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SYNTHETIC DOLOMITE TEXTURES

By

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ABSTRACT

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Selective dolomitization of carbonate rocks is common in nature. Experiments in this study were conducted to test the effect of precursor crystal size and mineralogy on relative rates of dolomitization and textures of dolomitized fossils.

Cryptocrystalline and microcrystalline carbonate skeletal fragments composed of high Mg-calcite (HMC), low Mg-calcite (LMC) or aragonite (ARA) were hydrothermally altered at 250°C. The artifically produced dolomites showed distinct textural similarities to natural dolomites.

Cryptocrystalline skeletal materials composed of HMC and LMC were more readily dolomitized than microcrystalline substrates composed of LMC or aragonite. LMC was as readily dolomitized as HMC in cryptocrystalline fossils whereas microcrystalline LMC resisted dolomitization. Aragonite converted readily to dolomite at the skeleton-dolomitizing solution interface or to LMC in the fossil interior. Mimic replacement was observed in cryptocrystalline substrates composed of HMC and LMC.

ACKNOWLEDGEMENTS

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INTRODUCTION

The differential response of various fossils to dolomitization has been used to infer the mineralogy of fossils at the time of dolomitization (Schofield and Nelson, 1978; Buchbinder, 1979; Sibley, 1980 and 1982). This differential response might reflect mineralogy and/or crystal size of the material being dolomitized. This study examines the effects of mineralogy and crystal size on the texture of synthetically dolomitized fossils.

The experimental conditions employed in this study are vastly different ($T=250°C$) from the conditions under which dolomite usually forms. There is no way to rigorously ascertain the effect of this difference on the applicability of our results to sedimentary dolomite textures. Rock textures are a function of crystal nucleation and growth which are, in turn, determined by the solution and substrate. We have to infer the relative importance of the processes and variables through experiments and petrographic analysis. As discussed below, we conclude that our experiments are applicable to sedimentary dolomite because 1) the textures produced in artifical dolomites are similar to those found in natural dolomites and 2) the results are consistent with inferences made from petrographic analysis of natural dolomites.

PREVIOUS EXPERIMENTAL STUDIES

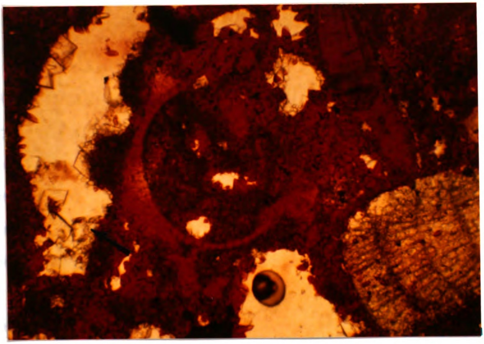
Previous experimental studies provide some insight into the relative rates of dolomitization of low Mg-calcite (LMC) and aragonite (ARA), but the experiments were not designed to test the rate of dolomitization as a function of both mineralogy and crystal size of the reactants. Katz and Matthews (1977) showed that ARA is dolomitized faster than LMC at 252°C, but they did not specify the relative surface area of the reactants. Grethen (1979) dolomitized LMC at 150°C and found the rate of dolomite formation is directly related to surface area of LMC. He also dolomitized HMC and ARA but it is not possible, with his data, to evaluate the effects of mineralogy on the rate of dolomite formation because the ARA and HMC were impure and had different surface areas. Gaines (1980) reports the following relative rates of dolomitization: ARA > HMC > LMC. Again surface areas of reactants were not determined.

Gaines (1980) also found that the addition of protodolomite to the reactants increased the reaction rate. He concluded that nucleation of the dolomite phase is an important factor in the reaction kinetics. Katz and Matthews (1977) seeded some of their experiments with synthetic dolomites and found no appreciable effects. Perhaps the disordered surface of protodolomite is a more efficient nucleant than the more ordered surface of dolomite.

PREVIOUS PETROGRAPHIC STUDIES

Lime mud is often more susceptible to dolomitization than calcite spar (Murray and Lucia, 1967) and aragonite (ARA) and HMC are more susceptible to dolomitization than LMC (Steidtmann, 1911; Fairbridge, 1957; Schmidt, 1965; Schofield and Nelson, 1978; Buchbinder, 1979; Armstrong, et. al., 1980; Baker and Kastner, 1981; Sibley, 1982). These inferred relative susceptibilities are based on petrographic interpretations which can be ambiguous. For instance, a selectively dolomitized coralline algal fragment (thin section 1) could be attributed to the fossil's fine crystal size, permeability, or original mineralogy (HMC). Another sample collected within a few meters of the sample shown in thin section 1 has a generation of LMC cement which preceded dolomitization. We interpret the LMC to indicate a period of freshwater diagenesis preceded dolomitization and, therefore, the fossil in thin section 1 probably converted to LMC prior to dolomitization.

Obviously, assessment of dolomite selectivity based on petrographic analysis is difficult. On the other hand, correct interpretation of dolomite selectivity may be useful for inferring the pre-dolomitization diagenetic history (Cullis, 1904; Sibley, 1980). The experimental results presented below are consistent with the interpretation that the dolomitized coralline algal fragment in thin section 1 was LMC at the time of dolomitization.



Thin section #1: Partially dolomitized packstone (Pliocene) from Curacao. Coralline algae (lower right) has been selectively dolomitized while the other fossils have been converted to LMC. Dolomite and calcite cement partially fill pores (arrow).

EXPERIMENTAL PROCEDURE

Experiments consisted of hydrothermally altering six different kinds of carbonate fossils (Table 1). These fossils were composed of HMC, LMC, or ARA and were classified as either microcrystalline or cryptocrystalline. Skeletal materials used in this study were: coralline algae, echinoids, forams, pelecypods, gastropods, and corals. Coralline algae and echinoids were dolomitized from their original HMC mineralogy and after hydrothermal alteration to LMC. All other fossils were dolomitized from their original mineralogies.

Fossils were prepared for experimentation in the following manner. First, fossils were broken into pieces ranging from .02-.07 grams and sonically rinsed to remove fine particles from their surfaces. Fossils were soaked for 15-60 minutes in 5.25% sodium hypochlorite to remove surface organics, rinsed with distilled water, and air dried on filter paper. X-ray diffraction analysis before and after soaking in the sodium hypochlorite solution showed that no mineralogical changes had taken place during removal of the organics.

Experiments were run in 6.6 and 18.5 ml stainless steel hydrothermal bombs with copper gasket seals (Appendix 1) placed in a Lindberg Hevi-duty muffle furnace or a Sybran Thermolyne 2000 furnace at 250°C. Pressure within the bombs was calculated using standard steam tables at 39 atmospheres.

Table 1. Composition and grain size classification for skeletal materials.

Fossil	Grain size	Mineralogy	Mole % $MgCO_3$
Coralline Algae	CRYPTO-X	HMC	16.9
Echinoid	CRYPTO-X	HMC	10.7
Foram	CRYPTO-X	HMC	13.0
		LMC	1.9-3.0
Pelecypod	MICRO-X	LMC	1.4
		ARA	0
Gastropod	MICRO-X	ARA	0
Coral	MICRO-X	ARA	0

CRYPTO-X = Cryptocrystalline
MICRO-X = Microcrystalline

Solutions used in the synthesis of dolomite and LMC were prepared using $CaCl_2 \cdot 2\ H_2O$ and $MgCl_2 \cdot 6H_2O$ Baker reagent grade chemicals to form 2M $MgCl_2$ and 2M $CaCl_2$ solutions.

Chemistry of the dolomitizing solution was similar for all experiments and was patterned after the work of Rosenberg and Holland (1964). Calculated $Ca^{2+}/Ca^{2+} + Mg^{2+}$ ratios for the total substrate and solution chemistry fell in the range of .70-.76, which is near the dolomite-magnesite boundary if temperature is interpolated to 250°C (Figure 1). This composition was chosen because it is the most Mg^{2+} rich chemistry within the dolomite stability range.

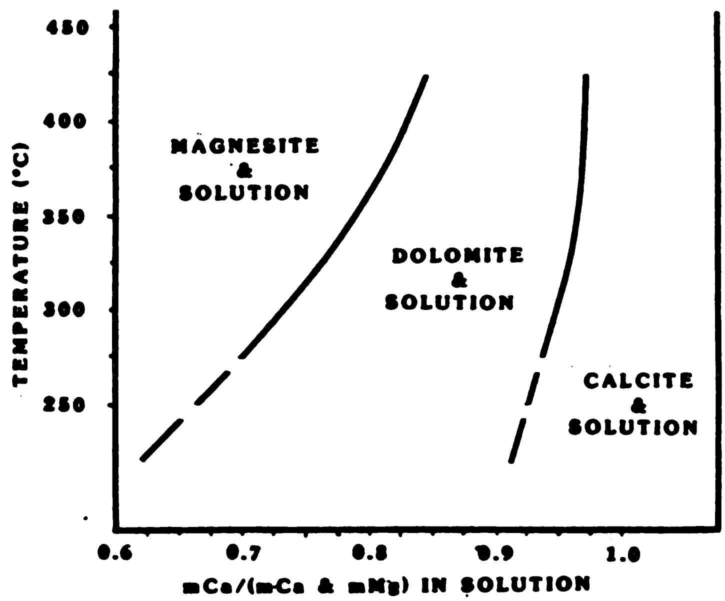


Figure 1. Stability fields for magnesite, dolomite and calcite (after Rosenberg and Holland, 1964).

Hydrothermal alteration of HMC coralline algae and echinoids to LMC was accomplished by using the 2 molar $CaCl_2$ solutions at 250°C.

Experiments run in 6.6 ml hydrothermal bombs had .0015-.5600 grams of sample with 4.9-5.2 ml of solution at 250°C for 4.5-398 hours. Bombs were quenched in cold water after removing from the oven.

Samples were removed soon after quenching and dried on filter paper or rinsed with acetone.

Experiments carried out in the 18.5 ml bomb followed the same procedure as above but contained .74-1.00 grams of substrate and 14.0-14.1 ml of solution. A complete listing of experimental parameters is shown in Table 2.

ANALYSIS

Samples were analyzed using X-ray diffraction or microprobe to determine mineralogy and were observed in thin section and scanning electron microscope to determine textural qualities.

X-ray diffraction was performed on a General Electric X-ray diffractometer using CuK radiation and a nickel filter. The apparatus was equipped with a 1° exit slit and a 0.1° and 0.05° scatter slits. Samples were scanned no less than five times at a rate of 2° 2 Θ/minute through the major peaks of fluorite, calcite, and dolomite and at least twice through the dolomite ordering peaks. Fluorite was used as an internal standard.

Mole % compositions for calcite and dolomite were determined from the following equations:

Dolomite (104 peak)

$$\text{mole \% } CaCO_3 = \frac{30.970 - 2\Theta}{.0323} + 50$$

Calcite (104 peak)

$$\text{mole \% } CaCO_3 = \frac{261.59}{\sin(2\Theta/2)} - 930.20$$

Table 2. Experimental Parameters.

Fossil	Reaction	Exp #	Sample Wt	ml Fluid	$Ca^{2+}/Ca^{2+} + Mg^{2+}$	Hours
C. Algae	HMC → DOLO	1*	.2136	5.1	.76	120
		14	.1930	5.2	.73	187.5
		29	.2288	5.0	.72	76
		35	.2533	5.0	.73	22
		41**	.3457	14.0	.70	126
		57	.2130	5.1	.71	120
		58	.1742	5.1	.72	4.5
	HMC → LMC	20	.3626	4.9	.95	116
		21	.3027	4.9	.96	116
		30	.4012	5.0	.95	52
		31	.4713	5.0	.94	139
		59	.3904	4.9	.95	283
	LMC → DOLO	37	.2648	5.0	.74	384
		39	.1310	5.1	.74	398
		55	.1223	5.1	.72	22
Echinoid	HMC → DOLO	7	.1361	5.1	.77	174.5
		15	.2013	5.2	.74	187.5
		26	.2532	4.9	.74	22
		52	.2564	4.9	.74	35
	HMC → LMC	16	.2591	5.0	.98	120
		17	.2877	5.0	.98	120
		32	.3914	5.0	.97	92
		38	1.0060	14.0	.97	186
	LMC → DOLO	36	.2238	5.0	.75	395
		40	.1401	5.1	.74	398
		54	.2205	5.1	.74	22

Table 2. (Continued).

Fossil	Reaction	Exp #	Sample Wt	ml Fluid	$Ca^{2+}/Ca^{2+} + Mg^{2+}$	Hours
Foram	HMC → DOLO	47	.0097	5.2	.71	92
		48	.0092	5.0	.71	92
	LMC → LMC	45	.0017	5.2	1.00	129.5
		46	.0015	5.2	1.00	129.5
	LMC → DOLO	42	.0035	5.2	.71	141.5
		43	.0034	5.2	.71	141.5
Coral	ARA → DOLO	12	.2101	5.2	.72	209
		23	.2143	5.0	.74	175
		24	.3443	5.2	.74	304.5
		27	.2048	5.0	.73	34
		34	.3604	5.0	.74	11.5
		53	.3021	5.0	.72	326.5
	ARA → LMC	56***	.4198	5.0	1.00	11.5
		60***	.5600	5.0	1.00	11.5
Gastropod	ARA → DOLO	11	.2003	5.2	.73	169
		18	.3703	5.2	.76	23
		19	.3105	5.2	.75	23
		22	.2243	5.0	.74	175
		41**	.4068	14.0	.70	126
		49	.3783	5.0	.71	343
	ARA → LMC	56***	.4198	5.0	1.00	11.5
		60***	.5600	5.0	1.00	11.5

Table 2. (Continued).

Fossil	Reaction	Exp #	Sample Wt	ml Fluid	$Ca^{2+}/Ca^{2+} + Mg^{2+}$	Hours
Pelecypod	ARA → DOLO	13	.2554	5.2	.73	209
		25	.3473	5.2	.74	183.5
		28	.1932	5.0	.73	23
		33	.2891	5.0	.74	11.5
		50	.2981	5.0	.71	247
	ARA → LMC	56***	.4198	5.0	1.00	11.5
		60***	.5600	5.0	1.00	11.5
	LMC → DOLO	61	.3361	5.0	.72	320
		62	.4131	5.1	.72	320

* Denotes experiments conducted with uncleaned samples.
** Denotes experiments run on sample mixtures of coralline algae and gastropods.
*** Denotes experiments run on sample mixtures of aragonitic pelecypods, gastropods, and corals.

Foram samples, too small to conveniently analyze by X-ray diffraction were prepared in polished section and microprobed for $CaCO_3$ and $MgCO_3$.

S.E.M. analysis was performed on an I.S.I. Super III and an I.S.I. Super III-A S.E.M.; the Super III-A was equipped with a Kevex X-ray system with a 7000 uX analytical spectrometer. This was used to identify chloride precipitates in several samples.

RESULTS

Coralline Algae

Seven experiments were run on the conversion of HMC coralline algae to dolomite lasting from 4.5 to 187.5 hours (Table 3). All experiments lasting 22 hours or more produced well-ordered dolomite. The experiment run for 4.5 hours produced a calcium-rich, poorly ordered dolomite.

Thin section #2 shows the unalterd skeleton. It is cryptocrystalline with no preferred optical orientation of grains. Micrographs #1 and 2 are high and low magnification shots of this texture seen by S.E.M.; micrograph #1 at 20,000X shows cryptocrystalline (< 1 um), subhedral, and tightly packed HMC. Micrograph #2 at 2,000X shows the porous nature of the fossil.

Dolomite produced from the HMC composition is seen in thin section #3. This particular specimen came from an experiment run 22 hours at 250°C. It is cryptocrystalline like its precursor and has retained a partial imprint of the original, porous texture. Micrographs #3 and 4 are comparison shots taken at the same magnification as those for the HMC coralline algae. At high magnification, crystal size and shape of the dolomite appears similar to that of the HMC, although intercrystalline porosity has increased during dolomitization. At low magnification, other dolomite textures are seen. Pores in the upper and lower righthand corners of the shot show dolomite rhombs similar to naturally

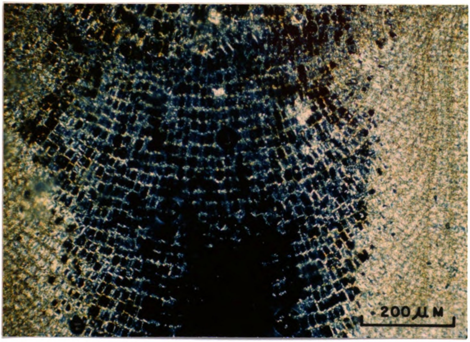
Table 3. X-ray diffraction results for experimentation on coralline algae. Initial composition: HMC with 16.9 mole % $MgCO_3$. Crystal size: cryptocrystalline.

Reaction	Hrs. of Exp.	End Product	Mole % $CaCO_3$	Exp. #
HMC → DOLO	4.5	P-O-DOLO*	53.6	58
	22	DOLO	49.9	35
	76	DOLO	48.5	29
	96	DOLO	49.3	57
	120	DOLO	50.6	1**
	126	DOLO	48.4	41***
	187.5	DOLO	50.0	14
LMC → DOLO	22	DOLO	51.0	55
	384	DOLO	50.0	37
	398	DOLO	49.8	39
HMC → LMC	52	HMC	89.1	30
	116	LMC	96.7	20
	116	LMC	96.4	21
	139	LMC	96.9	31
	283	LMC	97.4	59

* Denotes poorly ordered dolomite as the end product.
** Denotes experimentation on fossil framents which had organic coatings.
*** Denotes an experiment run with coralline algae-gastropod mixture.

Thin section #2: Unaltered coralline algae skeleton composed of HMC. Crystals are cryptocrystalline and show no preferred optical orientation.

Thin section #3: Dolomite produced from a natural, HMC coralline algae after 22 hours at 250°C. (Exp. #35). Texture is similar to the precursor. Cryptocrystalline crystals show no preferred optical orientation.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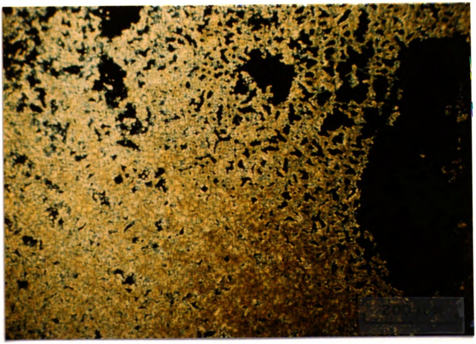
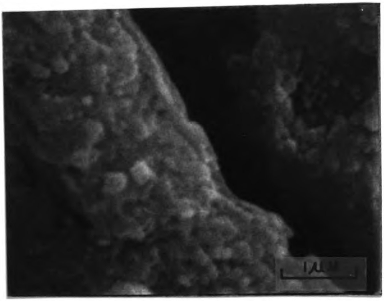


Micrograph #1: Unaltered, HMC coralline algae (20,000X). Crystals are less than 1 micron in size, subhedral, and tightly packed.

Micrograph #2: Unaltered, HMC coralline algae (2,000X). Porous nature of the fossil is seen.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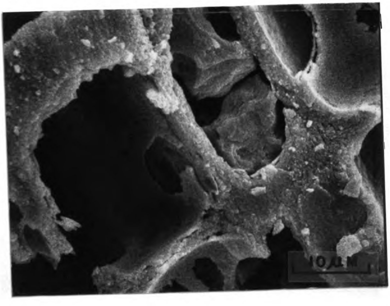
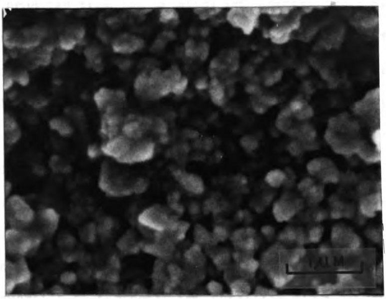

10μM

Micrograph #3: Dolomitized HMC coralline algae (20,000X) from experiment #35. Dolomite is cryptocrystalline, subhedral, and more porous than the original HMC crystals.

Micrograph #4: Dolomitized HMC coralline algae (2,000X) from experiment #35. Porous nature of the original skeleton has been preserved during dolomitization. Crystal coarsening is observed. Dolomite cement lines central pore (see arrow).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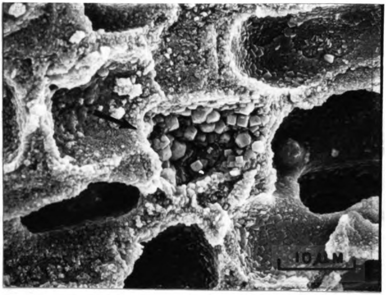

10µM

dolomitized coralline algae (micrograph #54). Dolomite cement lines the pore in the center of the shot. Overall skeletal structure has been preserved during dolomitization.

LMC for the reaction of LMC coralline algae to dolomite was synthetically produced from the original HMC composition. Experiments lasted from 52 to 283 hours and produced LMC in all experiments run for 116 hours or more (Table 3). The original 16.9 mole % $MgCO_3$ composition was altered to 10.9 mole % $MgCO_3$ after 52 hours and became LMC with @ 3.5 mole % $MgCO_3$ in two experiments run for 116 hours.

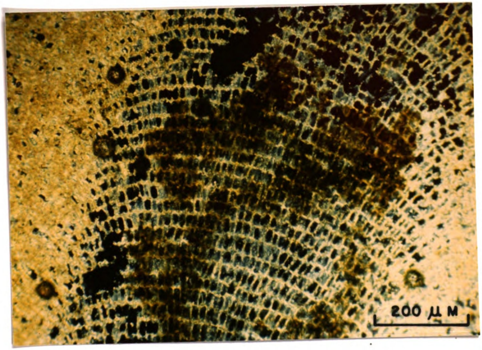
LMC produced from an experiment run 116 hours is seen in thin section #4. It is cryptocrystalline and has a fabric like that of the HMC coralline algae. Using S.E.M. (micrographs #5 and 6), a slight increase in crystal size is apparent.

The conversion of synthetic LMC coralline algae to dolomite took place in three different experiments lasting from 22 to 398 hours (Table 3). All experiments produced well-ordered dolomite.

Thin section #5 shows the texture produced from the reaction of synthetic LMC to dolomite. This dolomite resulted after 384 hours of reaction and is virtually indistinguishable from the dolomite produced in the reaction of HMC to dolomite. Both are predominantly cryptocrystalline with no preferred orientation of crystals and have retained partial imprints of the original fabric. Crystal size and shape of the dolomite produced from LMC (micrographs #7 and 8) appears somewhat coarser and more euhedral than the dolomite produced from HMC. Overall texture at low magnification is similar.

Thin section #4: Cryptocrystalline LMC from an experiment (#21) run 116 hours at 250°C. Texture is like that of the natural, HMC.

Thin section #5: Dolomite produced after 384 hours or experimentation. Texture is indistinguishable from that of dolomite produced from an HMC coralline algae.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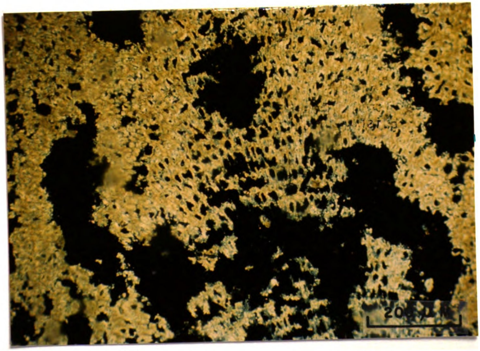
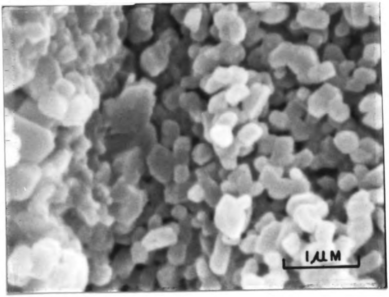


Micrograph #5: LMC produced from an HMC coralline algae after 116 hours of experimentation. LMC is cryptocrystalline and subhedral. Intercrystalline porosity has increased during the conversion of HMC to LMC.

Micrographs #6: LMC produced from a HMC coralline algae after 116 hours of experimentation (2,000X). Overall texture has been preserved.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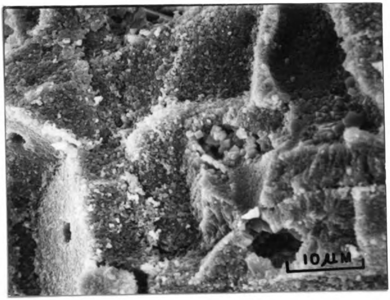
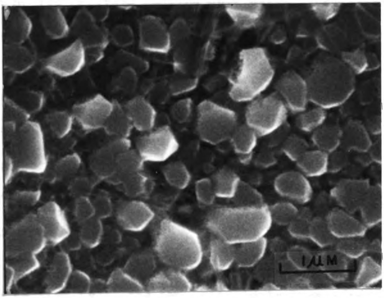

10μM

Micrograph #7: Dolomitized LMC coralline algae after 384 hours at 250°C (20,000X). Dolomite is cryptocrystalline and subhedral. It is slightly coarser than the dolomite produced from the HMC composition.

Micrograph #8: Dolomitized LMC coralline algae from and experiment run 384 hours (2,000X). Overall structure has been preserved.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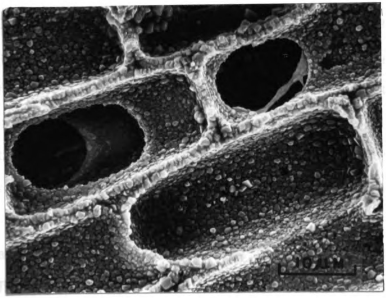

10μM

Echinoid

Echinoids were dolomitized from their original HMC composition and also after conversion to LMC. Thin section #6 is an unaltered fragment. It is porous, cryptocrystalline, and had a common optical orientation of its crystals causing unit extinction (Bathurst, 1975). S.E.M. view of this texture is seen at 2,000X and 200X in micrographs #9 and 10. The porous nature of the substrate is best seen at low magnification. Crystal size is so small that it is not visible even at high magnification.

Conversion of HMC echinoids to LMC was accomplished in four experiments run from 92 to 186 hours (Table 4). All experiments produced LMC with slightly lower mole % $MgCO_3$ than experiments run on coralline algae. Original composition of the echinoid was 10.7 mole % $MgCO_3$.

In thin section (#7), the LMC echinoid texture after 120 hours of experimentation appears similar to that of the HMC composition. It is cryptocrystalline, has unit extinction, and the same porous texture as the HMC echinoid. S.E.M. view of this is seen in micrographs #11 and 12. At 2,000X, the surface texture appears less smooth than that of its precursor. The tight, interlocking texture of LMC crystals makes crystal definition difficult. At 200X, the HMC and LMC textures look nearly identical.

Dolomitization of the HMC echinoid was studied in four different experiments run from 22 to 187.5 hours (Table 4). All experiments which used fossils soaked in sodium hypochlorite solution prior to experimentation produced well-ordered dolomite as the single phase end product. The experiment run with an uncleaned echinoid for 174.5 hours produced well-ordered dolomite and LMC as the end product phases. The

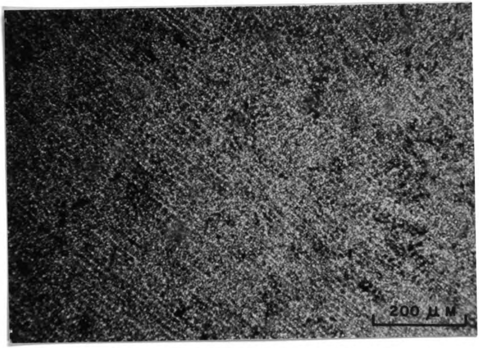
Table 4. X-ray diffraction results for experimentation on echinoids. Initial composition: HMC with 10.7 mole % $MgCO_3$. Crystal size: cryptocrystalline.

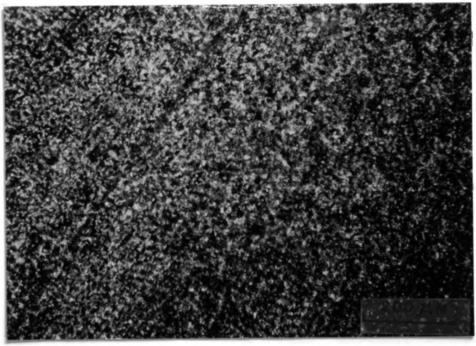
Reaction	Hrs. of Exp.	End Product	Mole % $CaCO_3$	Exp. #
HMC → DOLO	22	DOLO	50.0	26
	35	DOLO	50.2	52
	174.5	DOLO	49.8	7*
		LMC	97.7	
	187.5	DOLO	50.1	15
LMC → DOLO	22	DOLO	50.0	54
	395	DOLO	49.2	36
	398	DOLO	47.8	40
HMC → LMC	92	LMC	98.3	32
	120	LMC	99.0	16
	120	LMC	99.0	17
	186	LMC	96.6	38

* Denotes experiments run on fossils with organic coatings.

Thin section #6: Unaltered, cryptocrystalline echinoid skeleton. Preferred optical orientation of crystals is exhibited by unit extinction.

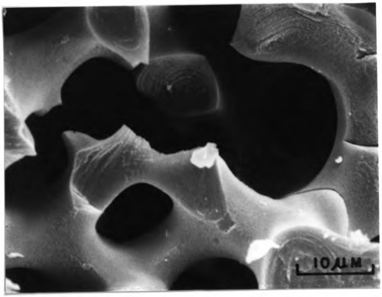
Thin section #7: LMC texture from an experiment (#17) conducted for 120 hours at 250°C. Texture is like that of its HMC precursor with cryptocrystalline crystals making up the porous structure. Preferred orientation of the crystals is exhibited by unit extinction.


200 μM



Micrograph #9: Unaltered HMC echinoid (2,000X). Skeleton is composed of a porous network. Crystals are too fine and densely packed to identify.

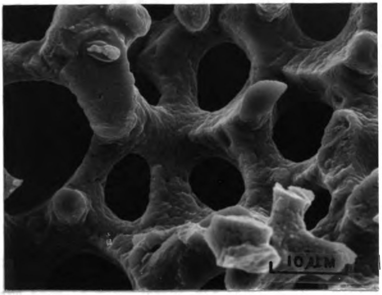
Micrograph #10: Unaltered HMC echinoid (200X). Homogeneous, porous network of the skeleton is seen.


10µM


100µM

Micrograph #11: LMC echinoid from an experiment run for 120 hours (2,000X). Surface undulations are seen but actual crystals are not identifable. LMC crystals appear as densely packed as the HMC.

Micrograph #12: LMC echinoid after 116 hours of experimentation (200X). Overall texture is preserved during conversion to LMC.



experiments run for 22, 35, and 187.5 hours with cleaned fossils produced well-ordered dolomite.

Dolomitization of HMC echinoids produced numerous cryptocrystalline and microcrystalline textures. These were not seen in thin section as they appear similar at low magnification but were well-defined by S.E.M. observation.

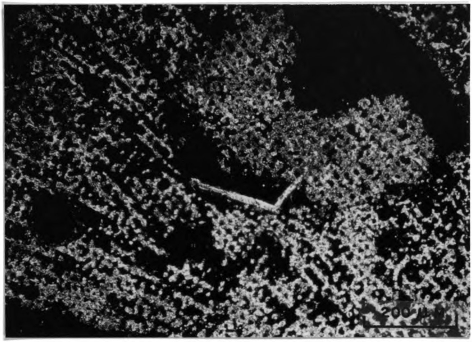
The thin section texture of the dolomitized HMC echinoid (#8) is cryptocrystalline to very fine microcrystalline and has retained the porous network fabric of its precursor. Mimic replacement of the HMC texture is displayed in the preservation of unit extinction. Zones of dissolution and zones of porosity occlusion were readily observed from dolomitization of this substrate.

Dolomite textures observed by S.E.M. for the conversion of HMC echinoids are seen in micrographs #13 through 16. Micrographs #13 and 14 came from an experiment run for 22 hours, and are from the same experiment as thin section #8. Micrographs #15 and 16 are from an experiment run 187.5 hours. At 200X, the texture looks the same throughout and from sample to sample. At higher magnification, the differences are obvious. The texture seen in micrograph #13 at 2,000X shows crystals growing into open pore space. The oriented, euhedral crystals appear to have grown in a zone where porosity occlusion was taking place; this may be related to a zone of dissolution nearby. Micrograph #15 at 2,000X shows cryptocrystalline, anhedral dolomite which replaced the fossil.

Three experiments were run on the dolomitization of LMC echinoid fragments (Table 4). They lasted from 22 to 398 hours. All produced well-ordered dolomite.

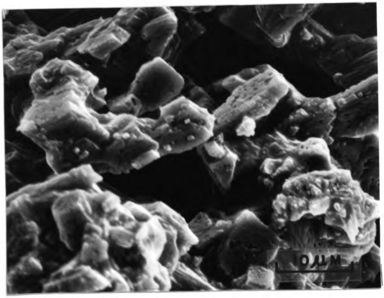
Thin section #8: Dolomitized HMC echinoid from experiment #26 after 22 hours of experimentation. Mimic replacement is exhibited by preservation of unit extinction. Crystals are cryptocrystalline to very fine microcrystalline.

Thin section #9: Dolomitized LMC echinoid after 395 hours at 250°C. Texture is indistinguishable from that of the dolomitized HMC echinoid. Mimic replacement of crystals was observed.



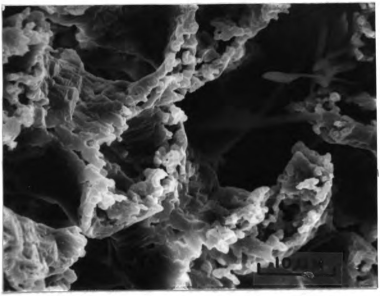
Micrograph #13: Dolomitized HMC echinoid from an experiment lasting 22 hours (2,000X). Crystals are from 5 to 10 microns in size, euhedral, and oriented.

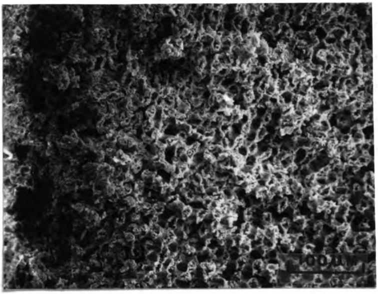
Micrograph #14: Dolomitized HMC echinoid after 22 hours of experimentation (200X). Original texture is recognizable although growth of crystals into open pores has partially occluded the porous network.



Micrograph #15: Dolomitized HMC echinoid from an experiment run for 187.5 hours (200X). Crystals are less than 1 micron in size, anhedral, and coallesce to form an undulating surface.

Micrograph #16: Dolomitized HMC echinoid from an experiment lasting 187.5 hours (200X). Overall texture of the echinoids is recognizable and like that seen in micrograph #14. Porosity occlusion occurs (see arrow) closer to the fragment surface.





Dolomite produced after 395 hours of experimentation on a LMC echinoid is seen in thin section #9. It is cryptocrystalline to very fine microcrystalline and porous. Mimic replacement of the dolomite is exhibited by unit extinction. S.E.M. view of the dolomite is seen in micrographs #17 and 18. At 200X, the dolomite texture appears identical to those produced from the dolomitization of HMC echinoid fragments. At 2,000X, the dolomite texture appears much different than either texture produced from dolomitization of a HMC echinoid. Crystals of the dolomitized echinoid are subhedral, oriented, and coarser crystalline than the dolomite seen in micrograph #15 but finer than those in micrograph #13.

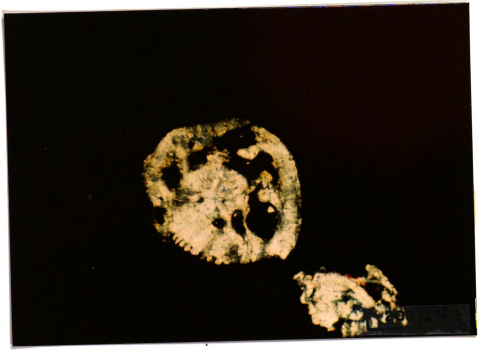
Forams

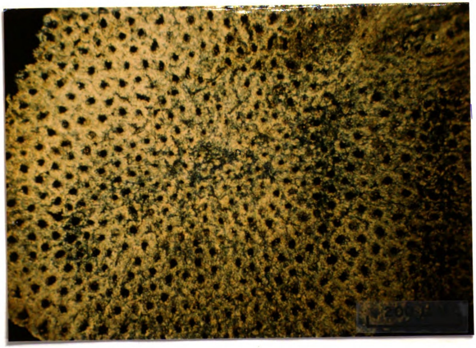
Experimentation on forams consisted of dolomitizing natural HMC and LMC varieties along with recrystallizing natural LMC forams. Precursor forams were cryptocrystalline in all cases and exhibited radiaxial extinction when observed petrographically. Thin section #10 is a representative shot of a LMC foram with 1.9 mole % $MgCO_3$. An S.E.M. view of this texture is seen in micrographs #19 through 21. This texture is similar to that of the HMC echinoid in that it is so finely crystalline and tightly packed that crystals cannot be identified even at 20,000X. Lower magnification shots at 2,000X and 200X delineate the porous nature of the substrate.

The texture of the HMC foram is seen in micrographs #22 and 23. It has a texture like the HMC coralline algae (and dolomitized HMC coralline algae) at 20,000X. Crystals are coarser than those of the LMC

Thin section #10: Natural LMC foram which is cryptocrystalline and exhibits radiaxial extinction.

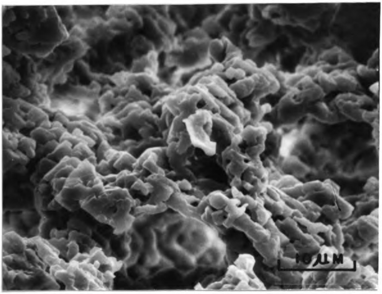
Thin section #11: Dolomitized HMC foram after 92 hours of experimentation. Cryptocrystalline dolomite fabric exhibits mimic replacement as observed by its radiaxial extinction.

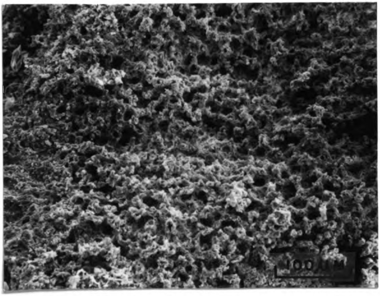




Micrograph #17: Dolomitized LMC echinoid after 395 hours of reaction (2,000X). Cryptocrystalline, euhedral, oriented, crystals, 1 to 5 microns in size make up the porous texture.

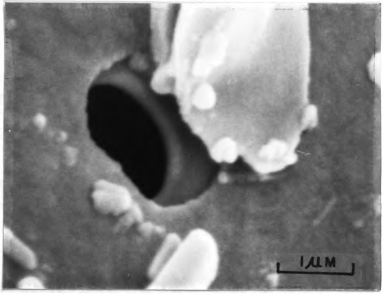
Micrograph #18: Dolomitized LMC echinoid after 395 hours of experimentation (200X). Texture appears similar to those formed from the dolomitization of HMC echinoids when observed at this magnification.

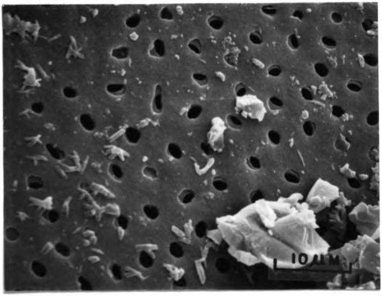

10 μM

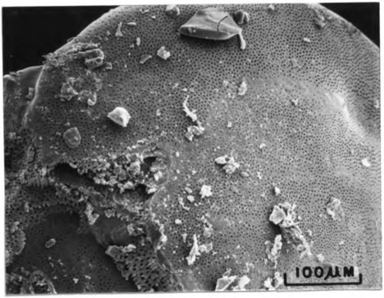

100 μM

Micrograph #19: Unaltered LMC foram at 20,000X. Crystals are too fine to identify even at high magnification.

Micrograph #20: Unaltered LMC foram at 2,000X. Porous nature of the skeletal material is observed.


1μM

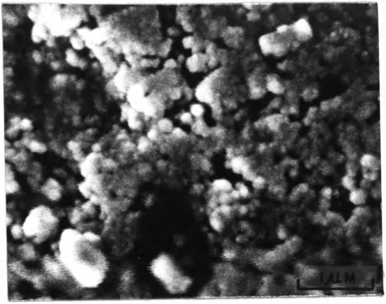

10μM

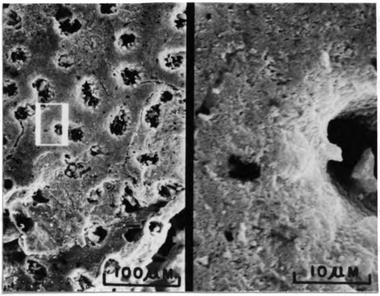


Micrograph #21: Unaltered LMC foram at 200X. Homogeneous nature and pore distribution is seen.

Micrograph #22: Unaltered HMC foram at 20,000X. Cryptocrystalline crystals are anhedral and form a porous texture.

Micrograph #23: Unaltered HMC foram at 2,000X (right) and 200X (left). Porous skeletal structure is seen at lower magnification.


1 µM


100 µM
10 µM

foram but still cryptocrystalline. Crystals are rounded and have more intercrystalline porosity between individual crystals. At low magnifications of 2,000X and 200X, the porous nature of the substrate is observed from a different perspective.

Dolomitization of HMC forams was accomplished in two experiments run for 92 hours, both of which produced dolomite (Table 5). Ordering of the dolomite was not studied.

Dolomite produced from a HMC foram is seen in thin section #11. It is cryptocrystalline like its precursor and has undergone mimic replacement. Micrographs #24 and 25 show the corresponding S.E.M. textures at 2,000X and 200X. Replacement crystals are coarser than the original HMC and subhedral. Pore-filling crystals are euhedral. At 200X, the gross structure of the central portion of the fossil appeared to have been destroyed during dolomitization as skeletal perforations were filled with dolomite.

Conversion of natural LMC forams to dolomite was studied in two experiments lasting 141.5 hours (Table 5).

Thin section #12 shows a dolomitized LMC foram fragment. It appears identical to its precursor seen in thin section #10. Both are cryptocrystalline and exhibit radiaxial extinction. S.E.M. view of the dolomite is seen in micrographs #26 and 27. Dolomite crystals are euhedral and much coarser than the original LMC. At low magnification of 200X, the partial loss of skeletal structure from crystal coarsening during dolomitization and precipitation of fibrous crystals is seen.

The recrystallization of LMC forams was studied in two experiments lasting 129.5 hours. An original LMC composition of 3.0 mole % $MgCO_3$ was recrystallized to a composition with approximately 1 mole % $MgCO_3$.

Table 5. Microprobe results for experimentation on forams.
Initial compositions: HMC with 13 mole % $MgCO_3$;
LMC with 1.9 mole % $MgCO_3$;
LMC with 3.0 mole % $MgCO_3$.
Crystal size: cryptocrystalline.

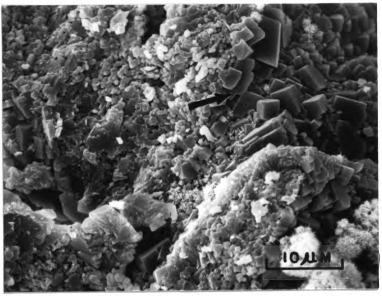
Reaction	Hrs. of Exp.	End Product	$CaCO_3$	$MgCO_3$	Exp. #
HMC → DOLO	92	DOLO	51.1	48.9	47
	92	DOLO	52.8	47.3	48
LMC* → DOLO	141.5	DOLO	51.0	49.0	42
	141.5	DOLO	51.1	49.0	43
LMC** → LMC	129.5	LMC	99.3	0.7	45
	129.5	LMC	98.9	1.2	46

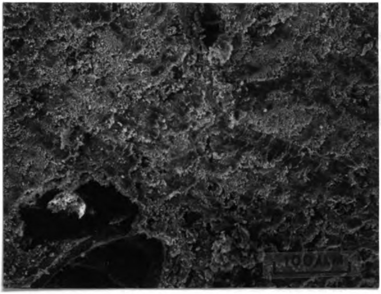
* LMC for the reaction of LMC → DOLO was originally composed of 1.9 mole % $MgCO_3$.

** LMC for the reaction of LMC → LMC was originally composed of 3.0 mole % $MgCO_3$.

Micrograph #24: Dolomite produced form a dolomitized HMC foram after 92 hours at 250°C (2,000X). Cryptocrystalline, subhedral crystals make up the replacement texture while coarser, euhedral crystals make up the cement (see arrow).

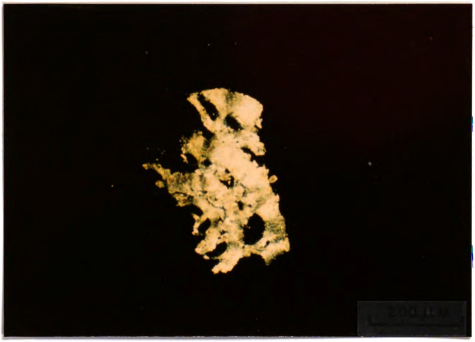
Micrograph #25: Dolomitized HMC foram after 92 hours of reaction (200X). Small pores in the central portion of the skeleton have been occluded. General texture has been preserved.

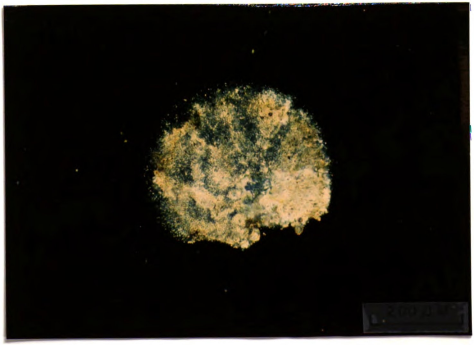

10µM



Thin section #12: Dolomitized LMC foram from an experiment run 141.5 hours. It appears identical to its precursor (thin section #10) and is cryptocrystalline and undergoes radiaxial extinction.

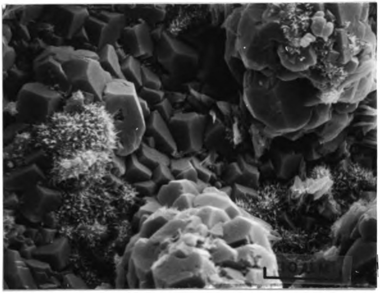
Thin section #13: Recrystallized LMC foram. Cryptocrystalline crystals undergo radiaxial extinction.

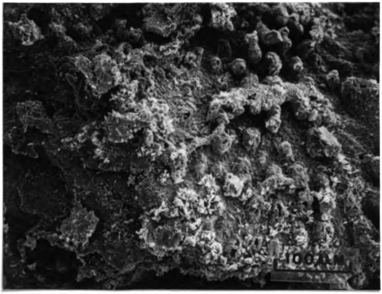




Micrograph #26: Dolomitized LMC foram from an experiment lasting 141.5 hours (2,000X). Dolomite crystals are euhedral and much coarser grained than the original LMC texture.

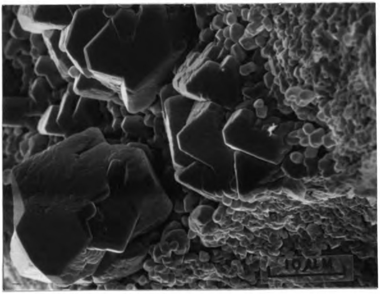
Micrograph #27: Dolomitized LMC foram after 141.5 hours of reaction (200X). Overall texture has been preserved during dolomitization.

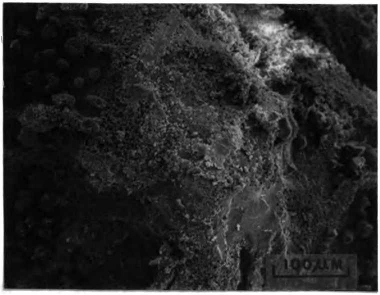



100μm

Micrograph #28: Recrystallized LMC foram at 2,000X (from an experiment run 129.5 hours). LMC replacement crystals are less than 1 micron in size and anhedral. Cement crystals are 20 microns in size and euhedral.

Micrograph #29: Recrystallized LMC foram after 129.5 hours of reaction. Overall texture is preserved during recrystallization.


10µM


100µM

Coral

Experimentation with corals consisted of dolomitizing natural aragonitic, microcrystalline samples. Most of the dolomite replaced a LMC phase, so the conversion of aragonite to LMC was also studied.

An aragonitic coral is composed of rows of spherulites (oriented vertically in the picture) separated from one another by masses of cryptocrystalline aragonite (thin sections #14 and 15). S.E.M. view of the undolomitized coral is seen in micrographs #30 and 31 at 1760X and 200X. Micrograph #30 shows a spherulite surrounded by a tightly packed mass of aragonite which appears cryptocrystalline. At low magnification, the massive area appears to have fibrous crystals in it, although the tight packing makes crystal definition impossible. Porosity of the massive zone is delineated by perforations throughout.

Dolomitization of aragontic coral fragments was studied in six experiments lasting from 11.5 to 326.5 hours (Table 6). Experiments produced dolomite and calcite as end product phases, although X-ray diffraction analysis shows dolomite as the sole end product in experiments lasting 304.5 hours or more. Dolomite in all experiments was well-ordered.

Thin section #16 was taken from an experiment lasting 304.5 hours. The fragment was composed primarily of LMC with a rim of dolomite. Dolomite at the very rim of the sample is cryptocrystalline to very fine microcrystalline. Crystals further inward are fine microcrystalline, anhedral, and have undulose extinction. Dolomite textures seen in S.E.M. micrographs #32 and 33 show the tightly packed nature of the end product. Crystal sizes and shapes could not be identified by S.E.M. observation.

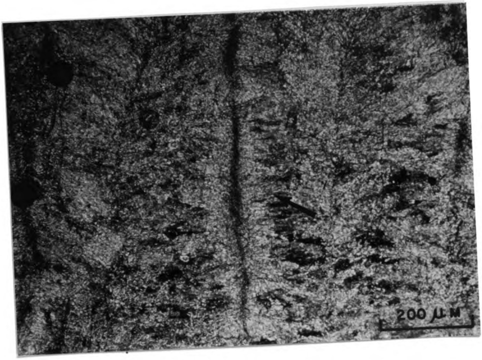
Table 6. X-ray diffraction results for experimentation on corals. Initial composition: aragonite. Crystal Size: Microcrystalline.

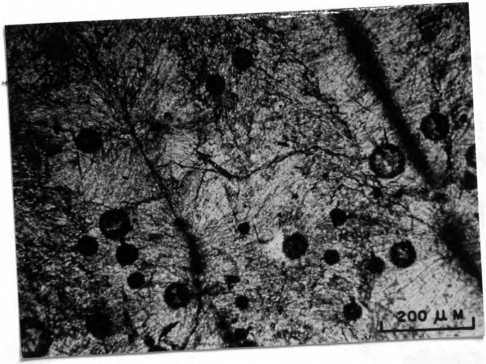
Reaction	Hrs. of Exp.	End Product	Mole % $CaCO_3$	Exp. #
ARA → DOLO	11.5	DOLO	53.6	34
		LMC	95.5	
	34	DOLO	50.7	27
		LMC	98.9	
	175	DOLO	49.6	23
		LMC	98.5	
	209	DOLO	50.1	12
		LMC	99.7	
	304.5	DOLO	49.6	24
		LMC**	——	
	326.5	DOLO	49.1	53
ARA → LMC	11.5	LMC	99.6	56*
	11.5	LMC	99.1	60*

* Denotes experiments run with a mixture of aragonitic fossils.
** X-ray analysis identified dolomite as the sole phase. Staining of thin sections showed that some fragments had both LMC and dolomite present.

Thin section #14: Unaltered aragonitic coral. Very fine grained needles compose spherulites (oriented vertically near arrow). Cryptocrystalline masses separate sucessive spherulites.

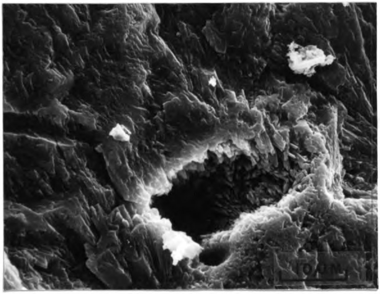
Thin section #15: Unaltered aragonitic coral showing a cross section view through spherulites (see arrow at edge). Zones between rows of spherulites are composed of cryptocrystalline and microcrystalline aragonite.

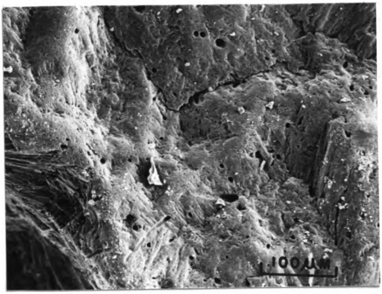

200 µ M


200 µ M

Micrograph #30: Unaltered aragonitic coral at 1,760X. Aragonite needles line the pore in the central portion of the photo. The predominant texture is massive and cryptocrystalline.

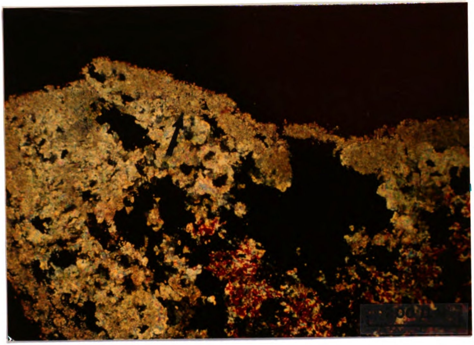
Micrograph #31: Unaltered aragonitic coral at 200X. It appears massive and cryptocrystalline with a system of fine pores.

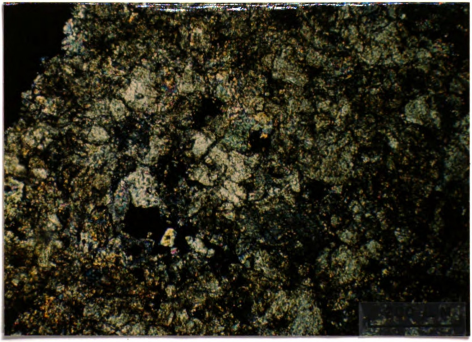



100µm

Thin section #16: Dolomite and LMC (stained red) from an experiment run 304.5 hours in a dolomitizing solution (Exp. #24). Two different dolomite textures were observed. Rim dolomite (at arrow) is cryptocrystalline to very fine microcrystalline, with no visible extinction character. Crystals further inward are anhedral and undulose in nature.

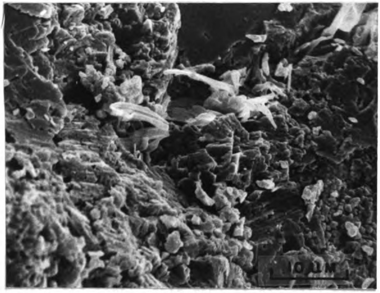
Thin section #17: LMC texture produced from an aragonitic coral after 11.5 hours at 250°C in a $CaCl_2$ solution. Crystals are microcrystalline, subhedral and tightly packed.

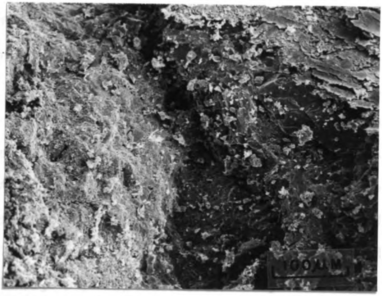




Micrograph #32: Dolomite texture produced from an aragonitic coral after 304.5 hours of experimentation (2,000X). Dolomite is very fine microcrystalline to cryptocrystalline and massive.

Micrograph #33: Dolomite texture produced from an aragonitic coral (200X). Overall texture is massive.





LMC was produced from two experiments run for 11.5 hours on aragonitic coral fragments. Both experiments produced 100% LMC (Table 6).

Thin section #17 is the texture produced from the reaction of aragonite to LMC in corals. The end product is a tightly packed fabric of fine to medium microcrystalline calcite. Crystals are undulose and often showed curved twins. Micrograph #34 at 2,000X shows the texture at the boundary of 3 LMC crystals. Crystals appear rough with angular edges. At 200X, the tight packing of the crystals is seen. Some crystal boundaries are definable because of their straight edges. The predominant texture appears massive.

Gastropod

Dolomitization of an aragonitic, microcrystalline gastropod was studied. As with the coral, thin rims of dolomite formed while the major portion of the fossil was converted to LMC. Later dolomitization of the LMC produced the predominant dolomite texture.

Gastropods (thin section #18) are composed of microcrystalline aragonite fibers making up a cross-lamellar structure. Alternating lamellae are in optical continuity and simultaneously undergo extinction. the tightly packed nature of this substrate is best seen by S.E.M. (micrographs #36 and 37). At 2,000X, the fabric making up a single lamellae appears to have little porosity due to the crystal packing. At 200X, the tight packing of sucessive lamellae is seen.

Conversion of aragonitic gastropod to LMC was studied in two experiments lasting 11.5 hours (Table 7). Each produced LMC as an end product, although one also had residual aragonite.

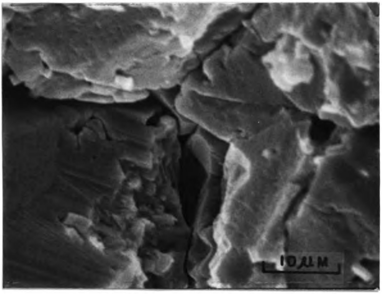
Table 7. X-ray diffraction results for experimentation on gastropods. Initial composition: aragonite. Crystal size: microcrystalline.

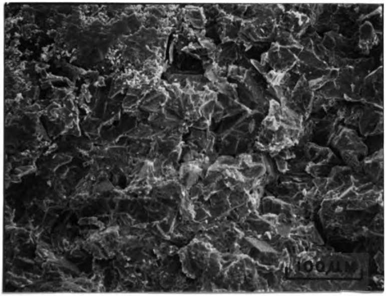
Reaction	Hrs. of Exp.	End Product	Mole % $CaCO_3$	Exp. #
ARA → DOLO	23	TRACE DOLO	——	18
		LMC	98.8	
	23	DOLO	49.5	19
		LMC	96.9	
	126	DOLO	50.7	41*
		LMC	99.8	
	169	DOLO	49.6	11
		LMC	99.2	
	175	DOLO	49.9	22
		LMC	99.1	
	343	DOLO	49.3	49
		LMC	99.2	
ARA → LMC	11.5	LMC	99.9	56*
		TRACE ARA		
	11.5	LMC	97.5	60*

* Denotes experiments run with a mixture of skeletal fragments.

Micrograph #34: LMC produced from an aragonitic coral after 11.5 hours of reaction at 250°C (2,000X). Resulting spar is medium crystalline and anhedral.

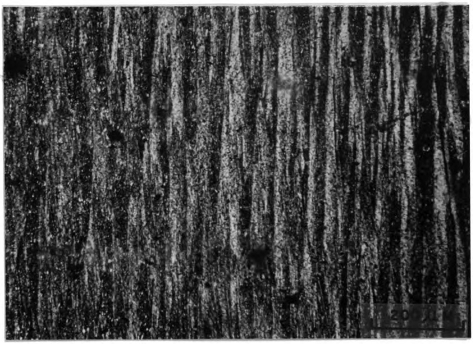
Micrograph #35: LMC from an aragonitic coral after 11.5 hours of reaction (200X). Texture appears massive.

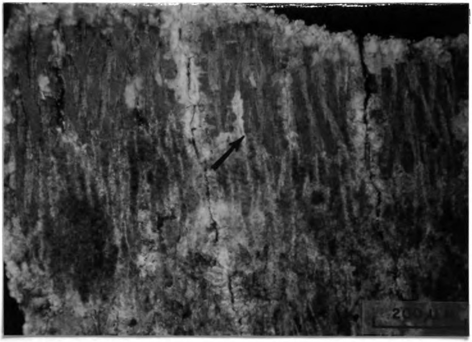

10μm


100μm

Thin section #18: Unaltered aragonitic gastropod composed of very fine microcrystalline fibers in a tightly packed cross-lamellar structure. Alternating lamellae are in optical continuity and simultaneously undergo extinction.

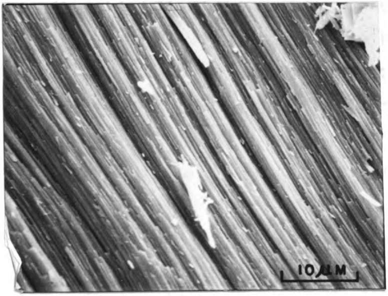
Thin section #19: Aragonitic gastropod partially converted to LMC after 11.5 hours at 250°C. Grey zone at top of photo (see arrow) is believed to be aragonite because of the alternating extinction pattern of alternating lamellae. Brown zone in lower half of photo is of very fine microcrystalline LMC. LMC cement lines cracks and forms on the sample surface.





Micrograph #36: Unaltered aragonitic gastropod at 2,000X. Tight interlocking fibers compose lamellae of the cross-lamellar structure.

Micrograph #37: Unaltered aragonitic gastropod at 200X shows the arrangment of plates in the cross-lamellar structure and the densely packed nature of the skeleton.


10μM


100μM

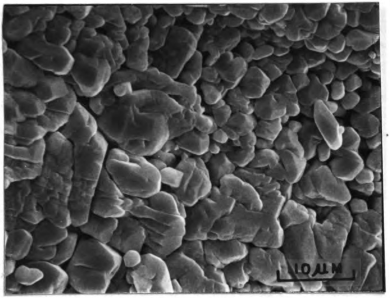
The texture produced from the alteration of an aragonitic gastropod to LMC is seen in thin section #19. The brown portion of the fossil in the lower 2/3 of the picture is of a microcrystalline LMC. The upper 1/3 seen in grey has retained the characteristic alternating extinction pattern of aragonite and is believed to be aragonite which was not converted to LMC after 11.5 hours at 250°C. White crystals forming at the rim and through cracks in the sample are of LMC cement growing into open space. Skeletal structure of the lamellae was preserved during alteration to LMC. The texture of the LMC is best seen by S.E.M. (micrographs #38 and 39). At 2,000X, subhedral crystals of very fine crystalline LMC are seen. At 200X, these crystals are on the left 2/3 of the picture. Preservation of the cross lamellar structure is apparent. Crystals in the upper right portion of the picture are believed to be aragonite crystals which were not converted to LMC.

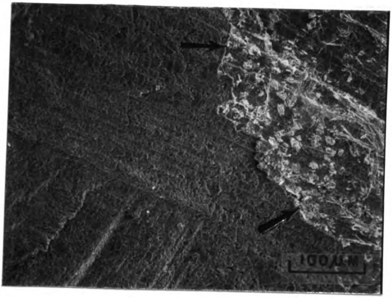
Six experiments on the dolomitization of aragonitic gastropod were studied ranging from 23 to 343 hours. All experiments produced both dolomite and LMC as end product phases. one experiment, run for 23 hours, produced only a trace amount of dolomite (Table 7).

Thin section #20 is from a dolomitized gastropod taken from an experiment lasting 343 hours. The dolomite appears cryptocrystalline with zones of anhedral, undulose, very fine microcrystalline crystals of dolomite and LMC. The gross texture of the original cross lamellar texture has been preserved from the conversion of aragonite to LMC and dolomite. S.E.M. view of the dolomite is seen in micrograpahs #40 and 41. At 2,000X, dolomite cement crystals growing at the crystal interface appear euhedral and much coarser in comparison with the interior

Micrograph #38: LMC texture of a converted gastropod (2,000X). Very fine crystalline to cryptocrystalline, anhedral crystals make up the tightly packed structure.

Micrograph #39: LMC and aragonite (?) from a gastropod after 11.5 hours of reaction. Texture to left is of anhedral, LMC crystals. The fibrous nature of the texture on the right (see arrows) may be aragonite which was not converted to LMC. Relicts of the original cross-lamellar structure are recognizable.


10µM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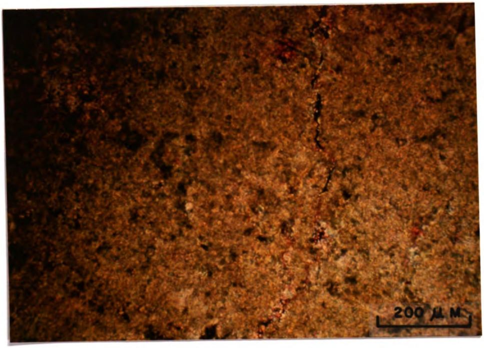
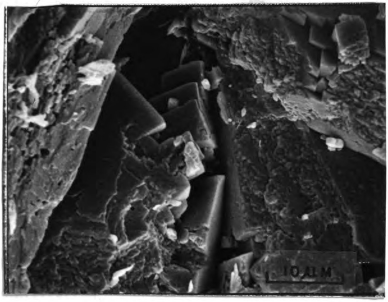
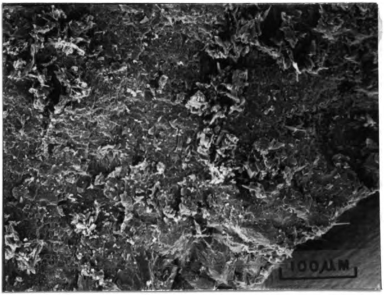


Thin section #20: Dolomitized gastropod after 343 hours of experimentation. Crystals are cryptocrystalline to very fine microcrystalline. Very fine crystals are anhedral, undulose and composed of dolomite or LMC (when stained red).

Micrograph #40: Dolomitized gastropod from an experiment lasting 343 hours (2,000X). This shot is of euhedral cement crystals near the rim growing into open pore space.

Micrograph #41: Dolomitized gastropod at 200X. Texture appears massive and similar to the dolomitized coral texture.


10µM


100µM

dolomite texture which is seen at 200X. Tight packing of the interior dolomite makes textural description difficult.

Pelecypod

Microcrystalline pelecypods were dolomitized from natural aragonite and LMC compositions. Aragonite was also converted to LMC for the same reason cited for gastropods and corals. The reaction of microcrystalline LMC to dolomite was studied to help determine if the formation of dolomite from aragonite was proceeded by a 100% LMC phase. The natural LMC pelecypod was finer microcrystalline than the synthetic LMC's from originally aragonitic fossils; for this reason, it was believed that the natural LMC pelecypod would dolomitize more readily than the aragonitic fossils if the aragonite was converted to a coarser LMC phase prior to dolomitization.

Thin section #21 is of an aragonitic pelecypod. It is composed of a cross lamellar structure similar to that of the gasropod. Thin section #22 is a shot of the pelecypod from a different angle. S.E.M. view of an undolomitized pelecypod is seen in micrographs #42 and 43. Aragonite fibers are fine but slightly coarser than those of the gastropod; intercrystalline porosity is greatly increased over the gastropod.

Dolomitization of an aragonitic pelecypod was studied in five experiments lasting from 11.5 to 247 hours (Table 8). The end product in all experiments was dolomite and calcite. One experiment, lasting 209 hours, produced a sample with 100% dolomite; other specimens in the experiment produced dolomite and calcite.

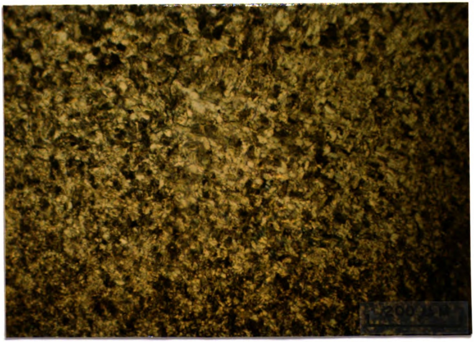
Table 8. X-ray diffraction results for experimentation on pelecypods. Initial compositions: aragonite and LMC with 1.4 mole % $MgCO_3$. Crystal size: microcrystalline.

Reaction	Hrs. of Exp.	End Product	Mole % $CaCO_3$	Exp. #
ARA → DOLO	11.5	TRACE DOLO	——	33
		LMC	95.9	
	23	DOLO	53.9	28
		LMC	99.1	
	183.5	DOLO	49.8	25
		LMC	96.0	
	209	DOLO	50.9	13
	247	DOLO	49.0	50
		LMC	97.2	
ARA → LMC	11.5	LMC	99.1	56*
	11.5	LMC	98.8	60*
		TRACE ARA		
LMC → DOLO	320	P-O-DOLO**	60.1	61
		LMC	98.8	
	320	P-O-DOLO**	60.5	62
		LMC	98.1	

* Designates experiments run with mixtures of aragonitic fossils.
** Designates poorly ordered dolomite as an end product phase.

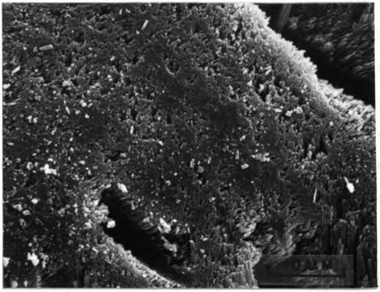
Thin section #21: Unaltered aragonitic pelecypod exhibiting cross-lamellar structure. Fibers are very fine microcrystalline.

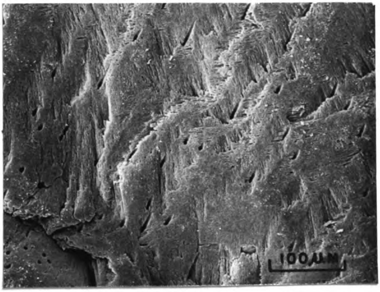
Thin section #22: Unaltered aragonitic pelecypod from another angle.



Micrograph #42: Unaltered aragonitic pelecypod at 2,000X. Fibers appear coarser than the unaltered gastropod. Porosity of the pelecypod is greater than that of the gastropod.

Micrograph #43: Unaltered aragonitic pelecypod at 200X. Cross lamellar structure and pore distribution are well defined at this magnification.




100µM

The texture produced from dolomitization of an aragonitic pelecypod is seen in thin section #23. The crystals stained red are of coarse LMC from the sample interior which resisted dolomitization after 247 hours of reaction. The grey crystals along the rim are dolomite. Dolomite crystals grade from a fine, undulose, xenotopic texture at the rim to medium sized, elongate crystals oriented approximately perpendicular to the surface. Micrographs #44 and 45 show the contact between LMC and dolomite. The dolomite crystal size and shape is not identifable using S.E.M. LMC crystals are coarse and euhedral.

Thin section #24 is another view of a LMC-dolomite contact. The crystal size and shape of both the dolomite and LMC resemble the aragonite texture seen in thin section #22.

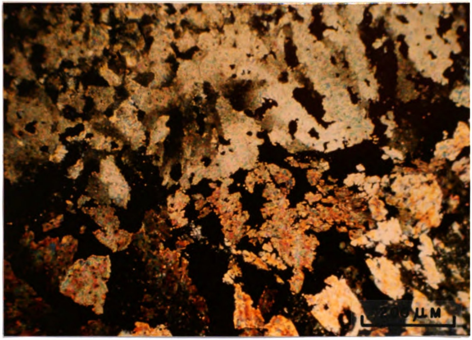
LMC was produced from aragonitic pelecypod fragments in two experiments lasting 11.5 hours (Table 8). One experiment produced both LMC and aragonite. The other produced LMC as the sole phase (Table 8).

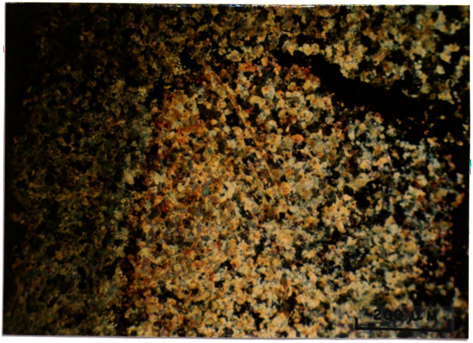
Thin section #25 is from the experiment which produced aragonite and LMC. The brown fabric on the right side of the plate is of the very fine grained aragonite which was undergoing conversion to the coarse grained, euhedral LMC. LMC is not undulose but frequently has curved twins. Micrographs #46 and 47 show the LMC texture at 2,000X and 200X. At 2,000X, the uneven surface texture is reminiscent of the original aragonite fibers. This is also obvious at 200X where skeletal pores also appear preserved. The coarse, euhedral nature of the LMC grains is also seen at 200X.

Dolomitization of LMC pelecypods fragments was studied in two experiments lasting 320 hours (Table 8). Both experiments produced calcium-rich, poorly ordered dolomite and a LMC phase.

Thin section #23: Dolomite and LMC from a dolomitization experiment on an aragonitic pelecypod (Exp. #50) after 247 hours at 250°C. Dolomite crystals grade from fine to medium microcrystalline from the fossil surface inward while coarse microcrystalline LMC comprises the skeleton's interior.

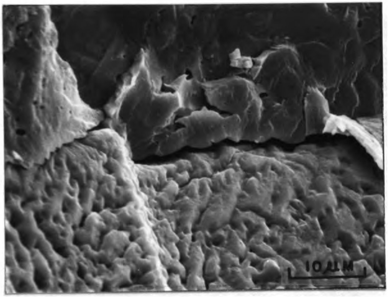
Thin section #24: Dolomite and LMC (stained red) from the same experiment as thin section #23. Very fine crystals have a similar shape and distribution pattern as those seen in thin section #22 of the unaltered aragonite.

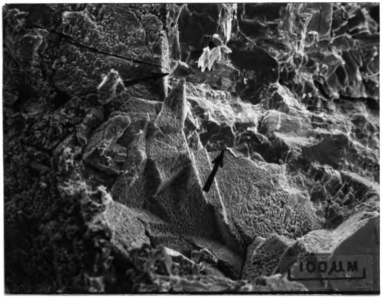


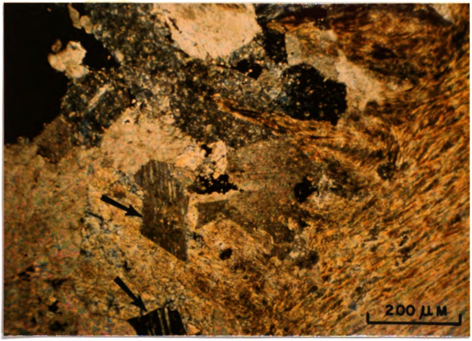

200 µM

Micrograph #44: Contact between dolomite (upper portion) and LMC (lower portion) in dolomitization experiment on an aragonitic pelecypod (2000X). Both crystals are too coarse to identify at this magnification.

Micrograph #45: Dolomite - LMC contact at 200X from a dolomitization experiment on an aragonitic pelecypod. Arrows point toward the contact, with densely packed dolomite crystals in the upper right corner. LMC crystals are euhedral, coarse, and also densely packed.


10µM

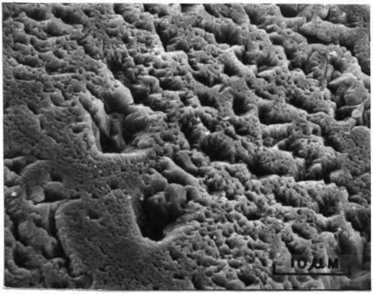

100µM



Thin section #25: Aragonitic pelecypod recrystallized to form LMC after 11.5 hours in a $CaCl_2$ solution at 250°C. Fibrous crystals in the lower right corner are of aragonite. Coarse grained, euhedral LMC is seen in the upper right. Arrows point to LMC crystals with curved twins.

Micrograph #46: LMC produced from an aragonitic pelecypod after 11.5 hours of reaction (2000X). Crystal surface is uneven and appears similar to the surface texture of the original aragonitic fibers.

Micrograph #47: LMC from an aragonitic pelecypod (200X). Coarse, euhedral crystals form a tighlty packed structure. Pores from the original aragonitic texture have been preserved during conversion to LMC.


10 µM

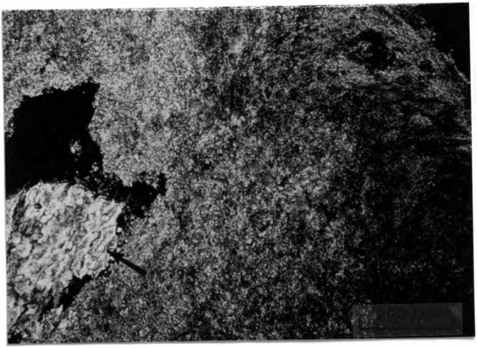

100 µM

The original LMC texture (thin section #26) is composed of short, very small, foliated fibers with a vesicular texture. Micrographs #48 and 49 show both LMC textures at 2,000X and 200X. In both cases, a tightly packed foliated texture of unrecognizable crystal size makes up the upper portion of the micrograph while a porous, vesicular texture makes up the lower.

Dolomitization of the LMC pelecypod produced the texture seen in thin section #27. Calcium-rich, poorly ordered dolomite from this experiment produced a cryptocrystalline to very fine microcrystalline, xenotopic dolomite similar to the texture produced from the dolomitization of an aragonitic gastropod or the rim dolomite texture of the coral. Brownish colored, fine crystalline zones did not stain from alizarine red and are believed to be of the same composition as the fine grained, poorly ordered dolomite. LMC is seen as the coarser grained area in the lower left-hand corner. S.E.M. view of the dolomite and calcite phases are seen in micrographs #50 and 51. At 2,000X, the dolomite phase is seen as fine crystalline, coalescing rhombs which appear to have a common orientation and massive zones of indeterminable crystal size. At 200X, the tightly packed, foliated region appears preserved, perhaps composed of LMC, while the porous, vesicular zone appears to have been replaced by the calcium-rich dolomite phase described above.

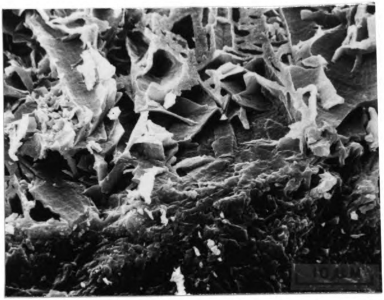
Thin section #26: Unaltered LMC pelecypod composed of short, very fine, densely packed fibers.

Thin section #27: Calcium-rich, poorly ordered dolomite and LMC from a LMC pelecypod after 320 hours of experimentation. Fine, undulose crystals in the lower left (near arrow) are LMC. Very fine microcrystalline to cryptocrystalline region to the right is of poorly ordered, calcium-rich dolomite.



Micrograph #48: Unaltered LMC pelecypod at 2,000X. Tightly packed, foliated structure (in upper portion of photo near arrow) is made up of crystals of indeterminable size. Vesicular structure (lower portion of photo) is porous and very fine crystalline.

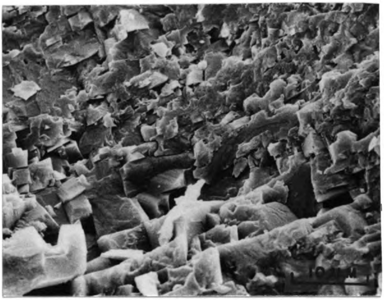
Micrograph #49: Unaltered LMC pelecypod at 200X. Contrast between the porosity of the vesicular and foliated structures are obvious at low magnification (arrows point toward the foliated structure at the contact).

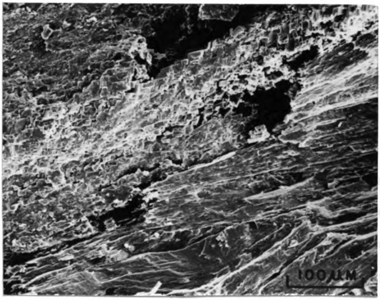

10μM


100μM

Micrograph #50: Calcium-rich, poorly ordered dolomite from a LMC pelecypod. Replacement of the vesicular structure produced very fine crystalline, coallescing rhombs which appear to have a common orientation. Massive zones of the "dolomite" were also observed.

Micrograph #51: Calcium-rich, poorly ordered dolomite and LMC from experimentation on a LMC pelecypod (200X). Foliated structure (upper left near arrow) appears preserved and may be composed of LMC. Vesicular structure in lower portion of photo is replaced by oriented rhombs of the "dolomite".


10μM


100μM

DISCUSSION

Dolomitization of Cryptocrystalline Substrates

Dolomitization of cryptocrystalline fossils was accomplished in 19 experiments on HMC and LMC substrates. Experimentation on coralline algae and echinoids produced well-ordered dolomite in all experiments run for 22 hours or more; based on these experiments, LMC was dolomitized as readily as HMC in cryptocrystalline substrates.

Similar textures were produced from the dolomitization of HMC and LMC compositions of each cryptocrystalline fossil studied. In thin section and at low magnification using the S.E.M., textures appeared virtually indistinguishable. At higher magnifications, variability of crystal sizes and shapes within a sample and from sample to sample were more pronounced.

Hydrothermal dolomitization of both HMC and LMC compositions of echinoids and forams resulted in mimic replacement of the original texture. This shows that optical orientation of the original crystals was not destroyed in the conversion of HMC to LMC in the echinoids, or HMC and LMC to dolomite in echinoids and forams.

Comparison of dolomite crystal size between the cryptocrystalline substrates indicates a relationship between crystal size and orientation. Dolomite produced from the echinoids and forams was consistently coarser than dolomite produced from coralline algae. It is hypothesized that the parallel orientation of crystals in unaltered forams and

echinoids allows for coarser crystal growth while the random grain orientation in coralline algae inhibits growth.

Dolomitization of Microcrystalline Substrates

Dolomitization of microcrystalline aragonite fossils was much slower and more complicated than that of cryptocrystalline substrates. Aragonite was unstable at high temperature and converted readily to dolomite if in the presence of sufficient Mg^{2+} ions or to LMC if not (see Table 2). Thin rims of dolomite formed at the substrate-dolomitizing solution contact while the major portion of the fossil was converted to LMC. The predominant dolomite texture was formed from the conversion of LMC to dolomite with nucleation taking place on the dolomite rim. Variables such as porosity, permeability, surface area: volume ratio, the rate of reaction of aragonite to LMC, and the presence of numerous aragonite and LMC textures within a sample complicated the study. There is no simple correlation between crystal size and mineralogy of the precursor with the rate of dolomitization in aragonite substrates.

Complete dolomitization of an aragonite fossil was not accomplished in any experiment in this study. X-ray diffraction analysis of small fragments (with large surface area: volume ratios) produced dolomite as the single end product phase but larger fragments (with smaller surface area: volume ratios) produced LMC and dolomite from the same experiment.

The identification of dolomite produced from aragonite and LMC compositions was most easily accomplished in corals and pelecypods. Thin section #16 from the coral is the best example of this. Rim dolomite produced from the precursor cryptocrystalline to very fine crystalline aragonite is also cryptocrystalline with no preferred crystallographic orientation; it formed within 11.5 hours of reaction (as X-ray diffraction analysis showed that dolomite and LMC were the only phases after that period of time). Later dolomitization of the homogeneous, fine-medium crystalline, subhedral LMC produced the fine crystalline, anhedral, undulose dolomite crystals adjacent to the cryptocrystalline rim.

Thin section #23 of a pelecypod also shows two dolomite textures. The fine to very fine crystalline dolomite at the rim is the texture produced from direct dolomitization of the aragonitic substrate. The medium sized, bladed grains further inward form the second dolomite texture which was produced from the coarse grained, euhedral, LMC spar. Contact between the two dolomite textures is not as pronounced as in the coral due to the cloudy nature of the dolomite produced from the pelecypod.

Comparison of the dolomite rim thickness between the coral and pelecypod indicates that the amount of dolomite formed directly from aragonite is greater in the pelecypod. This means that the rate of dolomitization in the coarser crystalline pelecypod may be faster than in the finer crystalline coral. Variables in porosity (micrograph 42), $Ca^{2+}/Ca^{2+} + Mg^{2+}$ ratio, or sample proximity to dolomitizing solution may account for this difference.

Dolomitization of the aragonite gastropod produced a single dolomite texture. The very fine grained, densely packed, aragonite needles produced a cryptocrystalline dolomite rim and a very fine crystalline LMC (thin section #19). The LMC texture in thin section

appeared very similar to that of the precursor aragonite (thin section #18). Later dolomitization of the LMC produced a dolomite texture indistinguishable from that produced from the direct dolomitization of the precursor aragonite (thin section #19). A general preservation of the gross skeletal structure was observed from the original aragonite to the resulting LMC and dolomite compositions. The fine crystal size of all three minerals is believed to account for this phenomenon.

The dolomitization of a LMC pelecypod for 320 hours resulted in a poorly ordered, calcium-rich dolomite and a LMC phase. Experiments run for similar time periods on aragonitic fossils (305 and 343 hours for corals and gastropods) produced well ordered dolomite and LMC. This evidence indirectly supports the hypothesis that dolomite forms directly from aragonite in experiments on aragonitic fossils. The LMC pelecypod was finer crystalline than any of the synthetic LMC's, and therefore should have been more susceptible to dolomitization than a 100% LMC of a coarser crystal size. Because the LMC pelecypod resisted dolomitization, it is reasonable that the dolomite produced from the synthetic LMC nucleated on a pre-existing dolomite formed from the aragonite precursor.

Comparison of Synthetic and Natural Dolomites

Comparison of naturally dolomitized coralline algae from an original HMC composition was made with synthetic equivalents. The naturally dolomitized specimens were formed under completely different conditions (i.e. pressure, temperature, solution chemistry, etc.) than those in the lab, yet distinct similarities were observed.

Micrographs #54 and 55 are comparison shots of dolomitized HMC coralline algae. Micrograph #52 at 17,000X is a naturally produced dolomite with a cryptocrystalline, rhombic texture. It appears very similar to micrograph #53 (15,000X) which is a synthetic dolomite produced from an experiment lasting 126 hours. Packing, crystal size, and shape are all similar between the two specimens, yet the only variables they have in common concerning their formation are the original mineralogy and texture.

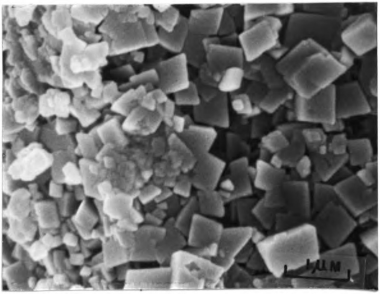
Micrographs #54 and 55 are comparison shots at 4,000X of natural and synthetic dolomites produced from HMC coralline algae. Micrograph #54 is from a natural dolomite which has retained the original skeletal structure. The dolomite is very fine grained to cryptocrystalline and rhombic. The artificial dolomite came from the experiment run 126 hours and has also retained the original skeletal structure. In this example, the crystal size of the synthetic dolomite is somewhat smaller than the natural specimen which is opposite to that of the previous example. Textures of the two samples are similar.

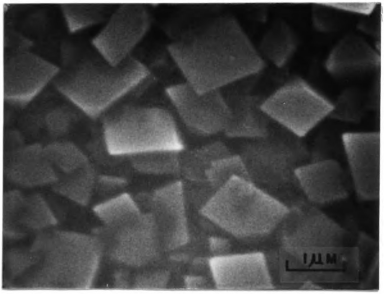
Micrograph #54 also displays a great resemblance to the synthetic dolomite seen in micrograph #4 at 2,000X. The artificial dolomite was produced from a HMC to dolomite reaction at 250°C for 22 hours and has approximately the same crystal size, shape, and packing as the naturally occurring dolomite rhombs.

Another texture produced from a naturally dolomitized coralline algae is seen in micrograph #56 at 2,000X. This specimen has undergone a complete loss of the original texture during dolomitization. Micrograph #56 also at 2,000X, was taken from a LMC to dolomite reaction lasting 22 hours; dolomite cement growing on the dolomitized

Micrograph #52: Naturally dolomitized HMC coralline algae at 17,000X. Crystals are cryptocrystalline (5-10 microns), euhedral, and form a porous texture.

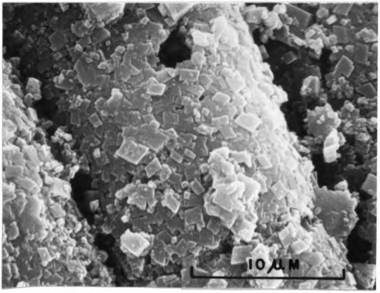
Micrograph #53: Artificially dolomitized HMC coralline algae from an experiment conducted for 126 hours at 250°C (15,000X). Crystals are euhedral, cryptocrystalline and of the same porous nature as the natural dolomite in micrograph #52.

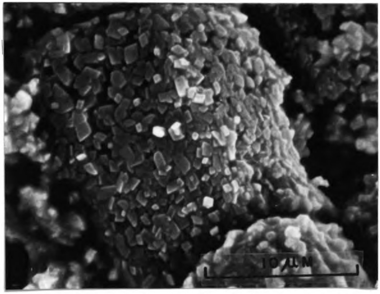

1μM


1μM

Micrograph #54: Naturally dolomitized HMC coralline algae at 4,000X. Euhedral rhombs are cryptocrystalline and appear oriented. Original texture of the HMC as been preserved.

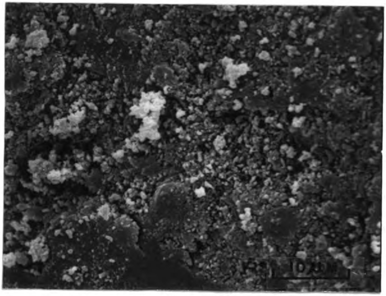
Micrograph #55: Artifically dolomitized HMC coralline algae from the experiment run 126 hours (4,000X). Crystals are euhedral and cryptocrystalline. Original structure of the coralline algae has been preserved.

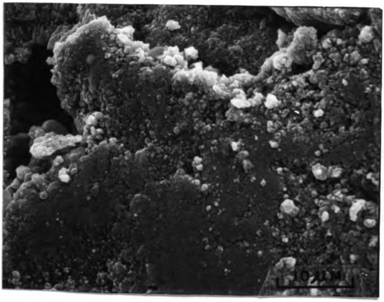

10 μM


10 μM

Micrograph #56: Naturally dolomitized HMC (?) coralline algae at 2,000X. This specimen has undergone a complete loss of texture during dolomitization.

Micrograph #57: Artifically dolomitized LMC coralline algae from an experiment conducted 22 hours at 250°C (2,000X). This specimen has undergone a complete loss of original texture during dolomitization. Cement has filled the pore space completely masking the original skeletal structure.


10μm



coralline algae has masked the original skeletal structure and produced a texture like that of the natural specimen. These two samples were formed under completely different conditions, yet resulted in the same texture. The only variable in common between the substrates was their original crystal size, as the natural specimen is believed to have formed from a HMC composition.

Naturally dolomitized echinoid and foram fragments commonly show mimic replacement but they may also resist dolomitization (Sibley, 1982). Mimic replacement may occur prior to or after conversion of HMC to LMC. The fragments resist dolomitization after conversion to LMC. Therefore, there is only a partial correspondence between the experimental results and naturally dolomitized echinoids and forams.

Aragonitic fossils seldom show mimic replacement in nature or in the experiments. Aragonitic fossils subjected to dolomitizing solutions in nature generally are either dissolved or replaced by microcrystalline dolomite. The major difference between natural and hydrothermal dolomitization is that the natural dolomites tend to be coarser crystalline and euhedral whereas the hydrothermal dolomites tend to be finer and anhedral.

LMC mollusk fragments commonly resist dolomitization in nature (Sibley, 1982) as they did in our hydrothermal experiments.

The similarity between natural and artifical dolomites demonstrates a substrate control on the orientation and frequency of dolomite nuclei. The "control" could be a function of substrate reactivity and/or permeability. For nucleation, the two aspects of reactivity that are important are the solubility of the substrate and the surface energy of the substrate-nuclei. The solubility of the substrate is a

function of its crystal size and mineralogy. The experiments rule out the latter being of major importance because LMC coralline algae, echinoids, and forams were dolomitized as readily as the same fossils with HMC mineralogy. Crystal size may effect the reactivity because coarse crystalline LMC oysters reacted to form only small amounts of poorly ordered dolomite.

The HMC fossils studied are finer crystalline, more porous and permeable than the other fossils. When these fossils were converted to LMC, their structure was not significantly changed: they retained their high porosity and permeability. Thus it may be the access to fluids that caused the abundant nucleation sites. The aragonite fossils and calcitic oyster formed reaction rims which may represent the limit to which dolomitizing fluids were able to penetrate into the fossil. They could also represent the more complex situation: the reaction rims might be the result of the penetration of dolomitizing fluids causing dolomite to nucleate along with coarsening of LMC in the fossils, which inhibitied the nucleation.

Mimic Replacement During Hydrothermal Dolomitization

Mimic replacement of oriented crystals was observed in echinoids and forams composed of HMC or LMC but not in aragonitic corals. As explained previously, control over crystal orientation during dolomitization may be related to the mineralogy or crystal size of the precursor or to its permeability. Echinoids and forams were cryptocrystalline, but the coral spherulites were very fine crystalline. If crystal size is the main control over replacement crystal orientation, the finer crystalline echinoids and forams would be more apt to undergo mimic replacement because of their greater surface area: volume ratios, greater solubility, and their abundant nucleation sites.

The effect of mineralogy or perhaps more importantly, the difference in crystal systems between the calcitic minerals (trigonal system) and aragonite (orthorhombic) during the replacement by dolomite (trigonal) is a second consideration. If the change in crystal system has an effect on crystal orientation, the aragonitic coral would be less apt to undergo mimic replacement whereas the calcitic fossils wouldn't be affected.

A third consideration in reactivity is permeability. If the greater permeability of the echinoids and forams is the major control over replacement crystal orientation, they would be expected to be more reactive than the less permeable coral. As only the rims of the coral were dolomitized, the effect of permeability over crystal orientation does not appear to be significant.

CONCLUSIONS

The main conclusions of this study concerning the effect of precursor crystal size and mineralogy on resulting dolomite textures and rates of dolomitization are listed in Table 9. These conclusions are as follows:

1) Cryptocrystalline HMC is very susceptible to dolomitization and exhibits mimic replacement in fabrics with oriented crystals.
2) Cryptocrystalline LMC is as susceptible to dolomitization as HMC substrates under the conditions of this experimentation and also undergoes mimic replacement.
3) Microcrystalline LMC resists dolomitization and does not undergo mimic replacement.
4) The susceptibility of microcrystalline aragonite to dolomitization could not be determined under the experimental constraints. The reaction of ARA to LMC at high temperature converted most of the substrate to LMC before appreciable amounts of dolomite could form.

These results lead to the conclusion that crystal size is more important than mineralogy in determining the nature of dolomite selectivity in HMC and LMC substrates. Further study is needed to delineate the relationship in aragonitic substrates.

Table 9: Conclusions of Study

MINERAL	CRYSTAL SIZE	SUSCEPT. DOLON	MIMIC REPLACE
HMC	CRYPTO-X	VERY HIGH	YES
LMC	CRYPTO-X	VERY HIGH	YES
LMC	MICRO-X	LOW	NO
ARAG	MICRO-X	NOT DETERMINED	NO

CRYPTO-X = cryptocrystalline
MICRO-X = microcrystalline

Other conclusions are as follows:

5) Comparison of natural dolomite textures with those produced synthetically in the laboratory at higher P-T conditions and under different chemical constraints, leads to the conclusion that the original texture (i.e. crystal size) is more important in determining the resulting dolomite texture than any other variable.

6) These results can be applied to natural dolomites in the following manner. Selective dolomitization of originally HMC fossils (such as shown in Figure 1) is probably a result of the original fossil texture and could occur after conversion to LMC. Fresh water diagenesis which changes fossil textures will affect the susceptibility of those fossils to dolomitization.

FUTURE WORK

Subjects directly related to this study which deserve further investigation are listed as follows:

(1) Fossil mixtures of substrates which resist dolomitization and those which are readily dolomitized should be hydrothermally dolomitized to better understand the $CO_3^=$ ion exchange between substrates undergoing dissolution-reprecipitation reactions. This will allow a better understanding of whole rock reactions during dolomitization.

(2) Hydrothermal dolomitization experiments should be run to better understand the mechanics of crystal growth and dissolution. Bombs should be sampled at specific intervals to determine if dolomite grains become more rounded (i.e. dissolve at points of greatest surface area) with time after initial dolomite formation.

(3) The number of dissolution-reprecipitation events should be studied for the reaction of HMC to dolomite. This reaction is specifically interesting because of the number of different dolomite textures produced within a single sample and from sample to sample in coralline algae and echinoids.

(4) Echinoids should be studied more thoroughly in hydrothermal alteration experiments. This substrate has a similar surface

area: volume ratio no matter how it is fractured and seems quite suitable to experimentation.

(5) Microcrystalline substrates which exhibit optical characteristics related to crystal orientation should be studied to determine the replacement mechanics during hydrothermal alteration.

(6) The rate of reaction of aragonite to LMC in different substrates deserves further investigation to determine the relationship between the rate of reaction, the precursor texture, and the resulting texture. Pelecypods which convert to coarse crystalline, euhedral, LMC should be studied along with those substrates which form finer grained, anhedral, LMC crystals. This type of study would better define the relative importance of porosity and grain size during crystal growth.

(7) Comparison of a greater variety of naturally dolomitized fossils should be made with artificially dolomitized equivalents. This is important not only for stressing the dependence of dolomite texture on precursor texture, but also for comparing dolomite textures formed by a local source of $CO_3^{=}$ ions with dolomites formed in an open system (i.e. with an outside source of $CO_3^{=}$ ions).

(8) Recrystallization of both natural and artificially produced well-ordered dolomites should be attempted to determine if recrystallization of a stable mineral phase takes place, and if so, why recrystallization occurs.

(9) The importance of grain size and mineralogy during hydrothermal dolomitization should be quantified. Synthetic aragonitic

and calcitic precipitates of similar grain size should be hydrothermally dolomitized under the same P-T and chemical conditions to determine relative dolomitization rates for specific grain sizes and mineralogies without the consideration of different porosities. This would be especially important in the study of aragonitic substrates.

(10) The rate of dolomitization in substrates which resist dolomitization deserves further study. Experiments run in the presence of dolomite (and protodolomite) seeds could be studied to determine:

(a) If the presence of dolomite speeds the reaction rate in the resistive substrate,

(b) If the presence of dolomite favors dissolution of the resistive substrate with corresponding cementation cement formation on the dolomite, or

(c) if the presence of dolomite has no effect on the reaction rate in the resistive substrate.

A study of this nature would allow a better understanding of whole rock reactions during dolomitization.

APPENDIX 1

HYDROTHERMAL BOMB DESIGNS

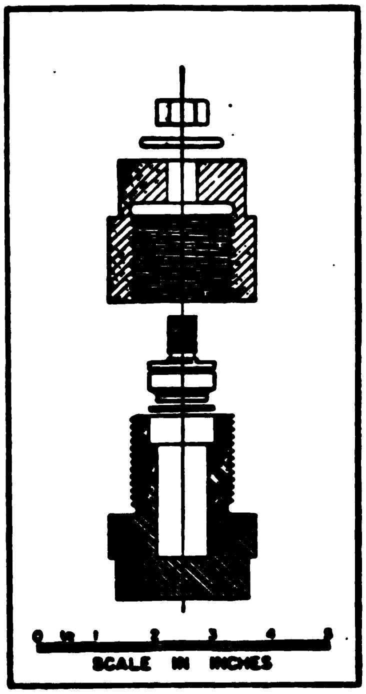


Figure 1

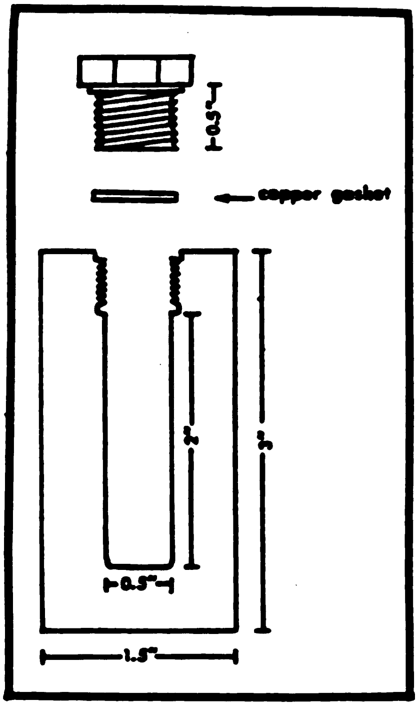


Figure 2

Figure 1. 18.5 ml capacity Morey-type hydrothermal bomb (Morey, 1953).

Figure 2. 6.5 ml stainless steel bomb.

APPENDIX 2

EXPERIMENTAL RESULTS

EXPERIMENT #: 1

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae (uncleaned sample)

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 50.6 m% $CaCO_3$

SAMPLE WT: .2136 gm

MOLECULAR WT: 97.42 m/gm

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00037

moles Ca^{2+}: 0.01820

SOLUTION CHEMISTRY: 1.3 ml $MgCl_2$ (2M)

3.9 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0026

moles Ca^{2+}: 0.0078

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.75$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.76$$

TEMPERATURE: 250°C

REACTION TIME: 120 HRS.

EXPERIMENT #: 7

REACTION: HMC to Dolomite

FOSSIL: Echinoid (uncleaned sample)

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 49.8 m% $CaCO_3$

SAMPLE WT: 0.1361 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00015

moles Ca^{2+}: 0.00124

SOLUTION CHEMISTRY: 1.3 ml $MgCl_2$ (2M)

3.9 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0026

moles Ca^{2+}: 0.0078

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.75$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.77$$

TEMPERATURE: 250°C

REACTION TIME: 174.5 HRS.

EXPERIMENT #: 11

REACTION: Aragonite to Dolomite

FOSSIL: Gastropod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.6 m% $CaCO_3$ (DOLO) + 0.8 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2003 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0020

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.67$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 120 HRS.

EXPERIMENT #: 12

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 50.1 m% $CaCO_3$ (DOLO) + 0.8 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2101 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0021

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.67$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 209 HRS.

EXPERIMENT #: 13

REACTION: Aragonite to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 50.9 m% $CaCO_3$ (DOLO)

SAMPLE WT: 0.2554 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0026

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.67$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 209 HRS.

EXPERIMENT #: 14

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 50.0 m% $CaCO_3$

SAMPLE WT: 0.1930 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00033

moles Ca^{2+}: 0.00164

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0074

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 187.5 HRS.

EXPERIMENT #: 15

REACTION: HMC to Dolomite

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 50.1 m% $CaCO_3$

SAMPLE WT: 0.2013 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00022

moles Ca^{2+}: 0.00182

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0074

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 187.5 HRS.

EXPERIMENT #: 16

REACTION: HMC to LMC

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 1.0 m% $CaCO_3$

SAMPLE WT: 0.2591 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00028

moles Ca^{2+}: 0.00235

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.98$$

TEMPERATURE: 250°C

REACTION TIME: 120 HRS.

EXPERIMENT #: 17

REACTION: HMC to LMC

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 1.0 m% $CaCO_3$

SAMPLE WT: 0.2877 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00031

moles Ca^{2+}: 0.00260

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.98$$

TEMPERATURE: 250°C

REACTION TIME: 120 HRS.

EXPERIMENT #: 18

REACTION: Aragonite to Dolomite

FOSSIL: Gastropod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: Trace Dolomite + 1.8 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3703 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0037

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.67$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.76$$

TEMPERATURE: 250°C

REACTION TIME: 23 HRS.

EXPERIMENT #: 19

REACTION: Aragonite to Dolomite

FOSSIL: Gastropod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.5 m% $CaCO_3$ (DOLO) + 3.1 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3105 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0031

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.67$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.75$$

TEMPERATURE: 250°C

REACTION TIME: 23 HRS.

EXPERIMENT #: 20

REACTION: HMC to LMC

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 3.3 m% $MgCO_3$

SAMPLE WT: 0.3626 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00063

moles Ca^{2+}: 0.00309

SOLUTION CHEMISTRY: 4.9 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0098

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.95$$

TEMPERATURE: 250°C

REACTION TIME: 116 HRS.

EXPERIMENT #: 21

REACTION: HMC to LMC

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 3.3 m% $MgCO_3$

SAMPLE WT: 0.3027 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00053

moles Ca^{2+}: 0.00258

SOLUTION CHEMISTRY: 4.9 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0098

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.96$$

TEMPERATURE: 250°C

REACTION TIME: 116 HRS.

EXPERIMENT #: 22

REACTION: Aragonite to Dolomite

FOSSIL: Gastropod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.9 m% $CaCO_3$ (DOLO) + 0.9 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2243 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0022

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.68$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 175 HRS.

EXPERIMENT #: 23

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.6 m% $CaCO_3$ (DOLO) + 1.5 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2143 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0021

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.68$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 175 HRS.

EXPERIMENT #: 24

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.6 m% $CaCO_3$

SAMPLE WT: 0.3443 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0034

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0064

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.65$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 304.5 HRS.

EXPERIMENT #: 25

REACTION: Aragonite to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.8 m% $CaCO_3$ (DOLO) + 4.0 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3473 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0035

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0064

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.65$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 183.5 HRS.

EXPERIMENT #: 26

REACTION: HMC to DOLO

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 50.0 m% $CaCO_3$

SAMPLE WT: 0.2532 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00028

moles Ca^{2+}: 0.00230

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.69$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 22 HRS.

EXPERIMENT #: 27

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 50.7 m% $CaCO_3$ (DOLO) + 1.1 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2048 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0020

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.68$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 34 HRS.

EXPERIMENT #: 28

REACTION: Aragonite to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 53.9 m% $CaCO_3$ (DOLO) + 1.1 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.1932 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0019

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.68$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 23 HRS.

EXPERIMENT #: 29

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 48.5 m% $CaCO_3$

SAMPLE WT: 0.2288 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00040

moles Ca^{2+}: 0.00195

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.70$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.72$$

TEMPERATURE: 250°C

REACTION TIME: 76 HRS.

EXPERIMENT #: 30

REACTION: HMC to LMC

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 10.9 m% $MgCO_3$

SAMPLE WT: 0.4012 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00070

moles Ca^{2+}: 0.00342

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.95$$

TEMPERATURE: 250°C

REACTION TIME: 52 HRS.

EXPERIMENT #: 31

REACTION: HMC to LMC

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 3.1 m% $MgCO_3$

SAMPLE WT: 0.4713 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00082

moles Ca^{2+}: 0.00402

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.94$$

TEMPERATURE: 250°C

REACTION TIME: 139 HRS.

EXPERIMENT #: 32

REACTION: HMC to LMC

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 1.7 m% $CaCO_3$

SAMPLE WT: 0.3914 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00043

moles Ca^{2+}: 0.00355

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.97$$

TEMPERATURE: 250°C

REACTION TIME: 92 HRS.

EXPERIMENT #: 33

REACTION: Aragonite to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: Trace DOLO + 4.1 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2891 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0029

SOLUTION CHEMISTRY: 1.7 ml $MgCl_2$ (2M)

3.3 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0034

moles Ca^{2+}: 0.0066

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.66$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 11.5 HRS.

EXPERIMENT #: 34

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 53.6 m% $CaCO_3$ (DOLO) + 4.5 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3604 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0036

SOLUTION CHEMISTRY: 1.8 ml $MgCl_2$ (2M)

3.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0036

moles Ca^{2+}: 0.0064

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.64$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 11.5 HRS.

EXPERIMENT #: 35

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 49.9 m% $CaCO_3$

SAMPLE WT: 0.2533 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00044

moles Ca^{2+}: 0.00216

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.70$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.73$$

TEMPERATURE: 250°C

REACTION TIME: 22 HRS.

EXPERIMENT #: 36

REACTION: LMC to Dolomite

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 1.73 m% $MgCO_3$

FINAL COMPOSITION: 49.2 m% $CaCO_3$

SAMPLE WT: 0.2238 gm

MOLECULAR WT: 99.81 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00004

moles Ca^{2+}: 0.00220

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.70$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.75$$

TEMPERATURE: 250°C

REACTION TIME: 395 HRS.

EXPERIMENT #: 37

REACTION: LMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 3.09 m% $MgCO_3$

FINAL COMPOSITION: 50.0 m% $CaCO_3$

SAMPLE WT: 0.2648 gm

MOLECULAR WT: 99.59 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00008

moles Ca^{2+}: 0.00258

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.68$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 384 HRS.

EXPERIMENT #: 38

REACTION: HMC to LMC

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 3.4 m% $MgCO_3$

SAMPLE WT: 1.0060 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00110

moles Ca^{2+}: 0.00912

SOLUTION CHEMISTRY: 14.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0280

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.97$$

TEMPERATURE: 250°C

REACTION TIME: 186 HRS.

EXPERIMENT #: 39

REACTION: LMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 3.09 m% $MgCO_3$

FINAL COMPOSITION: 49.8 m% $CaCO_3$

SAMPLE WT: 0.1310 gm

MOLECULAR WT: 99.59 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00004

moles Ca^{2+}: 0.00127

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.6 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0072

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 398 HRS.

EXPERIMENT #: 40

REACTION: LMC to Dolomite

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 1.73 m% $MgCO_3$

FINAL COMPOSITION: 47.8 m% $CaCO_3$

SAMPLE WT: 0.1401 gm

MOLECULAR WT: 99.81 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00002

moles Ca^{2+}: 0.00138

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.6 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0072

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 398 HRS.

EXPERIMENT #: 41

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae; Gastropod

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$ (C.A.); $CaCO_3$ (G)

FINAL COMPOSITION: 48.4 m% $CaCO_3$ (C.A.);
50.7 m% $CaCO_3$ (DOLO) + 0.2 m% $MgCO_3$ (LMC) (G)

SAMPLE WT: C. Algae - 0.3457 gm; Gastropod - 0.4068 gm

MOLECULAR WT: C. Algae - 97.42 gm/mole; Gastropod - 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: C. Algae - 0.00060; Gastropod - 0.0000

moles Ca^{2+}: C. Algae - 0.00295; Gastropod - 0.0041

SOLUTION CHEMISTRY: 5.0 ml $MgCl_2$ (2M)

9.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0100

moles Ca^{2+}: 0.0180

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.64$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.70$$

TEMPERATURE: 250°C

REACTION TIME: 126 HRS.

EXPERIMENT #: 42

REACTION: LMC to Dolomite

FOSSIL: Foram

ORIGINAL COMPOSITION: 1.9 m% $MgCO_3$

FINAL COMPOSITION: 51.0 m% $CaCO_3$

SAMPLE WT: 0.0035 gm

MOLECULAR WT: 99.78 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00000067

moles Ca^{2+}: 0.00003441

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0072

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 141.5 HRS.

EXPERIMENT #: 43

REACTION: LMC to Dolomite

FOSSIL: Foram

ORIGINAL COMPOSITION: 1.9 m% $MgCO_3$

FINAL COMPOSITION: 51.1 m% $CaCO_3$

SAMPLE WT: 0.0034 gm

MOLECULAR WT: 99.78 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00000065

moles Ca^{2+}: 0.00003343

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0074

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 141.5 HRS.

EXPERIMENT #: 45

REACTION: LMC to LMC

FOSSIL: Foram

ORIGINAL COMPOSITION: 3.0 m% $MgCO_3$

FINAL COMPOSITION: 0.7 m% $MgCO_3$

SAMPLE WT: 0.0017 gm

MOLECULAR WT: 99.62 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00000051

moles Ca^{2+}: 0.00001655

SOLUTION CHEMISTRY: 5.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0104

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.0$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.0$$

TEMPERATURE: 250°C

REACTION TIME: 129.5 HRS.

EXPERIMENT #: 46

REACTION: LMC to LMC

FOSSIL: Foram

ORIGINAL COMPOSITION: 3.0 m% $MgCO_3$

FINAL COMPOSITION: 1.2 m% $MgCO_3$

SAMPLE WT: 0.0015 gm

MOLECULAR WT: 99.62 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00000045

moles Ca^{2+}: 0.00001465

SOLUTION CHEMISTRY: 5.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0104

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

TEMPERATURE: 250°C

REACTION TIME: 129.5 HRS.

EXPERIMENT #: 47

REACTION: HMC to Dolomite

FOSSIL: Foram

ORIGINAL COMPOSITION: 13.0 m% $MgCO_3$

FINAL COMPOSITION: 51.1 m% $CaCO_3$

SAMPLE WT: 0.0097 gm

MOLECULAR WT: 98.04 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.000012

moles Ca^{2+}: 0.000086

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0074

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 92 HRS.

EXPERIMENT #: 48

REACTION: HMC to Dolomite

FOSSIL: Foram

ORIGINAL COMPOSITION: 13.0 m% $MgCO_3$

FINAL COMPOSITION: 52.8 m% $CaCO_3$

SAMPLE WT: 0.0092 gm

MOLECULAR WT: 98.04 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.000012

moles Ca^{2+}: 0.000082

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.7 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0074

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 92 HRS.

EXPERIMENT #: 49

REACTION: Aragonite to Dolomite

FOSSIL: Gastropod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.3 m% $CaCO_3$ (DOLO) + 0.8 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3783 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0038

SOLUTION CHEMISTRY: 2.0 ml $MgCl_2$ (2M)

3.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0040

moles Ca^{2+}: 0.0060

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.60$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 343 HRS.

EXPERIMENT #: 50

REACTION: Aragonite to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.0 m% $CaCO_3$ (DOLO) + 2.8 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.2981 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0030

SOLUTION CHEMISTRY: 1.9 ml $MgCl_2$ (2M)

3.1 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0038

moles Ca^{2+}: 0.0062

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.62$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 247 HRS.

EXPERIMENT #: 52

REACTION: HMC to Dolomite

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 10.7 m% $MgCO_3$

FINAL COMPOSITION: 50.2 m% $CaCO_3$

SAMPLE WT: 0.2564 gm

MOLECULAR WT: 98.40 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00028

moles Ca^{2+}: 0.00233

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.4 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0068

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.69$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 35 HRS.

EXPERIMENT #: 53

REACTION: Aragonite to Dolomite

FOSSIL: Coral

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 49.1 m% $CaCO_3$

SAMPLE WT: 0.3021 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0030

SOLUTION CHEMISTRY: 1.8 ml $MgCl_2$ (2M)

3.2 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0036

moles Ca^{2+}: 0.0064

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.64$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.72$$

TEMPERATURE: 250°C

REACTION TIME: 326.5 HRS.

EXPERIMENT #: 54

REACTION: LMC to Dolomite

FOSSIL: Echinoid

ORIGINAL COMPOSITION: 1.05 m% $MgCO_3$

FINAL COMPOSITION: 50.0 m% $CaCO_3$

SAMPLE WT: 0.2205 gm

MOLECULAR WT: 99.92 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00002

moles Ca^{2+}: 0.00218

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.69$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.74$$

TEMPERATURE: 250°C

REACTION TIME: 22 HRS.

EXPERIMENT #: 55

REACTION: LMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 3.6 m% $MgCO_3$

FINAL COMPOSITION: 51.1 m% $CaCO_3$

SAMPLE WT: 0.1223 gm

MOLECULAR WT: 99.52 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00004

moles Ca^{2+}: 0.00118

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.69$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.72$$

TEMPERATURE: 250°C

REACTION TIME: 22 HRS.

EXPERIMENT #: 56

REACTION: Aragonite to LMC

FOSSIL: Gastropod; Coral; Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 0.1 - 0.9 m% $MgCO_3$ + Trace ARAG (G)

SAMPLE WT: Coral - 0.1855; Gastropod - 0.1327; Pelecypod - 0.1016 gm/mole

MOLECULAR WT: Coral - 100.09; Gastropod - 100.09; Pelecypod - 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0042

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

TEMPERATURE: 250°C

REACTION TIME: 11.5 HRS.

EXPERIMENT #: 57

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 49.3 m% $CaCO_3$

SAMPLE WT: 0.2130 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00037

moles Ca^{2+}: 0.00182

SOLUTION CHEMISTRY: 1.6 ml $MgCl_2$ (2M)

3.5 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0032

moles Ca^{2+}: 0.0070

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.69$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 120 HRS.

EXPERIMENT #: 58

REACTION: HMC to Dolomite

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 53.6 m% $CaCO_3$

SAMPLE WT: 0.1742 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00030

moles Ca^{2+}: 0.00149

SOLUTION CHEMISTRY: 1.5 ml $MgCl_2$ (2M)

3.6 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0030

moles Ca^{2+}: 0.0072

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.72$$

TEMPERATURE: 250°C

REACTION TIME: 4.5 HRS.

EXPERIMENT #: 59

REACTION: HMC to LMC

FOSSIL: Coralline Algae

ORIGINAL COMPOSITION: 16.9 m% $MgCO_3$

FINAL COMPOSITION: 2.6 m% $CaCO_3$

SAMPLE WT: 0.3904 gm

MOLECULAR WT: 97.42 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.00068

moles Ca^{2+}: 0.00333

SOLUTION CHEMISTRY: 4.9 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0098

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.95$$

TEMPERATURE: 250°C

REACTION TIME: 283 HRS.

EXPERIMENT #: 60

REACTION: Aragonite to LMC

FOSSIL: Gastropod; Coral; Pelecypod

ORIGINAL COMPOSITION: $CaCO_3$

FINAL COMPOSITION: 0.1 - 2.5 m% $MgCO_3$ + Trace ARAG (P)

SAMPLE WT: .5600 gm TOTAL

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0056

SOLUTION CHEMISTRY: 5.0 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0000

moles Ca^{2+}: 0.0100

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 1.00$$

TEMPERATURE: 250°C

REACTION TIME: 11.5 HRS.

EXPERIMENT #: 61

REACTION: LMC to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: 1.4 m% $MgCO_3$

FINAL COMPOSITION: 60.1 m% $CaCO_3$ (DOLO) + 1.2 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.3361 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.000047

moles Ca^{2+}: 0.003311

SOLUTION CHEMISTRY: 1.9 ml $MgCl_2$ (2M)

3.1 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0038

moles Ca^{2+}: 0.0062

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.62$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.71$$

TEMPERATURE: 250°C

REACTION TIME: 320 HRS.

EXPERIMENT #: 62

REACTION: LMC to Dolomite

FOSSIL: Pelecypod

ORIGINAL COMPOSITION: 1.4 m% $MgCO_3$

FINAL COMPOSITION: 60.5 m% $CaCO_3$ (DOLO) + 1.9 m% $MgCO_3$ (LMC)

SAMPLE WT: 0.4131 gm

MOLECULAR WT: 100.09 gm/mole

SUBSTRATE CHEMISTRY:

moles Mg^{2+}: 0.000058

moles Ca^{2+}: 0.004070

SOLUTION CHEMISTRY: 2.0 ml $MgCl_2$ (2M)

3.1 ml $CaCl_2$ (2M)

moles Mg^{2+}: 0.0040

moles Ca^{2+}: 0.0062

SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.61$$

SOLID + SOLUTION RATIO:

$$\frac{mCa^{2+}}{mCa^{2+} + mMg^{2+}} = 0.72$$

TEMPERATURE: 250°C

REACTION TIME: 320 HRS.

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