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CARBONATE MINERALOGY OF THE LOWER ORDOVICIAN BURCHARDS LIMESTONE IN WEST-CENTRAL VERMONT

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ABSTRACT. The mineralogy of mottled limestones and associated dolostones of the Lower Ordovician Burchards limestone in west-central Vermont was quantitatively studied by x-ray diffraction. The dolomitic mottled patches consist of dolomite and calcite, and the bulk chemical composition calculates out consistently to about 30 percent of $MgCO_3$ by weight, which is verified by wet chemical analysis. Among the mottled patches, outlines of mollusks can be discerned locally. This fact, together with the constant chemical composition of the patches, in contrast with the nearly dolomite-free limestone matrix, suggests that the patches may be recrystallized organic debris with the magnesium derived locally from original high-magnesium calcite. The bedded nature of the Burchards further suggests a fore reef detrital origin, which agrees with present knowledge of the paleogeography of the area during Early Ordovician time.

The Burchards limestone of west-central Vermont, whose stratigraphic relations are discussed in another contribution (Cady and Zen, in preparation), has been studied mineralogically in an effort to understand its origin. The dolomite-mottled limestone, the associated massive dolostone, and also limestone and dolostone from the adjacent Weybridge member, have been collected from the Seager Hill-Willow Brook area in the vicinity of Brandon.

On a fresh surface, the dolomitic patches of the Burchards limestone can be distinguished, by their olive-gray color and coarser grain size, from the aphanitic, dark grey "matrix". The weathered surfaces of the dolomitic patches are smooth and yellow-gray in color, and of the "matrix", light bluish gray. Rarely, gastropod and brachiopod forms can be identified and associated with the dolomitic patches on weathered surfaces. The two rock types can also be distinguished in thin sections, as the "matrix" is much darker and finer grained; the dolomitic patches, in rare instances, show curved outlines of fossil remains, some of which are brachiopods, but which generally cannot be recognized.

Samples of the two lithologies were obtained by careful drilling of the specimens. The x-ray data on these, and on the other rock types, are given in table 1. The (10.4) spacings of calcite and dolomite were measured on the Norelco diffractometer at a goniometer speed of $\frac{1}{4}°$ per minute and chart speed of $\frac{1}{2}''$ per minute; quartz was used as internal standard, $2\Theta_{CuK\alpha}$ (10.1) quartz = 26.664. For estimating the relative amounts of the two carbonates in a given sample, the method and calibration curves of Schmalz (1958) were used. Schmalz's method may be applied in two ways: either (1) by direct fixed-time counting of the reflected intensities at peak positions, with standardized corrections for the background, or (2) by measuring the peak height above background on the x-ray charts. Results using the latter method are given in tables 1 and 3 in parentheses.

Within limits of experimental error, estimated at $\pm$ 0.002Å, there is no difference between spacings of dolomite from the "matrix" and from the dolomitic patches, nor among different specimens. The same is true of calcite. This is understandable, since all but one sample contain both carbonates, and during regional metamorphism (Zen, in press) these carbonates, collected from a limited area, presumably have attained mutual chemical equilibrium and ought to show the same lattice spacings. X-ray fluorescence analyses on specimens 1162-1 and 1955-2 show their iron content to be negligible and manganese to be absent, both in the "matrix" and in the dolomitic patches. The lattice spacings also suggest that both calcite and dolomite are nearly pure $CaCO_3$ and $CaMg(CO_3)_2$, respectively.

Assuming that iron is absent and the phases are stoichiometric, the relative weight percents of $MgCO_3$ and $CaCO_3$ in the samples can be calculated. These are given in the last two columns of table 1. It is seen that errors of a few percent in the relative amounts of the two carbonates will not lead to large errors in the bulk chemical composition.

The dolomitic patches of the Burchards limestone are quite constant in composition, having about 70 percent of $CaCO_3$ by weight. The "matrix" is uniformly low in $MgCO_3$, although a dolomite phase is generally present. The other rock types show no consistent trend, although the massive dolostones show the highest $MgCO_3$ content. A partial chemical analysis of the dolomitic patches of specimen 1162-1 is given in table 2, with the calculated weight percents of $CaCO_3$ and $MgCO_3$. The agreement with x-ray data is remarkable.

In table 3 are listed for comparison the x-ray chemical data on a number of Lower- to Middle-Ordovician carbonate rocks from adjacent areas. Among the specimens, numbers 1, 2, and 7 require comment. Specimen no. 1 is lithologically identical with the Burchards type of the Willow Brook area and shows an internal cast of a gastropod on the weathered surface. The two lithologies are hard to distinguish in the fresh sample, however, and mutual contamination during drilling was possible. The dolomite content of the dolomitic patch and the "matrix", therefore, must be taken as minimal and maximal values, respectively. Specimen no. 2, from Fort Cassin, is correlative of the Burchards limestone (W. M. Cady, letter, May, 1958). Where broadly similar in lithology, however, the dolomitic patches are olive-brown on fresh surfaces and weather into light gray, slightly sandy areas, quite distinct from the typical Burchards of the Willow Brook area. They may not represent the same kind of material. It is thus interesting to note that data from specimen no. 1 agree with those from the Willow Brook area, whereas data from specimen no. 2 do not.

Specimen no. 7 is included because it contains the fossil *Girvanella* (?) which is supposed to be a calcareous alga. X-ray data show however that the fossil form contains no detectable dolomite and therefore it is presumably low in the $MgCO_3$ content as well.

Cady and Zen (in preparation) suggest a reef-origin for the Burchards limestone. The high magnesium content of the dolomitic patches might correspond to high-magnesium calcite which is present in the hard parts of many reef-forming organisms (Chave, 1954a, b; Goldsmith, Graf, and Joensuu, 1955; Schmalz, 1955). High-magnesium calcite is metastable (Graf and Goldsmith, 1955; Harker and Tuttle, 1955), and during diagenesis or regional metamorphism would break up into two phases, a calcite of lower magnesium content and a dolomite. This might be the mechanism for the formation of the

TABLE 1

X-ray Data on the Burchards Limestone and Related Rocks, Seager Hill-Willow Brook Area

Sample number	Locality	d (10.4), ±0.002Å Dol.	Calc.	Weight % Dol.	Calc.	Weight % $MgCO_3$	Weight % $CaCO_3$
1158-1 (massive dol.)	600′ el., ¼ mi. E. of Willow Br. School	2.886	3.032	81 (83)	19 (17)	36 (38)	64 (62)
1158-2 (ls.)	Same	2.886	3.030	10 (18)	90 (82)	5 (8)	95 (92)
1162-1 Dol. patch	550′ el., ⅛ mi. NW of 523′ road corner near Seager Hill	2.886	3.030	63 (70)	37 (30)	29 (32)	71 (68)
Matrix		2.887	3.032	(6)	(94)	(3)	(97)
1162-2	Same						
Dol. patch		2.887	3.030	(66)	(34)	(30)	(70)
Matrix		2.888	3.032	(9)	(91)	(4)	(96)
1953-1 (massive dol.)	630′ knob, 7/16 mi. SW of same road corner	2.887	3.030	(70)	(30)	(32)	(68)
1955-2 Dol. patch	690′ knob, 3/16 mi. S of the same road corner	2.888	3.032	65 (69)	35 (31)	30 (31)	70 (69)
Matrix		—	3.032	0	100	0	100
1955-3 (massive dol.)	Same	2.887	3.032	(0) (84)	(100) (16)	(0) (38)	(100) (62)
1955-4 Dol. patch	Along road ⅛ mi. SE of the same road corner	2.887	3.030	(64)		(36) (29)	(71)
Matrix		?	3.030	(7)		(93) (3)	(97)

TABLE 2

Partial Chemical Analysis of the Dolomitic Patches from Specimen 1162-1 (Burchards limestone from near Seager Hill near Brandon, Vermont)

J. Ito, analyst

CaO*	37.5
MgO	13.0
Fe, total, as Fe_2O_3	0.5
SiO_2	4.5
R_2O_3**	1.3

TABLE 2 (Continued)

* Spectrographic analysis shows only trace amounts of SrO and BaO in the CaO precipitate.

** Exclusive of Fe_2O_3. Spectrographic analysis shows this to be dominantly Al, Mn, Ni, Zn, and Cu but contains trace amounts of Mo, Cd, and Sn.

Spectrographic analysis of the "matrix" material from the same sample shows it contains order of 0.001% SrO.

Relative weight percents of the carbonates in the dolomitic patches:

	By chemical analysis	By x-ray
$CaCO_3$	71.1	71
$MgCO_3$	28.9	29

dolomitic patches, at least for the typical Burchards limestone of the Willow Brook area. The proposed mechanism is also suggested by Chave (1954b, p. 598) to account for some two-carbonate crinoid skeletons of Silurian and Triassic ages.

Calcareous algae were likely major reef-forming organisms during Lower Ordovician time. A modern form, *Goniolithon*, is reported by Chave (1954a, p. 273) to take up as much as 29 percent of $MgCO_3$ in solution in the calcite phase. This value is close to the 30 percent found in the dolomitic patches. Mollusk and possibly brachiopod remains in these patches, however, cannot be reconciled with Chave's data on their modern equivalents, and at least locally chemical readjustments must have occurred. The source of magnesium however may not have been outside of the rock; the sequence of phenomena here envisioned is similar to Schlanger's description (1957) of the dolomite growth of Eocene coralline algae from the Eniwetok drill core.

The presence of dolomite in the "matrix" suggests that fine particles of high-magnesium calcite may have been mixed in with the calcite at the time of deposition, thus they might correspond to a fore-reef detrital deposit, in agreement with the bedded nature of the Burchards limestone in the Willow Brook area. The dolomite may, however, be due merely to contamination by tiny dolomitic patches during the separation.

To see if one or the other of these two portions of the Burchards limestone could originally have been aragonitic, the "matrix" and the dolomitic patches were examined both by spectrographic and x-ray fluorescence methods, since any strong discrepancy in their strontium and barium contents might be correlated with the original mineralogy. X-ray fluorescence studies of specimen 1162-1 and 1955-2 show that these elements are virtually absent, both in the "matrix" and the dolomitic patches, to the limit of detection by the instrument on the untreated samples. Spectrographic results on specimen 1162-1 are given in table 2 and confirm the conclusions. The data are thus inconclusive for genetic interperetations.

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TABLE 3

X-ray Data on Lower and Middle Ordovician Carbonate Rocks from Cornwall, Waltham, and Ferrisburg Townships

Sample number	Locality	Description	Weight % Dol.	Weight % Calc.	Weight % $MgCO_3$	Weight % $CaCO_3$
1	1.0 mi. S of Cornwall village	Burchards ls.				
		Dol. patch, fresh	(65)	(35)	(30)	(70)
		Same, weathered	(91)	(9)	(42)	(58)
		Matrix	(4)	(96)	(2)	(98)
2	E shore of peninsula, Fort Cassin, Ferrisburg	"Reefy" ls. correlative of Burchards				
		Dol. patch	(85)	(15)	(39)	(61)
		Matrix	(3)	(97)	(1)	(99)
3	N end of peninsula, same	Gyracone from loose block near exposure of Bascom ls.				
		Shell	(84)	(16)	(38)	(62)
		Filling, black ls.	(0)	(100)	(0)	(100)
4	SW end of peninsula, same	Massive dol. between Bascom and Burchards types	(97)	(3)	(44)	(56)
5	1.0 mi. S of Cornwall village, E of road	Bridport dolomite	(86)	(14)	(39)	(61)
6	0.3 mi. S of road intersection 1.3 mi. SE of Fort Cassin	Chazyan limestone				
		Dol. patch	(68)	(32)	(31)	(69)
		Matrix	(12)	(88)	(6)	(94)
7	1.0 mi. NW of Buck Mtn., Waltham	Chazyan limestone				
		Girvanella (?)	(0)	(100)	(0)	(100)
		Matrix	(0)	(100)	(0)	(100)
8	Same as above, loose fragment	Black ls, filling of *Maclurites magnus*, Crown Point ls.	(17)	(83)	(8)	(92)

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