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Correlation of Glacial sediments Using Heavy-Minerals Assemblages

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CORRELATION OF GLACIAL SEDIMENTS USING HEAVY-MINERAL ASSEMBLAGES

by

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USING HEAVY-MINERAL ASSEMBLAGES

ABSTRACT

An optical study of the heavy minerals of the till in two lithostratigraphic units in Polk, Red Lake, and Norman Counties in northwestern Minnesota was undertaken. The purpose was to determine whether the assemblages are different enough to differentiate the two tills and whether the assemblages are laterally consistent enough to be used as a basis for correlation.

An earlier study (Hobbs, 1973) showed that these tills outcropping in the Red Lake Falls area could be distinguished on the basis of heavy-mineral analysis.

Both units contain hornblende, pyroxene, garnet, magnetite, and epidote, but in different proportions. The upper unit, the Huot Formation, has significantly more epidote and amphibole and less garnet and pyroxene than the Red Lake Falls Formation. It was found that these differences are laterally too variable to be used as a direct basis for correlation.

INTRODUCTION

Sitler (1968) found that heavy-mineral studies were useful in lithostratigraphy of glacial sediments of northeastern Ohio providing three conditions were met. (1) Each unit must have an internally consistent heavy-mineral assemblage. (2) The assemblage in each unit should be different from that of adjacent units. (3) Each assemblage should persist for a long distance laterally.

Previous studies of the Huot and Red Lake Falls Formations by Hobbs (1973) and Hobbs and Karner (1972) have shown that the units do have different assemblages though the differences aren't great and that internally the Red Lake Falls Formation is not consistent.

The purpose of this study is to examine a series of samples of these two Pleistocene units (Figure 1) south of the area sampled by Hobbs in 1973 and determine if the differences in the heavy minerals are consistent laterally.

The samples used in this study were provided by Dr. Ken Harris of the North Dakota Geological Survey. All were from power auger holes averaging about 12 m deep with the exception of the northern-most sample, N-1011 which is an outcrop sample.

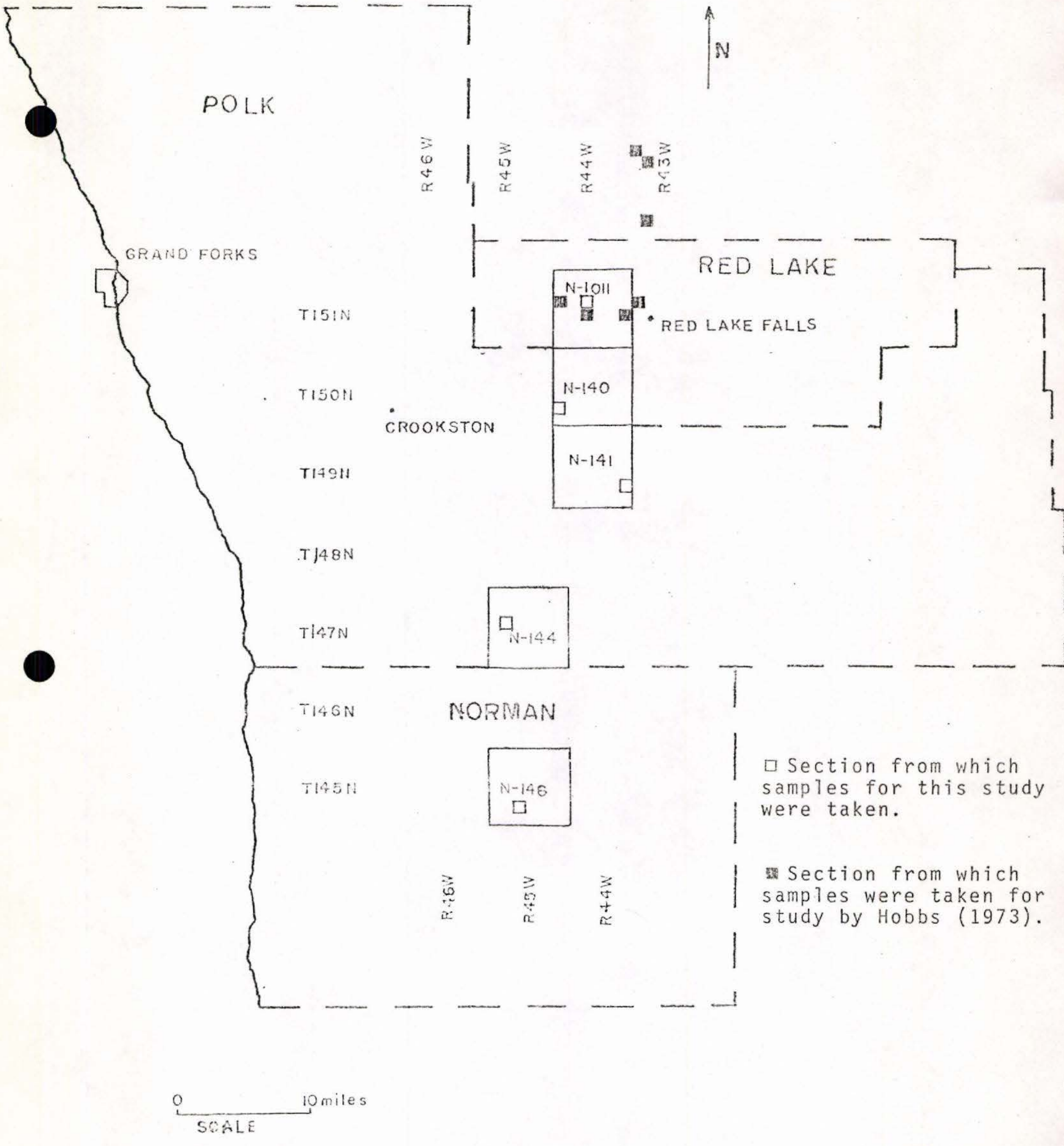


Figure 1.--Sample locations of this study and some of those of Hobbs (1973).

Each sample was given a three element designation, such as N-144-11. The first two elements indicate sample location and the third indicates the sample's depth in feet except in outcrop samples in which the third element indicates the sample number as the samples were numbered from bottom to top. Samples from each location were chosen in such a way that they were somewhat equidistant throughout the section (see Figure 2).

After preparation, (see Appendix A) the samples were examined optically in order to correlate the results with those of Hobbs, who discontinued the use of x-ray analysis because only hornblende, pyroxene, and garnet could be recognized consistently on difractograms.

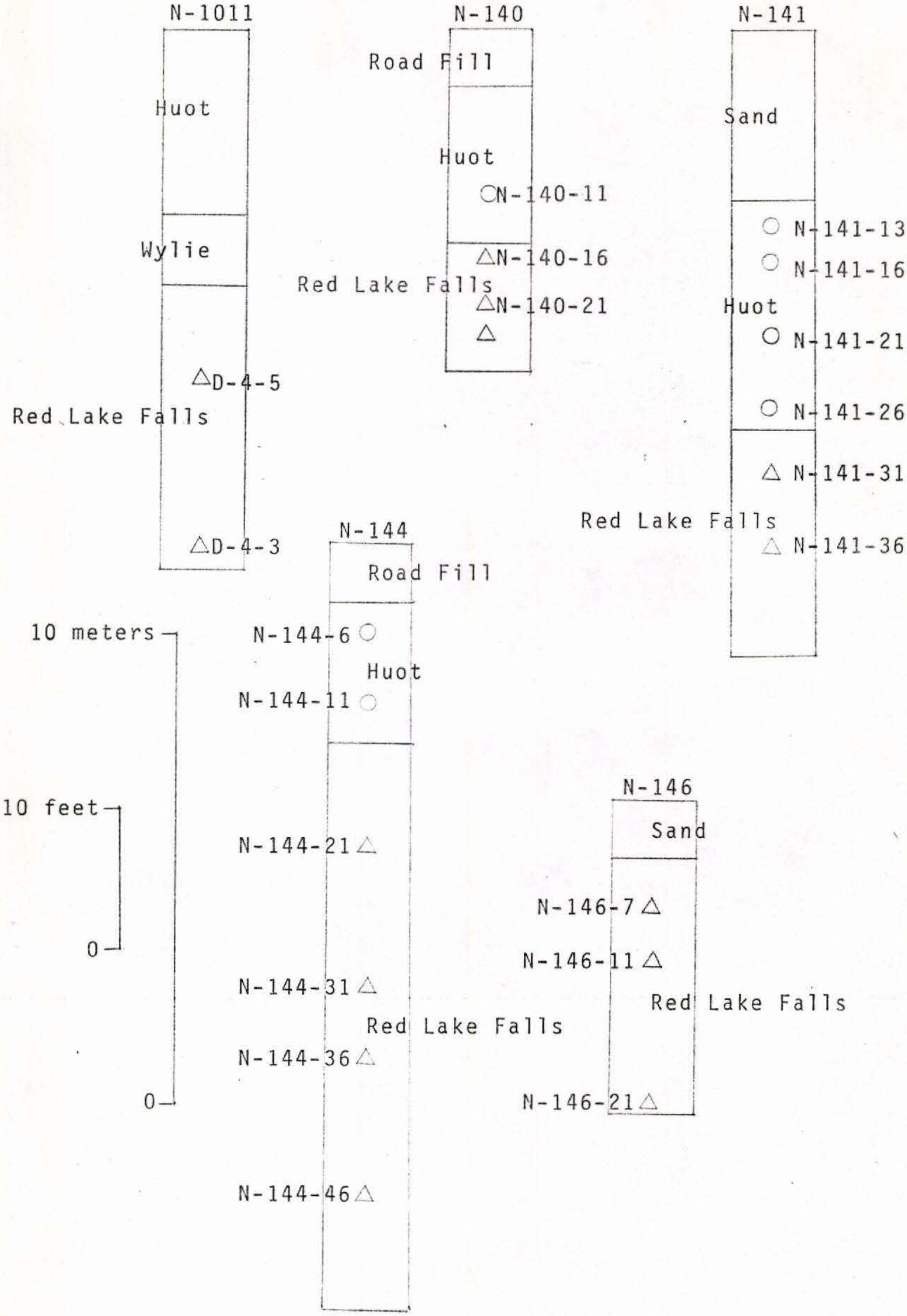


Figure 2.--Sample distribution within the five sample locations.

CHAPTER 1

STRATIGRAPHIC SUMMARY

The following lithostratigraphic units (Harris, 1973) were involved in this study.

Red Lake Falls Formation

The Red Lake Falls Formation, thought to be late Wisconsinan in age, consists largely of unbedded glacial sediment. It is olive brown pebbly loam. Pebbles (4 to 64 mm) are about 33 percent igneous and metamorphic rock types and 66 percent carbonate rock types. Numerous sand and gravel inclusions range from thin beds to channel fills with scoured bases.

Huot Formation

The Huot Formation consists largely of unbedded glacial sediment. It is very slightly pebbly clay that is dark olive gray. Most of the pebbles in the unit are limestone and dolomite. Small tan, calcareous, chalk-like inclusions are also present. The Huot Formation is thought to be late Wisconsinan in age.

CHAPTER 2

METHODS FOR RECOGNIZING HEAVY MINERALS

Introduction

Heavy-mineral grains are recognized generally by their high relief and uniform extinction. They were counted only when composed primarily of one crystal. Twinned crystals were counted as one but aggregates of crystals were considered rock fragments.

Many heavy-mineral grains have some inclusions and alteration. The altered grains were counted as mineral grains unless they were too badly altered to be recognized.

After preparation (see Appendix A), the heavy-mineral grains in the sample were counted using a petrographic microscope and a mechanical stage and point counter. On each slide 100 to 500 grains were counted to determine the proportion of the different heavy minerals. Light minerals, recognized by low birefringence and low relief, and rock fragments were disregarded.

The precision and accuracy of the counting procedure are discussed in Appendix C.

Heavy Minerals

The criteria for identification for each of the most abundant heavy minerals is discussed below.

Hornblende

Hornblende grains are generally recognized by their usually predominant pleochroism and low extinction angle. Hornblende grains range in color from straw yellow to dark green to black. The charateristic cleavage and moderate relief helped to distinguish it from clinopyroxene grains in certain orientations. Some actinolite grains may have been confused with hornblende because they were differentiated by only differences in extinction angle and birefringence.

Pyroxene

Pyroxene grains are identified by their high relief and characteristic cleavage, which creates a jagged appearance on the edges of the grains. Orthopyroxene has low to medium birefringence and parallel extinction, and it may have pink and green pleochroism ranging from barely detectable to pronounced. Clinopyroxene can be differentiated by its inclined extinction, its birefringence, which is higher than that of orthopyroxene, and its absence of pleochroism. Most clinopyroxene is colorless or less commonly is various shades of green.

Garnet

Garnet is isotropic, lacks cleavage, and has very high relief. Of all the heavy minerals, garnet is the most easily identified.

Epidote

Epidote is characteristically greenish yellow with an absence of cleavage, and has high relief and high birefringence. Epidote has parallel extinction but crystal structure or cleavage with which to compare the extinction is rarely present. Many grains are fractured or contain inclusions and alteration. These are not easily identifiable because they do not have uniform extinction and it is hard to determine birefringence.

Magnetite

Magnetite is steel gray in reflected light. The grains were counted if they had an even perimeter and no light came through the edges. Many grains have hemitite stains. If the entire surface is covered the grain was counted as hemitite.

Some opaque steel gray grains have white patches on the surface. Those were counted as ilmenite. If more than half of the surface is white, the grain was counted as leucoxene.

Biotite

Biotite and chlorite grains were not counted in this study because many of the grains were lost in the washing process described in Appendix A.

CHAPTER 3

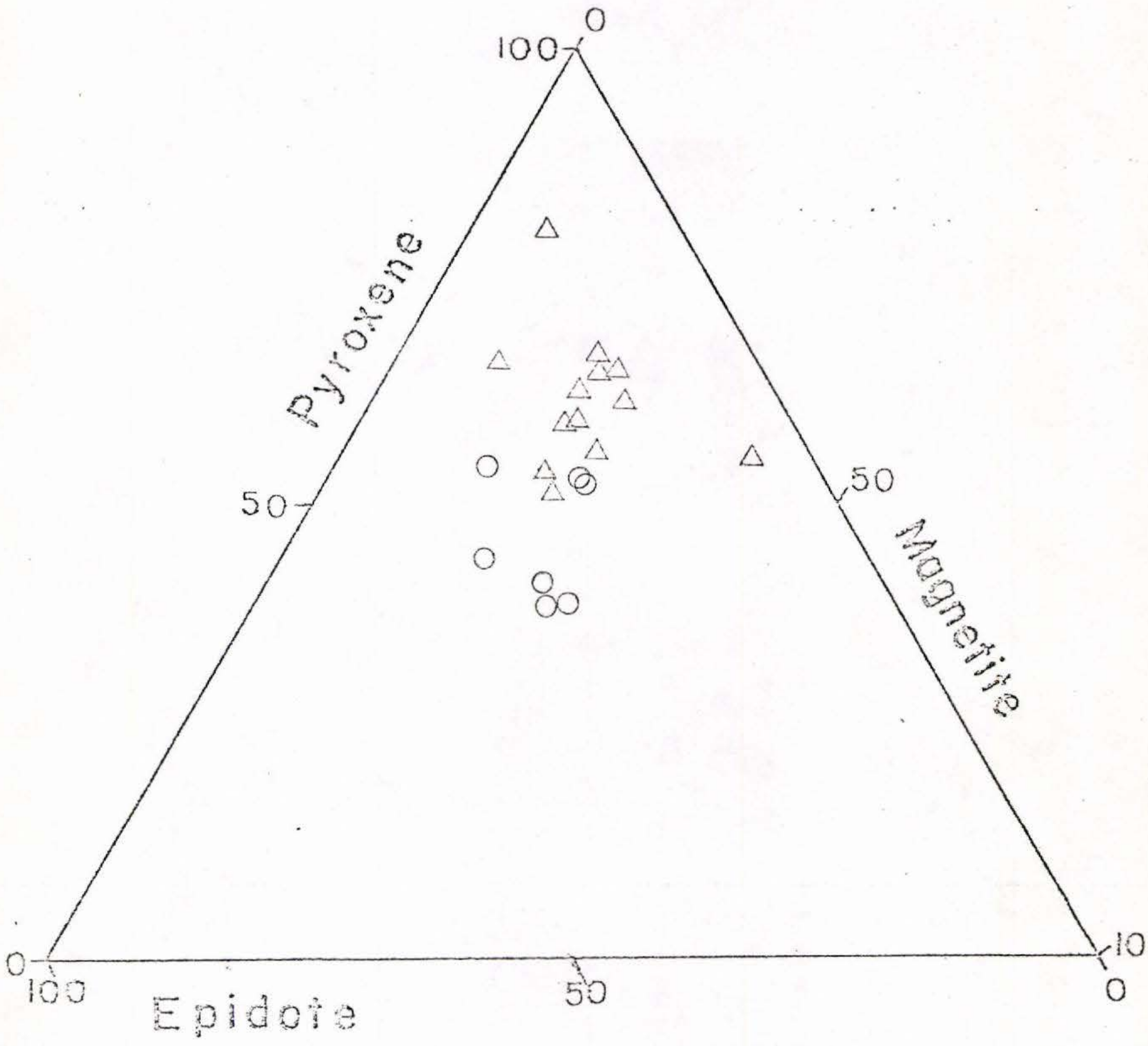
CHARACTERISTIC HEAVY-MINERAL ASSEMBLAGES IN EACH UNIT

Red Lake Falls Formation

The Red Lake Falls Formation has greater internal variation than the Huot. this variation results in an overlap with the assemblage of the Huot (Figure 3 and 4). Generally the Red Lake Falls has more garnet and pyroxene than the Huot Formation (Table 1a). This is especially true for the orthopyroxene. The Red Lake Falls also has less epidote and possibly less amphibole, but this is extremely slight. These characteristics generally agree with the results of Hobbs (1973), but there is a small variation in that he found the mean amphibole content of the two to be almost equal. The differences between the two units are more evident when the means of ratios of three abundant minerals are compared (Table 1b).

Huot Formation

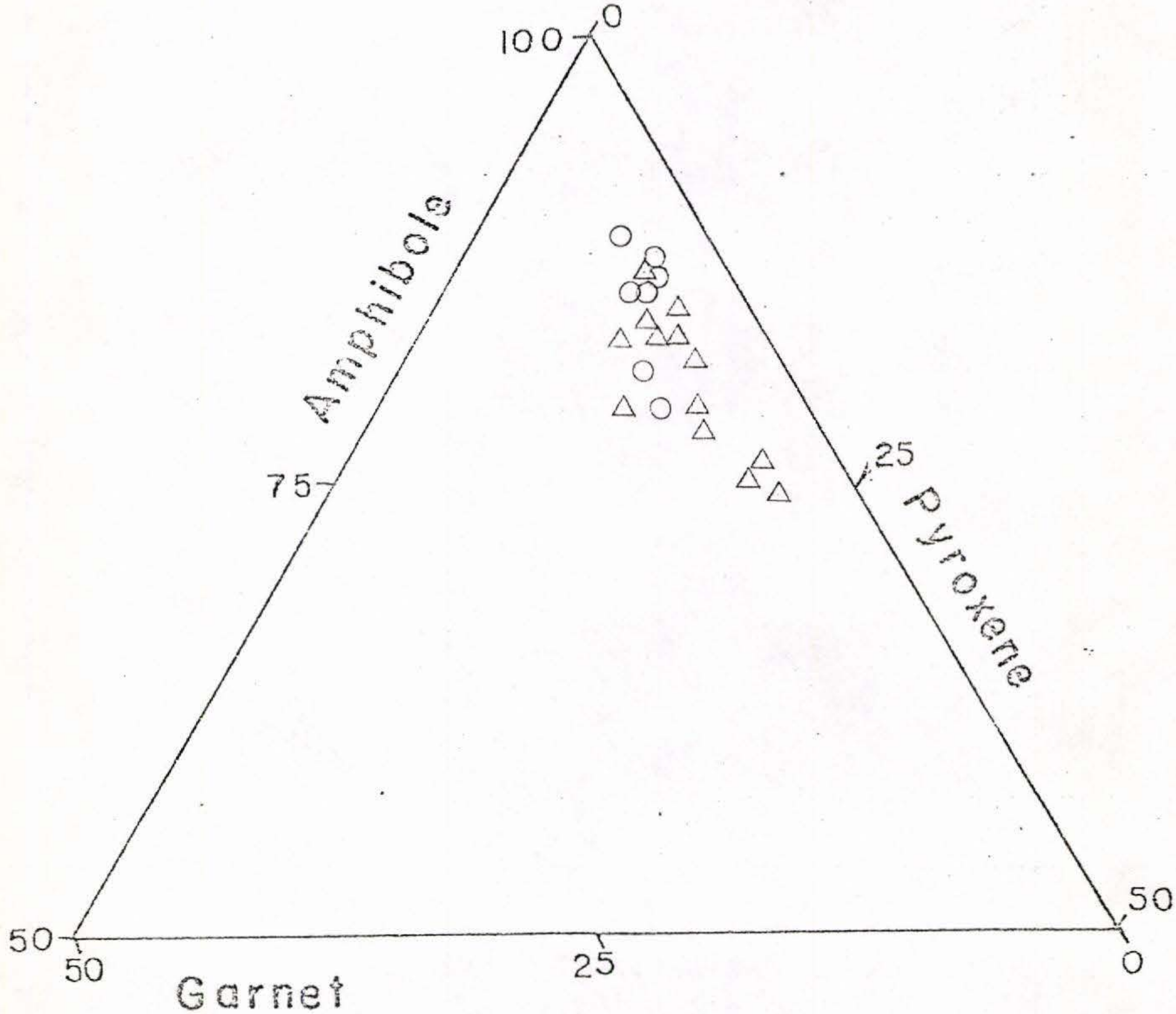
The Huot has greater internal consistency, less garnet and pyroxene, and more epidote and amphibole (Figure 3 and 4 and Tables 1a and 1b).



△ Red Lake Falls Formation

○ Huot Formation

Figure 3.--Pyroxene, magnetite, and epidote ratios.



△ Red Lake Falls Formation

○ Huot Formation

Figure 4.--Amphibole, pyroxene, and garnet ratios.

Table 1a

Mean (M) and standard deviation (S) of the proportions of the most abundant heavy minerals.

	Huot		Red Lake Falls	
	M	S	M	S
Amphibole	73	4	72	4
Garnet	4	1	5	1
Epidote	6	1	4	1
Clinopyroxene	6	2	8	2
Orthopyroxene	3	1	5	2
Magnetite	5	1	4	2

Table 1b

Mean (M) and standard deviation(S) of three-mineral ratios by unit.

	Huot		Red Lake Falls	
	M	S	M	S
Amphibole	85	4	81	4
Pyroxene	10	2	15	4
Garnet	5	1	5	2
Magnetite	24	5	20	8
Pyroxene	45	7	61	8
Epidote	31	6	18	6

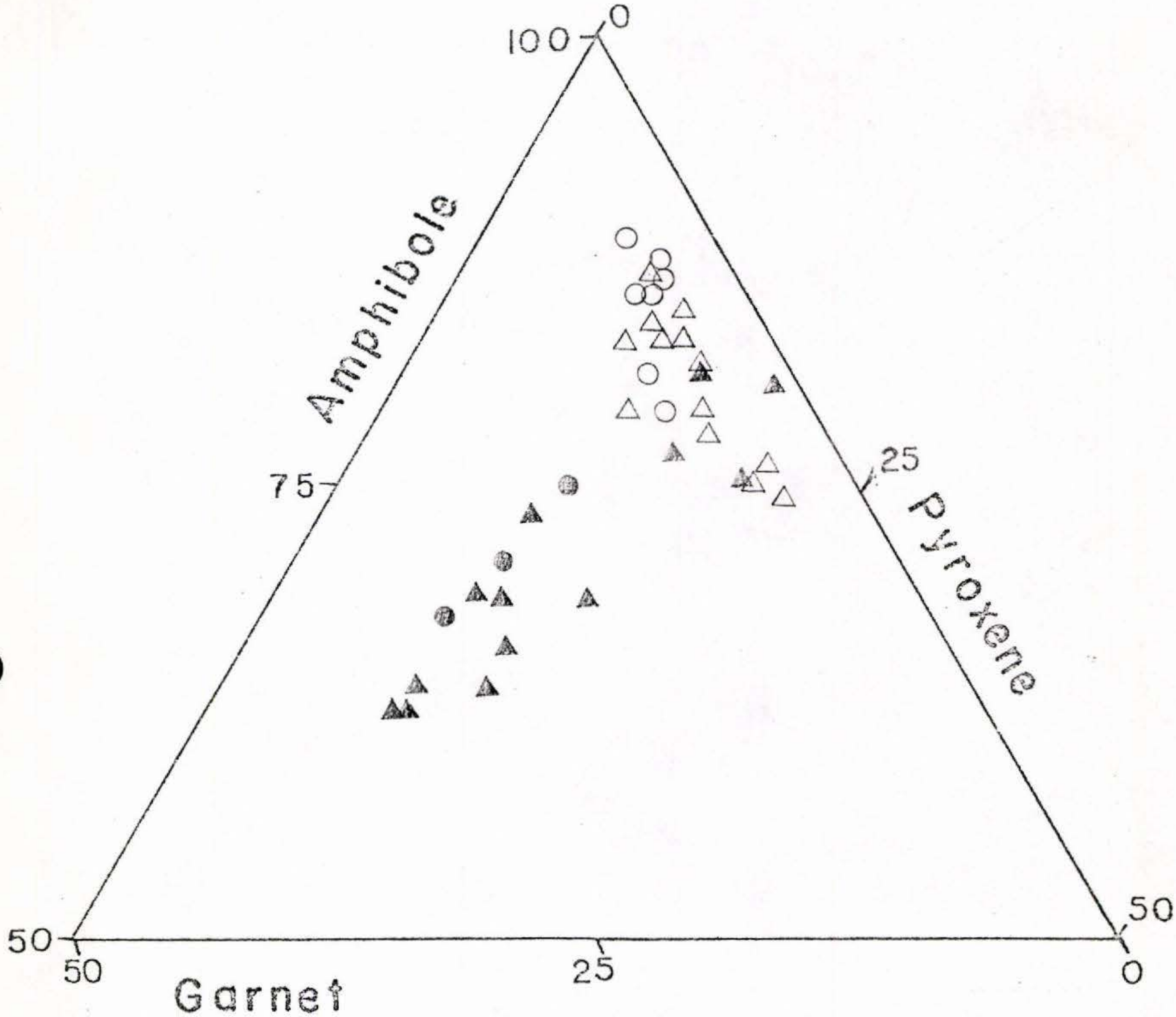
CHAPTER 4

CONCLUSIONS

The results of this study support the conclusions that there are significant differences in the heavy-mineral assemblages of the Red Lake Falls and Huot Formations, as proposed by Hobbs (1973). This study shows, however, that the assemblages to not remain laterally consistent. The samples of the Huot used in this study, compared to those used in the study by Hobbs (1973) from the Red Lake Falls area, show a larger proportion of amphibole, a slightly larger proportion of pyroxene, and a smaller proportion of the other heavy minerals. The samples of the Red Lake Falls Formation show a similar change between the two study areas. This change shows up well in Figures 5 and 6, where the shift to the amphibole and pyroxene ends of the graphs can be seen.

The possibility of this change being due to variation in technique rather than difference in geographic location is discussed in Appendix C.

These results lead to the conclusion that heavy-mineral assemblages cannot be used directly for correlation of these two lithostratigraphic units. Heavy-



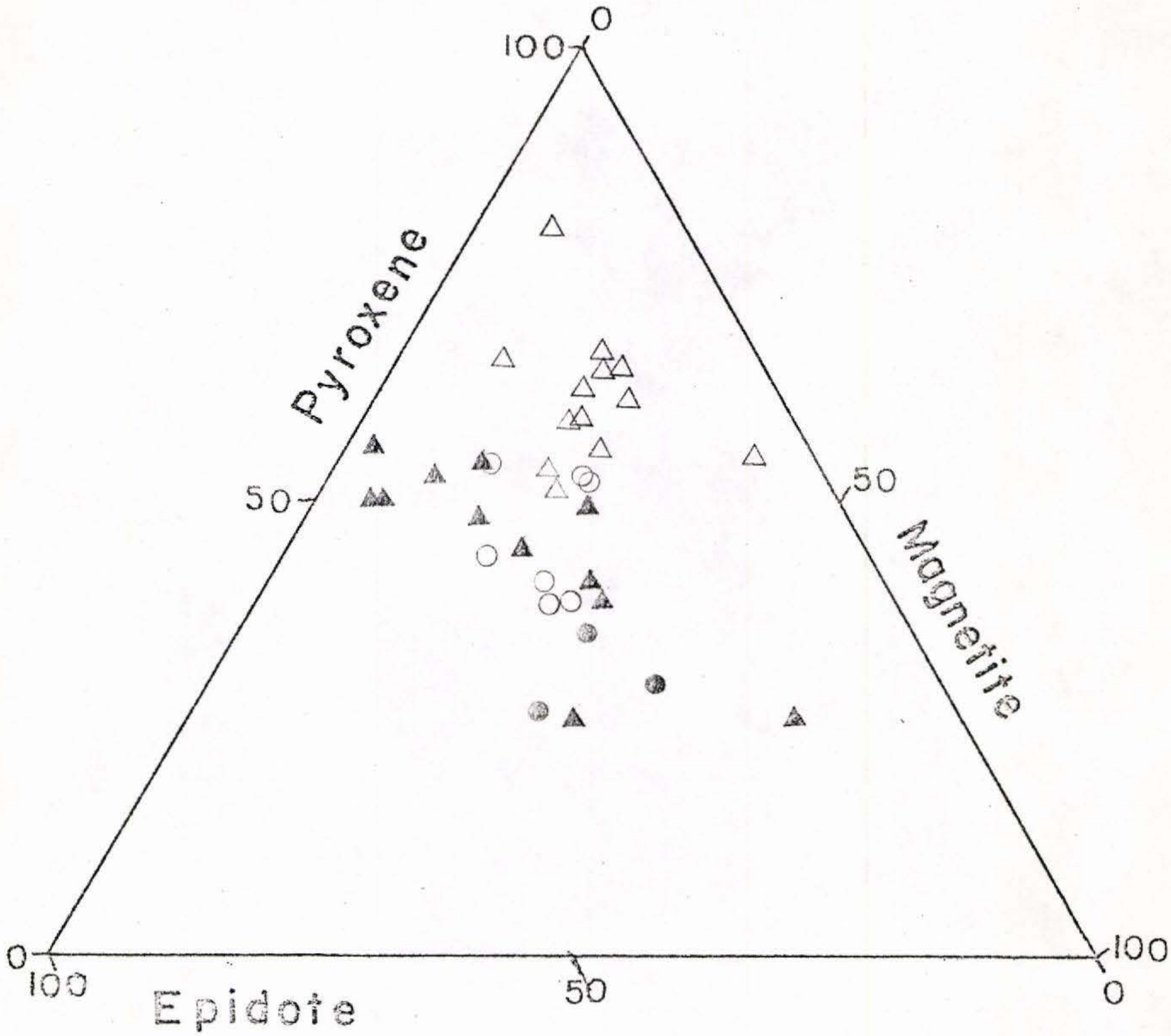
▲ Red Lake Falls Formation (Hobbs, 1973)

● Huot Formation (Hobbs, 1973)

△ Red Lake Falls Formation (This study)

○ Huot Formation (This study)

Figure 5.--Mineral ratios determined by this study as compared to those found by Hobbs (1973).



▲ Red Lake Falls Formation (Hobbs, 1973)

● Huot Formation (Hobbs, 1973)

△ Red Lake Falls Formation (This study)

○ Huot Formation (This study)

Figure 6.--Mineral ratios determined by this study as compared to those found by Hobbs (1973).

mineral analysis would be useful in the area if a change gradient could be worked out so that a mean heavy-mineral assemblage could be predicted for each unit in each location sampled.

APPENDIX A

SAMPLE PROCESSING METHODS

SAMPLE PROCESSING METHODS

The samples were sieved and the fine sand (0.125 to 0.250 mm) was removed for further processing. Each sand sample was washed in concentrated HCl for about five minutes to remove surface stains. The samples were rinsed several times. Many grains of biotite and chlorite washed out in the rinsing process. The samples were thoroughly dried and the magnetite grains were then removed with a hand magnet. The heavy-mineral fraction was then removed with a Franz magnetic separator set at 0.8 amp. with a forward slope of 25° and a side slope of 15°. After the first separation both the heavy and the light mineral fractions were put through again.

The heavy-mineral fraction (including the grains separated with the hand magnet) was mounted on a petrographic slide with a drop of coedex and pressed down with a cover slip.

These methods are almost identical to those used by Hobbs (1973). This was done in order that the results of the two studies could be related with the least amount of error. The only major difference in technique is that Hobbs used a forward slope of 30° on the Franz magnetic separator. I found that a forward slope of greater than 25° resulted in a small amount of grains being spilled by the separator.

APPENDIX B

TABLES OF BASIC DATA

Table 2

	OUTCROP N-1011			BOREHOLE N-140	
	Red Lake Falls		Huot	Red Lake Falls	
Sample Number	D-4-3	D-4-5	140-11	140-16	140-21
Mineral Proportions:					
Hornblende	68	72	70	68	74
Garnet	4	4	5	8	6
Epidote	5	3	5	3	4
Clinopyroxene	8	7	7	6	5
Orthopyroxene	6	5	4	5	4
Magnetite	2	5	5	3	4
Hematite	4	2	3	6	3
Actinolite	2	2	1		
Staurolite			1		
Ilmenite			1		
Leucoxene					
Three-mineral Ratios:					
Amphibole	79	82	82	79	83
Pyroxene	16	14	12	12	10
Garnet	5	4	6	9	7
Magnetite	10	25	26	19	24
Pyroxene	66	61	52	62	56
Epidote	24	14	22	19	20

Table 3

BOREHOLE N-141

	Huot				Red Lake Falls	
Sample Number	141-13	141-16	141-21	141-26	141-31	141-36
<u>Mineral Proportions</u>:						
Hornblende	75	71	77	66	67	69
Garnet	2	3	3	5	5	4
Epidote	7	8	5	5	3	3
Clinopyroxene	5	5	4	8	9	13
Orthopyroxene	4	3	2	4	7	8
Magnetite	4	6	5	6	5	2
Hematite	2	3	3	2	1	2
Actinolite		1	1	1	2	1
Staurolite				1		
Ilmenite	1					
Leucoxene				1		
<u>Three-mineral Ratios</u>:						
Amphibole	88	86	89	79	77	74
Pyroxene	9	10	7	14	17	22
Garnet	3	4	4	7	6	4
Magnetite	19	28	30	26	21	7
Pyroxene	43	38	39	51	65	81
Epidote	38	34	31	23	14	12

Table 4

BOREHOLE N-144

	Huot		Red Lake Falls			
Sample Number	144-6	144-11	144-21	144-31	144-36	144-46
Mineral Proportions:						
Hornblende	74	77	65	78	74	72
Garnet	5	3	5	4	5	4
Epidote	6	6	4	4	1	4
Clinopyroxene	5	6	9	5	7	6
Orthopyroxene	3	3	9	3	5	4
Magnetite	5	3	5	4	8	4
Hematite	2	3	4			2
Actinolite			1	1	1	2
Staurolite						1
Ilmenite			1			
Leucoxene						2
Three-mineral Ratios:						
Amphibole	86	86	75	87	83	84
Pyroxene	9	10	20	9	12	11
Garnet	5	4	5	4	5	5
Magnetite	25	15	18	22	39	20
Pyroxene	41	53	67	51	55	59
Epidote	34	32	15	27	6	21

Table 5

BOREHOLE N-146

	Red Lake Falls		
Sample Number	146-7	146-11	146-21
Mineral Proportions:			
Hornblende	71	65	74
Garnet	4	4	3
Epidote	4	4	6
Clinopyroxene	9	10	7
Orthopyroxene	2	6	4
Magnetite	4	5	4
Hematite	5	5	
Actinolite	1		2
Staurolite			
Ilmenite		1	1
Leucoxene			
Three-mineral Ratios:			
Amphibole	83	76	85
Pyroxene	13	20	12
Garnet	4	4	3
Magnetite	20	20	20
Pyroxene	59	64	52
Epidote	21	16	28

APPENDIX C

PRECISION AND ACCURACY

PRECISION AND ACCURACY

Precision

Recounts of two of the slides were done to test my precision (see Table 6). These showed that at the end of my study I was counting slightly less amphibole and slightly more pyroxene and garnet than at the beginning. This I believe is because I was counting fewer rock fragments containing only amphibole as amphibole grains at the end of the study. This caused the proportions of the next two most abundant minerals to increase slightly. These changes are quite small and would have little effect on the idea that the shift in the assemblages is due to geographic location.

Accuracy

A statement of the accuracy of the study is difficult to make because there is no accurate method to compare any of the point counts to. Also samples and slides from any of the locations studied by Hobbs (1973) were unavailable so a comparison of results was impossible. There is one place, however, where samples for this study were collected only about one and a half miles from a location sampled by Hobbs (see Figure 1). In a com-

Table 6

Comparison of heavy-mineral proportions from three counts of two slides.

Sample Number	D-4-5			N-144-11		
Count	1	2	3	1	2	3
Mineral Proportions:						
Hornblende	72	65	67	77	65	67
Garnet	4	7	10	3	6	5
Epidote	3	2	2	6	4	5
Clinopyroxene	7	9	7	6	6	7
Orthopyroxene	5	7	5	3	4	4
Magnetite	5	5	4	3	4	3
Hematite	2	3	4	3	3	4
Actinolite	2	1	1			
Staurolite						
Ilmenite		1			1	1
Leucoxene						

parison of the samples from these two locations, I counted slightly more amphibole and slightly less garnet and epidote on some slides than did Hobbs, but on others the proportions are about the same. Hobbs had no samples of the Huot from this location so the comparison was made only with slides of the Red Lake Falls Formation. If these variations indicate that there is some inaccuracy in the techniques of either of the studies, then the change due to geographic location will be decreased. The variations in mineral proportions, however, are quite slight and could not erase the entire change due to location, also the internal variation of the Red Lake Falls Formation could possibly cause the variations in the mineral proportions.

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