SPOTTED CHLORITIC ALTERATION

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ABSTRACT

Chlorite-rich spots, 1 to 5 mm in diameter, occur in many of the rocks intruded by the Nipissing diabase in the Cobalt-Gowganda region. Each spot is ordinarily accompanied by an appropriately-sized chlorite-deficient aureole, suggesting that only a local movement of material was involved. The mineralogy of the spots is simple, with chlorite and sphene being the only two minerals persistently associated with unreplaced clasts or residual matrix grains. Microprobe analyses of the chlorites indicate that their compositions vary from place to place, and chemical analyses of the rocks suggest that spotting may have been accompanied by a slight increase in oxidation in the host rocks.

The chlorite spots are pre-ore and hence neither the presence nor intensity of spotting coincides with the occurrence of productive veins. In the affected rocks, a high argillaceous content and a grain size sufficiently coarse to readily permit intergranular movement of matrix components are factors favouring spot development. The general distribution of spotting suggests a blanket-like development in proximity to the Nipissing diabase and extending about 100 meters beyond the intrusion contacts. Spot development may have occurred only where temperature, grain boundary water, and pressure coincided to form a suitable environment for blast growth.

INTRODUCTION

Chlorite spotting in the country rocks in the Cobalt-Gowganda region is a peculiar phenomenon which is of importance because attempts have been made to use its presence as an exploration guide for silver veins. The spotting is present as dark chlorite-rich areas which generally range from 1 to 5 mm in diameter. They are present in Archean volcanics, in Archean lamprophyre dykes which intrude the volcanics, and in the unconformably overlying Proterozoic sediments. The Nipissing diabase does not contain this type of alteration.

Although no mine has yet been discovered in an area selected because of the presence of well-developed spotting, the feature has generally been regarded as a favourable sign in the evaluation of the potential of silver prospects. For this reason principally, and as a complement to studies of the wall rock alteration along ore veins, the distribution and mineralogy of the spots were studied in detail.

Previous Studies

Chlorite spotting in Huronian sediments within a meter of the Nipissing diabase contact was recognized many years ago by Collins (1913, 1917), but the more widespread spotting which occurs for a hundred meters beyond the contacts appears not to have been mentioned until Thomson's (1961b, c, 1965) detailed mapping of the Cobalt area. Thomson (1965) was of the opinion that the presence of such alteration has favourable economic significance.

Various additional statements about spotted alteration are to be found in the papers and theses by Scott (1964), Moore (1967), Thorniley (1967), Boyle (1968a), and Halls & Stumpfl (1969). Barker's (1966) study of the spotting at the Silverfields mine, Cobalt, appears to have the only work which focused exclusively on this type of alteration. Barker concluded (p. 23) that "the spots likely formed in the Huronian sediments at Silverfields prior to the development of vein fractures and the emplacement of vein mineralization". He also concluded that the spots probably formed by recrystallization of the original argillaceous material in the sediments through heating from an indefinite source.

Regional Distribution

The general appearance of spotted alteration is shown in Figure 197. Spotting of this type occurs in variable amounts throughout the Cobalt-Gowganda region. It is best-developed at Cobalt and in Casey township, with only sparse amounts being present in the region to the west of these areas. Some spotting, particularly in Huronian sediments, is present at South Lorrain and in the intervening area to Cobalt. Despite the presence in such a large area, the occurrence of this type of alteration is localized in that most rocks are barren of spots. On the whole, the Huronian argillaceous sediments appear to have been the most susceptible to spotting as the alteration in them is more widespread than in the Archean volcanics and lamprophyre dykes.

Mineralogical Character

Spots in the Huronian sediments are generally spheroidal, but in lamprophyre and Keewatin volcanics they commonly have angular rather than rounded outlines. Alteration in the pre-Huronian rocks is more varied, particularly where the spotting is intense. Some of the effects include the grouping of spots into trains following fractures, the development of thick chloritic seams along fractures, and the development of thick chloritic sheaths around altered pillows (Fig. 198). The seams and sheaths were probably pre-existing structures whose features have been enhanced by the spotting process. As a very general rule, spots in the Archean rocks are larger than those in the Proterozoic.

Spotting in the Huronian sediments is usually present as individual spheroids less than a centimeter in diameter. The spots are well-developed both in finely laminated and in relatively massive sediments (Fig. 199). In conglomerates, both the matrix and boulder rims and centres are affected (Fig. 197B). Although the spots are in most cases spheroidal, an angular habit is evident in the cores of some volcanic boulders.

In addition to their variable size and angularity, the spots may be sharply outlined and solidly dark (Fig. 199B), or may have a light core or lighter-coloured outer halo (Fig. 199E, F). Although the spotting closely follows bedding, the larger chlorite spheres encompass several sedimentary laminae. Such spots are commonly aggregated into elongate streaks which

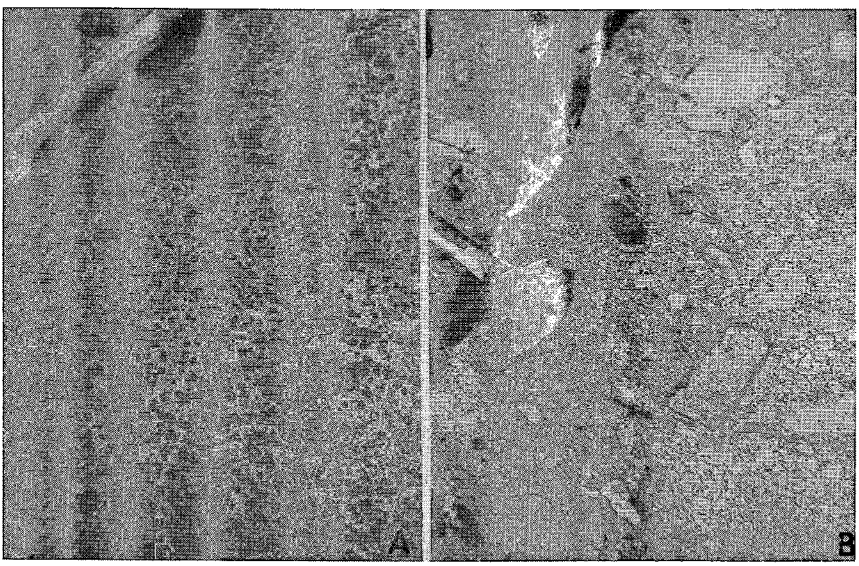

FIG. 197. General appearance of chlorite spotting: (A) intense chlorite spotting in massive Archean flow rock near Vein 113, claim RL 404, east side of Cobalt Lake; (B) chlorite spotting in Coleman (Gowganda Fm.) conglomerate at the north end of Cart Lake, Cobalt. The pick head is parallel to the dip of the bedding. Chlorite spots occur in the matrix and are prominent around the rims of some cobbles, especially the angular cobble of lamprophyre near the centre of the photograph.

follow the bedding (Fig. 199G) but in detail may extend across it. In finely-laminated sediments it is generally the coarser beds that contain the spots. Rarely, if ever, do trains of spots cut across the bedding. In one case where this was found, a thin section examination showed that the apparent cross-cutting effect was due to spotting along a small, coarser-grained clastic dyklet. This emphasizes the influence that the character of the host rock plays in governing the intensity of spotting within an affected area.

Chloritic spots near ore veins seem to have been favourable sites for the deposition of dispersed traces of ore minerals. Disseminated pre-ore

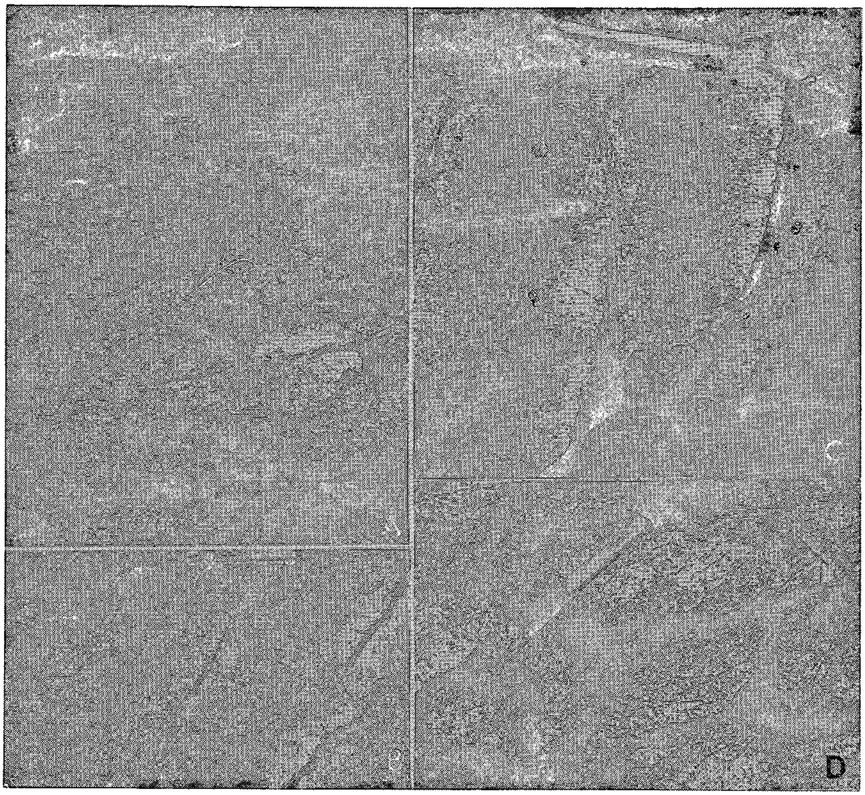

FIG. 198. Chlorite alteration effects in Archean andesite near Vein 65, claim RL 401, parcel 1, northeast side of Cobalt Lake: (A) thick, dark chloritic sheaths simulating pillow structure in the foreground are gradational to a breccia matrix (at hammer). The breccia at this locality marks the transition from Archean volcanics to the Proterozoic sediments at the top of the photograph; (B, C, D) chlorite seams in the volcanics at the same locality as A.

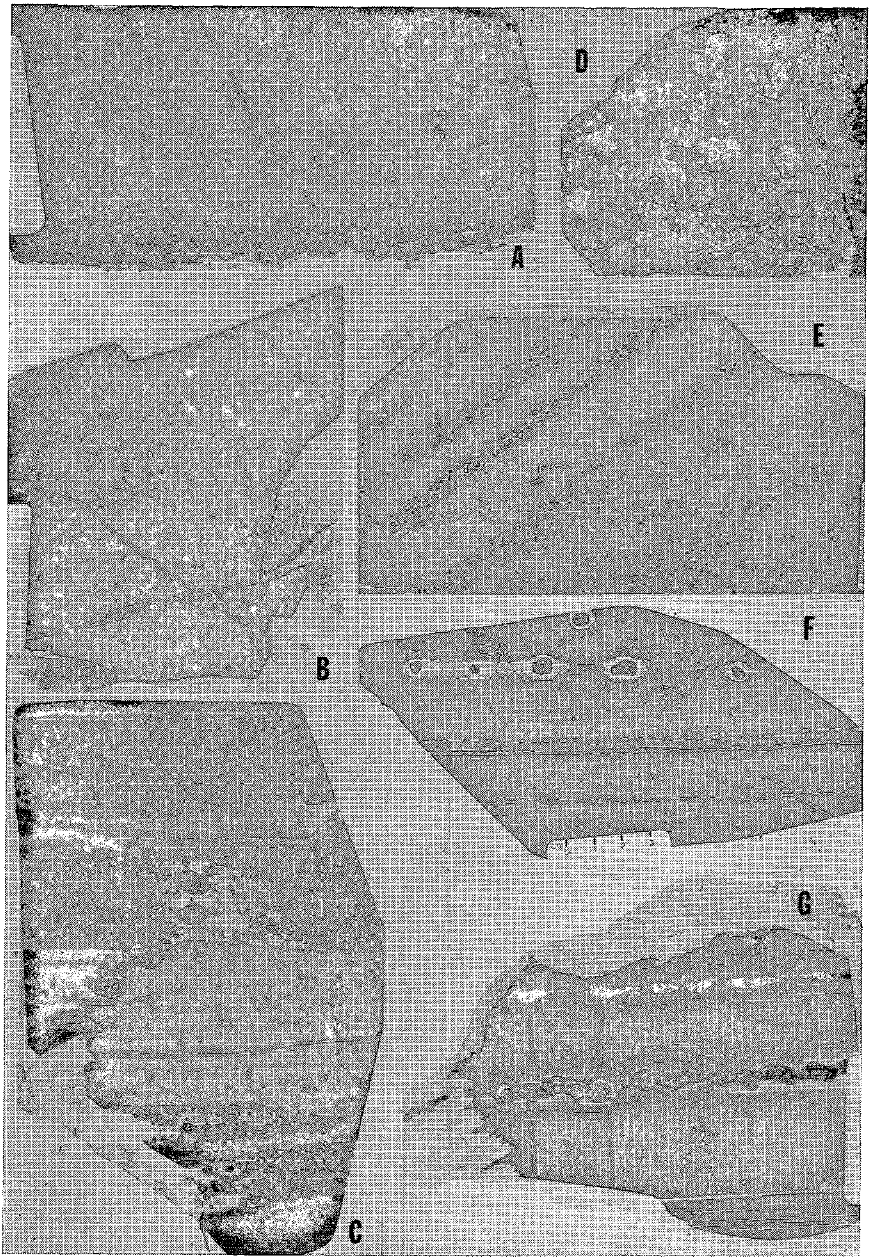

FIG. 199. (A) Spotted alteration in Gowganda quartzite wall rock along an ore vein, Silverfields mine, Cobalt. The bottom part shows wall rock alteration effects and partial

(Continued on next page)

base metal sulphides derived from the weathered Archean (see p. 24) may have been favourable nucleation sites for some chlorite spots, but as most sulphides are not accompanied by spots and as many spots are not accompanied by sulphides, the association is an incidental one.

Thin section studies show that the spots have in most cases originated by migration of material from the encompassing host rock. The scale of the reaction involved is exemplified by the dark, chlorite-rich cores and bleached aureoles shown in Figure 199. The cores consist largely of fine-grained chlorite aggregates surrounding residual clastic grains. The latter, which commonly comprise 50 to 75 per cent of the cores, are usually the coarser-grained clasts and are predominantly quartz with minor albite. The sediments in the bleached halos are generally devoid of chlorite, but are otherwise little changed. Although spots in some polished hand specimens appear to lack bleached rims (Fig. 199B), the halos are nevertheless usually readily apparent in thin sections. In some light-coloured bands or beds, however, the components of the chlorite may have been derived from a larger volume of encompassing rock. An indication that this may have occurred is the presence of diffuse aureoles around the larger chlorite spots, and the gradual disappearance of bleaching along the strike of some beds (Fig. 199C, G). That this disappearance is not related to primary sedimentary structures is evident from the continuity of laminated beds through both the bleached and unaffected portions of the rock.

Sphene is persistently associated with chlorite spotting and is occasionally accompanied by traces of anatase. In rocks lacking spotting, and in the unaltered portions of spotted rocks, sphene is generally present as finely-disseminated turbid grains averaging less than 0.01 mm in diameter. As is the case for chlorite, there seems to have been extraction of material from the surrounding sediment and redeposition either in the chlorite core or at the periphery of the bleached aureole. Although rarely euhedral,

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obliteration of the spotting; (B) chloritic spots in massive (Gowganda) quartzite unit, Silverfields mine; (C) different proportions of spot development in dark and light units of Huronian greywacke, Meteor adit No. 2, Silver Summit property, Cobalt. Note the gradual disappearance of the bleaching effect in the light band second from the bottom. The light colour of individual spots throughout the specimen results from the presence of abundant sphene. (Length of specimen is 18 cm); (D) chloritic spots with weakly-developed bleached aureoles in Archean flow, claim RL 404, Cobalt; (E) well-developed chlorite-deficient halos around spots in Huronian sediment, Silverfields mine; (F) chloritic spots in greywacke, Silverfields mine. Abundant sphene in the halos accounts for their brightness. Minute specks of sphene are also disseminated in the areas between spots; (G) trains of chlorite selectively developed in certain beds of greywacke, Silverfields mine. Note the bleaching effects accompanying the centrally-located chloritic band, and the myriad of disseminated sphene specks on either side.

sphene grains of up to 0.5 × 0.5 mm may be in optical continuity despite the fact that most of their volume consists of unreplaced clasts. Carbonate minerals do not normally occur within the cores or bleached rims of spots, but are associated with sphene at the outer margins of the bleached aureoles. Much of the carbonate also occurs in the sediments as independent spots about a millimeter in diameter. Thus, they are smaller than the associated chloritic spots, and are also less conspicuous in hand specimens because of the relatively subdued colour contrast. In thin section, most of the carbonate occurs as optically continuous single grains of calcite with ragged edges and with a large part of the volume occupied by unreplaced clasts. Although chlorite and carbonate spotting are commonly closely associated, carbonate spots are present in some rocks in which chlorite and sphene show no signs of agglomeration.

Apatite in anhedral grains averaging 0.2 to 0.3 mm in diameter is the principal constituent of a few spots in Huronian sediments. Although present in several thin sections, the mineral seems to be erratically distributed. A few weakly-developed spots of the chlorite type have been found to contain sericite in the relatively infrequent cases where appreciable amounts are present in the rock matrix. Barker (1966) suggested that small sericitic masses in the contact metamorphic zone at the Silverfields mine may be the degradation products of minerals such as andalusite or cordierite. The latter mineral especially is common in spotted rocks (Bosma 1964; Schwartz 1943, 1949; Woodward 1968), but has not been found in this study. Retrograde pseudomorphism of porphyroblasts by mica or chlorite cannot be unequivocally ruled out for all diabase contacts in the region, but the absence of large or well-developed spotting near the contacts is nevertheless a general rule. Spots about a millimeter in diameter occur within about 10 metres of the contacts, but at distances less than this the chloritic concentrations in hand specimens are smaller and correspondingly less definitely recognizable as spots.

The relationship of spotting and host rock constituents in Archean volcanics is less well-defined, but does not seem to differ appreciably from that in Huronian sediments. Bleached aureoles are present around spots (Fig. 199D) and also occur adjacent to chloritic seams and veinlets. In general, however, the indications of extraction from the adjacent rock are less pronounced than in the Huronian. Chlorite and sphene are again the principal constituent of the spots and seams. Some turbid areas contain extremely fine aggregates of rutile. Although chlorite pseudomorphs after amphibole or pyroxene are evident in some thin sections, the reason for the well-developed angularity of the chlorite spots in the volcanics is not known. Presumably the influence of the textures and physical properties of the compactly intergrown minerals in the matrix of the volcanic rocks differed from that of clastic Huronian sediments, but this in itself is no explanation for the angularity. Thomson (1967) has suggested that the angularity may represent the crystal shape of the chlorite. With the exception of this feature, no radical differences in the spotting in the Proterozoic or Archean rocks were noted. Most spots have a chlorite-rich core surrounded by an appropriately-sized chlorite-deficient aureole. This initially suggests that only a local movement of material was involved, with the trend being toward the formation of polycrystalline monomineralic clusters (glomeroblasts in the terminology of Ramberg 1952).

Other spots and markings

Chlorite spotting of the type described above does not occur as a wall rock alteration along the ore veins, nor does it occur in the Nipissing diabase. A spotting effect which is present adjacent to some veins in diabase is attributable to the preferential alteration and pseudomorphism of orthopyroxene.

Other kinds of greenish spherical spotting were observed near the upper contact of the diabase in Henwood township [1], and in sedimentary inclusions in the diabase in James township [2]. At the latter locality several small inclusions averaging about 3 cm in diameter occur in granophyric diabase well-exposed in a creek bed. Altered aggregates of plagioclase are surrounded by narrow rims of chlorite, the combination giving a prominent spotting effect within the inclusions. In the Henwood township diabase, sharply demarcated spheres about one millimeter in diameter are abundant in a specimen taken about a meter from the contact. The spots are microscopically heterogeneous, but consist mostly of amphibole, probably titaniferous, which occurs as matted needles averaging about 0.1 mm in length. The diabase at this locality has undergone extensive autometamorphism and contains abundant prehnite, epidote, pumpellyite. and sphene.

The peculiar markings exemplified in Figure 200 have also been examined, though not in thin section. Markings of this type occur along bedding planes in fine-grained argillaceous sediments in a few places at Cobalt. X-ray powder diffraction patterns indicate that the principal mineral is well-crystallized chlorite. In some specimens the individual chlorite grains are clearly visible with a low-power binocular microscope. The zonal

[1] Lot II, concession V. The outcrop is described by Thomson (1966, p. 25).

[2] Lot II, concession IV, at the outlet of Shane Lake. The closest sedimentary outcrop is approximately 200 m to the south.

pattern of the markings arises from variable chlorite abundances in the zones. The markings are planar features generally less than a millimeter thick, and the limited examination done here tentatively indicates that they are mineralogically similar to chlorite spots.

Chemical Character

Composition of the chlorite

Microprobe analyses of chlorite spots in Huronian sediments and Archean volcanics and lamprophyre are given in Table 79. There is no relationship with the general type or age of the host rock. Chlorite spots within a single thin section are not necessarily of uniform composition, and in some cases individual spots contain chlorites of variable composition.

Specimen JF69L-48 (Table 79) may be cited as an example for explaining the diversity of chlorite composition. The rock is a thinly-bedded, fine-grained greywacke-type sediment from the lower (Coleman) member of the Gowganda Formation. Small chloritic spots and well-defined bleached aureoles, together averaging about a millimeter in diameter, occur throughout the thin section. Microprobe analyses (a) and (b) in Table 79 were made on chlorite spots in different beds 1.3 cm apart, the results indicating that the chlorites have different compositions and oxidation ratios. The chlorites in the unspotted portions of the rock matrix were, as usual, too fine-grained for analysis. The values obtained for the spots are difficult to explain unless it is assumed that the compositions of the argillaceous

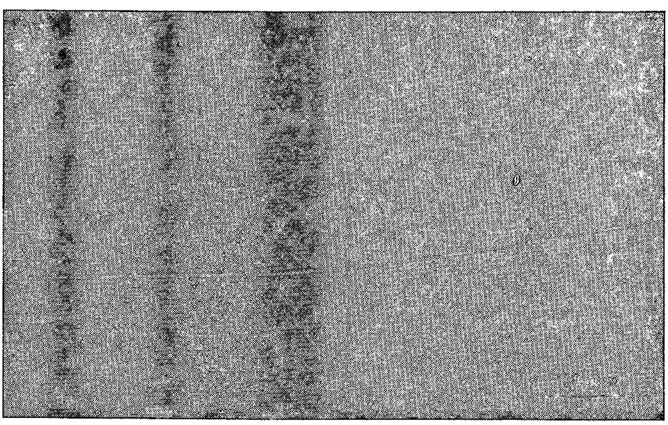

FIG. 200. Bedding plane markings in Gowganda (Coleman) greywacke near Little Silver vein, south of Cobalt Lake.

materials differ slightly in each bed and the spots were formed by local diffusion of these materials.

Chemical changes

Thin section examination of spotted Archean lamprophyres and volcanics, and their "unaltered" equivalents, indicates that in some cases

TABLE 79. MICROPROBE ANALYSES OF CHLORITES ASSOCIATED WITH SPOTTED ALTERATION.

No. (JF–)	69C-443		69C-	69S-1		68-	68-467		69L-48		69-442		
Wt. %	(a)	(b)	449	(a)	(b)	501	(a)	(b)	(a)	(b)	(a)	(b)	(c)
SiO_2	27.5	24.5	25.4	25.1	24.2	29.0	29.0	27.4	26.4	25.6	—	—	—
Al_2O_3	15.8	18.9	18.4	16.5	15.8	20.6	21.0	20.1	18.0	18.7	19.9	19.1	21.1
FeO*	23.3	25.9	21.4	20.2	21.2	24.9	23.5	27.4	25.0	25.8	29.4	28.6	29.9
MgO	18.2	15.8	19.4	19.6	18.6	16.8	15.1	16.6	16.8	14.1	12.5	13.5	13.0
MoO				0.3	0.3								
FeO**	22.6	22.9	18.1	16.3	16.4	—	—	18.8	24.0	—			
Fe_2O_3	0.8	3.3	3.4	4.3	5.3	high Fe^{3+}	high Fe^{3+}	5.2	1.2	high Fe^{3+}			

Analyst: A.G. Plant
* Total Fe as FeO
** FeO and Fe_2O_3 calculated as shown in Appendix, p. 261.

Notes:

JF69C–443: Archean andesite near Vein 65, RL 401, parcel 1, Cobalt. The analyses were made on coexisting chlorites, 2 mm apart, showing (a) blue and (b) brownish interference colours.

JF69C–449: Archean andesite near high grade mill site, Nipissing RL 404, Cobalt.

JF69S–1: Lamprophyre dyke near Vein 44, Nipissing RL 404, Cobalt. Analyses made on coexisting chlorites showing blue (a) and greenish (b) interference colours.

JF68–501: Greywacke, Meteor adit No. 2, Silver Summit property, Cobalt. Analysis made on a large spot in the central area of the specimen shown in Figure 199C.

JF68–467: Cobalt sediment, 3rd level, Silverfields mine, Cobalt. Analysis (a) is from the core of a spot from which a chlorite-bearing (b) half-millimeter wide fracture extends.

JF69L–48: Greywacke, claim HR 3, South Lorrain. Analyses made on chlorite spots in different beds 1.3 cm apart.

JF69–442: Archean pillow flow near Vein 65, RL 401, Cobalt. Analysis (a) from core, and (b) from edge of a 1.5 × 0.5 mm rectangular pseudomorph. Chlorite in the section also occurs in intergrowths (c) partly replacing biotite.

chemical changes may have occurred during spot development. Although changes in bulk composition are not evident in Huronian sediments, some spotted Archean rocks may have sustained a change in mineralogy and texture. This apparent contradiction arises because amphibole and biotite are abundant only in some Archean rocks which have not been affected by spotting; in spotted rocks the melanosomes are always chlorite. Thomson (1961c, p. 103) also noted that "In places quartz veinlets and irregular shapes up to 1½ inches wide make up 5 to 10 per cent of the (Archean volcanic) rock over small areas; the quartz veinlets appeared to be genetically associated with the development of chlorite". On the east side of Cobalt Lake (claim RL 404) the present writer noted that numerous pink

TABLE 80. CHEMICAL ANALYSES OF SPOTTED ARCHEAN ROCKS AND THEIR UNAFFECTED EQUIVALENTS FROM NIPISSING RL 404, COBALT

Wt. %	Pillow andesite [1]		Lamprophyre dyke [2]		
	spotted	unaffected	spotted	unaffected	lightly spotted
SiO_2	60.75	55.64	50.9	53.2	52.8
Al_2O_3	18.51	16.33	12.9	12.4	12.5
Fe_2O_3	0.59	nil	3.5	1.6	2.2
FeO	4.56	7.38	8.8	7.9	9.1
MnO	0.03	0.27	0.20	0.32	0.20
MgO	3.10	3.39	10.9	9.5	9.6
CaO	0.31	4.03	2.1	6.7	5.9
Na_2O	5.72	5.38	1.6	3.8	4.0
K_2O	1.65	1.46	0.5	1.2	0.4
TiO_2	1.28	1.49	0.93	0.76	0.73
Cr_2O_3	0.03	0.03	*	*	*
V_2O_3	0.05	0.04	*	*	*
P_2O_5	trace	trace	0.51	0.42	0.42
H_2O^+	2.37	2.58	7.0	3.3	3.9
H_2O^-	0.08	0.04			
CO_2	1.14	2.44	0.1	0.1	0.1
	100.17	100.50	99.94	101.20	101.85

* Not determined.

[1] Analyses from Thomson (1961c).

[2] Spotted dyke sample approximately 35 m southeast of vein 44; unaffected sample 120 m southeast, and lightly spotted sample 150 m southeast of the spotted one. Analyses by Rapid Methods Group, G.S.C.

feldspar veinlets averaging less than half a centimeter in width occur in the Archean volcanics only where spotting is weak or absent. The distribution of the veinlets, which consist of maximum microcline with small amounts of actinolite and axinite, suggests that homogenization or absorption of the veinlets may have coincided with spot development. These relationships may, on the other hand, be purely fortuitous for there are also a few localities where swarms of quartz veinlets occurring in Huronian sediments have no discernible relationship with spotting.

Chemical analyses to determine whether spotted alteration has been accompanied by changes in the bulk composition of the host rock are extremely difficult to interpret. Complications arise both because of the possible heterogeneity of the rocks, and because of the uncertainty as to whether the variations are wholly or partly attributable to reactions involving spot development. Two samples of spotted and unaffected andesite, 120 meters apart along strike, were examined by Thomson (1961c) who concluded from the analytical results (Table 80) that: (1) no very substantial change in composition was effected by the alteration, and (2) the abundance of carbonates in the unspotted sample and the low lime content of the spotted sample suggests that some carbonate was extracted during the spotting process.

Because the validity of these conclusions is difficult to assess, supplementary chemical analyses were obtained for three specimens of the Archean lamprophyre dyke exposed on the southeast corner of claim RL 404 on the east side of Cobalt Lake. Only one of the samples showed prominent spotting. In thin section the rocks contain several per cent biotite phenocrysts up to a millimeter in diameter in a fine-grained matrix of sodic plagioclase and actinolitic amphibole. Much of the biotite has been replaced by chlorite, but by far the most obvious difference among the rocks is the much lower amphibole and higher chlorite content of the prominently spotted sample.

Chemical analyses of the three dykes samples are given in Table 80. In comparing all 5 columns in the Table, the only consistent changes are the accompaniment of spotting by a decrease in CaO and an increase in Fe_2O_3. In the dyke, the principal mineralogical change involved is the above-mentioned substitution of chlorite for amphibole. Other chemical changes with spotting in the andesite and dyke are inconsistent. For example, spotting in the dyke is accompanied by a notable increase in H_2O (as would be anticipated from chloritization), but this trend is not present in the andesite. Likewise, Fe_2O_3 increases with spotting in all 5 analyses, but neither ferrous oxide nor total iron have consistent variation trends. The increase in ferric iron is nevertheless consistent and shows that the unspotted rocks are in a more reduced state. The only other uniformly demonstrable chemical change accompanying spotting is the decrease in calcium and this is in large measure attributable to the decrease in amphibole. The presence or absence of carbonate does not seem to be significant.

Origin of the Spots

Neither the presence nor intensity of spotting coincides with the occurrence of productive veins. Ore veins cut through spotted rocks either without effect, or with the effect being limited to a partial obliteration of the spots in the zone of wall rock alteration. Barker's (1966) conclusion that the chloritic spots were formed prior to the development of the ore vein fractures is concurred with.

In his study of the distribution of the spotting on claim RL 404 on the east side of Cobalt Lake, Thomson (1961c, p. 84) noted the following :

> "In considering proximity of the causative agency, it is well to note that proximity of the diabase is not important.... The only hypothesis that seems to afford an explanation of the position of the area of intense alteration... is proximity to channelways permitting access and circulation of heated fluids. The channelways cannot be pointed out precisely but the vicinity is traversed by numerous surfaces of breakage. In part the channelways associated with the metamorphism appear to be the same as those followed later by the fluids causing silver-cobalt mineralization". On the LaRose property to the north of RL 404, Thomson (1961b, p. 94) stated that "A somewhat greater development (of spots) in proximity to the Cobalt Lake fault as well as the Violet fault suggests that the causative agencies followed the faults".

That major faulting coincides in some cases with intense spotted alteration is an unquestionable fact; that there is genetic connection is decidely tenuous, for most spotting lacks any relationship with faults. Even in the cases referred to by Thomson, the associations are of a general nature and maximum spot development is not adjacent to the faults as might be expected if these were solution channelways. There is, on the other hand, a consistent association of spot development with respect to the contacts of the Nipissing diabase. Where the diabase and spotting can be examined in continuous outcrop, or in mine workings, the spotting occurs as an envelope approximately 100 meters thick above and below the diabase contacts. Thomson's (1961c) comment that the spotting on the east side of Cobalt Lake shows no important correlation with the proximity of the Nipissing diabase must refer to the presently-exposed contact rather than the pre-erosional one; as shown by Knight (1924), reconstruction of the geological contacts in this area shows that prior to faulting and erosion, the lower contact of the diabase was probably less than 75 meters from the present surface.

The mineral species present in the chloritic spots do not alone provide clear indications of whether extraneous metasomatic effects have been involved in their formation. Chlorite, sphene, calcite, apatite, and the other minerals could have been derived by movement of material from the area surrounding each spot. In most cases this has apparently occurred, but in some spots the indications of movement are less obvious. The abundance of apatite, for example, appears to be too great in some spots if it is to be accounted for by local extraction. On the other hand, all of the minerals found in the spots also occur in variable amounts in unspotted rocks and in the unaltered portions of spotted rocks. If widespread metasomatism had occurred, expectations are that at least some degree of compositional homogenization might have been attained. The available microprobe analyses suggest, however, that the chlorites are considerably heterogeneous. The absence or rarity of spots in Lorrain arkose and quartzite also strongly suggests that metasomatism is not the cause of spot development.

Though they are of a smaller size and different mineralogy, the spots at Cobalt are megasopically similar to the "fleck" or "stictolithic" structures (Mehnert 1968) which have been described in great detail by Loberg (1963) and Russel (1969) because of their possible importance as models for metamorphic differentiation towards migmatites and granites. The fleck rocks, however, contain minerals such as muscovite, biotite, cordierite, sillimanite, and andalusite. In most parts of the world, spot development occurs in the thermal aureole around intrusions as a result of contact metamorphism. Though chlorite porphyroblasts do form in such situations (e.g. Woodland 1963 ; Brooks 1967) the occurrence of chlorite glomeroblasts seems to be rare.

The intensity of spotting at Cobalt is partly dependent upon passive factors, namely, the composition and physical properties of the affected rock. A high argillaceous content and a grain size sufficiently coarse to readily permit intergranular movement of matrix components are factors favouring spot development. Accordingly, spots occur more widely in Gowganda Formation sediments than in the relatively compact Archean rocks. These textural differences may also account for the commonly similar size and correspondingly greater number of spots in most Huronian occurrences, as a generally smaller domain was necessary to supply the chlorite components.

The active component essential to spot formation was probably heat from the Nipissing diabase. Spot development occurred after intrusion of the diabase sheets, but may have been completed before the total crystallization of all diabase components was attained. All rocks of apparently suitable composition have not been affected by the spotting process, but sporadic effects in contact metamorphism are not unique to Cobalt. The discontinuous blanket-like distribution of the spots could partly be a function of the grain boundary water present in the aureole rocks. Although heat was probably the critical activation factor, pressure may also have played a role. Hawkes (1969), for example, has suggested that erratic pressure fluctuations may occur in an aureole through the mechanical effects exerted by the magma during intrusion. If compressive stresses were involved in the intrusion of the Nipissing diabases (*see* Gretener 1969), pressure relief could have accompanied the cooling of the sheets. The most intense spotting may have occurred only where temperature, grain boundary water, and pressure effects (though the last were probably very small), coincided to form a more ideal environment for blast growth.

Spotting is not directly related to ore deposition and is not a guide to individual ore veins. However, nearly all ore deposition occurred within the boundaries of the Nipissing diabase thermal aureole, and in this respect only can the presence of spotting be considered as a favourable exploration guide.