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Résumé de l'article

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Geochemistry of Silurian-Devonian alkaline basalt suites from the Gaspé Peninsula, Quebec Appalachians

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Products of Late Silurian and Early Devonian volcanism in the Northern Appalachians are well exposed in the Chaleurs Bay area of the Gaspé Peninsula. The volcanic association is dominated by plagioclase basalts and andesites, and includes pyroclastic flows of dacitic and rhyolitic composition. Major and trace-element chemical analyzes of 174 rocks show that the volcanic association derives from alkaline and high-alumina basalt magmas. The basalts are usually olivine normative and high in Al_2O_3, TiO_2, P_2O_5 and in incompatible elements such as Y and Zr. They follow the course of a calc-alkaline differentiation trend.

This volcanism is interpreted to have been related genetically to a regime of tectonic compression, and controlled structurally by fault zones. The Quaternary volcanism associated with the major transcurrent fault zones of northern Anatolia and Iran within the Alpine Orogen provides a modern analog to the Silurian-Devonian volcanism of the Gaspé Peninsula and Newfoundland.

Les produits du volcanisme silurien et dévonien des Appalaches du Nord sont bien exposés dans la région de la Baie des Chaleurs de la péninsule gaspésienne. L'association volcanique comprend surtout des basaltes plagioclasiques et des andésites, tout en incluant une quantité plus faible de coulées pyroclastiques de composition dacitique et rhyolitique. Les analyses chimiques des éléments majeurs et traces de 174 roches indiquent que l'association volcanique dérive de magmas de type basalte alcalin et basalte alumineux. Les basaltes ont fréquemment de l'olivine normative, et ils sont riches en Al_2O_3, TiO_2, P_2O_5 , ainsi qu'en éléments incompatibles tels que Y et Zr. Ils suivent une tendance de différenciation de type calco-alcaline.

Ce volcanisme est interprété comme étant génétiquement lié à un régime tectonique de compression, et sa localisation est contrôlée structuralement par des zones de failles. Le volcanisme quaternaire associé aux grandes failles de décrochement du nord de l'Anatolie et de l'Iran, à l'intérieur de l'orogène alpin, est considéré comme un analogue moderne du volcanisme siluro-dévonien de la péninsule de Gaspé et de l'ile de Terre Neuve.

INTRODUCTION

Although volcanic rocks make up a significant amount of the geological record of Gaspé Peninsula, their chemistry and petrology have remained poorly known until recently. This information, however, is critical for an understanding of the tectonic environment that characterized the evolution of this segment of the Appalachian Orogen in mid-Paleozoic time. We report herein a summary of our work carried out since 1980 on the Silurian-Devonian volcanic rocks and which involved detailed mapping as well as petrological studies (Bélanger et al. 1981).

The Silurian-Devonian sedimentary and volcanic rocks of southern Gaspé Peninsula lie at the northeastern end of the Gaspé-Connecticut Valley Synclinorium. Thick sequences of shallow marine and subaerial volcanic rocks occur at the Silurian-Devonian stratigraphic boundary in the Chaleurs Bay area (Fig. 1). Two volcanic groups are distinguished on the basis of structure and stratigraphic position: (1) the Late Silurian rocks of the Mont Alexandre syncline, and (2) the Earliest Devonian volcanic rocks of the Restigouche area. These two groups are separated by a stratigraphic unconformity.

The volcanic rocks of the Mont Alexandre syncline are interbedded with sedimentary rocks that laterally grade in composition from clastic to calcareous. At Lake McKay, in the western part of the syncline, the volcanic rocks are interbedded within the Saint-Léon mudstone and siltstone whereas at Mont Observation, in the eastern part of the syncline, they are interbedded within the reef limestone of the West Point Formation (Fig. 1). Both sequences are of Late Ludlovian and Pridolian age (Bourque and Lachambre 1980).

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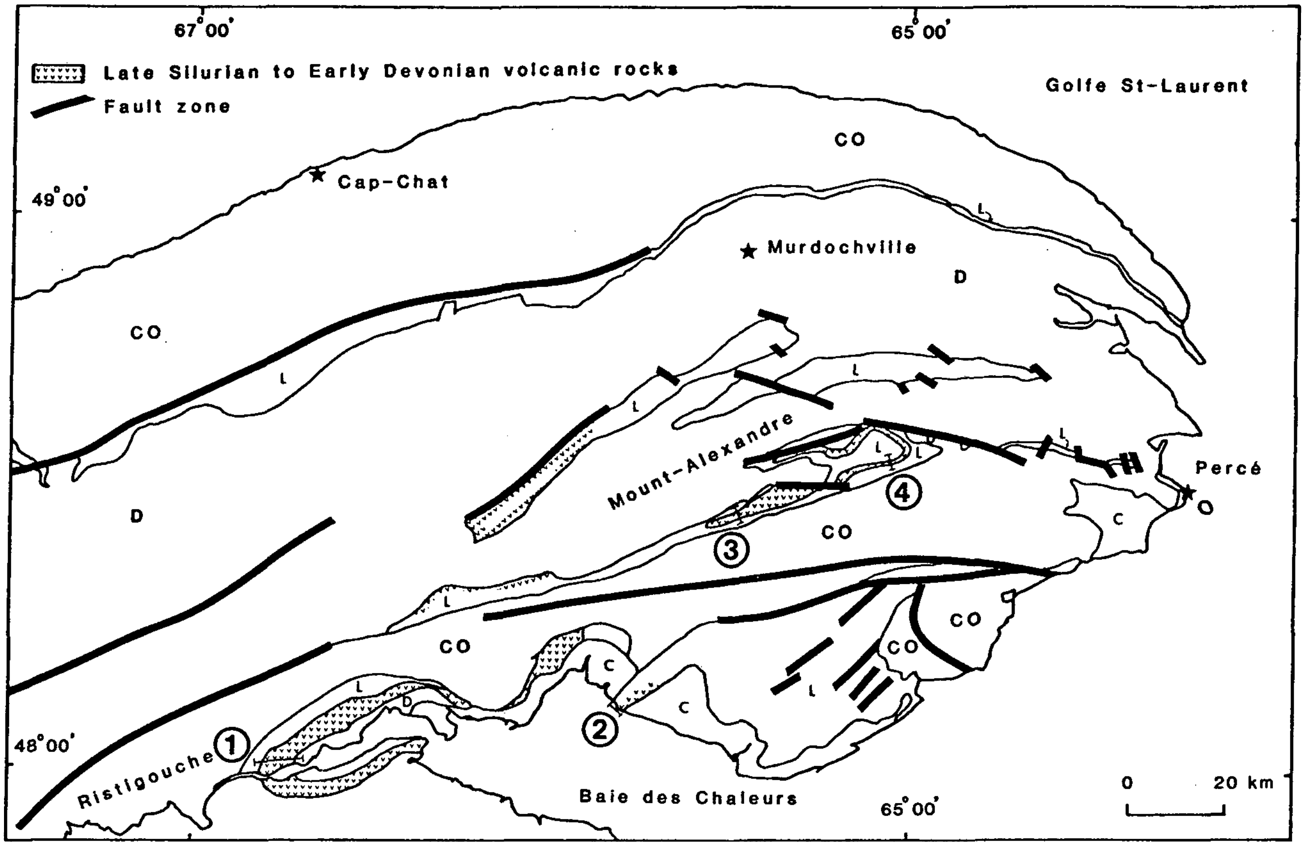

Fig. 1 - Outline map of the Gaspé Peninsula showing then Silurian-Devonian outcrop and the location of the volcanic rocks studied.

In the Ristigouche area, most of the volcanic rocks occur above the regional unconformity and are in close association with the Indian Point Formation of Gedinnian age (Bourque and Lachambre 1980). The latter consists of basal conglomerates, made up of Late Silurian limestone and lava pebbles, overlain by sandstone and mudstone.

The volcanic sequence of the Mont Alexandre syncline has a maximum thickness of about 1200 m in the Mont Observation area and of about 1000 m in the Lake McKay area (Bourque and Lachambre 1980). It consists of basaltic lava flows ranging in thickness from a few to 50 m. Most flows are massive. Some flows are brecciated (flow breccias), others locally display columnar jointing or pillowed structures. Lenticular beds of volcaniclastic conglomerate and coarse-grained sandstone are common within this sequence, but pyroclastic tuffs and breccias are rare. Textures of lavas vary from aphyric to porphyric. All porphyric lavas are characterized by ubiquitous plagioclase phenocrysts from 1 to 20 mm long, forming from less than 3% to more than 25% of their volume. These plagioclase basalts are highly vesicular, the vesicles being partly filled by calcite, chlorite and quartz. Swarms of dikes consanguinous with these volcanics are intrusive within the underlying Silurian sedimentary rocks of the syncline.

The 5 km thick volcanic belt of Ristigouche is part of the northern limb of the Chaleurs Bay syncline, the southern limb of which crops out in New Brunswick. The volcanic sequence consists of lava flows and pyroclastic rocks varying in composition from basaltic to rhyolitic. Andesites predominate. The lava flows are vesicular and massive or brecciated; locally they display columnar jointing but never pillowed structures. The pyroclastic rocks occur as thin layers of well-bedded pumice or scoria and ash deposits, and as thick units of unsorted block and ash deposits. Blocks in this type of deposit are up to 3 m long, though most of them are less than 40 cm in diameter. The matrix consists of lithic and crystal fragments of the same composition as the blocks. This type of deposit is commonly oxidized and purple-red in color. Textures of lavas are most frequently aphyric or microporphyric. The porphyric lavas are characterized by 5 to 30% plagioclase phenocrysts from 2 to 20 mm long. Small amounts of clinopyroxene phenocrysts occur in some lavas. Lava vesicles contain calcite, quartz, chalcedony, chlorites, leucoxene, pumpellyite and zeolites. Consanguinous intrusive bodies are few and always of small size. The Black Cape volcanic member (Fig. 1) also belongs to the Chaleurs Bay syncline. Though structurally related to the Ristigouche volcanic belt, the Black Cape basaltic and andesitic lavas are stratigraphically equivalent to the Late Silurian Mont Alexandre volcanic rocks. They are also included in the present study.

PRESENTATION OF DATA

The major and trace element chemical analyzes of 174 rocks have been used in this paper to identify the main features of the volcanic association. The sampling was systematically made from four continuous sections studied in detail, and is assumed to be representative of the four localities listed on Table 1. We believe that these volcanic rocks were extruded into a distinctive tectonic setting during an essentially continuous 10 Ma time interval spanning the Late Silurian and the Earliest Devonian. Although there is a continuum in the composition of this volcanic association, the sequence is divided on a stratigraphic basis into a Late Silurian and an Early Devonian group (Table 1). This subdivision allows a better understanding of the evolution of the volcanism through time.

The silica content varies from less than 50% to more than 70%, which justifies the practice of using silica content in classifying rocks with these compositions. The samples have been classified on the basis of silica content into basalt (<53% SiO_2), andesite (53-63% SiO_2), dacite (63-70% SiO_2), and rhyolite (>70% SiO_2) following the silica limits proposed by Taylor **et al.** (1969).

The Late Silurian volcanic group consists of 75% basalt, 24% andesite, and 1% rhyolite; the Early Devonian volcanic group consists of 28% basalt, 45% andesite, 22% dacite and 5% rhyolite (Table 1 and Fig. 2). No group is bimodal. The Late Silurian volcanism was predominantly basaltic while the Early Devonian volcanism was mainly andesitic and represents a wider spectrum of compositions. It was also characterized in the Ristigouche belt by several cycles of igneous activity that locally led to accumulations of more than 3 km of volcanic rocks.

Most basalts are aphyric or microporphyric, especially in plagioclase. Average

Table 1

DISTRIBUTION OF SAMPLES BY LOCALITY AND BY AGE

LOCALITY

	Number of samples:				Percentage			
	Basalt	Andesite	Dacite	Rhyolite	Basalt	Andesite	Dacite	Rhyolite
Mont-Observation	27	8	-	-	85.4	14.6	-	-
Lake McKay	43	4	-	-				
Black Cape	8	12	-	-	32.6	48.9	14.1	4.4
Ristigouche	22	32	14	4				

AGE

	Number of samples:				Percentage			
	Basalt	Andesite	Dacite	Rhyolite	Basalt	Andesite	Dacite	Rhyolite
Late Silurian x	82	27	-	1	75	24	-	1
Early Devonian y	18	29	14	3	28	45	22	5

Total number of samples: 174
x = samples from Mont-Observation, Lake McKay, Black Cape and Ristigouche
y = samples from Ristigouche

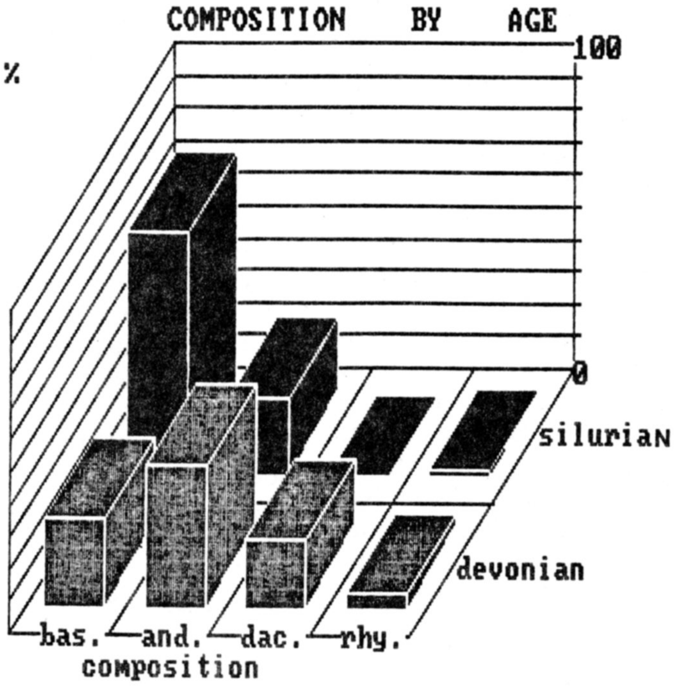

Fig. 2 - Histogram showing the relative proportion of the volcanic rock types in function of their age.

chemical compositions of the samples analyzed are given on Table 2. All basalts and andesites are rich in TiO_2 (>1.8%) and Al_2O_3 (>17%), but they are relatively poor in MgO (<6%), Ni (<60 ppm) and Cr (<130 ppm). They have many of the chemical features characteristic of alkali rock series. About 40% of the basalts have normative olivine. The remaining basalts, andesites and more differentiated rocks are oversaturated in silica and are quartz-hypersthene normative. However, most rocks have undergone post-crystallization oxidation and the analyzes are anomalously high in Fe_2O_3 content (Table 2). In order to avoid high normative magnetite and misleading high normative hypersthene and quartz contents, the Fe_2O_3 value has been corrected (Table 2).

The igneous mineralogy of basalts consists of microphenocrysts and microlites of plagioclase (An 45-30, microprobe analysis), augite (composition of pyroxenes are given on Table 3), and Fe-Ti oxides in an altered glassy to cryptocrystalline groundmass. Olivine phenocrysts are rare and replaced by secondary amphibole and chlorite. The andesites are rich in phenocrysts of zoned plagioclase (An 60-45, microprobe analysis). Phenocrysts of augite are frequent but normally in lesser amounts than the plagioclase. Both minerals occur also in the matrix as microlites and small grains with fine-grained Fe-Ti oxides. The amphibole hornblende is locally present as phenocrysts. The orthopyroxene has not been positively identified, though some chloritized pyroxene phenocrysts of unknown composition were observed in some andesites. Dacites are essentially composed of phenocrysts and microlites of plagioclase, and of only a few quartz phenocrysts; they are poor in pyroxene and Fe-Ti oxides and their matrix is quartzo-feldspathic, but the feldspars are partly altered to clays. Rhyolites are identical to dacites except that their groundmass is richer in quartz and poorer in feldspar than the dacites. Ferromagnesian minerals are accessory and deeply altered to chlorite, secondary magnetite and carbonates.

Our chemical data plotted in alkalis vs. silica and AFM diagrams (Figs. 3 and 4) indicate that the volcanic association is not tholeiitic. The Late Silurian group appears to be dominantly alkalic, while the Early Devonian group covers both the

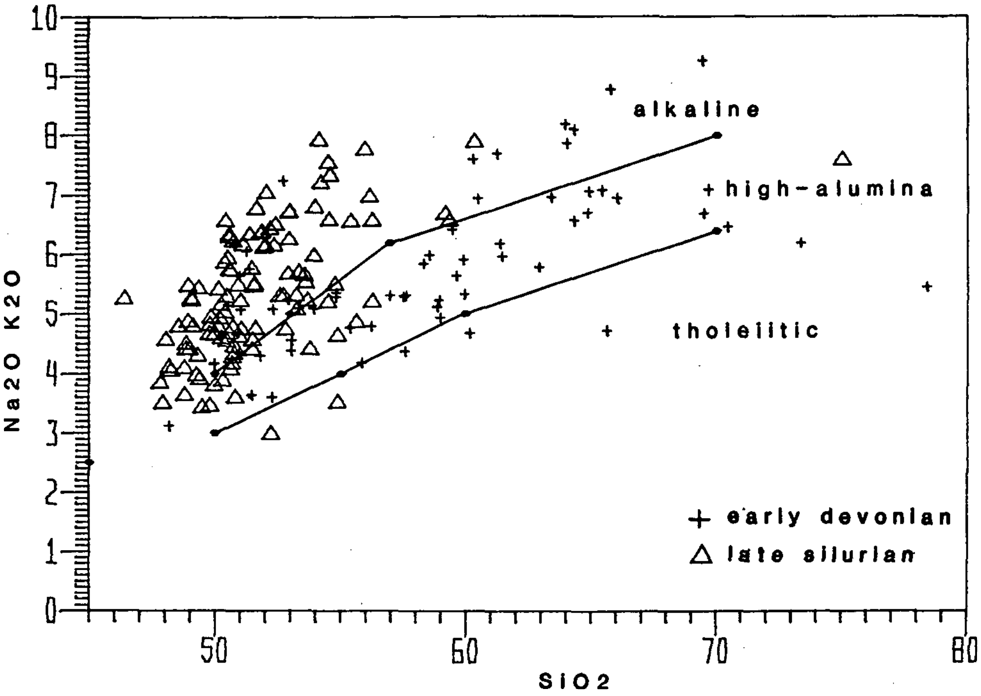

Fig. 3 - Alkalis versus silica diagram with the respective fields of tholeiitic, high-alumina and alkaline basalts of Kuno (1968).

alkalic and high-alumina basalt fields. Thus, the volcanic association is transitional between the alkalic and the high-alumina rock series. This is consistent with the fact that the rocks have high alkalis (mainly Na_2O), TiO_2 and P_2O_5 contents, which is typical of the alkalic rock series, and that they are also rich in alumina ($Al_2O_3 > CaO + Na_2O + K_2O$, Table 2), a feature that has determined the early and extensive crystallization of plagioclase in the sequence. Pyroxenes are also of alkaline affinity (Table 3). Nisbet and Pearce (1977) have shown that there is a marked compositional difference between pyroxenes of the within-plate alkali basalt group (WPA) and the volcanic arc-basalt group (VAB). Our pyroxenes plot (Fig. 5) is near the WPA field and within the variation spread of this group.

The differentiation of the volcanic association follows a calc-alkaline trend (MFA, fig. 4). It is characterized by a lack of significant iron enrichment. As shown by the linear relationship between FeO* and MgO in Figure 6, the Fe/Mg ratio does not vary much during differentiation. This observation also applies to the relationship between TiO_2 and MgO (Fig. 7). It can be seen that the sequence is also characterized by a lack of significant titanium enrichment.

Major-element chemistry suggests the possibility of two distinct series, respectively of alkalic and high-alumina basalt type. This point can be illustrated by using such relatively immobile elements as titanium and phosphorus. The variation diagram P_2O_5 vs. TiO_2 (Fig. 8) shows that the Ristigouche Early Devonian volcanics are clearly poorer in P_2O_5 than the Late Silurian group for similar TiO_2 contents. On the other hand, the wider TiO_2 spectrum of the Ristigouche volcanics, particularly in the low values, is not significant because of the limited extent of the differentiation of the Late Silurian group. The same observation can be made by using trace elements such as yttrium and zirconium. Y and Zr, both of which have low bulk partition coefficients (about 0.1, Treuil and Joron 1975), should plot along one line in a binary diagram if the series were perfectly consanguinous. Figure 9, with Y vs. Zr, shows that this is not the case. Many Ristigouche volcanics are richer in Zr and poorer in Y than most Late Silurian rocks. The two series appear to be geochemically distinct and could derive from two different parent magmas. How-

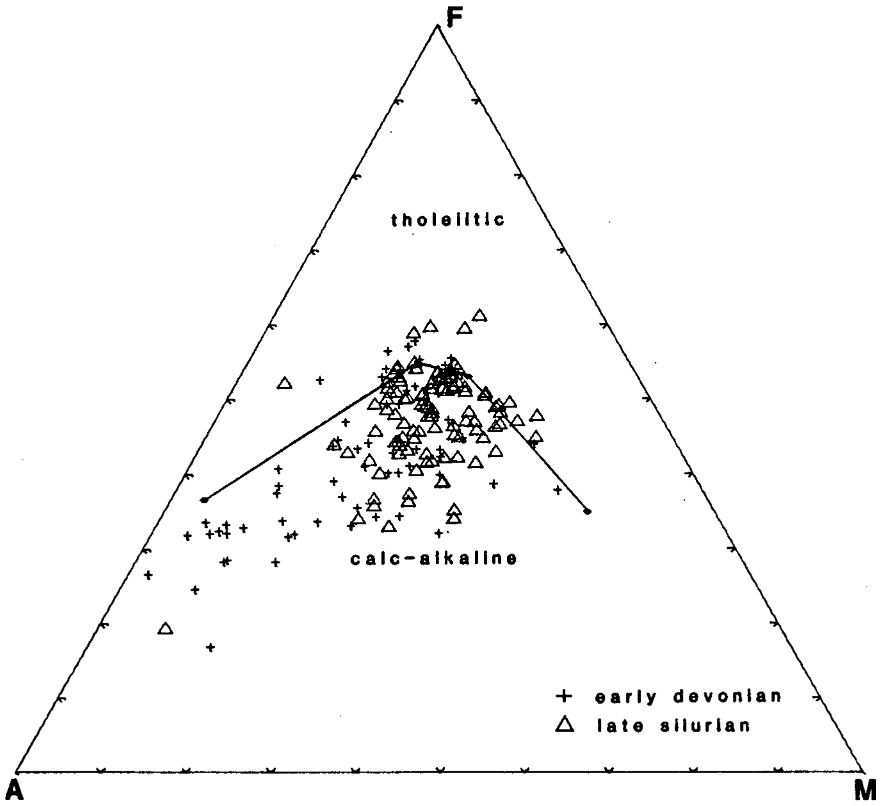

Fig. 4 - AFM diagram with the calc-alkaline - tholeiitic boundary defined by Irvine and Baragar (1971).

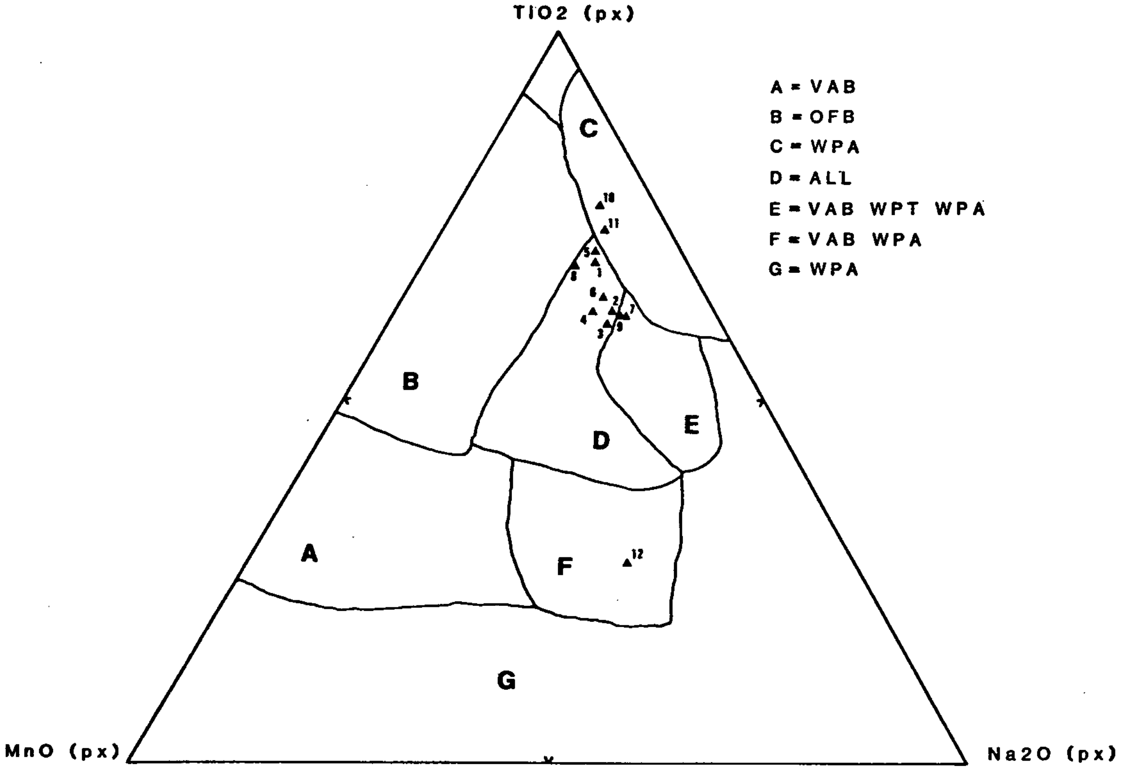

Fig. 5 - Plot of pyroxene compositions (Table 3) in the triangular diagram TiO_2 - MnO - Na_2O for discriminating between pyroxenes from different magma types by Nisbet and Pearce (1977).

ever, both stratigraphic groups have samples representative of either one of the two series.

Other trace elements can be used to characterize a particular locality. For instance, the Late Silurian basalts and andesites from Mont Observation are higher in niobium and barium (>10 ppm Nb, >500 ppm Ba) than those from Ristigouche (<10 ppm Nb, <250 ppm Ba).

INTERPRETATION

Our present understanding of Appalachian igneous rock assemblages relies heavily on plate tectonic models and the concept of a "Wilson cycle". According to Wilson (1966), the development of the Appalachian Orogen involved the creation and destruction of a Paleozoic proto-Atlantic (Iapetus) Ocean. The evolution began with a period of continental rifting in Hadrynian (Late Precambrian) time, manifested by extrusions of tholeiitic lavas, and ended with continental collision and progressive suturing in Devonian time (Bird and Dewey 1970). The Early Paleozoic proto-Atlantic Ocean is believed to have closed to a large extent during the Ordovician leading to the formation of an island arc complex (Strong 1973), and to the emplacement of the Taconic Allochthon and ophiolites on the western margin of the Taconic Orogen (Bird and Dewey 1970, Church and Stevens 1971, Williams and Stevens 1974, St. Julien and Hubert 1975, Laurent 1975). By Silurian time, and prior to the Acadian

Table 2

AVERAGE COMPOSITION OF ROCK TYPES, CALCULATED ACCORDING TO THE NUMBER OF SAMPLES GIVEN IN TABLE 1, AND C.I.P.W. NORM

	BASALTS		ANDESITES		DACITES		RHYOLITES	
oxide wt %	L. Silurian	E. Devonian	L. Silurian	E. Devonian	L. Silurian	E. Devonian	L. Silurian	E. Devonian
SiO_2	50.48	51.10	55.11	57.96	---	65.80	75.00	74.06
TiO_2	2.02	2.14	1.78	1.220	---	0.79	0.15	0.49
Al_2O_3	17.98	17.84	17.63	18.82	---	17.34	13.73	13.43
Fe_2O_3	5.81	5.79	5.79	4.19	---	3.12	1.94	1.97
FeO	4.70	4.52	3.10	2.60	---	1.14	0.27	2.00
MgO	5.15	4.62	4.13	3.16	---	1.29	0.82	0.80
MnO	0.16	0.16	0.13	0.11	---	0.06	0.02	0.08
CaO	8.17	8.65	5.80	6.25	---	3.00	0.46	2.01
Na_2O	3.89	3.95	4.71	4.42	---	5.06	3.91	3.72
K_2O	1.17	0.94	1.37	1.07	---	2.23	3.67	2.31
P_2O_5	0.46	0.28	0.46	0.24	---	0.17	0.03	0.12
FeO(total)	9.93	9.73	8.31	6.36	---	3.94	2.01	2.78
element ppa								
Ni	45	37	37	28	---	9	21	6
Cr	61	76	66	32	---	6	5	1
Zr	231	192	258	236	---	271	270	250
Y	31	29	29	21	---	23	44	26
Ba	530	240	404	242	---	358	340	410
Nb	17	4	16	6	---	6	24	10
C.I.P.W. Norm - wt %								
quartz	1.10	2.50	5.74	10.92	---	19.48	36.04	37.72
orthoclase	6.92	5.56	8.10	6.33	---	13.18	21.70	13.66
albite	32.93	33.43	39.87	37.41	---	42.83	33.10	31.49
anorthite	28.15	28.18	22.93	28.36	---	13.95	2.21	9.33
corundum	--	--	--	--	---	1.49	2.52	1.39
zircon	0.04	0.04	0.05	0.05	---	0.05	0.05	0.05
hedenbergite	0.39	0.22	--	--	---	--	--	--
diopside	7.11	10.01	2.41	0.98	---	--	--	--
ferrosilite	0.60	0.17	--	--	---	--	--	1.39
enstatite	9.54	6.87	9.17	7.42	---	3.21	2.04	1.99
magnetite	8.43	8.40	5.28	5.28	---	1.59	0.51	2.86
chromite	0.01	0.02	0.02	0.01	---			
hematite	--	--	2.15	0.55	---	2.02	1.59	--
ilmenite	3.84	4.07	3.38	2.28	---	1.50	0.28	0.93
apatite	1.07	0.65	1.07	0.56	---	0.39	0.07	0.28

Notes:

a) analyses values are recalculated to 100% without H_2O and CO_2

b) C.I.P.W. Norms are calculated with a correction for Fe_2O_3: maximum $Fe_2O_3 = TiO_2 + 1.5$ wt % the excess of Fe_2O_3 is converted to FeO (Irvine and Baragar 1971)

c) analyses were done by XRF. FeO and Fe_2O_3 were separately determined by titration

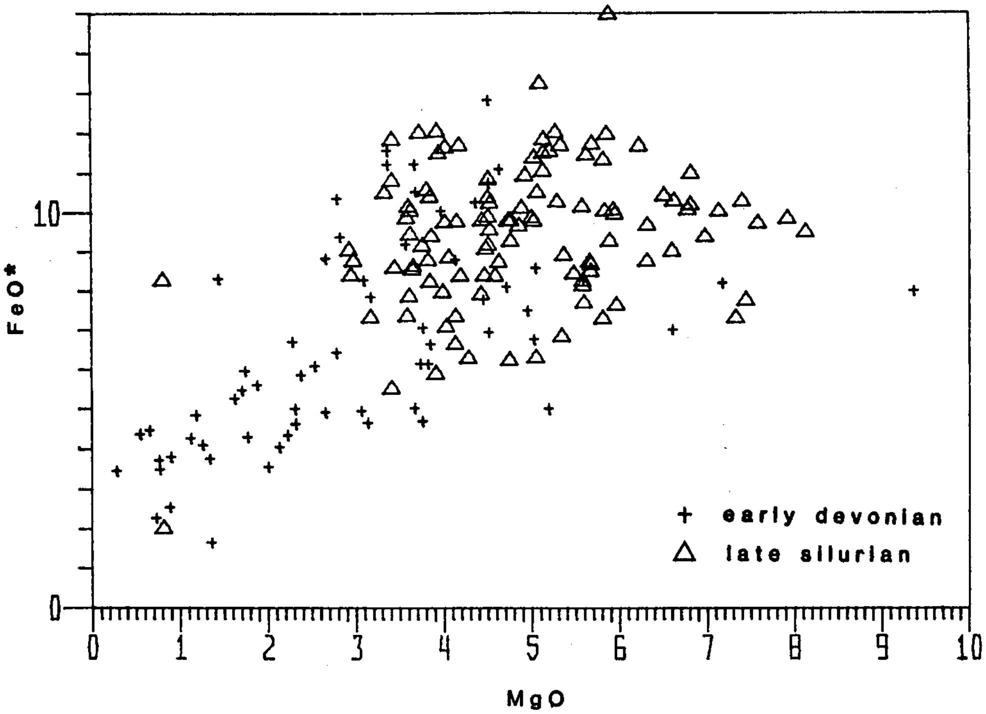

Fig. 6 - FeO* (total FeO + Fe_2O_3) versus MgO. The line indicates the approximate trend of fractionation.

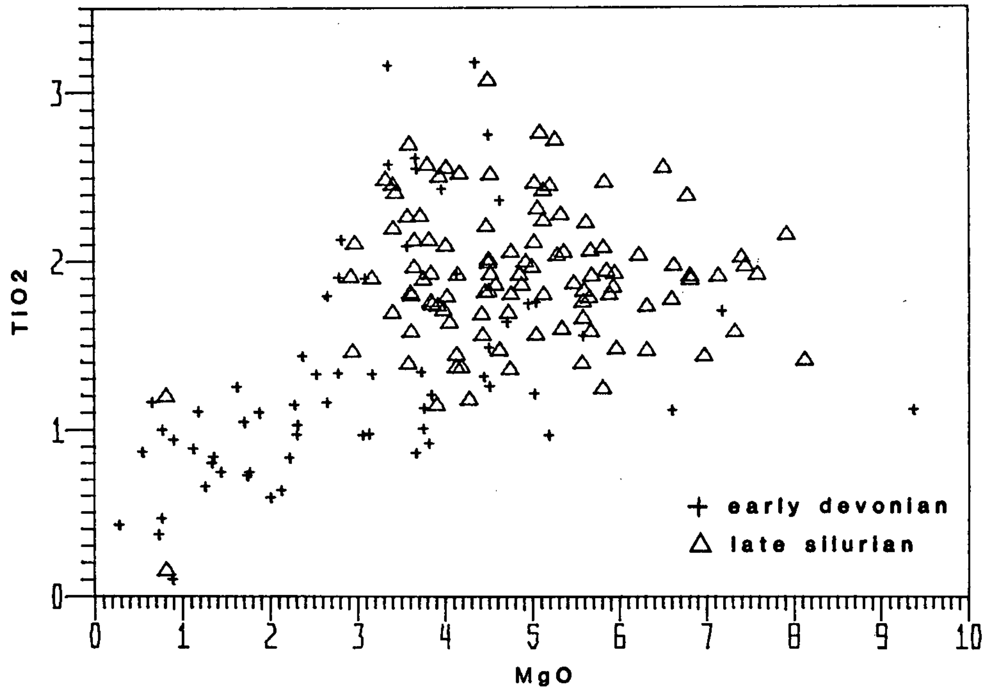

Fig. 7 - TiO_2 versus MgO. The line indicates the approximate trend of fractionation.

Orogeny, the Iapetus Ocean may have been reduced to a narrow sea. This hypothesis is also supported by paleomagnetic evidence (e.g. Morris 1976).

During the Silurian period, the areas previously affected by the Taconic orogeny were progressively covered by shallow seas. Marine sedimentation was widespread in the northern Appalachians during the Early Devonian, lasting until the Acadian

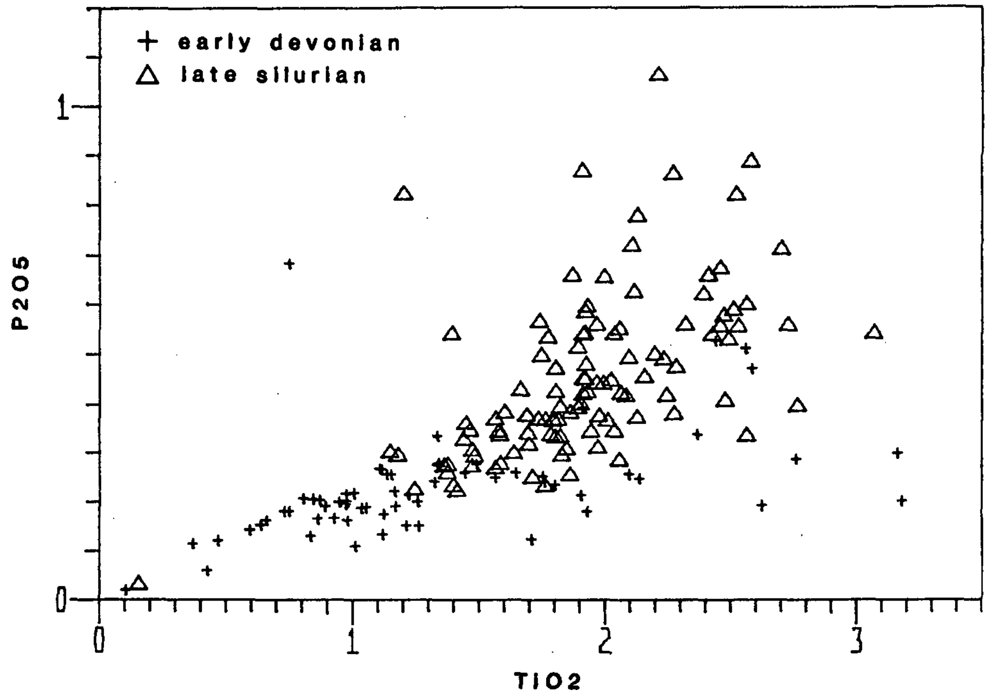

Fig. 8 - P_2O_5 versus TiO_2. The point distribution for these two immobile elements suggests there are two chemically distinct groups in the volcanic association.

deformation and the post-Early Devonian uplift (Boucot 1968). A carbonate platform bordered by furrows of clastic rocks characterizes the main paleogeographic features of Gaspé Peninsula in Late Silurian and Early Devonian time (Bourque 1977, Bourque and Lachambre 1980). These features constitute the framework for the ensuing volcanism.

Paleogeographic reconstruction indicate intracontinental or continental border conditions at the time of volcanism, with a tectonically active environment. Because of progressive northwest-southeast compression, strike-slip faults developed across the Paleozoic terrane of Gaspé Peninsula and northern New Brunswick (Fyffe 1982). The Late Silurian and Early Devonian volcanic rocks of Gaspé Peninsula lie near these faults (Fig. 1). We think that the volcanism was genetically related to a regime of tectonic compression and was controlled by strike-slip faults.

The nature of the volcanism is different from that of arc- and trench-systems generated by ocean plate subduction. Circum-oceanic volcanic rocks associated with convergent ocean plate boundaries are low in titanium, phosphorus and other incompatible elements, and most of them are highly oversaturated in silica (e.g. Kuno 1968, Johnson et al. 1978, Gill 1981). The Late Silurian and Early Devonian volcanic rocks studied herein are rich in titanium, phosphorus and other incompatible elements. Do alkaline and high-alumina basalt series of this type represent the products of intraplate rifting? In the volcanic association of most continental rifts, tholeiite is predominant in the early stages of the evolution. This component is absent from the volcanic association studied as are other typical components of rift volcanism such as ultrabasic lavas and highly alkaline rocks. Furthermore, we know of no field evidence supporting the development of rifts in Gaspé Peninsula during the Late Silurian and Early Devonian. The structures mapped are dominantly related to compression tectonics.

Intraplate continental volcanism occurs within the Alpine Orogen, especially along the Northern Anatolian fault zone in Turkey and in the western Elburz Mountains of Azeirbeidjan (Fig. 10). The volcanic centers, Ararat, Savalan, Sahand and Damavand, are the largest, but only the volcano Damavand is presently active. It consists of alkaline lavas (Jung et al. 1975). Smaller volcanoes are widespread in northern

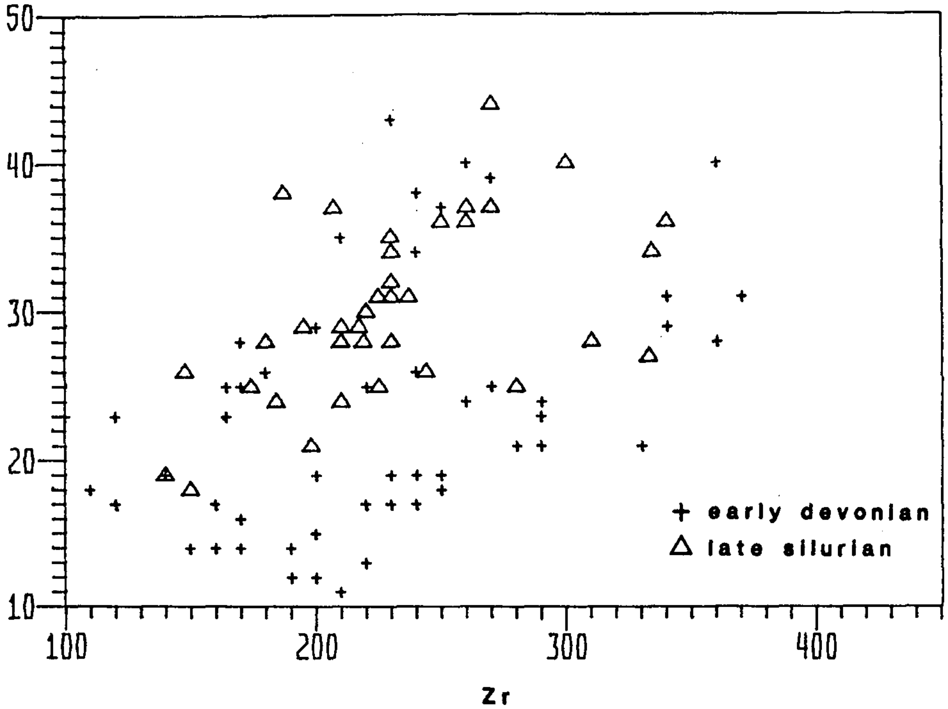

Fig. 9 - Y versus Zr. The distibution of these two incompatible elements follows two different lines, which indicates that there are two chemical groups in the volcanic association, each being characterized by a distinct Y/Zr ratio.

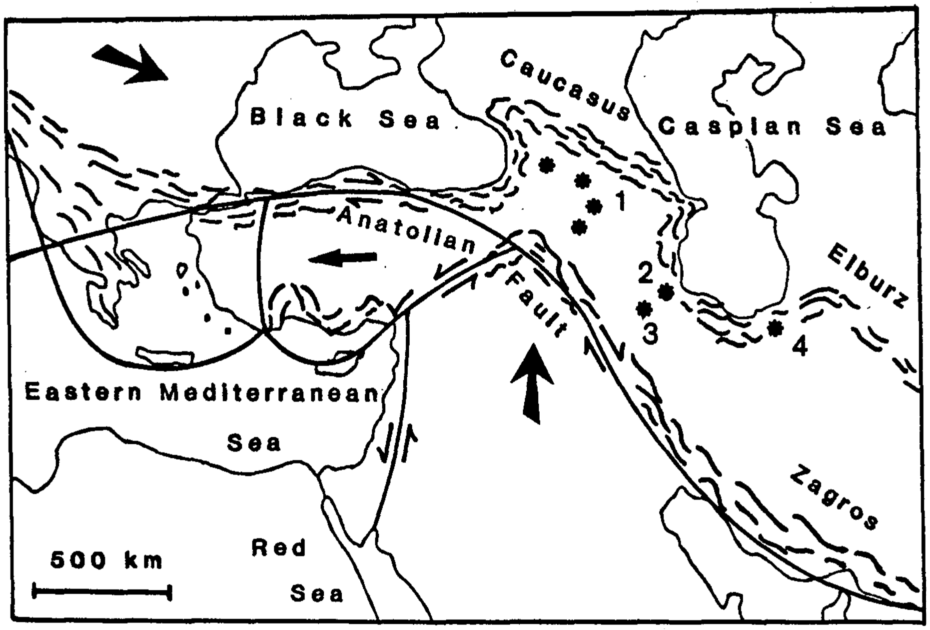

Fig. 10 - Schematic map showing the geotectonic setting of the Quaternary volcanism of northern Anatolia and Iran, modified from McKenzie (1970). Main volcanic centers are: 1, Ararat; 2, Savalan; 3, Sahand; 4, Damavand.

Iran and many are predominantly andesitic (Gansser 1971). The association of alkaline and calc-alkaline suites is typical of this Quaternary volcanic province. The region is being squeezed between Eurasia and Africa. Presently, Africa seems to be rotating relative to Eurasia, producing compression south of the Caspian Sea region. Farther west, the same motion produces dextral shearing along the Azores-Gibraltar fault zone (McKenzie 1970). As a working hypothesis we draw an analogy between this Alpine situation and the tectonic setting of the Silurian-Devonian volcanism of Gaspé Peninsula. This volcanism is of regional importance since it extends northeastward into Newfoundland with similar characteristics (Strong 1977, p. 77-84). Strong (1977) has suggested that the Newfoundland volcanic association originated in a regime of tectonic compression. Our results and interpretation also support this conclusion.

Composition of magmas extruded into continental collision zones of this type must depend on many factors such as the rate of compression (in relation with the thermal regime), the nature and thickness of crust (thickening of the crust may initiate crustal anatexis), the composition of the upper mantle, the depth and percentage of melting and, finally, the conditions of ascent of magma (extent of crystal fractionation, magma mixing and assimilation). We do not, however, have enough information at this stage to discuss the relative role of these factors in determining the petrological features of these rocks, and we must limit ourselves only to define the problem at hand.

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Table 3

SELECTED PYROXENE ANALYSES

ref. no:	1	2	3	4	5	6	7	8	9	10	11	12
SiO_2	49.8	51.2	50.8	50.9	49.8	50.9	50.8	51.3	49.5	47.8	48.9	52.7
TiO_2	1.3	1.1	0.9	1.3	1.4	1.4	0.9	1.5	1.1	2.3	1.9	0.3
Al_2O_3	2.6	2.4	2.2	1.4	3.9	3.0	1.8	1.7	3.3	3.9	3.5	0.9
FeO	9.6	8.5	8.4	11.5	8.6	10.2	9.0	10.8	9.4	10.6	9.9	10.7
MgO	14.1	15.4	16.2	13.4	14.5	14.5	16.3	14.6	15.4	13.5	14.1	14.9
MnO	0.2	0.2	0.3	0.3	0.2	0.3	0.2	0.3	0.2	0.2	0.2	0.3
CaO	21.1	21.0	21.2	21.3	21.5	21.2	21.3	20.5	19.7	20.9	21.4	21.3
Na_2O	0.4	0.4	0.4	0.5	0.4	0.5	0.4	0.4	0.5	0.5	0.5	0.5
TOTAL	99.4	100.2	100.2	100.5	100.4	101.8	100.6	101.0	99.1	99.7	100.4	101.6

Note:

Microprobe analyses were done with an ARL electron microprobe at 20 Kv and 10 uA using natural olivine and diopside standards. The data were corrected using a ZAF program.

sample no:	ref. no	age	rock type	location
24-A778	1	L. Silurian	basalt	Lake McKay
25-A778	2	L. Silurian	basalt	Lake McKay
19-A778	3	L. Silurian	basalt	Lake McKay
36-A778	4	L. Silurian	basalt	Lake McKay
38-A778	5	L. Silurian	basalt	Lake McKay
56-A778	6	L. Silurian	basalt	Lake McKay
58-A778	7	L. Silurian	basalt	Lake McKay
15-B778	8	L. Silurian	andesite	Black Cape
16-B778	9	L. Silurian	basalt	Black Cape
39-B778	10	L. Silurian	basalt	Black Cape
40-B778	11	L. Silurian	basalt	Black Cape
25-C778	12	E. Devonian	dacite	Ristigouche

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