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Preliminary Study of Some Wyoming Paleozoic Carbonates[1]

M. M. Riddler Tucker

Abstract: A preliminary petrologic investigation of some Paleozoic carbonates from the Wind River Range, Wyoming, has been conducted from thin section study revealing various rock fabrics and a preponderance of diagenetic alteration evidence. The limestones and dolostones are from five principal units: the Gros Ventre, Gallatin, Bighorn, Darby, and Madison formations. Three areas of study are considered. First, it has been found that rather uniform depositional conditions must have existed on this shelf with a decrease in depositional energy at or near the tops and/or bottoms of each system. Secondly, there appears to be a relatively strong correlation between secondary dolomite and non-carbonate material in these sediments which may or may not be indicative of an unstable shelf environment. Finally, Robert L. Folk (1959, pp. 1-38) has made several conclusions about the relative abundance of principal constituents in carbonate rocks. His opinions have been substantiated by this study.

A preliminary petrologic investigation of some Paleozoic carbonates from the Wind River Range in Wyoming has been conducted as the first step in a more extensive study of carbonate fabrics and their relationship to depositional environments. The Wind River carbonates were deposited on an unstable shelf east of the Cordilleran Geosyncline. They consist of limestones and dolostones of varying fabric, calcite-dolomite ratio, insoluble residue content, and diagenetic alteration. This study is a report of a two year project on thin section analysis which has been undertaken concurrently with Misses Terrie Thompson and Marcia Fisk who have performed insoluble residue and staining and etching analyses respectively.

CARBONATE INVESTIGATION PROCEDURES

The author has chosen to use the classification of Robert L. Folk (1959, pp. 1-38) in naming and describing the different carbonate lithologies with one modification. Rather than terming a rock "dolomite," the author prefers to use "dolostone" and reserve "dolomite" to refer only to the mineral, calcium-magnesium carbonate. Dr. Folk's method of describing authigenic calcite has also been adopted but is utilized primarily in the appendix (Folk, 1965, pp. 14-48).

GENERAL GEOLOGY

The Wind River Mountains are located in west-central Wyoming forming a series of large asymmetrical anticlines trending northwest-southeast. The Range is approximately 150 miles long and 40 miles wide. The Paleozoic sediments form the foothills on the northeast side of the mountains with some of the more resistant beds supporting long slopes to the plains. The carbon-

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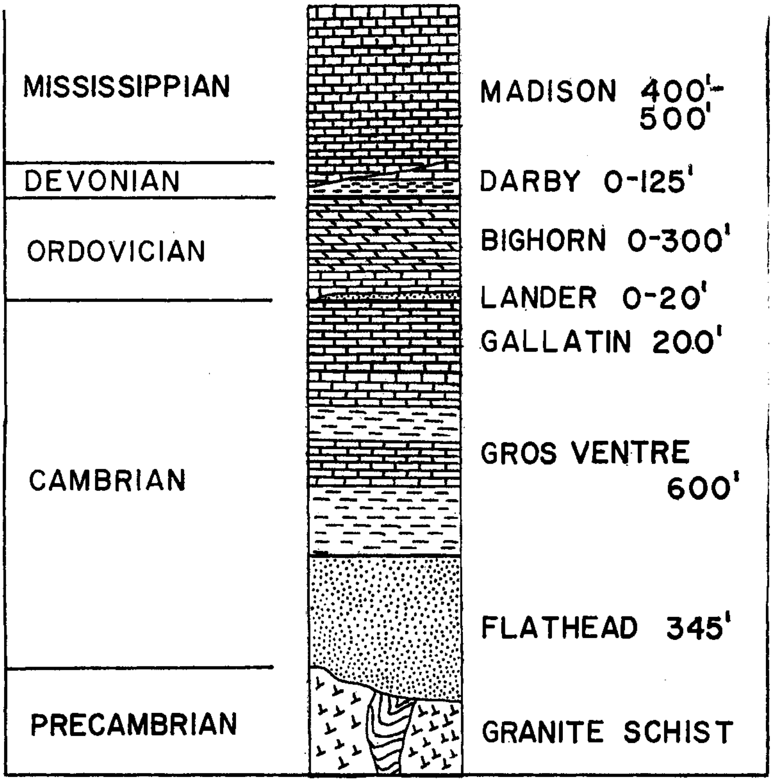

Fig. 1. Columnar section.

GENERALIZED COLUMNAR SECTION

Mesozoic Erathem	
Paleozoic Erathem	
Permian System	
Phosphoria Formation	250 feet
Pennsylvanian System	
Tensleep Formation	275 feet
Pennsylvanian-Mississippian Systems	
Amsden Formation	320 feet
Mississippian System	
Madison Formation	865 feet
Devonian System	
Darby Formation	275 feet
Ordovician System	
Bighorn Formation	205 feet
Cambrian System	
Gallatin Formation	310 feet
Gros Ventre Formation	715 feet
Flathead Formation	235 feet
Precambrian	

ate sequences vary in total thickness from 1700 to 2500 feet and are found in five principal formations.

The Gros Ventre formation primarily consists of carbonate-shale sequences, exhibiting a great deal of diagenetic alteration. The lower Gros Ventre lithologies are medium crystalline dolostones appearing to support the idea of early contemporaneous dolomitization and neomorphism. The middle section of the Gros Ventre, the Death Canyon member, illustrates dolomitic mottling effects and ranges from a neomorphic biomicrite at the base to intrasparites at the top. The mottling in the lower portions is a result of algae remains. The dolomite appears to replace the centers of the colonies first, then proceeds to the peripheries. It has been postulated that the magnesium content of algae is high enough to facilitate dolomitization. In the upper sections of the Death Canyon the mottling is a consequence not only of algae but also of magnesium connate water. The upper Gros Ventre consists of biomicrites, pelsparites, and intrasparudites. Mottling effects are observed but are not as pronounced as in the Death Canyon member.

Above the Gros Ventre formation is the second principal carbonate formation, the Gallatin. It consists at the base of oosparites in the Dunior member, oolithic biosparites in the middle Gallatin, and dolostones in the upper Gallatin. The Dunoir member is rather interesting in that the oolites are associated with terrigenous quartz which appears to have had a calcite coating before deposition and subsequent secondary growth. A relative decrease in dolomitization is noted in the formation as a whole along with a corresponding decrease in insoluble material.

The Bighorn formation is the third carbonate unit and consists principally of dolostones which Heinrich (1956. p. 145-146) describes as clastic, a rather unique variety considering the solubility of carbonate. According to this study it is rather difficult to substantiate his theory except perhaps in the upper unit of the Bighorn, the Leigh member, which is considered to be a primary dolostone. The lower units show extensive alteration and obliteration of fabric which indicates a secondary rather than primary dolostone.

Above the Bighorn is an unconformity marking extended emergence of this area during the Silurian and early Devonian Periods. The Darby formation has been placed in Devonian time and exhibits widely varying lithologies of interbedded dolostones, dolomitic limestones, marls, mudstones, calcareous sandstones. Dolomitization and neomorphism have not been quite as active in the Darby sequences as in some of the lower carbonate units.

Above the Darby is the fifth principal carbonate unit, the Madison formation. This is a gray to bluish crystalline limestone with some dolostones and several fossiliferous horizons. Diagenetic processes have been very active in some areas yet not so active in others. This may be due to the presence of stable or unstable minerals, the presence or absence of connate water, or the extent of solution activity. The sequence begins with sparite lithologies, continues with dolostones, micritic lithologies, biosparites and biomicrites, and finally dolomitized biosparites.

It can be seen from the columnar section that these units comprise most of the Paleozoic rocks up to the Mississippian System. All of these sediments represent periods of marine invasion from the Cordilleran geosynclinal area to the west. The cyclic pattern of emergence and submergence during the Paleozoic Era continued until upper Cretaceous time when the Wind River Mountains were formed (Branson and Branson, 1941, p. 146).

CARBONATE ANALYSIS

In order to organize this data for general study, the author has chosen to investigate three factors: 1) the depositional energies of the sediments, 2) the relationship between dolomite and insoluble residue (non-carbonate) content, and 3) the relative amounts of the principal carbonate constituents.

The parameters for the energy index investigation have been taken from W. J. Plumley, G. A. Risley, R. W. Graves, Jr., and

TABLE I
ENERGY INDEX CRITERIA

I. Quiet
  A. Micritic matrix
  B. Poor sorting
  C. Angular allochems
  D. Simple fossil assemblages
  E. Quartz, less than 5%, clay, less than 50%
II. Intermittently agitated
  A. Micritic matrix
  B. May be some pore space
  C. Fair sorting
  D. Angular allochems
  E. Simple fossil assemblages
  F. Quartz, less than 50%, clay, less than 25%
III. Slightly agitated
  A. Sparry cement, some micrite
  B. May be some pore space
  C. Fair sorting
  D. Subrounded allochems
  E. Varied fossil assemblages
  F. Quartz, less than 50%, no clay
IV. Moderately agitated
  A. Sparry cement or pore space
  B. Good sorting
  C. Rounded allochems
  D. Complex fossil assemblages
  E. Quartz, less than 50%, no clay
  F. May be graded bedding
V. Strongly agitated
  A. Sparry cement
  B. Either well sorted or remixed sediments
  C. Well rounded and/or broken allochems
  D. Very complex fossil assemblages
  E. Quartz, less than 25%, clay, less than 5%

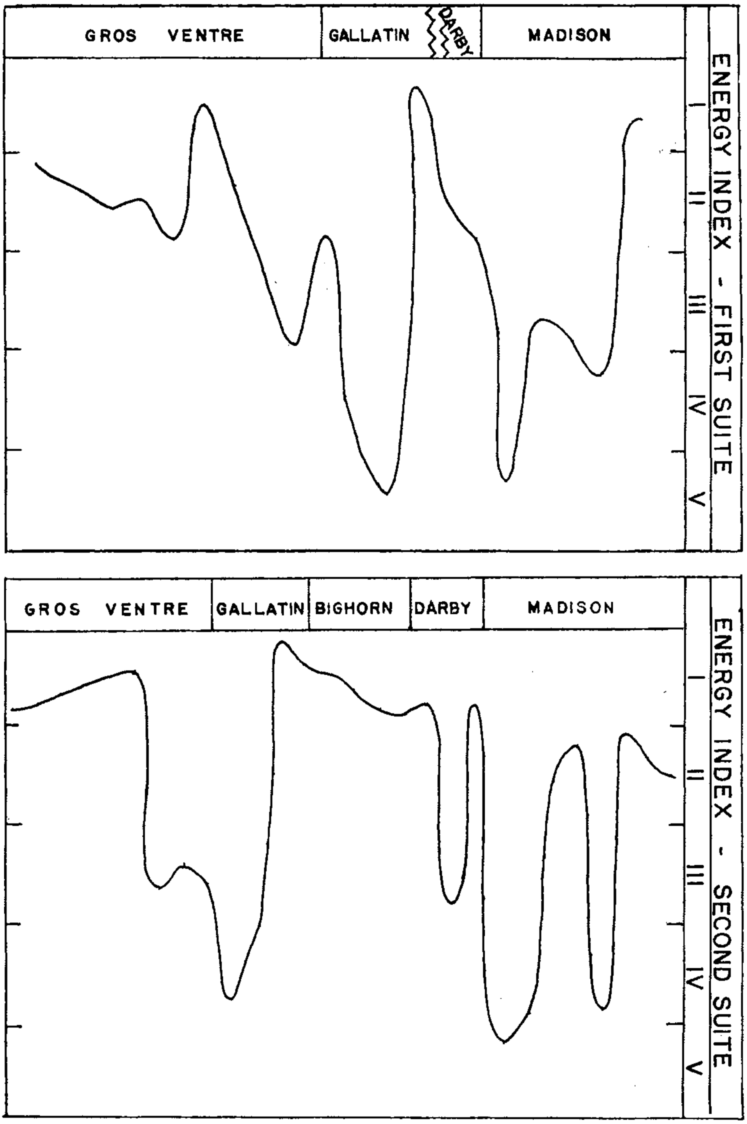

Fig. 2. Energy Index of the Stratigraphic column.

M. E. Kaley (1963, pp. 88-89) and R. L. Folk (1963, p. 81) and combined with slight modification to fit into five categories. The first change is in the area of micrite content. Folk's second energy class has no micrite, while Plumley, et al., indicate greater than 50% microcrystalline matrix in their corresponding class. The author has simply extended micrite content to her third class which is agreeable with Plumley, et. al. The second modification concerns the equivocation of pore space and sparry cement which Folk advocates and Plumley, et. al., do not mention. The five categories are represented by Roman numerals. (Table I). No rock will have all the characteristics of one energy type, and most of the time the characteristics of the rock overlap classes. Therefore, the author had to decide which criteria were most indicative of the depositional environment. Figure 2 is a plot of the energy index against the stratigraphic column. There are two graphs because the Paleozoic section is sampled twice in two different localities. Note that in the first suite the Bighorn formation has been omitted because only the Leigh member is represented and its fabric is very difficult to interpret. The points plotted are equally spaced, so that each formation space is proportional to the number of samples from that unit. If the charts are compared directly they do not correspond. However, if one follows the index line according to its position within a particular formation, a correspondence does exist. For example, at the Gros Ventre—Gallatin contact, the upper Gros Ventre energy is approximately IV, at the contact it reduces to III, than in the lower Gallatin increases to IV and V in both graphs. It appears, therefore, that the depositional energy conditions were relatively uniform throughout the shelf area.

The second study envolves a correlation between dolomite and insoluble residue content. In the lower Gros Ventre (fig. 3), at one point the dolomite and insoluble residue percentages add up to more than 100%. The author attributes this to the fact that different samples were used for the two tests and even though they are from the same horizons a slight variation of these percentages is likely to be present. Note, also, that a sandstone is present in the Darby formation which gives a high insoluble percentage. This may not produce a significant correlation. It has been suggested that the presence of non-carbonates (in this case the insoluble residue) may facilitate dolomitization in sediments. Only rough correlations have been made, however. In this study the major deviations of the two lines are at the Darby sandstone, which the author previously mentioned, the lower Gallatin, and the upper Bighorn. As pointed out in the general discussion of the formations, the lower Gallatin (the Dunoir member) is an oosparite. This means that dolomitization could easily be active but that insoluble material would have to be low because of the high energy of deposition which would winnow out all of the fine material. The Leigh member of the upper Bighorn is a primary dolostone which indicates that dolomitiza-

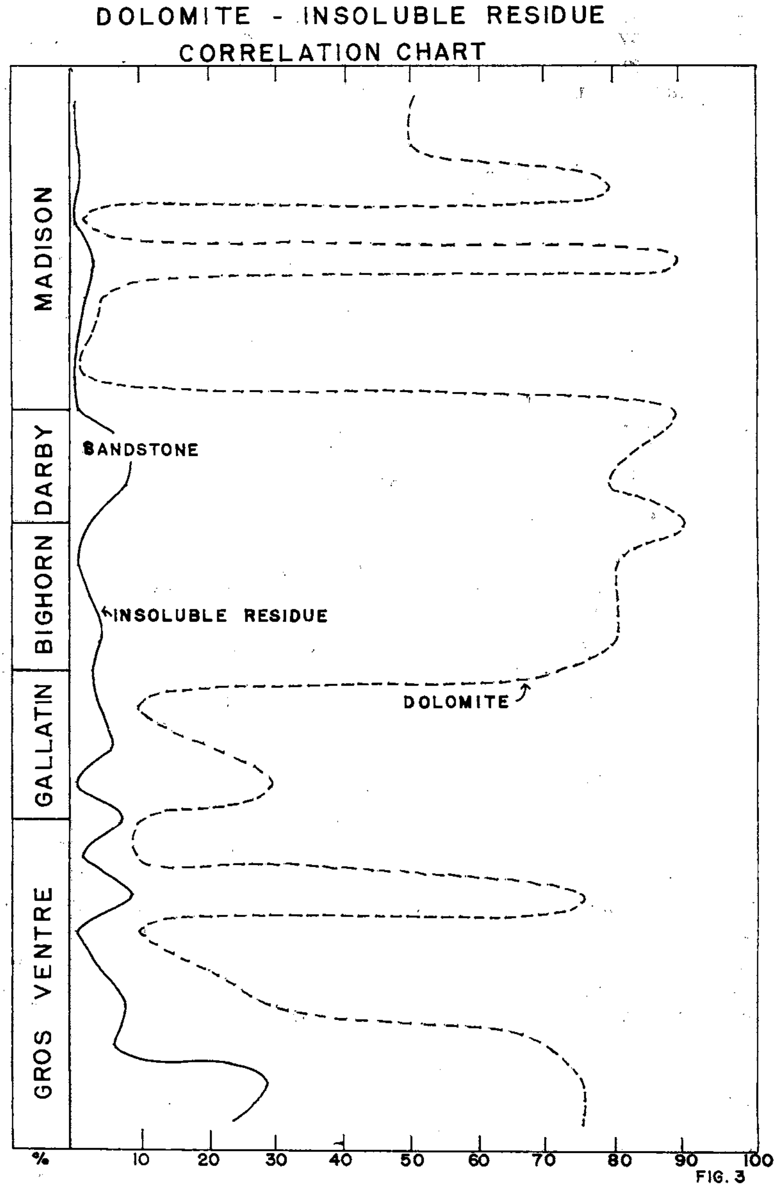

FIG. 3

Fig. 3. Dolomite-Insoluble Residue Corretatism Chart.

tion did not occur and therefore can not be a function of insoluble material. With these facts in mind, the correlation can be more significant than it first appears and a direct proportionality may exist between dolomite and insoluble residue content.

The third facet of this investigation deals with the principal carbonate constituents and their relative abundances. The two ternary diagrams (fig. 4) show rather conclusively that the majority of these carbonates contain 1) either micritic matrix or sparite cement but rarely both, 2) a majority of fossils and pellets, some intraclasts, and few oolites.[2] A blending of fossil-pellet and intraclast allochems appears to exist, while oolites are generally alone. The histogram deals with microspar and indicates relative abundance of the average sizes of recrystallized mud matrix. The measurements have been performed using a petrographic microscope with which four microns is the smallest size to be measured to any degree of accuracy. The majority of the crystals are 4 to 8 microns with a principal subsidiary grade of 8 to 16 microns. Folk (1965, p. 37) predicts 4 to 8 microns as the dominate size grade, but indicates some recrystallized micrite has been frequently as large as 30 microns and perhaps even larger. Therefore, the carbonates from Wyoming appear to substantiate his predictions concerning microspar.

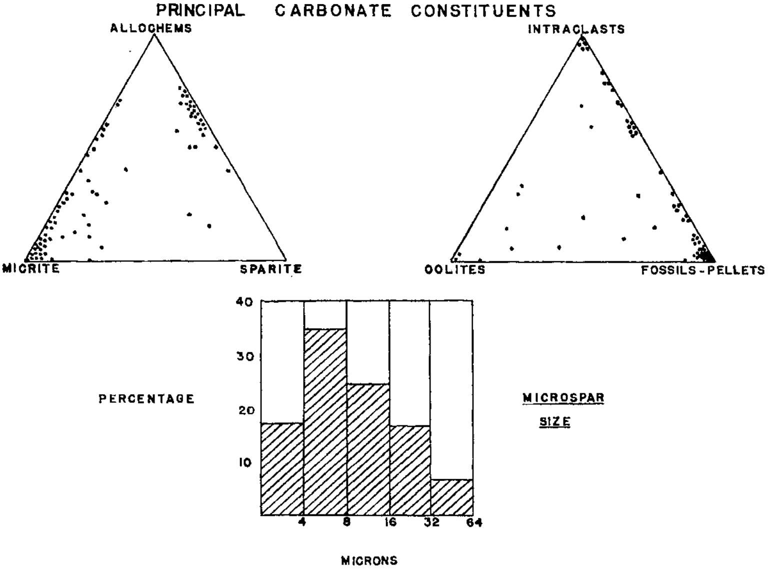

Fig. 4. Principal corbonate Constituents.

Summary and Conclusions

The Paleozoic carbonate sequence from the Wind River Range exhibits many fabric types with a preponderance of diagenetically modified textures. The energy index suggests fairly uniform depositional conditions with a rather interesting cyclic pattern

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[2] The positions of the points on the ternary diagrams have been moved into the field in order that they may be seen and not blend with the lines of the chart.

of alternating high and low energies, the low energies often occuring at the contacts between formations. This may be indicative of unstable shelf environment energies and a means of identifying such. The author can not offer an explanation for this decrease in energy which corresponds to shallow water of early transgression or late regression of the seas, unless burial was so rapid mud did not get winnowed out and allochems did not become rounded and well sorted. There seems to be a fairly good correlation between dolomite and insoluble residue content when the three exceptions of the Darby sandstone, the Dunoir oosparite, and the Leigh primary dolostone are explained. This correlation may also be indicative of the unstable shelf environment where dolomitization is a function of the presence of noncarbonate material. The principal carbonate constituents, as proposed by R. L. Folk, have shown abundances in type and size supporting his opinion of what they should be.

ACKNOWLEDGEMENTS

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APPENDIX

This section includes brief descriptions of all the thin sections used in the study. There are two numbers for each sample because sections were cut perpendicular and parallel to the bedding. The two suites have been placed in stratigraphic sequence. Only the major size grades have been given for the allochems and microspar in each description.

No.	Name	Allochems		Cement/Matrix		Mineral Content		Authigenic Features	Paragenesis
		Type	Size	Type	Size	Major	Minor		
Gros Ventre Formation, Lower Gros Ventre									
43 44	V:D4	ghosts		microspar	62µ	dolomite 70% calcite 30%	glauconite iron oxide clay	secondary enlargement of dolomite rhombs N_rE_4 dolomitization	Originally micritic calcite or aragonite, possibly disrupted. Dolomitization and neomorphism began early causing an increase in crystal size and concentration of calcite and clay at peripheries of the dolomite crystals.
Gros Ventre Formation, Death Canyon Member									
1 2	RIIIb: dLa	fossils	1/4-1/2 mm	micrite 50% sparite 30% microspar	14µ	calcite 40% dolomite 25% quartz 10% iron oxide 15%	glauconite chalcedony	secondary enlargement of dolomite rhombs N_rE_2, $P.B_5$ dolomitization	Originally a biomicrite, possibly disrupted. Early dolomitization and neomorphism obliterated and mottled the texture with increase in crystal size.
3 4	RIIIb: dLa	fossils intraclast	1/2-1 mm	micrite 25% sparite 40% microspar	12µ	calcite 60% dolomite 20% iron oxide 10%	quartz glauconite	secondary enlargement of dolomite rhombs N_rE_2 dolomitization	Originally an intraclastic biomicrite. Early dolomitization and neomorphism obliterated and mottled the texture with gradational increase in crystal size.
5 6	RIIIb: dLa	fossils	1/2-1 mm	micrite 10% sparite 65% microspar	20µ	calcite 50% dolomite 30% iron oxide 10%	quartz glauconite	secondary enlargement of dolomite rhombs N_rE_3	Originally an algal biomicrite. Early dolomitization and neomorphism obliterated and mottled the texture - dolomitization beginning in algae centers.

		Allochems		Cement/Matrix		Mineral Content			
No.	Name	Type	Size	Type	Size	Major	Minor	Authigenic Features	Paragenesis
45 46	V:D3	fossils	1/16-1/32 mm	microspar	10μ	dolomite 75% calcite 15%	glauconite iron oxide quartz	N_rE_2 dolomitization	Originally a biomicrite. Neomorphic processes have increased the crystal sizes. Dolomite has replaced the calcite.
47 48	RIIIb: dLa	fossils intraclast	1/16-1/8 mm	microspar	10μ	dolomite 40% calcite 50%	quartz glauconite iron oxide	Secondary enlargement dolomite rhombs N_rE_2 dolomitization	Originally a biomicrite with some terrigenous material. Dolomitization and neomorphism have obliterated most of the primary fabric.
7 8	IIb: dLa	fossils intraclast oolite	1/2-1mm	micrite 40% sparite 35% microspar	10μ	calcite 60% dolomite 30%	quartz iron oxide	N_rE_2, $N.E_5O_m$ dolomitization	Originally a biomicrite, disrupted by current or organism. Early diagenesis proceeding slowly.
9 10	RIIIb: dLa	fossils intraclast	1/2-1mm	micrite 50% sparite 30% microspar	16μ	calcite 80% dolomite 10%	iron oxide	N_rE_2 dolomitization	Deposited as a biomicrite, disruption and sparite deposition. Diagenetic processes further modified the sediment.
11 12	IIIm: dLa	fossils	1/2-1mm	micrite 95%		calcite 80% dolomite 10%	iron oxide	neomorphism dolomitization	A fossiliferous micrite, possibly a dismicrite due to some disturbance. Minimum diagenesis.
49 50	IIImX: dL	fossils pellets	1/16-1/32 mm	micrite 65% microspar	4μ	calcite 60% dolomite 30%	iron oxide	N_rE_1 dolomitization	Deposited as a micrite, disruption of the sediment occurred. May have given connate water a chance to begin facilitating diagenesis.

No.	Name	Allochems		Cement/Matrix		Mineral Content		Authigenic Features	Paragenesis
		Type	Size	Type	Size	Major	Minor		
51 52	IIb:dLa	fossils	1/2- 1mm	micrite 70% sparite 15%		calcite 70% dolomite 20%	iron oxide	secondary enlargement of dolomite rhombs N_rE_4 dolomitization	Deposited as a biomicrite which was disrupted allowing the loosely packed areas to succumb to recrystallization.
53 54	IIb:La	fossils intraclast	1/4- 1/2 mm	micrite 75% sparite 15%		calcite 80%	dolomite iron oxide	$P.E_4$ dolomitization	Deposited as a biomicrite with some intraclasts, disruption, voids and fractures filled with calcite, later dolomitization.
13 14	Ii:Lr	intraclast fossils oolites	1-2 mm	sparite 30%		calcite 90%	iron oxide dolomite glauconite quartz	sparite after intraclast dolomitization authigenic quartz recrystallization ?	Deposited as an intrasparudite with micritic intraclasts. Dolomitization and recrystallization began, then later formation of authigenic quartz.
55 56	IIb: dLr	intraclast fossils	1-2 mm	micrite 60%		calcite 70% dolomite 20%	glauconite iron oxide quartz	$N.E_6O_m$ dolomitization recrystallization ?	Deposited as an intramicrudite with numerous fossil fragments. Recrystallization began in some of the intraclasts. Later dolomitization.
Gros Ventre Formation, Upper Gros Ventre									
15 16	Ip:La	pellets fossils intraclast ?	1/16- 1/8 mm	sparite 35%		calcite 90%	glauconite iron oxide	$N.E_5O_m$, $P.E_4$	Deposited as a pelsparite with some disruption and formation of voids or sheltered areas, subsequently filled with calcite
17 18	Ib:La	intraclast fossils pellets	1/4- 1/2 mm	sparite 40%		calcite 90%	glauconite	$N.B_3O.$ recrystallization of pellets ?	Deposited as a biosparite with pellets and intraclasts. Calcite overgrew the fossils during and

		Allochems		Cement/Matrix		Mineral Content			
No.	Name	Type	Size	Type	Size	Major	Minor	Authigenic Features	Paragenesis
									after lithification.
19 20	RIII:L	pellets	1/16-1/8 mm	microspar	16μ	calcite 90%	quartz iron oxide glauconite	N_rE_2 solution deposition in some fractures	Probably deposited as a micrite which immediately began to be altered by neomorphic processes. Later fracture opened seams where material was deposited.
57 58	Ibp: La	fossils pellets intraclast	1/16-1/8 mm	sparite 25% micrite 5% microspar	20μ	calcite 90%	glauconite quartz iron oxide	$N.E_4O$, N_rE_3, $P.E_4$	It appears that these sediments were deposited in an alternating high and low energy environment, thus biopelmicrites and sparites. Neomorphism occurred along with some direct precipitation of calcite.
59 60	Ii:dLa	intraclast fossils	1/2-1 mm	sparite 50%		calcite 80% dolomite 10%	quartz iron oxide glauconite	N_rE_2, $N.E_5O_m$ dolomitization authigenic quartz	Originally deposited as an intrasparite with quite a few fossils. Early diagenesis altered the sediments somewhat and quartz began to grow in place.
Gallatin Formation, Dunoir Member									
21 22	Io:dLa	oolites	1/4-1/2 mm	sparite 40%		calcite 60% dolomite 30%	iron oxide quartz	quartz after calcite secondary enlargement of dolomite rhombs	Deposited as an oosparite whose nucleii facilitated dolomite growth. Terrigenous quartz deposited with the sediment began to grow secondarily.
61 62	Io:dLa	oolites	1/4-1/2 mm	sparite 40%		calcite 60%	quartz iron oxide	quartz after calcite	Deposited as an oosparite with quartz grains which had an original calcite coating.

		Allochems		Cement/Matrix		Mineral Content			
No.	Name	Type	Size	Type	Size	Major	Minor	Authigenic Features	Paragenesis
						dolomite 30%			Succeeding dolomitization and secondary enlargement of the quartz grains modified the texture
Gallatin Formation, Middle Gallatin									
23 24	Io:La	oolites fossils intraclast pellets	1/2-1mm	sparite 40% microspar	?	calcite 90%	dolomite iron oxide glauconite	N_dE_2	Deposited as a mixture of all four major allochem types cemented by sparry calcite. Subsequent degrading neomorphism modified the texture.
63 64	Io:La	oolites fossils intraclast	1/4-1/2 mm	sparite 30% micrite 15% microspar	20μ	calcite 75% dolomite 15%	glauconite iron oxide quartz	N_rE_3 secondary enlargement of dolomite rhombs dolomitization	Oolites, fossils, and intraclasts were deposited with a sparry calcite cement and micrite which the current was unable to winnow out of the cavities. Diagenetic processes then slightly modified the texture.
65 66	IIIm			micrite microspar	4μ	calcite 80% dolomite 10%	iron oxide	N_rE_2	Deposited as a micrite which was disrupted. Some subsequent recrystallization occurred, possibly porphyroid.
Gallatin Formation, Upper Gallatin									
25 26	RIII:L			microspar	8μ	calcite 80% dolomite 10%	iron oxide	N_rE_2	Deposited as a micrite and has been subsequently recrystallized.

		Allochems		Cement/Matrix		Mineral Content			
No.	Name	Type	Size	Type	Size	Major	Minor	Authigenic Features	Paragenesis
27 28	RIII: L & Ii:Lr	fossils pellets intraclast	1-2 mm	sparite 35% microspar	4μ	calcite 35%	dolomite iron oxide	N_TE_2 dolomitization	Two lithologies are present. One is an intrasparite deposited in moderately agitated waters, the other is a microspar deposited in quieter waters and subsequently recrystallized.
67 68	V:D3			microspar	35μ	dolomite 70% calcite 30%	iron oxide clay ?	N_TE_3 dolomitization	Probably deposited as a micrite which underwent early neomorphism.
Bighorn Formation, Lower Bighorn									
69 70	V:D3			microspar	20μ	dolomite 75% calcite 15%	iron oxide	N_TE_3 dolomitization	The sediment was originally micritic but has recrystallized. Dolomitization accompanied that recrystallization.
Bighorn Formation, Middle Bighorn									
71 72	V:D3			sparite microspar	35μ	dolomite 80% calcite 10%	iron oxide	N_TE_3 dolomitization	The sediment was originally micritic but has almost totally recrystallized to spar. Dolomitization accompanied this.
73 74	V:D3			sparite		dolomite 80% calcite 10%	iron oxide	dolomitization	The sediment was originally micritic but has recrystallized to spar. Accompanying dolomitization has almost replaced the entire rock.

No.	Name	Allochems Type	Allochems Size	Cement/Matrix Type	Cement/Matrix Size	Mineral Content Major	Mineral Content Minor	Authigenic Features	Paragenesis
Bighorn Formation, Upper Bighorn									
75 76	V:D4	ghosts		sparite		dolomite 90%	calcite iron oxide	dolomitization N_rE_4	May have been deposited as a biomicrite which has subsequently recrystallized and dolomitized to a sparry mosaic.
Bighorn Formation, Leigh Member									
29 30	Ip: Da	pellets	1/8-1/4 mm	sparite 40%		dolomite 100%		recrystallization of pellets ?	A primary dolomite sediment deposited as a pelsparite. Some alteration of the pellets may have taken place.
Darby Formation, Lower Darby									
77 78	TsV: D4	intraclast ?	1/8-1/4 mm	microspar	16µ	dolomite 80% quartz 10%	calcite glauconite iron oxide	N_rE_2 dolomitization quartz after carbonate	Deposited as a terrigenous micrite which underwent dolomitization and recrystallization with secondary replacement of carbonate by quartz.
Darby Formation, Middle Darby									
79 80				micrite		quartz 60% carbonate 30%	iron oxide glauconite	quartz after carbonate	Deposited as a calcareous sandstone. Subsequent replacement of carbonate by quartz has modified the fabric.
Darby Formation, Upper Darby									
81 82	V:D3	ghosts		microspar	30µ	dolomite 90%	calcite iron oxide	N_rE_3 dolomitization	Deposited as a coarse micrite which was then dolomitized. The energy conditions were alternating between low and mod-

No.	Name	Allochems Type	Allochems Size	Cement/Matrix Type	Cement/Matrix Size	Mineral Content Major	Mineral Content Minor	Authigenic Features	Paragenesis
									erate agitation.
31 32	V:D4			sparite		dolomite 80% calcite 10%	iron oxide	N_rE_4 dolomitization solution deposition	Deposited as a micrite. Dolomitization. Recrystallization enlarged the crystals to spar. After lithification, the rock was fractured allowing for solution deposition to take place in the cracks.
Madison Formation, Lower Madison									
33 34	Io:La	oolites fossils intraclast	1/2-1mm	sparite 30%		calcite 90%	iron oxide	inversion ?	Oolites, fossils, and intraclasts were deposited in a sparry cement. Possible inversion of aragonitic shells and oolites.
83 84	Ii:La	intraclast pseudo-oolite fossils	1/4-1/2 mm	sparite 30%		calcite 100%		$N.E_5O_m$	Intraclasts were formed by a disruption of sediment with the coating of some fossils with the micritic sediment. These were cemented in spar. Overgrowths of crinoid plates subsequently occurred.
85 86	Ii:La	intraclast pseudo-oolite fossils	1/4-1/2 mm	sparite 30%		calcite 90%	dolomite iron oxide	$N.E_5O_m$ dolomitization recrystallization ?	Similar to #83-84 except that some microspar may be present and dolomitization has occurred.
Madison Formation, Middle Madison									
87 88	Ii:Lr	intraclast pellets	1/2-1mm	sparite 25%		calcite 90%	iron oxide	N_rE_2 quartz after	Deposited as an intrasparudite with pellets (which may be

No.	Name	Allochems		Cement/Matrix		Mineral Content		Authigenic Features	Paragenesis
		Type	Size	Type	Size	Major	Minor		
				microspar	8μ		quartz	calcite	the results of recrystallizing micrite). Neomorphism occurred and quartz began to attack the calcite.
89 90	V:D2	intraclast ?		microspar	16μ	dolomite 90%	calcite quartz iron oxide	N_rE_2 dolomitization	May have been deposited as an intramicrite. The sediment underwent early dolomitization and neomorphism.
Madison Formation, Upper Madison									
35 36	III:L			micrite 90% microspar	 5μ	calcite 90%	iron oxide	N_rE_2, $P.E_3$	Deposited as a micrite which may have been disrupted slightly. Some recrystallization took place, with void filling.
37 38	III:dL			microspar	30μ	calcite 70% dolomite 20%	iron oxide	N_rE_3	Deposited as a coarse micrite in an alternating low to moderately agitated environment. Subsequent recrystallization occurred.
39 40	II:La	intraclast fossils oolites	1/2-1mm	sparite 30%		calcite 90%	aragonite ?	inversion ? $N.E_5O_m$	The allochems were deposited in a sparry cement. Some of the fossils and oolites may have inverted. Secondary overgrowths of some fossils occurred
41 42	IIb: Lr	fossils intraclast oolites pellets	1-2 mm	micrite 40% microspar	 15μ	calcite 90%	dolomite iron oxide	N_rE_2 dolomitization inversion ?	Deposited as a biomicrudite with the other allochems probably in fairly quiet waters. Inversion may have occurred, then dolomitization and recrystallization simultaneously.

No.	Name	Allochems		Cement/Matrix		Mineral Content		Authigenic Features	Paragenesis
		Type	Size	Type	Size	Major	Minor		
91 92	Ib:La	fossils intraclast	1/2-1mm	sparite 30%		calcite 100%		$N.E_5O_m$, $N.E_6O_m$	Fossils and intraclasts were deposited in a sparry cement. Some inversion may have occurred and certainly secondary overgrowth occurred.
93 94	V:D3	ghosts	1/4-1/2 mm	microspar	35µ	dolomite 90%	calcite iron oxide	N_rE_3 dolomitization	Deposited as some kind of micrite. It was then subjected to contemporaneous dolomitization and recrystallization which has enlarged the crystals to spar.
95 96	V:D2	fossils	1/2-1mm	microspar	6µ	dolomite 60% calcite 40%		N_rE_2, $N.E_5O_m$ dolomitization	Probably deposited as a biomicrite. It appears as if the diagenetic processes are caught at an intermediate stage of dolomitization and recrystallization.
97 98	V:D5	fossils intraclast	1/2-1mm	microspar	30µ	dolomite 80% calcite 10%		N_rE_3 dolomitization	Very similar to #95-96 except for the intraclast content and the higher dolomite percentage.