United States

Department of the Interior

U.S. Geological Survey

Washington

Geological Investigations

Naval Petroleum Reserve No. 4

Alaska

Appendix A

POROSITY AND PERMEABILITY OF LISBURNE LIMESTONE SPECIMENS COLLECTED IN 1950

Report 40

SELECTED SECTIONS OF LISBURNE LIMESTONE, BROOKS RANGE, ALASKA

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By

P. D. Krynine

May 1951

APPENDIX A, May 1951

POROSITY AND PERMEABILITY OF LISBURNE LIMESTONE SPECIMENS

COLLECTED IN 1950

The 18 specimens studied in the laboratory are from collections 50ARr, 50ASN, and 50ABe. The samples include six dolomites, two incipient dolomites, and six clastic limestones (two of these have predominantly inorganic chemiclastic constituents, three are predominantly bioclastic,[1] and one is evenly composed of both chemiclastic and bioclastic constituents). Of the four remaining samples, one is texturally a very poorly sorted silty calcareous sandstone, closely resembling a graywacke. Three are fine-grained calcareous siltstone of sandy siltstone or microconglomerate type, and texturally strongly resemble detrital siliceous rocks (siltstone).

As a whole the relationships which have been established for the Lisburne limestone in Report 40 and Special Report 17 are also true for this particular collection. Thus the porosity as a whole is related to well-sorted and relatively coarse grained dolomite. However, in these samples, secondary enlargement of pore space is more evident than usual. Of five specimens having more than 5 percent visible porosity, two show secondary leaching, two apparently have pore pattern produced by dolomitization and not changed since, and one shows considerable reduction of original pore space by secondary fillings.

Collection 50ARr as a whole is typical of the Lisburne limestone and includes three dolomites; four clastic limestones, two predominantly inorganic chemiclastics; and one unusual, very poorly sorted, angular, silty, clastic limestone that is high in organic matter and texturally resembles a graywacke (sample 50ARr 1). None of the samples in this collection has good porosity, with the exception of 50ARr 0, a clastic limestone. This sample seems to have escaped primary cementation; possibly the open network of pores allowed additional leaching.

Collection 50ASN, consisting of five specimens, contains two dolomites, two highly dolomitic limestones, and one bioclastic limestone. One of these, sample 50ASN 4, is a calcareous sandy siltstone. The porosity is fair in the two well-sorted dolomites and considerable in one of the bioclastic limestones that has escaped cementation. This specimen, 50ASN 10, shows porosity of the cavity or "reef" type.

Collection 50ABe as a whole is very high in organic matter and other impurities such as glauconite and phosphate, which are well represented in every specimen. One dolomite (specimen 50ABe 26) represents alteration of a pellet-bearing limestone and shows fair residual porosity left after plugging of original pore space. Except for this specimen,

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1/ As used in this report, bioclastic refers to material consisting of fragmental hard parts of organisms.

there is no dolomite, but there are two siltstones or microconglomerates (specimens 50ABe 105 and 102). The two remaining specimens are very dark bioclastic limestones, with one of them (specimen 50ABe 101) showing both primary and secondary porosity.

All the genetic interpretations in Report 40 apply in full to the present collection: (1) bioclastic or chemiclastic inorganic material, represented by grains and matrix, accumulated with various degrees of sorting; (2) this clastic material was partly or totally cemented by clear calcite; and (3) some of these rocks were dolomitized, beginning with the replacement of the finer-grained matrix. The same relationship exists between the size of replacing dolomite crystals and the size and sorting of the original clastic limestones. As a whole, the dolomite crystals are smaller than the clastic calcite that they replace; possibly they are only half the size of the original calcite. A review of the earlier described Lisburne collections will be made in order to confirm this apparent relationship between original calcite size and size of replacing dolomite.

A detailed description of each specimen and a summary table follow.

COLLECTION 50ARr

Specimen 50ARr 202--cherty, impure dolomite.--(Kiruktagiak member, west Etivluk River section, pl. 3, Rept. 40.) The bulk of the rock is made of dolomite crystals averaging about 0.8-0.15 mm. in size. They occur in two modes: one about 0.05 and one about 0.10 mm. These crystals replace the original calcite grains of indeterminate bioclastic or chemiclastic origin. The bioclastic fragments are large crinoid plates (?) (as large as 0.8 mm.), partly replaced by chert; indeterminate fossils up to 0.3 mm. partly replaced by collophane; broken calcite fragments unreplaced or partly replaced by chert or by collophane.

The rock consists of bands of clear dolomite and bands of yellowish, collophane-loaded silt particles with an average diameter 0.02 mm. The collophane bedding bands are crinkled and represent in part either original cross bedding or in part considerable contemporaneous slumping.

The rock contains chert (average grain size of micro-quartz about 0.01-0.02 mm.). The chert preferentially replaces the larger calcite fragments, possibly crinoid plates. A minor amount of chert is interstitial and roughly follows some of the bands.

Sorting is poor.

Composition: Less than 5 percent chert, 5-6 percent collophane, and 90 percent carbonate, about two-thirds of which is dolomite.

The porosity is low (visible porosity less than 1 percent, with pore size less than 10 microns), frequently along bedding planes.

Specimen 50ARr 30--bioclastic limestone.--(Zone 3, Wachsmuth member, Alapah Creek section, pl. 2, Rept. 40.) The rock consists of: (1) Two to 3 percent pellets. (2) Less than half the grains are bioclastic fragments--remains of Foraminifera, broken shells of larger organisms, and a few broken crinoid plates. (3) About half the grains are chemiclastic fragments--oolites as much as 0.6 mm. in diameter and rounded structureless grains up to 0.3 mm. in diameter, possibly rolled calcite crystals.

These grains ($\pm$80 percent) are imbedded in an interstititial matrix that consists partly of fine black calcareous silt up to 0.05 mm. in diameter.

This matrix is cemented by white sparry calcite. It is hard to distinguish some of the individual elements of the sparry calcite cement from broken chemiclastic fragments. Average diameter of the grains, 0.6-0.8 mm.

Sorting is extremely poor.

Composition: 100 percent calcite. Very little dolomite is present; there is no silica. One unidentified fossil containing considerable dendritic carbon was seen.

The porosity is less than 1 percent, mostly related to the interior of fossils.

Specimen 50ARr 25--crystaline dolomite.--(Zone 1, Wachsmuth member, Alapah Creek Section, pl. 2, Rept. 40.) The rock is a crystalline dolomite with most evidence of its early clastic origin obliterated. It consists mostly of well-developed dolomite crystals 0.2 mm. in diameter (range 0.1-0.4 mm.). The dolomite contains very small inclusions of black organic specks, oxidized pyrite (now limonite), and vacuoles and fluid bubbles.

Sorting is fair to good.

Composition: 98$\pm$ percent dolomite. A small amount of chert (1-2 percent) is distributed as interstititial, elongated aggregates. Phantom aggregates of dolomite pointing to early clastic texture reach a measure of 0.5 mm.

The visible porosity is low, not exceeding 1 percent, and the principal mode of the pores is also low, on the order of 10 microns.

Specimen 50ARr 21--incipiently dolomitized clastic limestone.--(Zone 1, Wachsmuth member, Alapah Creek section, pl. 2, Rept. 40.) Very poorly sorted bioclastic limestone consisting of large fragments (crinoid plates, maximum 2 mm. in diameter); possible chemiclastic crystals of calcite 0.5-1.0 mm. in diameter; oolites up to 0.6 mm. in diameter; broken bryozoa fragments up to 1 mm. in diameter; miscellaneous fossil fragments--Foraminifera; and broken fossils, etc., ranging from 0.05 to 0.2 mm. The smaller fragments of chemiclastic calcite grains act as matrix for the larger fragments. The whole mass is cemented by white sparry calcite which forms secondary overgrowths in optical continuity with the calcite grains.

There is incipient dolomitization by clear dolomitic rhombs roughly 0.1 mm. in diameter which have formed in the matrix.

The clastic grains form roughly 75 percent; sparry calcite cement, 5-10 percent; carbonate matrix, 10-15 percent; and dolomite replacing sundry portions of the matrix, less than 5 percent.

The sorting is poor.

Composition: Calcite, 95 percent; dolomite, 5 percent.

Porosity is less than 2-3 percent, with visible pore diameter about 20 microns; porosity commonly is related to bedding planes.

Specimen 50ARr 17--clastic (bioclastic) limestone.--(Zone 1, Wachsmuth member, Alapah Creek section, pl. 2, Rept. 40.) The rock consists of reasonably well preserved and abundant fossil remains, bryozoa up to 1.0 mm., crinoid plates up to 2 mm., gastropods or snail-like organisms (?), numerous Foraminifera, brachiopod fragments (?), and many small unidentified fragments. In addition, the rock contains ±30 percent of calcite crystals 1.5-2 mm. in size of dubious origin which are quite probably inorganic chemiclastic elements. The rock is cemented by white sparry calcite and contains little calcite matrix. The sparry calcite is more of the pore-filling type and less frequently overgrowths, but nevertheless has a tendency to be in optical continuity with the surrounding large calcite grains.

Approximately 80 percent of the rock consists of grains; 10-15 percent is sparry calcite cement, and less than 5 percent is organic calcareous matrix.

Sorting is fair to poor.

Composition: 100 percent calcite.

Approximately one fossil in ten contains small pieces of pyrite that have been oxidized.

Visible porosity is low, under 1 percent, with pore diameter less than 10-20 microns, except for better development along bedding planes.

Specimen 50ARr 7--fine crystalline dolomite.--(Zone 4, Alapah member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock consists of fine dolomite crystals averaging about 0.1 mm. (range 0.05-0.2 mm.) The rock is locally spotted with limonite bands, distributed very evenly, intergranular, possibly parallel to bedding. There is no evidence of substantial post-depositional weathering except the limonite spots.

Sorting is good.

Composition: 100 percent dolomite.

Very few phantom effects are present that suggest the original texture of the rock, which is in doubt.

Visible porosity is of the order of 2-3 percent with a principal mode of 20 microns.

Specimen 50ARr 1--fine clastic limestone.--(Zone 3, Wachsmuth member, Anaktuvuk River section, pl. 2, Rept. 40.) Extremely poorly sorted rock that consists of chemiclastic fragments of calcite, most slightly rounded. They average 0.2 mm. in size and range from 0.02 mm. to 0.4 mm. Most of the fragments appear to be slightly elongated (axial length 1:1½ and in some 1:3). The rock is extremely well bedded. The larger grains show extreme rounding and the smaller grains are very angular; there are very few fossil fragments. The rock could be described as a calcite grit with some of the calcite flakes behaving like mica flakes. Texturally the rock is analogous to a highly micaceous, poorly sorted silty graywacke.

The rock contains about 5-10 percent of black organic matter along the bedding planes, some oxidized to limonite.

Composition: 90-95 percent calcite, 5-10 percent black organic matter.

No porosity.

Specimen 50ARr 0--clastic (and chemiclastic) limestone.--(Zone 4, Alapah member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock consists of large calcite grains averaging between 0.5 and 1.0 mm. and ranging from 0.2 to 2.0 mm. About 75 percent of the large calcite grains appear to be rolled and rounded inorganic calcite crystals (chemiclastic). Less than 25 percent seem to be undoubted organic remains, mostly bryozoa. The rock seems to be loosely cemented by calcite and has visible porosity on the order of 10 percent or more and a pore diameter (principal mode) between 20 and 50 microns.

This bonding and high porosity are due to lack of primary cementation, although part (not over a third) may be due to secondary leaching.

COLLECTION 50ASN

Specimen 50ASN 31--coarse crystalline dolomite.--(Zone 3, Alapah member, Alapah Creek section, pl. 2, Rept. 40.) The rock is a crystalline dolomite developed from a clastic limestone with many remnant structures. Dolomite crystals are well-sorted and relatively coarse grained, average about 0.3 mm. with a limited range of 0.2-0.4 mm. Approximately 25 percent of the rock shows definite relic structures of oolites up to 0.6 mm. in diameter, fossil fragments (Foraminifera and bryozoa) up to 0.2 mm., and some other less well defined phantoms. The rock contains about 5 percent of very black interstitial organic specks that form a sort of matrix which is, however, bunched in spots.

Composition: 90 percent dolomite, 5 percent organic matter, and 5 percent calcite.

At least 4-5 percent of the rock is visible pore space; the well-interconnected pores have a principal mode of 20-60 microns. There is little evidence of major secondary alteration, although some leaching and secondary enlargement of pores took place.

Specimen 50ASN 18--crystalline dolomite.--(Zone 3, Alapah member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock is strongly dolomitized. Sorting is good to fair. Average dolomite crystal size approximately 0.2 mm., ranging from 0.1 to 0.4 mm. There apparently are two modes, one about 0.2 mm. (70 percent) and a smaller one about 0.1 mm. (30 percent).

The few remains of previous structure are elongated calcite grains with irregular boundaries.

Composition: 95 percent dolomite, 5 percent calcite.

Dolomite contains numerous inclusions of tiny fluid bubbles and vacuoles. The visible porosity is high, over 8 percent. The intergranular visible porosity is not less than 3-4 percent, possibly 5 percent, with a principal mode of approximately 30-40 microns. At least another 2-4 percent of pore space is made of much larger pores of the cavity type (over 100 microns). These larger pores may be due to secondary enlargement or leaching.

Specimen 50ASN 10--clastic (bioclastic) limestone.--(Zone 4, Wachsmuth member, Anaktuvuk River section, pl. 2, Rept. 40.) This poorly sorted clastic limestone contains large calcite grains as much as 5 mm. in diameter; they are of dubious origin, possibly coral fragments. The other grains, almost as large, are structureless and may be inorganic chemiclastic rolled grains. In addition to those granules (less than half) there is a large amount of fossil fragments ranging from 0.3 to 0.5 mm. These consist of Foraminifera, shell fragments of larger species, oolites, and dubious calcite fragments. The average grain size is around 0.8 mm. The material is embedded in a fine calcareous matrix consisting of dark and light calcite grains with average size of 0.02-0.03 mm. Dolomitization is incipient (1-2 percent within the matrix). Texturally the rock is a conglomerate, as in the hand specimen the large calcite grains reach 5 mm. in diameter.

Composition: 95 percent calcite, 3-4 percent dolomite, and traces of collophane replacing fossil fragments.

The rock shows considerable large-scale pores of the cavity or "reef" type (5-6 percent with a pore diameter (principal mode) of 100 to 300 microns). There is little evidence of leaching. At least half the porosity is primary, and the balance is due to enlargement by leaching.

Specimen 50ASN 4--cherty dolomitic clastic (bioclastic) limestone.--(Zone 3, Wachsmuth member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock is very well bedded and extremely poorly sorted. The rock consists of numerous small fossil fragments including elongated fragments of shell (dubious), some Foraminifera, and some bioclastic material. Texturally it is a sandy siltstone of the microconglomerate type.

The larger grains are 1 mm. in diameter; the grains average about 0.05 mm. in diameter, and are embedded in a finer matrix that averages about 0.01 mm. or less. Some of the larger fossils have been replaced by silica (chert usually of flamboyant type which in turn is being replaced by clear dolomite crystals).

At least 10 percent of the rock, including every possible type of fossil, is replaced by collophane.

Composition: Dolomite, 60 percent; calcite, 20 percent; chert, less than 10 percent; and collophane, 15± percent.

Porosity, less than 1 percent, is mostly related to bedding planes.

Specimen 50ASN 3--dolomitized bioclastic limestone.--(Zone 3, Wachsmuth member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock consists of large fossil fragments embedded in a fine matrix which has been largely dolomitized. The sorting is extremely poor. The larger fragments range in size from 0.2 to 3.2 mm. and average between 0.6 and 0.8 mm. The larger fragments consist of bryozoa, possible crinoid plates (?), and shell remnants, and the smaller fragments are numerous Foraminifera. These grains form approximately 60 percent of the rock. Some of them have no organic structure and may be chemiclastic inorganic. The matrix forms approximately 40 percent and consists of colorless or dark organic material which has been almost completely dolomitized. The fossils, however, are still largely calcite.

Some of the dubiously chemiclastic grains show patchy and irregular replacement by chert (2-3 percent).

Composition: Calcite, approximately 60 percent; dolomite, approximately 40 percent; chert, 2-3 percent.

The porosity is very low.

COLLECTION 50ABe

Specimen 50ABe 105--poorly sorted and banded sandy siltstone of clastic limestone type.--(Kiruktagiak member, head of East Fork of Kiligwa River, section not illustrated.) The rock consists of very small angular grains. Less than 10 percent of small fossils are recognizable bioclastics. The average grain size of the silt (two thirds of the rock) is 0.02-0.03 mm.; larger grains (one third) are approximately 0.05-0.06 mm. Texturally the rock is a slightly sandy siltstone.

Organic matter in black parallel bands forms approximately 20 percent of the rock. The carbonates are fairly well dolomitized. The rock is cut by two subparallel systems of veins of pure white sparry calcite. The veins range from 0.05 to 1.0 mm. in width; they are subparallel, cutting each other at approximately 30°. The veins may represent desiccation and contraction of the rock or slumping, or may be of late tectonic age.

About 1-2 percent of pyrite is faintly oxidized.

There is no porosity whatsoever.

Specimen 50ABe 104--clastic (bioclastic) limestone.--(Kiruktagiak member, Chandler Lake section, pl. 2, Rept. 40.) The rock is poorly sorted and is made up of fairly large fossil fragments, mostly crinoid stems (canal in middle), fragments of dubious shells, and practically no Foraminifera. The fossil fragments are extremely angular. The larger grains range from 0.4 to 1.0 mm. in size, averaging 0.6 mm. They form 40-50 percent of the rock. The balance (50-60 percent) is a matrix of the same finely broken fossils plus a dark calcareous ooze. The average grain size of the matrix is around 0.02 mm. Black organic matter along bedding planes is widespread (5 percent of rock).

Composition: 100 percent calcite.

Porosity is less than 1 percent, of the minute intergranular type. Traces of collophane and oxidized pyrite are present. There is no evidence of weathering.

Specimen 50ABe 102--bioclastic limestone (microconglomerate type).--(Zone 2, Alapah member, Galbraith Lake section, pl. 2, Rept. 40.) The rock consists of relatively large fossils or fossil fragments and oolites averaging between 0.2 and 0.5 in diameter, embedded in an organic silt (average 0.05 mm.) of smaller Foraminifera and calcite grains. This silt, in its turn, is embedded in a dense bituminous carbonate matrix having grain size less than 0.01 (10 microns). The larger grains comprise about 20 percent, smaller grains about 30 percent, and dark carbonate matrix about 50 percent. Smaller grains are incipiently dolomitized (under 5 percent). The rock is beautifully bedded with perfect orientation of all elongate elements parallel to the bedding planes. Black organic bands (2-3 percent) are concentrated along bedding planes.

Over-all composition: Calcite, 95 percent; organic material, 2-3 percent, and dolomite, less than 2 percent.

Some of the larger fossils are filled with white sparry calcite.

Very large and elongated calcite elements that look exactly like calcite veins except for being abraded and worn are parallel to the bedding planes. These may be fragments of large shells (probable) or possibly intraformational conglomerate fragments produced by reworking of penecontemporaneous sparry calcite fillings along bedding planes. Some of

the larger fossils are rounded, but small ones are extremely well preserved. The rock exhibits extreme variations in grain size, coupled with perfect parallelism and bedding.

No porosity to speak of.

Specimen 50ABe 101--recrystallized clastic (chemiclastic) limestones.--(Zone 9, Alapah member, Galbraith Lake section, pl. 2, Rept. 40.) The rock is a coarse clastic well-sorted limestone made of subuniform chemiclastic grains, some of them well-rounded and subequant, ranging in size from 0.2 to 1.0 mm. (average about 0.5 mm.). Grains are large calcite crystals, some of them recognizable crinoid plates, but most are inorganic. There is considerable mutual accommodation and suturing between the calcite grains or between the grains and the dark sparry calcite cement. This cement, originally in optical continuity with some of the grains, is so close optically speaking to the grain itself that it is generally hard to distinguish, and hence helps to produce an exaggerated impression of interpenetration of grains. Some of the sparry calcite cement is mixed with the fine calcareous matrix, and both of these show incipient dolomitization.

The rock contains approximately 1 percent of green glauconite either as rounded fairly structureless grains or as replacement of fossils (one Foraminifera). The rock also contains approximately 1 percent of phosphate pebbles loaded in most cases with unreplaced calcite fossils. These are rock fragments.

The sorting is poor.

Visible porosity is approximately 2-4 percent; about half the pores have a principal mode (diameter) of about 20-30 microns, and the remaining half have a principal mode of 500 microns. These larger pores are due to leaching. This leaching is confirmed by oxidation of organic matter and of pyrite, which has taken place throughout the entire specimen. Hence in this specimen, porosity is definitely secondary.

Specimen 50ABe 26--crystalline dolomite (recrystallized pellet-bearing clastic limestone).--(Zone 3, Alapah member, Anaktuvuk River section, pl. 2, Rept. 40.) The rock is a crystalline dolomite, very uniform in grain size and averaging between 0.07 and 0.125 mm. This dolomite is a recrystallized clastic limestone containing approximately 50 percent pellets (average size 0.05 mm.), that show very clearly as dark rounded phantoms inside the dolomite grains, although some of the dolomite grains cut across them. One large calcite blob of indeterminate origin, 1 by 5 mm. in size, is only partly dolomitized, and a couple of shell fragments are unreplaced. Traces of black organic matter follow a bedding plane along which is a relic of a calcite vein which is also dolomitized.

Black organic matter and pyrite also occur in the intergranular pore space of the dolomite. The original intergranular porosity produced by dolomitization was quite high, possibly 10 percent, with a principal mode of 10-20 microns. At least half of this has been filled by carbonaceous matter and pyrite. However, present residual visible porosity may be between 4 and 5 percent, with a principal mode of 10-50 microns, which is quite fair for a dolomite. This pore space is very evenly distributed.

TABLE 1. SUMMARY OF THIN SECTION STUDY OF LEBURNE LIMESTONE, 1950 COLLECTIONS

Sample number	Pellets (percent)	Limestone fragments (percent)	Composition[1] (percent)		Median(mm) and sorting[4]	Dolomite[5] (percent)	Silica (chert) (percent)	Calcite (percent)	Miscellaneous[6] (percent)	Porosity[7]
			chemiclastic[2]	bioclastic[3]						
50ARr202	--	--	?	?	0.12(p)	80(0.12)	5	20	5-6,coll	low,vp,1; pm,10
30	2-3	--	55	45	0.6(p)	--	--	100	80-20, dark org	low,vp,1
25	--	--	--	--	0.2(fg)	100(0.20)	trace	--	--	low,vp,1+; pm, 10
21	--	--	100		0.6(p)	5	trace	95	--	vp,2-3;pm,20
17	--	--	30±	70±	0.9(p-f)	--	--	100	py tr.	vp,1;pm,10-20
7	--	--	--	--	0.1(g)	100(0.1)	--	--	--	vp,2-3;pm,20
1	--	--	80±	20±	0.2(p)	--	--	90-95	5,black org	none
0	--	--	75±	25±	0.7(g)	--	--	100	--	vp,10;pm,20-50
50ASN 31	--	--	--	remnants	0.3(g)	90(0.3)	--	5	5, org	vp,4-5;pm,20-60
18	--	--	remnants	--	0.2(g)	95(0.1-0.2)	--	5	--	vp,3-4;pm,30-40; also 4% secondary pm,100
10	--	--	40±	60±	0.8(f)	3-4	--	95	tr.coll	vp,5-6;pm,100-300 half due to leaching
4	--	--	--	--	0.05(p)	60	10	25	15,coll	low,vp,1
2	--	--	20±	80±	0.7(p)	40(0.02)	2-3	60	--	very low
50ABe105	--	--	?	10+	0.04(p)	10-20	--	60+	20,org	none
104	--	--	20±	70-80±	0.4(p)	--	--	100	5,org	very low
102	--	--	10±	80-90±	0.1(p)	2	--	95	3,org	none
101	--	1-2	80±	20±	0.5(p)	2	--	95	1,glauc 1,phos	low,vp,1-2;pm, 20-30;plus pm, 1-2%due to leaching,100-300
26	50	--	--	--	0.1(g)	100(0.1)	--	--	5,org and py	vp,4-5;pm,10-50 (residual)

Footnotes for Table 1

1. Composition of clastic portion, which comprises 85 to 95 percent of the rock.

2. Chemiclastic inorganic material (rolled calcite crystals).

3. Bioclastic (fossil) debris.

4. Median grain size and sorting of clastic material; p, poor sorting, f, fair, and g, good.

5. If this comprises a sizeable portion of the rock, the median size of the dolomite crystals is given in parentheses in millimeters.

6. Glauc, glauconite; coll, collophane; org, organic material; py, pyrite; phos, phosphate.

7. Porosity in thin section: vp, visible porosity (i.e., total percent of pores greater than 10 microns); pm, principal mode in microns of these visible pores.