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Trace Element Geochemistry and Till Provenance in The Pas - Flin Flon Area, Manitoba

by Erik Nielsen and Heather Groom

TABLE OF CONTENTS

FIGURES

TABLES

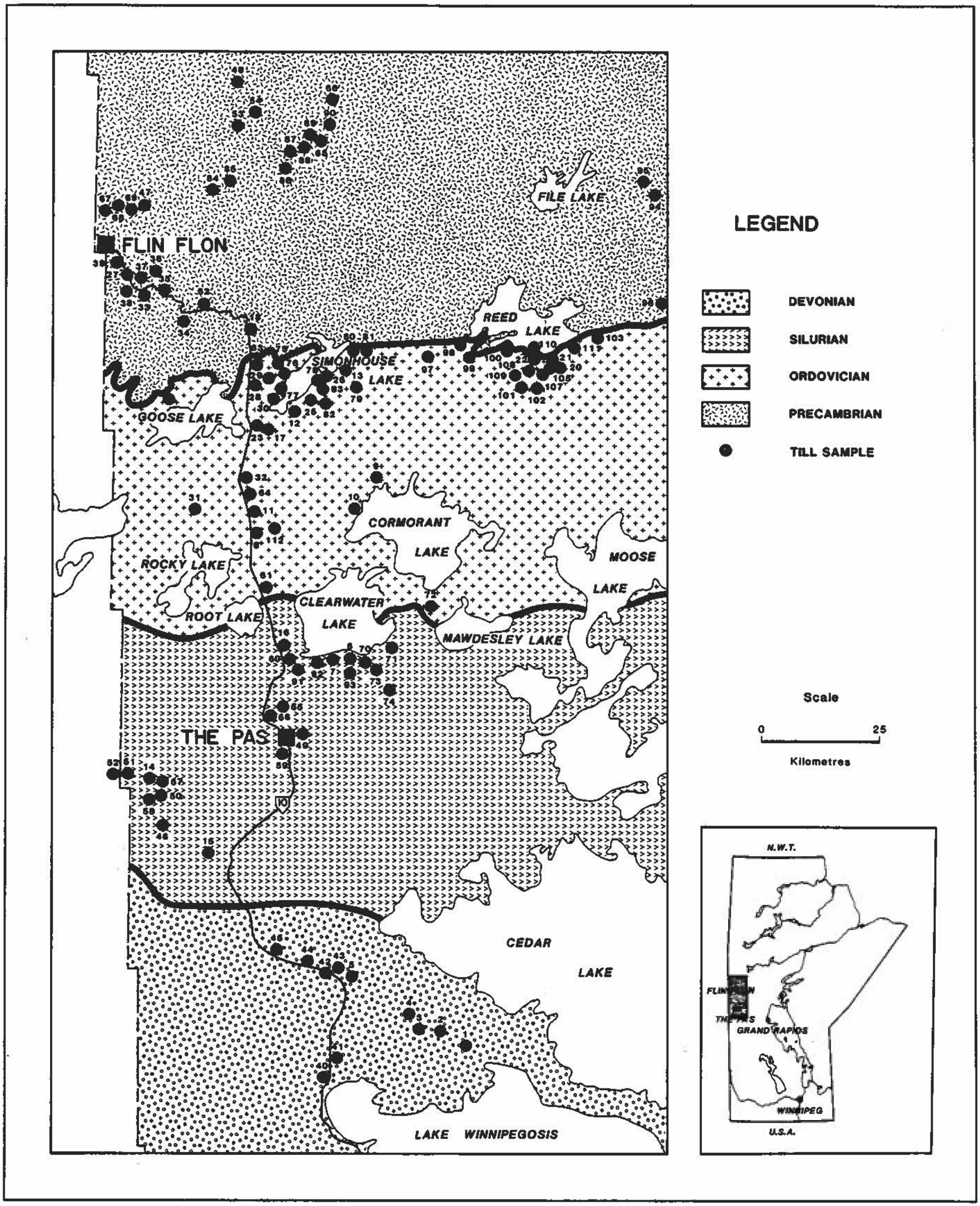


Figure 1: Bedrock geology and till sample locations.

INTRODUCTION

Regional basal till investigations and surficial geological mapping have been conducted throughout much of northwestern Manitoba to provide baseline geochemical and surficial geological maps to assist the mineral exploration industry in the search for mineralization (Kaszycki and DiLabio 1986, DiLabio and Kaszycki 1987). These geochemical surveys have however been restricted to areas underlain exclusively by metasedimentary, metavolcanic and intrusive rocks of Precambrian age. Difficulties in correlation arise when till sheets are traced across different bedrock lithologies and physiographic regions. A till sheet associated with a particular bedrock unit will show compositional changes across bedrock contacts making correlation of widely spaced till exposures tenuous. Till correlation is essential in any area in order to determine the sequence of glacial events (Stea, 1984).

This regional till sampling program was undertaken in The Pas - Flin Flon area to document trace element geochemical, petrographical and textural changes in the surface till across the Precambrian - Paleozoic boundary and to elucidate the ice flow history of the area (Fig. 1).

Previous Work

Antevs (1931) summarized the work of earlier geologists and described the geomorphology of The Pas moraine. Craig (1966) noted that The Pas moraine had been overridden by a minor glacial readvance as evidenced by flutes on top of the moraine. Klassen (1967) noted two and possibly three tills outcropping near Grand Rapids and related them to the formation of The Pas moraine and subsequent glacial overriding. Singhroy and Westler (1980) mapped the sand and gravel resources and commented on the Quaternary history. Surficial geological mapping has recently been completed by Clark (in press).

Geomorphology

The terrain is generally flat with low relief and numerous lakes and swamps covering much of the surface. Elevations vary from 260 m (a.s.l.) south of the The Pas to 335 m north of Flin Flon.

Drift cover is patchy on the Precambrian terrane with till occurring mainly on the down ice side of bedrock knolls. The bedrock surface has been glacially streamlined and whalebacks and drumlinoid ridges are common. Local relief in places exceeds 10-15 m. Although the till cover is thicker and more extensive over the Paleozoic bedrock than over the Precambrian terrane, areas of near surface Paleozoic bedrock are extensive.

The dominant morphological feature is The Pas moraine. The moraine is over 300 km long, up to 60 m high and from 5-20 km wide. The orientation of the moraine is concave to the northeast (Fig. 2). The south and west facing sides are steep and covered with Lake Agassiz beach sediments. The east and north facing sides have gentle slopes and Lake Agassiz beaches are rare. The gently sloping north and east facing surfaces are covered with fluted till. The flutes are up to 5 km long, 0.5 km wide and generally less than 2 m high. The orientation of the flutes is normal to the trend of the moraine.

Antevs (1931) records two morainic ridges oriented northeast, lying between the northern tip of The Pas moraine and Reed Lake. Two sand plains, also oriented northeast, link Reed and File lakes (Fig. 2).

Two prominent drumlin fields are found in the area. One of these is a small group of 9 drumlins located in the Pasquia basin southwest of The Pas. The drumlins which are composed of till are oriented toward 150° and are up to 2.0 km long, 0.5 km wide and up to 8 m high. Nothing is known of the composition of the other dumlin field located approximately 25 km south of Reed Lake (Fig. 2). The 13 drumlins in this field are about 2.0 km long and 0.2 km wide and record ice flow toward 260°.

Bedrock Geology

The Precambrian - Paleozoic contact trends westward across the area such that the southern two-thirds is underlain by Ordovician, Silurian and Devonian sandstone and carbonate bedrock and the northern one-third by Precambrian metavolcanic, metasedimentary and intrusive rocks (Fig. 1).

The Precambrian basement slopes less than 1° to the south and is overlain by flat-lying Paleozoic bedrock which thickens southward at approximately 2.3 m/km (H.R. McCabe, pers. comm.). The contact with the Precambrian is irregular and in the west marked by north facing cuestas 5-10 m high.

The Precambrian terrane comprises the Flin Flon greenstone belt in the south and the Kisseynew sedimentary gneissic belt to the north. The greenstone belt consists of primarily mafic to intermediate volcanic rocks of the Amisk Group and metamorphosed sandstone of the overlying Missi Group. The belt is segmented by large areas of granodiorite terrane. The Kisseynew belt consists of thick sequences of turbidite-derived gneisses and migmatites (Richardson and Ostry, 1987).

The unconformity between the Precambrian bedrock and the Paleozoic carbonates is marked by the Ordovician Red River Formation. This formation is 20-30 m thick and composed of fossiliferous dolomite. The lower part of the Red River Formation is arenaceous. The overlying 15-30 m thick Stony Mountain Formation, is primarily argillaceous dolomite.

The Silurian Interlake Group underlies the southern third of the area. The formations are primarily argillaceous dolomites but are in part stromatolitic and biostromal. There are difficulties in correlation and the formations are not easily delineated in the northwestern part of the outcrop belt. The lower portion of the Devonian Elk Point Group, consisting of dolomitic shale and dolomite, underlies the extreme southern part of the area.

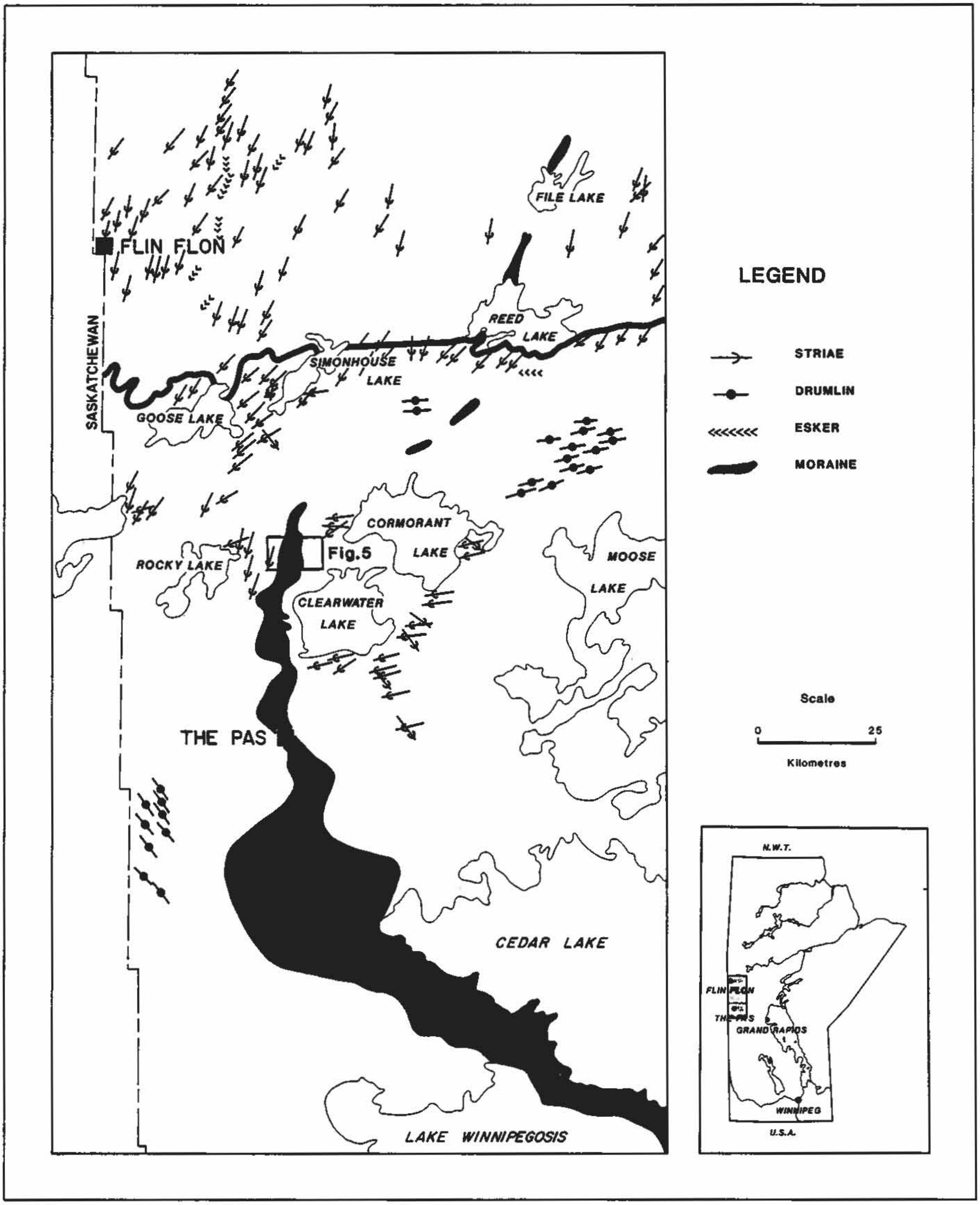


Figure 2: Ice flow directional indicators and location of The Pas moraine.

Ice Flow and Till Provenance

Striae, *roche moutonée* and the orientation of eskers on the Shield indicate the ice flow in this area was almost uniformly toward 210° (Fig. 2). By contrast, striations, crescentic gouges and drumlins on the Paleozoic terrane vary regionally, The Pas moraine forming the approximate boundary between regions of different ice flow. The Rocky Lake - Goose Lake area west of The Pas moraine was affected primarily by ice, from the Keewatin Sector of the Laurentide Ice Sheet, flowing toward approximately 210°. The area to the east of the moraine was dominated by ice flowing from the Hudsonian Sector of the Laurentide Ice Sheet toward the southwest (235°) and west (270°) (Fig. 3). Crossing striae, south of Simonhouse Lake, (Fig. 4) and flutes on top of The Pas moraine (Fig. 5) indicate the moraine was overridden by a glacial readvance during the general retreat of Hudsonian ice. Cutting relations of striae and crescentic gouges in the Rocky Lake area west of the moraine further indicate the westerly ice flow that crossed the moraine was superceded by a readvance of Keewatin ice from the north (Fig. 6).

Sampling, Analytical and Data Processing Methods

A total of 116 till samples were collected from natural exposures, road cuts and hand-dug holes (Fig. 1). The samples are all surface samples and are the product of the last ice advance to affect the area.

The less than 2 micron fraction was concentrated by centrifuging and the copper, lead, zinc, nickel, cobalt, chromium, iron, manganese and barium contents were determined by atomic absorption spectrophotometry after hot nitric-hydrochloric acid extraction. Arsenic was determined colorimetrically after nitric-perchloric acid digestion. The carbonate content (expressed as $CO_3^=$) was determined on the less than 63 micron fraction using the Leco furnace. Pebble counts were done on the 4-16 mm size fraction of selected samples. Similarly, pipette and sieve analyses were performed between -5 and 8 phi on selected samples using the technique outlined by Folk (1968).

Pearson linear correlations were calculated to determine the relationship between geochemical variables.

The geochemical data was transformed to Z scores and Ward's cluster analysis was performed using SPSS (Norusis, 1986) to determine natural groupings in the till data.

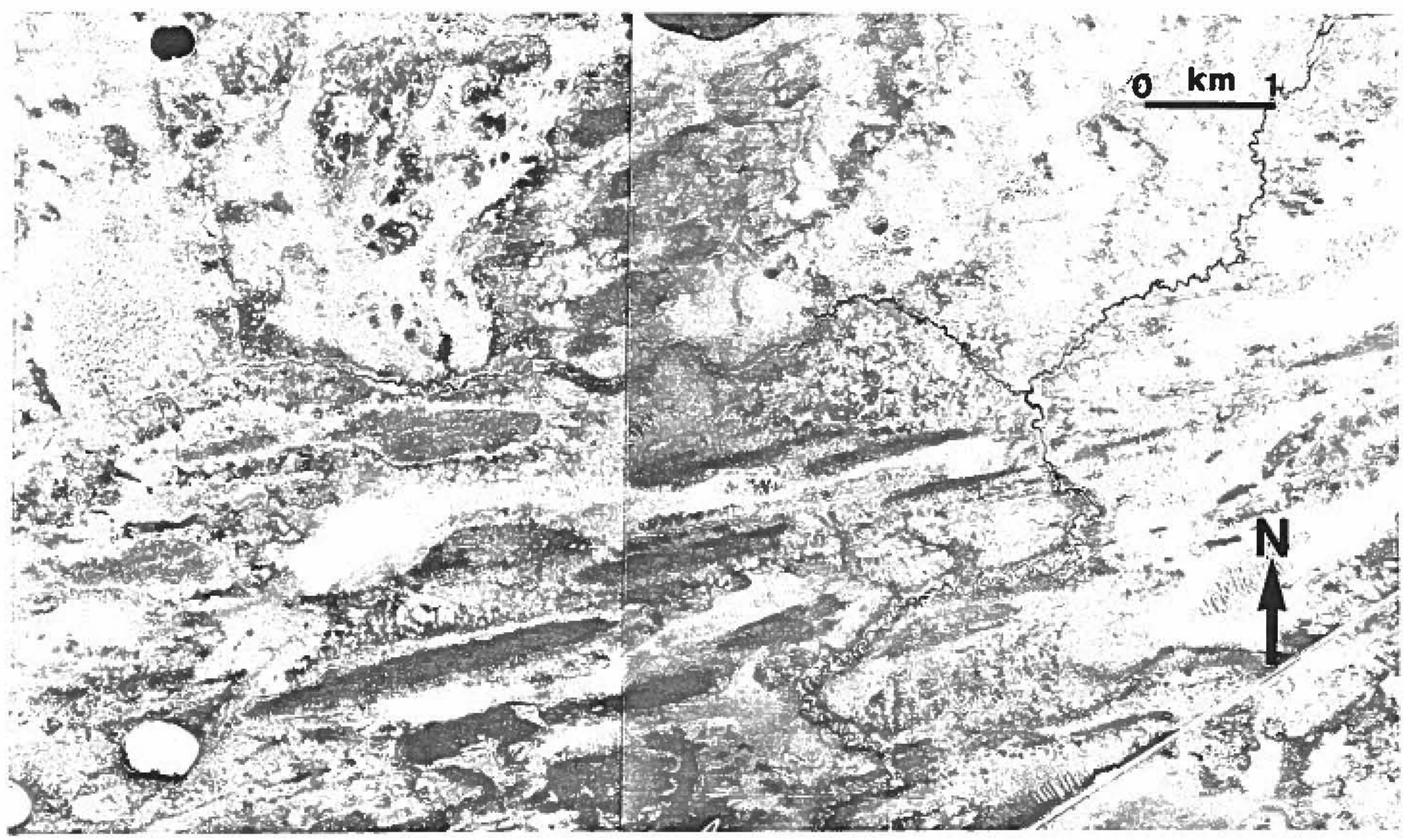


Figure 3: Air photo showing the drumlins south of Reed Lake.

Figure 4: Striae south of Simonhouse Lake indicating an early ice flow toward 225° followed by a later ice flow toward 270°.

Figure 5: Fluted till surface on The Pas moraine. Location is indicated on Figure 2.

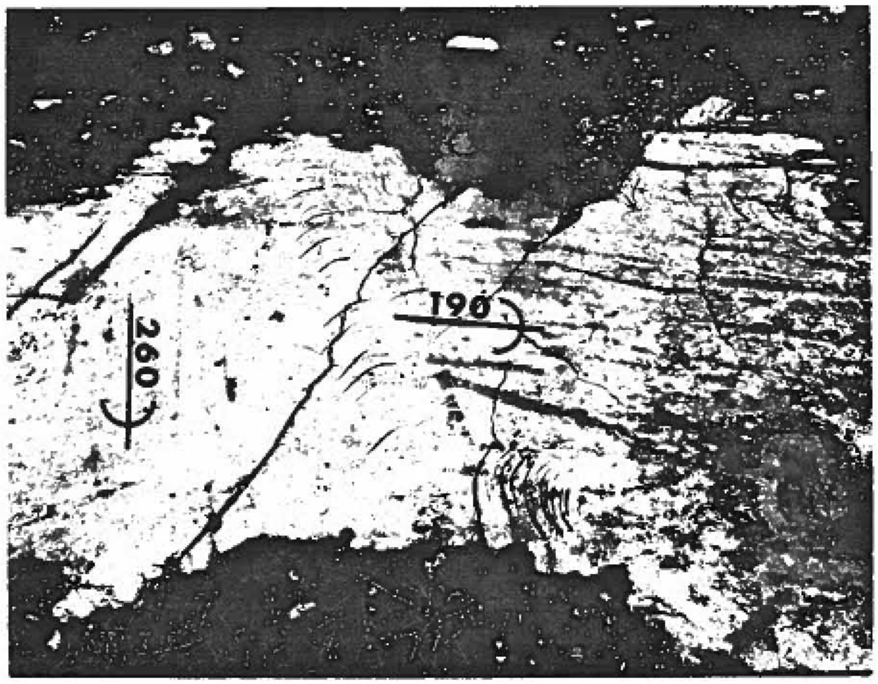


Figure 6: Striae and crescentic fractures at Rocky Lake indicating an early ice flow toward 260° followed by a later ice flow toward 190°.

RESULTS

The geochemical data are listed in Appendix I and the Pearson linear correlation matrix is presented in Table 1.

The trace elements all show a significant positive correlation except for lead. The poor correlation of lead may be due to the low concentrations of lead close to the detection limits and consequent problems with reproducibility. The trace elements are all strongly negatively correlated with the carbonate content indicating that as the trace element concentrations go up the carbonate content goes down.

The results of the hierarchical clustering is shown in the dendrogram in Figure 7. The dendrogram shows that three natural clusters or groupings, labelled groups I, II and III, occur in the data. The distribution of the samples in each of the three groups is plotted in Figure 8 and the summary statistics for each group are listed in Table 2. The frequency distribution of the trace elements and carbonate content in the three groups is shown in Figure 9.

The group I samples, found exclusively on the Shield, are characterized by relatively high trace element concentrations and low carbonate contents (Fig. 10). These samples are also sandy and contain no carbonate erratics (Fig. 11). The presence of moderate amounts of carbonate in some of the samples may be due to secondary carbonate leached from calcareous Lake Agassiz sediments in places overlying the till. The group I till samples were derived exclusively from the comminution of metavolcanic, metasedimentary and intrusive rocks of the Shield and are associated with the south southwesterly (210°) ice flow.

The till samples in group II are found over the Paleozoic terrane in the area dominated by south southwesterly (210°) ice flow (Fig. 8). In the eastern part of this area, the group II samples overlie Paleozoic bedrock in a narrow band along the southern edge of the Shield. The area widens to the west and extends southward along the Saskatchewan-Manitoba border as far as The Pas. The trace element content of the group II till samples is lower and the carbonate content is higher than those of group I (Table 2) (Fig. 10). The group II till samples are relatively silty (Fig. 11) and Shield clasts comprise 40% and carbonate clasts 60% of the pebble fraction. The trace element content, carbonate content, pebble composition, texture and areal distribution indicate group I and group II till samples are the product of the same ice advance. The differences in composition and texture reflect the differences in the source areas of the two till groups.

Group III till samples, bordering the southern and eastern margin of group II overlie Paleozoic bedrock with ice flow forms indicating western, southwestern and southeastern ice movements (Fig. 8). This group has the highest carbonate content and the lowest trace element content of the three groups (Table 2) (Fig. 10). Also, this group of tills contains the highest proportion of silt and clay (Fig. 11) and the fewest Shield pebbles (15% Shield and 85% carbonate). The trace element content, carbonate content, texture and pebble composition, as well as the associated striae directions indicate that this group of till samples was derived primarily from Paleozoic carbonate bedrock and that the Shield contributed relatively little to the composition of the till.

Table 1: Pearson correlation coefficient on trace element and carbonate data

	Cu	Ni	Zn	Pb	Co	Cr	Mn	Fe	Ba	As	CO_3
Cu	1.0000	0.5666	0.7217	-0.0459	0.6942	0.5285	0.6300	0.7621	0.4808	0.5633	-0.7476
Ni		1.0000	0.6488	-0.1066	0.5721	0.8431	0.4113	0.6622	0.5480	0.3025	-0.5731
Zn			1.0000	0.0902	0.6044	0.7159	0.5888	0.8203	0.7051	0.5010	-0.8173
Pb				1.0000	-0.0322	0.0423	0.0050	-0.0047	-0.2372	-0.1109	0.0746
Co					1.0000	0.4707	0.6979	0.8238	0.2408	0.4915	-0.6747
Cr						1.0000	0.4737	0.7189	0.5969	0.2828	-0.6539
Mn							1.0000	0.7501	0.2904	0.3774	-0.6771
Fe								1.0000	0.5002	0.4999	-0.8879
Ba									1.0000	0.3243	-0.6084
As										1.0000	-0.5138
CO_3											1.0000

Table 2: Summary statistics for the trace element geochemical, and carbonate data for groups I, II, III

Group I	Cu (ppm)	Ni (ppm)	Zn (ppm)	Pb (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	Ba (ppm)	As (ppm)	CO_3 (%)
Mean	227	94	183	8	32	188	569	60443	399	42	7.1
Low	112	49	83	0	19	71	410	37500	60	7	2.1
High	560	155	308	14	80	328	910	79000	739	238	27.3
Group II											
Mean	108	60	102	8	21	100	479	38808	242	13	21.7
Low	53	39	56	0	12	65	260	23500	113	6	2.9
High	215	92	167	17	58	155	640	61500	406	57	48.4
Group III											
Mean	45	51	72	8	11	78	355	22690	211	5	39.7
Low	26	27	47	0	7	45	230	14000	109	3	28.8
High	78	120	86	17	18	111	450	31500	363	8	47.0

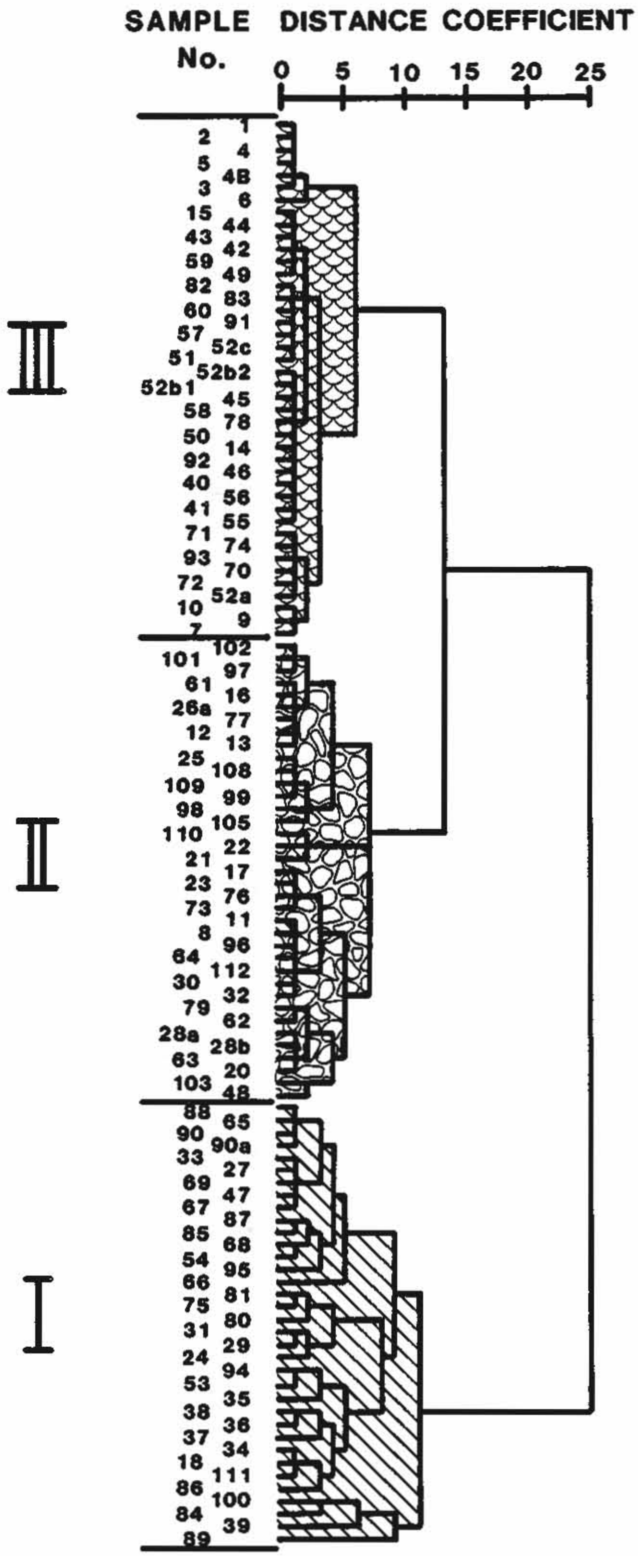


Figure 7: Dendrogram showing the result of cluster analyses of till geochemical data.

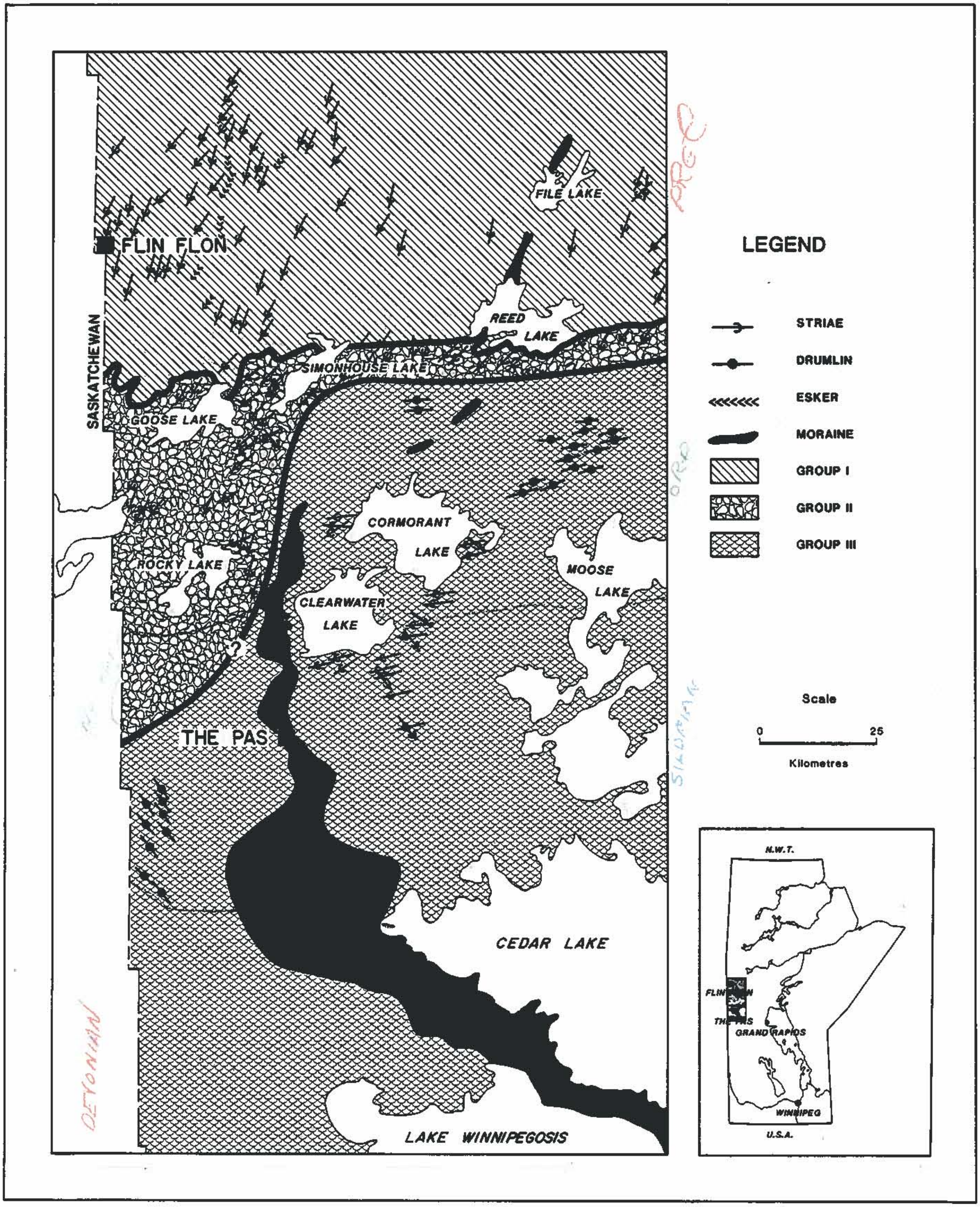


Figure 8: Areal distribution of groups I, II and III and the ice flow directional indicators.

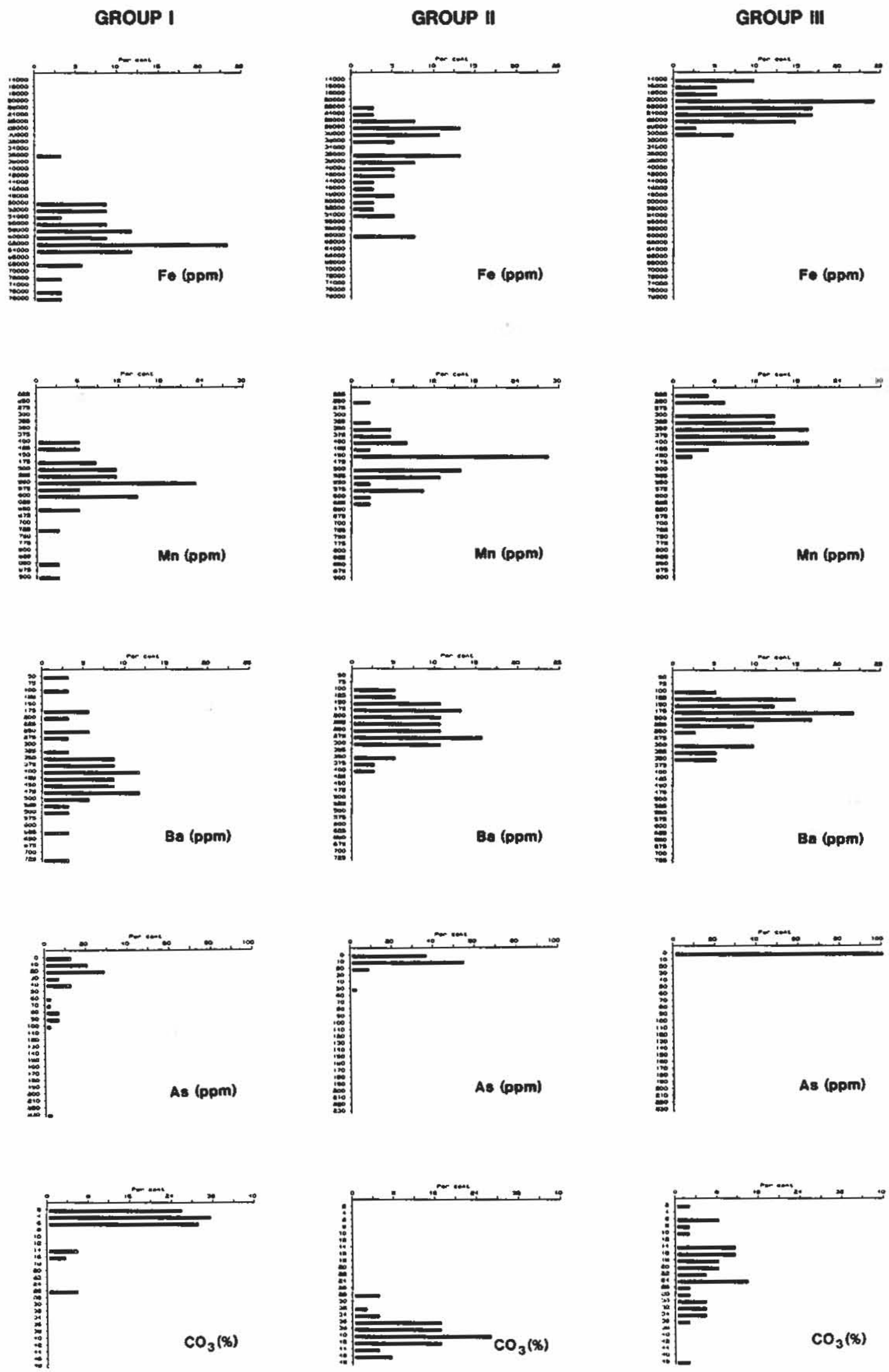
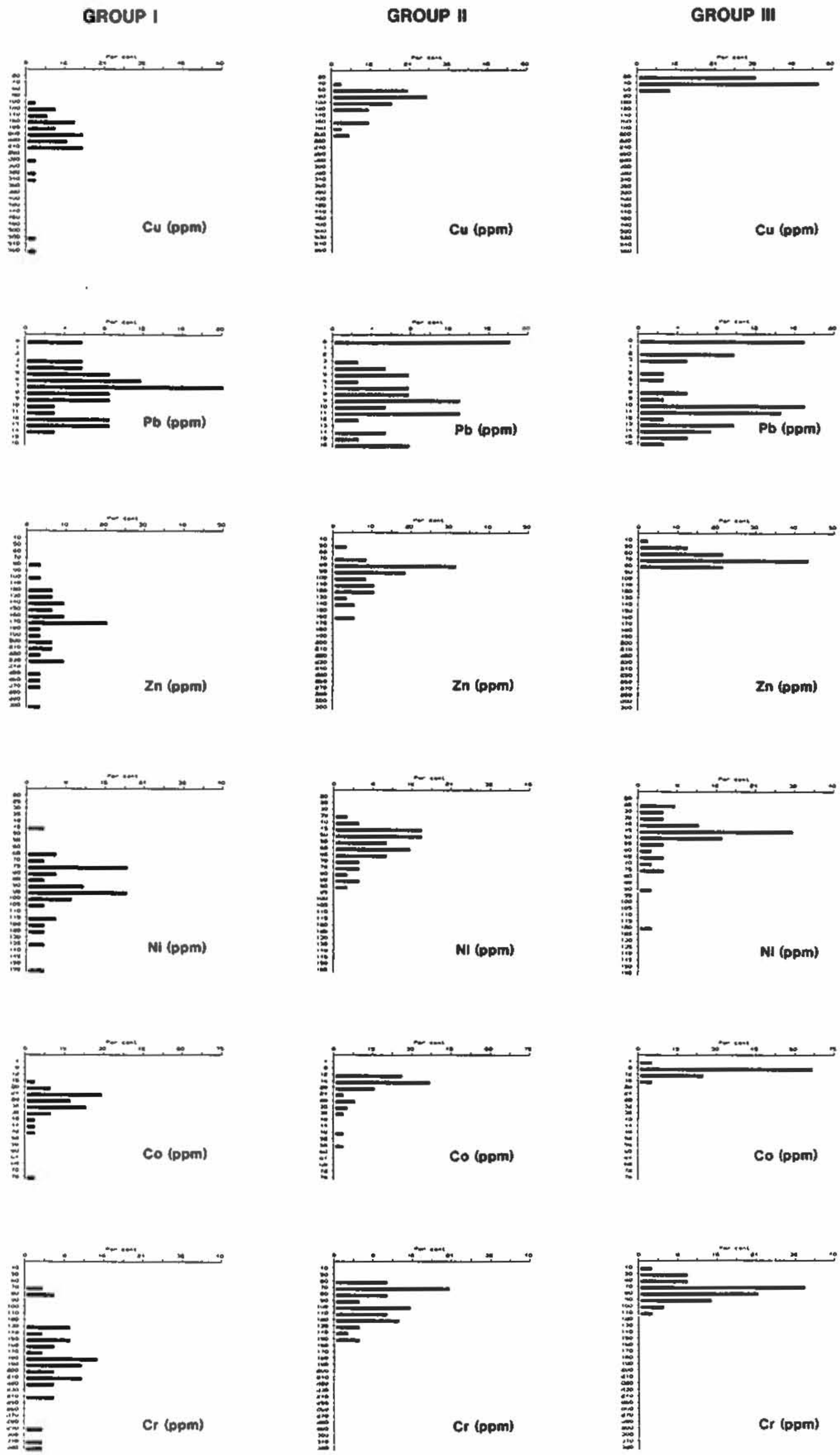


Figure 9: Frequency distribution of trace elements in groups I, II and III.


GROUP I
GROUP II
GROUP III
Cu (ppm)
Cu (ppm)
Cu (ppm)
Pb (ppm)
Pb (ppm)
Pb (ppm)
Zn (ppm)
Zn (ppm)
Zn (ppm)
Ni (ppm)
Ni (ppm)
Ni (ppm)
Co (ppm)
Co (ppm)
Co (ppm)
Cr (ppm)
Cr (ppm)
Cr (ppm)

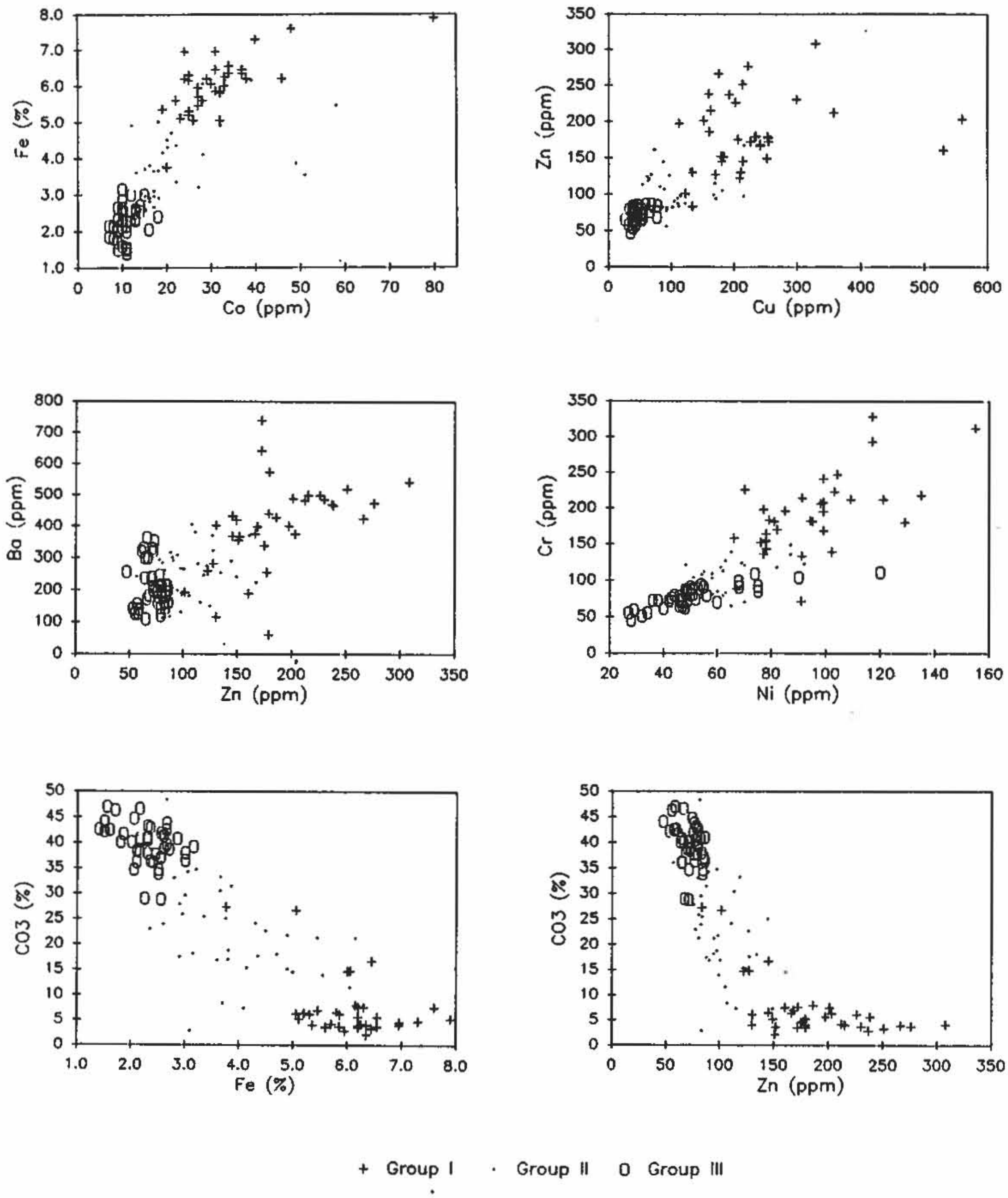


Figure 10: Selected scatter plots showing the relationship between 1) trace element concentrations, and 2) trace element concentrations and carbonate content.

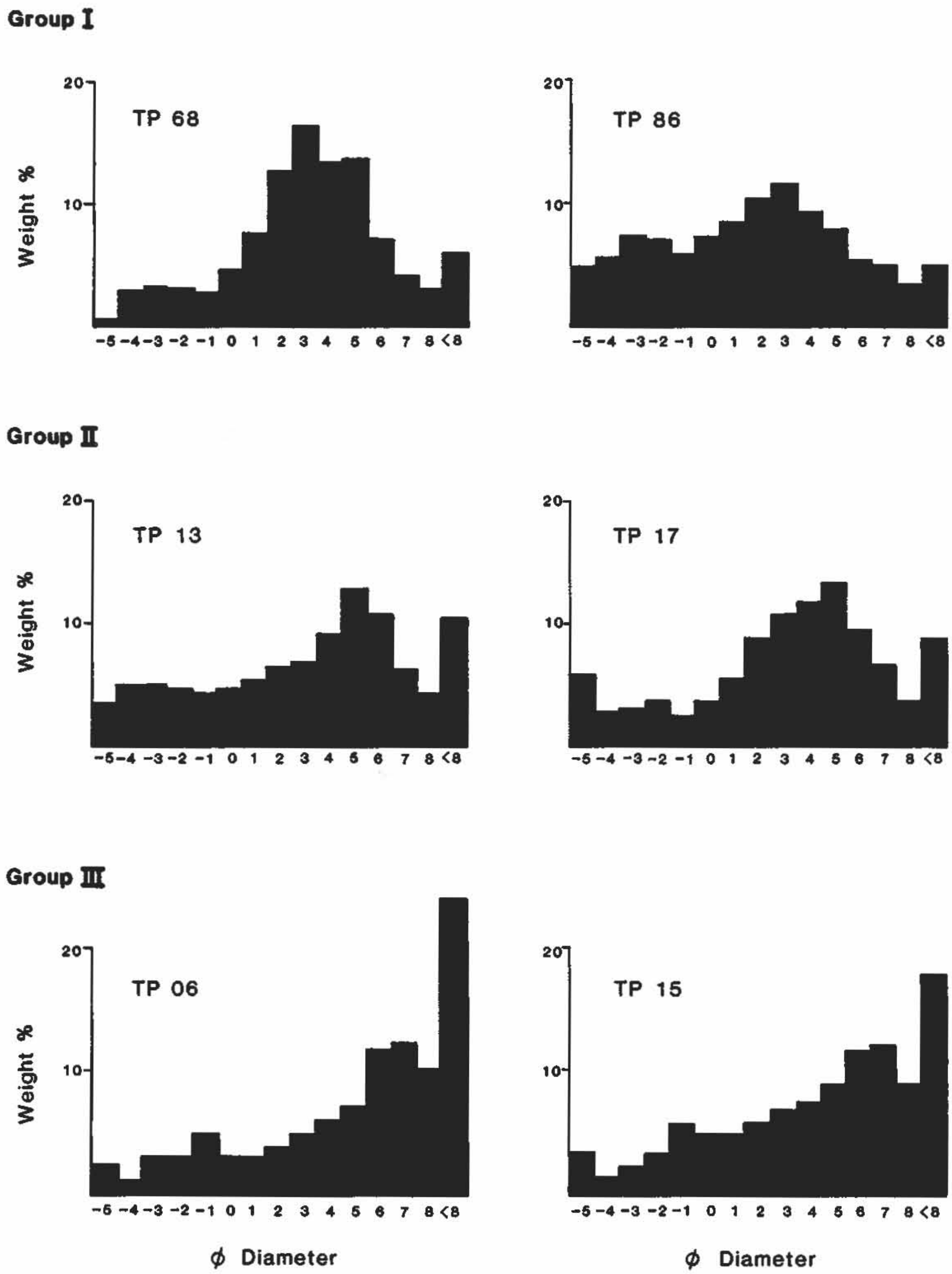


Figure 11: Histograms showing the grain size distribution of representative till samples from groups I, II and III.

DISCUSSION

Cluster analyses of the trace element geochemistry allows the surface till to be divided into three distinct groups. The trace element concentrations and carbonate content may be related to the distance from the Shield along the ice flow path. Group I till is composed entirely of material derived from the Precambrian terrane whereas group II till is composed of a mixture of Precambrian and Paleozoic material. The till samples of groups I and II were deposited by the same ice advance which was the main ice flow from the Keewatin Sector of the Laurentide Ice Sheet. Group III till samples, on the other hand, is composed mainly of Paleozoic carbonate material and is relatively deficient in trace elements reflecting longer glacier transport than the group II samples. The Shield component in the group III till samples experienced the longest glacial transport. At The Pas, the closest Shield rocks outcropping along the westerly ice flow path are 160 km to the east northeast near Ponton. Similarly, the closest shield outcroppings along the southeasterly ice flow path west of The Pas are 120 km to the northwest in the Amisk Lake area of Saskatchewan.

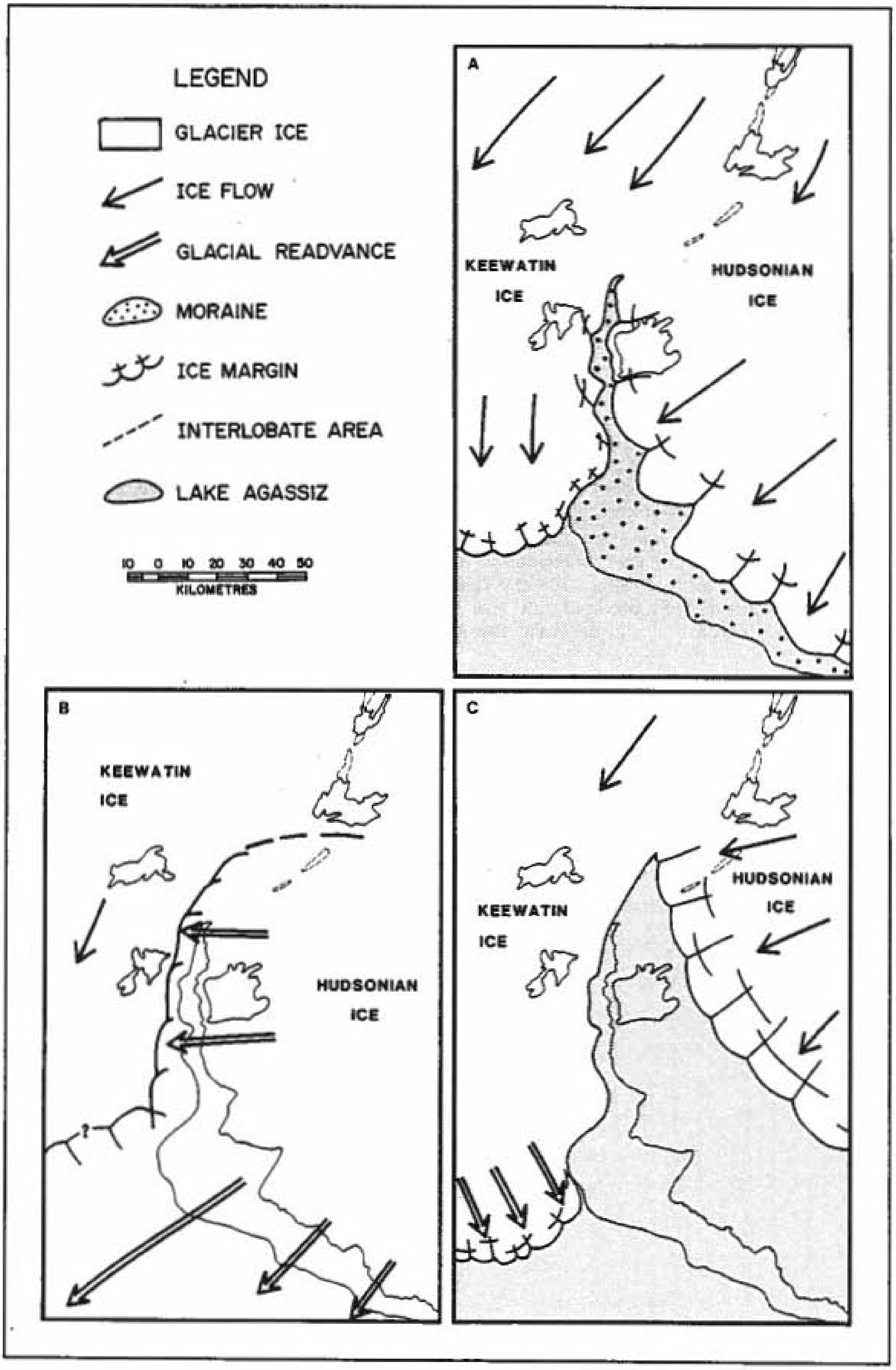


Figure 12: Late glacial history of The Pas-Flin Flon area.

CONCLUSIONS

Three distinct tills can be differentiated using cluster analyses on trace element and carbonate geochemical data. The group I till occurs only on the Shield and has high trace element concentrations but little or no carbonate. The group II till is found on Paleozoic bedrock adjacent to the Shield and has concentrations of trace elements and carbonate intermediate between group I and III tills. Group III till has the highest concentrations of carbonate and the lowest concentrations of trace elements. The trace element concentrations and the carbonate content of the till is related to the source areas whether it be mainly metasedimentary, metavolcanic or intrusive rocks of the Shield or Paleozoic carbonate rocks. The relative concentrations of trace elements is thus a function of the distance of glacial transport from the Shield.

Based on field mapping of ice flow directional indicators, ice margin positions, geochemical analyses of trace element concentrations and carbonate content of till samples the following sequence of event can be postulated.

The main Wisconsinan ice flow (125°-140°) to affect most of Manitoba west of Lake Winnipeg originated in the District of Keewatin north of Manitoba. As the Late Wisconsinan ice margin receeded northward, ice flow of Hudsonian provenance increased in intensity and the regional ice flow was deflected toward the southwest (Fig. 12a). During a halt in the general ice recession The Pas moraine formed possibly about 11 000 years ago (Christiansen 1979, Klassen 1983). The Reed Lake moraine and the northern part of The Pas moraine north of Westray marked the contact between Hudsonian and Keewatin ice (Fig. 12a). The ice margin south of Westray terminated in glacial Lake Agassiz.

A resurgence of Hudsonian ice resulted in a glacial readvance (Fig. 12b). The Pas moraine was over-ridden resulting in the fluting of the moraine. South of The Pas the ice advanced over The Pas moraine into Lake Agassiz, whereas north of The Pas Hudsonian ice abutted or overrode Keewatin ice (Fig. 12b). The interaction of Hudsonian and Keewatin ice west of the moraines is indicated by crossing striae in the Rocky Lake and Simonhouse Lake areas. At Rocky Lake southerly trending striae (190°) postdate westerly trending striae (260°) whereas at Simonhouse Lake southwesterly trending striae predate westerly trending striae (270°).

Hudsonian ice retreated quickly and was gone from the area by about 10 000 years BP. Keewatin ice readvanced in the Pasquia basin and remoulded the till into drumlins (Fig. 12c).

ACKNOWLEDGEMENTS

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Appendix I:

Trace element geochemistry of the <2 micron fraction and carbonate content of the <63 micron fraction

Sample Number	Cu (ppm)	Ni (ppm)	Zn (ppm)	Pb (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	Ba (ppm)	As (ppm)	CO_3 (%)
69-86-TP-1	47	75	72	3	8	85	320	18000	320	4	40.1
69-86-TP-2	45	75	61	1	7	92	320	18500	321	3	41.7
69-86-TP-3	41	90	63	1	9	104	380	20000	331	3	40.1
69-86-TP-4	44	68	71	1	8	91	340	21500	329	6	40.3
69-86-TP-4B	51	74	73	1	10	109	250	26000	353	5	38.9
69-86-TP-5	44	56	66	3	11	79	320	20000	363	3	40.1
69-86-TP-6	52	120	64	1	18	111	390	24000	300	5	36.1
69-86-TP-7	35	28	47	2	9	45	240	15000	256	4	44.1
69-86-TP-8	81	61	110	1	20	118	500	43000	381	6	24.2
69-86-TP-9	55	34	67	2	12	55	300	22500	300	8	29.0
69-86-TP-10	53	32	71	2	10	51	370	25500	240	7	28.8
69-86-TP-11	96	69	126	1	20	124	530	45000	370	6	22.7
69-86-TP-12	92	69	80	1	17	102	460	29500	285	12	25.9
69-86-TP-13	91	70	56	1	15	70	450	25500	242	6	36.1
69-86-TP-14	45	52	70	1	14	74	400	27000	233	5	38.7
69-86-TP-15	41	47	64	1	7	70	330	21500	237	5	40.8
69-86-TP-16	63	51	89	1	14	94	420	30500	302	6	34.3
69-86-TP-17	104	77	90	1	13	155	450	36000	292	7	16.9
69-86-TP-18	210	77	130	1	25	136	530	53000	402	9	6.1
69-86-TP-20	113	70	98	16	32	121	620	49000	185	17	21.8
69-86-TP-21	133	87	80	9	39	149	340	61500	113	11	21.3
69-86-TP-22	121	65	87	14	49	65	410	38500	118	12	31.5
69-86-TP-23	114	79	97	11	16	154	450	38000	267	10	18.8
69-86-TP-24	170	117	127	9	30	328	510	60500	282	9	14.8
69-86-TP-25	67	52	75	11	16	83	530	29000	223	8	27.9
69-86-TP-26a	101	54	82	9	14	76	460	30000	215	9	29.6
69-86-TP-27	151	99	201	13	25	195	570	63000	488	17	7.5
69-86-TP-28a	181	63	105	4	28	83	510	60500	182	21	11.6
69-86-TP-28b	167	62	99	4	28	79	540	55500	195	18	14.0
69-86-TP-29	133	117	83	7	20	293	490	37500	212	13	27.3
69-86-TP-30	88	62	107	5	15	113	460	37000	406	10	8.4
69-86-TP-31	122	103	101	7	26	223	560	50500	192	7	26.7
69-86-TP-32	72	65	161	12	18	139	590	50000	371	9	14.6
69-86-TP-33	160	79	18	6	25	183	620	61500	427	21	7.9
69-86-TP-34	179	66	152	6	22	158	560	56000	367	24	3.6
69-86-TP-35	133	78	130	7	37	164	610	63500	116	101	4.0
69-86-TP-36	183	77	15	8	34	198	740	63500	355	45	2.1
69-86-TP-37	254	70	177	7	40	226	910	73000	255	16	4.7
69-86-TP-38	206	82	175	7	31	170	590	69500	339	38	4.5
69-86-TP-39	233	91	179	4	80	71	860	79000	60	95	5.2
69-86-TP-40	39	48	72	11	10	84	370	21000	197	5	38.5
69-86-TP-41	40	55	76	13	13	91	380	23500	194	6	36.4
69-86-TP-42	39	53	78	10	9	88	320	23000	246	6	43.2
69-86-TP-43	39	48	78	9	9	87	330	23500	214	4	42.9
69-86-TP-44	36	46	71	15	9	78	330	20500	210	4	34.7
69-86-TP-45	39	49	79	13	10	87	420	24500	120	4	37.7
69-86-TP-46	47	50	79	12	9	80	390	26500	190	6	39.6
69-86-TP-47	234	99	179	9	24	241	540	69500	439	24	4.0
69-86-TP-48	60	48	124	17	12	121	260	49000	150	17	15.2
69-86-TP-49	52	68	80	11	10	99	350	26500	214	3	42.5
69-86-TP-50	40	49	75	17	14	71	410	25500	191	7	41.8
69-86-TP-51	38	43	80	14	10	76	340	31500	184	7	39.2

Sample Number	Cu (ppm)	Ni (ppm)	Zn (ppm)	Pb (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	Ba (ppm)	As (ppm)	CO_3 (%)
69-86-TP-52a	26	40	65	15	8	61	360	21000	109	4	36.2
69-86-TP-52b1	33	47	79	14	13	74	440	26000	144	3	41.3
69-86-TP-52b2	38	49	83	10	12	83	450	30000	142	6	38.0
69-86-TP-52c	42	44	82	10	10	79	390	28500	160	7	40.8
69-86-TP-53	252	78	149	9	23	154	550	51000	420	85	5.2
69-86-TP-54	226	85	172	7	24	196	560	62000	643	41	3.5
69-86-TP-55	45	54	85	8	12	94	430	25500	213	5	37.1
69-86-TP-56	48	50	84	14	10	91	380	25000	215	5	33.9
69-86-TP-57	40	43	76	13	9	71	370	26500	157	6	43.8
69-86-TP-58	59	51	86	13	15	88	420	30000	161	7	36.5
69-86-TP-59	39	48	66	10	11	82	340	21500	172	4	46.6
69-86-TP-60	40	36	77	11	10	72	360	23000	178	5	40.5
69-86-TP-61	53	51	113	11	17	104	440	36500	282	7	30.5
69-86-TP-62	215	55	167	9	23	112	580	52000	224	23	6.7
69-86-TP-63	169	58	115	3	33	109	500	61500	162	7	7.4
69-86-TP-64	67	63	127	11	22	127	450	43500	324	6	17.7
69-86-TP-65	202	95	226	5	31	181	550	58500	499	33	6.1
69-86-TP-66	329	155	308	12	33	312	590	62500	542	10	4.1
69-86-TP-67	159	104	238	14	34	247	610	65500	466	23	5.6
69-86-TP-68	253	94	179	13	28	182	510	56000	573	26	3.5
69-86-TP-69	112	91	197	12	29	214	520	62000	400	10	5.6
69-86-TP-70	37	47	59	11	11	64	300	14000	139	5	42.6
69-86-TP-71	39	48	53	10	11	62	230	15000	142	5	42.2
69-86-TP-72	32	46	58	10	11	64	350	15500	127	4	47.0
69-86-TP-73	62	82	118	15	18	118	450	36500	246	7	33.3
69-86-TP-74	37	46	55	11	9	72	250	17000	126	3	46.3
69-86-TP-75	209	135	122	5	33	218	550	60000	260	26	14.7
69-86-TP-76	127	87	100	10	16	136	460	38000	265	10	17.0
69-86-TP-77	86	52	82	10	14	97	420	26000	231	8	24.0
69-86-TP-78	78	42	84	11	13	72	420	25000	179	8	34.7
69-86-TP-79	130	54	134	11	21	108	590	47000	254	12	18.1
69-86-TP-80	180	102	145	4	37	139	560	64500	368	16	16.7
69-86-TP-81	214	129	145	1	32	180	520	58000	432	28	6.5
69-86-TP-82	66	29	76	2	11	59	410	23000	198	5	37.8
69-86-TP-83	77	27	68	16	11	55	410	21500	183	8	38.2
69-86-TP-84	560	91	203	12	32	133	610	50500	375	97	6.3
69-86-TP-85	357	99	212	7	27	168	490	57000	482	43	4.2
69-86-TP-86	162	49	215	5	19	83	670	53500	500	24	4.0
69-86-TP-87	299	99	230	8	32	195	530	58500	486	40	3.7
69-86-TP-88	192	99	237	8	27	208	420	59500	469	26	2.8
69-86-TP-89	213	98	251	3	31	206	480	64500	519	238	3.3
69-86-TP-90	222	121	276	11	34	212	540	65500	474	27	3.7
69-86-TP-90a	175	109	266	13	38	212	430	62000	424	8	3.9
69-86-TP-91	68	38	86	8	13	72	350	23000	201	8	41.0
69-86-TP-92	55	51	74	10	16	80	41	20500	200	6	44.7
69-86-TP-93	43	60	57	5	10	70	260	16000	156	6	42.5
69-86-TP-94	241	78	166	6	25	143	440	52000	376	88	6.4
69-86-TP-95	255	81	172	3	46	181	620	62000	739	75	7.6
69-86-TP-96	64	58	121	16	19	103	470	41500	276	10	15.4
69-86-TP-97	109	41	94	5	15	73	500	31500	309	12	18.2
69-86-TP-98	215	60	97	9	27	85	640	32000	131	18	34.8
69-86-TP-99	92	45	81	14	17	66	580	26500	144	11	48.4
69-86-TP-100	530	67	160	10	48	88	650	76000	189	65	7.5
69-86-TP-101	109	45	87	9	18	78	370	29000	317	20	17.5
69-86-TP-102	91	39	77	8	17	67	370	23500	294	19	23.0
69-86-TP-103	178	58	149	1	28	81	390	41000	241	57	7.4

Sample Number	Cu (ppm)	Ni (ppm)	Zn (ppm)	Pb (ppm)	Co (ppm)	Cr (ppm)	Mn (ppm)	Fe (ppm)	Ba (ppm)	As (ppm)	CO_3 (%)
69-86-TP-104	71	45	82	8	15	72	390	26000	261	13	
69-86-TP-105	83	49	83	7	17	79	570	31000	168	17	2.9
69-86-TP-107	78	41	83	7	15	74	510	29500	176	13	
69-86-TP-108	82	45	79	8	16	68	530	28000	153	11	33.1
69-86-TP-109	111	48	83	7	22	73	540	33500	201	17	25.5
69-86-TP-110	171	92	94	6	58	123	500	54500	199	17	21.3
69-86-TP-111	241	76	168	6	27	152	410	54500	398	18	6.9
69-86-TP-112	86	54	144	5	19	108	470	37500	291	7	25.1