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SPODUMENE-BEARING PEGMATITE FROM THE EASTMAIN RIVER AREA

SPODUMENE-BEARING PEGMATITE FROM THE EASTMAIN RIVER AREA, QUEBEC.

By

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A thesis submitted to the Faculty of Science in partial fulfilment of the requirements for the degree of Bachelor of Science (Honours).

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OTTAWA, ONTARIO
MARCH 15, 1976

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ABSTRACT

Regional mapping was done along the Matagami-LG2 road around the Eastmain River at an approximate scale of 1:31,280. The mapping shows effectively a N-S cross-section of the Eastmain River Greenstone Belt. The rock units consist of biotite gneiss, biotite schist, conglomerate, metavolcanic rocks, batholithic granite and gabbro dikes. Most of the units are steeply dipping and show an E-W trend except for the gabbro dikes which are of variable orientation.

Spodumene-bearing pegmatite dikes have been found at the biotite schist-metavolcanic contact. Dikes known as the Cyr outcrops have been mapped in detail. Other dikes lying to the west are westerly dipping, cross-cut the local foliation and show a curvature implying a possible source to the WSW where the major portion of the batholith lies. The latter is quite similar mineralogically to the dikes but lacks spodumene.

Whole rock analyses were done by the Centre de Recherche Minerales du Quebec (CRMQ) on samples from the Cyr outcrops and the results show a 1.70 wt% Li_2O content. Microprobe analysis of spodumene suggests the composition $(Li_{.99}Na_{.01})AlSi_2O_6$.

Acknowledgements

Thanks are due to Yves Pelletier and the Societe de Developement de la Baie James who kindly released field data, samples and analytical results, to Dr. D. Watkinson for guidance during the course of this study and to Paul Mainwaring for invaluable assistance as well as the microprobe analyses.

INTRODUCTION

The Eastmain and Opinaca River area had been previously mapped by Eade in 1957 and 1959 at a scale of 1:1,000,000. Prospecting by Jean Cyr in the early 1960's resulted in the discovery of spodumene-bearing pegmatite dikes in Quebec township 2312. The recent construction of the Matagami-LG2 road provided easy access to the property and detailed mapping and sampling were undertaken in the summers of 1974-75 by the Societe de Developement de la Baie James (SDBJ) to determine its economic significance. Regional mapping by the author was done on a scale of 1:31,280 along the road in June and July of 1975, covering approximately 90 square km. around the pegmatite dikes. The mapping and subsequent petrographic study of the rocks form the basis for a genetic interpretation of these spodumene-bearing dikes.

METHOD OF MAPPING

Detailed mapping of the Cyr pegmatite outcrops was done by Yves Pelletier, assisted by the author, in August, 1974. The mapping and sampling were done using a grid system over a 3 week period, at the end of which a fast regional survey was done by helicopter. A larger series of spodumene-bearing pegmatite outcrops were observed 2 km. to the west. In June, 1975, a regional airphoto (1:31,280) reconaissance was undertaken by the author which lasted approximately 6 weeks. The airphotos of the region were studied prior to the actual field work, during the course of the field work as the field information accumulated as well as during the compilation of the regional map.

LOCATION

The regional map area is shown in Figure 1 and is contained within the geological map of Eade (1966) and on National Topographic Survey (NTS) map 33 c/3 and 33 c/6.

REGIONAL GEOLOGY

The southern part of the regional map area was mapped by Shaw (1942) as undifferentiated granite, granitic gneiss, paragneiss and schist. Eade (1966) mapped the Eastmain River Greenstone Belt on a 1:1,000,000 scale. He described the volcanic rocks as andesite with well developed pillow structures in some localities, dacite, rhyolite, tuff and their metamorphic equivalents and schists. The sediments include conglomerate, quartzite and metagreywacke, and paragneiss or schist derived from them, mostly of quartz, plagioclase, biotite composition.

Highly deformed biotite gneiss is found at the southern edge of the regional map. The contact between this rock and the granitic batholith to the north is covered by overburden. This batholith is believed to extend west, close to the shore of James Bay (Ferpaz, personal communication); the eastward

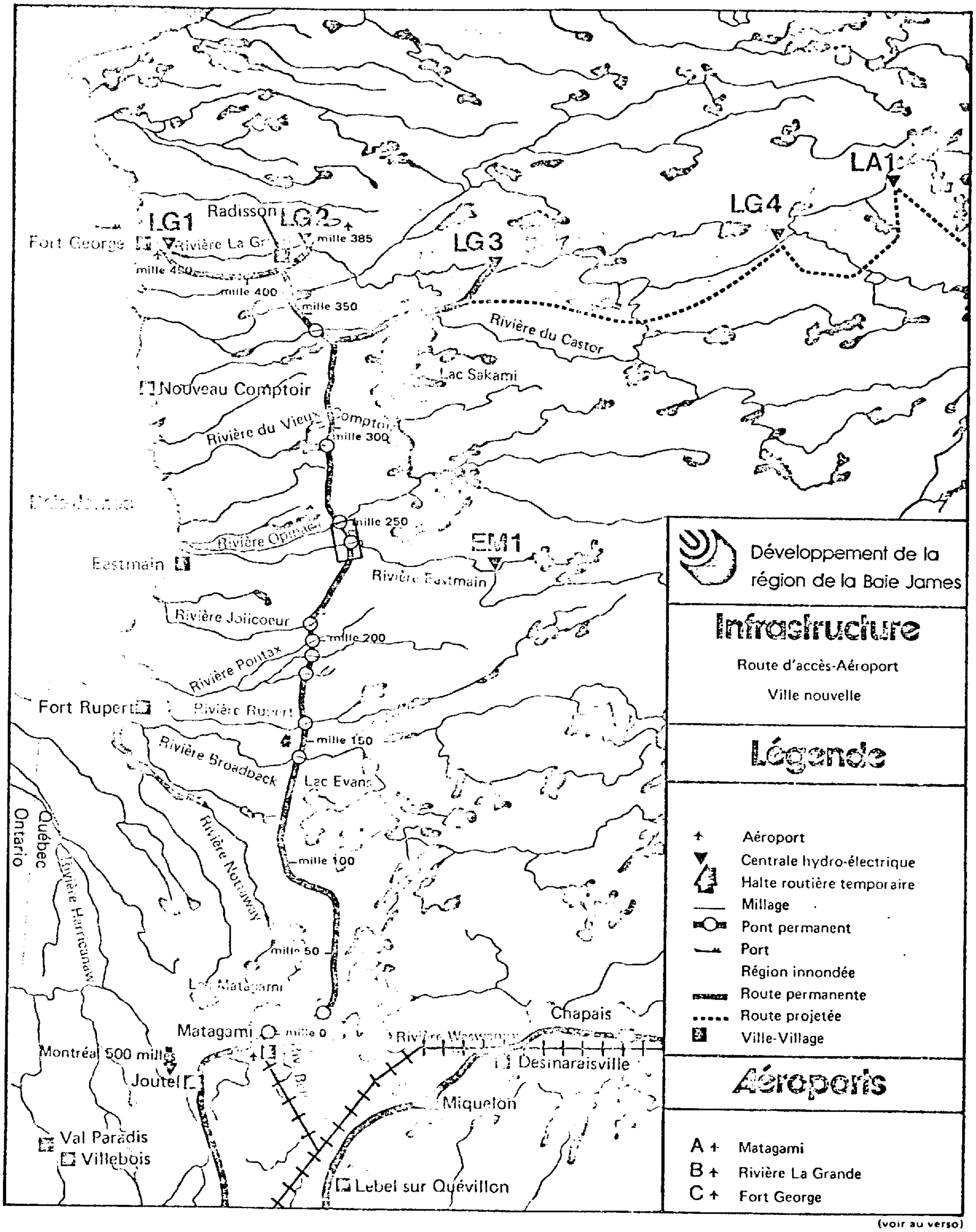


Figure 1 Location of the regional map

extension is unknown at the present time. Similar rocks mapped over roughly 8 km. in the Eastmain River greenstone Belt are believed to form a single magmatic complex. The batholith can be observed on the regional map to intrude east-west trending metasediments.

The Cyr pegmatite is exposed in a 1.4 km. long series of outcrops about 4 km. north-east of the batholith. It is found at or very close to the contact of metasedimentary and metabasaltic rocks.

A thick metabasalt is observed north of the pegmatite body which is followed by metaconglomerate grading into metagreywacke. Another thick section of metabasalt, commonly pillowed, lies between the metaconglomerate and another metaconglomerate observed in Conglomerate Gorge on the Eastmain River. The pillow tops are generally to the NNW. There is an iron-rich, pillowed metavolcanic band 2 km. south of the Eastmain River on the road.

Many rocks of probable sedimentary origin were observed on the north side of the river. More granite occurs near the Opinaca River, but on a much smaller scale than the batholith to the south.

Throughout the map area steeply dipping gabbro dikes up to 10 meters wide cross-cut all the rock units observed.

Biotite gneiss and schist

Biotite gneiss seems to be the oldest rock because it shows many phases of deformation on a miniature to relatively large scale. The gneiss is bordered and cut by dikes of much less deformed gneissic granite.

Remnants of the original lithology can be still observed in the biotite schist. It dips steeply both to the south and north.

The contact between the biotite schist and the granitic rocks is generally sharp (Plate 1). Locally it is characterized by granitic dikes projecting a few tens of meters into the biotite schist. The contact often sharply truncates the schist without development of additional foliation in either rock. The schist is grey to buff coloured on the weathered surface and grey to black on fresh surface.

Metasedimentary Rocks

The conglomerate usually appears as bands a few tens of meters wide. In the metaconglomerates, pebbles range in size from a few millimeters to many centimeters. Most pebbles are flattened and aligned. Fine-grained (0.1-0.5 mm.) to medium-grained (1-3mm) black amphibolite pebbles contain up to 5% almandine garnet and up to 3% pyrite. Very fine-grained dacitic or rhyolitic pebbles are also observed. Grey diorite pebbles (hornblende, biotite, garnet) are fine to medium-grained and are usually foliated. Other pebbles are schist, and quartzite. The matrix is often hard to define; when observed it has an aphanitic texture and is usually black.

Metavolcanic Rocks

Most of the metavolcanic rocks are basic, equivalent to andesite or basalt in composition. In the band of metavolcanic rocks just south of the Eastmain River, deformed pillows are visible in a fine-grained amygdaloidal andesite. These rocks are generally fine-grained, medium to dark green on fresh surfaces, medium to pale green on weathered surfaces.

Pegmatite

Pegmatitic rocks are abundant, both in the granite batholith and in nearby schist. They commonly occur with aplites, showing gradational contacts in the batholithic rocks. The aplite usually consists of quartz and two feldspars with minor

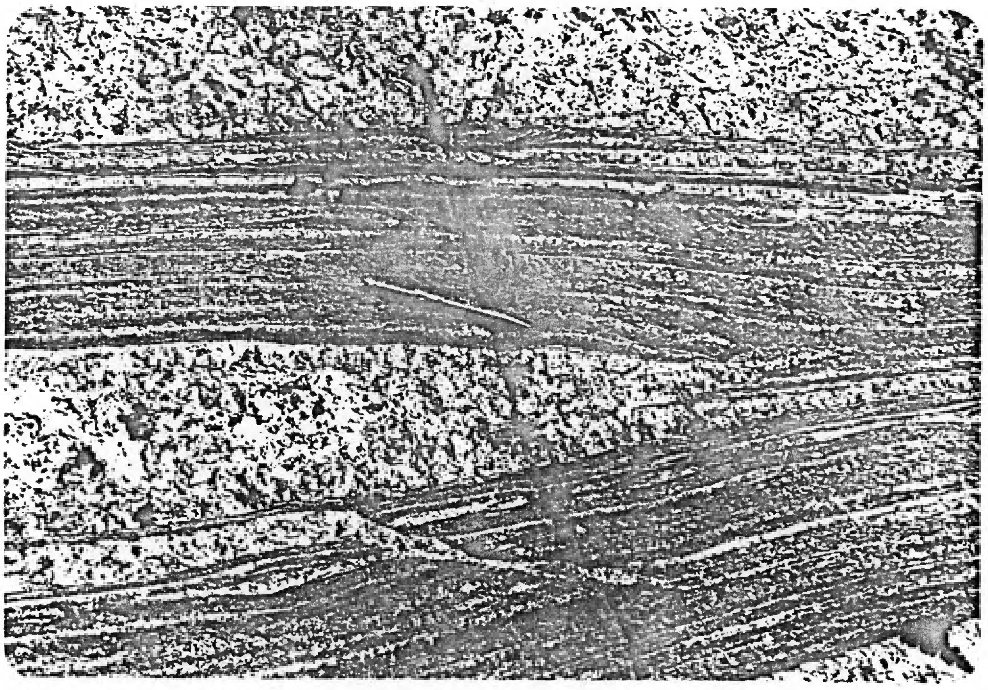


PLATE 1 Biotite Schist-Granite Contacts

muscovite and occasionally biotite, tourmaline, garnet and rarely beryl. Most of the pegmatite is similar in composition to aplite, but the one of economic interest contains spodumene and lacks garnet.

Dikes

Contacts of the gabbro dikes with the adjacent rocks are clear and sharp and the dikes have aphanitic chilled borders. The country rocks normally show no obvious contact metamorphic effects. Jointing in the dikes is usually perpendicular to the walls. The brown weathering surface has a hackly appearance resulting from the differential weathering of mafic constituents. The gabbro dikes with diabasic texture in part are considered to be Proterozoic (Eade, 1966).

Metamorphism

The metabasalt and metasedimentary rocks of the greenstone belt in a metamorphic aureole around the batholith and the Cyr pegmatite are characterized by the presence of andalusite and is therefore a contact metamorphism (hornfels facies). The regional grade of metamorphism lies in the lower amphibolite facies (Eade, 1966).

Radioactivity

None of the rock units show more radioactivity than a background value of 50 cps.

Age

The relative age of the rock units is shown on Table I.

TABLE I Relative Age of the Rock Units

YOUNGEST	gabbro-diabase
	spodumene-bearing pegmatite
	granitic batholith
	metavolcanic rocks
	metaconglomerates
	biotite schist
OLDEST	gneiss

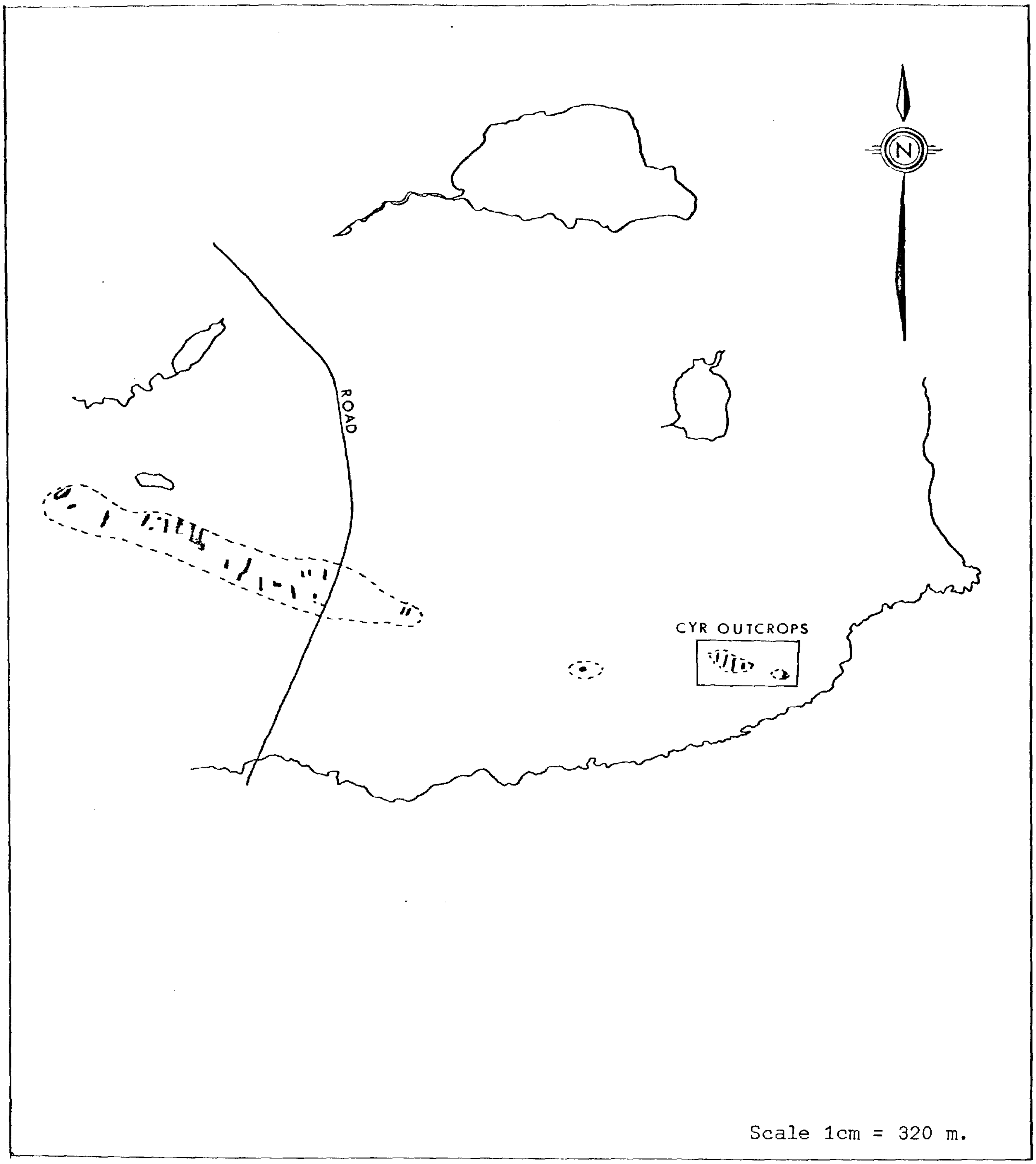


Figure 2 Location of the pegmatite dikes

Cyr Spodumene Pegmatite

Location and Access

The pegmatite outcrops as a dozen dikes that occur near kilometer 384 (mile 239) on the road from Matagami to LG2 (Fig. 1). These outcrops are located in township 2312, within National Topographic Survey (NTS) map 33 c/3. The detailed map only describes the most easterly dikes of the series called the Cyr pegmatite. This specific area is enclosed by a square in Fig. 2. The detailed map is included in the map pocket.

General Features And Geological Setting

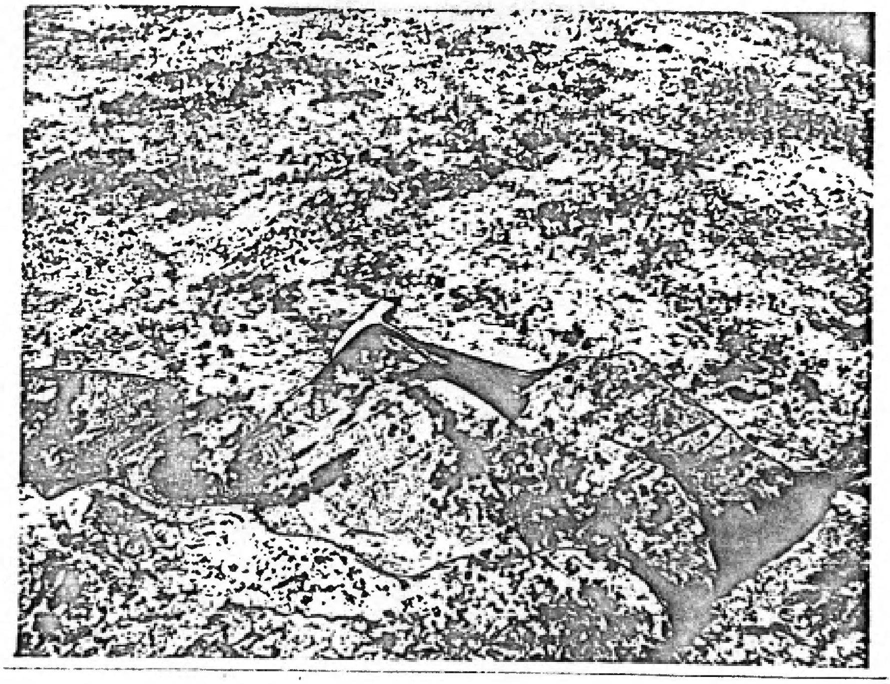
The spodumene-bearing pegmatite lies within the Eastmain River Greenstone Belt. The pegmatite dikes intrude biotite schist of probable sedimentary origin near and at its northerly contact with basic metavolcanics.

The outcrops form a 3 kilometer long discontinuous ridge (Fig. 2) closely parallel to the regional foliation of approximately 100°. The ridge shows a relief of up to 35 meters relative to the neighbouring muskeg.

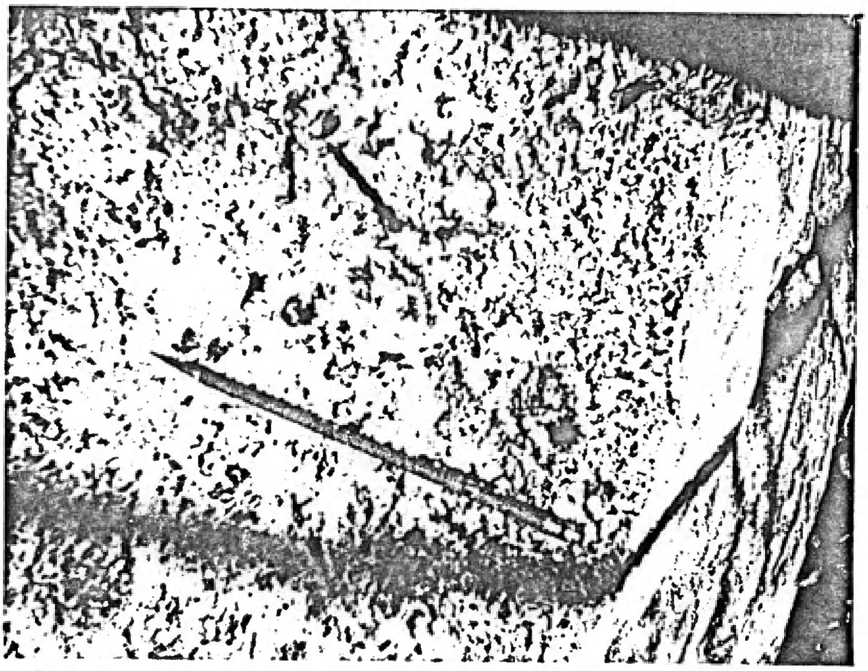
The pegmatite dikes are associated spatially and probably genetically with the granitic batholith to the south-west. In this case they can be described as an exterior pegmatite relative to the batholith.

Internal Features

The pegmatite bodies are lenticular, occasionally forming complicated patterns where mutually interconnected and attain widths of 60 meters and lengths of over 100 meters. Sharp contacts with the metasediments and metavolcanics are characteristic. The pegmatite bodies cross-cut the steeply dipping E-W trending local and regional structures.



A) Xenolith in a Pegmatite Dike



B) Wall Zone of a Pegmatite Dike

PLATE 2

Spodumene crystals are found uniformly distributed from wall to wall. No obvious mineral zoning in the pegmatite was observed except for narrow discontinuous border and wall zones that are muscovite-rich and spodumene-poor (Plate 2-b). Almost all of the spodumene crystals are oriented perpendicular to the dike walls. The long axes plunge between 15° and 30° East. Thus the pegmatite dikes dip 65° westerly.

Xenoliths of country rocks were found in the dikes (Plate 2-a). The inclusions are square, round, lenticular and diamond-shaped. Xenoliths in general are softer than the surrounding pegmatitic rocks and weather low. Some were originally metasediments, others, metavolcanic rocks. They invariably show sharp contacts and possess aphanitic chilled borders. Xenolith orientation relative to the country rock is variable, and apparently is post-foliation.

Spodumene crystal attitudes suggest a vague curvature in the dikes with concavity to the west which suggests intrusion into radial fractures emanating from a center to the west (Pelletier, 1975).

Mineralogy

The common rock forming minerals of this lithium pegmatite are quartz 28.0%, albite 27.7%, spodumene 23.7%, potash feldspar 14.4% and muscovite 4.29%.

Accessory minerals present are apatite, beryl, arsenopyrite, lithiophillite ($Li(Mn,Fe)PO_4$), ilmenite and tourmaline. Tourmaline is usually found in the schist near the pegmatite contact.

Within individual dikes there is some slight variation in the proportions of the 4 major minerals. In spite of some local variations, mineral proportions remain remarkably uniform from one wall to the other. There is no evidence that the present minerals were formed by replacement of earlier minerals in the dikes.

Feldspars

Feldspar as a group, is the most abundant constituent of the pegmatite. The feldspars are usually white and often show perthitic textures. Albite (An 2-5) generally fills the interstices, crystallizing in a manner similar to microcline.

Quartz

Quartz is the second most abundant constituent. It may occur in large blebs, one or more meter in diameter, irregularly scattered in the dikes. Small veins transect parts of some dikes. Quartz varies from colourless to milky white and in grain size from a few millimeters up to 10 centimeters. There is no evidence of crushing or recrystallization.

Spodumene

Spodumene is white or green and varies in length from a few millimeters to 1 meter. It is usually prismatic and crystal faces are often striated. Spodumene shows strong cleavage in 3 directions, one parallel with the elongation of the crystal, another at right angles and a third one inclined to the other two.

Some of the spodumene is highly altered in a few samples where it changes colour due to incipient replacement by sericite. As the alteration becomes more intense, some crystals develop a brown woody coating apparently due to the presence of iron oxides. Some spodumene alters to a lithium-bearing (?) mica which occurs in platy aggregates pseudomorphous after spodumene. Where the alteration is not complete, fractures in the grains may be filled with this micaceous material.

The spodumene crystals appear to have been partially resorbed and replaced by quartz at their termination during crystallization but more likely, this texture could be described as symplectitic (Plate 3).

Plate 3 Symplectitic texture of quartz and spodumene.
(Width of field is 11 millimeters)

Muscovite

About 5% muscovite is generally present in the pegmatite. It may be concentrated along the discontinuous border zone. It varies in grain size from microscopic to a few centimeters and is colourless to pale green.

Beryl

Beryl occurs in a few dikes. It is usually light blue to milky white and generally shows partly developed hexagonal crystal outline with no cleavage.

From the evidence, it would appear that the mineral assemblage crystallized directly from the melt, first the spodumene, then the feldspars followed by quartz and muscovite.

TABLE II

Quantitative Analyses

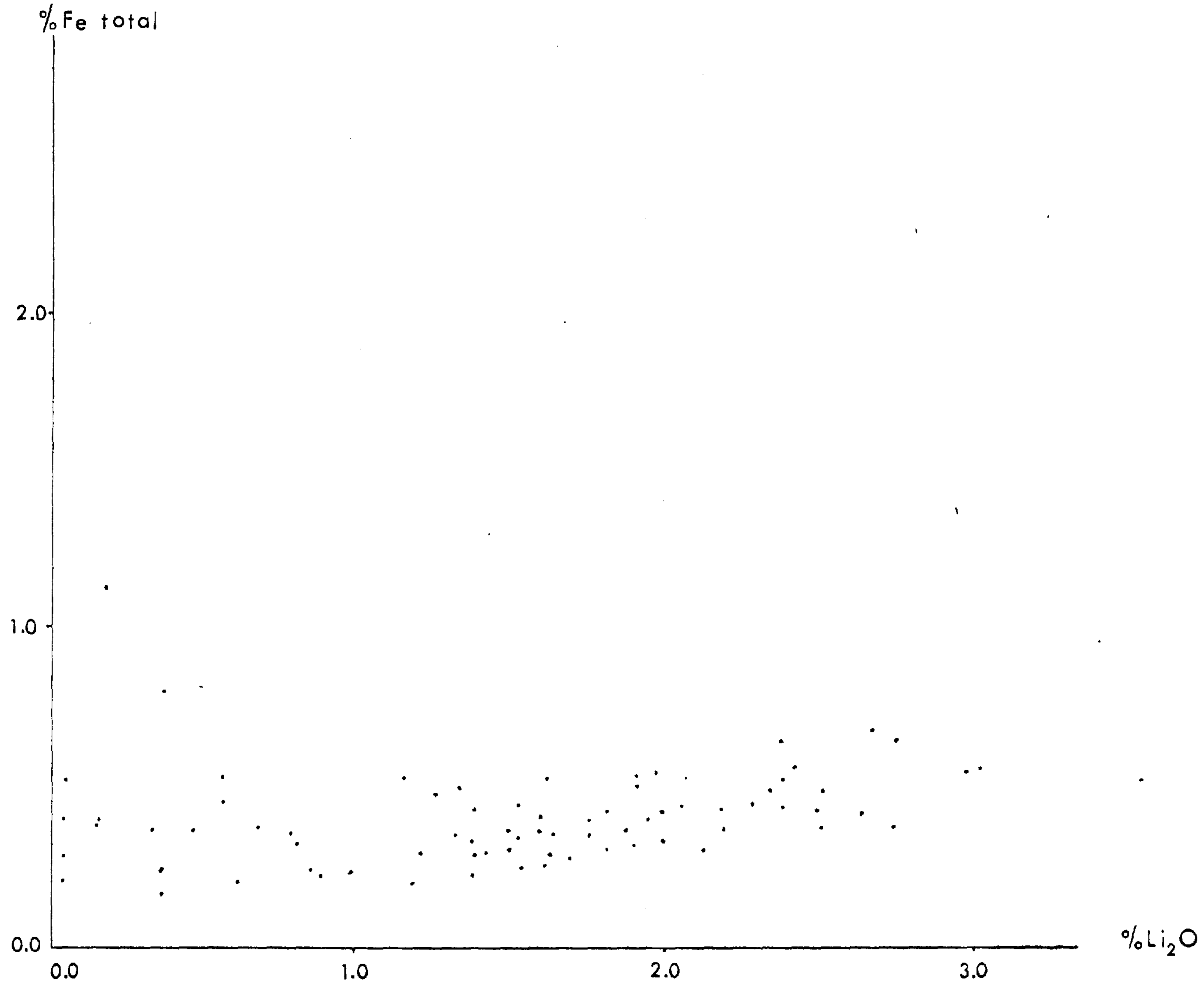
	Sample 30	Sample 79
	%	%
SiO_2	73.60	72.15
Al_2O_3	15.50	15.60
Fe_2O_3	0.26	0.16
FeO	0.10	0.19
MgO	0.04	0.05
CaO	0.22	0.25
Na_2O	3.22	3.21
K_2O	2.24	3.25
TiO_2	0.00	0.00
P_2O_5	0.17	0.15
MnO	0.04	0.04
Fe(t)	0.33	0.31
Li_2O	1.88	1.60
	ppm	ppm
Cu	50	10
Pb	22	19
Ni	24	20
Cr	460	370
Sn	25	25
Zr	22	27
Sr	110	67
Cs	100	100
Be	211	208
Ba	85	75

TABLE III

RECALCULATED CHEMICAL ANALYSIS OF A COMPOSITE SAMPLE OF PEGMATITE

FORMULA OF COMPONENT	SYMBOL	VOLUME %	
$NaAlSi_3O_8$	ab	27.70	
$KAlSi_3O_8$	or	14.40	
$CaAl_2Si_2O_8$	an	0.14	
SiO_2	qtz	28.90	
$LiAlSi_2O_6$	spod	23.70	(1.70 wt.% Li_2O
$KAl_2(AlSi_3O_{10})(OH)_2$	musc	4.29	
$Be_3Al_2(Si_6O_{18})$	be	0.40	
$Ca_5(PO_4)_3(OH)$	ap	0.32	
Fe_3O_4	mt	0.26	
Fe_2O_3	hem	0.08	
Fe	"drill rod"	0.02	

Figure 4 %Fe total VS Li_2O % in pegmatite powder samples.



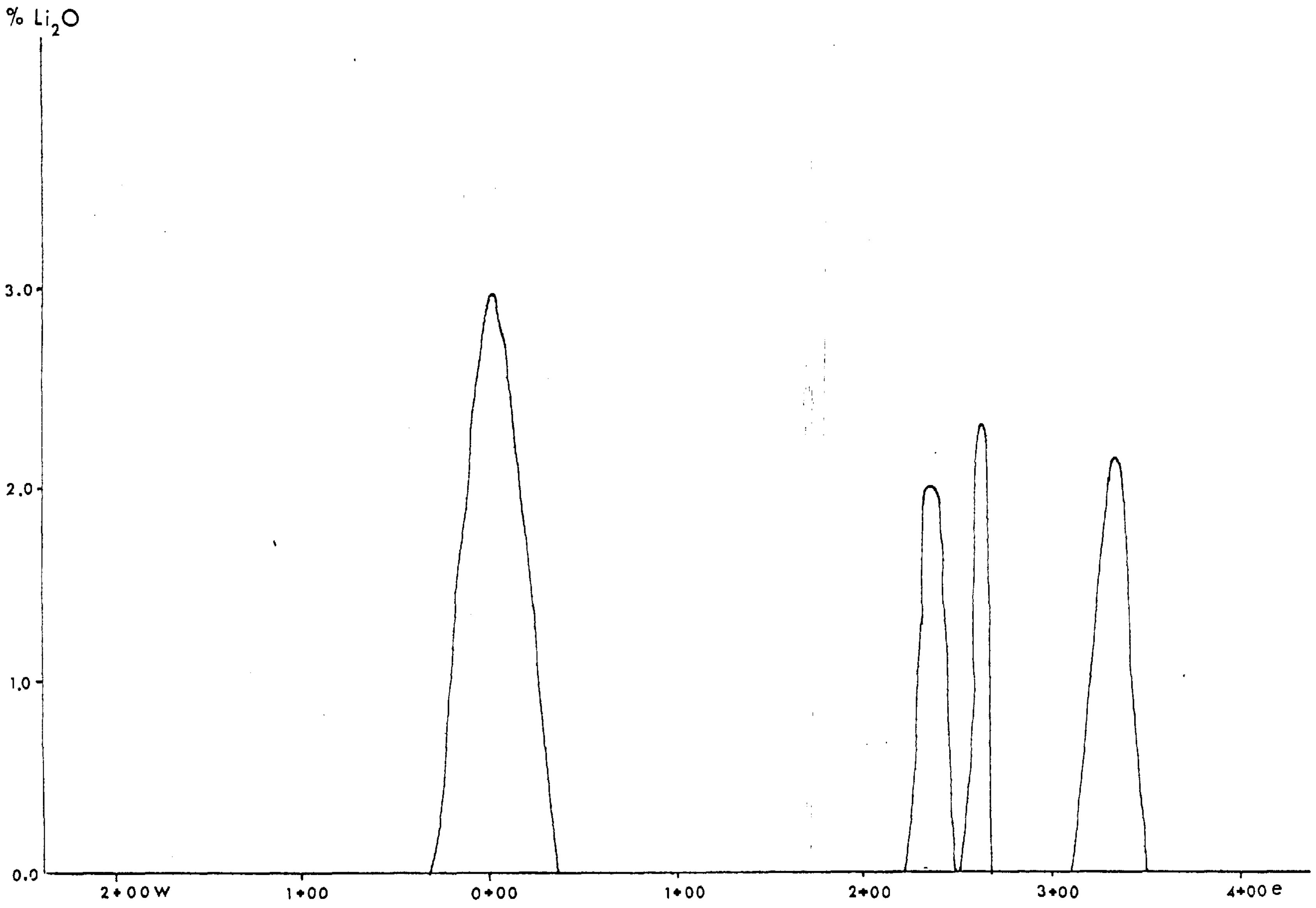

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Figure 5 Li_2O content across 4 dikes. scale 1"=100'
Sampling done every 20 ft.

Chemistry

A complete chemical analysis was performed by the Centre de Recherche Minerales du Quebec (CRMQ) on powder samples collected in 1974. The results are listed in table II. The oxide weight percentages are recalculated in table III (compounded from all the analyses) in terms of volume percentage of normative mineral components (Pelletier, 1975).

Statistical analysis is shown as a plot of Li_2O vs Fe in individual pegmatite samples and shows a positive correlation with a slope implying approximately 0.8% Fe within spodumene (Fig. 4) (Pelletier, 1975). The measured value by electron microprobe is 0.96% as Fe_2O_3. Microprobe analyses of 2 spodumene samples are compared with the one of Deer, Howie and Zussman (p. 107) in table IV. **Too** much Fe in spodumene would prevent an effective extraction of Lithium.

Li_2O content of the sample lines across the dikes analyzed have also been drawn. Some of these show a regular increase of Li_2O from the walls to the core of the dikes (Fig. 5). This observation suggests that wider dikes should show a better Li_2O grade. Such is not the case as many sample lines do not show this simple variation and a very limited geostatistical analysis by Pelletier (1975) of some outcrops indicates that samples as close as 30 centimeters apart have random Li_2O content.

Lithium is listed (Rankama and Sahama, 1950 p.42) as sixteenth in atomic abundance in igneous rocks. In ordinary igneous and metamorphic rocks the small amount of lithium contained is distributed among the ferromagnesian minerals: biotite, pyroxene and amphibole. On this basis, mafic rocks formed at relatively high temperature might be expected to contain more lithium than granitic rocks.. However, the lithium to magnesian ratio in igneous rocks shows a decided increase through the series from amphibolite-monzonite-granodiorite-granite (Siroonian et al, 1959, p.330).

This suggests that lithium enters to any appreciable extent only into those ferromagnesian minerals that are formed in the late stages of low temperature differentiation. The relative scarcity of such minerals in the late stages and the limited degree of substitution possible in them results in the formation of independent lithium minerals such as spodumene and lithiophillite, wherever the lithium concentration in the final fluid phase reaches a sufficient value. This seems to be the normal mode of occurence of lithium in granite pegmatites.

TABLE IV

Spodumene Partial Analyses by Electron Microprobe

OXIDE WT. %

	Spodumene 1	Spodumene 2	Spodumene (reference)
SiO_2	64.21	63.68	64.89
TiO_2	0.00	0.00	0.00
Al_2O_3	27.90	27.86	26.74
Fe_2O_3	1.05	0.86	0.57
MgO	0.06	0.06	0.00
CaO	0.01	0.00	0.00
NaO	0.15	0.15	0.05
K_2O	0.00	0.00	0.16
TOTAL	93.38	92.61	92.41
Lithium content found by difference			
	6.62%	7.39%	7.59%

Reference: Deer, Howie and Zussman (p.107)

Origin of the Cyr Pegmatite

The field relationships suggest that the batholith is an intrusive body that shouldered aside the Archean sedimentary and volcanic rocks. No ghost strata were found, which is compatible with a magmatic origin of the pegmatite and of the batholith.

The contacts of the batholith and the pegmatite with the surrounding rocks are almost invariably sharp. Foliation of the wall rocks has been truncated and near the contact, contain dikes of granitic and pegmatitic rocks (Plate 2). The wall rocks display a metamorphic aureole around the batholith that is characterized by the presence of andalusite and is a contact metamorphism rather than regional grade of metamorphism. These criteria suggest a sharp thermal and chemical difference between the wall rocks and the granitic rocks rather than a continuous gradation and hence intrusion of magma into solid wall rocks rather than passive granitization in situ.

Xenoliths in the pegmatite outcrops do not necessarily occur close to the wall rocks from which they were derived. They are often rotated from the wall rocks. Some xenoliths seem to have been stretched, folded and show partial digestion. These factors suggest magma in motion, transporting xenoliths from source areas and causing their deformation, local digestion and heterogeneous distribution.

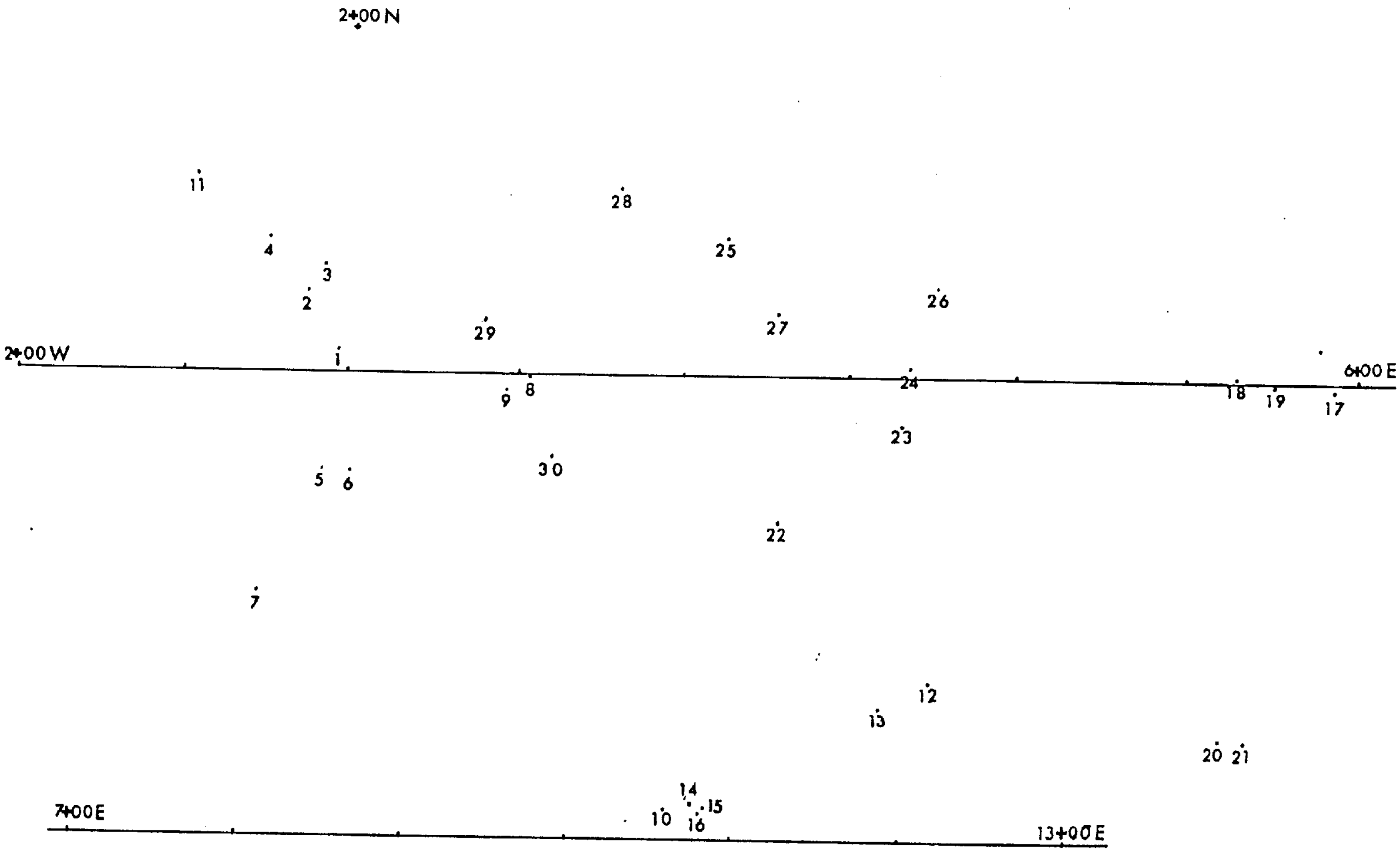
Pegmatites are commonly found as dikes cutting intrusive igneous rocks, often extending beyond the contacts into adjacent metamorphic rocks. Pegmatites also are common as pockets and stringers in metamorphic rocks far from intrusive contacts as in the case of the Cyr dikes.

The suggested hypothesis of origin of the pegmatite, based on field geology and petrography as well as geochemistry, is that spodumene pegmatite represents products of residual solutions derived from fractional crystallization of the batholithic rocks already enriched in Li. The coarse texture of pegmatites has commonly been ascribed to crystallization from a residual melt saturated in water (Jahns and Burnham, 1957).

Formation of large crystals necessitates the existence of a fluid of high mobility which can readily transport chemical species to a nucleation site. This is indirectly evidenced in the Cyr pegmatite by the existence of delicate aggregates of spodumene crystals which would be destroyed by movement of a viscous fluid around them and also by the replacement of the spodumene terminations by quartz.

All of the pegmatite dikes are probably late differentiates of the albite rich granite batholith. This view is substantiated by the fact that in general these dikes have similar mineralogical composition as the batholith. The last extract of this late differentiate gave rise to the complex pegmatite dikes and their high spodumene content would be explained by the concentration of the lithium content of the original magma in this last pegmatitic phase.

Sample locations of the detailed map.



Thin Section #	Pegmatite	Schist	Microcline	Albite	Quartz	Spodumene	Muscovite	Biotite	Apatite	Tourmaline	Andalusite	Actinolite
1	x			x	x	x	x		x			
2a	x		x	x	x	x	x					
2b		x		x	x		x	x	x	x		
3		x		x	x		x	x		x		
4	x			x	x	x	x					
5	x			x	x		x					
6		x		x	x		x	x	x	x		
7		x						x	x	x		
8		x		x	x		x		x			
9	x		x	x	x			x	x			
10		x	x	x				x				
11	x			x	x		x	x				
12	x			x	x		x					
13		x		x	x		x	x	x	x		
14	x		x		x		x	x				
15		x		x	x			x	x			
16	x			x	x	x	x	x				
17	x		x	x	x		x	x				
18	x		x	x	x		x	x	x			
19		x	x	x	x			x				
20	x		x	x	x		x					
21		x		x	x			x				
22		x		x	x			x				
23	x			x	x		x					
24	x			x	x	x	x					
25	x		x	x	x	x	x					
26	x		x	x	x		x					
27		x			x			x	x	x		
28	x			x	x	x	x	x				
29a		x	x		x		x	x				
29b		x		x	x		x	x				
29c	x		x	x	x							
30	x		x	x	x	x	x					
E-7		x			x			x	x		x	

Mineralogy of the Samples From the Pegmatite

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