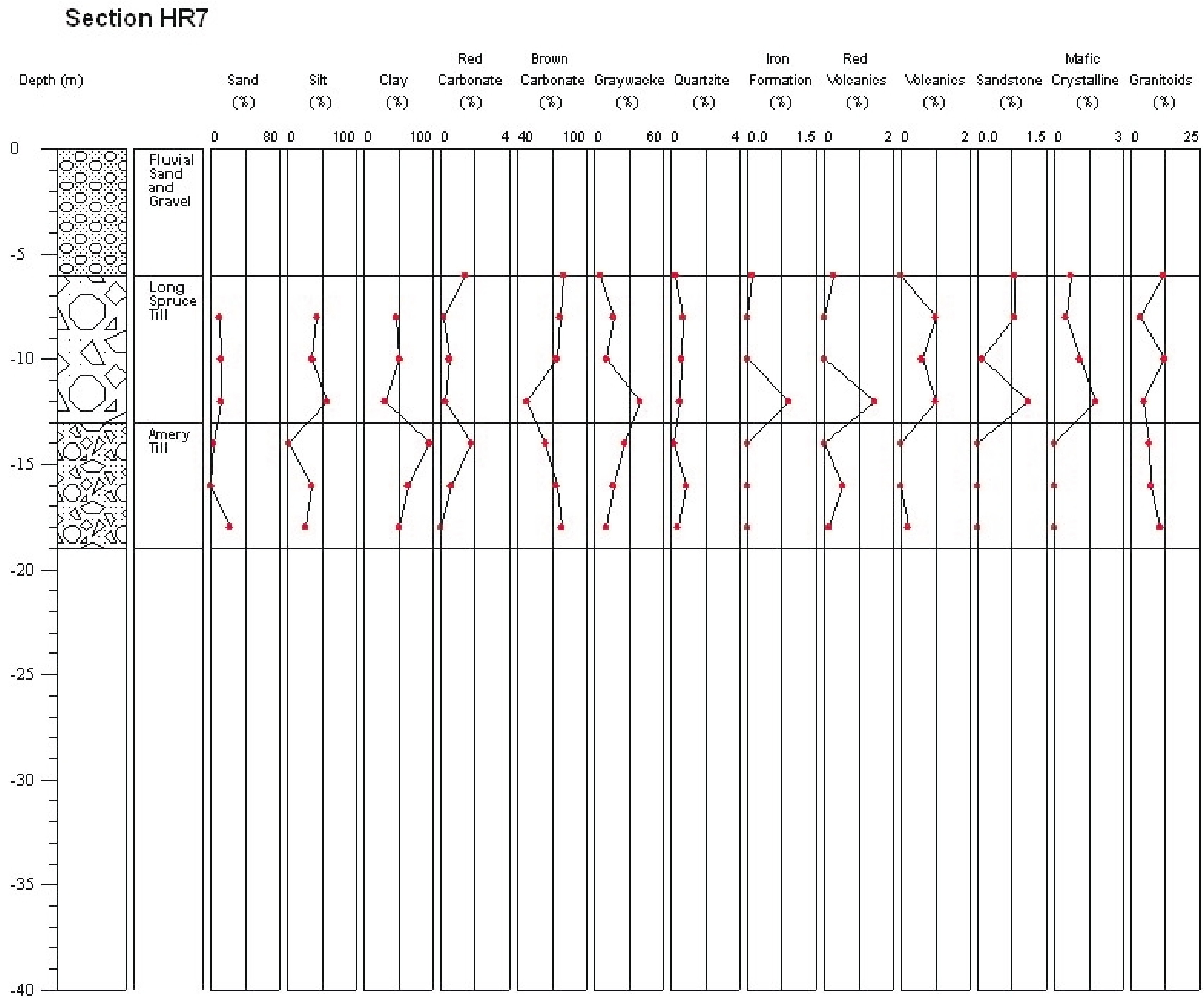


Appendix 1B: Texture And Pebble Count Data (as Percentages)

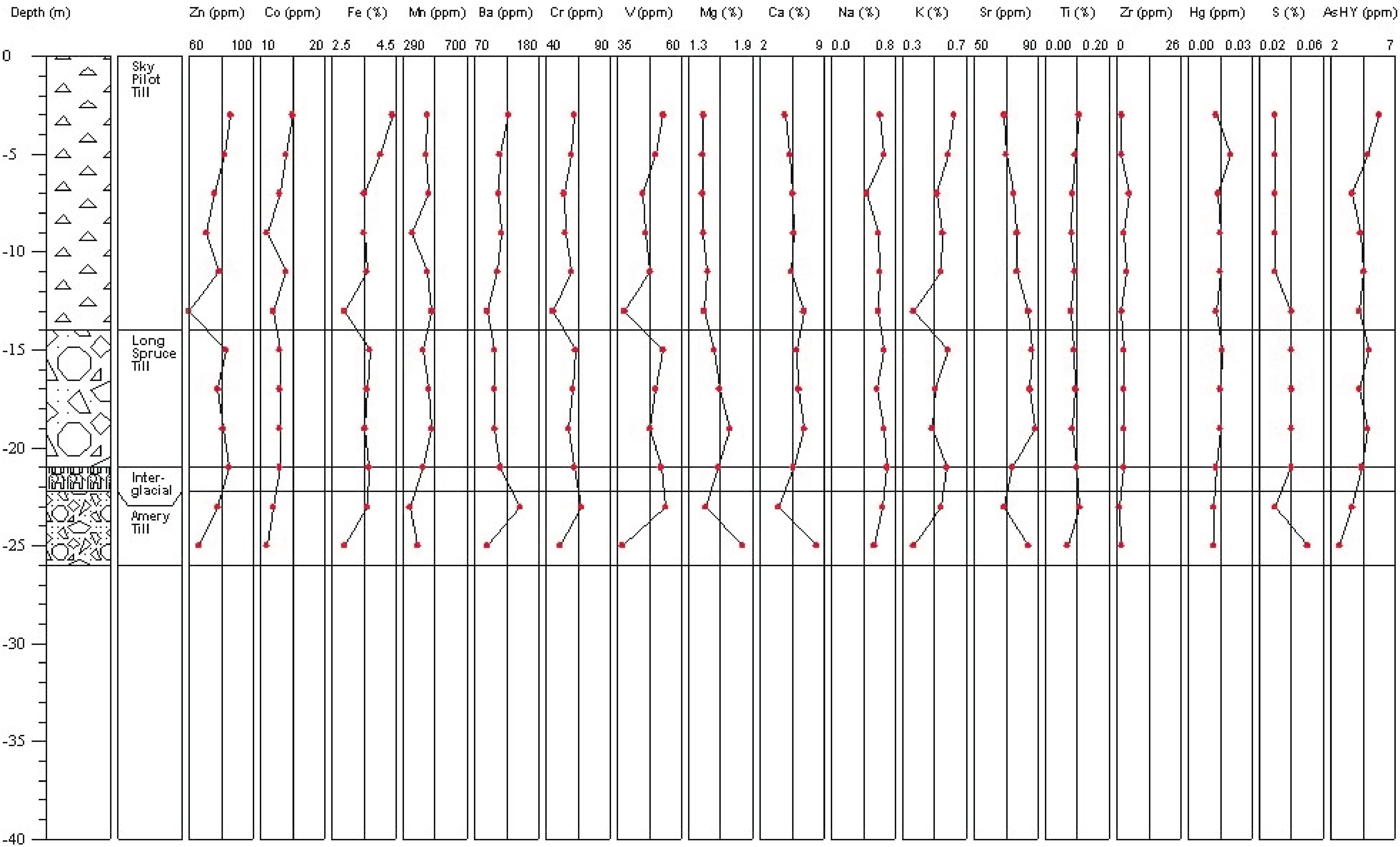
Section 1	Depth	Sand	Silt	Clay	Red Carbonate	Brown Carbonate	Greywacke	Quartzite	Iron Formation	Red Volcanics	Volcanics	Sandstone	Mafic Crystalline	Granitoids
HR1-01-00	3	46.49	11.51	42.00	0.8	74.1	10.3	0.5	0.0	0.1	0.1	0.5	0.5	13.0
HR1-01-02	5	26.36	44.30	29.35	3.1	77.9	6.1	0.0	0.1	0.3	0.0	0.7	0.0	11.9
HR1-01-04	7	16.62	49.06	34.32	0.0	82.0	11.6	0.1	0.0	0.0	0.0	0.0	0.0	6.3
HR1-01-06	9	29.12	30.49	40.40	1.1	82.7	9.8	0.5	0.2	0.0	0.3	0.1	0.8	4.5
HR1-01-08	11	6.64	61.38	31.98	0.4	82.8	6.3	0.8	0.0	0.0	0.0	0.1	0.8	8.7
HR1-01-10	13	40.63	21.46	37.91	0.1	79.2	10.9	0.1	0.0	0.1	0.8	0.1	1.4	7.2
HR1-01-12	15	56.08	6.02	37.91	0.0	82.4	7.5	0.0	0.3	0.1	0.2	0.5	0.8	8.2
HR1-01-14	17	49.84	10.79	39.37	1.3	81.2	9.2	0.0	0.7	0.1	0.2	0.2	0.2	7.0
HR1-01-16	19	21.64	37.31	41.04	0.3	91.3	3.1	0.4	0.3	0.0	0.0	0.0	0.1	4.4
HR1-01-18	21	51.74	11.63	36.63	0.1	82.5	7.3	0.0	0.0	0.0	0.2	0.0	0.7	9.3
HR1-01-20	23	1.43	11.88	86.70	0.6	82.5	8.3	0.7	0.0	0.0	0.0	0.0	0.0	7.9
HR1-01-22	25	0.54	40.87	58.58	0.0	81.1	12.9	0.0	0.0	0.0	0.0	0.1	0.2	5.7
Section 2														
HR2-01-20	18				0.6	68.7	13.0	0.3	0.3	0.0	1.1	0.6	0.0	15.3
HR2-01-00	20	13.00	41.93	45.07	0.0	89.5	2.6	0.5	0.0	0.0	0.0	0.0	0.5	6.9
HR2-01-03	23	39.31	9.63	51.06	0.0	73.1	2.9	0.5	0.5	0.2	0.7	0.2	1.4	20.5
HR2-01-06	26	19.85	25.45	54.71	0.0	79.6	3.9	0.0	0.0	0.3	0.6	0.4	3.0	12.2
HR2-01-09	29	17.41	53.29	29.31	0.0	85.1	6.7	0.2	0.0	0.0	0.3	0.0	0.5	7.2
HR2-01-11	31	63.96	11.44	24.60	0.1	79.6	12.2	0.3	0.1	0.0	0.0	0.1	0.4	7.4
HR2-01-13	33	50.06	30.08	19.86	0.0	81.4	10.7	0.0	0.2	0.0	0.0	0.0	0.1	7.5
HR2-01-15	35	39.67	41.32	19.01	0.0	86.4	5.5	0.8	0.4	0.0	0.0	0.0	0.3	6.6
HR2-01-17	37	29.33	30.40	40.27	0.2	82.0	11.5	0.0	0.2	0.2	0.1	0.1	0.4	5.2
HR2-01-19	39	1.72	47.71	50.57	0.0	60.7	31.9	0.4	0.2	0.0	0.3	0.0	0.7	5.8
Section 3														
HR3-01-00	3	19.15	31.40	49.45	1.1	58.5	30.9	2.8	0.0	0.0	0.0	0.7	0.2	5.8
HR3-01-03	6	7.24	60.33	32.43	2.2	63.6	17.3	0.0	0.2	0.2	0.2	0.0	0.2	16.0
HR3-01-06	9	62.56	15.38	22.05	0.4	80.9	15.4	0.6	0.0	0.1	0.0	0.0	0.7	2.1
HR3-01-09	12	62.65	36.14	1.20	0.0	82.5	11.3	1.1	0.1	0.0	0.1	0.1	0.1	4.8
HR3-01-12	15	5.96	46.05	47.99	0.6	86.6	9.6	0.0	0.0	0.0	0.0	0.0	0.0	3.2
HR3-01-15	18	37.64	27.59	34.77	0.0	74.8	16.1	0.6	0.1	0.0	0.6	0.0	1.8	5.9
HR3-01-19	21	45.00	28.95	26.05	0.0	76.0	16.3	0.0	0.6	0.1	0.0	0.2	0.5	6.3
HR3-01-21	24	77.75	16.09	6.17	0.0	81.7	11.9	0.5	0.0	0.0	0.0	0.0	0.1	5.8
HR3-01-23	26	67.43	19.62	12.95	0.0	79.5	12.0	0.1	0.1	0.0	0.0	0.1	0.1	8.1
HR3-01-25	28	16.14	44.14	39.72	0.3	76.3	20.8	0.1	0.3	0.0	0.0	0.0	0.1	2.2
Section 4														
HR4-01-00	12	42.33	39.19	18.48	0.3	81.8	12.3	0.0	0.1	0.4	0.2	0.0	0.2	4.7
HR4-01-03	15	37.73	42.32	19.95	0.0	75.9	16.7	0.0	0.2	0.0	1.9	0.0	0.1	5.2
HR4-01-06	18	23.89	30.94	45.17	0.3	72.4	21.0	0.1	0.5	0.0	0.4	0.0	0.0	5.3
HR4-01-09	21	16.67	56.39	26.94	0.0	42.2	56.7	0.0	0.0	0.0	0.0	0.0	0.0	1.0
HR4-01-12	24	12.57	57.14	30.29	0.0	63.3	34.6	0.0	0.0	0.0	0.0	0.1	0.0	1.9
HR4-01-15	27	24.36	53.55	22.09	0.6	75.8	17.3	0.0	0.1	0.1	0.6	0.0	0.2	5.3
HR4-01-18	30	24.54	61.35	14.11	0.0	74.6	19.8	0.2	0.0	0.0	0.0	0.0	0.0	5.3
HR4-01-21	33	7.64	55.56	36.81	0.0	67.3	26.1	1.2	0.0	0.0	1.6	0.0	0.0	3.9

Appendix 1B: Texture And Pebble Count Data (as Percentages) *(continued)*

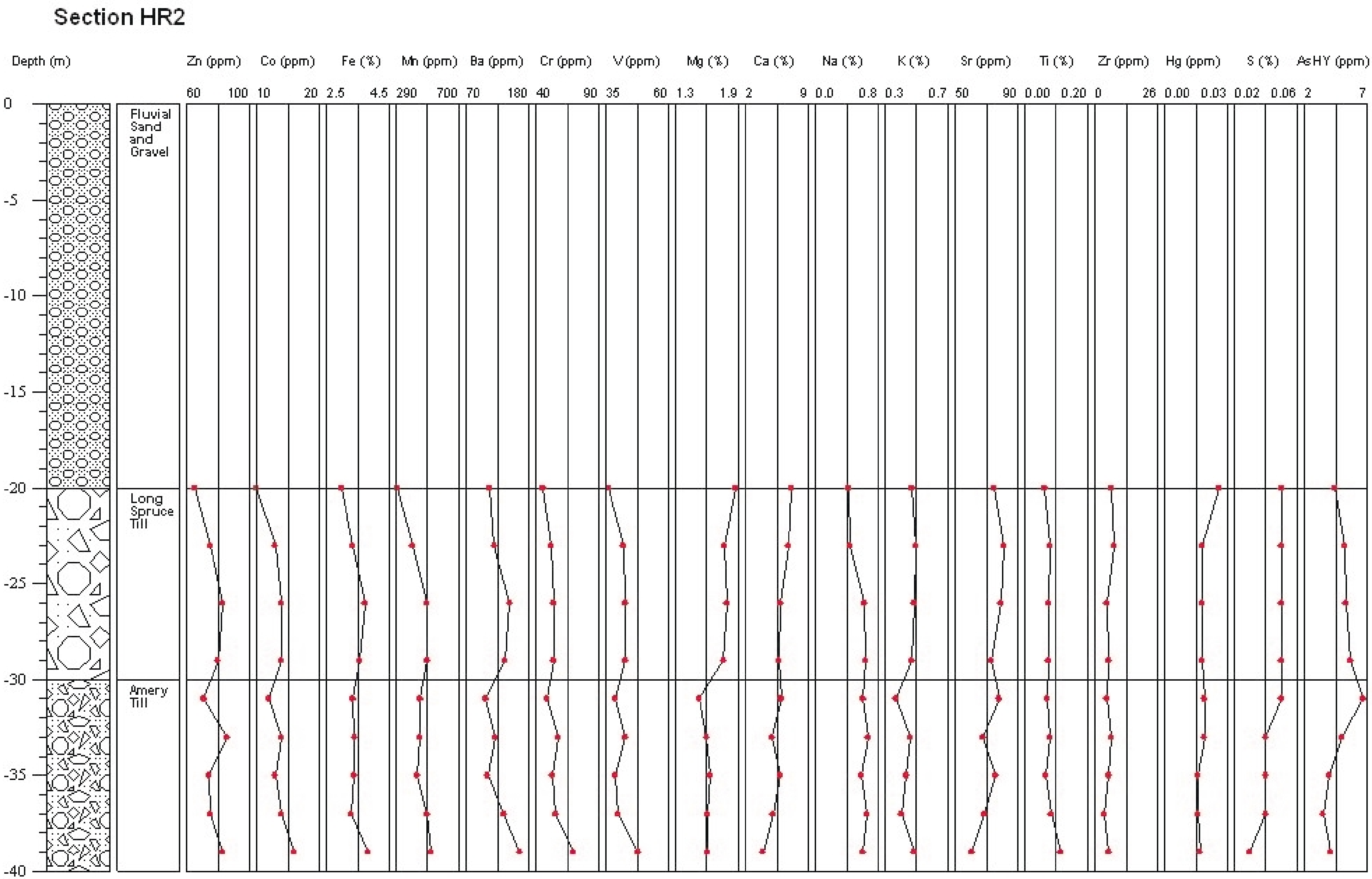
Section 5	Depth	Sand	Silt	Clay	Red Carbonate	Brown Carbonate	Greywacke	Quartzite	Iron Formation	Red Volcanics	Volcanics	Sandstone	Mafic Crystalline	Granitoids
HR5-01-100TOP	1	42.52	45.78	11.70	2.4	75.9	13.3	0.2	0.3	0.0	0.6	0.8	0.0	6.5
HR5-01-00	9	14.65	37.76	47.58	0.5	71.7	18.8	0.5	0.0	0.0	0.2	0.7	0.0	7.6
HR5-01-03	12	7.62	90.44	1.94	0.5	66.1	24.0	0.0	0.2	0.2	0.0	0.1	0.0	9.0
HR5-01-06	15	10.17	55.64	34.18	0.8	64.5	25.8	0.0	0.6	0.5	0.0	0.3	0.0	7.4
HR5-01-09	18	30.19	28.38	41.43	0.1	63.9	30.5	0.2	0.0	1.4	0.1	0.7	0.1	3.0
HR5-01-12	21	10.51	31.29	58.20	0.7	65.5	25.2	0.0	0.7	0.0	0.0	0.1	1.1	6.7
HR5-01-15	24	4.95	36.09	58.96	0.4	61.6	26.3	3.5	0.0	0.0	0.5	1.4	0.6	5.6
HR5-01-18	27	6.47	77.36	16.17	1.0	67.8	20.6	0.2	0.0	0.4	0.0	0.4	1.3	8.2
HR5-01-31	33	0.88	43.86	55.26	0.0	78.1	17.7	0.0	0.0	0.0	0.0	0.7	0.0	3.6
Section 6														
HR6-01-00	0.5	21.94	54.59	23.47	0.1	80.8	16.2	0.9	0.0	0.0	0.0	0.0	0.0	2.1
HR6-01-02	2	13.62	49.16	37.22	0.8	77.0	16.2	0.2	0.0	0.1	0.4	0.0	0.1	5.1
HR6-01-04	4	24.10	42.46	33.44	0.3	82.6	14.4	0.3	0.0	0.1	0.0	0.1	0.0	2.2
HR6-01-06	6	21.49	47.23	31.29	0.2	78.3	15.1	0.0	0.0	0.0	0.3	0.2	0.4	5.5
HR6-01-08	8	18.36	37.35	44.29	0.0	86.3	8.9	0.0	1.2	0.0	0.0	0.0	0.5	3.1
HR6-01-10	10	4.89	51.98	43.14	0.0	87.2	10.3	0.0	0.0	0.0	0.0	0.0	0.1	2.4
HR6-01-12	12	32.21	40.77	27.01	0.9	90.0	2.2	0.5	0.1	0.0	0.0	0.2	0.4	5.6
HR6-01-14	14	22.57	50.61	26.82	0.0	91.2	4.2	1.0	0.0	0.0	0.2	0.0	0.2	3.2
HR6-01-16	16	40.19	52.26	7.55	0.3	86.8	2.5	0.1	0.0	0.0	0.6	0.2	0.6	8.9
HR6-01-18	18	48.40	50.10	1.50	0.5	87.6	2.5	0.0	0.2	0.2	0.5	0.2	0.2	8.1
HR6-01-20	20	36.57	49.26	14.17	0.2	80.7	6.7	0.3	0.0	0.3	0.9	0.3	0.0	10.7
HR6-01-22	22	46.74	40.09	13.17	0.0	78.9	10.6	2.4	0.0	0.0	0.2	0.2	0.0	7.8
HR6-01-23	23	36.53	61.92	1.55	0.5	72.8	15.9	0.6	0.2	0.1	0.0	0.0	0.3	9.6
HR6-01-24	24	19.05	78.80	2.15	0.5	79.1	12.1	0.2	0.6	0.0	0.0	0.6	0.2	6.6
HR6-01-25	25	13.17	85.13	1.70	0.6	74.9	17.0	0.1	0.4	0.0	0.0	0.2	1.5	5.3
Section 7														
HR7-01-00	6				1.4	79.8	5.2	0.3	0.1	0.2	0.0	0.8	0.7	11.6
HR7-01-02	8	10.17	43.29	46.54	0.2	76.8	16.8	0.7	0.0	0.0	1.0	0.8	0.5	3.2
HR7-01-04	10	11.96	36.24	51.80	0.5	74.1	11.0	0.6	0.0	0.0	0.6	0.1	1.1	12.0
HR7-01-06	12	11.65	58.15	30.20	0.3	48.4	40.2	0.5	0.9	1.1	1.0	1.1	1.8	4.7
HR7-01-08	14	3.57	1.79	94.64	1.8	64.6	26.9	0.2	0.0	0.0	0.0	0.0	0.0	6.5
HR7-01-10	16	0.48	35.97	63.55	0.6	74.0	16.8	0.9	0.0	0.4	0.0	0.0	0.0	7.3
HR7-01-12	18	22.24	26.15	51.61	0.0	78.3	10.4	0.4	0.0	0.1	0.2	0.0	0.0	10.7

Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically)

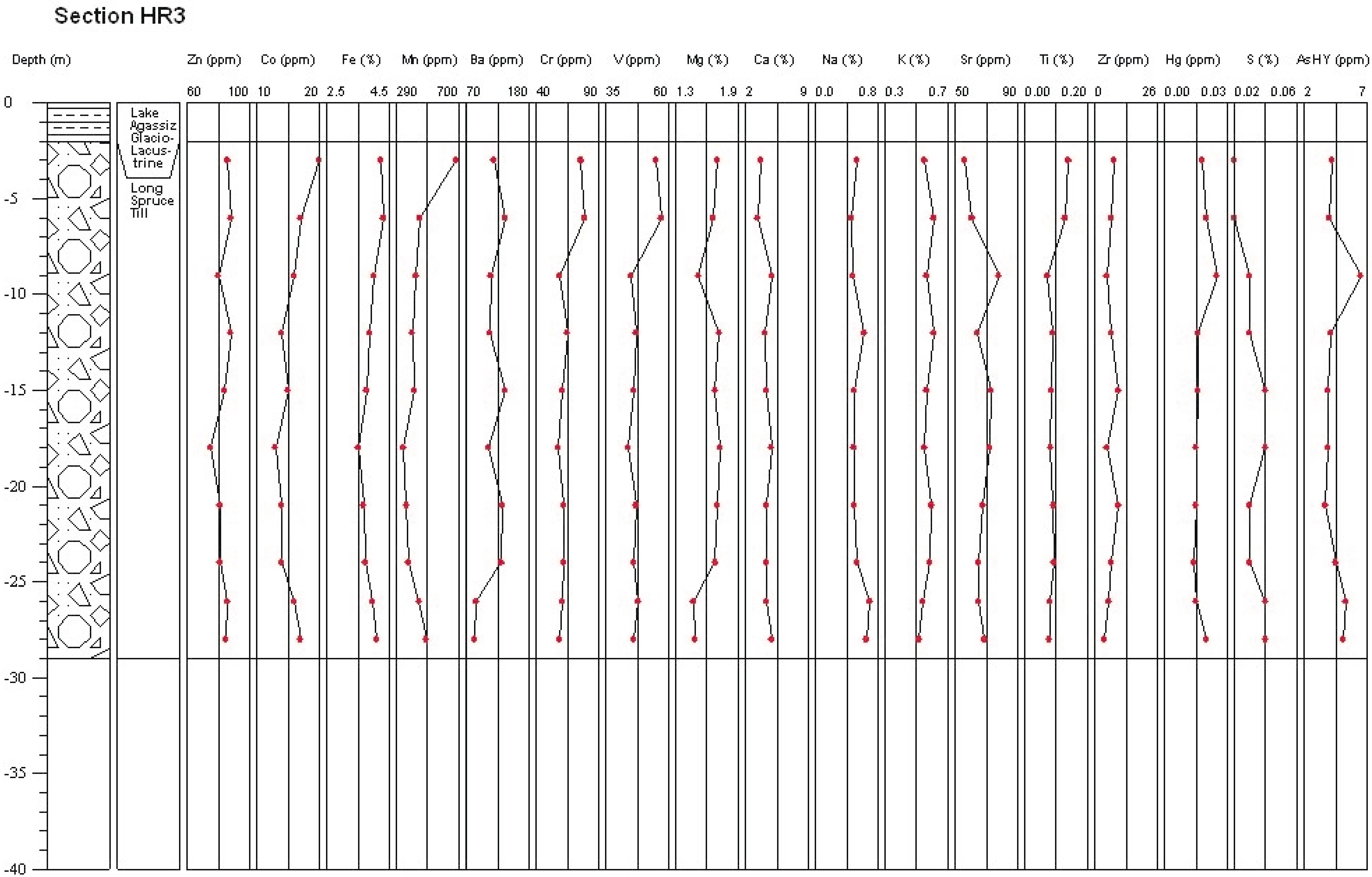
Section HR1



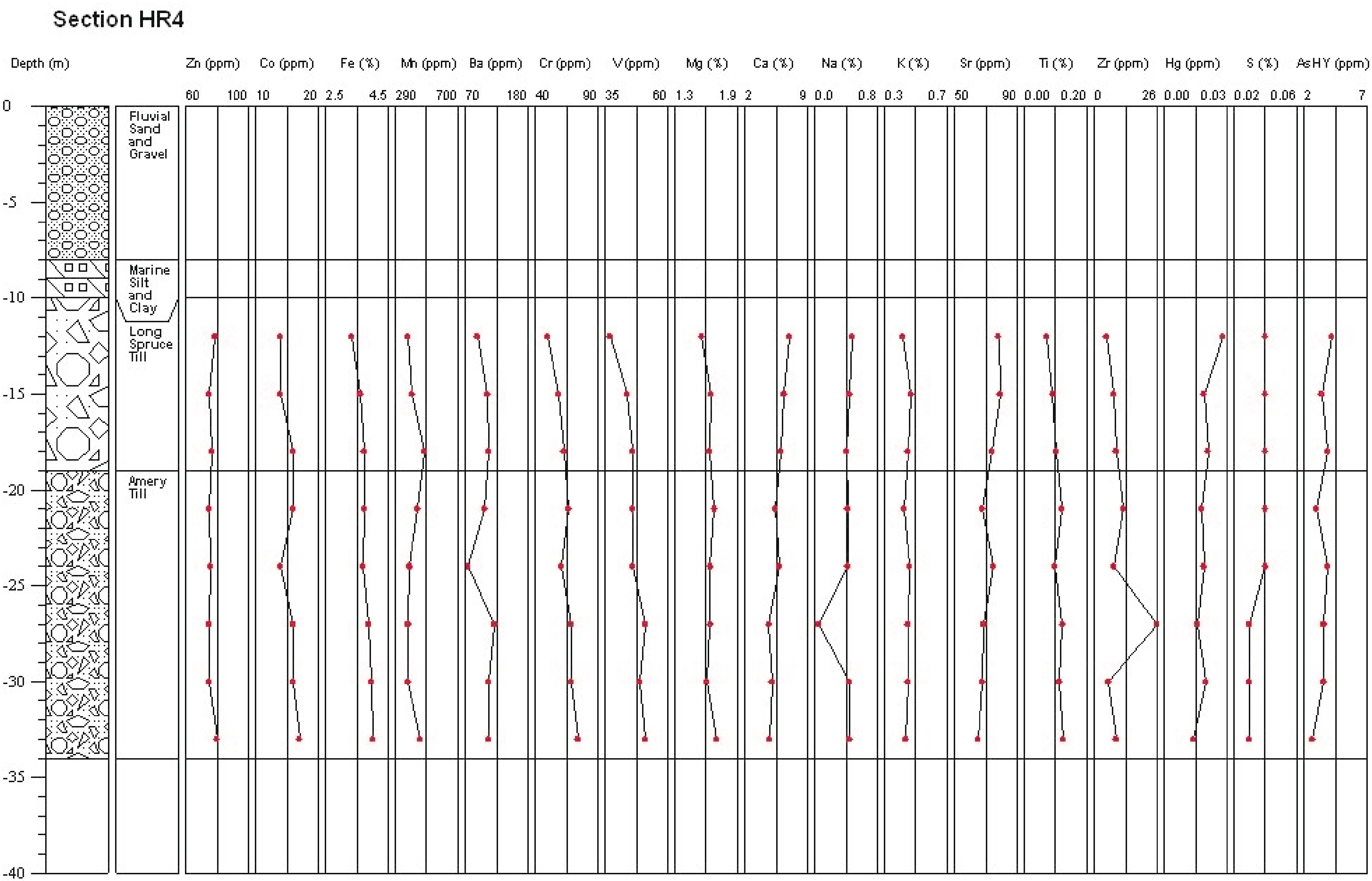
Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*



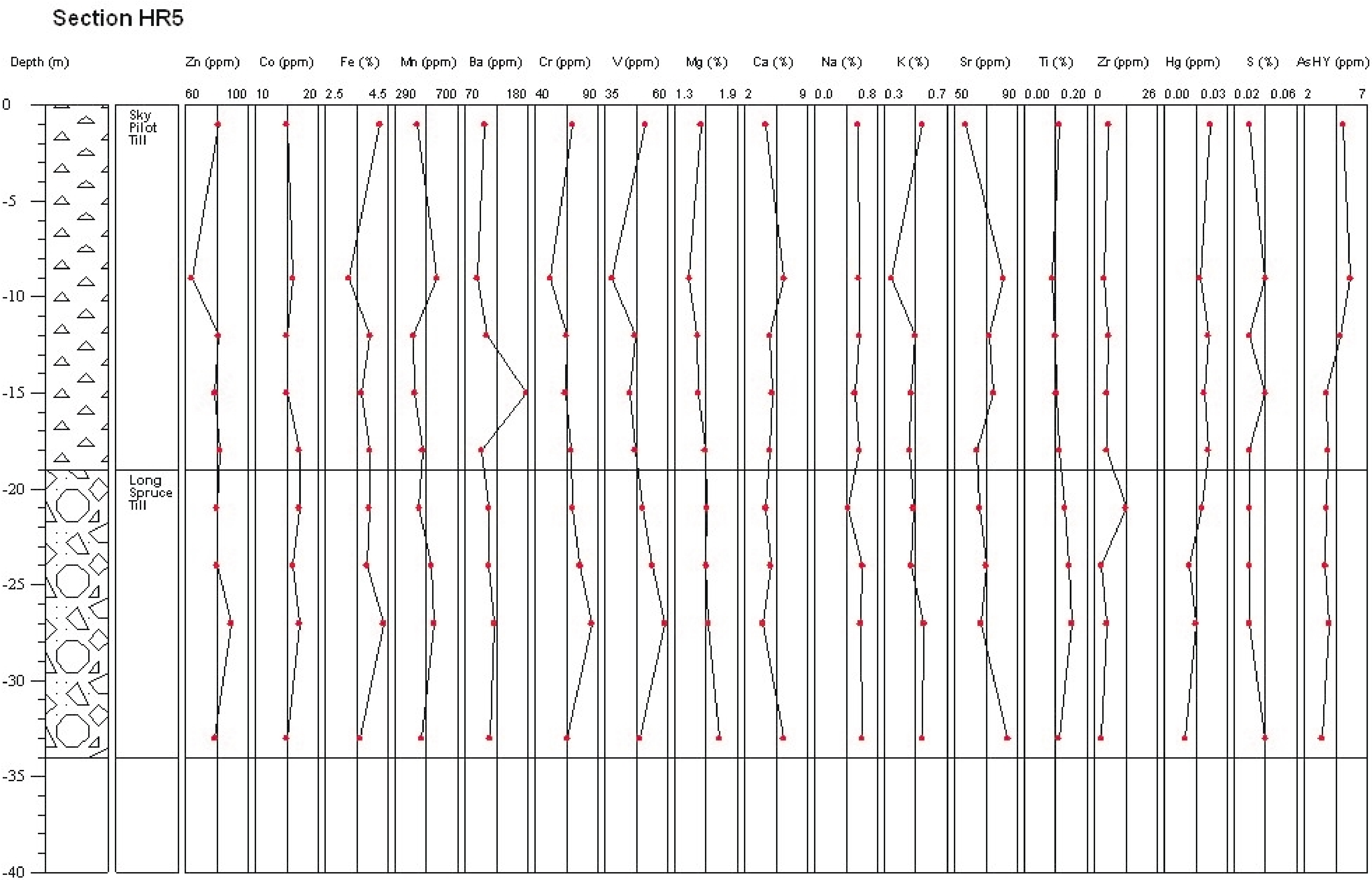
Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*



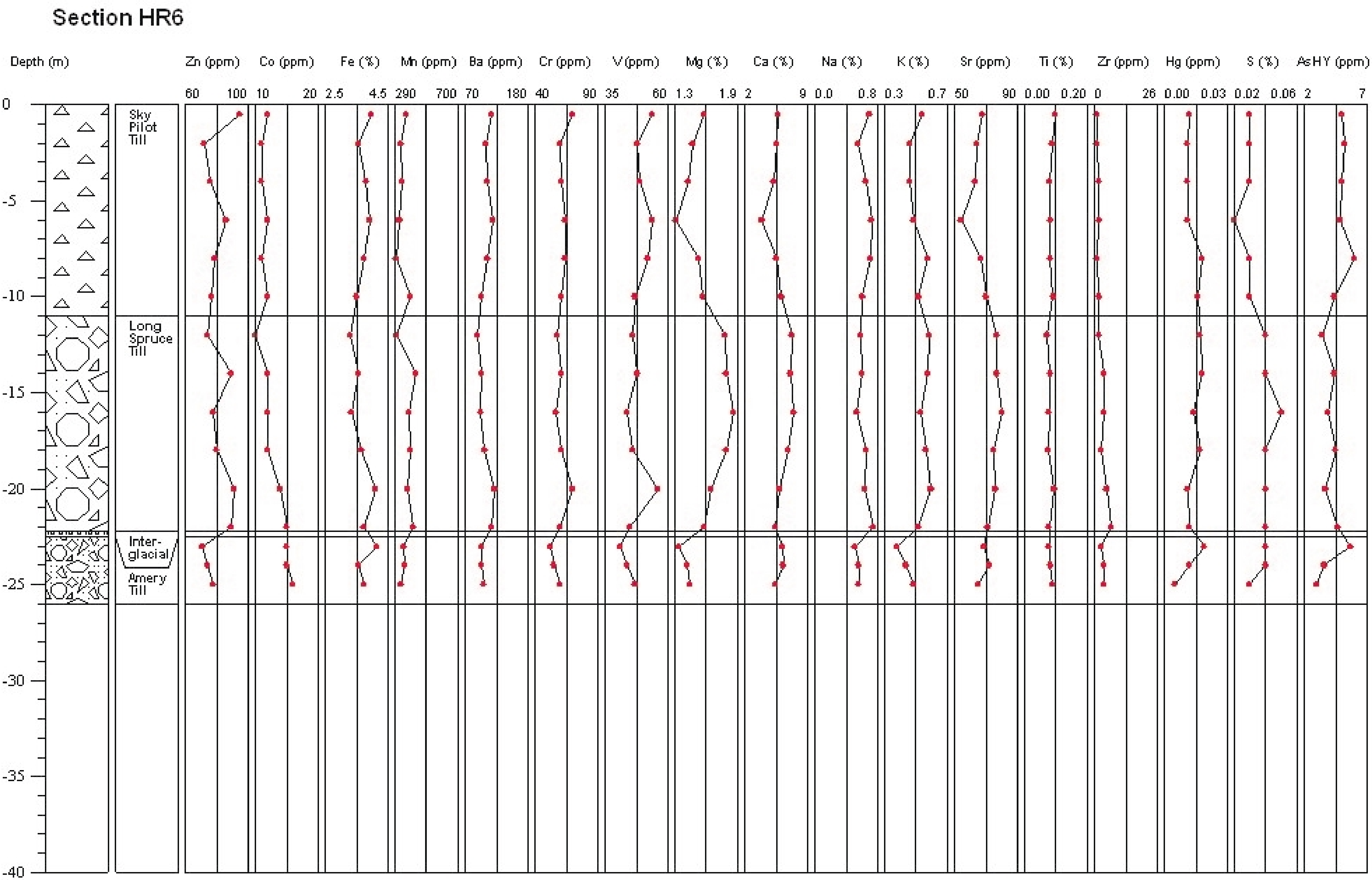
Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*



Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*

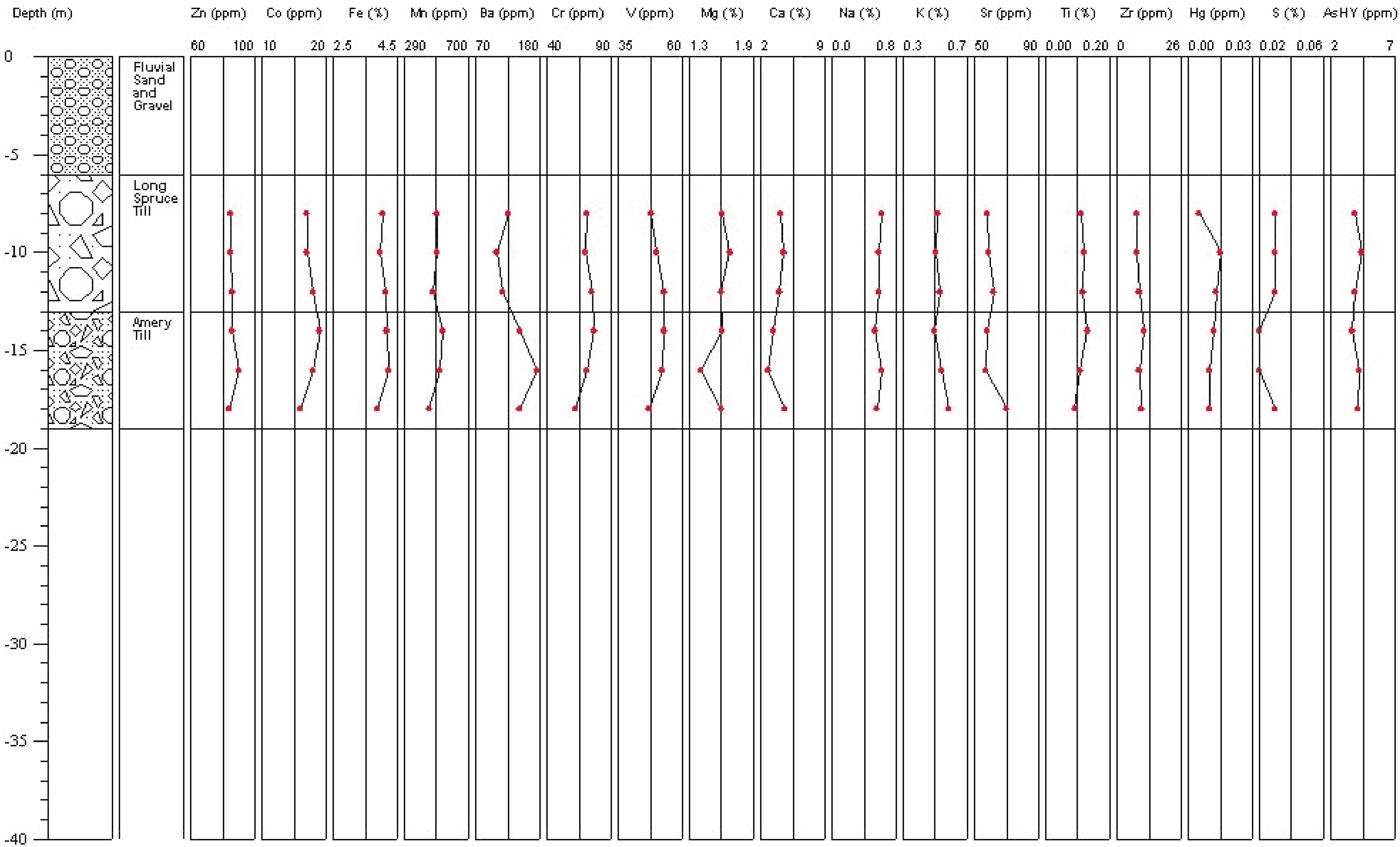


Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*



Appendix 2A: Geochemical Data for the <2 mm Size Fraction. (Shown Graphically) *(continued)*

Section HR7



Appendix 2B: Geochemical Data For The <2 mm Size Fraction

Section 1	Depth m	Zn ppm	Co ppm	Fe %	Mn ppm	Te ppm	Ba ppm	Cr ppm	V ppm	Mg %	Ca %	Na %	K %	Sr ppm	Ti %	Zr ppm	Hg ppm	S %	AsHY* ppm
HR1-01-00	3	86	15	4.39	443	5	129	62	53	1.44	4.73	0.61	0.63	69	0.105	2	0.013	0.03	5.8
HR1-01-02	5	82	14	4.03	436	5	113	60	50	1.43	5.27	0.66	0.60	70	0.092	2	0.020	0.03	4.9
HR1-01-04	7	76	13	3.51	452	5	111	54	45	1.43	5.62	0.44	0.54	75	0.085	5	0.014	0.03	3.7
HR1-01-06	9	71	11	3.50	349	5	116	55	46	1.44	5.68	0.59	0.57	77	0.082	3	0.015	0.03	4.3
HR1-01-08	11	79	14	3.59	446	5	110	60	48	1.48	5.39	0.60	0.56	77	0.091	4	0.015	0.03	4.6
HR1-01-10	13	60	12	2.89	475	5	92	46	38	1.45	6.78	0.59	0.41	84	0.081	2	0.013	0.04	4.2
HR1-01-12	15	83	13	3.68	419	5	104	63	53	1.54	5.99	0.66	0.60	86	0.088	3	0.016	0.04	5.0
HR1-01-14	17	78	13	3.59	454	5	104	61	50	1.59	6.25	0.57	0.53	85	0.095	3	0.015	0.04	4.2
HR1-01-16	19	81	13	3.54	471	5	105	58	48	1.69	6.87	0.66	0.51	88	0.083	3	0.015	0.04	4.9
HR1-01-18	21	85	13	3.67	417	5	115	62	52	1.58	5.66	0.70	0.59	74	0.098	3	0.013	0.04	4.4
HR1-01-20	23	78	12	3.61	333	5	148	68	54	1.46	4.00	0.64	0.56	69	0.108	1	0.012	0.03	3.7
HR1-01-22	25	66	11	2.91	385	5	92	51	37	1.81	8.17	0.54	0.41	84	0.069	2	0.012	0.05	2.7
Section 2																			
HR2-01-20	18																		
HR2-01-00	20	65	10	2.98	299	5	111	46	36	1.87	7.13	0.42	0.50	75	0.064	7	0.026	0.05	4.4
HR2-01-03	23	75	13	3.34	397	5	120	52	42	1.77	6.77	0.44	0.52	81	0.081	8	0.018	0.05	5.2
HR2-01-06	26	83	14	3.73	490	5	147	54	43	1.79	5.93	0.63	0.51	79	0.076	5	0.018	0.05	5.3
HR2-01-09	29	80	14	3.56	494	5	139	54	43	1.76	5.77	0.64	0.50	73	0.074	6	0.018	0.05	5.7
HR2-01-11	31	71	12	3.36	448	5	105	49	39	1.53	5.98	0.61	0.41	78	0.071	5	0.019	0.05	6.7
HR2-01-13	33	86	14	3.41	445	5	121	58	43	1.60	5.01	0.67	0.49	68	0.080	7	0.019	0.04	5.0
HR2-01-15	35	74	13	3.40	429	5	108	53	39	1.63	5.85	0.59	0.47	76	0.067	6	0.016	0.04	4.0
HR2-01-17	37	75	14	3.31	493	5	137	56	40	1.61	5.06	0.66	0.44	69	0.083	4	0.016	0.04	3.5
HR2-01-19	39	83	16	3.84	517	5	164	70	48	1.61	3.95	0.61	0.51	61	0.114	6	0.017	0.03	4.1
Section 3																			
HR3-01-00	3	86	20	4.23	684	5	118	76	55	1.70	3.74	0.53	0.57	56	0.139	8	0.018	0.02	4.2
HR3-01-03	6	88	17	4.31	446	5	138	79	57	1.66	3.33	0.46	0.62	61	0.127	7	0.020	0.02	4.0
HR3-01-06	9	80	16	4.01	421	5	113	59	45	1.52	4.96	0.48	0.58	78	0.073	5	0.025	0.03	6.5
HR3-01-09	12	88	14	3.88	395	5	112	65	47	1.72	4.20	0.63	0.62	64	0.088	7	0.016	0.03	4.1
HR3-01-12	15	84	15	3.77	409	5	139	61	46	1.68	4.37	0.50	0.58	73	0.084	10	0.016	0.04	3.9
HR3-01-15	18	75	13	3.51	338	5	109	58	44	1.73	4.88	0.49	0.57	72	0.082	5	0.015	0.04	3.9
HR3-01-19	21	81	14	3.68	358	5	133	62	47	1.70	4.32	0.50	0.61	68	0.091	10	0.015	0.03	3.7
HR3-01-21	24	81	14	3.73	369	5	132	62	46	1.68	4.31	0.53	0.60	65	0.092	7	0.014	0.03	4.5
HR3-01-23	26	86	16	3.96	440	5	88	61	48	1.47	4.34	0.70	0.56	65	0.079	6	0.015	0.04	5.3
HR3-01-25	28	85	17	4.10	486	5	85	59	46	1.49	4.91	0.65	0.54	69	0.078	4	0.020	0.04	5.1
Section 4																			
HR4-01-00	12	79	14	3.35	373	5	91	50	37	1.56	6.96	0.48	0.45	78	0.072	5	0.028	0.04	4.2
HR4-01-03	15	75	14	3.63	402	5	110	59	44	1.65	6.42	0.45	0.50	79	0.091	8	0.019	0.04	3.4
HR4-01-06	18	77	16	3.73	481	5	111	63	46	1.63	6.07	0.41	0.48	74	0.102	9	0.021	0.04	3.9
HR4-01-09	21	75	16	3.74	439	5	105	67	46	1.68	5.44	0.42	0.46	68	0.120	12	0.018	0.04	3.0
HR4-01-12	24	76	14	3.71	385	5	75	61	46	1.64	5.85	0.42	0.49	75	0.097	8	0.019	0.04	3.9
HR4-01-15	27	75	16	3.88	375	5	122	69	51	1.64	4.72	0.05	0.48	69	0.122	26	0.016	0.03	3.6
HR4-01-18	30	75	16	3.97	375	5	111	69	49	1.61	5.06	0.44	0.48	68	0.113	6	0.020	0.03	3.6
HR4-01-21	33	80	17	4.02	453	5	112	74	51	1.70	4.81	0.45	0.47	65	0.124	9	0.014	0.03	2.7

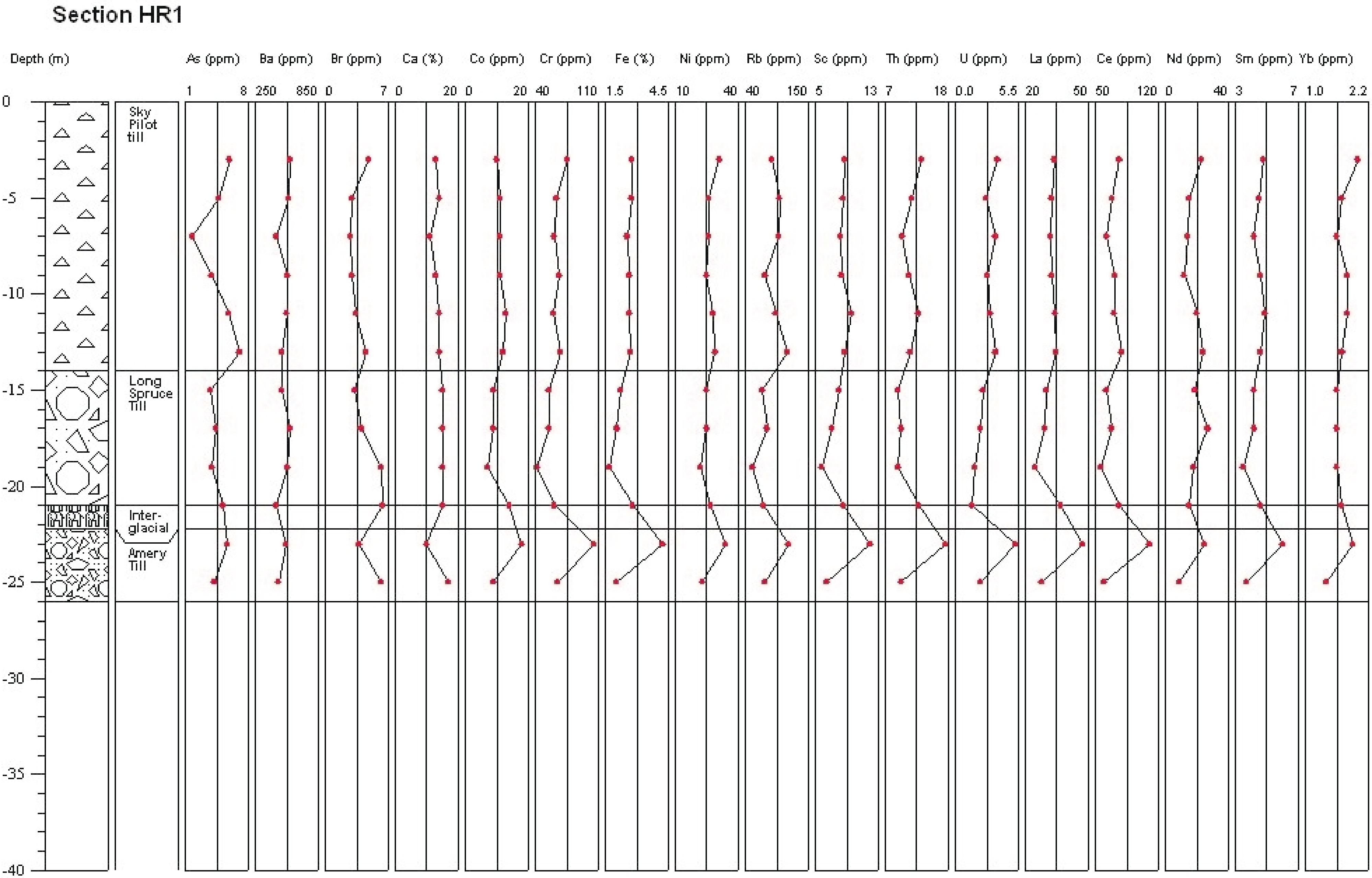
* Arsenic analysis by hydride generation

Appendix 2B: Geochemical Data For The <2 mm Size Fraction *(continued)*

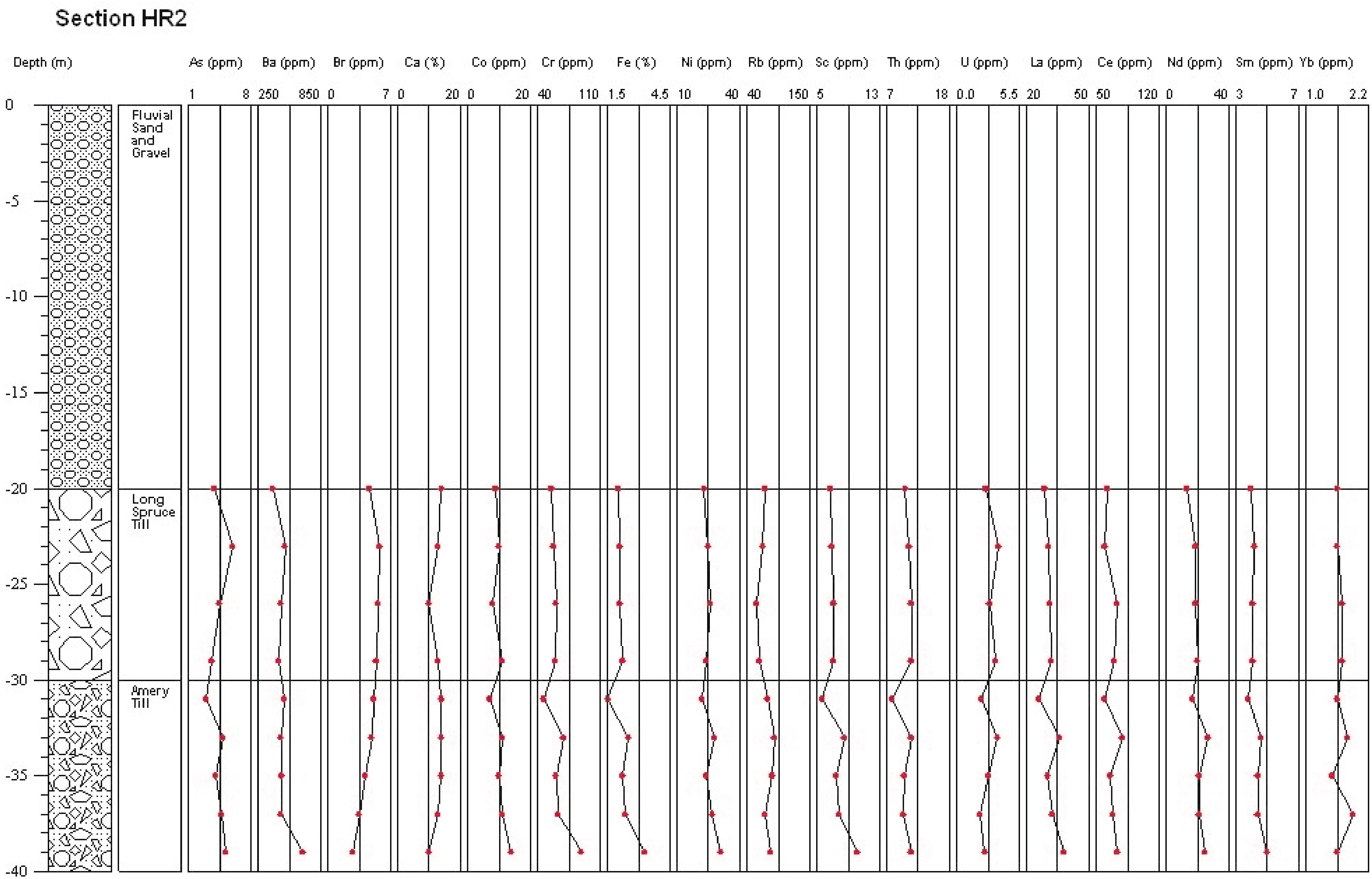
Section 5	Depth m	Zn ppm	Co ppm	Fe %	Mn ppm	Te ppm	Ba ppm	Cr ppm	V ppm	Mg %	Ca %	Na %	K %	Sr ppm	Ti %	Zr ppm	Hg ppm	S %	AsHY* ppm
HR5-01-100TOP	1	81	15	4.25	433	5	105	70	51	1.55	4.39	0.55	0.56	57	0.110	6	0.022	0.03	5.1
HR5-01-00	9	64	16	3.25	563	5	91	52	38	1.44	6.41	0.56	0.39	81	0.088	4	0.017	0.04	5.7
HR5-01-03	12	81	15	3.94	411	5	108	65	47	1.52	4.80	0.57	0.52	72	0.099	6	0.021	0.03	4.9
HR5-01-06	15	79	15	3.66	421	5	177	64	45	1.53	5.05	0.51	0.50	75	0.101	5	0.019	0.04	3.8
HR5-01-09	18	82	17	3.93	469	5	99	69	47	1.59	4.77	0.57	0.49	64	0.111	5	0.021	0.03	3.9
HR5-01-12	21	80	17	3.90	449	5	112	70	50	1.61	4.40	0.43	0.51	66	0.128	13	0.018	0.03	3.8
HR5-01-15	24	80	16	3.82	526	5	112	76	54	1.60	4.88	0.61	0.50	70	0.142	3	0.012	0.03	3.7
HR5-01-18	27	89	17	4.35	544	5	121	85	59	1.62	4.05	0.58	0.57	67	0.151	5	0.015	0.03	4.0
HR5-01-31	33	79	15	3.61	461	5	113	66	49	1.73	6.31	0.60	0.56	84	0.109	3	0.010	0.04	3.4
Section 6																			
HR6-01-00	0.5	95	12	3.96	361	5	117	70	54	1.58	5.73	0.70	0.56	68	0.097	1	0.012	0.03	5.0
HR6-01-02	2	72	11	3.56	329	5	107	60	48	1.47	5.54	0.55	0.49	64	0.087	1	0.011	0.03	5.2
HR6-01-04	4	76	11	3.81	337	5	109	61	49	1.43	5.22	0.65	0.49	63	0.081	2	0.011	0.03	5.0
HR6-01-06	6	86	12	3.93	321	5	119	64	54	1.31	3.92	0.72	0.51	54	0.082	2	0.011	0.02	4.9
HR6-01-08	8	79	11	3.75	296	5	110	64	52	1.53	5.51	0.71	0.59	67	0.082	1	0.018	0.03	6.0
HR6-01-10	10	77	12	3.50	391	5	99	61	47	1.57	6.10	0.61	0.54	70	0.091	2	0.016	0.03	4.4
HR6-01-12	12	74	10	3.31	297	5	92	58	46	1.78	7.22	0.59	0.60	77	0.073	2	0.017	0.04	3.4
HR6-01-14	14	89	12	3.56	425	5	99	61	48	1.79	7.07	0.60	0.59	77	0.082	4	0.018	0.04	4.4
HR6-01-16	16	78	12	3.33	379	5	98	57	44	1.86	7.50	0.54	0.55	80	0.078	4	0.014	0.05	3.9
HR6-01-18	18	80	12	3.67	392	5	105	61	46	1.79	6.85	0.66	0.58	75	0.075	3	0.017	0.04	4.5
HR6-01-20	20	91	14	4.11	370	5	122	70	56	1.65	5.91	0.64	0.61	76	0.095	5	0.011	0.04	3.7
HR6-01-22	22	89	15	3.73	411	5	117	60	45	1.58	5.39	0.74	0.54	71	0.078	7	0.012	0.04	4.7
HR6-01-23	23	71	15	4.14	348	5	99	52	41	1.34	6.18	0.51	0.42	69	0.078	3	0.019	0.04	5.7
HR6-01-24	24	74	15	3.57	352	5	99	55	44	1.42	6.28	0.56	0.47	72	0.082	4	0.012	0.04	3.6
HR6-01-25	25	78	16	3.75	330	5	103	60	47	1.45	5.42	0.56	0.51	65	0.088	4	0.005	0.03	3.0
Section 7																			
HR7-01-00	6																		
HR7-01-02	8	85	17	4.04	497	5	126	71	48	1.61	4.20	0.62	0.54	58	0.110	8	0.005	0.03	3.9
HR7-01-04	10	85	17	3.96	501	5	106	70	50	1.68	4.54	0.58	0.53	59	0.120	8	0.015	0.03	4.4
HR7-01-06	12	86	18	4.15	475	5	116	75	53	1.60	4.09	0.59	0.55	62	0.117	9	0.013	0.03	3.9
HR7-01-08	14	86	19	4.17	537	5	146	77	53	1.61	3.41	0.54	0.52	58	0.131	11	0.012	0.02	3.7
HR7-01-10	16	90	18	4.23	520	5	176	71	52	1.41	2.84	0.62	0.56	57	0.108	9	0.010	0.02	4.2
HR7-01-12	18	84	16	3.87	449	5	145	62	47	1.60	4.61	0.56	0.60	70	0.091	10	0.010	0.03	4.1

* Arsenic analysis by hydride generation

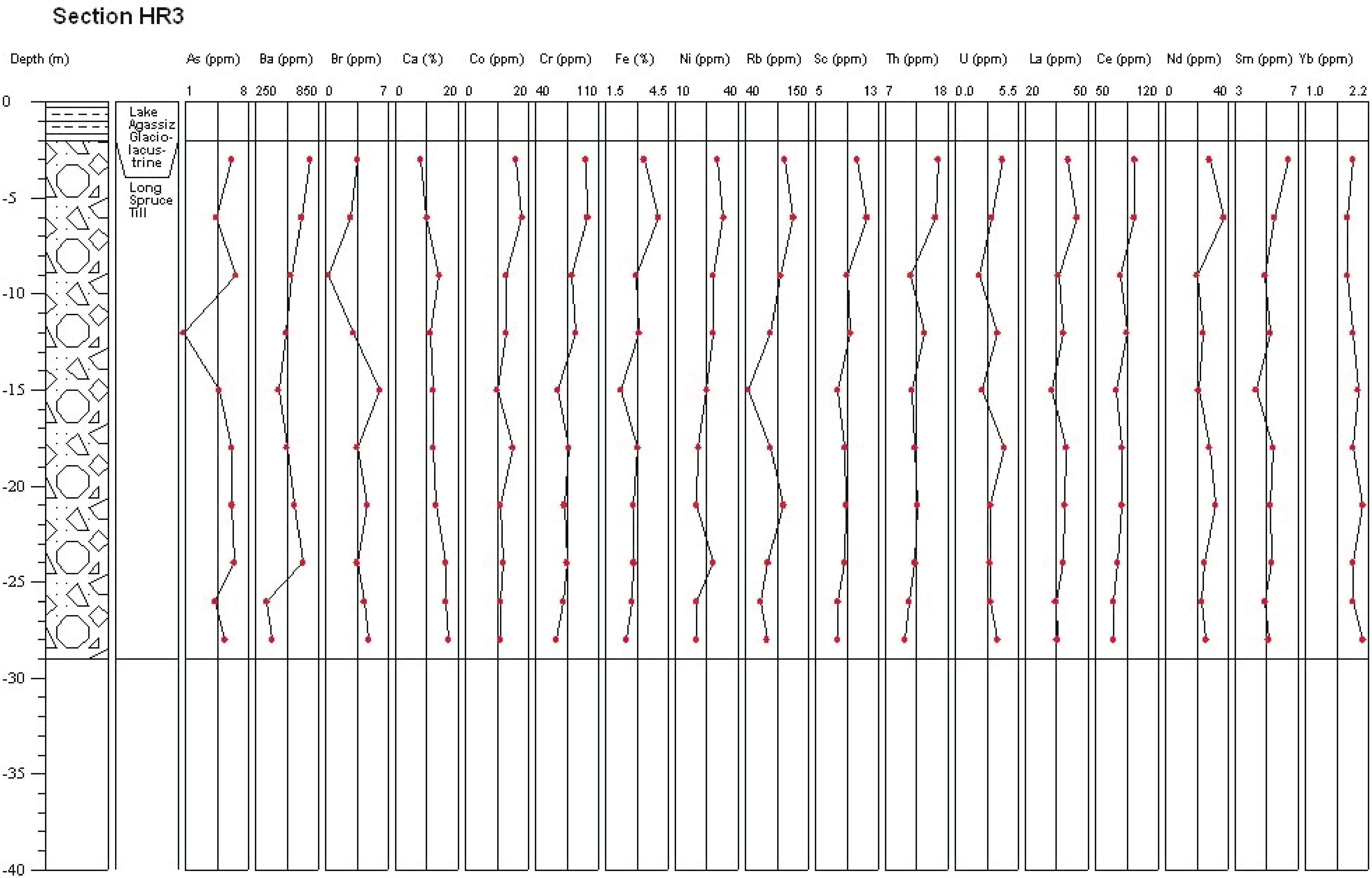
Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically)



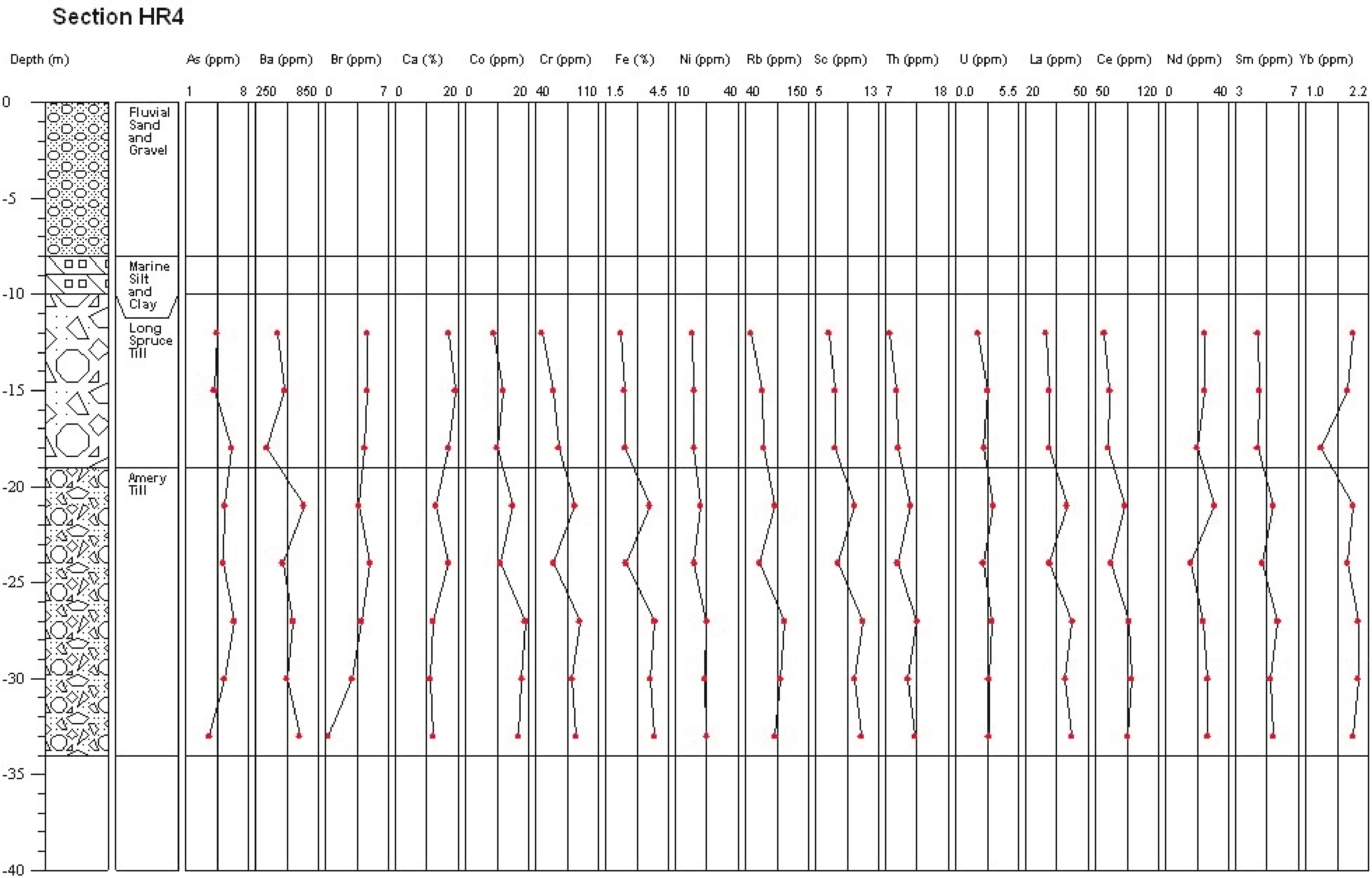
Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



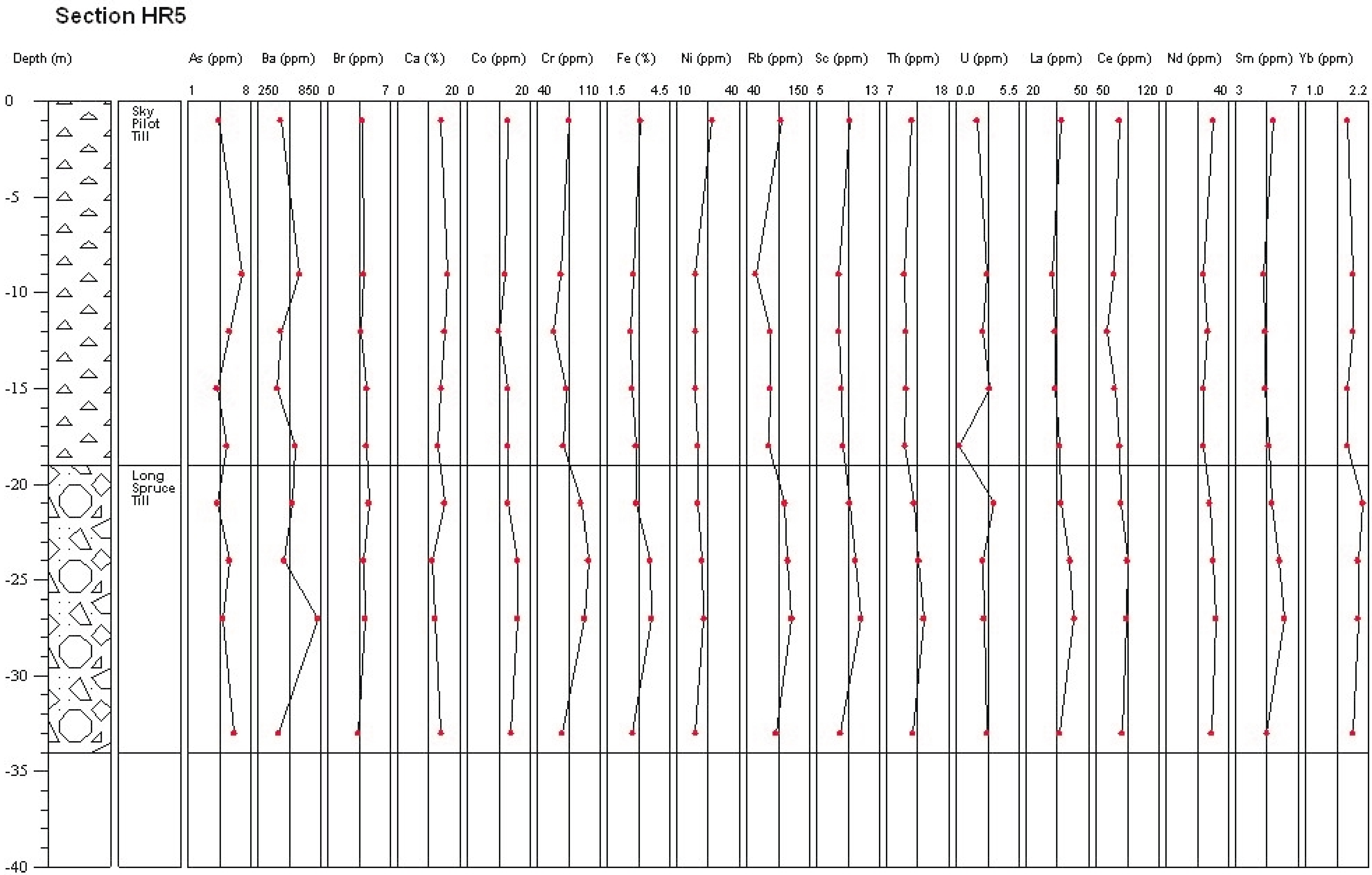
Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



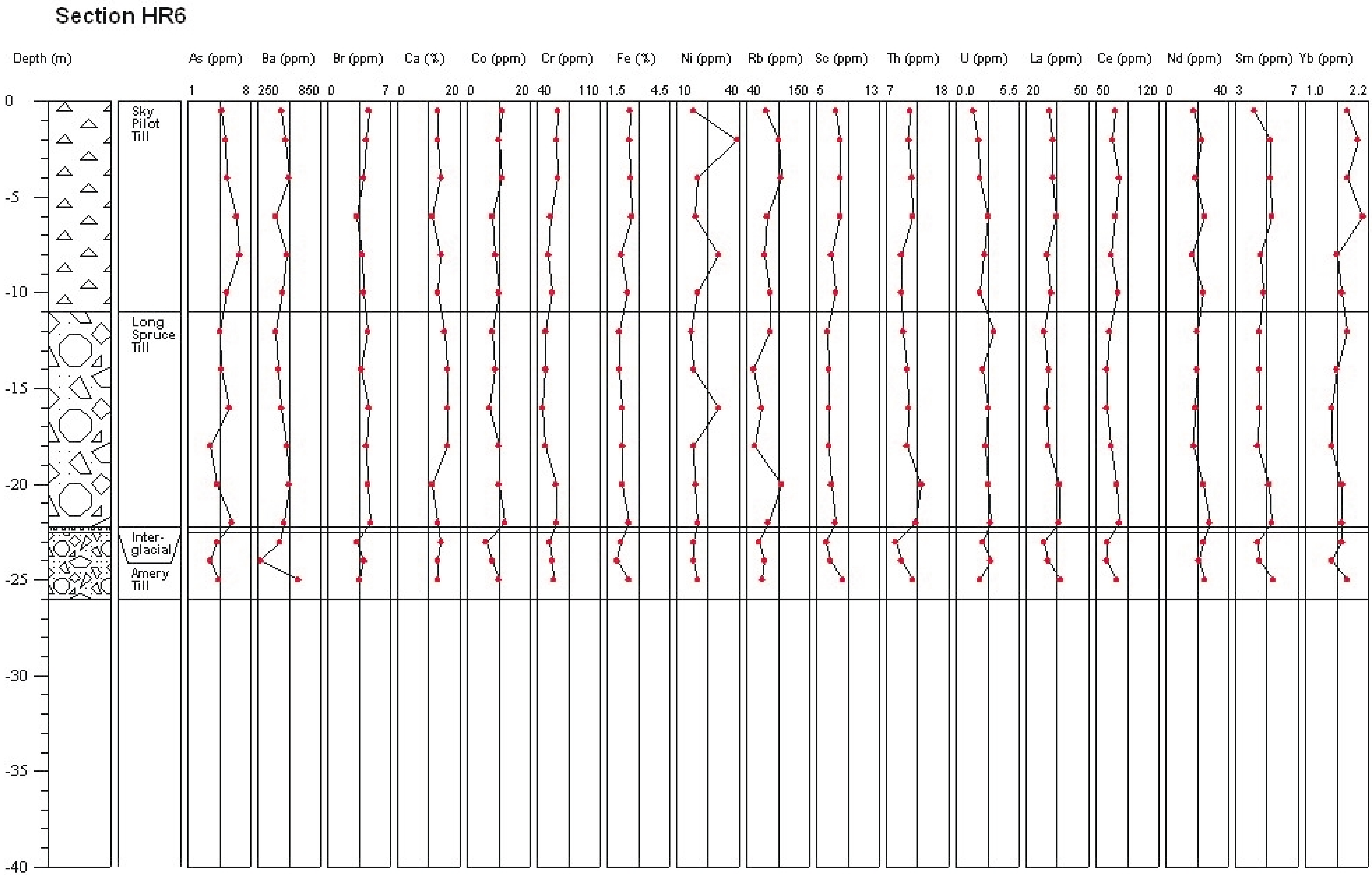
Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



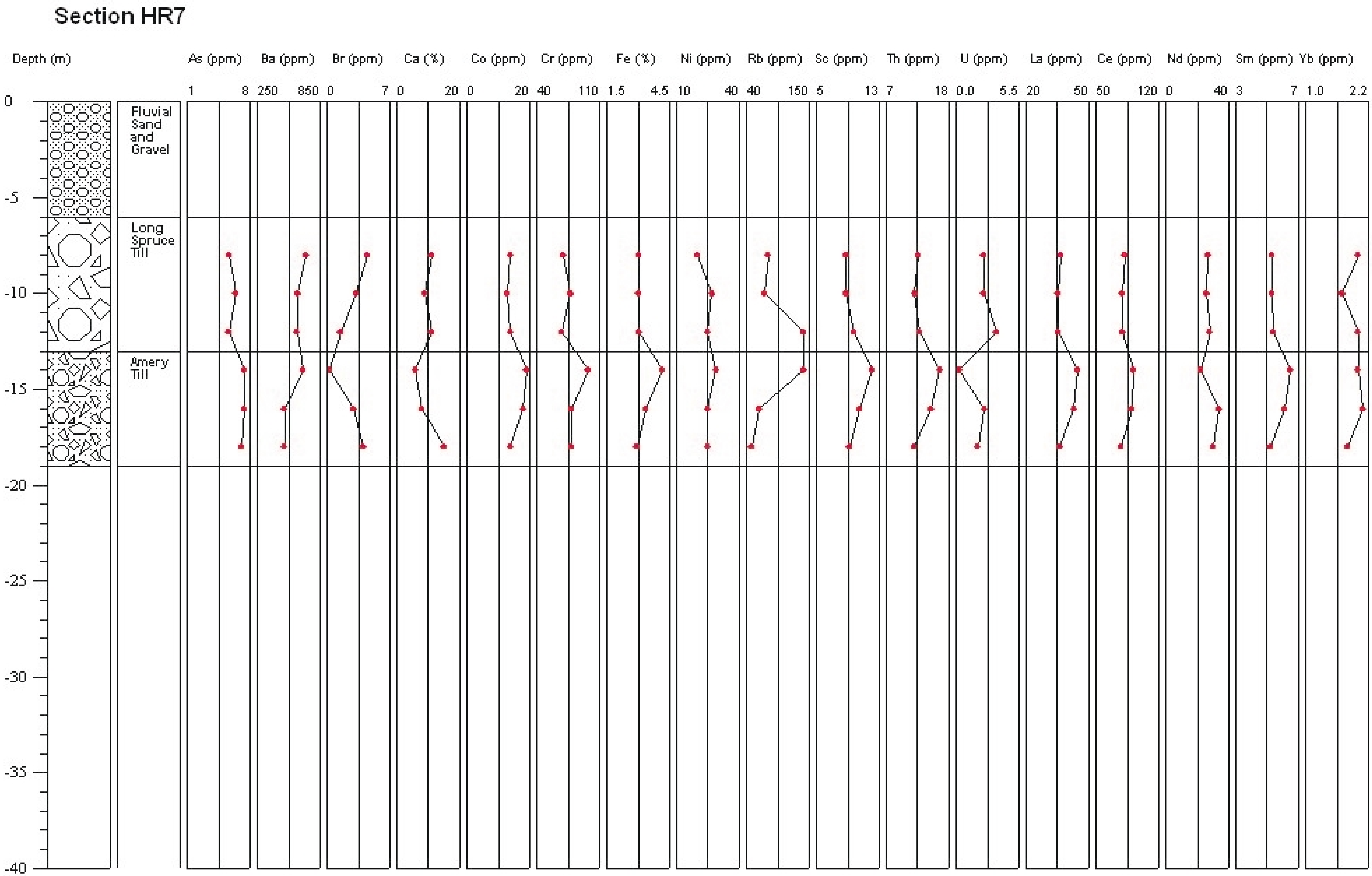
Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



Appendix 3A: Geochemical Data for the <63 mm Size Fraction. (Shown Graphically) *(continued)*



Appendix 3B: Geochemical Data For The <63 mm Size Fraction

Section 1	From	To	As ppm	Ba ppm	Br ppm	Ca %	Co ppm	Cr ppm	Fe %	Na %	Ni ppm	Rb ppm	Sc ppm	Th ppm	U ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Yb ppm	TREE* ppm
HR1-01-00	2.5	3	5.9	580	4.8	13	10	76	2.78	0.96	31	86	8.7	13.3	3.7	33.7	77	23	4.8	1.0	2.0	142.06
HR1-01-02	4.5	5	4.7	570	3.0	14	11	64	2.74	0.87	26	100	8.5	11.6	2.7	32.4	69	15	4.5	1.0	1.7	124.11
HR1-01-04	6.5	7	1.8	450	2.8	11	11	61	2.54	0.82	26	99	8.2	10.0	3.5	31.9	63	14	4.2	1.0	1.6	116.20
HR1-01-06	8.5	9	3.9	560	3.0	13	11	67	2.66	0.86	25	75	8.3	11.2	2.8	32.5	72	12	4.6	1.1	1.8	124.54
HR1-01-08	10.5	11	5.8	550	3.4	14	13	60	2.66	0.86	28	93	9.6	12.8	3.1	34.3	71	20	4.9	1.2	1.8	133.72
HR1-01-10	12.5	13	7.0	500	4.5	14	12	68	2.69	0.96	29	113	8.7	11.3	3.5	34.8	79	24	4.6	1.0	1.7	145.60
HR1-01-12	14.5	15	3.8	500	3.3	15	9	55	2.23	0.79	25	70	8.0	9.2	2.4	30.1	62	19	4.2	0.9	1.6	118.30
HR1-01-14	16.5	17	4.4	580	4.0	15	9	55	2.06	0.81	25	78	7.1	9.8	2.2	29.3	68	27	4.2	1.0	1.6	131.59
HR1-01-16	18.5	19	4.0	560	6.2	15	7	42	1.71	0.67	22	53	5.8	9.3	1.7	24.5	56	18	3.5	0.6	1.6	104.69
HR1-01-18	20.5	21	5.2	450	6.4	15	14	61	2.80	0.91	27	72	8.6	12.9	1.5	37.0	76	15	4.6	0.9	1.7	135.71
HR1-01-20	22.5	23	5.7	540	3.8	10	18	105	4.25	1.18	34	115	12.0	17.6	5.3	47.2	110	25	6.0	1.3	1.9	191.94
HR1-01-22	24.5	25	4.2	470	6.2	17	9	65	2.04	0.71	23	74	6.5	9.8	2.2	27.8	60	9	3.7	0.8	1.4	103.18
Section 2																						
HR2-01-20	17.5	18																				
HR2-01-00	19.5	20	3.9	390	4.6	14	9	56	2.04	0.58	23	71	6.7	10.3	2.6	28.9	62	13	4.0	0.9	1.6	110.89
HR2-01-03	22.5	23	6.0	510	5.8	13	10	58	2.12	0.82	25	68	6.9	11.0	3.7	30.7	60	19	4.2	0.9	1.6	116.89
HR2-01-06	25.5	26	4.5	470	5.6	10	8	61	2.12	0.81	26	57	7.2	11.3	2.9	31.4	73	19	4.1	0.5	1.7	130.20
HR2-01-09	28.5	29	3.7	450	5.4	13	11	60	2.26	0.80	24	62	7.1	11.3	3.4	32.0	70	20	4.1	1.2	1.7	129.50
HR2-01-11	30.5	31	3.0	500	5.1	14	7	47	1.53	0.89	22	76	5.7	8.0	2.2	26.1	59	17	3.8	0.9	1.6	108.89
HR2-01-13	32.5	33	4.9	470	4.9	14	11	69	2.53	0.90	28	88	8.5	11.3	3.6	36.0	79	27	4.6	1.1	1.8	150.03
HR2-01-15	34.5	35	4.1	480	4.2	14	10	61	2.25	0.82	24	85	7.5	10.1	2.8	30.3	66	21	4.4	0.8	1.5	124.47
HR2-01-17	36.5	37	4.7	470	3.5	13	11	63	2.39	0.88	27	72	7.8	10.0	2.1	32.4	69	21	4.4	0.2	1.9	129.43
HR2-01-19	38.5	39	5.2	680	2.8	10	14	89	3.29	1.17	31	82	10.2	11.3	2.5	37.9	74	25	5.0	0.8	1.6	144.80
Section 3																						
HR3-01-00	2.5	3	6.1	770	3.6	8	16	96	3.34	1.19	30	109	10.3	16.2	4.1	40.3	94	28	6.4	1.4	1.9	172.54
HR3-01-03	4.5	6	4.4	690	2.8	10	18	98	4.04	1.32	33	124	11.5	15.7	3.2	44.4	93	37	5.5	1.4	1.8	183.60
HR3-01-06	7.5	9	6.6	590	0.3	14	13	81	2.96	0.93	28	102	9.0	11.5	2.1	35.7	78	20	4.9	0.9	1.8	141.82
HR3-01-09	10.5	12	0.8	540	3.1	11	13	85	3.12	0.99	28	84	9.5	13.8	3.7	38.2	85	24	5.2	1.0	1.9	157.69
HR3-01-12	13.5	15	4.7	470	6.1	12	10	65	2.23	0.92	25	45	7.8	11.7	2.3	32.7	73	21	4.3	1.0	2.0	134.55
HR3-01-15	16.5	18	6.1	550	3.5	12	15	77	3.05	0.97	21	84	8.8	12.2	4.3	39.6	80	28	5.4	1.1	1.9	156.53
HR3-01-19	20.5	21	6.2	620	4.7	13	11	72	2.84	0.91	20	107	8.9	12.6	3.1	38.9	80	32	5.2	1.1	2.1	159.85
HR3-01-21	22.5	24	6.4	700	3.5	16	12	75	2.86	0.94	28	80	8.7	12.2	3.0	38.0	75	25	5.3	1.1	1.9	147.09
HR3-01-23	24.5	26	4.3	360	4.3	16	11	71	2.75	0.89	20	67	7.9	11.2	3.1	34.5	70	23	4.9	0.9	1.9	135.73
HR3-01-25	26.5	28	5.4	410	4.8	17	11	63	2.50	0.88	20	78	7.8	10.4	3.7	35.1	70	26	5.1	1.0	2.1	139.83
Section 4																						
HR4-01-00	11.5	12	4.5	460	4.7	17	9	47	2.24	0.76	18	50	6.7	7.8	2.0	29.7	60	25	4.4	1.0	1.9	122.51
HR4-01-03	14.5	15	4.2	530	4.7	19	12	60	2.40	0.86	19	69	7.5	8.9	2.8	31.5	66	25	4.5	1.1	1.8	130.41
HR4-01-06	17.5	18	6.1	360	4.4	17	10	66	2.46	0.91	19	72	7.5	9.3	2.5	31.4	64	20	4.4	1.0	1.3	122.56
HR4-01-09	20.5	21	5.4	710	3.7	13	15	84	3.60	1.15	22	92	10.0	11.4	3.3	39.7	83	31	5.4	1.3	1.9	162.83
HR4-01-12	23.5	24	5.2	510	5.0	17	11	60	2.47	0.95	19	64	7.8	9.1	2.4	31.6	67	16	4.7	1.3	1.8	122.91
HR4-01-15	26.5	27	6.4	610	4.0	12	19	89	3.86	1.17	25	108	11.0	12.5	3.2	42.3	87	24	5.7	1.2	2.0	162.73
HR4-01-18	29.5	30	5.3	550	3.0	11	18	81	3.62	1.11	24	102	10.0	11.0	2.9	39.0	90	27	5.2	1.2	2.0	164.95
HR4-01-21	32.5	33	3.7	670	0.3	12	17	85	3.83	1.14	25	92	10.8	12.1	2.9	42.0	86	27	5.4	1.2	1.9	164.03

* Total Rare Earth Elements

Appendix 3B: Geochemical Data For The <63 mm Size Fraction *(continued)*

Section 5	From	To	As ppm	Ba ppm	Br ppm	Ca %	Co ppm	Cr ppm	Fe %	Na %	Ni ppm	Rb ppm	Sc ppm	Th ppm	U ppm	La ppm	Ce ppm	Nd ppm	Sm ppm	Eu ppm	Yb ppm	TREE* ppm
HR5-01-100TOP	0.5	1	4.4	470	3.9	14	13	76	3.12	1.07	27	100	9.3	11.5	1.8	37.0	76	30	5.4	1.3	1.8	152.01
HR5-01-00	8.5	9	7.0	650	4.0	16	12	67	2.77	0.84	19	56	7.9	10.1	2.7	32.7	70	24	4.8	1.2	1.9	135.13
HR5-01-03	11.5	12	5.6	470	3.7	15	10	59	2.64	0.95	19	82	7.8	10.4	2.3	33.8	63	27	4.9	1.3	1.9	132.41
HR5-01-06	14.5	15	4.2	440	4.4	14	13	73	2.69	0.98	19	81	8.2	10.5	2.9	33.9	71	24	4.9	1.2	1.8	137.86
HR5-01-09	17.5	18	5.3	610	4.3	13	13	69	2.88	1.05	20	79	8.4	10.3	0.3	36.0	77	24	5.1	1.0	1.8	145.42
HR5-01-12	20.5	21	4.3	580	4.6	15	13	89	2.92	1.11	20	107	9.2	11.8	3.3	36.8	78	28	5.3	1.3	2.1	152.06
HR5-01-15	23.5	24	5.6	500	4.0	11	16	97	3.55	1.16	22	112	10.0	12.7	2.3	41.0	85	30	5.8	1.4	2.0	165.72
HR5-01-18	26.5	27	4.9	820	4.2	12	16	93	3.62	1.22	23	119	10.7	13.5	2.4	43.0	84	32	6.1	1.3	2.0	168.91
HR5-01-31	32.5	33	6.2	450	3.4	14	14	68	2.73	0.88	19	92	8.1	11.6	2.7	35.9	79	29	5.0	1.1	1.9	152.42
Section 6																						
HR6-01-00	0	0.5	4.8	480	4.6	13	11	63	2.60	0.85	18	75	7.5	11.2	1.5	31.3	72	18	4.2	1.0	1.8	128.81
HR6-01-02	1.5	2	5.2	520	4.3	13	10	62	2.59	0.85	39	96	8.0	11.0	2.0	33.0	69	23	5.2	1.0	2.0	133.75
HR6-01-04	3.5	4	5.4	550	4.0	14	11	63	2.63	0.87	20	100	8.0	11.5	2.1	33.0	76	19	5.2	1.0	1.8	136.52
HR6-01-06	5.5	6	6.4	420	3.3	11	8	55	2.68	0.85	19	76	8.0	11.6	2.8	34.6	72	25	5.3	1.2	2.1	140.77
HR6-01-08	7.5	8	6.8	530	3.9	14	9	53	2.19	0.69	30	72	6.9	9.6	2.5	30.2	67	17	4.6	0.9	1.6	121.81
HR6-01-10	9.5	10	5.3	490	4.0	13	10	57	2.48	0.66	20	82	7.5	9.6	2.1	32.2	75	24	4.8	0.9	1.7	139.11
HR6-01-12	11.5	12	4.6	420	4.5	15	8	50	2.08	0.63	17	81	6.4	10.0	3.3	28.9	65	20	4.5	0.8	1.8	121.52
HR6-01-14	13.5	14	4.7	450	3.8	16	9	50	2.10	0.67	18	53	6.6	10.7	2.3	31.0	62	20	4.5	1.0	1.6	120.60
HR6-01-16	15.5	16	5.6	480	4.6	16	7	46	2.23	0.65	30	66	6.6	10.9	2.8	30.2	62	19	4.5	1.0	1.5	118.68
HR6-01-18	17.5	18	3.5	530	4.3	16	10	49	2.25	0.65	18	55	6.6	10.6	2.6	30.7	67	18	4.4	0.9	1.5	122.99
HR6-01-20	19.5	20	4.3	550	4.5	11	10	61	2.24	0.92	19	101	6.9	13.2	2.8	35.8	73	24	5.1	0.9	1.7	140.99
HR6-01-22	21.5	22	5.9	500	4.8	13	12	62	2.54	0.84	20	78	7.4	12.2	3.0	35.7	76	28	5.3	0.9	1.7	148.10
HR6-01-23	22.5	23	4.3	460	3.3	14	6	54	2.17	0.82	18	62	6.3	8.6	2.3	28.6	63	24	4.4	1.0	1.7	123.20
HR6-01-24	23.5	24	3.5	280	4.1	13	8	57	1.99	0.80	18	72	6.8	9.6	3.0	30.5	62	21	4.5	1.0	1.5	120.98
HR6-01-25	24.5	25	4.4	640	3.6	13	10	59	2.54	0.95	20	68	8.4	11.6	2.1	36.5	73	25	5.4	1.1	1.8	143.31
Section 7																						
HR7-01-00	5.5	6																				
HR7-01-02	7.5	8	5.7	720	4.5	11	14	70	3.03	1.03	20	78	8.8	12.6	2.4	36.8	82	27	5.3	1.0	2.0	154.65
HR7-01-04	9.5	10	6.4	640	3.3	9	13	78	3.01	1.10	27	72	8.8	12.0	2.4	35.1	79	26	5.3	1.0	1.7	148.60
HR7-01-06	11.5	12	5.6	630	1.5	11	14	68	3.05	1.28	25	140	9.8	12.9	3.5	35.5	80	28	5.4	1.2	2.0	153.40
HR7-01-08	13.5	14	7.4	690	0.3	6	19	97	4.15	1.35	29	141	12.1	16.4	0.3	44.8	92	22	6.5	1.2	2.0	169.04
HR7-01-10	15.5	16	7.4	510	3.0	8	18	79	3.38	1.17	25	63	10.5	14.9	2.5	43.0	90	34	6.1	1.1	2.1	176.87
HR7-01-12	17.5	18	7.1	510	4.1	15	14	79	2.94	0.96	25	49	9.2	11.9	1.9	36.2	78	30	5.2	1.0	1.8	152.72

* Total Rare Earth Elements

Appendix 4: Kimberlite Indicator-Mineral Chemistry, Classification And Abundance (0.3 mm)

Sample	Section	MnO %	Na_2O %	Al_2O_3 %	FeO %	SiO_2 %	TiO_2 %	CaO %	Cr_2O_3 %	MgO %	TOTAL	Classification
HR1-01-02	1	0.18	0.02	8.61	30.42	0.16	3.50	0.00	41.87	14.35	99.11	chrome spinel
HR1-01-14	1	0.17	0.57	1.70	3.23	53.17	0.06	22.81	0.86	16.09	98.66	non-titanian Cr-pyrope (G7)
HR1-01-14	1	0.13	0.00	17.72	19.65	0.46	1.25	0.00	44.47	15.47	99.16	chrome spinel
HR1-01-16	1	0.69	0.02	17.63	8.47	40.17	0.13	6.76	7.10	18.72	99.69	non-titanian Cr-pyrope (G9)
HR2-01-00	2	0.10	0.00	34.77	14.43	0.26	0.48	0.00	33.24	16.82	100.10	chrome spinel
HR2-01-00	2	0.15	0.00	10.88	27.55	0.09	2.52	0.00	43.44	14.43	99.06	chrome spinel
HR2-01-20	2	0.18	0.00	14.15	30.91	0.00	0.15	0.00	51.79	4.02	101.20	chrome spinel
HR2-01-20	2	0.21	0.11	21.16	25.42	0.01	0.29	0.00	42.70	10.04	99.94	chrome spinel
HR2-01-20	2	0.09	0.07	20.85	31.48	0.11	0.06	0.00	40.92	7.17	100.74	chrome spinel
HR3-01-21	3	0.35	0.22	10.93	33.02	0.13	0.27	0.00	50.45	4.16	99.52	chrome spinel
HR4-01-00	4	0.52	0.00	22.50	21.43	39.40	0.15	5.99	0.11	11.26	101.36	non-titanian Cr-pyrope (G7)
HR4-01-06	4	0.27	0.00	16.40	18.84	0.06	0.30	0.00	51.43	12.82	100.12	chrome spinel
HR5-01-15	5	0.46	0.00	9.37	37.92	0.04	1.03	0.00	46.15	4.34	99.31	chrome spinel
HR5-01-18	5	0.36	0.00	18.53	8.25	40.92	0.44	5.59	5.61	21.08	100.78	titanian Cr-pyrope (G11)
HR5-01-31	5	0.34	0.08	21.71	7.04	40.83	0.42	5.48	4.24	20.65	100.77	titanian Cr-pyrope (G11)
HR6-01-20	6	0.49	0.00	20.79	8.18	41.14	0.32	4.56	4.09	20.34	99.92	titanian Cr-pyrope (G11)
HR7-01-00	7	0.14	0.02	6.55	36.81	0.03	5.90	0.00	36.75	12.98	99.17	chrome spinel
HR7-01-04	7	0.37	0.00	16.12	6.62	40.79	0.52	6.57	8.51	20.81	100.32	titanian Cr-pyrope (G11)

Appendix 4: Kimberlite Indicator-Mineral Chemistry, Classification And Abundance (0.5 mm)

Sample	Section	MnO %	Na_2O %	Al_2O_3 %	FeO %	SiO_2 %	TiO_2 %	CaO %	Cr_2O_3 %	MgO %	TOTAL	Classification
H1-01-06M	1	0.28	0.06	0.29	30.23	0.03	53.07	0.01	2.46	12.32	98.75	Mg- ilmenite
H2-01-20M	2	0.29	0.00	0.21	33.38	0.06	52.88	0.00	2.53	11.01	100.35	Mg- ilmenite
H7-01-02M	7	0.51	0.08	20.30	9.00	42.10	0.13	5.31	3.39	19.71	100.52	non-titanian Cr-pyrope (G9)

Appendix 4: Kimberlite Indicator-Mineral Abundances (0.3 mm + 0.5 mm + 1.0 mm)

Sample	Section	Mg-Ilmenite	Cr-spinel	Cr-Diopside	G7	G9	G10	G11	Total Kimberlite Indicator Minerals
HR1-01-02	1		1						1
HR1-01-06	1	1							1
HR1-01-14	1		1		1				2
HR1-01-16	1					1			1
HR2-01-00	2		2						2
HR2-01-20	2	1	3						4
HR3-01-21	3		1						1
HR4-01-00	4				1				1
HR4-01-06	4		1						1
HR5-01-15	5		1						1
HR5-01-18	5							1	1
HR5-01-31	5							1	1
HR7-01-00	7		1						1
HR7-01-02	7					1			1
HR7-01-04	7							1	1