BRECCIATION AND ASSOCIATED MOBILE SUBMAGMATIC EMPLACEMENT OF ALKALI FELDSPAR RICH ROCKS AT LAKE LA CLOCHE, HARROW TWP, ONTARIO

Brecciation and Associated Mobile Submagmatic Emplacement of Alkali Feldspar Rich Rocks At Lake La Cloche, Harrow Twp, Ontario

by

Andy Legun

A Thesis

Submitted to the Faculty of Arts and Science
in Partial Fulfillment of the Requirements for the
Degree Bachelor of Science

McMaster University
May, 1971

Table of Contents

Page

Photos - see Dr. Schwarcz's copy

Petrography

List of Figures

List of Tables

Acknowledgements

- To Mikkel Schau who first suggested the study and aroused the author's interest
- To my patient and easy going advisor Dr H.P. Schwarcz who accepted the topic and gave freely of his time, advice and knowledge on a project not directly connected with any of his research
- To Don Falkiner who cut the sections
- To Frank Tebay who ran X-ray diffraction traces on my samples
- To Jack Whorwood who gave advice wrt photography
- To Carina Riccotone who typed the manuscript into a presentable form

- To all these people - the author's sincere gratitude.

Abstract

Tensile fracturing and expansion possible relating to tectonic activity and faulting have in part controlled the emplacement of alkali feldspar rich rocks in Huronian sediments at Lake La Cloche, south of Massey, Ontario. The rocks include

1. albitite - composed almost entirely of low albite ($Or_2Ab_{95}An_3$) and minor dispersed hematite.
2. perthosite - containing separate phases of microcline and albite with mutual replacement textures.

The seem to be physically separate but show similarities in spatial, textural and chemical aspects. They have been emplaced chiefly within a fracture zone at the top of the Mississagi quartzite. Perthosite is intimately related with

3. tuffisite - a somewhat mineralogically and modally variable rock emplaced as matrix within an irregular breccia pipe north of the fracture zone. The overall mineral assemblage is microcline + albite + perthite + epidote + chlorite + sericite+ hematite. Texturally it is reminiscent of crystal tuffs. Phenoclasts of the alkali feldspars (rounded, abraded) float in a hydrous silicate background. These phenoclasts are replicas of those in perthosite. Fragments of perthosite (phenoclast poor) were also found in tuffisite in one local. Tuffisite ranges from alkali feldspar poor to feldspar rich varieties. It is typically a silica poor alumina, lime, iron and potash-rich rock.

Tuffisite was probably emplaced as a fluidized mass. Some similarities

to known fluidized bodies are present. These include rounding, attrition and fretting of the host rock, extensive penetration and exploitation of joints, bedding and planar weaknesses, internal sculpturing of the host rock, evidence for both mechanical and chemical emplacement.

It may also be classed as a hydrothermalite. This refers to crytallization under submagmatic conditions, the pneumatolytic to hydrothermal range, hydroxyl minerals commonly developing. In this respect and others it is comparable with weilbergites, alkali feldspar-chlorite rocks within the Lahn region of Germany.

Certain nearby breccia pipes and red feldspar rocks have been associated with alkalic igneous activity. (An alkaline rock province has been postulated along the North Shore of Lake Huron) Specifically soda rich fenite breccias are present at Nemag and Kusk lakes, 12 miles southwest of Sudbury.

The red feldspar rock albitite is common along the North Shore. It is often adjacent or spatially related to diabase and has been interpreted accordingly in terms of genesis. Some albitites are not related spatially to diabase bodies and their emplacement has been controlled by fracture systems. Their origin is more hazy.

The author suggests two alternative interpretations dependent on whether alkali feldspars in tuffisite are considered to be primar~~il~~y o~~n~~r allochthonous.

Alternative One - (Alkali feldspars primary): Perthosite and albitite are special fractionates, concentrated initially within the proto-tuffisite magma as an alkali-volatile rich phase. These juvenile liquids were emplaced within a fracture zone at the top of the Mississagi. At about the same time tuffisite was emplaced within an irregular breccia pipe.

The author throws open for argument the possibility that tuffisite is an upper crustal altered fenite breccia with associated red feldspar rock emplacement in fracture zones.

Alternative Two-(Alkali feldspars allochthonous): Tuffisite is a hybrid rock type akin to a weilbergites (also interpreted as hybrid). Crystallization of red feldspar rocks within the pneumatolytic stage involved contamination in part by mafic material (possibly diabase). The resultant mechanical, chemical mixture was emplaced as a fluidized mass-tuffisite.

More work needs to be done in determining which alternative is valid and what the exact relationships ~~a~~ and sources of albitite, perthosite and tuffisite are.

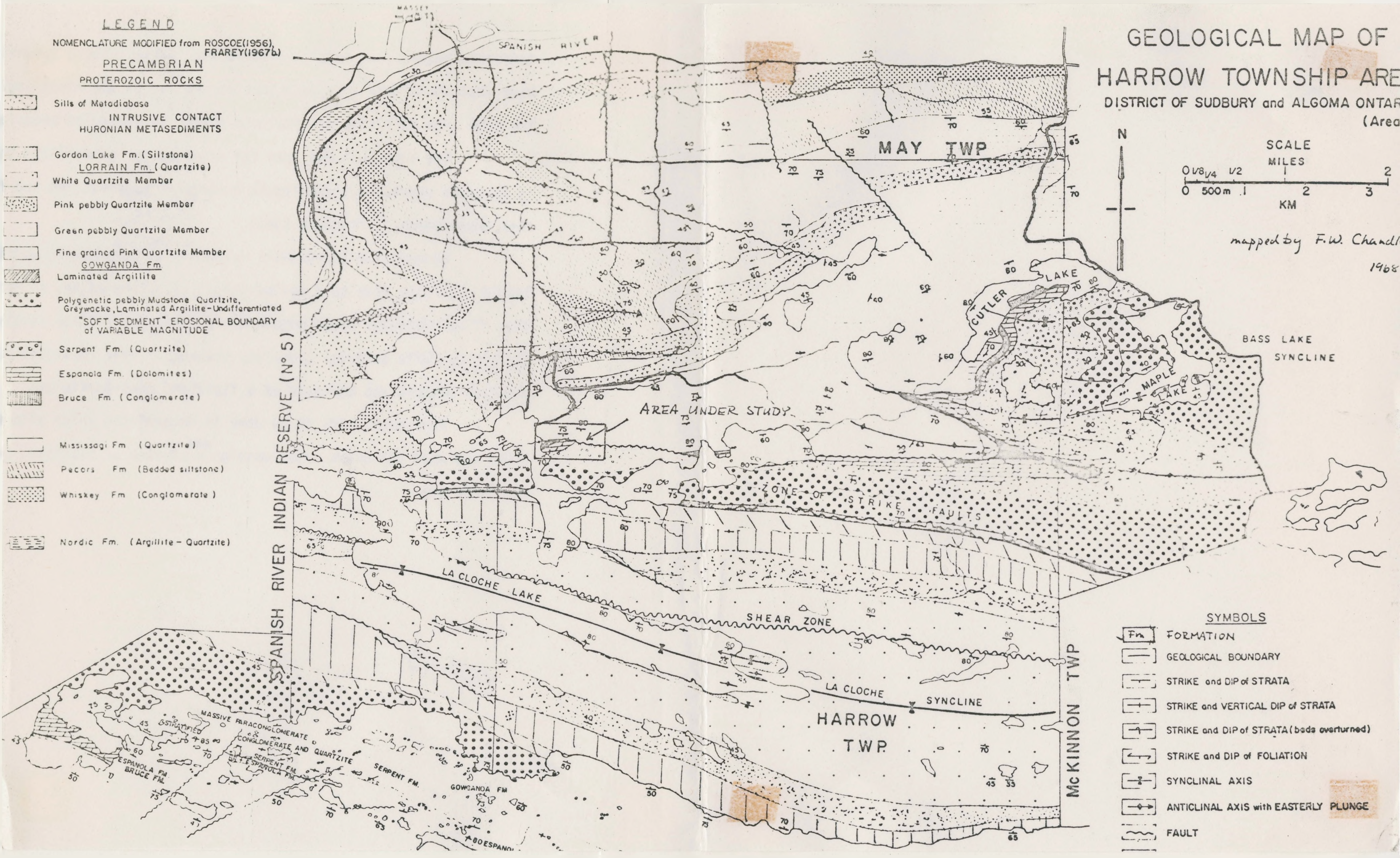
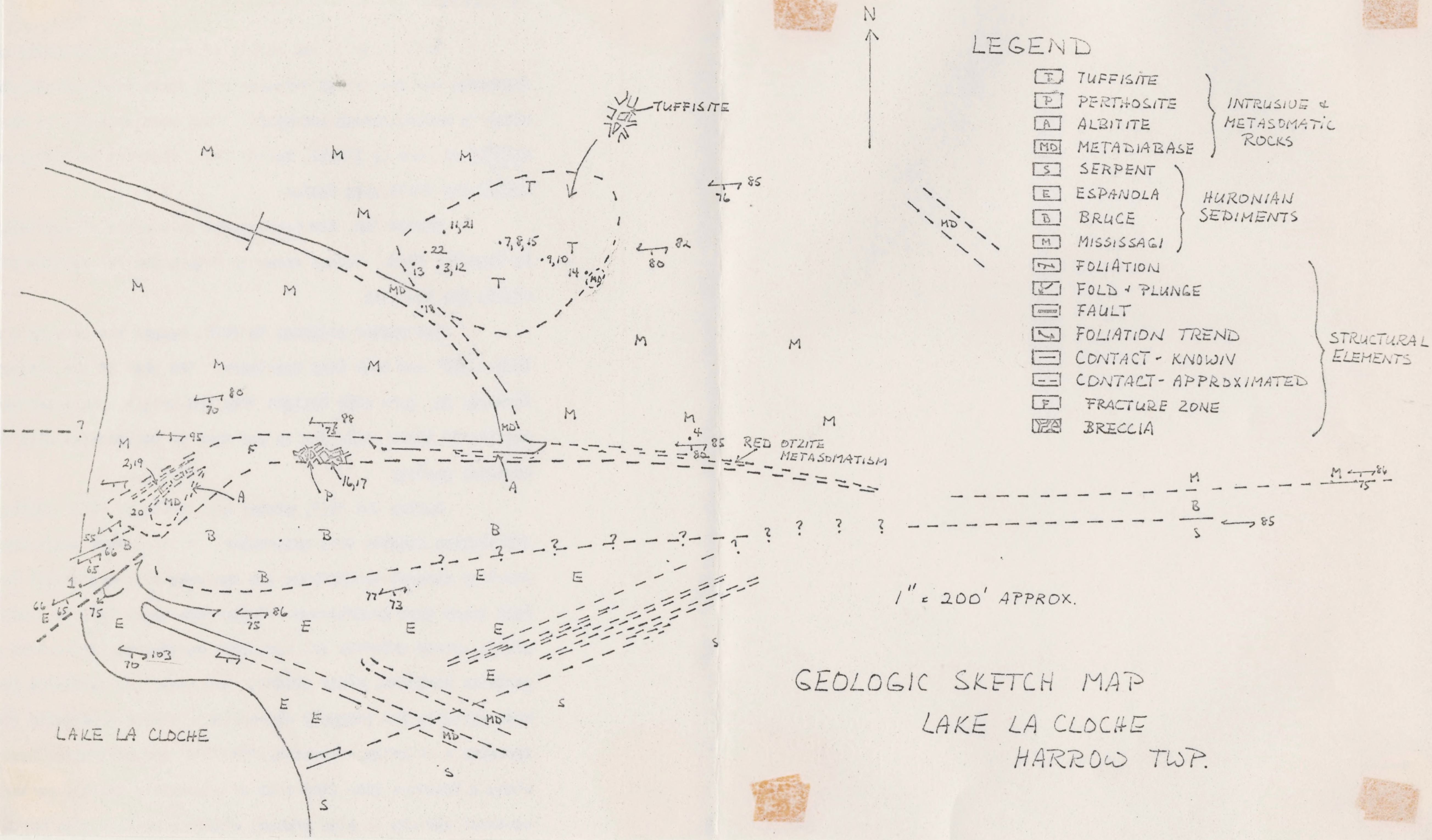


FIG 1 SETTING OF THESIS AREA WITHIN HARROW TWP.



GEOLOGIC SKETCH MAP
LAKE LA CLOCHE
HARROW TWP.

Introduction

This study is the result of an initial curiosity concerning certain intrusive red and orange feldspar rich rocks within brecciated zones in slightly metamorphosed sediments. They were observed by the author who was mapping at Lake La Cloche, Harrow Twp., District of Algoma during the 1969 university field camp season.

Harrow Twp. has been mapped on a scale of one inch to one mile by Chandler 1968. Please refer to Figure One for setting of thesis area within the township.

The author returned in 1970, mapped the area on a scale of one inch = 200' and took hand specimens. The goal of the project was straightforward: to gain some insight into the origin, character and structural setting of these rocks and to put them in perspective with respect to the regional geology.

During the fall, winter and spring of 70/71 petrographic and x-ray diffraction studies were undertaken. A literature seach ensued once the peculiar mineral assemblages and textures of these alkali feldspar rich rock types were ascertained. These rock types include albitite (mostly albite, minor chlorite and hematite) perthosite (microcline + albite + perthite dominant, minor chlorite and hematite) tuffisite (minerclogy and mode variable but commonly microcline + albite + perthite + epidote + sericite + chlorite + hematite) Albitite and perthosite have been emplaced along a fracture zone (the site of a possible fault), perthosite in one textural variety is also present within a breccia pipe north of the fracture zone as fragments in tuffisite. Tuffisite is largely restricted to the breccia pipe but does sporadically occur south to the fracture zone. Most rocks are slightly metamorphosed Huronian sediments. At Lake La Cloche they are part of the north limb of the Lake La Cloche syncline, a tight fold with a shallow plunge to the west. Diabase bodies (subsequently metamorphosed) have intruded these sediments.

Several shear zones extending east-west, crudely parallel to the axial trace cut across the syncline.

One of these faults passing the field of study is depicted as truncating a discordant wedge of Huronian sediments. To the west this shear zone (a possible strike-slip fault; personal communication James Robertson) disappears under Lake La Cloche, appears in breccia zones on a few islands, swings NW, displaces the Murray granite and joins the major Murray fault (map of North Shore of Lake Huron; ODM - in press).

Many faults in Huronian rocks are the loci of extensive brecciation. Many are occupied by meta-diabase. Hematitization, epidotization, feldspathization and silicification are common in some (Ginn 1961).

Closer to Sudbury some breccias have been ascribed to the Sudbury type (Thomson 1952, pg. 20, Card 1965, pg. 21,22). Sudbury type breccias occur in a wide variety of rock types and are characterized by a granulated crushed matrix derived largely from host rocks.

Fenite breccias have been observed related to carbonatites and alkalic igneous activity within a postulated alkaline rock province along the North Shore of Lake Huron (Doig 1970, Gittins 1967 and others). Fenites are typically rich in alkali feldspars, alkalic pyroxenes and amphiboles.

Red feldspar rocks may occur as replacement veins along fractures faults or lineaments in alkalic provinces. (Heinrich and Moore 1970) Albitites along the north shore of Lake Huron have not been related to any alkalic igneous activity. Many are adjacent diabase bodies and have been interpreted accordingly. The interpretation of others distant from any diabase bodies, their emplacement controlled by fracture zones, has been left open to discussion.

The matrix of a breccia pipe within the field of study has been called tuffisite. Tuffisite does not seem to be either an igneous or a metamorphic rock, its closest textural equivalent being crystal tuffs. There is strong evidence for an extremely mobile form of emplacement. This has led the author to literature on gaseous transport of material-fluidization, (the vapor rich invading material being termed tuffisite (Cloos 1941)) and hydrothermalites (Lehman 1952). Hydrothermalite refers to 'magmas' which consolidated at low temperatures. Two examples of such 'magmas', the first of stronger affinity to the tuffisite at Lake La Cloche, are weilburgites (Lehman 1952) and potash unakites (Saksela 1935) Weilburgites display variable composition and they are essentially alkali feldspar-chlorite rocks.

Geologic Setting

1) Huronian Rocks (Please refer to the geologic sketch map, Figure 2)

(See Figure 3 for stratigraphic column)

The Mississagi, Bruce, Espanola and Serpent formations are represented in the field area. The Mississagi and Serpent quartizites are fairly well exposed; the Espanola siltstone-argillite and Bruce paraconglomerate are poorly exposed and largely drift covered. The contact of Serpent and Espanola is gradational, intertonguing. The other lithologies display sharp contacts gradational over a few feet.

The Mississagi is a medium grained quartzite, well foliated and typified by a cataclastic texture. A thin lens-like surfacies or argillite and siltstone locally forms the top of the unit thinning both east and west.

The Bruce is a non-bedded polymictic grit to conglomercite, grit size quartz grains, pebbles, cobbles of red and white granitic rocks in a chloritic matrix.

The overlying Espanola (see photo #1) is an argillite - siltstone with a predominantly basal subfacies of calcareous siltstone. Some intertong ing of Espanola and Serpent is apparent. Thin beds of argillite-siltstone are found within the Serpent formation resembling those of the Espanola.

The Serpent is a massive white quartzite with a typical conchoidal fracture easily recognizable in the field.

Bruce and Espanola apparently thin eastward. At the western edge of the field, only a hundred feet of stratigraphic thickness separate Serpent

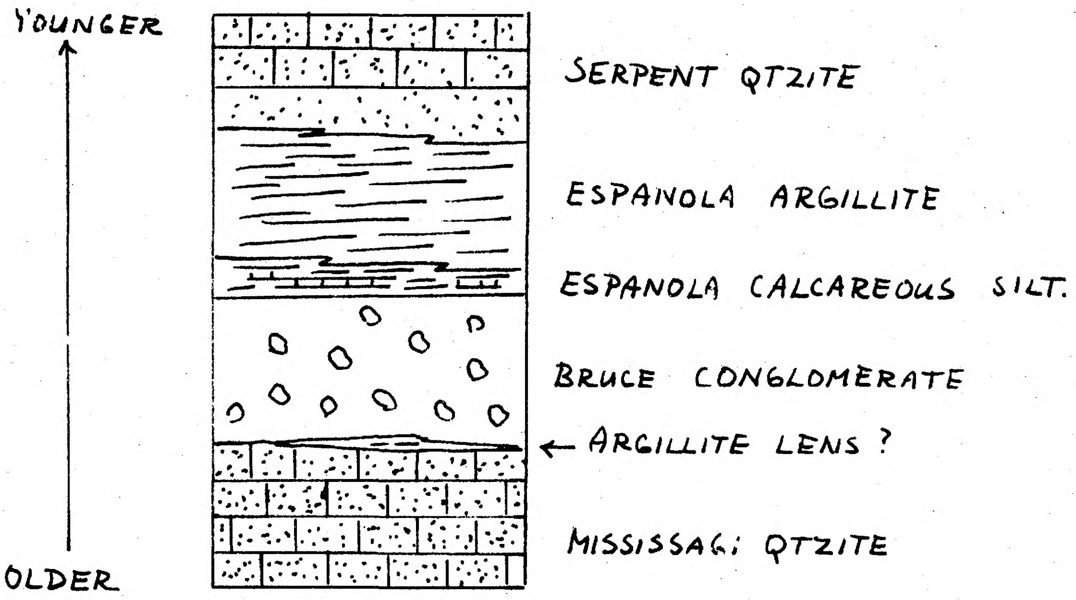


FIG 3 STRATIGRAPHIC COLUMN - HURONIAN SEDIMENTS

FIG 4 VARIATION IN FORM OF BRECCIATION OF MISSISSAGI QTZITE, EMPLACEMENT OF TUFFISITE

from Mississagi. On the east the apparent sequence is Mississagi, Bruce, Serpent; the Espanola has disappeared.

2) Structural Setting and Intrusive Rocks - A) Descriptive

Please refer to the geologic sketch map, Figure 2. Mississagi quartzite occupies most of the northern half of the map area. Its foliation and bedding strike at 80 to 90 degrees dipping between 75 to 90 degrees to the South. Thin dikes of meta-diabase cut across this trend. One such dike trends NW-SE, swings southward and fans into a sill at ~~(to)~~ the top of the Mississagi. Another dike (much more poorly exposed) is present in the NE corner of the map area, brecciated Mississagi immediately adjacent.

The regional trend of the Mississagi is partially disrupted within a vein and stockwork breccia zone. It has been depicted on the sketch map as roughly oval in outline. Brecciation with intrusion of tuffisite prevails within the dashed borders, but it is also sporadically present south and east of the pipe.

A small very poorly defined body of meta-diabase (almost entirely drift covered) is present towards the borders of the pipe and is in contact with emplaced tuffisite.

Emplacement of tuffisite within this pipe was structurally controlled in part, the matrix taking advantage of joints, bedding and any planar weaknesses resulting in an anastomosing structure. However many isolated pods of tuffisite sit in relatively undistrubed quartzite. A replacement process must be postulated in this case. Pods (a foot to over twenty feet in length, usually narrower in width) often have apophyses into the host. Veins take tortuous paths and have highly variable widths (Many of these aspects may be seen in photos 3-11) Some thin diffuse greenish (chlorite rich?) veins cut the quartzite toward the periphery of the breccia zone.

Small "stocks" of tuffisite are present usually with a high ratio of matrix to breccia. A central portion relatively free of breccia is sometimes present.

There seems to be no correlation between randomness in orientation of breccia fragments, blocks and proportion of matrix. In fact in one portion of the pipe bedding has been broken, the blocks rotated and jammed against each other with no apparent vertical movement (see photos 7 and 8) Matrix is minor (<10%). Elongate parallelsided blocks are common. Some of the blocks are in such a position that it is necessary to postulate expansion followed by collapse to explain their wedged position (photo 8).

Breccia fragments range from subangular to rounded in character. Rounded varieties are usually centrally located within the matrix, the more angular material towards the extremities. Contacts between matrix and fragments range from sharp to gradational. In the first instance, if the rock is weathered a fragment may be plucked out of the tuffisite. Some fragments are welded together by material which seems to consist predominatly of disrupted recrystallized? quartzite. This welded material then grades into the matrix. Where contacts are distinct boundaries range from fairly smooth to irregular and slightly fretted varieties. Vague flow lines and swirls sometimes suggest themselves in the matrix about breccia fragments.

The conveyed three dimensional pattern varies from place to place within the pipe: (see Figure 4)

1. an internally broken, sculptured Mississagi quartzite with remnant pillars, arches and protruberances.
2. matrix filling in the voids of a breccia framework.
3. suspended blocks of breccia in a sea of matrix.

2/ is implied in outcrops of high fragment low matrix ratios (in photos 7 and 8), 1/ is suggested in the irregular borders of intrusive tuffisite pods sitting in undistrubed quartzite (photo 11), 3/ is apparent in the vertical face exposure illustrated in photos 9 and 10.

South of the pipe the upper contact of the Mississagi is characterized by sills of metadiabase rimmed by albitite and brecciated Mississagi intruded by albitite and perthosite (red feldspar rocks) Mississagi quartzite and argillite take take on a reddish-pink tinge of varying intensity.

The upper Mississagi quartzite begins to deviate from its regional trend near the shore of Lake La Cloche. From several hundred feet out strike gradually changes from E.W. to NE-SW at the upper contact of the Missassagi with a fanning sill of meta-diabase. With increasing deviation brecciation of the Mississagi into huge blocks is more apparent as is albitite intrusion. A semi-continuous rim of albitite surrounds the meta-diabase body.

This body is complexly infolded with Bruce Conglomerate such that the two are nearly indistinguishable.

At the southwestern base of this fanning sill massive hematite-specularite associated with albitite is found. At this locale Bruce Conglomerate is recognized as a distinct unit emerging out of its unmappable relationships within the meta-diabase. Pebbles and cobbles are quite visibly flattened and elongated parallel to the foliation striking 65° dipping 65° to the south. This deformation disappears rapidly along strike, as do brecciated areas, albitite and meta-diabase bodies. At the shore of Lake La Cloche contact relationships of the Mississagi, Bruce, Espanola formations are well exposed as the sequences disappear under the lake.

Truncating these formations to the east is a fault trending at 45°. It separates Huronian rocks of two structural trends. To the east of the fault the regional foliation varies from 105 to 75° dipping to the south at 70 to 80°.

Complexities in foliation trends arise close to the fault:

A small fold in Espanola argillite, its axial trace parallel to the fault and plunging 75° to the south is truncated by the fault along its western limb. A hundred feet south-east of this fold argillite lies crumpled against the terminus of a meta-diabase dike. This argillite then swings sharply northward to nearly parallel the fault (north-east of the truncated fold).

B) Interpretive

Poor outcop and structural complexity hamper interpretation. However:

The top of the Mississagi is characterized by a fracture zone defined by meta-diabase sills and red feldspar rocks occupying tensile fractures and spaces. To the west a brittle flexure zone is apparent as part of the same fracture trend, Mississagi quartzite being brittly rotated through an arc of up to 45°, the resultant breccia cemented by albitite.

Compression related to rotation and flexure has also played a part. This is suggested in deformed cobbles of the Bruce, infolding within the meta-diabase, crumpling of argillite against the terminus of a meta-diabase dike (or is this a result of the intrusion?). Perhaps Bruce behaved incompetently, the Mississagi competently during flexure.

Intensity of deformation is perhaps related to radius of curvature, rocks close to the axis of a rotation being the more severely affected, deformation, brecciation diminishing in rocks further away from the axis where rotation without flexure will occur (radius of curvature approaches zero).

Some differential movement is suspected in argillite paralleling a fault in a sort of drag fold.

Varying three dimensional patterns of the internal form of the breccia pipe described above are compatible and reflect a brecciation mechanism in part tectonic (image two) in part motivated by intrusion of tuffisite (images 1 and 3).

It is not uncommon for breccia pipes to develop along intersections of faults or fissures (Park and MacDiarmind 1970, pg. 75, 76). Movements along an undulating fault surface will also result in collapse breccias along pinch and swell structures.

The structural setting at Lake La Cloche is not incompatible with these views.

Outcrop Photos

Please refer to the geologic sketch map for locations.

#1 Fairly sharp contact of Bruce Conglomerate with overlying Espanola at the Shore of La Cloche Lake. Largest cobble in the photo is about 5" across.

#2 Albitite pod in Mississagi quartzite within the brittle flexure zone. Note the contact with host varies from sharp to gradational. Also note reddish tones of host rock.

#3 Locale from which rock and thin section L-13 derived; towards "borders" of pipe. Replacement veins of tuffisite.

#4 Anastomosing breccia vein of tuffisite. Note rotation of blocks relative to the regional trend of the host quartzite.

#5 A partial view of the main breccia zone. The regional trend of the Mississagi is still discernable at the right. At the fore, right of centre exploitation of bedding planes by matrix.

#6 Chaotic somewhat rounded breccia fragments and blocks within tuffisite.

#7 Randomly orientated tectonically broken blocks of Mississagi quartzite. Matrix is minor, tending to fill interstices, cementing the mass.

#8 A closer view. Tight wedging implies expansion followed by collapse.

#9 Angular to rounded (base of large block to right of hammer handle) blocks and fragments of Mississagi quartzite of different shapes and sizes suspended in flesh-coloured tuffisite.

#10 A close-up view (just above the hammer) illustrating in this case sharp contacts between matrix and brecciated rock.

#11 Locale from which land specimen and thin section L-12 derived. An intrusive pod of tuffisite, somewhat free of breccia, with small apophyses into broken host rock.

Microphotos

All photos are negative prints (i.e. opaque minerals are white and transmitting minerals are black (e.g. quartz). One centimetre on the photo is equal to 1.8 mm. in thin section.

Please refer to the geologic sketch map for locations.

#12 Tuffisite Veinlet (Thin Section L-15).

A vein of tuffisite carrying fragments of Mississagi quartzite in random orientation is gradationally bordered by a zone of internally disrupted Mississagi quartzite with minor to moderate amounts of epidote (as quartz grain rim networks) and alkali feldspar scattered throughout. This zone transitionally passes into relatively undistrubed quartzite with the minor epidote or alkali feldspar (zone 3).

#13 Feldspar - free Tuffisite (Thin Section L-23)

Grains and fragments of Mississagi quartzite and recrystallized quartz are contained and partially inundated within chlorite-sericite. A relatively large fragment of cataclastic Mississagi quartzite (sericite rich) in places rimmed by recrystallized quartz presents an irregular margin to this material.

#14 Tuffisite (Thin Section L-42-A)

A relatively large fragment of phenoclast poor nearly cryptocrystalline perthosite sits in the upper right hand corner. The rest of the thin section consists of phenoclasts of microcline, albite, perthite (dark grey) sitting in

1. patches of alkali feldspar (medium grey) indurated by epidote and chlorite (white to light grey)

2. chlorite-epidote alone.

#15 Tuffisite - Welded Quartzite (Thin Section L-41)

A tapering gouged (at the head) fragment of Mississagi quartzite with minor metasomatic feldspar sits within a chaotic mass of internally disrupted quartzite (minor epidote, feldspars, sericite) rich in clots of hydroxyl and feldspar minerals.

#16 Perthosite (Thin Section L-36-B)

Mircocline (potassium stained) predominates over albite as "agitated" grains displaying various degrees of roundness, replacement, and suturing against an interlocking sutured albite rich? background grading down in a seriate texture to near cryptocrystalline aspects.

Patches of earthy hematite (minor chlorite - clay? minerals) diffusely vein through the feldspars. Textural aspects comparable to intimately broken perthosite in L-42-A.

#17 Perthosite veining in Quartzite (Thin Section L-36-A)

The slide is intensely and rather badly stained with cobaltinitrite. Note that one arm of quartzite fragment is in the process of breaking off. A few (black elongate) fragments of quartzite detached from the walls have been incorporated into the vein.

The Mississagi quartzite shows many grains of replacement feldspar.

#18 Meta-Diabase (Thin Section L-28)

A remnant diabasic texture is apparent in the photo. Patches of chlorite, epidote aggregates predominate.Mosaic albite sieved by the above minerals still exhibits a remnant plagioclase lath outline.

Scattered quartzite and some high relief grains of sphene? are also present

Note: uneven thickness is responsible for uneven shade.

#19 Albitite (Thin Section L-37)

A phenocrystic aggregate of albite is set against an interlocking albite background, various shades reflecting varying concentration of hematite dust. Note: the fine hematite fracture network within the aggregate.

#20 Albitite with Hematite - Specularite (Thin Section SBX-2)

A network of specularite laths against a background of albite and albite antiperthite illustrating by shading varying concentrations of hematite dust.

#21 Tuffisite (Thin Section L-12)

Somewhat rounded grains of microcline albite and perthite caught in vague swirls within sericite-epidote chlorite, reminiscent of a greywacke texture. Discontinuous veins and clots of these hydroxyl minerals (chiefly epidote) with earthy hematitic stains are present.

#22 Tuffisite (Thin Section L-13)

Alkali feldspar grains (microcline, albite, perthite), grains and fragments of quartzite set against a texturally and mineralogically diverse assemblage of epidote sericite, earthy iron oxides and minor chlorite. This characterizes the matrix left of centre on the photo.

To the right an influx of more homogenous felty sericite epidote almost devoid of feldspars or quartz.

Contact against the relatively large quartzite fragment is fairly sharp and suggestive of a series of broad swoops or scallops.

Petrography 1) Introduction

Thin section modes of albitite, perthosite, tuffisite, meta-diabase and weilbergites (Lehman, 1952) are listed in Table 1. A triangular diagram (Figure 5) is used to plot the modes in terms of albite, microcline, hydroxyl minerals and hematite .

Thin section studies of modes suggest that a total modal variation from a nearby pure alkali feldspar rock (perthosite) to a feldspar-free rock composed entirely of hydroxyl minerals and hematite may exist. This is the possible range of tuffisite as defined here. The greater percentage of tuffisite probably lies within the labelled field on Figure 5 (more darkly shaded oval outline). I have assumed a rather constant potash to albite ratio (derived by staining and point counting). This may not be so.

Weilbergites average 60-65% alkali feldspar, the rest being chlorite. The potash to albite ratio varies widely but no figures were quoted in Lehman's paper. It is depicted as an elongate diffuse zone.

Petrography 2) Descriptions

A) Albitite

Albitite is a fine-grained rock coloured orange pink to reddish shades possibly due to varying amounts of dispersed hematite. It is present in various shapes and sizes ranging from sheet-like to pod-like to irregular

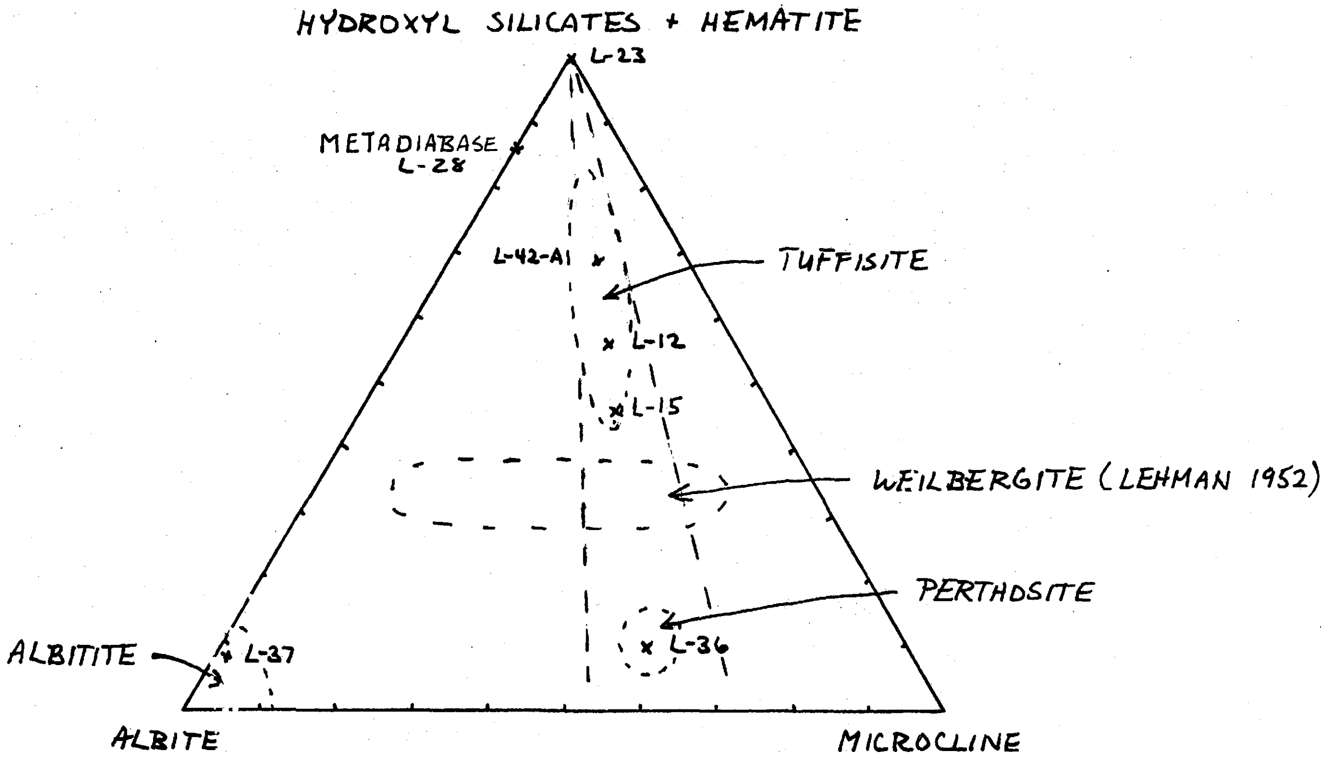


FIG 5 MODAL PLOT OF TUFFISITE ALBITITE PERTHOSITE META-DIABASE AND WEILBERGITES IN TERMS OF ALBITE MICROCLINE HYDROXYL SILICATES AND HEMATITE

anastomosing masses. Contacts against meta-diabase are fairly sharp; against Mississagi quartzite they range from sharp to gradational. Some Mississagi is tinged a deep red but retains its original texture.

In thin section it is apparent that the rock is essentially composed of albite. It agrees with Joplin's (1964) description of albitites in thin section; allotriomorphic granular textures and highly s~~a~~utura~~te~~d grain boundaries.

The anorthite content of the albite was determined to be three weight percent by the Michel-Levy method. Carlsbad, pericline, albite-twinned grains as well as untwinned grains are present. Earthy hematite grains and dust are extensive. Dust is associated with fractures in the rock often occupied by chlorite-hematite veinlets. A seriate fabirc is apparent, phenocrystic aggregate trains of sutured albite lie in a background of interlocking grains ranging down to microcrystalline size. Some phenocryst grains display faulting of twins, fracture, bending and breakage of the crystal. Grains may be developing from the coagulation of microcrystalline granules resulting in sutured interlocking boundaries. However phenocrystic aggregates display sharp sutured truncation of twinned grains which is more suggestive of corrosion and a slight cataclastic texture? A faint foliation roughly parralleling phenocrystic trains is apparent.

Potassium staining showed quite faint discoloration associated with fractures chlorite-hematic veinlets, dense-hematite dust.

The fine texture of this rock is possibly due to

1. Rapid heat loss to the country rock
2. Loss of a vapour phase to surrounding rocks; a decrease in pressure resulting in a higher crystallization temperature.

The foliation possibly represents

1. an igneous lamination
2. retainment of the original quartzite foliation during selective replacement by albite
3. compression after emplacement.

Where albitite contains large amounts of hematite - specularite slightly different textural character is displayed. A good portion of the albite (and antiperthite in the thin section under study - SBX - 2) is present in random stubby laths and rhombs of albite closely associated with a thin lath network of speccularite with minor calcite. The above minerals are set in an interlocking microcrystalline albitic groundmass stained red-brown to various degrees by hematite dust.

X-ray diffraction traces of L-37 (albitite) and SBX-2 (albite + speccularite) support microscopic mineral identifications.

L-37 is composed essentially of triclinic low temperature albite with a single sharp 201 peak at d = 4.03 ±.01 Compositionally this is pure soda alkali feldspar according to the graph of Mackenzie.

The albite associated with speccularite contains minor amounts of potassium. One strong sharp 201 peak is present at d = 4.03 ±.01, another occurs at d = 4.23 ±.01, this peak is low and somewhat diffuse. Respective d spacings represent compositions of pure soda and potash alkali feldspar. The antiperthitic texture in thin section is verified.

B) Perthosite

Perthosite may be described as a dirty orange-pink (flesh) coloured rock of a rather fine granular appearance. It occurs in the field as a dense interconnecting network of veins in Mississagi quartzite (giving it a breccia appearance) in a very poorly exposed area within the brittle flexure zone, a bit northeast of the fanning wedge of the meta-diabase complex. Thin section L-36-B is representative (see photo 16). It is also present as broken fragments and ragged patches within tuffisite (see photo 14).

The name perthosite is used to describe a rock composed largely of microcline and albite physically separate but with extensive replacement textures evident under the microscope. Thin section study (L-36) photo 14 reveals anhedral equidimensional grains of microcline, albite as dense phenoclasts in a finer somewhat interlocking textured background. It is seriate textured with earthy hematite, dust and chlorite which either diffusely vein through the feldspars or sharply cut across them in thin fracture veinlets.

K-staining showed very interesting results. Extensive replacement textures (no crystallographic control) prevail. Smooth oval grains of microcline are rimmed by albite. Patch perthites and rather irregular albite grains with potash replacement rims are not uncommon.

The finer background tends to be interlocking in texture with groups of grains as "veins" or patches of either microcline or albite. There is a suggestion that this finer "matrix" is enriched in albite relative to the phenoclasts.

Many phenoclasts display splitting, breakage (and subsequent annealing) and perforation gouges by other grains. Split grains are separated by injected albitic material (no stain).

Some grains display a semi-oval shape truncated in mid portion by an irregular edge. These may represent broken oval fragments. Some grains seem to sit neatly in gouges? along quartzite walls (see photo 7). Detached? fragments of Mississagi quartzite as well as free quartz grains are present in some of the thinner veins. Elongate quartzite fragments tend to parallel the walls.

Internally the host Mississagi quartzite contains scattered oval, lozenze and lenticular metasomatic grains of alkali feldspar which tend to be elongate parallel to the cataclastic foliation. However many are not. In some cases a slight molding of cataclastic quartz about the grain is apparent.

Assuming all stained portions to be pure end member K-feldspar and all unstained portions to be pure end member Na-feldspar an approximate overall composition of the feldspar in perthosite is Ab_{38} Or_{62}.

Two textural varieties of perthosite are found in tuffisite. The first occurs in discrete fragments and is discussed under this heading. Intimately broken fragments of perthosite probably originally similar to perthosite within veins in the fracture zone are discussed under tuffisite because they are more closely related to the phenoclasts of alkali feldspar comprising in large part the inerology of tuffisite.

The internal texture of the fragments is allotriomorphic seriate oval, lozenze (well rounded) and very irregular bounded grains (defining a good foliation) grading down to almost cryptocrystalline material.

Untwinned, twinned (gridion, linear) microcline perthite and untwinned glossy albite (minor) grains are represented. There is very little distinction (in terms of relief etc.) of "phenocrysts" against background. A bit of chlorite outlines some of them and they tend to be lighter than the hematite dust stained background. Irregular grains illustrate sutured-interpenetrative boundaries with the finer matrix. Some semi-homogenous gr grains illustrate granular mosaic microcrystalline portions against a cryptocrystalline background. With the strong foliation this mortar? texture is possibly suggestive of cataclasis. Other than minor earthy hematite and dust, a bit of chlorite and epidote (secondary?) the fragment is essentially alkali feldspar.

An x-ray diffraction trace was obtained from the fragment. Most of the peaks coincide with microcline. Peaks not coincident match albite (unmatched peaks compared to L-37 albitite trace).

There are two 201 peaks, a fairly strong one at $d = 4.23 \pm .01$ (pure K-feldspar) and a weaker at $d = 4.03 \pm .01$ (pure soda-feldspar) $2\theta_{cuk\alpha}$ $1\bar{3}0 - 2\theta_{cuk\alpha}\ 130 = 0.74$ making the potash end member a near maximum microcline.

C) Tuffisite

Tuffisite is a fine-grained rock varying from buff to orange-pink on the weathered surface. Sometimes tones of green modify the colour. On a fresh surface the rock is medium grey with a distinct purple tone.

From thin section work it is apparent that the orange of the weathered surface is due to alkali feldspars and hematite. Greenish overtones are probably a result of concentrations of chlorite and other hydroxyl mineral. It is thus semi-homogenous in aspect. In one locate it contains discrete fragments of a red feldspar rock (perthosite). Tuffisite is a very peculiar rock, neither metamorphic nor igneous. Texturally its closest equivalents are crystal tuffs. The observed mineral assemblages in this rock include

1. epidote + chlorite + sericite + microcline + perthite ± albite
2. epidote + chlorite + microcline + perthite + albite
3. epidote + sericite + microcline + perthite ±albite
4. chlorite + sericite commonly with earthy iron oxides and dust, quartzite grains and fragments. In some cases unstrained recrystallized quartz is locally present along host rock boundaries. Tuffisite typically (photo #12) consists of somewhat rounded grains of microcline, albite and perthite caught in vague swirls within sercite - epidote and chlorite reminiscent of a greywacke texture. Discontinuous veins and clots of these hydroxyl minerals (chiefly epidote) with earthy hematite stains are present.

Sericite is commonly concentrated around feldspar grains, alson developing internally along fractures and optical discontinuities. It is also present in dense mats of chlorite-sericite (thin section L-23 photo

#13) or epidote-sericite (photo #21, L-13) as well as clots (L-41, photo #15).

Discontinuous veins of euhedral epidote, the grains crudely radiating from an axis rich in hematite(?) dust are common (L-12, photo #21, L-15 photo #12). The epidote ranges from yellow green to green pleochroism to a nearly colourless variety (L-15 photo #12). However it is epidote rather than clinozoisite. This is supported by its high birefringence and optically negative character. Zoned eipidote is not uncommon.

Feldspar grains seem to have undergone some abrasion and corrosion as evidenced by sharp truncation of twinning, partial separation and infill of an original single grain, rounded but irregular boundaries against the matrix.

In cases (L-12 photo #21) where hematite and epidote occur in veins and clots relatively intact in a background of scattered epidote and earthy hematite two generations of minerals are suggested.

Mentioned under the breccia pipe heading were occurrences where transitional borders were exhibited between host and matrix. In thin section this welded aspect consists of internally disrupted Mississagi quartzite with minor to moderate amounts of epidote (as quartz-grain-rim networks) and microcline scattered throughout. With increased disruption clots of alkali feldspar-hydroxyl minerals occur (L-41) or we pass into a vein of tuffisite (L-15). In the other direction this "welded" zone passes into relatively undisturbed well foliated quartzite with the minor epidote or metasomatic microcline.

Besides grains of microcline, albite and perthite there are also fragments of alkali feldspar rocks (perthosite). In one locale near a meta-diabase body (photo 14, thin section L-42-A). There are two textural varieties. One variety consists of relatively large (up to an inch or two) discrete well foliated phenoclast-poor nearly cryptocrystalline textured fragments of perthosite. The other variety consists of intimately broken and indurated (by chlorite and epidote) patches of perthosite rich in phenoclasts.

This broken-patchy perthosite is similar to the unbroken homogeneous form characterized by photo #16 which was described in terms of its extensive replacement textures. What is astonishing is that individual grains of microcline, albite and perthite are found in tuffisite. The question to ask is: are feldspar grains in tuffisite derived from perthosite, i.e. are they allocthonous and tuffisite a hybrid magma or are they primary and perthosite a product of differentiation of this magma. I will discuss this question in the last section.

TABLE ONE. THIN SECTION MODES

1	2	3	4	5	6	7	MINERAL
			14.5	×			QUARTZ
11.9	16.6	60-65		×	34.2	92.3	ALBITE
19.5	27.1			×	56.2		MICROCLINE
38.8	35.4		38.4	×	0.4		EPIDOTE
0.4	18.0	30-35	42.5	×	4.6	3.5	CHLORITE
25.4	0.6						SERICITE
4.4	2.4		0.2		4.7	4.2	HEMATITE
		5	4.4				OTHER
100.4	100.1	100	100.0		100.1	100.0	TOTAL

1 TUFFISITE (L-12)
2 TUFFISITE (L-42-A)
3 WEILBURGITES (AVERAGES) LEHMAN 1952
4 DIABASE NEAR SUDBURY WALKER 1897 - ANALYSIS (L-28 MODE)
5 POTASH-UNAKITE MARTII SAKSELA 1935
6 PERTHOSITE L-36
7 ALBITITE L-37
8 ALBITITE PRONTO MINE ROSCOE 1968

TABLE TWO. CHEMICAL ANALYSES

1	2	3	4	5	6	7	8	COMP.
45.5	45.4	46	47.00	55.25	60.8	63.6	66.32	SiO_2
			3.6					TiO_2
23.9	19.9	<25	16.44	21.23	18.0	19.1	19.43	Al_2O_3
11.4	9.8	9.0	3.31	1.62	4.6	4.2	1.00	Fe_2O_3
0.3	4.1		12.34	3.13	1.3	0.9	1.05	FeO
			0.04					MnO
	2.8	4.5	3.32	1.56	0.8	0.6	2.20	MgO
10.3	9.4	4.0	9.57	7.28	0.1	0.4	0.58	CaO
1.4	2.8	7.5	3.38	1.94	4.0	10.4	7.60	Na_2O
5.3	4.1		.67	5.30	9.4	0.3	0.52	K_2O
			0.33					P_2O_5
2.0	2.8	4.0		1.60	0.6	0.4	0.59	H_2O
100.1	101.1	100.0	99.97	98.91	99.7	99.9	99.29	TOTAL

Chemical Compostions and Comparisons

Chemical analyses derived from thin section modes are listed in Table 1. These are very crude approximations to the actual compositions. Individual mineral analyses for epidote, an average chlorite and muscovite were obtained from Deer, Howie and Zucsman. Analyses and sources are listed in the appendix. The composition of the feldspar in albitite was determined by a combination of x-ray and optical studies. The overall composition of the alkali feldspars in perthosite was obtained by staining and point-counting. Since it is believed that the alkali feldspar phenoclasts in tuffisite are equivalent to those in perthosite the same composition was utilized ($Or_{62.2}Ab_{37.8}$). It was difficult to assess the volume % of earthy hematite and hematite dust and even more difficult to guess at the density. Thus the Fe_2O_3 wt. percentages especially in perthosite and albitite are subject to error.

Analyses one and two are of tuffisites which I believe are typical. Tuffisites are silica poor (low silica in epidote, chlorite, sericite) alumina lime, iron and potash rich rocks (due to alkali feldspars + epidote). In some respects they can be compared to potash-unakite (analysis two) but the comparison is limited due to discrepancies in silica and iron oxide contents.

A stronger comparison of tuffisite can be made with weilbergites alkali feldspar chlorite rocks (discussed subsequently) Lehman 1952 did not give a complete analysis so some reconstruction was necessary (specifically AL_2O_3). However except for being a bit high on MgO and low on CaO they are quite comparable.

The Lake La Cloche albitite compares favourably well with albitite at Pronto Mine which the author would guess contains a bit of quartz.

Diabase is comparable to tuffisite. However it contains less alumina, ~~no~~ little potash and a reduced form of iron.

Fluidization Hydrothermalites and the Crystallization of Feldspars

1) Fluidization

The intrusion of tuffisite via a vapour phase.

Reynolds (1954) lists three characteristics of gas emplaced bodies, as follows:

1) Intense brecciation, with admixture of blocks in a central zone and non-dilational or replacement veins in the margins of the bodies.

2) Abrasion and rounding of particles.

3) A deep penetration into cracks and fissures of pre-existing spaces.

The process is called fluidization borrowed from industrial chemistry where in gas and sand systems, increase in gas velocity leads to expansion and eventually to circulation with solid particles entirely entrained and transported by gas.

A recent paper by K. Coe 1966 describes several gas emplaced bodies on the S-W coast of Ireland. They consist of breccia plugs, sills and dikes of comminuted material derived from included blocks. These "tuffisites" are interpreted as having risen into their present position by replacement of pre-existing rock by both a chemical and mechanical process motivated by a rising gas stream.

Contacts between intrusions and host rocks are commonly controlled by pre-existing structural surfaces and planes of weakness such as bedding, joints and faults. On a small scale apophyses, pods and anastomoses of intrusive tuff are common.

Zonal form is sometimes apparent with a central conduit with or without exotic breccia and an outer rim of locally derived material.

Fretting and attrition of host rocks is common.

Blocks of country rock sometimes seem to be enclosed in tuffisite but maintain their original orientation. These are most easily explained as remnants of arches or bridges of country rock connected to the wall, but made to appear detached blocks by the level of erosion.

There is no correlation between size of xenoliths and position in the intrusion. Neither is there any degree or sense of sorting.

Many of these aspects echo my description of the Lake La Cloche breccia pipe. Specifically the presence of a vapour phase during intrusion of tuffisite is evidenced by

1. liberal distribution of metasomatic alkali feldspar grains throughout quartzite breccia fragments. No such replacement feldspar was observed in quartzite outside the breccia zone.

2. in the field:

deep penetration of material into cracks and fissures of pre-existing spaces with corrosion, fretting and attrition apparent. High mobility of the transporting medium is implied.

in thin section:

"Welded qtzites" transitional zones of internally disrupted quartzite (little recrystallization apparent) with moderate amounts of hydroxyl and alkali feldspar minerals introduced (photo #12).

3. fabric relationships of microcline, perthite and albite in

tuffisite characterized by rounding, fracturing, splitting.

2) Hydrothermalites

Hydrothermalite was coined by Lehman (1952) to describe rocks where the consolidation of magma took place to a large extent in the hydrothermal stage. That such is evident in tuffisite is indicated by:

1. hydroxyl bearing minerals which make up the greater proportion of tuffisite

2. fabric and textures - earthy hematite and dust, open space veining along fractures, veins and clots of hydroxyl minerals, swirls and eddies of hydroxyl minerals in tuffisite.

The assemblage alkali feldspar - hydroxyl minerals in tuffisite is also characteristic of certain potash-unakites and weilburgites.

Potash-unakite is a Fenno-Scandian term. The following excerpt is taken from Martii Saksla's paper (kindly translated from the German by Miss MaryAnn Hinton)

"In this connection the Unakites, which have been found in three places in the field of investigation and which are to be considered as members of the late orogenic series can be mentioned. The most extensive occurence of unakite lies in the parish of Alajarvi. The rock can be called K-unakite according to the unakite classification of Asklund.

Its characteristic chief constituents are microcline, green epidote and chlorite (penninite). Albite and quartz are often present but in small quantities. In texture, the rock is porphyritic, changing in marginal parts to fine-grained varieties. The mineral constituents are generally allotriomorphic; only with the epidote and especially where it is next to quartz have idiomorphic features been observed. The epidote is zoned and is probably primary since it occurs in quite independent rather long rods, which often are arranged in radial actinomorphic groups. The feldspar grains are often somewhat crushed. The author himself agrees with the ideas of many unakite investigators such as Eskola, Laitakari, Wilkman, Asklund, and Eckerman and considers unakite originating magmatically, crystallizing out at a low temperature from the water rich portion of a magma".

There is a much stronger relationship between tuffisite (+ related red feldspar rocks) at Lake La Cloche and certain peculiar rocks known as weilburgites. These rocks possibly related to keratophyres outcrop in lenticular (fish-like) forms within the Lahn - region of Germany. They have been described by Lehman 1952.

Alkali feldspars (60-65%) and chlorite (30-35%) are the essential constituents. The chemical composition of the rock is variable. The feldspars are without exception pure alkaline feldspars but of variable composition. (albite, orthoclase, soda orthoclase and anorthoclase being represented) Albite mantles potash-soda feldspars and orthoclase zones surround the anorthoclase. In outcrop the potash generally seems to be concentrated in the outer parts of the mass. Chlorite seems to be primary, crystallizing later than the feldspars.

Lehman believes there is a close relationship between weilburgites and keratophyres (rather than diabase) based upon similar richness in alkali, a tendency to variation in the character of the alkalies, the kinds of feldspars present and the deficiency of ore minerals.

With respect to petrogenesis Lehman postulates remobilization of keratophyric magma through volatiles originating from an ascending diabasic magma (allopegmagenesis). This hybrid magma was extremely mobile and vapour rich. To quote: "An abundant vapour phase,arose accelerating the loosening and breaking off of blocks of compact rocks such as limestone and as the case may be initiating chemical and metasomatic reactions" (pg. 67)

The consolidation of the magma took place to a large extent in the hydrothermal stage. Lehman consequently describes them as hydrothermalites and concludes that they are not products of residual solutions in fractional crystallization. "Intracrustal movement is no less decisive for this genesis than purely magmatic evolution. During periods of great magmatic activity the deep crustal parts can be assumed to have been extremely sensitive to any dislocating process. This increases the probability that different magmas, or separated magmatic bodies interacted.

Points of similarity between weilbergites and alkali feldspar rich rocks at Lake La Cloche include

1. the close association of alkali feldspars with hydroxyl minerals. (Nevertheless epidote is lacking in weilbergite)

2. mutual replacement of sodic and potassic feldspars

3. the mode of emplacement

4. temperature of crystallization within the greenschist facies of metamorphism - hydrothermalites.

Lehman mentions the pneumatolytic stage that marks the end of actual igneous rock formation. In this context it will be worthwhile to discuss the textures and composition of perthosite in view of experimental work on the Na-K fedlspar - H_2O system.

3) Perthosite

The low temperature crystallization of alkali feldspars:

Tuttle and Bowen (1950) in their work on the Na-K feldspar - H_2O system remarked that somewhere below 700°C (at 4kb pressure) residual liquid in the system will pass into the vapour state with the introduction of solid vapour equilibrium. Furthermore it is such vapours and vapours boiling off at earlier stages that introduce material into surrounding rocks with resultant granitization of these rocks.

The introduction of solid-vapour equilibrium initiates the pneumatolytic stage of crystallization which is operative roughly between 600 and 400°C.

At about 400°C a liquid phase returns in the feldspar system and extensive replacement of feldspars should occur as a result of hydrothermal activity. Equilibrium is maintained between crystals, aqueous solution and aqueous gas.

With respect to replacement Wyart and Sabatier (1956, 1959, 1962) have shown that in alkali feldspars, as well as in plagioclase, alkali exchange takes place relatively easily at temperatures above 400°C and H_2O pressures of a few hundred bars.

Orville 1962 observed a very rapid interchange of alkalis between feldspar and a coexisting alkali-bearing vapour phase of different composition with respect to the Na/K ration at temperatures greater than 300°C.

It is interesting to note that replacement rims experimentally observed by Orville pictured in Figure 6 are very similar to the entire texture of perthosite.

It was noted before that microcline and albite in perthosite are present as separate phases but with extensive mutual replacement textures (no crystallographic control) apparent.

Tuttle and Bowen (1958) have emphasized that alkali feldspar components can separate especially in the present of H_2O so much that ultimately independent crystals without crystallographic intergrowth result. Two feldspars do not verify subsolvus magmatic crystallization in this case. However the crystallization was subsolvus in the sense that it took place at T<Tc of solvus. This is supported by field and thin-section evidence. There is no evidence in the mineralogy of tuffisite or in the contact features of perthosite with host rocks that temperatures were ever much above that characteristic of greenschist facies in metamorphic rocks.

Textures of perthosite seem compatible with a pneumatolytic to hydrothermal stage of crystallization. This bears directly on the crystallization of tuffisite and reinforces evidence for its submagmatic fluidized mode of emplacement.

It is interesting to note that there are textural similarities between perthosite and feldspars in fenites. Quoting Tuttle and Gittins

1966:

"The minerals of the fenites are:

Feldspars: Microcline perthite usually in large crystals rimmed by albite and surrounded by a matrix of small polygonal grains of albite and non-perthitic microcline (mortar structure). It is typically mesoperthitic with about equal amounts of potassium and sodium feldspar. In places the sodium component increases and albite antiperthite dominates the rock".

Alkalic provinces and the N shore of Lake Huron:

According to Heinrich red feldspar rocks (especially potash-rich) are usually associated with alkalic rock provinces. Such an alkaline rock province has been postulated by Doig, Gittins and others to extend along the North Shore of Lake Huron. It is defined by:

1. structural setting - a rift system extending from central Canada to eastern Sweden

2. petrologic character - intrusive alkaline rocks including carbonatities, syenites, mica pyroxenites, lamprophyres, alnoites, and some gabbroic, granitic rocks

3. age groupings.

Alkaline igneous activity in the region generally north of Lake Huron has been exemplified in the literature by the following locales and rock types: (taken largely from Tuttle and Gittins 1966) Various occurrences are plotted in Figure 7.

Lake Nipissing:

Calander Bay-nepheline syenite on shore as ring dikes. No carbonatite

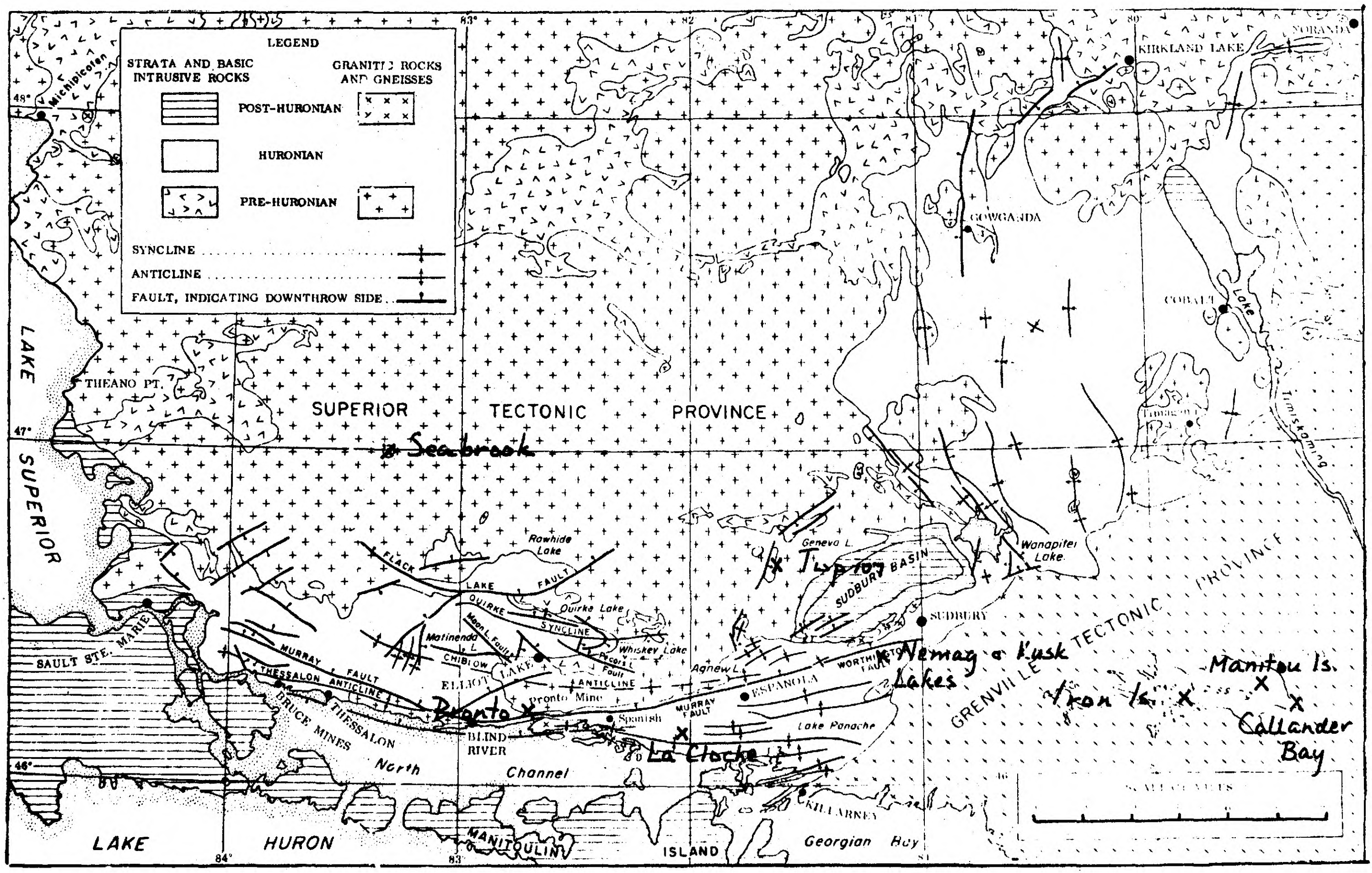


FIG. 7 DISTRIBUTION OF ALKALIC IGNEOUS INTRUSIONS. PRONTO MINE (ALBITITE ALNOITIC LAMPROPHYRE) AND LAKE LA CLOCHE (ALBITITE PERTHOSITE TUFFISITE) ALSO INCLUDED

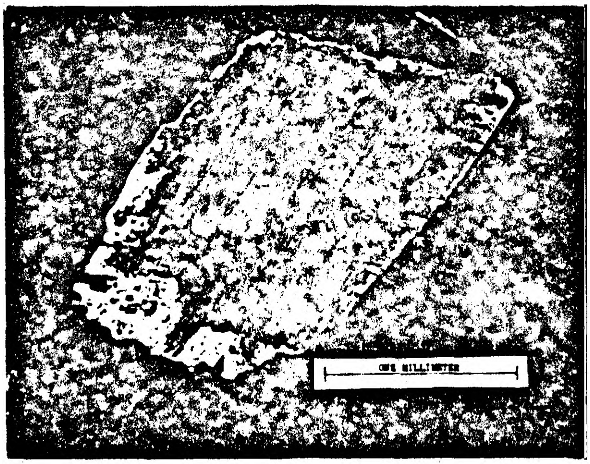


FIG 6 ORVILLE 1962 THIN SECTION PHOTOMICROGRAPH OF MICROCLINE RIMMED BY CRYSTALLOGRAPHICALLY CONTINUOUS Na-RICH FELDSPAR

exposed.

Maniton Islands - from rim to centre of the complex

a) potash feldspar - soda pyroxene-quartz rocks

b) potash feldspar - soda pyroxene rocks and minor carbonatite

c) the core-altered pegmatitic soda pyroxene syenite.

Dikes of lamprophyre and feldspar porphyry occur in the outer parts.

Twp. 107:

Carbonate rock and nepheline syenite are present in a ring structure.

Seabrook:

A circular intrusion. General sequence from rim to core as follows:

a) fenite in granitic rocks

b) ijolite, pyroxenite, breccia

c) mafic breccia (carbonate, biotite, pyroxene)

d) carbonatite-sovite (with pyroxene, amphibole and magnetite, pyrochlore accessory).

Nemag and K$\overset{u}{a}$sk Lakes: (Siemiatkowska 1971)

These are fenite breccias within three miles of each other. They are the closest known occurrence of alkalic activity to the authors's thesis area.

Blue sodic amphibole as an incipient alteration of Mississagi quartzite fills cracks and joint planes at the borders of these irregularly shaped bodies. Where alteration is intense sodic pyroxenes (aegirine-augiteaegirine) form veins which replace or crosscut quartzite fragments and earlier sodic amphibole veins. In the Nemag Lake body coarse albitic veins containing niobium bearing rutile cut across a quartzite breccia and its matrix of aegirine. Several episodes of brecciation have been recognized. The youngest can be atrributed to late shearing. Both breccias are composed of fragments of sodic pyroxene, albitic feldspar and altered quartzite.

Many authors have noted occurrences of alnoitic and lamprophyric (biotite-carbonate rich) dikes in the north shore region. Most have been tentatively interpreted as representing end stage fluids (femic differentiate associated with the Nipissing diabase. Age dates by Van Schmus (1530 m. yrs.) 1965, p. 768 and Lowden et. al. (1395 m. yrs.) 1963, p. 86-87 however give ages much younger than those associated with Nipissing diabase (avg. 2160) and they may be more closely related to alkaline igneous activity.

Red Feldspar Rocks

Heinrich and Moore (1970) classify the occurrences of red feldspar rocks into the following main types:

1. units within alkalic - carbonatitic complexes
2. wall rock replacements adjacent to alkalic carbonatitic complexes
3. Breccia pipes and vent breccias in or near alkalic-carbonatitic complexes
4. Dikes and rheomorphic dikes (trachytic textures) in or near complexes
5. Replacement veins along fractures, faults or lineaments in alkalic provinces
6. Fracture-controlled replacement veins in districts devoid of any other manifestations of alkalic igneous activity.

The rocks are commonly red, owing to abundant minutely disseminated hematite, show a variety of textures depending on the degree of replacement of the original rock (e.g. Wet Mtns Colorado - gneissic to massive aphanitic to trachytoid).

The feldspars (either orthoclase or microcline) are turbid (owing to dusty hematite, rarely show gridion twinning and may have relicit cores of clear, older feldspar. X-ray determinations of their sodium contents indicate that they contain usually less than 5 mole percent albite. Structural state studies show that they are near maximum microclines with a usual range for $\Delta = 0.65 - 0.92$. Further evidence of their low temperature genetic environment is advanced by the co-present of chalcedony, opal and Schachbrett albite, and associated fluorite, barite and quartz crystals.

Some feldspar rock contains hematitic albite. In the Wet mountains of Colorado albite (nearly pure, low K_2O , CaO) increases in amount in veins with increasing distance from the center of the carbonatite district.

An idealized sequence wall to center of a composite rock carbonatite vein consists of fenite, albite, microcline, carbonatite.

Trachyte dikes consist chiefly of microcline ± sodic plagioclase. There are no field relations here that even suggest a gradation from metasomatic microcline rock to trachyte. No significant carbonatite occurs within the dikes.

"The rocks were formed by potash metasomatism, and are replacements of or variants of fenites, representing a relatively high level of alteration associated especially with complexes displaying sub-volcanic or hypabyssal characteristics"(Heinrich and Moore)

Alkali feldspar rocks (albitite, perthosite) at Lake La Cloche display some similarities to red feldspar rocks associated with alkalic rock provinces. These similarities include:

1. abundant disseminated hematite dust
2. near maximum microcline
3. purity of albite (low CaO, K_2O)
4. a low temperature genetic environment postulated
5. close association with a breccia pipe
6. metasomatic to intrusive character

7. emplacement in fracture zones

8. texture of perthosite similar to that of feldspars in fenite.

Contrary evidence includes lack of alkalic pyroxenes and amphiboles usually associated with fenitization. Most red feldspar rocks associated with carbonatites are potash rich; albite and albitic rocks typically minor.

Occurrences of red feldspar rocks in the North Shore of Lake Huron region are largely restricted to albitites associated with diabase bodies. S. M. Roscoe (1968) has synthesized much of the available field data":

"Piennar (1963, p. 39) described a zone four feet thick south of Stinson Lake, wherein subarkose near diabase has been altered to a rock composed of 60 per cent fresh albite with quartz and antiperthite. Red altered zones noted in subarkose adjacent to diabase intrusives at Whiskey, Pecors and Quirke Lakes, and many other places, are probably similar to the Stinson Lake occurrence".

Albitite veinlets along fractures and joints in subarkose may extend appreciable distances from diabase intrusives. In places for example at Met Lake albitized subarkose may be remote from any exposed diabase contact.

In the Algom Nordic mine and the Dennison mine, a number of altered zones have been found immediately adjacent to east-west trending steeply dipping diabase dikes; chloritization is dominant. The most extensive albitized zones in the area are in the deeper levels of the Pronto mine, where the alteration bears no obvious relationship to diabase dikes but does seem to be related to fractured zones. In the Can Met mine, an appreciable proportion of the ore zone has been chloritized, albitized and carbonatized.

The pattern and character of the alteration is complex, much of it is along faults and fractures a considerable distance from any intrusive rocks.

The commonly accepted views of many ODM authors for e.g. (Robertson, 1962, 63, 70) as to the origin of these albitites echoes Harkeris (1939) comments on albitization and adinolization (the albitization of argillaceous sediments adjacent to certain basic intrusions) as follows:

"The igneous rocks responsible for this transformation are themselves rich in soda, and are generally interpreted as normal diabases which after their first consolidation have been albitized by the action of juvenile liquid carrying sodic compounds. The same liquid solutions have invaded the adjacent rocks for a few feet from the contact, not merely along fissures but by intimate permeation and have there brought about metasomatic changes of a radical kind".

The Lake La Cloche albitite is similar in aspect to other albitites in the North Shore of Lake Huron region. Similar aspects include:

1. spatial association with diabases
2. metasomatic and intrusive character
3. suggestions of a hydrothermal source and a low temperature environment
4. hematite dust, specccularite
5. Fracture controlled emplacement
6. Chloritization

2, 3, 4, 5 also characterize red feldspar rocks found within alkalic provinces.

Synthesis

Several lines of evidence suggest a common source for albitite, perthosite and tuffisite. These lines of evidence are

1. grains of microcline, perthite, albite in tuffisite are replicas of phenoclasts within one textural variety of perthosite,
2. all rock types are restricted to brecciated zones,
3. all rock types bear a similar spatial relationship to meta-diabase (or is this coincidental with emplacement along a tensile zone?),
4. each rock type consists of an alkali feldspar or feldspars + hydroxyl minerals + hematite,
5. fabric similarities of one textured variety of perthosite and a corresponding tuffisite,
6. suggested modal range of tuffisite from pure hydroxyl silicate mineral assemblage to alkali feldspar rich (perthosite).

If the association is valid, evocation of some fractionation process seems necessary to explain variations in the mineral assemblages and chemical composition.

It is apparent that tuffisite is closely related to perthosite. Weilbergites exhibit segregation of sodic and potassic alkali feldspar phases. Mutual replacement textures are reminiscent of perthosite. Was fractionation occurring during emplacemnt? Did it occur in an alkali-feldspar rich proto-"magma" at Lake La Cloche?

Is perthosite a differentiation product of this proto-"magma" or is it allochthonous, a contaminant and tuffisite a hybrid rock. In both cases the following comparison to crystal tuffs is appropriate:

Crystallized grains of alkali feldspars were carried (and abraded) by a vapour rich medium. Previously crystallized fragments of rock were also transported (phenoclast poor perthosite). Some of the transported material had not as yet consolidated (patchy perthosite). See photo 14.

The first alternative suggests that tuffisite carried fragments of its own fractionates. Two considerations support the postulate that the alkali feldspars are primary:

1. Individual grains of alkali feldspar overwhelmingly predominate fragments of perthosite. If the phenoclasts are allochthonous why has the interlocking matrix been preferentially absorbed?

2. The introduction of alkali feldspar grains into the host rock and into the transitional zones between tuffisite and host could not have been mechanical.

Perthosite within the brittle flexure zone by this interpretation bears mineralogical traces of its parentage (minor chlorite and hematite, traces of epidote). The mineralogy of tuffisite approaches that of its differentiate perthosite in certain thin sections.

Albitite and massive speccularite are also products of fractionation - juvenile liquids originating from proto-tuffisite.

Nearly pure alkali feldspar rocks were emplaced along a fracture zone at the top of the Mississagi shortly before the emplacement of tuffisite in an irregular breccia pipe towards the north.

The author suggests (and throws open to discussion and evaluation) that a deeper (higher temperature) expression of such a relationship of alkali feldspar rich rocks as found at Lake La Cloche might comprise a fenite breccia pipe perhaps similar to the one at Nermag and Kusk Lakes and associated red feldspar rocks in adjacent fracture zones. Obviously this means total alteration and destruction of alkalic pyroxenes and amphiboles characterizing fenites. However red rock metasomatism as characterized in fenitization is present and textures of feldspars in fenites is quite comparable to that of perthosite (even though the feldspars are higher temperatures forms).

Alternative two considers the alkali feldspars in tuffisite as allochthonous. Evidence supporting this view is as follows:

1. Inhomogenous distribution of the feldspars in tuffisite (see photo 22). In some cases tuffisite is feldspar free.

2. The bulk composition of typical tuffisite to the author's knowledge does not relate to any standard rock type. However it can be explained as a mixture. Oxidize FeO to Fe_2O_3, add K_2O, a bit of alumina and diabase can be converted chemically to tuffisite.

Alternative two suggests that alkali feldspar rich material perhaps within the pneumatolytic stage of crystallization became contaminated in part by mafic material (possibly diabase) and rose as a vapor rich slurry carrying feldspar grains and perthosite fragments. Perthosite was in the process of intimate breakage, abrasion within the rising gas stream. Metasomatism of the host rock by vapors resulted in replacement of quartz by alkali feldspars.

In conclusion more work would have to be done in determing which alternative is valid and what the exact relationships of albitite, perthosite, tuffisite are.

References - Cited

1. Bowen, N.L. and Tuttle, O.F., 1950. The System $NaAlSi_3O_8$-$KAlSi_3O_8$-H_2O. J. Geol., 58: 489-511.
2. Card, K.D., 1965. Hyman and Drury Twp.'s Geol. Rpt., No. 34. Ontario Department of Mines.
3. Chandler, F.W., 1968. Ph.D. Thesis, University of Western Ontario.
4. Cloos, H., 1941. Ban and Tatigkeit von Tuffschloten. Untersuchungen an dem Schwabischen Vulkan. Geol. Rdsch. 32, 709-800.
5. Coe, K., 1966. Intrusive Tuffs of West Cork, Ireland. Quarterly Journal, Geological Society of London, V. 122, 1-23.
6. Doig, 1970. An Alkaline Rock Province Linking Europe and North America. Can. Journal of Earth Sciences, V. 47, No. 1, 22-28.
7. Ginn, R.M., 1961. Geology of Porter Township. Geol. report, No. 5, Ontario Department of Mines.
8. Gittins, J. et al, 1967. Carbonatite Complexes in Eastern Ontario. Can. Journal of Earth Sciences, V. 4, pp. 651-655.
9. Harker, A., 1939. Metamorphism. Methuen and Co. Ltd., London.
10. Heinrich & Moore, 1970. Metasomatic Potash Feldspar Rocks associated with Igneous Alkalic Complexes. [in Alkaline Rocks, the Monteregian Hills, edited by Guy Perrault, Mineralogical Association of Canada], p. 571-583.
11. Joplin, Germaine A., 1964. A Petrography of Australian Igneous Rocks. Angus & Robertson Ltd., Sydney, London & Melbourne.
12. Lehman, 1952. The Significance of the Hydrothermal Stage in the

Formation of Igneous Rocks. Geol. Mag., 89, pp. 61-69.

13. Lowdon, J.A., Stockwell, C.H., Tipper, H.W. and Wanless, R.K., 1963. Age Determinations and Geological Studies (including isotopic ages - Report 3). Geol. Survey of Canada, Paper 62-17, 140 p.

14. Orville, P.M., 1960. Alkali Feldspar - Alkali Chloride Hydrothermal Ion Exchange. Ann. Rept. Geophys. Lab., 1159-60, p. 104-108.

15. Orville, P.M., 1962. Alkali Metasomatism and Feldspars. Norsk Geologisk Tidskrift, Vol. 42, 283-316.

16. Park & MacDiarmid, 1970. Ore Deposits. Freeman & Co., San Francisco.

17. Reynolds, Doris L., 1954. Fluidization as a Geological Process, and its Bearing on the Problem of Intrusive Graintes. Journal of Science V. 252, 577-613.

18. Robertson, James A., 1962. Geology of Townships 137 and 138. Geol. Rept. No. 10. Ontario Department of Mines.

19. Robertson, J.A., 1963. Iron Bridge Area. Geol. Rept. No. 76, O.D.M.

20. Robertson, J.A., 1970. Spragge Area. Geol. Rept. No. 76, O.D.M.

21. Roscoe, S.[illegible]., 1968. Huronian Rocks and Uraniferous Conglomerates in the Canadian Shield. 6.S.C. paper, 68-40, pg. 96-97 esp.

22. Saksela, Martin, 1935. Uber den geologischen Bau Sud-Ostbothniens. Bulletin de la Commission Geologique de Finlande, No. 110.

23. Siemiatkowska, 1971. Fenite Breccias in the Sudbury Area. Abstract from Geological Assoc. of Canada, Mineralogical Assoc. of Canada joint annual meeting.

24. Thomson, Jas. E., 1952. Geology of Baldwin Twp. Sisty-First Annual Report of the Ontario Department of Mines, Vol. LXI, Part 4.

25. Tuttle, O.F., and Bowen, N.L., 1958. Origin of Granite in the Light of Experimental Studies in the System $NaALSi_3O_8$ - $KALSi_3O_8$ - H_2O. Geol. Soc. Am. Mem., 74, 1-153.

26. Tuttle, O.F. and Gittins, J. (editors), 1966. Carbonatites. Interscience Publishers (John Wiley & Sons), New York, London, Sidney.

27. Van Schmus, W.R., 1965. The Geochronology of the Blind River - Bruce Mines Area, Ontario, Canada. Jour. Geol., Vol. 73, No. 5, pp. 755-780.

28. Wyart, J. et Sabatier G.,1959. Nouvelles Observations sur la Mobilite des Ions Silicium et Aluminium dans les Cristaux de Feldspath. Bull. Soc. France. Mineral Crist 82:216.

29. Wyart & Sabatier, 1961. Echange des Atomes dans les Feldspaths. Action d'eau. Cursillos Conf. Inst. "Lucas Mulluda" 8:23-26.

30. Wyart, J. & Sabatier, G., 1962. L'equilibre des Feldspath et des Feldspathoides en Presence de Solutions Sodi-Potassiques. Norsk Geol. Tidsskr, 42:317-329.

Appendix

MINERAL COMPOSITIONS

1	2	3	COMPONENT
36·52	25·62	4587	SiO_2
	0·88		TiO
20·97	21·19	38·69	AL_2O_3
17·22	3·88		Fe_2O_3
0·45	21·55		FeO
	0·35		MnO
	15·28	0·10	MgO
23·05	0·16		CaO
		0·64	Na_2O
		10·08	K_2O
			P_2O_5
1·98	11·06	4·67	H_2O
100·19	99·99	99·95	TOTAL

1 EPIDOTE VEIN IN DIABASE WESTFIELD MASSACHUSETTS (PALACHE 1936) ANAL F.A. GONYER P 199 VOL. 1 DEER HOWIE & ZUSSMAN

2 CHLORITE CHLORITE EPIDOTE-ALBITE SCHIST LIMEBURY PT SADCOMBE ESTUARY SOUTH DEVON (TILLEY 1938) ANAL H.C.G VINCENT P141 VOL 3 D.H&Z.

3 MUSCOVITE CLEAR FLAWLESS CRYSTAL METHUEN TWP ONTARIO (HURLBUT 1956) ANAL. F.A. GONYER P16 VOL 3 D.H&Z