AN UNUSUAL OCCURRENCE OF DIOPSIDE AND UVAROVITE NEAR THETFORD, QUEBEC

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ABSTRACT

Some small vug-like cavities in a diopside pyroxenite dyke near Thetford, Quebec, are found to contain perfect acicular chromian diopside, fine uvarovite, and calcite rhombohedra. Comparisons are made with similar mineral assemblages in the Montreal Chrome Pit and it is proposed that the divergencies in crystallographic and optical properties of the chromian diopside arise largely from a higher alumina and possibly chromium content. Comparison of the chemical composition of the enclosing pyroxenite host rock with that of the minerals in the partially filled cavities suggests a hydrothermal origin similar to that outlined for similar mineral assemblages in the Black Lake area by Poitevin & Graham (1918).

INTRODUCTION

An unidentified specimen collected by Dr. G. Baker at the Normandie (asbestos) open cut near Thetford, Quebec was kindly made available

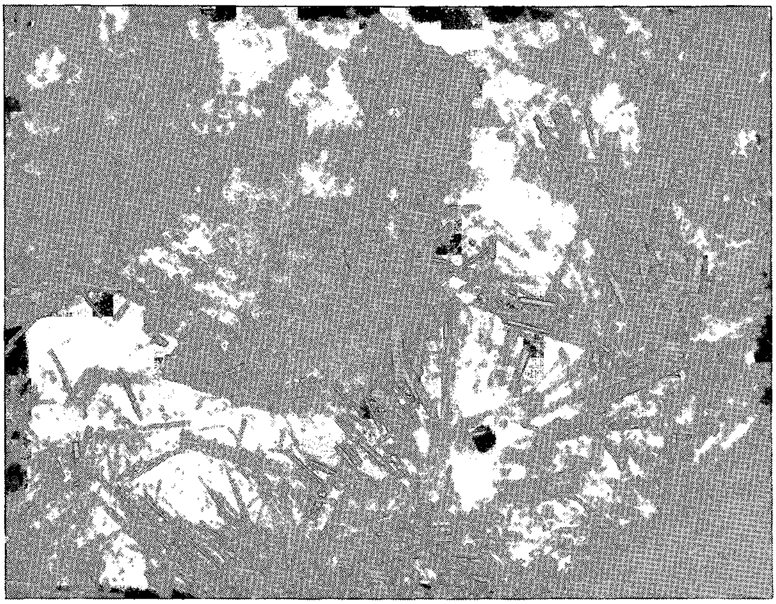

FIG. 1. Chromian diopside needles with a large calcite rhombohedron and minute uvarovite crystals in a cavity in massive white diopside from Normandie, near Thetford, Quebec. ×4 magnification.

to the writer for examination. The specimen, Fig. 1, consists of a fine grained white diopside rock with one large and two smaller vug-like cavities containing abundant green and a few colourless acicular inward-growing diopside crystals—with some minute euhedral bright green uvarovite crystals and two large colourless calcite rhombohedra.

The specimen derives from a large pyroxenite dyke intruding the serpentinised ultrabasic mass (Baker, personal communication), and is thus similar to certain diopside dykes and veinlets in the Montreal Chrome Pit (Poitevin & Graham 1918).

Mineralogy

Optical properties

The enclosing white pyroxenite consists almost exclusively of colourless interlocking diopside prisms which are complexly twinned parallel to (100). Within the main partially filled cavity on the other hand, these crystals are distinctly needle-like, and show a conspicuous radiating structure. The larger crystals which are up to 2.5 cm long, also possess a strong longitudinal colour (and compositional) zoning, those portions adjacent to the cavity walls being off-whitish, but grading inwards to a greenish colour in the cavity centre. In addition perfectly formed uvarovite dodecahedra are closely associated with the green diopside but are not very abundant. Most of the uvarovite crystals, which range from 0.1 to 1.0 mm. in diameter, have been almost entirely pseudomorphed by a conspicuous retinalite-type antigorite with a β-refractive index of 1.550 and practically no associated magnetite as indicated by both optical and x-ray diffraction means. Calcite is relatively common in the main cavity forming euhedral rhombohedra of up to 7 mm. across.

The optical properties of the colour varieties of the diopside from Normandie and the Black Lake area (Poitevin & Graham 1918), are compared in Table 1.

Table 1. Optical Properties of Diopside, Thetford and Black Lake

Refractive indices	White diopside of host rock	Green diopside of cavity	Colourless diopside[1]
α	1.677	1.673	1.669
β	1.688	1.684	1.671
γ	1.707	1.703	1.698
Optic axial angle ($2V_z$)	63°–65°	66°–69°	59°29′
Extinction angle $Z \wedge c$	43°	45°	38°21′
Specific gravity	3.26	3.29	3.267

[1] Crystals from drusy cavity in diopside dyke Montreal Pit (Poitevin & Graham (1918)).

X-ray diffraction data

The principal mineralogical identifications were confirmed by *x*-ray diffraction, and it is probable that the secondary antigorite after uvarovite is comparable with the chromium variety described by Glass, Vlisidis, & Pearre (1959).

(1) *Uvarovite.* Although the lattice constant of the Normandie uvarovite (Table 2) is rather low compared with the majority of recorded specimens, these ranging from 11.915 Å to 12.000 Å (Geller & Miller 1959; Menzer 1928–29; Frankel 1959), it is nevertheless fairly close to a specimen reported from Orford, Quebec (11.87 Å) by Gillery*, although compositionally the latter might be closer to grossularite (Geller & Miller 1959); synthetic grossularite has a = 11.851 Å. In view of this the Normandie uvarovite might alternatively be termed a chromian grossularite, and it is noteworthy that like the Orford garnet it shows no direct relationship between the unit cell constant, specific gravity, and chromium content as suggested by Frankel for comparable Bushveld specimens (1959).

TABLE 2. *X*-RAY POWDER DATA FOR NORMANDIE UVAROVITE

hkl	*d* obs	*d* calc	*I*	*hkl*	*d* obs	*d* calc	*I*
400	2.96	2.97	60	800	1.483	1.481	20
420	2.65	2.65	100	840	1.327	1.326	25
332	2.52	2.53	20	842	1.294	1.294	45
422	2.42	2.42	40	664	1.264	1.263	15
431	2.32	2.33	25	941	1.199	1.198	5
521	2.16	2.17	20	10.20	1.167	1.162	1
611, 532	1.92	1.92	40	10.40, 864	1.103	1.100	25
620	1.88	1.87	5	10.42	1.094	1.082	22
444	1.710	1.71	25	880	1.049	1.048	20
650	1.646	1.644	50	12.00	.990	.989	10
642	1.585	1.584	75	12.20	.977	.975	10
732, 651	1.504	1.504	2				

a_0 = 11.855 Å Specific gravity (meas.) = 3.79 Refractive index = 1.867

(2) *Diopside.* The *x*-ray diffraction data and unit cell dimensions for the diopsides from Normandie are compared in Table 3. The two varieties are found to be structurally very similar although their intensities diverge quite considerably. This is best illustrated in the accompanying *x*-ray diffraction traces (Fig. 2). In these diffraction traces a few extra peaks, not previously observed, have been indexed (Table 3) but the green colouration of the "cavity" diopside cannot be due to finely disseminated uvarovite.

Finally it seems probable that the slight divergencies in the unit cell constants for the two colour varieties of diopside at Normandie arise

*ASTM data file No. 7–70.

TABLE 3. *X*-RAY POWDER SPACING DATA FOR DIOPSIDE FROM NORMANDIE, QUEBEC

Green diopside needles in cavity				White diopside of pyroxenite host rock		
d (meas.)	*d* (calc.)	*I*	*hkl*	*d* (meas.)	*d* (calc.)	*I*
4.682	4.670	2	200	—	—	—
4.446	4.454	5	020	4.449	4.472	30
3.333	3.335	2	021	3.342	3.344	4
3.221	3.222	54	220	3.223	3.224	48
2.982	2.975	27	221	2.990	2.989	58
2.937	2.941	100	310	2.941	2.932	53
2.880	2.874	12	$31\bar{1}$	2.895	2.883	11
2.830	2.847	2	211	2.832	2.864	6
2.551	2.555	5	$13\bar{1}$	2.556	2.568	30
—	—	—	$32\bar{1}$, 002, $20\bar{2}$	2.522	2.522	8
2.509	2.512	15	230, 221	2.508	2.508	16
2.343	2.417	6	$21\bar{2}$	—	—	—
2.290	2.288	5	$41\bar{1}$, $30\bar{2}$, 311	2.297	2.293	5
2.208	2.210	2	112	2.211	2.208	2
2.188	2.190	2	022	2.195	2.195	2
2.143	2.149	15	330	2.150	2.15	26
2.121	2.122	8	$33\bar{1}$	2.126	2.131	21
2.096	2.095	2	$42\bar{1}$	2.102	2.100	5
—	—	—	321	2.070	2.092	3
2.031	2.010	4	$14\bar{1}$, 041	2.039	2.044	16
2.005	1.998	2	$40\bar{2}$	2.009	2.010	8
1.962	1.960	2	$13\bar{2}$	1.963	1.969	1
—	—	—	$43\bar{1}$	1.854	1.860	3
1.826	1.829	8	430	1.829	1.835	6
1.746	1.750	12	150	1.750	1.757	100
—	—	—	003	1.679	1.680	1
1.618	1.616	15	$22\bar{3}$	1.621	1.620	18
1.611	1.611	12	440	1.614	1.613	21
—	—	—	530	1.583	1.580	1
1.557	1.557	28	600	1.559	1.551	3
1.543	1.547	4	350	1.547	1.550	15
—	—	—	$35\bar{1}$	1.542	1.543	6
1.520	1.517	2	$62\bar{1}$	1.521	1.518	5
—	—	—	521	1.501	1.513	4
1.481	1.482	2	060	1.497	1.490	2
—	—	—	242	1.484	1.487	24
—	—	—	450, 260	1.419	1.418	19
1.418	1.420	60	531	1.415	1.415	10
1.403	1.403	16	$35\bar{2}$	1.406	1.410	3
—	—	—	252	1.327	1.331	2
—	—	—	—	1.324	—	—
1.324	1.324	15	512	1.314	1.317	1
1.277	1.278	10	$26\bar{2}$	1.279	1.282	9
1.245	1.258	5	004	1.246	1.258	3

Calculated unit cell data	*Calculated unit cell data*
$a_0 = 9.720 \pm 0.003$ Å	$a_0 = 9.724 \pm 0.003$ Å
$b_0 = 8.920 \pm 0.003$ Å	$b_0 = 8.940 \pm 0.003$ Å
$c_0 = 5.235 \pm 0.003$ Å	$c_0 = 5.254 \pm 0.003$ Å
Volume = 436.5 Å^3	Volume = 438.5 Å^3
$\beta = 105°21' \pm 5'$	$\beta = 106°6' \neq 5'$
$a_0:b_0:c_0 = 1.088:1:0.587$.	$a_0:b_0:c_0 = 1.087:1:0.587$.

largely from the relatively small variations in the alumina (and possibly also the chromium) contents, while at the same time the greenish chromium diopside has inherited a degree of disorder that is now reflected in its conspicuously different order of diffraction peaks. This apparent disorder may also be reflected in the even more complex multiple twinning of the greenish diopside compared with the white variety.

Chemical Data

Chemical analyses were made by standard volumetric and gravimetric techniques, but also by combined chemical and quantitative spectrographic means when only relatively minute quantities of sample were available. The gravimetric analyses together with the calculated atomic contents are listed in Table 4. The molecular compositions calculated from these results are compared in Table 5.

The most significant features of these analyses are the slightly higher wollastonite and ferrosilite contents of the greenish diopside together

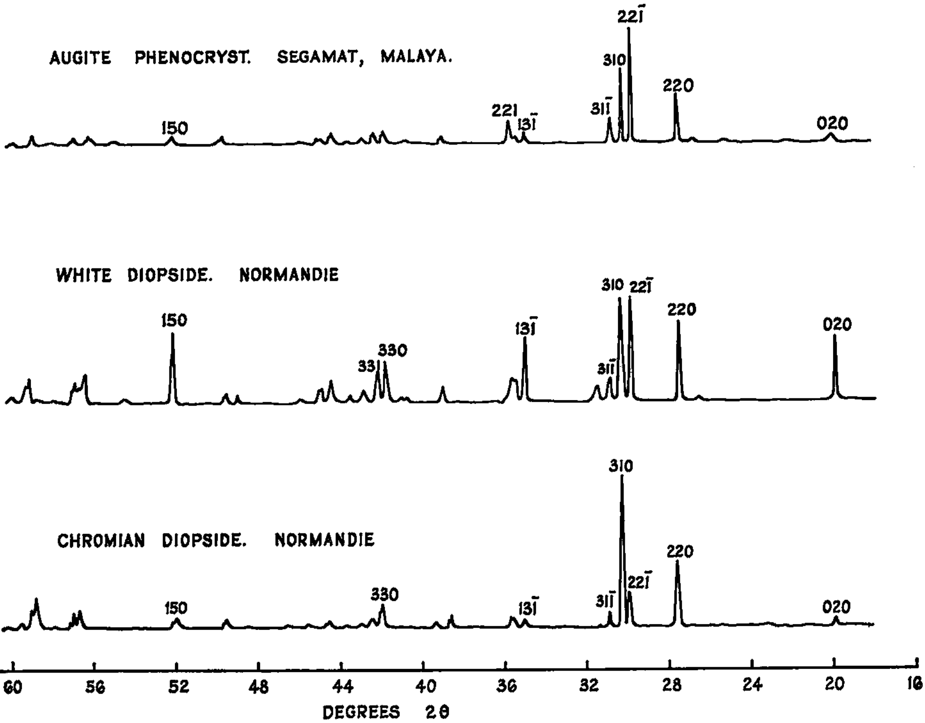

FIG. 2. X-ray diffraction traces of chromian and white diopside from Normandie, Quebec compared with calcium-rich augite phenocryst from a leucite-tephrite lava at Segamat, Malaya. Cu$K\alpha$ Ni filter.

with the fact that both pyroxenes are situated in the extreme margin of the diopside field. This crystallization trend does not conform to most pyroxene crystallization trends in basic intrusive bodies, although Le Bas (1962) has observed an increased substitution of Al for Si in the *Z* group of the pyroxene structure in late stage alkaline—as opposed to tholeiitic—differentiates. As an alternative it is probable that the extremely volatile—and calcium-rich hydrothermal conditions at Normandie were more conductive to late-stage calcium enrichment in the diopside.

TABLE 4. CHEMICAL ANALYSES AND UNIT CELL CONTENTS OF DIOPSIDE FROM NORMANDIE, NEAR THETFORD, QUEBEC

	White				Green			
	% by weight		Atomic contents		% by weight		Atomic contents	
SiO_2	52.70	Si	7.62	*Z*	51.7	Si	7.45	*Z*
Al_2O_3	1.87	Al	.32		4.3	Al	.74	
Fe_2O_3	0.43	Fe^{3+}	.05	*WXY*	0.4	Fe^3	.04	*WXY*
FeO	2.97	Fe^{2+}	.36		3.04	Fe^2	.37	
MgO	15.75	Mg	3.40		14.40	Mg	3.11	
CaO	24.57	Ca	3.80		24.90	Ca	3.83	
Na_2O	0.42	Na	.12		0.40	Na	.12	
K_2O	0.18	K	.03		nil			
Li_2O	0.12	Li	.03		nil			
H_2O	0.08				n.d.			
Cr_2O_3	Nil				0.92	Cr	.10	
TiO_2	0.12	Ti	.01		0.05	Ti	.005	
P_2O_5	Nil	Mn	.01		n.d.	O	23.69	
MnO	0.10	O	23.67		n.d.			
Total	99.31				100.1			

Analyst: T. H. Donnelly.

TABLE 5. CALCULATED MOLECULAR COMPOSITIONS OF GREEN AND WHITE DIOPSIDE FROM NORMANDIE, NEAR THETFORD, QUEBEC

	Green chromian diopside	White diopside
	%	%
$CaSiO_3$	51.90	49.80
$MgSiO_3$	42.10	44.60
$FeSiO_3$	5.14	4.72
$CrNaSi_2O_6$	.67	—
$NaFe^3{-}Si_2O_6$	.16	.26
$LiAlSi_2O_6$	—	.39
Total	100.07	99.77

An analysis of the Normandie uvarovite (Table 6) conforms fairly closely to published data, notably from S. Africa (Frankel 1959). Furthermore whereas the relationship between unit cell parameter (*a*) and the Cr_2O_3 content is closer to that observed by von Knorring (1951), the relationships between this and the refractive index and specific gravity are rather closer to those obtained by Frankel (1959).

TABLE 6. CHEMICAL ANALYSIS OF UVAROVITE FROM NORMANDIE, NEAR THETFORD, QUEBEC

SiO_2	35.0
Al_2O_3	8.76
Fe_2O_3 FeO	5.26
MgO	0.77
CaO	37.50
Cr_2O_3	10.20
TiO_2	0.09
Total:	97.58

Analyst: T. H. Donnelly.

Petrogenesis

The occurrence of dykes and veinlets containing diopside, garnet, and calcite—often with a subsidiary drusy texture—has previously been described from the Montreal Chrome Pit and the Sherbrooke district, yet this appears to be the first example of such an assemblage from Normandie.

The origin of the diopside dykes in the Black Lake area was discussed in some detail by Poitevin & Graham (1918), who concluded that they are of hydrothermal origin and formed after the solidification of the late aplite and granitic intrusives within the serpentinite. The abundant calcium they considered was derived largely through leaching of the serpentinite country rock and not by enrichment in the residual magma by fractional crystallization. In addition it was observed that these diopside dykes are far more common in the more calcium rich peridotite of the chrome pits than in the asbestos cuts. Thus although there seems little reason to suggest an alternative origin for the diopside dyke at Normandie, its very occurrence in this serpentinite, in addition to the presence of uvarovite and chromian diopside in the late drusy cavities, might suggest an even more selective solvent action of the residual fluids towards calcium, while both the chromium and aluminium show further enrichment in the final stages of crystallization in the dyke. This latter feature is clearly indicated by the presence of chromian diopside, uvarovite, and large calcite rhombohedra within the partially filled drusy cavities.

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