PETROLOGY OF THE "ARCHAEAN" SEDIMENTS IN THE WEST HAWK LAKE AREA

A Thesis

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of the Requirements for the Degree

Master of Science

by

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PETROLOGY OF THE ARCHAEAN SEDIMENTS IN THE WEST HAWK LAKE AREA, MANITOBA.

CHAPTER I

INTRODUCTION

Purpose of Study

The Archaean sediments of the West Hawk Lake area are interbedded with the volcanic rocks (andesites and basalts) and form a belt which strikes eastward across the Manitoba-Ontario boundary. This Archaean belt of rocks is surrounded by intrusive granitic rocks and has been metamorphosed into biotite and amphibole schists.

The purpose of the study of the Archaean sediments and volcanics of the West Hawk Lake area was to determine the type of sediments present, the degree of metamorphism on a regional scale, and whether there are any local effects due to the intrusives or other causes.

Location

The West Hawk Lake area is situated in southeastern Manitoba along the Ontario-Manitoba boundary (Plate I). This area is part of the Whiteshell Forest Reserve. Manitoba Highway No.1 crosses the area making it very accessible.

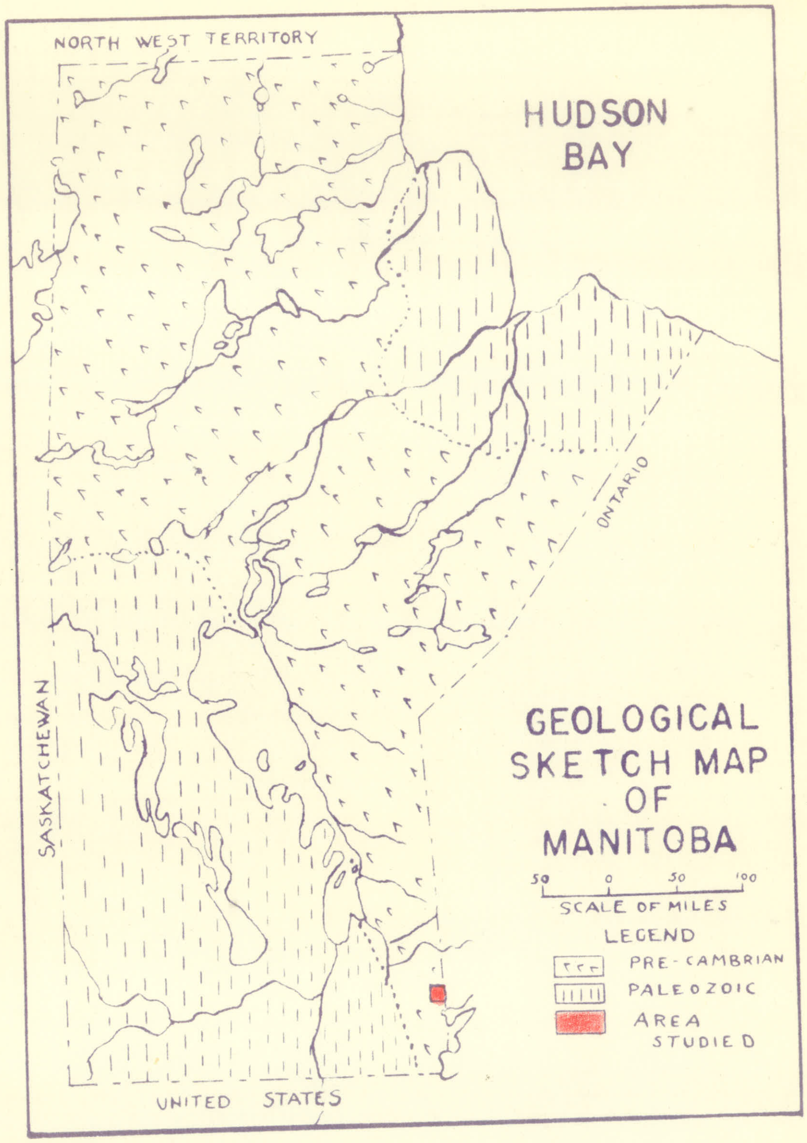
NORTH WEST TERRITORY
HUDSON BAY
ONTARIO
SASKATCHEWAN
GEOLOGICAL SKETCH MAP OF MANITOBA
50 0 50 100
SCALE OF MILES
LEGEND
PRE-CAMBRIAN
PALEOZOIC
AREA STUDIED
UNITED STATES

PLATE I

History of the Area

Prospectors were attracted to the area by the numerous occurrences of pyrrhotite, molybdenite, gold, scheelite, spodumene and tin. There are numerous pits and shafts scattered throughout the area as evidence of this intensive search. No large commercial deposits were found. The Penniac Mine was the only property developed for production. This venture was a very small gold producer for a short period. Two other development shafts; the Goldbeam and Sunbeam Kirkland were sunk by Goldbeam Mines Limited in the Falcon Lake stock, but not enough ore was found for commercial production.

CHAPTER II

GENERAL GEOLOGY OF THE AREA AS DESCRIBED IN PREVIOUS LITERATURE

Review of the Literature

A.C. Lawson of the Geological Survey of Canada mapped the area in conjunction with the Lake of the Woods-Shoal Lake region and was the first geologist to examine the volcanic and sedimentary belt, but did not describe it in great detail. He mentions the presence of andesites, basalts, agglomerates, siltstones, graywackes, arkoses and conglomerates.

E.S. Moore studied the area briefly in 1913 for the Geological Survey of Canada. He described the sediments of the area as having a porphyritic appearance (i.e. fine grained matrix of quartz, epidote, zoisite, chlorite and biotite with large grains of feldspar).

J.S. DeLury in 1937 mapped the area on a scale of one half mile to the inch and described the volcanic and sedimentary belt as a belt of schists striking northeast to east across Star Lake and West Hawk Lake and continuing into Ontario. He believed that the hornblende schists in the belt were derived from ellipsoidal lavas. DeLury described the sediments as consisting of Lawson's types: graywackes, arkoses, siltstones and conglomerates with such minerals as biotite, garnet, sericite and some graphite. He apparently found a conglomerate west of Star Lake containing boulders and pebbles varying greatly in size and composition with a quartzitic matrix.

L. Greer in 1930 studied the Shoal Lake area of interbedded sediments and lavas for the Ontario Department of Mines and found the ellipsoidal greenstone to be composed of plagioclase (andesine and oligoclase) and hornblende, with chlorite, epidote and sericite in the altered areas. He found a peculiar type of rock which he called "volcanic conglomerate" which is composed of well rounded fragments of felsitic material in a dark green fine grained matrix. These locally grade into granitic fragments and become pebble like and stratification is present. The pebbles are not uniformily distributed across the strike and the layers of pebbles pass gradually to cherty sediments in beds six inches thick. The volcanic material in this conglomerate prevails over the granitic. This deposit may be of Piedmont type.

G.E. Springer mapped the area for the Manitoba Geological Survey and found the Archaean belt in the West Hawk Lake area to be composed of siltstones, graywackes, argillites, and arkoses interbedded with ellipsoidal andesite and basalt. An area of agglomerate grading into conglomerate was found west of Star Lake.

Summary of General Geology of the Area

The geology of this West Hawk Lake area comprises an Archaean belt of sediments and lavas which strikes eastward into Ontario and is partially intruded by granitic rocks and covered by glacial drift in the west. The lavas and the sediments have been metamorphosed into schists. The area was glaciated during the Pleistocene epoch leaving thin glacial deposits of sands and gravel. The relief is moderate with numerous lakes and swamps and outcrops are abundant.

The following table of formations was suggested by G.E. Springer;

Table of Formations

Recent and Pleistocene Deposits		Fine sandy loam, sand and gravel
Proterozoic or Archaean	Granitic intrusives	Pegmatites Falcon Lake Stock Pink Porphyritic Granodiorite Gray gneissic Granodiorite, quartz diorite and quartz feldspar dikes
Archaean	Sedimentary rocks	Graywackes, siltstones, argillites, arkoses and conglomerates
	Volcanic rocks	Andesite, basalts and agglomerates

Volcanics

The volcanics in this area consist of metamorphosed andesites, basalts and some agglomerates which are interbedded with the sediments. The basalts appear to be the commonest of the three. The agglomerates are found south west of Star Lake.

The andesites show evidence of having been ellipsoidal lavas and are composed of actinolite with a very fine grained andesine matrix. Tabular grains of epidote and some zoisite are present near the contacts of the andesites and the intrusives.

The basalts are dark greenish to black and are composed of tabular grains of hornblende in a very fine grained matrix of soda-lime feldspar.

The agglomerate appears to grade into a conglomerate with a basic matrix according to G.E. Springer who studied these rocks in detail.

Sediments

The sediments of the West Hawk Lake area consist of graywackes, siltstones, arkoses, and argillites interbedded with the lavas and the conglomerate mentioned above southwest of Star Lake. The sediments all have a light to dark gray color, very fine grained texture, and have been metamorphosed to produce biotite-garnet schists, sericite schists and biotite-graphite schists.

The graywackes have a fine grained matrix with angular fragments of feldspar disseminated through it. The matrix is composed of quartz, biotite, some feldspar, sericite, calcite and locally epidote.

The biotite occurs as tiny blades well lineated along the schistosity.

The siltstones are very fine grained and occur in conjunction with the graywackes. They are composed of fine quartz with sericite, biotite, and locally, garnets.

The arkoses were found to be abundant in a sedimentary band at the northeast end of West Hawk Lake (see Plate VI). These rocks are predominantly feldspar with small lenses of quartz, some biotite and epidote.

The argillites are not common but occur locally as thin beds. They are dark gray to black and are composed of a fine grained matrix of quartz, some sericite and disseminated specks of graphite.

G.E. Springer found the conglomerate northwest of Star Lake and there appeared to be a gradation from the agglomerate to conglomerate. The conglomerate contains granitic and andesitic pebbles with a fine grained arkosic matrix.

Intrusives

Two large intrusives, the gray gneissic granodiorite and the pink porphyritic granodiorite, and the smaller Falcon Lake stock occur in the area studied. Other intrusives in the area are the feldspar porphyry dikes near the north shore of Falcon Lake and the pegmatite, aplite dikes present near the large intrusives. The table of formations (Page 6) shows the probable relative ages of these intrusives. There are some "quartz veins" present in the area which appear to be younger in age than the above mentioned intrusives.

Feldspar Porphyry Dikes

The feldspar porphyry dikes (or sills) are thirty feet wide and are composed of large zoned phenocrysts of feldspar in a fine grained matrix of quartz, feldspar and biotite. These dikes are concordant with the lavas and might be easily mistaken for sediments in the field, because they have the same color and texture.

Gray Gneissic Granodiorite

The gray gneissic granodiorite is present in the northeast and southeast parts of the area (Plate VI). The granodiorite is a medium grained rock composed of oligoclase, quartz, and biotite, zircons and apatite as accessory minerals. Schlieren are abundant near the contact of the granodiorite and the Archaean rocks (sediments and lavas) but decrease in number from the margin of the intrusive.

Pink Porphyritic Granodiorite

The pink porphyritic granodiorite is the largest intrusive in the West Hawk Lake area and occurs south of Falcon Lake and west of Star Lake. This granodiorite is composed of large phenocrysts of orthoclase and microcline in a medium grained groundmass of oligoclase, quartz, microperthite, biotite and locally garnets.

Falcon Lake Stock

The Falcon Lake stock is an irregular body four miles long and as much as six thousand feet wide. The stock is situated between Star Lake and Falcon Lake (Plate VI). Dr. G.M. Brownell made a detailed study of this stock and divided it into three zones: the central core of quartz monzonite, the intermediate zone of granodiorite and the outer rim consisting of quartz diorite, diorite and gabbro. The central core and the intermediate zone are separated by a contact breccia consisting of granodiorite fragments in the quartz monzonite. The other contacts are predominantly gradational. Some mineralization consisting of pyrite with a little copper and gold occurs in the central core. Two exploratory shafts; the Goldbeam and the Sunbeam-Kirkland were sunk into the stock, but the gold mineralization was not rich enough for production.

Dikes

The pegmatite and aplite dikes are found near the periphery of the two large granitic intrusives and intrude the sediments parallel to their schistosity. The pegmatites are typically coarse grained and are composed of orthoclase, quartz and a small amount of rare minerals such as spodumene, scheelite and molybdenite. The aplites are narrow and equigranular and contain no rare minerals.

Veins

The "quartz veins" are irregular bodies of pure quartz which occur in the sedimentary schists, but do not necessarily strike along the schistosity. The pyrrhotite and pyrite occurrences appear to be associated with these veins.

Structure of the Area

The Archaean belt of sediments and lavas in the West Hawk Lake area appears to be the north limb of an anticline whose axis was obliterated by the intrusion of the porphyritic granodiorite south of Falcon Lake. The volcanic belt north of Indian Bay of the Lake of the Woods in the Shoal Lake area may possibly be the southern limb of the anticline.

CHAPTER III

METHODS OF RESEARCH

Field

The material for this study was gathered during a five day field trip in West Hawk Lake with the assistance of W.J. Koop. Representative samples of the sediments, greenstones and intrusives were taken in the four traverses across the Archaean belt of rocks and along the shores of Star Lake (Plate VII). Large outcrops of sediments were sampled at shorter intervals in order to obtain a better picture of the texture and composition of these rocks.

Laboratory

The laboratory study consisted of the examination of thin sections, separation and identification of minerals by refractive index liquids and X-rays, and the preparation of two tables; one on Regional Metamorphism, the other on Thermal Metamorphism.

Petrographic Study

Thin sections of the sediments, greenstones and intrusives were studied under the petrographic microscope to determine the composition of the rocks and the abundance of each mineral. The first examination of the thin section was of the reconnaissance type to determine the general texture and composition of the sediments, lavas and intrusives. The rocks were then examined in a detailed manner to identify all the minerals and

and estimate their abundance. The minerals were identified by their optical properties and the estimate of content was calculated visually on a basis of the grains of a mineral filling the whole eye-piece being 100% of the rock, $\frac{1}{2}$ eye-piece 50%, $\frac{1}{4}$ eye-piece 25%. Several estimates were taken across a thin section to determine the overall composition.

The grain size of the sediments was measured by using a micrometer eye-piece in the petrographic microscope. The average grain size was determined by taking twenty readings of the grains across each thin section. Two separate readings were taken for the graywackes; one on the fine grain matrix, the other on the feldspar fragments. A table showing the grain size of the rocks was drawn up.

Mineral Determination

The minerals that could not be identified by their optical properties were separated from the main rock mass by crushing, sieving and separating in heavy liquids. The samples which contained the unknown minerals were crushed in a steel mortar and sieved. The (-100 +200) sieve sample was quartered with a spatula and one quarter was used for separation in Bromoform or Clerici solution. The heavy fraction containing the unknown mineral (e.g. epidote) was dried and identified by obtaining its index of refraction with standard index oils. The unknown minerals were confirmed by X-ray analyses. Hand picking of the heavy minerals had to be done in samples where the matrix of the rock was so fine grained that some of the light fraction came down with the heavy fraction in the heavy liquid separations. This hand picking was done by means of a sharpened tooth pick or a needle.

Preparation of Tables

Two tables; one on Regional Metamorphism, the other on Thermal Metamorphism were compiled to be used in conjunction with the study of the sediments of this area. The table on Thermal Metamorphism is divided into three grades: low, medium and high, whereas the Regional one is divided into five zones: chlorite, biotite, garnet, kyanite and sillimanite. A system of arrows was used to show the changes of all the possible minerals in the most common rock types with increasing metamorphism (see Plate VIII in pocket.

CHAPTER IV

PETROGRAPHIC DESCRIPTION OF THE ROCKS

The petrographic study of the Archaean rocks of this area was confined chiefly to the sediments, although some samples of the lavas and intrusives were examined. This study revealed that the sediments could be divided into five common types: graywackes, siltstones, arkoses, argillites and "other sediments". The "other sediments" represent those sediments which are near the "quartz-pyrrhotite dikes". The "quartz-pyrrhotite dikes" represent those areas which have pyrrhotite and sugary textured quartz occurring usually near the contacts of the sediments with the lavas. These sediments differ from the common sediments due to the introduced quartz, feldspar, and pyrrhotite, and have different metamorphic minerals (tremolite, cordierite). Such occurrences can be found at Merritt Road on Manitoba Highway No.1 and at the south end of Star Lake Island (Plate VII).

The Sediments

The dark gray color, fine grained texture and large feldspar fragments are the striking features of the sediments. There are variations to these typical features such as the absence of large feldspar fragments in the siltstones, argillites and arkoses.

The three tables compiled below show the grain size of the sediments as taken across the strike north to south at three different locations. Table 1 represents a traverse across the sedimentary band near shaft No.2 east of West Hawk Lake. Table II represents a traverse across the sediments along Manitoba Highway No.1 west of Sam's Corner. Table III represents a traverse across the sediments of Star Lake (see Plate VII).

Table I

Sample No.	Rock Type	Grain Size in Millimeters
-87	Arkose	.05 to .5
-88	"	.05 to .2
-89	"	.02 - .1
-90	"	.05 -..2
-91	"	.05 - .3
-92	"	.02 - .2

Table II

Sample No.	Rock Type	Grain Size in Millimeters	
		Matrix	Feldspar Fragments
- 78 b	Graywacke	.003 - .005	.01 - .02
- 78 c	"	.002 - .005	.02 - .03
- 78 d	"	.001 - .004	.02 - .04
- 79	Siltstone	.01 - .02	
- 80	Graywacke	.02 - .05	.1 - .4
- 81 - (1)	Argillite	.001 - .002	
- 81 - (2)	Graywacke	.01 - .02	.05 - .08
- 82	"	.002 - .03	.05 - .1
- 83	Siltstone	.01 - .03	
Merritt Road Sample	Graywacke	.02 - .05	.08 - .25
- 84	Siltstone	.001 - .002	
- 86	Graywacke	.05 - .1	.15 - .3

Table III

Sample No.	Rock Type	Grain Size in Millimeters	
		Matrix	Feldspar Fragments
- 23	Graywacke	.01 - .05	.08 - .4
- 25 A	Argillite	.001 - .003	
- C	Siltstone	.003 - .006	
- D	Graywacke	.003 - .005	.05 - .1
- E	Siltstone	.002 - .005	
- F	"	.001 - .002	
- G	"	.002 - .005	
- 50	Graywacke	.01 - .08	.1 - .3
- 48	Siltstone	.01 - .05	
- 47	Graywacke	.01 - .06	.1 - .2

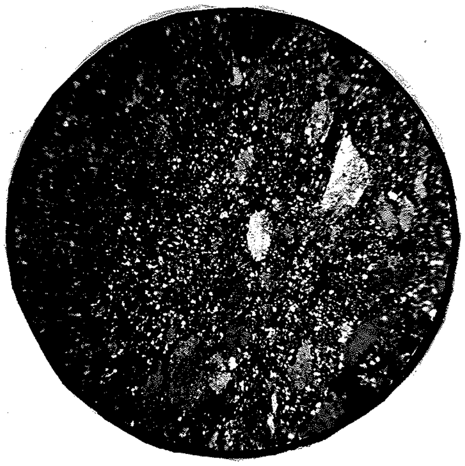

Figure 1
X 30

Graywacke (X-Nicols) showing the fine grained matrix with large angular fragments of feldspar.

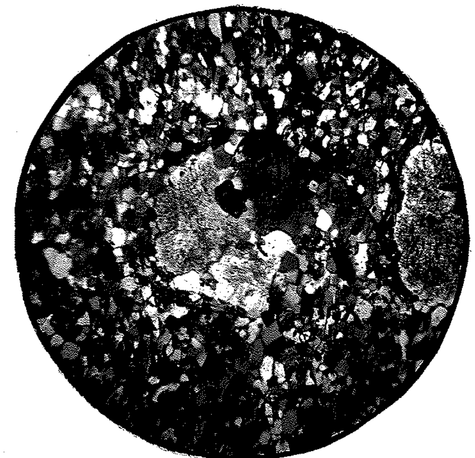

Figure 2
X 75

A typical feldspar fragment showing a partial recrystallization at the outer perimeter.

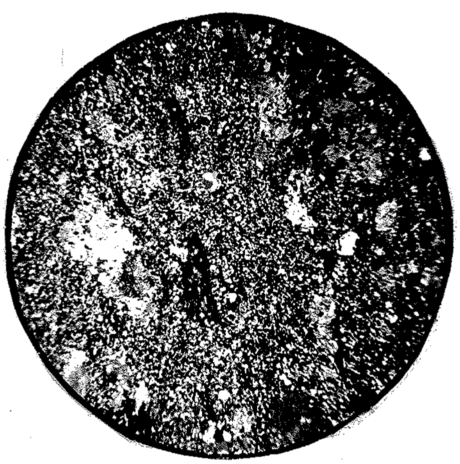

Figure 3
X 30

Siltstone (X-Nicols) showing the very fine grained matrix of quartz, biotite and sericite.

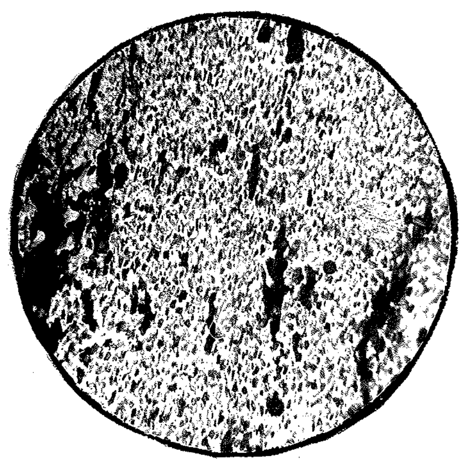

Figure 4
X 75

Siltstone with tiny blades of biotite showing lineation.

PLATE II

The tables do not show any gradation across the strike of the sediments, but do show their fine grained texture.

Graywackes

The graywackes are the most abundant of the sedimentary rocks and have the striking property of having relatively large (.01 to .4mm) irregular fragments of feldspar (andesine) imbedded in a very fine (.003 to .08mm) grained matrix (see Plate II Fig.1). The matrix is inequigranular and is composed chiefly of quartz with some feldspar, biotite, sericite, epidote, and calcite. The biotite occurs in tiny blades well lineated along the schistosity. The sericite occurs in small clusters (poeciloblasts) disseminated through the matrix. Epidote and calcite occur in very small grains scattered through the matrix. The feldspar fragments are irregular and range in size from .01 to .4mm. The fragments are usually filled with impurities with the exception of a thin corona around the edge which has been recrystallized and does not contain impurities (see Plate II Fig.2). The variations in composition of the graywackes examined are shown in Table No.4.

The irregular very fine grained matrix, the partially recrystallized feldspar fragments and the minerals present indicate that the rock was not highly metamorphosed.

Table IV

The Composition of the Graywackes

Sample No.	Matrix (quartz, some feldspar)	Feldspar fragments	Biotite	Sericite	Epidote, calcite garnets
23	71%	13%	10%	5%	1% garnets
25 D	71%	10%	15%	3%	1% epidote and calcite
29	50%	25%	20%	2%	2% garnets 1% epidote
47	66%	15%	10%	8%	1% garnets
50	62%	20%	10%	6%	1% garnets 1% calcite
57	63%	11%	10%	5%	1% calcite
52	65%	9%	15%	10%	1% calcite
53	68%	12%	13%	6%	1% calcite
78 b	80%	6%	3%	10%	1% calcite
78 c	79%	8%	10%	3%	
78 d	70%	12%	10%	7%	1% epidote
81 - 2	70%	20%	10%		
82	65%	15%	15%	3%	1% calcite 1% epidote

Siltstones

The siltstones are a common Archaean sediment in the West Hawk Lake area and are interbedded with the graywackes. They differ from the graywackes because of the absence of feldspar fragments. The siltstones are very fine grained (Plate II Fig.3) and are composed of quartz, biotite, sericite, calcite and locally epidote and garnets. The quartz is very

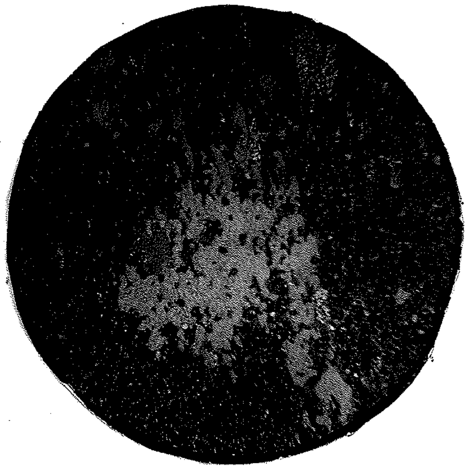

Figure 5
X 75

Siltstone showing a cluster of poeciloblastic sericite.

Figure 6
X 75

Siltstone showing a cluster of small tabular grains of epidote.

Figure 7
X 30

A fold in the siltstone showing euhedral crystals of epidote.

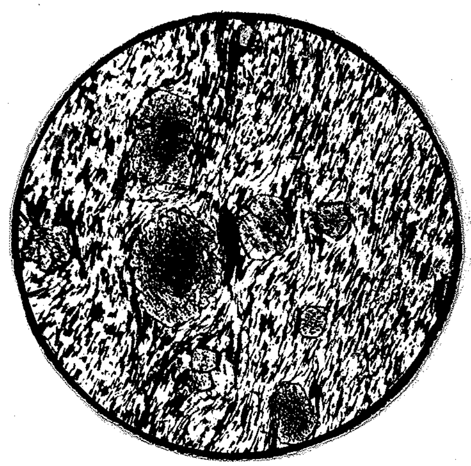

Figure 8
X 30

Crystalloblastic garnets in the siltstone.

PLATE III

fine grained (.005 - .1mm) and is frequently of the .005mm size. Biotite is the next most abundant mineral and occurs as tiny (.001 X .05mm on (010) cleavage) blades well lineated parallel to the schistosity. Irregular blobs of biotite occur (Plate II Fig.4) near the pyrrhotite areas. Sericite is abundant in large and small poeciloblastic clusters (Plate III Fig.5) which are disseminated through the siltstone. The calcite is present as small grains scattered through the rock, but seldom exceeds one percent of the total composition. Epidote is present in the siltstones as separate small grains or as clusters of small grains (Plate III Fig.6). Euhedral grains of epidote were found in a small flexure of a siltstone (Plate III Fig.7). Local beds of siltstones contain well developed subhedral to euhedral red garnets which show a strong power of crystallization by pushing aside the biotite and quartz (Plate III Fig.8). The presence of biotite blades in the garnets indicates that they were formed after the biotite.

Table V

The Composition of the Siltstones

Sample No.	Quartz	Biotite	Sericite	Epidote	Calcite	Garnets
25 C	80%	15%	3%	1%	1%	
25 E	84%	10%	5%		1%	
25 F	85%	10%	4%		1%	
25 G	82%	15%	2%		1%	
30	75%	15%	4%	1%		5%
79	80%	13%	2%		1%	4%
83	83%	10%	5%	1%	1%	
84 - (3)	75%	12%	10%			3%

Arkoses

The arkoses in this area were found near Shaft No.2 east of West Hawk Lake (Plate VI). This rock is medium grained and is composed of feldspar (andesine), quartz, biotite, sericite, epidote, and locally calcite. The andesine is usually recrystallized and shows good polysynthetic twinning with an occasional carlsbad twin. The quartz occurs as lenses (Plate IV Fig.9) parallel to the schistosity and it is difficult to determine whether it was introduced into the rock or was present in the original composition. The biotite occurs as irregular grains with a dark green extinction and in many places is associated with tiny grains of epidote. A small amount of tabular sericite and small grains of calcite are disseminated through the rock.

Table VI

The Composition of the Arkoses

Sample No.	Andesine	Quartz	Biotite	Sericite	Epidote
87	80%	10%	7%	2%	1%
88	74%	15%	5%	5%	1%
89	64%	20%	10%	5%	1%
90	72%	18%	6%	3%	1%
91	80%	10%	5%	4%	1%
92	77%	12%	8%	2%	1%

Argillites

The argillites are not very abundant in this area and appear to form a thin band near the center of the sedimentary belt. This rock is composed of quartz, sericite, biotite, graphite and pyrrhotite. The quartz is the major component and is very fine grained (.005mm) with graphite and some pyrrhotite disseminated through the rock. Sericite and biotite occur as tiny blades aligned parallel to the schistosity. The sericite content exceeds that of the biotite. Two samples of this Archaean sediment were studied and their composition is tabulated below:

Table VII

The Composition of the Argillites

Sample No.	Quartz	Graphite	Sericite	Biotite	Pyrrhotite
25 A	75%	10%	5%	3%	7%
81 - 1	70%	15%	7%	3%	5%

"Other Sediments"

Under this classification may be listed those sediments which contain minerals that appear to have been introduced into the country rock. These sediments occur near the "quartz-pyrrhotite dikes". Their original composition appears to have been that of the graywackes or silt-stones. The introduced mineral quartz, pyrrhotite and in places small amounts of feldspar, apparently have produced a local type of metamorphism. This local metamorphism appears to have produced such minerals as tremolite and cordierite and destroyed the biotite. The Merritt Road section on Highway No.1 appears to be such an example. Here the main part of the rock appears to be a metamorphosed graywacke, tremolite and cordierite are present, but there is a conspicuous absence of biotite. Another example is sample 29 on the southwest end of Star Lake. This sample is near a "quartz-pyrrhotite dike" and shows the biotite completely replaced by garnets which show evidence of pseudomorphic structures of biotite (Plate IV Fig.10).

Table VIII

Composition of "Other Sediments" in the Merritt Road Section

Sample No.	Quartz	Feldspar	Biotite	Sericite	Epidote	Cordierite Tremolite Garnet	Pyrrhotite
134	50%	22%	10%	8%			10%
M -1A	80%		8%			2% gar.	10%
M -1B	70%	15%	10%				5%
M -3	74%		12%	5%	1%		8%
M -7	45%	25%		5%		10% trem.	15%
M -9A	65%	10%				10% trem. 5% cord.	10%
M -10	85%			3%		2% cord.	10%

The petrographic study of the sediments of the West Hawk Lake area suggests that there are five types of Archaean sediments: graywackes, siltstones, arkoses, argillites and the sediments near the "quartz-pyrrhotite dikes". The graywackes are the most abundant of the sediments.

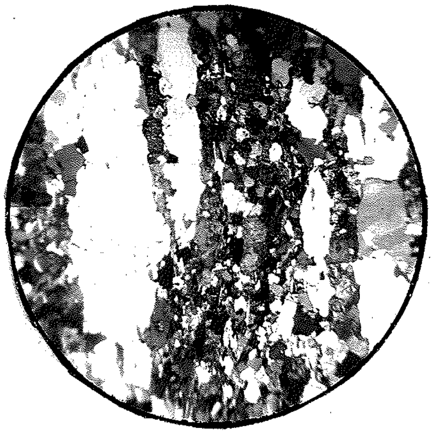

Figure 9
X 30

Feldspathic sediment showing quartz stringers.

Figure 10
X 75

Garnet replacing biotite in a siltstone intruded by quartz veinlets.

Figure 11
X 30

A typical metamorphosed greenstone showing the fibrous amphibole (actinolite) and hornblende with a fine grained feldspar matrix.

PLATE IV

They indicate fast deposition with poor sorting and an erosional area high in feldspar. The graywackes, siltstones and argillites have a very fine texture, although the graywacke contains feldspar fragments much larger in size than its matrix. This uniform fine grained texture is due to the recrystallization of the fine material earlier than the coarse feldspar fragments of the graywackes. The feldspar fragments have been partially recrystallized at the edges.

Lavas

The lavas are the most abundant Archaean rocks in this area and are composed of andesites, basalts and agglomerates. Ten samples of these lavas were studied and it was found that they have been recrystallized into hornblende-actinolite schists with a fine plagioclase matrix (Plate IV Fig.11). Hornblende is the commonest of the two types of amphiboles, although both may occur together. These amphiboles are lineated parallel to the schistosity. The plagioclase is uniformily fine grained (.03 to .05mm) with the grains often having cloudy centers, locally some of the grains show twinning. Epidote and zoisite are present in the lavas as accessories near the "quartz-pyrrhotite dikes". They occur in well developed tabular grains (Plate V Fig.12) with no definite orientation. The epidote is the commoner of the two minerals. These accessories are probably related to the origin of the "quartz-pyrrhotite dikes". Another common accessory is calcite and it occurs as irregular grains scattered through the lavas. The types of plagioclase present in the lavas were not determined as it was not optically possible due to their fine grained texture. The table below shows the composition of the greenstones examined.

Table IX

Composition of the Greenstones

Sample No.	Hornblende	Plagioclase	Biotite	Calcite	Epidote	Zoisite
25 -B	20%	75%		5%		
26	30%	68%		2%		
27	25%	74%		1%		
31	25%	60%	2%	1%	10%	2%
32	25%	75%				
46	20%	70%		4%	5%	1%
75	25% actinolite	75%				
77	25% actinolite	75%				
85	25%	70%		2%	3%	

Intrusives

The two intrusives studied were the pink porphyritic granodiorite and the gray feldspar porphyry dikes. The two samples of the pink porphyritic granodiorite were taken west of Star Lake and the three samples of feldspar porphyry dikes were taken just north of the northwest corner of Falcon Lake.

The pink porphyritic granodiorite has two outstanding features; the pink color and the large phenocrysts of orthoclase and microcline in a medium grained matrix of quartz and feldspar. The phenocrysts are generally fresh and show twinning (microcline). The feldspar in the matrix

Figure 12
X 75

Aureole alteration of a greenstone showing tabular epidote, a small amount of zoisite and remnants of the amphibole.

Figure 13
X 30

Granite porphyry showing zoned phenocrysts of orthoclase and the fine grained matrix.

Figure 14
X 75

Porphyry showing zoned feldspar phenocrysts.

PLATE V

is composed of oligoclase and a small amount of microperthite. The accessory minerals are biotite, epidote and garnet. The biotite is present in well developed blades and locally has small grains of epidote associated with it. Small garnets occur scattered through the matrix.

Table X

Pink Porphyritic Granodiorite

Sample No.	Quartz	Oligoclase	K-feldspar phenocrysts	Biotite	Epidote	Garnet
9	15%	72%	8%	3%	1%	1%
43	20%	62%	10%	6%	1%	1%

Feldspar Porphyry Dikes

The feldspar porphyry has large zoned phenocrysts of orthoclase in a very fine grained (.05mm) matrix of quartz, feldspar, biotite, sericite and calcite (Plate V Fig.13). The large (.3 to .4mm) phenocrysts of orthoclase show well developed zoning and alteration to sericite along some of these zones (Plate V Fig.14). The biotite occurs as tiny blades intergrown with the quartz and feldspar of the matrix. The calcite is present in small grains scattered through the quartz feldspar porphyry.

Table XI

The Composition of the Feldspar Porphyry Dikes

Sample No.	Matrix quartz feldspar	Feldspar phenocrysts orthoclase	Biotite	Sericite	Calcite
11	65%	20%	10%	3%	2%
12	65%	25%	5%	3%	2%
14	70%	15%	10%	3%	2%

CHAPTER V

SEDIMENTATION AND VOLCANISM

The material included in this chapter is of a speculative nature and was included as an aid in visualizing the origin of the Archaean rocks of the West Hawk Lake area before they were metamorphosed.

The West Hawk Lake area was unstable for some time during the Archaean period as indicated by the interbedded sediments and lavas. This association of sediments and lavas indicates that the area was part of a sinking basin, possibly of Kay's eugo-geosyncline type.

Sedimentation

The graywackes which are the most abundant sediments in the area indicate that deposition took place in a rapidly sinking basin with no sorting. The influx of material to the basin must have been rapid and not transported for a great distance, otherwise the feldspar in the graywackes and arkoses would have been destroyed physically and chemically. The presence of graphitic material in the sediments indicates a possible marine environment for deposition. The source area for the material appears to have been composed of both acid and basic rocks as indicated by the pebbles in the conglomerates west of Star Lake.

Volcanism

The edge of the basin must have been an active volcanic area in order to supply the periodical influx of volcanic material to form ellipsoidal lavas, basalts and agglomerates. These periodical influxes of lavas could have been due to stress along the hinge line between the basin and the source area and may have been caused by the downsinking of the basin. This stress produced fractures in the earth's crust which allowed the outflow of volcanic material. These volcanic lavas may represent the displacement of the basal complex rock of the basin by the increasing load of the sediments.

The area was one of high activity during part of the Archaean period. Sedimentation and volcanism appear to have taken place alternatly. These sedimentary and volcanic rocks indicate that the area could have been part of eugo-geosyncline.

CHAPTER VI

METAMORPHISM OF THE SEDIMENTS AND LAVAS

Metamorphism of the Sediments

The sediments show good evidence of regional metamorphism and contain such common metamorphic minerals as: biotite, sericite, garnet, epidote and calcite. These minerals indicate that the sediments were subjected to a low (biotite) grade of regional metamorphism.

Biotite, epidote and calcite can be found throughout all the sediments of the area, with exception of a small zone near the Merritt Road pyrrhotite occurrence, where tremolite is present instead of biotite. The biotite occurs in small tabular blades lineated along the schistosity, which indicates it was in an early stage of formation.

The sericite is present in zones of poeciloblastic clusters which are usually confined to the graywackes and represents the crystallization of excess sericite after the formation of all new metamorphic minerals.

Garnets occur in local siltstone beds and appear to represent zones which differ in composition from the common type of sediments, rather than zones which had reached a higher grade of metamorphism.

The graywackes show the most outstanding features of metamorphism. They have a completely recrystallized fine grained matrix with partially recrystallized feldspar fragments.

The sediments show that they were subjected to a low (biotite) grade type of regional metamorphism. The slight variations in the metamorphic mineral content across the strike appears to be due to thin zones of different original composition.

Metamorphism of the Lavas

Common metamorphic minerals present in the lavas are: hornblende, actinolite, calcite, and locally some epidote. The hornblende type of lavas represents the recrystallized basalts, while the actinolite type of lavas could possibly be a recrystallized andesite. The type of amphibole produced on recrystallization of the lavas depended on the content of the ratio of iron and magnesium in the original composition of the lavas. The basalts had a higher content of these two elements and thus produced hornblende.

The lavas have been recrystallized by a low (biotite) grade of regional metamorphism as shown by the metamorphic minerals and the partially recrystallized plagioclase matrix.

Reconstitution of Minerals

The reconstitution of the minerals in the lavas and sediments began when they were first subjected to the forces of metamorphism (shearing stress and hydrostatic pressure) and continued until these forces ceased. There are two important reactions which take place during the period of reconstitution. These are exothermic and endothermic reactions which consist of the yielding and the absorption of heat by the metastable minerals. The exothermic reaction is dominant at shallow depths, whereas the endothermic becomes dominant with the increasing depth. These reactions take place within the crystal structure of the minerals. The crystal structure is altered by an exchange and rearrangement of the atoms of each mineral to attain an atomic structure which will be stable under the new conditions.

Formation of Biotite

Biotite is the most common metamorphic mineral throughout the majority of sediments. The components for the formation of the biotite are: magnetite, rutile, silica, sericite and chlorite. Sericite appears to have been in excess compared to the other components and was recrystallized as poeciloblastic sericite. The biotite was one of the first minerals to form as indicated by the well developed crystal habit. The absence of biotite in the Merritt Road section may be explained by the original rocks which did not contain the required constituents; or by the later alteration of the biotite which produced the pyrrhotite occurrences in that area. The latter process may have altered the biotite to tremolite, calcite and epidote.

Formation of Sericite

Sericite represents the recrystallization of the remnant constituents (e.g. sericite and chlorite) which were not used in the formation of biotite. This mineral recrystallized in poeciloblastic clusters and may represent areas highly concentrated with sericite. These highly concentrated areas may be due to the poor sorting of the sediments during deposition.

Formation of Garnets

The red (almandine) garnets are found in thin bands of siltstone and were produced by the reaction of chlorite, magnetite and silica. This reaction formed euhedral garnets (Plate III Fig.8). These euhedral garnets indicate that they have a strong power of recrystallization. A sample (No.29) taken on the west shore of Star Lake gives evidence of the garnets replacing the biotite, and shows the structure of the biotite blades (Plate IV Fig.10). This phenomena indicates that the formation of the garnet took place at a slow rate, which allowed a perfect replacement of the biotite structure.

Formation of Calcite

Calcite is present in small irregular grains disseminated through the sediments and lavas and clusters of calcite grains can be commonly found near the feldspar fragments of the graywackes. The origin of these calcite grains is difficult to determine, however it may be due to any or all of the following causes: (1) recrystallization of calcite originally present in the rock (2) metamorphic alteration of calcium bearing minerals (3) addition of $CaCO_3$ by hot or cold water solution. The abundance of calcite grains near the feldspar fragments and disseminated through the lavas indicate that at least some, if not all, of the calcite may have originated from the metamorphic alteration of the feldspar. This alteration of the calcic feldspar to the more sodic feldspar releases calcium which if not used in other chemical reactions could recrystallize as calcite.

Formation of Epidote

Epidote is present as tabular grains and clusters of grains (Plate III Fig.6) in the sediments and as tabular grains in the lavas. This epidote occurs as subhedral to euhedral grains and was formed by the reaction of iron, alumina, calcite and silica. The epidote in the sediments may have formed during the period of regional metamorphism and is often present near the feldspar fragments in the graywackes. This indicates that some of the iron, alumina and silica present after the formation of biotite may have combined with some of the lime removed from the feldspar fragments during metamorphism and produced epidote. The amount of epidote formed in the sediments was governed by the amount of iron present after the formation of biotite. The epidote in the lavas occurs as tabular grains (Plate V Fig.12) near the pyrrhotite areas and appears to be contemporaneous with the formation of the pyrrhotite.

Regional Metamorphism and Evidences

The metamorphic minerals present in the Archaean sediments and lavas of West Hawk Lake indicate that the area was subjected to a low (biotite) grade of regional metamorphism. This grade of regional metamorphism is indicated by: (1) the lack of high grade metamorphic minerals in the sediments (2) the complete recrystallization of the groundmass of all the sediments and the partial recrystallization of the feldspar fragments in the graywackes (3) the uniform fine grained plagioclase matrix of the lavas with local incipient feldspar grains (4) the absence of zones of thermal metamorphism near the intrusives.

The constituents necessary for the formation of high grade metamorphic minerals do not appear to be absent as shown by the abundance of biotite and sericite in the sediments. A higher grade of metamorphism would have converted the majority of the biotite to new minerals like garnet and orthoclase, and would have completely decomposed the sericite.

The complete recrystallization of the groundmass of all the sediments and the partially recrystallized feldspar fragments of the graywackes further indicate that the area was subjected to a low grade of regional metamorphism. Higher grades of temperature and pressure would have produced a coarser grained matrix in the sediments and would have completely recrystallized the feldspar fragments in the graywackes.

The partially recrystallized lavas are an evidence of a low grade regional metamorphism in the area. This is shown by the ferro-magnesian minerals of the lavas which have been completely recrystallized while the uniform fine grained feldspar in the matrix locally have cloudy centers. The latter indicates incomplete recrystallization of the feldspar. Under high grade of regional metamorphism the feldspar grains would have been larger and would have shown good twinning, but this may be due to local regions of high stress.

Intrusives of this area appear to have had little or no local effect on the Archaean sediments and lavas which they intruded. The minerals present in the Archaean rocks near the intrusives are the same as those throughout the Archaean belt as shown by samples 8, 41, 85 and 86 (Plate VI in pocket). Since the intrusives do not appear to have had any local effect on the Archaean rocks it would indicate that these rocks were regionally metamorphosed by a uniform elevation of temperature and pressure throughout the area.

The available information indicates that the Archaean sediments and lavas of this area were subjected to a low grade (biotite) of regional metamorphism. This theory is upheld by the absence of high grade metamorphic minerals and by such regional metamorphic minerals as: tabular biotite and poeciloblastic sericite.

Causes of Regional Metamorphism

The true cause for regional metamorphism is not actually known but it appears to be closely associated with the orogenic movement of mountain building from a downward sinking geosyncline. Stress, hydrostatic pressure and temperature are the major factors in this type of metamorphism. These three factors reach their highest potentials during the uplift of a geosyncline. The temperature gradient may be somewhat increased by the heat from intrusives which become mobile around the same time as the regional metamorphism takes place. High stress, hydrostatic pressure and temperature cause the stable minerals to become metastable under these conditions. Finally these metastable minerals will form new minerals which are stable under these new conditions. These new minerals are the metamorphic minerals we find in the metamorphosed rocks (e.g. biotite and garnet in the sediments). This reconstitution appears to take place during orogeny or shortly after.

Regional metamorphism appears to take place during or shortly after the uplifting of a geosyncline. Stress, hydrostatic pressure and temperature play a major part in this type of metamorphism and they reach their peak of potential during or shortly after the orogenic movement.

CHAPTER VII

CONCLUSIONS

The study of the Archaean rocks of the West Hawk Lake area reveals that there are four types of sediments and three types of volcanics present. The sediments are composed of graywackes, siltstones, arkoses and argillites. The volcanics consist of andesites, basalts, and agglomerates. The interbedding of the lavas and sediments and the sorting in the sediments (e.g. graywackes) indicate that the area may have been an eugo-geosynclinal basin. The graywackes are the most abundant sediment and have a very striking feature which consists of a very fine (.005mm) grained quartz-feldspar matrix with relatively large (.2mm) feldspar fragments scattered throughout.

The common metamorphic minerals present in the sediments are: biotite, garnets, sericite and epidote. The biotite is the most abundant and occurs in the graywackes and siltstones as tiny blades lineated along the schistosity. Sericite occurs as small and large poeciloblasts in the graywackes and locally in the siltstones. The garnets are present as well developed porphyroblasts in thin siltstone beds. Epidote is found in small tabular grains and clusters of grains in the graywackes and siltstones. These minerals are formed by the chemical reactions between the components present in the original rock. The reactions are started by the three metamorphic forces: stress, heat and hydrostatic pressure. The metamorphic minerals produced are governed by the original composition of the rock and the environment under which the rock was subjected at the time of metamorphism.

The metamorphic minerals of the Archaean rocks of this area indicate that they have been subjected to a low (biotite) grade of regional metamorphism as revealed by: (1) the metamorphic minerals present (2) the partial recrystallization of the sediments (3) the absence of evidence indicating thermal metamorphism.

A local phase of metamorphism is evident near the "quartz-pyrrhotite dikes" and is related to the formation of these dikes, rather than to the regional metamorphism of the area. An example of this is apparent at the Merritt Road section where tremolite and cordierite were produced and the biotite destroyed.

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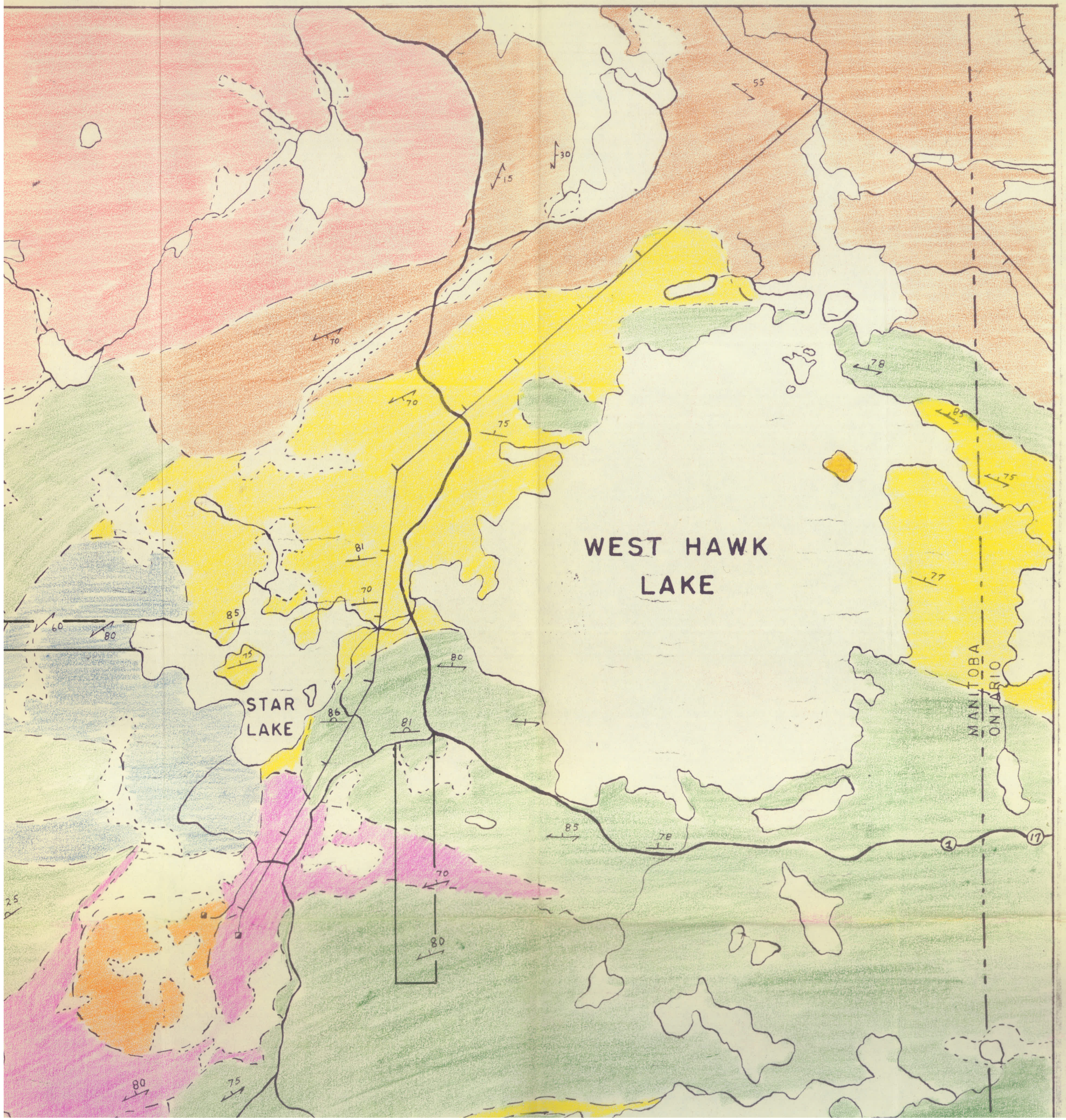
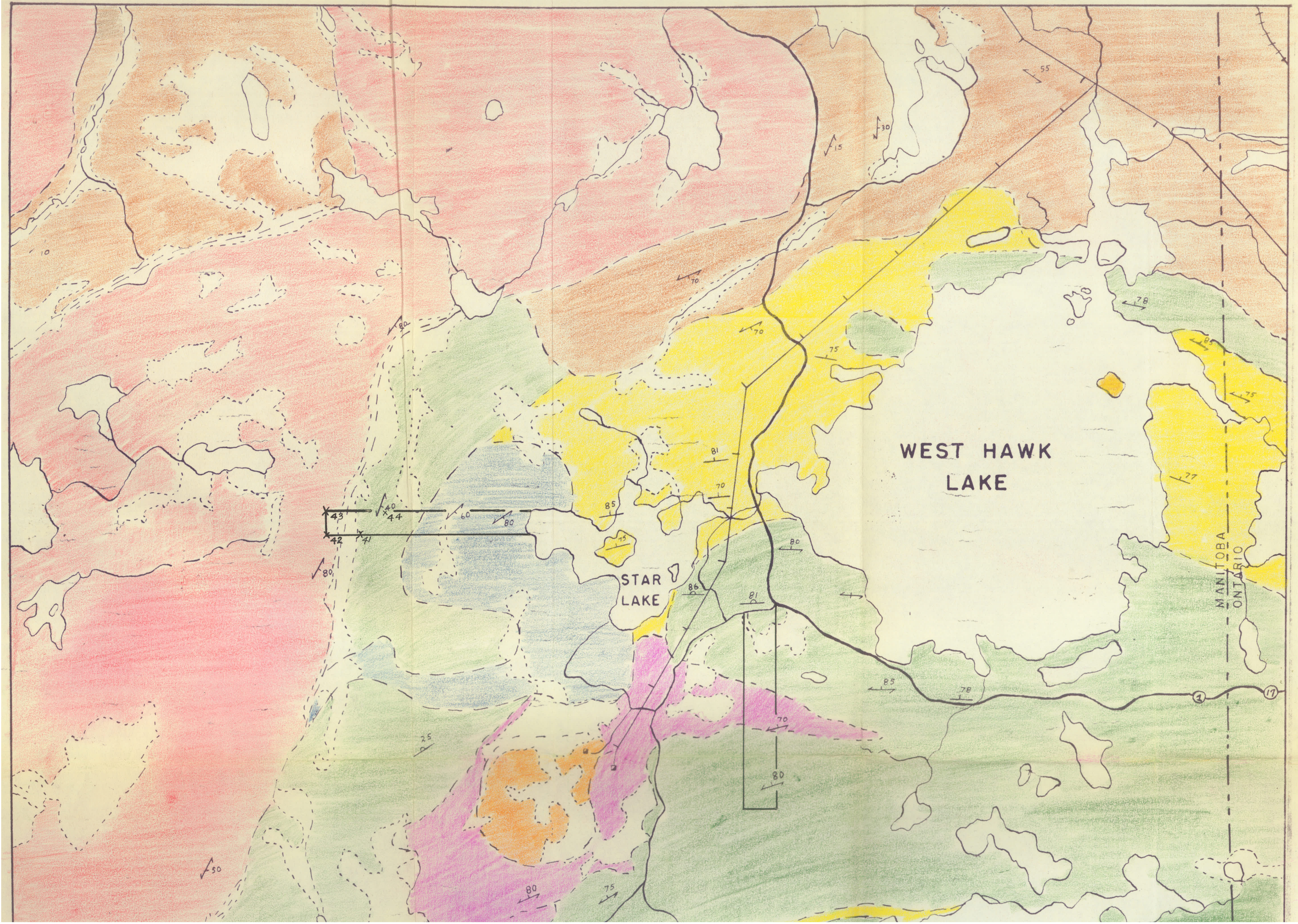


PLATE VI

LEGEND

- QUARTZ MONZONITE
- QTZ. DIORITE, DIORITE, GABBRO
- PINK PORPHYRITIC GRANODIORITE
- GRAY GNEISSIC GRANODIORITE, & QUARTZ DIORITE
- SEDIMENTS - GRAYWACKE, SILTSTONES, ARGILLITES, CONGLOMERATE.
- LAVAS - ANDESITES, BASALTS, RHYOLITES
- AGGLOMERATE
- CONTACTS
- SWAMPS
- POWER LINE
- TRAVERSE LINES
- HIGHWAYS & ROADS



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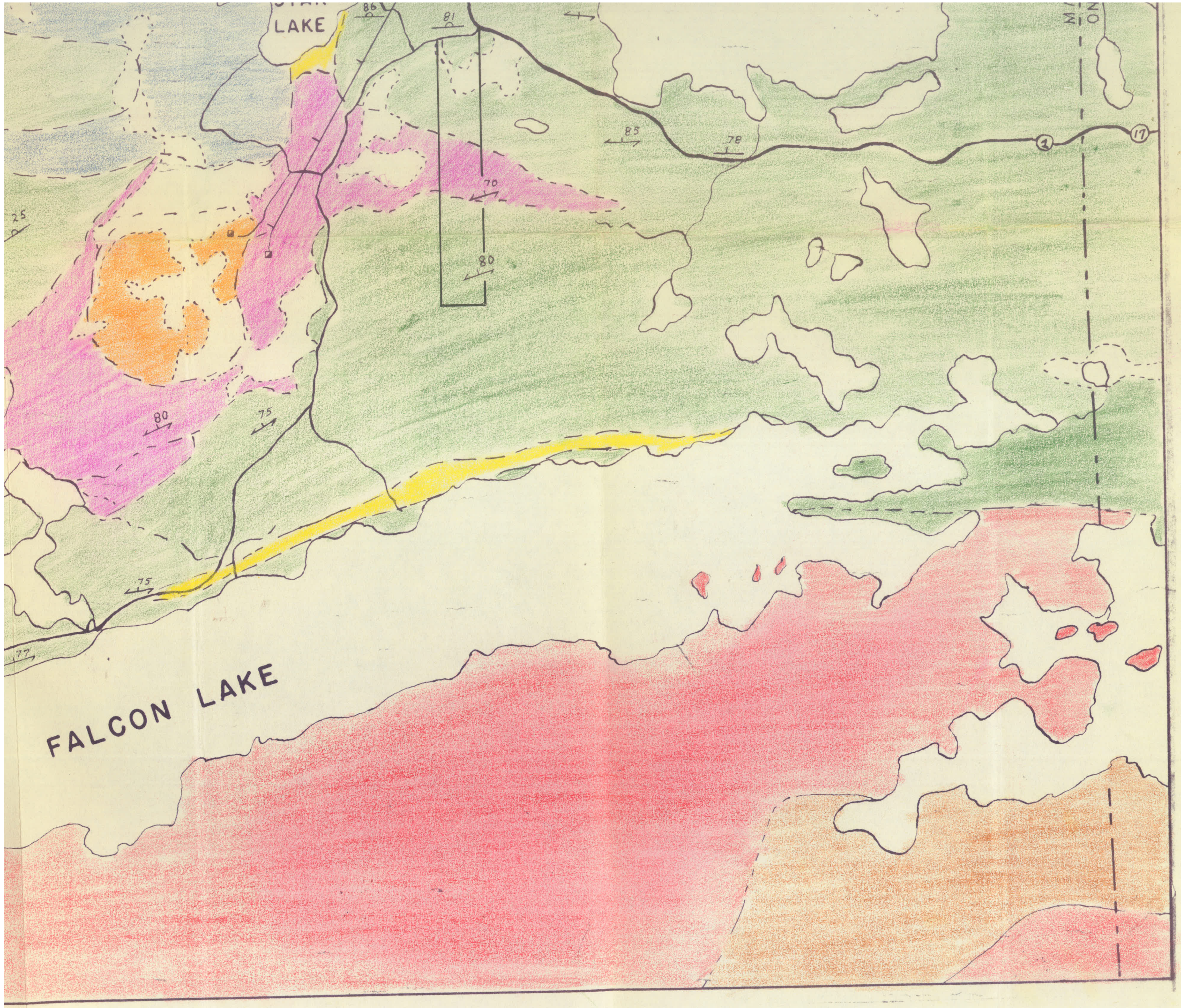


AGGLOMERATE

CONTACTS

SWAMPS

POWER LINE

TRAVERSE LINES

HIGHWAYS & ROADS

STRIKE & DIP

TOPS OF FLOWS

GNEISSOSITY & SCHISTOSITY

X SAMPLE LOCATIONS

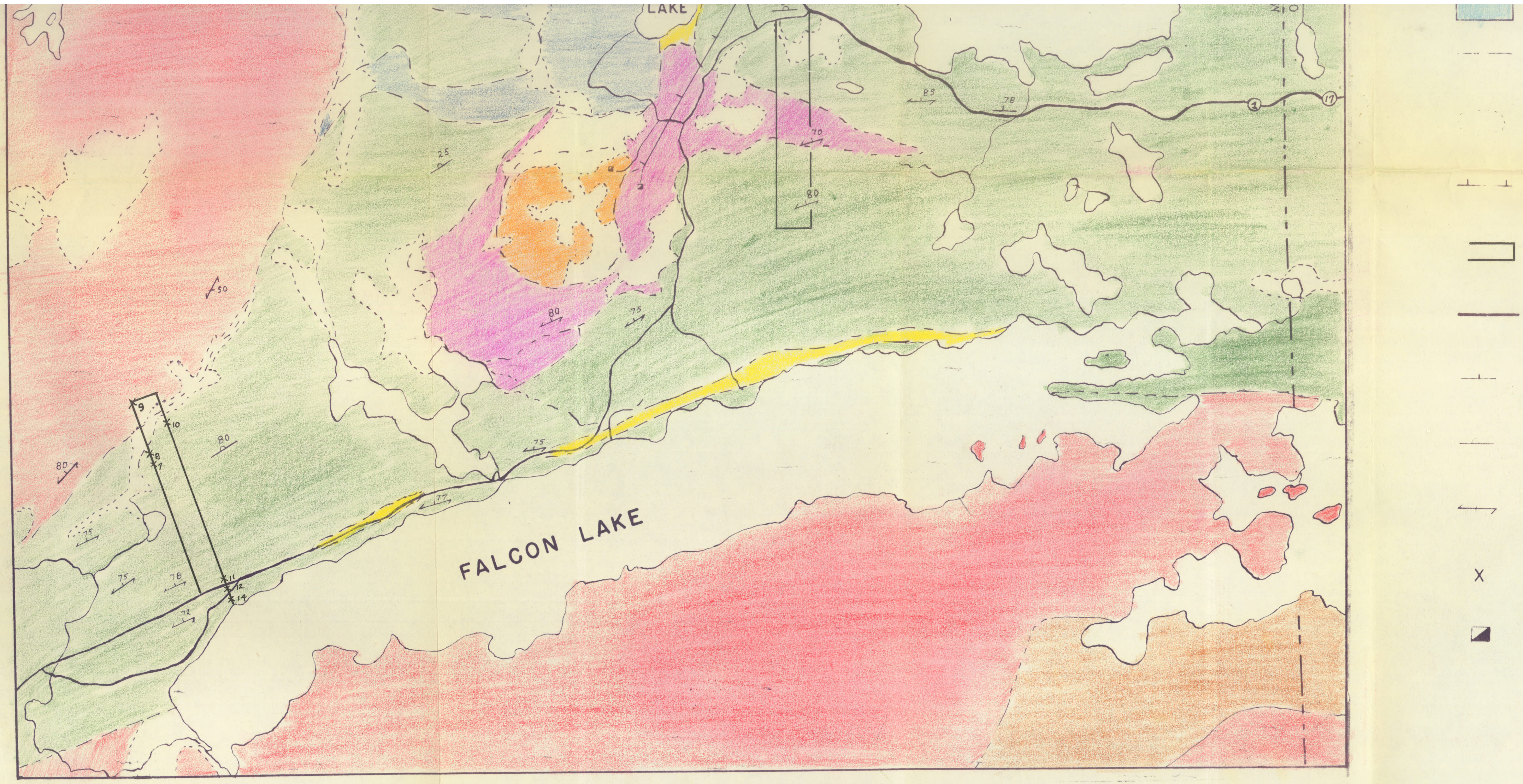
SHAFTS

L.S. BINDA & W.J. KOOP

ST HAWK LAKE AREA

SCALE 1 INCH = 3330 FEET

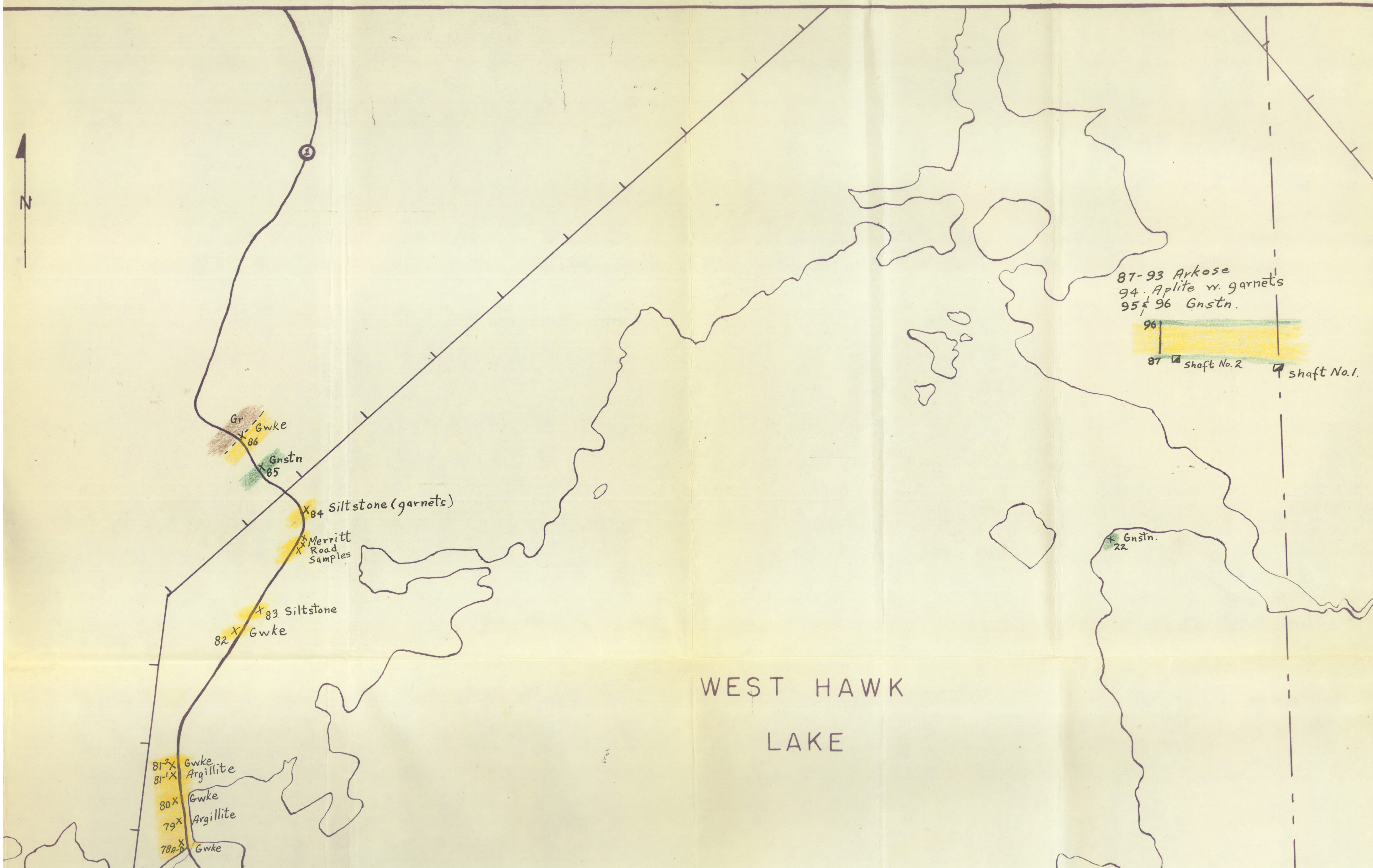
AFTER G.E. SPRINGER'S MAP



WEST HAWK LAKE AREA

SCALE 1 INCH = 3330 FEET

AFTER G.E. SPRINGER'S MAP


N
1
Gr
Gwke
86
Gnstn
85
84 Siltstone (garnets)
Merritt
Road
Samples
83 Siltstone
82 Gwke
81-2 Gwke
81-1 Argillite
80 Gwke
79 Argillite
78A-B Gwke
87-93 Arkose
94. Aplite w. garnets
95 & 96 Gnstn.
96
87
Shaft No. 2
Shaft No. 1.
Gnstn.
22
WEST HAWK
LAKE

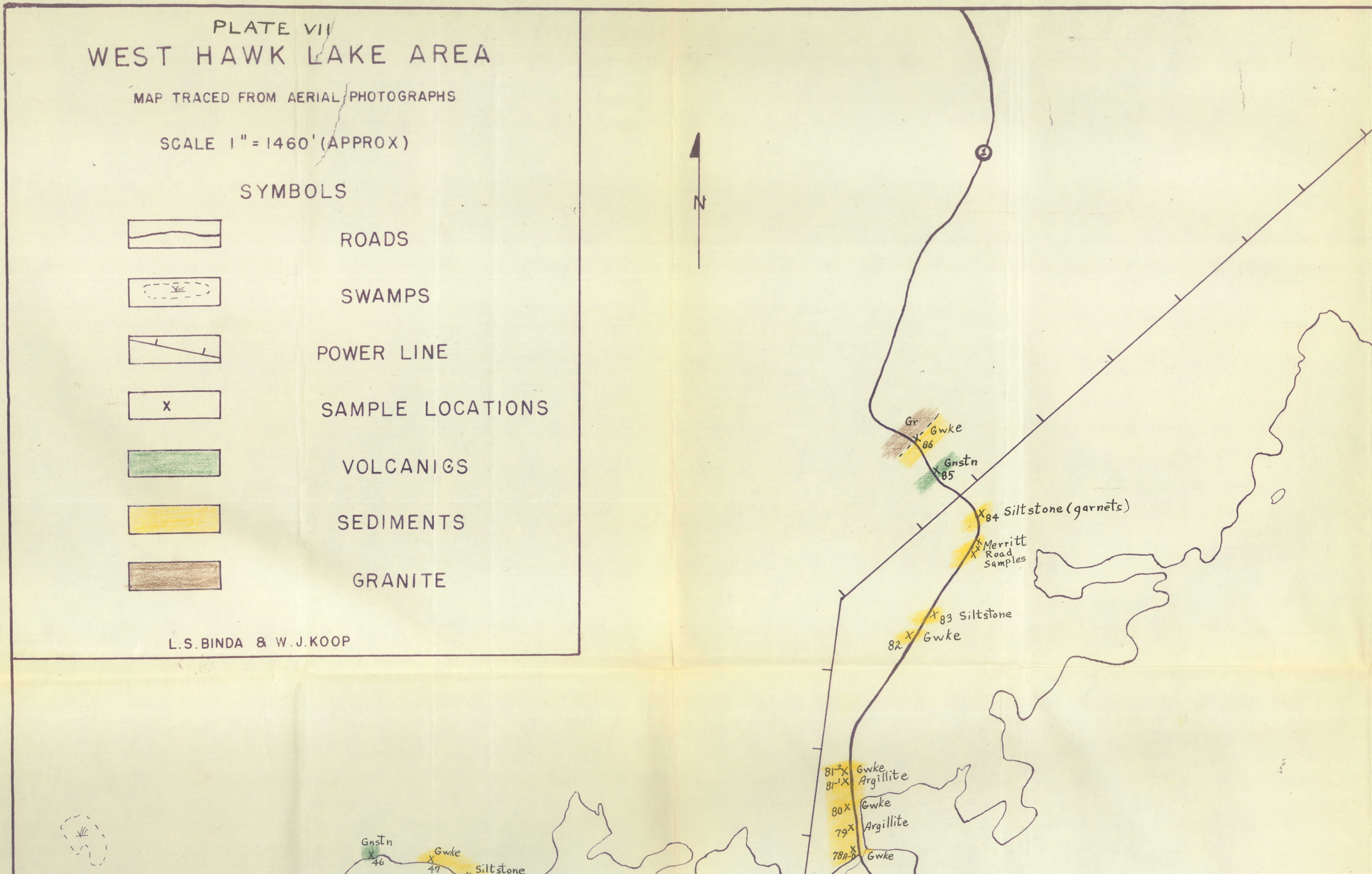
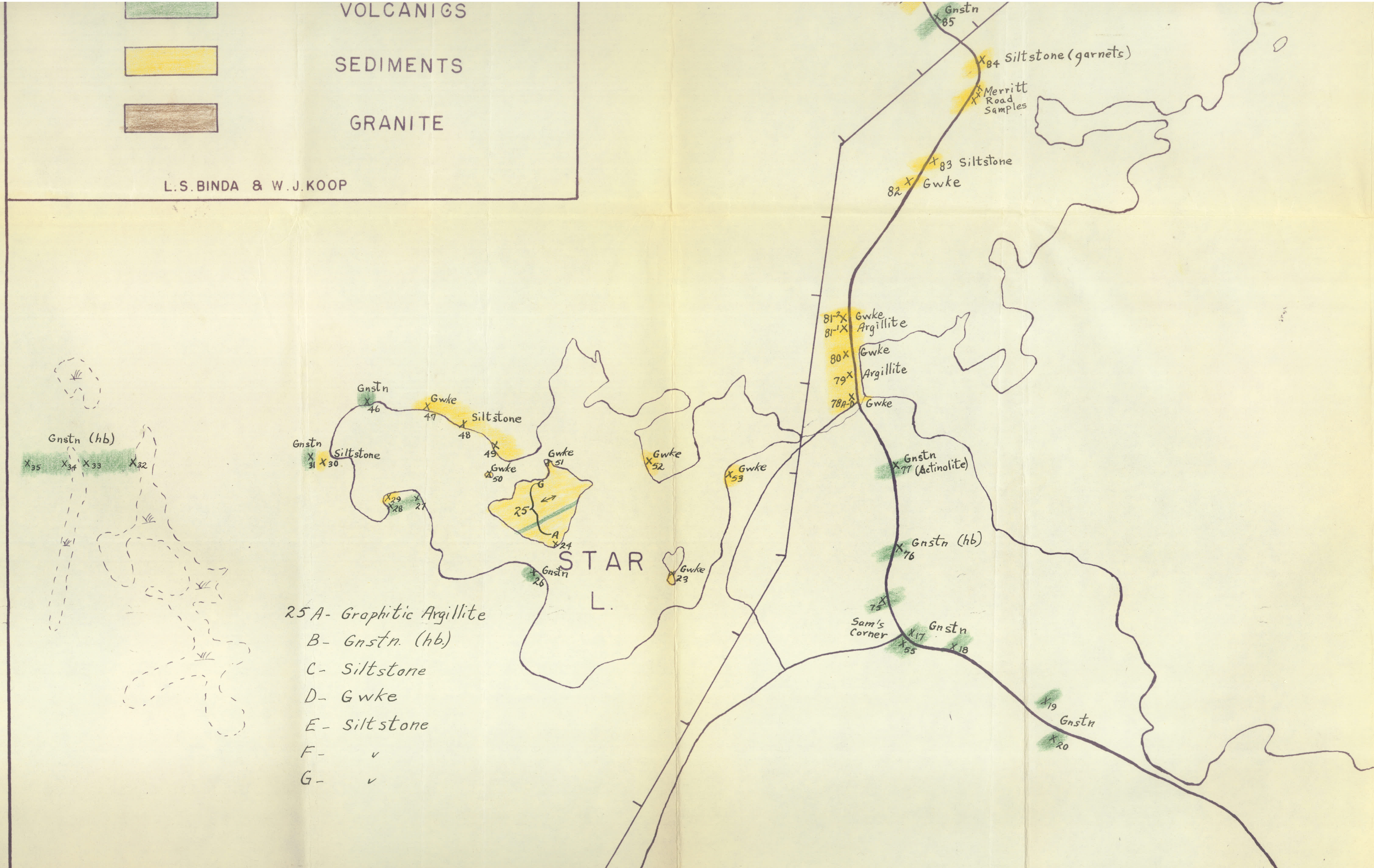


PLATE VII
WEST HAWK LAKE AREA
MAP TRACED FROM AERIAL PHOTOGRAPHS
SCALE 1" = 1460' (APPROX)
SYMBOLS
ROADS
SWAMPS
POWER LINE
SAMPLE LOCATIONS
VOLCANICS
SEDIMENTS
GRANITE
L.S. BINDA & W.J. KOOP
N
1
Gr
Gwke
86
Gnstn
85
84 Siltstone (garnets)
Merritt Road Samples
83 Siltstone
82 Gwke
81-2 Gwke
81-1 Argillite
80 Gwke
79 Argillite
78A-D Gwke
Gnstn
46
Gwke
47
Siltstone


Gnstn
85
84 Siltstone (garnets)
Merritt
Road
Samples
83 Siltstone
82 Gwke
WEST HAWK
LAKE
Gnstn.
22
81-2 Gwke
81-1 Argillite
80 Gwke
79 Argillite
78A-D Gwke
Gnstn
77 (Actinolite)
Gwke
53
Gnstn (hb)
76
Gwke
23
75
Sam's
Corner
17
Gnstn
55
18
19
Gnstn
20
MANITOBA
ONTARIO

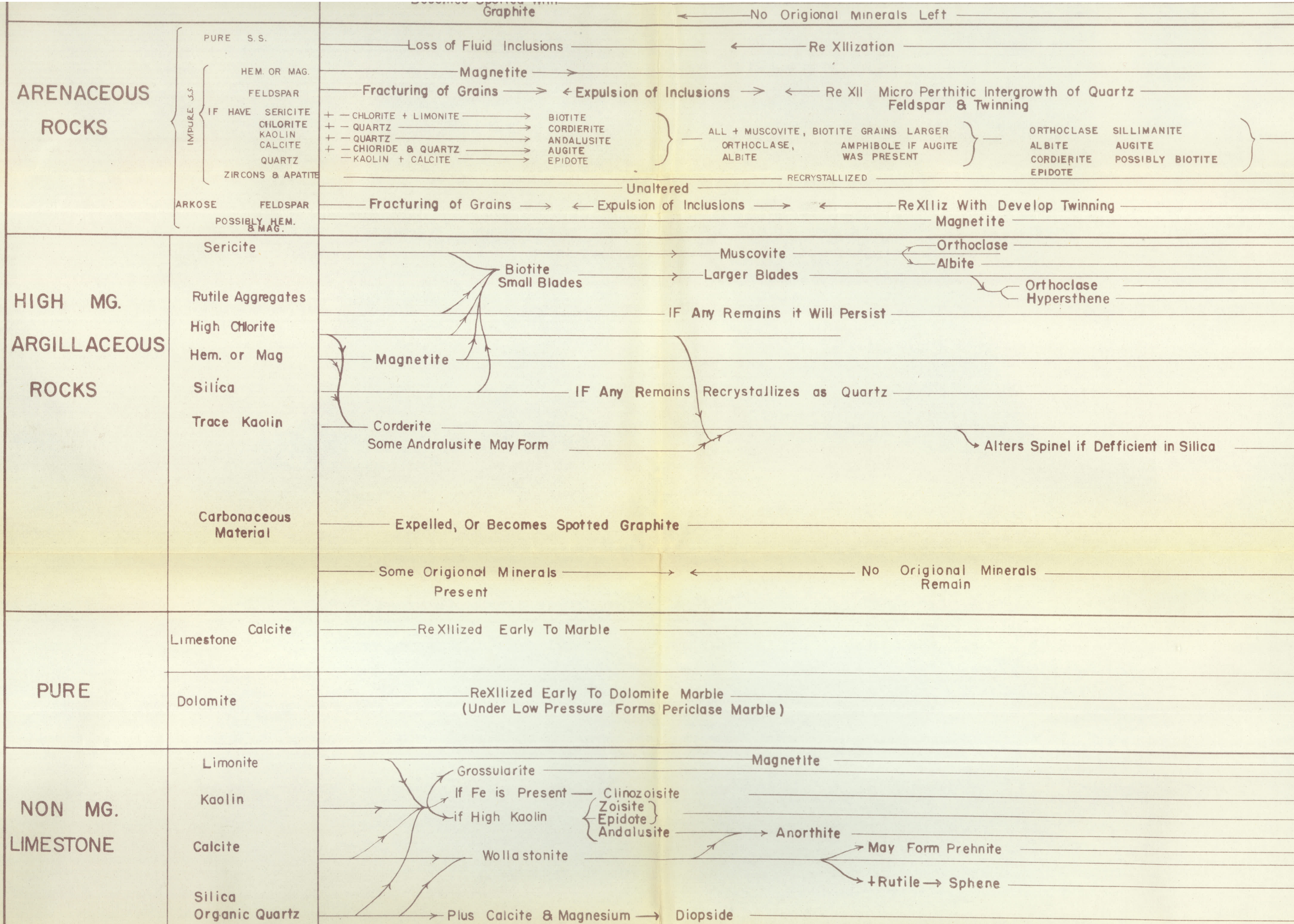

VOLCANICS
SEDIMENTS
GRANITE
L.S. BINDA & W.J. KOOP
Gnstn 85
84 Siltstone (garnets)
Merritt Road Samples
83 Siltstone
82 Gwke
81-2 Gwke
81-1 Argillite
80 Gwke
79 Argillite
78A-D Gwke
Gnstn 77 (Actinolite)
Gnstn (hb) 76
75
Sam's Corner
Gnstn 17
55
18
19 Gnstn
20
Gnstn (hb)
35 34 33 32
Gnstn 31
30 Siltstone
Gnstn 46
Gwke 47
Siltstone 48
49
Gwke 50
Gwke 51
29 28 27
25
G
A
24
Gnstn 26
Gwke 52
Gwke 53
Gwke 23
STAR L.
25 A- Graphitic Argillite
B- Gnstn. (hb.)
C- Siltstone
D- Gwke
E- Siltstone
F- "
G- "

THERMAL METAMORPHISM

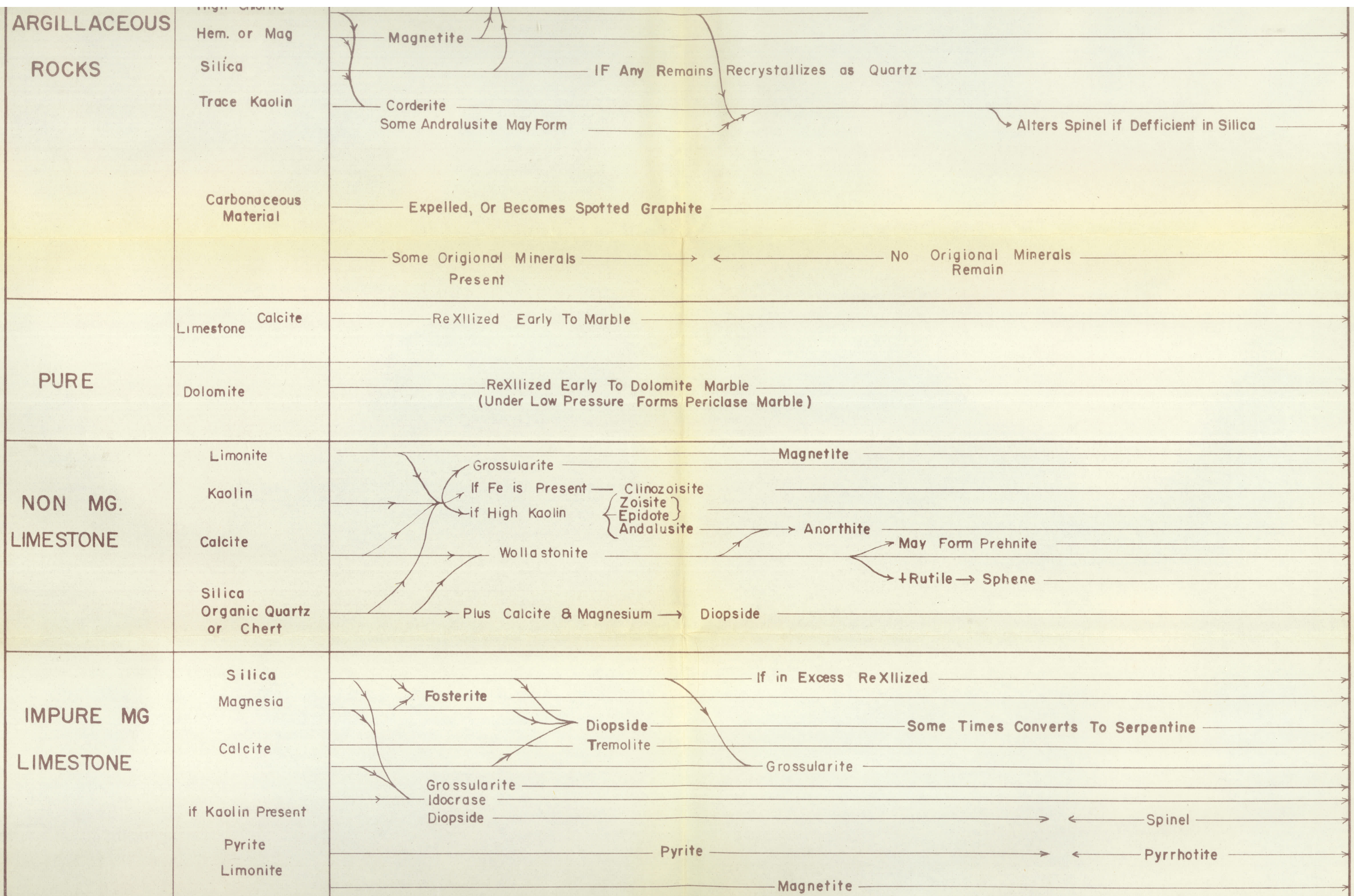
TABLE VIII

BY: L.S. BINDA

ROCK TYPE & CONSTITUENTS		LOW GRADE	MEDIUM	HIGH
GRANITE RHYOLITE	Quartz	Fracturing of Grains		Recrystallization
	Orthoclase		Rexlliz & Devlp. Twins	
	Biotite or Hornblende			Augite
	Chlorite	Alteration Biotite		Augite
	Magnetite	Biotite		Augite Sillimaite
	Zircons, Apatite		Unaltered	
	Origional Structures	Some Origional Struct. Present		No Origional Struct.
DIORITE AND ANDESITE		Alterations Same As Granite, Differing Only in Type of Feldspar & The Content of Quartz & Ferromags		
GABBRO OR BASALT	Plagioclase	Fracturing of Grains	Xlloblastic Inclusions Disappear	RE Xll & Twinning
	Pyroxene	Pyroxene	Amphibole	Pyroxene
	Apatite, Zircons, Ilmenite		No Change	
	Magnetite			
	Origional Structures	Some Origional Struct. Present		No Origional Stuct.
PERIDOTITES AND PYROXENITES		Pyroxene	Amphiboles	Pyroxene
(HIGH Al) ARGILLACEOUS ROCKS	Sericite		MUSCOVITE — ORTHOCLASE, ALBITE, ANDALUSITE (IN PRESENCE OF FREE SILICA)	
		Biotite Small Blades Cordierite	Andalusite	Sillimanite
	Chlorite (TRACE)		Biotite Large	BIOTITE, ORTHOCLASE, HYPERSTHENE
			Cordierite	SPINEL IF DEFFICIENT IN SILICA
	Limonite & Magnetite	Magnetite	Magnetite	
	Rutile Aggregates		Ilmenite	
	Silica		IF Any Remains It Will Persist	
		Recrystallization Quartz		
	High Kaolin	Andalusite		IF DEFFICIENT IN SILICA CORUNDUM FORMS; Sillimanite
	Carbonaceous Material	Cordierite Large Grains		Idioblastic Cordierite; ALTERS — SPINEL IF DEFFICIENT IN SILICA
		Becomes Spotted With Graphite	No Origional Minerals Left	



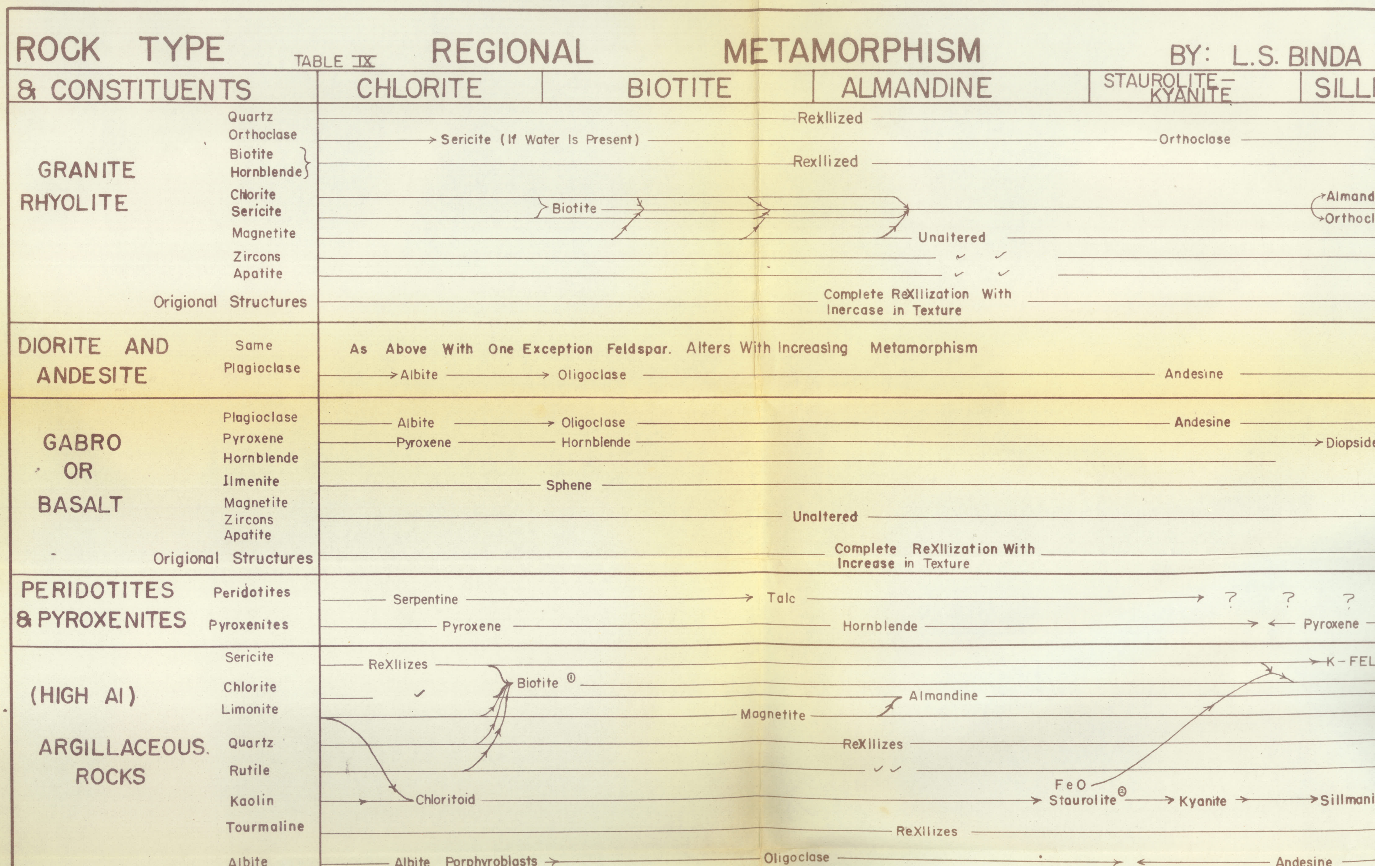
Graphite
No Origional Minerals Left
ARENACEOUS ROCKS
PURE S.S.
Loss of Fluid Inclusions
Re Xllization
IMPURE S.S.
HEM. OR MAG.
Magnetite
FELDSPAR
Fracturing of Grains
Expulsion of Inclusions
Re Xll Micro Perthitic Intergrowth of Quartz
Feldspar & Twinning
IF HAVE SERICITE
CHLORITE
KAOLIN
CALCITE
+ — CHLORITE + LIMONITE
+ — QUARTZ
+ — QUARTZ
+ — CHIORIDE & QUARTZ
— KAOLIN + CALCITE
BIOTITE
CORDIERITE
ANDALUSITE
AUGITE
EPIDOTE
ALL + MUSCOVITE, BIOTITE GRAINS LARGER
ORTHOCLASE,
ALBITE
AMPHIBOLE IF AUGITE
WAS PRESENT
ORTHOCLASE
ALBITE
CORDIERITE
EPIDOTE
SILLIMANITE
AUGITE
POSSIBLY BIOTITE
QUARTZ
RECRYSTALLIZED
ZIRCONS & APATITE
Unaltered
ARKOSE
FELDSPAR
Fracturing of Grains
Expulsion of Inclusions
ReXlliz With Develop Twinning
POSSIBLY HEM. & MAG.
Magnetite
HIGH MG. ARGILLACEOUS ROCKS
Sericite
Muscovite
Orthoclase
Albite
Biotite
Small Blades
Larger Blades
Orthoclase
Hypersthene
Rutile Aggregates
IF Any Remains it Will Persist
High Chlorite
Hem. or Mag
Magnetite
Silica
IF Any Remains
Recrystallizes as Quartz
Trace Kaolin
Corderite
Some Andralusite May Form
Alters Spinel if Defficient in Silica
Carbonaceous Material
Expelled, Or Becomes Spotted Graphite
Some Origional Minerals
Present
No Origional Minerals
Remain
PURE
Limestone
Calcite
ReXllized Early To Marble
Dolomite
ReXllized Early To Dolomite Marble
(Under Low Pressure Forms Periclase Marble)
NON MG. LIMESTONE
Limonite
Magnetite
Grossularite
Kaolin
If Fe is Present — Clinozoisite
if High Kaolin
Zoisite
Epidote
Andalusite
Anorthite
Calcite
Wollastonite
May Form Prehnite
+Rutile → Sphene
Silica
Organic Quartz
or Chert
Plus Calcite & Magnesium → Diopside

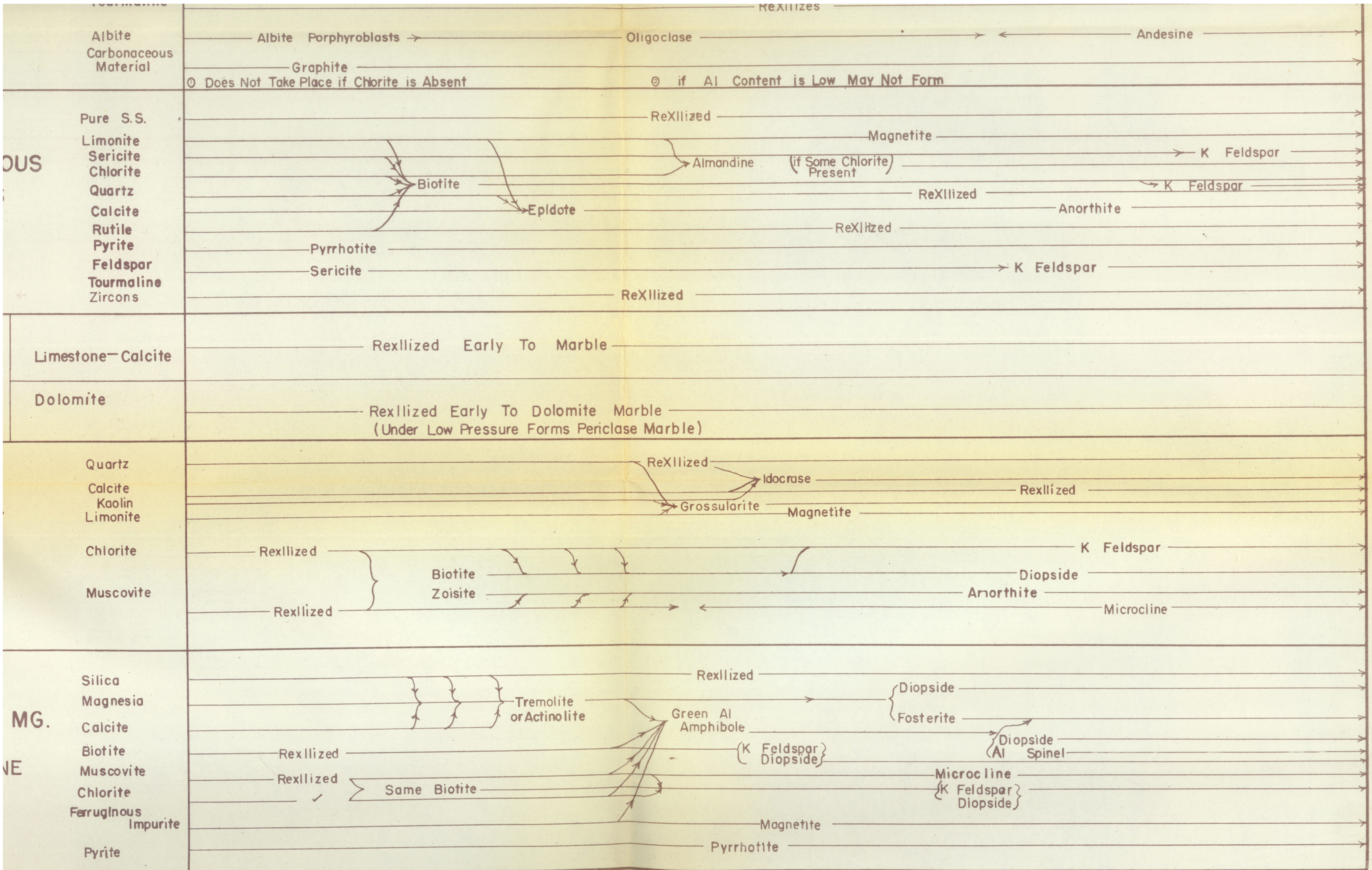

ARGILLACEOUS
ROCKS
Hem. or Mag
Silica
Trace Kaolin
Magnetite
IF Any Remains Recrystallizes as Quartz
Corderite
Some Andralusite May Form
Alters Spinel if Defficient in Silica
Carbonaceous Material
Expelled, Or Becomes Spotted Graphite
Some Origional Minerals Present
No Origional Minerals Remain
PURE
Limestone
Calcite
ReXllized Early To Marble
Dolomite
ReXllized Early To Dolomite Marble
(Under Low Pressure Forms Periclase Marble)
NON MG.
LIMESTONE
Limonite
Kaolin
Calcite
Silica
Organic Quartz
or Chert
Magnetite
Grossularite
If Fe is Present — Clinozoisite
if High Kaolin
Zoisite
Epidote
Andalusite
Anorthite
May Form Prehnite
Wollastonite
+Rutile → Sphene
Plus Calcite & Magnesium → Diopside
IMPURE MG
LIMESTONE
Silica
Magnesia
Calcite
if Kaolin Present
Pyrite
Limonite
Fosterite
If in Excess ReXllized
Diopside
Tremolite
Some Times Converts To Serpentine
Grossularite
Grossularite
Idocrase
Diopside
Spinel
Pyrite
Pyrrhotite
Magnetite

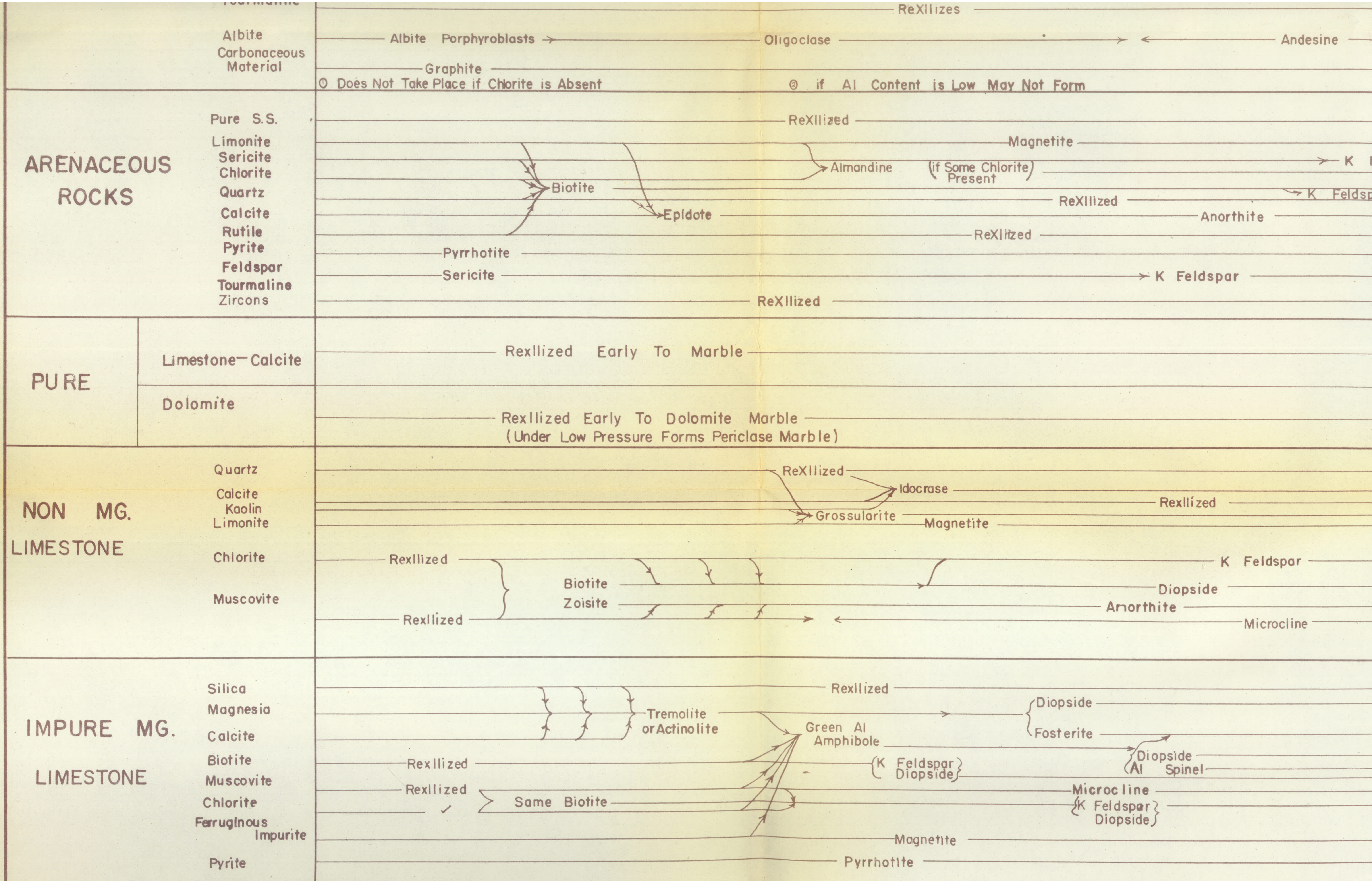
TYPE TABLE IX REGIONAL METAMORPHISM

BY: L.S. BINDA

ITUENTS		CHLORITE	BIOTITE	ALMANDINE	STAUROLITE — KYANITE	SILLIMANITE
	Quartz			Rexllized →		→
	Orthoclase	→ Sericite (If Water Is Present)			Orthoclase	→
	Biotite } Hornblende }			Rexllized		→
	Chlorite					→ Almandine →
	Sericite		} Biotite →	→		→ Orthoclase →
	Magnetite			Unaltered		→
	Zircons			✓ ✓		→
	Apatite			✓ ✓		→
	Origional Structures			Complete ReXllization With Inercase in Texture		→
AND	Same	As Above With One Exception Feldspar. Alters With Increasing Metamorphism				
E	Plagioclase	→ Albite →	Oligoclase		Andesine	→
	Plagioclase	Albite →	Oligoclase		Andesine	→
	Pyroxene	Pyroxene	Hornblende			→ Diopside if High in Ca. →
	Hornblende					
	Ilmenite		Sphene			→
	Magnetite Zircons Apatite			Unaltered		→
	Origional Structures			Complete ReXllization With Increase in Texture		→
TES	Peridotites	Serpentine →	Talc	→	? ?	? ?
ITES	Pyroxenites	Pyroxene		Hornblende	→	← Pyroxene →
	Sericite	ReXllizes				→ K - FELDSPAR →
	Chlorite	✓ Biotite ①				→
	Limonite			Almandine		→
			Magnetite			→
CEOUS.	Quartz			ReXllizes		→
S	Rutile			✓ ✓		→
					FeO	
	Kaolin	→ Chloritoid		→ Staurolite ②	→ Kyanite →	→ Sillmanite →
	Tourmaline			ReXllizes		→
	Albite	Albite Porphyroblasts →	Oligoclase	→	←	Andesine →


ROCK TYPE
TABLE IX
REGIONAL METAMORPHISM
BY: L.S. BINDA
& CONSTITUENTS
CHLORITE
BIOTITE
ALMANDINE
STAUROLITE–KYANITE
SILLIM
GRANITE
RHYOLITE
Quartz
Orthoclase
Biotite
Hornblende
Chlorite
Sericite
Magnetite
Zircons
Apatite
Origional Structures
Rexllized
Sericite (If Water Is Present)
Orthoclase
Rexllized
Biotite
Almandin
Orthoclas
Unaltered
Complete ReXllization With
Inercase in Texture
DIORITE AND
ANDESITE
Same
Plagioclase
As Above With One Exception Feldspar. Alters With Increasing Metamorphism
Albite
Oligoclase
Andesine
GABRO
OR
BASALT
Plagioclase
Pyroxene
Hornblende
Ilmenite
Magnetite
Zircons
Apatite
Origional Structures
Albite
Oligoclase
Andesine
Pyroxene
Hornblende
Diopside
Sphene
Unaltered
Complete ReXllization With
Increase in Texture
PERIDOTITES
& PYROXENITES
Peridotites
Pyroxenites
Serpentine
Talc
? ? ?
Pyroxene
Hornblende
Pyroxene
(HIGH Al)
ARGILLACEOUS
ROCKS
Sericite
Chlorite
Limonite
Quartz
Rutile
Kaolin
Tourmaline
Albite
ReXllizes
K-FELD
Biotite ①
Almandine
Magnetite
ReXllizes
Chloritoid
FeO
Staurolite ②
Kyanite
Sillmanite
ReXllizes
Albite Porphyroblasts
Oligoclase
Andesine


Tourmaline
ReXllizes
Albite
Albite Porphyroblasts
Oligoclase
Andesine
Carbonaceous Material
Graphite
① Does Not Take Place if Chlorite is Absent
② if Al Content is Low May Not Form
OUS
Pure S.S.
Limonite
Sericite
Chlorite
Quartz
Calcite
Rutile
Pyrite
Feldspar
Tourmaline
Zircons
ReXllized
Magnetite
K Feldspar
Almandine
(if Some Chlorite Present)
Biotite
ReXllized
K Feldspar
Epidote
Anorthite
ReXllized
Pyrrhotite
Sericite
K Feldspar
ReXllized
Limestone—Calcite
Rexllized Early To Marble
Dolomite
Rexllized Early To Dolomite Marble
(Under Low Pressure Forms Periclase Marble)
Quartz
Calcite
Kaolin
Limonite
ReXllized
Idocrase
Rexllized
Grossularite
Magnetite
Chlorite
Muscovite
Rexllized
K Feldspar
Biotite
Diopside
Zoisite
Anorthite
Rexllized
Microcline
MG.
NE
Silica
Magnesia
Calcite
Biotite
Muscovite
Chlorite
Ferruginous Impurite
Pyrite
Rexllized
Tremolite or Actinolite
Diopside
Green Al Amphibole
Fosterite
Diopside
Al Spinel
Rexllized
K Feldspar
Diopside
Rexllized
Same Biotite
Microcline
K Feldspar
Diopside
Magnetite
Pyrrhotite



Albite
Carbonaceous Material
ReXllizes
Albite Porphyroblasts
Oligoclase
Andesine
Graphite
① Does Not Take Place if Chlorite is Absent
② if Al Content is Low May Not Form
ARENACEOUS ROCKS
Pure S.S.
Limonite
Sericite
Chlorite
Quartz
Calcite
Rutile
Pyrite
Feldspar
Tourmaline
Zircons
ReXllized
Magnetite
Almandine
(if Some Chlorite Present)
K Fe
Biotite
ReXllized
K Feldspar
Epidote
Anorthite
ReXllized
Pyrrhotite
Sericite
K Feldspar
ReXllized
PURE
Limestone—Calcite
Dolomite
Rexllized Early To Marble
Rexllized Early To Dolomite Marble
(Under Low Pressure Forms Periclase Marble)
NON MG. LIMESTONE
Quartz
Calcite
Kaolin
Limonite
Chlorite
Muscovite
ReXllized
Idocrase
Rexllized
Grossularite
Magnetite
Rexllized
K Feldspar
Biotite
Diopside
Zoisite
Anorthite
Rexllized
Microcline
IMPURE MG. LIMESTONE
Silica
Magnesia
Calcite
Biotite
Muscovite
Chlorite
Ferruginous Impurite
Pyrite
Rexllized
Tremolite or Actinolite
Diopside
Fosterite
Green Al Amphibole
Diopside
Al Spinel
Rexllized
K Feldspar Diopside
Rexllized
Same Biotite
Microcline
K Feldspar Diopside
Magnetite
Pyrrhotite