December 19, 1995 Price: $2.00

Division of Geological & Geophysical Surveys

PUBLIC-DATA FILE 95-35

POROSITY, PERMEABILITY AND GRAIN DENSITY ANALYSES OF TWENTY KATAKTURUK DOLOMITE OUTCROP SAMPLES, NORTHEASTERN BROOKS RANGE, ALASKA

by

James G. Clough

In cooperation with the
Department of Geology and Geophysics
Tectonics & Sedimentation Research Group
University of Alaska Fairbanks

December 1995

THIS REPORT HAS NOT BEEN REVIEWED FOR
TECHNICAL CONTENT (EXCEPT AS NOTED IN TEXT) OR FOR
CONFORMITY TO THE EDITORIAL STANDARDS OF DGGS.

Released by

STATE OF ALASKA
DEPARTMENT OF NATURAL RESOURCES
Division of Geological & Geophysical Surveys
794 University Avenue, Suite 200
Fairbanks, Alaska 99709-3645

POROSITY, PERMEABILITY AND GRAIN DENSITY ANALYSES OF TWENTY KATAKTURUK DOLOMITE OUTCROP SAMPLES, NORTHEASTERN BROOKS RANGE, ALASKA

INTRODUCTION

Twenty outcrop samples of the Katakturuk Dolomite, exposed in the Sadlerochit and Shublik Mountains and near Kikiktat Mountain of the northeast Brooks Range, Alaska (figure 1), were tested for porosity, permeability and grain density. The samples were collected by the author during field studies in the Sadlerochit and Shublik Mountains. The locations of samples analyzed are given in figures 2, 3 and 4. The stratigraphic positions of samples are shown in figure 5. Table 1 provides the Katakturuk Dolomite member names and their abbreviations, member thicknesses, and the corresponding geologic map unit designations of Robinson and others (1989) and unit numbers of Dutro (1970). The results of the analyses, performed by Core Laboratories, Anchorage, Alaska, are given in table 2 and a brief description of each sample is provided in table 3. The samples chosen for analyses were selected to provide porosity and permeability data on tidal flat, lagoon to shoal, and deep-water paleoenvironments within the Katakturuk Dolomite, rather than testing a sample from each individual member. Outcrop sample drill core plugs used for testing are archived at the Alaska Geologic Materials Center, Eagle River, Alaska.

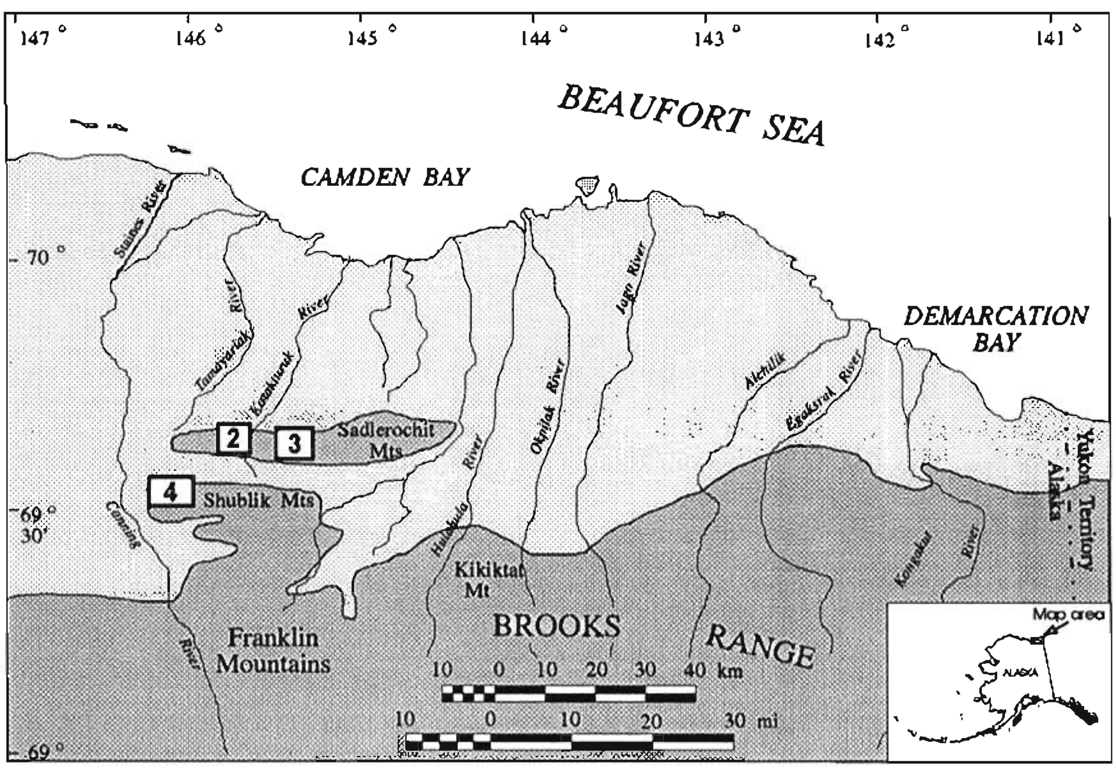

Figure 1. Location of the Sadlerochit and Shublik Mountain ranges, northeast Brooks Range, Alaska. Sample locations are shown in detailed maps in figures 2, 3 and 4 and are indicated by areas 2, 3 and 4, respectively, on this map.

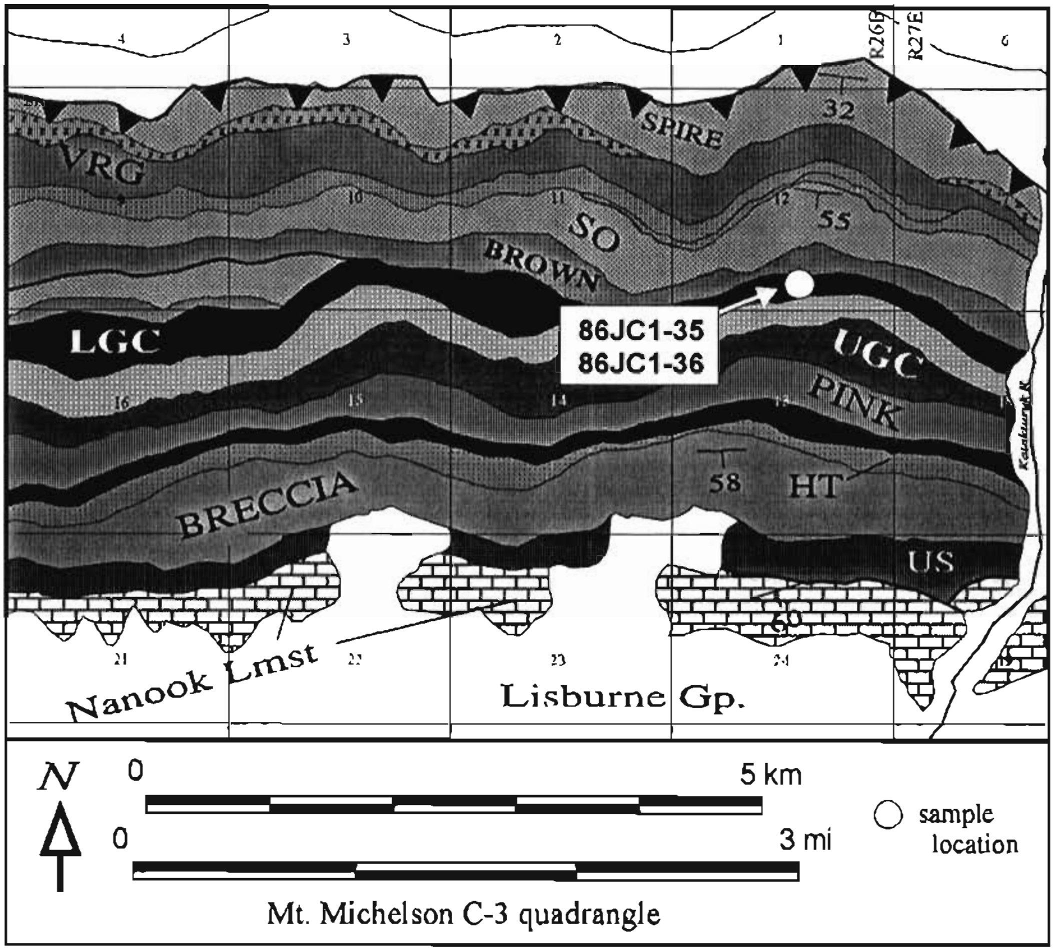

Figure 2. Western Sadlerochit Mts sample locations (area 2 shown in figure 1). Geologic map modified from Robinson and others (1989). See table 1 and figure 5 for member abbreviations.

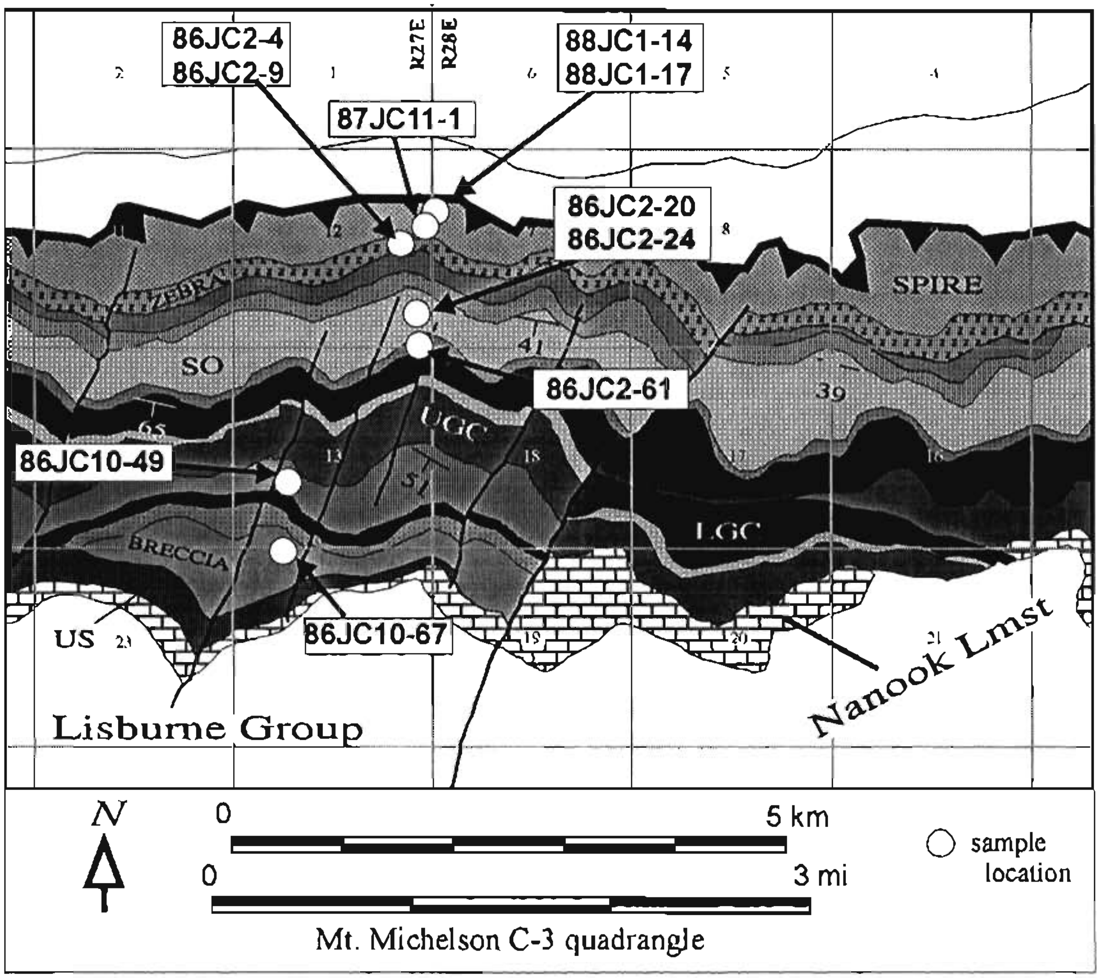

Figure 3. Central Sadlerochit Mts sample locations (area 3 shown in figure 1). Geologic map modified from Robinson and others (1989). See table 1 and figure 5 for member abbreviations.

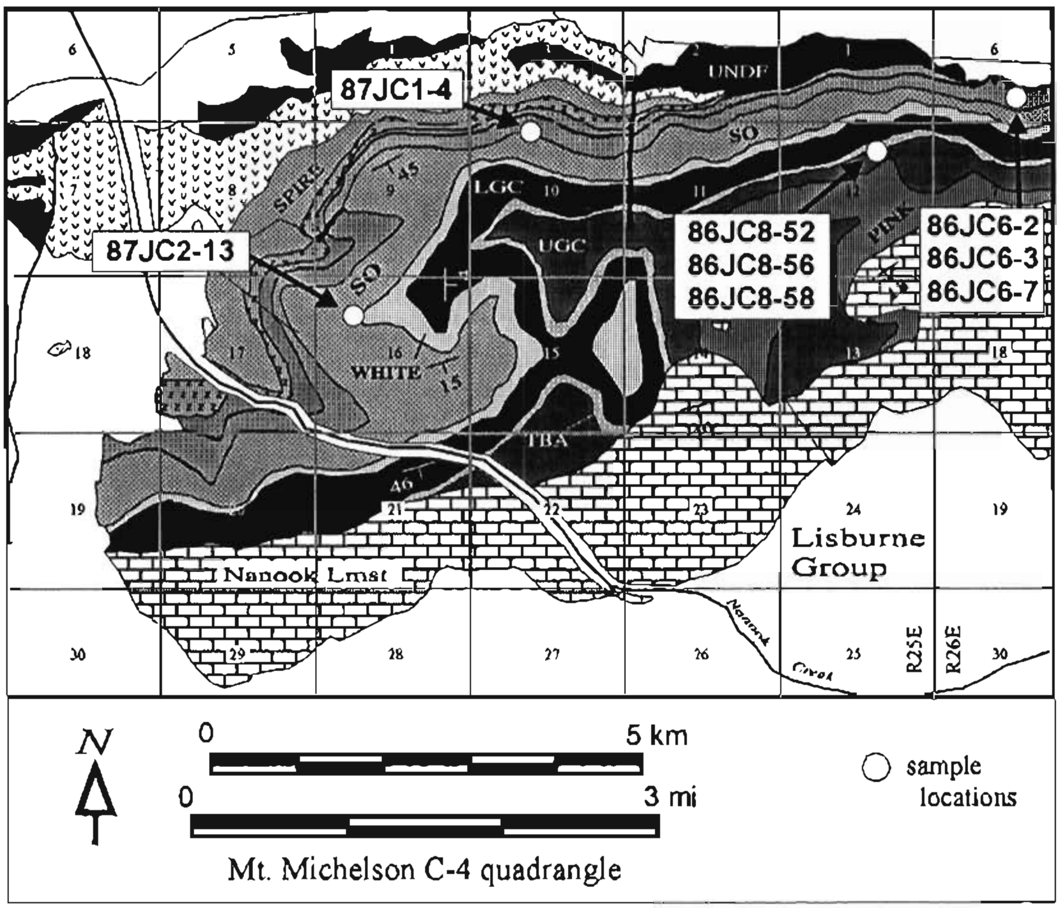

Figure 4. Western Shublik Mts sample locations (area 4 shown in figure 1). Geologic map modified from Robinson and others (1989). See table 1 and figure 5 for member abbreviations.

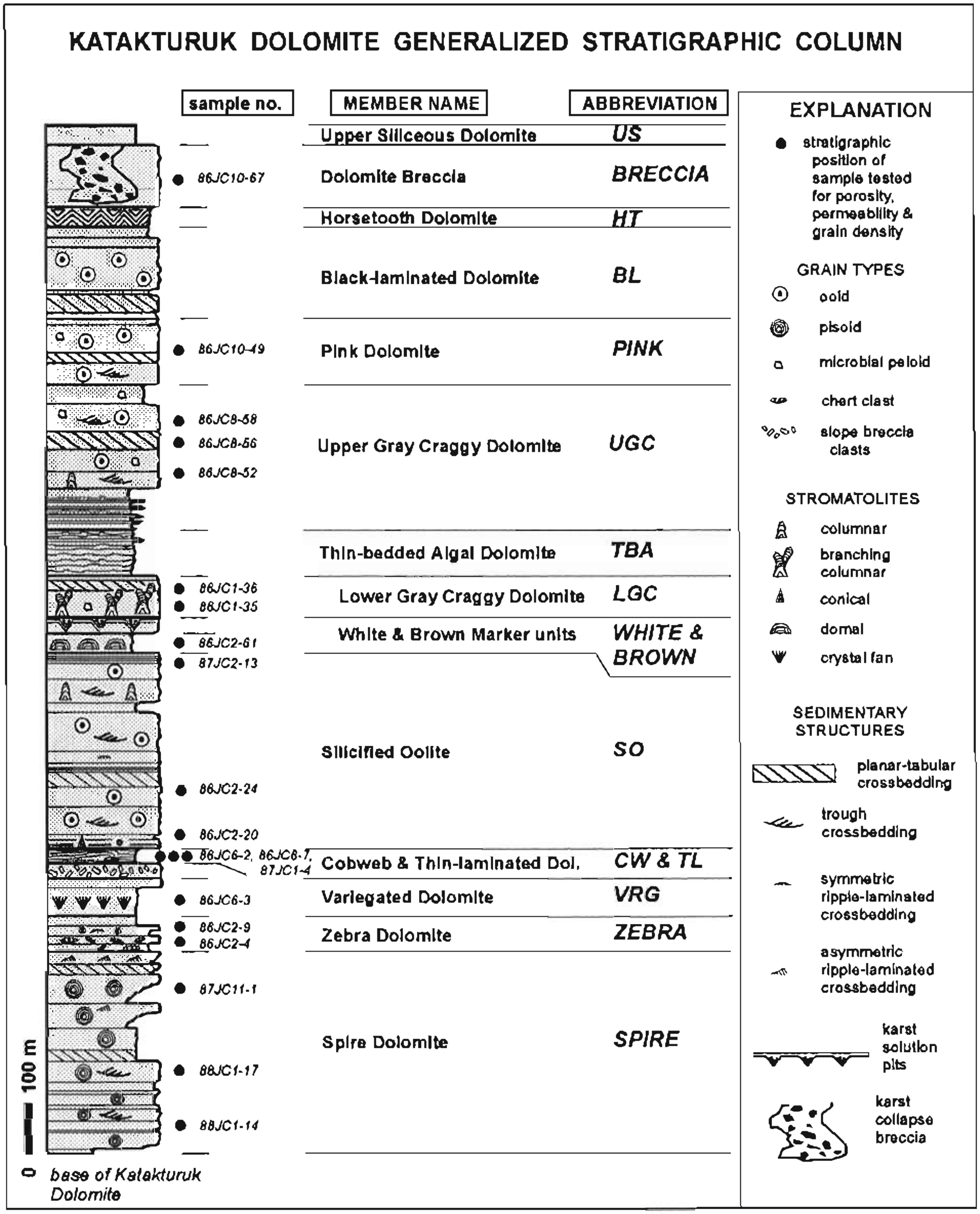

Figure 5. Composite stratigraphic column for the Katakturuk Dolomite indicating stratigraphic position of samples tested for porosity, permeability and grain density. Member names from Robinson and others (1989). Member abbreviations used in figures 2, 3 and 4 and tables 2 and 3 in text.

GEOLOGIC SUMMARY OF THE KATAKTURUK DOLOMITE

The Katakturuk Dolomite (Dutro, 1970) uncomformably underlies rocks of the Lisburne Group, Endicott Group, and Nanook Limestone in the Sadlerochit and Shublik Mountains, and structurally overlies rocks of the Sadlerochit Group, Lisburne Group, and Pre-Mississippian metasedimentary rocks ("Neruokpuk Formation" of Robinson and others, 1989) in the same ranges. The Sadlerochit and Shublik Mountains are part of the Front Ranges structural domain of Wallace (1993) which is characterized by doubly plunging anticlinoria cored by sub-Mississippian rocks. Robinson and others (1989) subdivided the Katakturuk Dolomite into sixteen informal members on the basis of mappable lithologic character. The formation is a very thick succession (~2400 m) of predominantly shallow-water subtidal to peritidal cyclical carbonates (Clough, 1986; 1989) which are Late Proterozoic in age (Blodgett and others, 1986; Clough and others, 1990). The Katakturuk Dolomite is subdivided into second-order supersequences (approximately 500 m thick; 25 million yr. duration) (Clough and Goldhammer, 1992). Each supersequence contains several third-order depositional sequences (100-150 m thick; 5 million yr. duration) (Clough and Goldhammer, 1992), which roughly correspond to the sixteen informal members of Robinson and others (1989).

Table 1. Summary table of the Katakturuk Dolomite informal members.

THIS REPORT			Robinson and others (1989)	Dutro (1970)
Informal member name[1]	*Abbreviation*[2]	*Thickness*[3]	*Map unit*	*Unit number*
Upper siliceous dolomite	US	~150 m	pCkus	not recognized
Dolomite breccia	BRECCIA	~300 m	pCkb	not recognized
Horsetooth dolomite	HT	~75 m	pCkh	upper unit 9
Black-laminated dolomite	BL	~75 m	pCkbk	middle unit 9
Pink dolomite	PINK	~170 m	pCkp	lower unit 9
Upper gray craggy dolomite	UGC	~330 m	pCkuc	unit 8
Thin-bedded algal dolomite	TBA	~100 m	pCka	upper unit 7
Lower gray craggy dolomite	LGC	~90 m	pCklc	middle unit 7
Brown marker unit	BROWN	~40 m	pCkbn	lower unit 7
White marker unit	WHITE	~45 m	pCkw	upper unit 6
Silicified oolite	SO	~450 m	pCkso	lower unit 6 & unit 5
Thin-laminated dolomite	TL	~60 m	pCkl	unit 3
Cobweb dolomite	CW	~50 m	pCkc	unit 2
Variegated dolomite	VRG	~75 m	pCkv	unit 1
Zebra dolomite	ZEBRA	~80 m	pCkz	unnamed dolomite
Spire dolomite	SPIRE	~450 m	pCks	unnamed dolomite

[1]*Informal member name*- from Robinson and others (1989)
[2]*Abbreviations*- used in tables 2 and 3 and figures 2, 3, 4 and 5
[3]*Thickness*- average thickness (approximate) of members

The Katakturuk Dolomite was deposited in a predominantly shallow-water, inner-ramp setting. This setting includes tidal flat, and shallow-water lagoon to shoal subenvironments. Tidal flat lithologies include peritidal mudstone comprised of planar- to undulatory-laminated dolomitic mudstone. Peritidal mudstone includes cryptalgal laminite and wavy to tufted microbialite ("stromatolitic") mats. Shallow-water lagoon lithologies include peloidal to intraclastic wackestone to packstone and wavy-lenticular dolosiltite. Peloidal grains are microbial-coated and are the abraded remains of subtidal to intertidal stromatolites. Aggregate grains composed of peloids, ooids or intraclasts commonly occur in this lithology. Shoal lithologies include oolitic-, pisolitic- and peloidal-crossbedded grainstone. Concentrically-coated aggregate and intraclast grains commonly occur in this lithology. Two major relative sea-level rises occurred during deposition of the Katakturuk Dolomite resulting in deep-water, mid- and outer-ramp slope settings. Lithologies deposited during these episodes include rhythmically-bedded, hemipelagic lime mudstone and slope breccias.

ANALYTICAL TECHNIQUES

The twenty samples of Katakturuk Dolomite were tested for by Core Laboratories utilizing standard grain density, porosity and permeability analytical techniques. The following description of procedures performed are from the Core Laboratories report (File No. BP-3-1349):

Sample Preparation

All samples arrived marked with plugging location. One inch samples were drilled using water as a bit lubricant.

Grain Density

Grain volume determinations were performed according to Boyle's Law utilizing a Helium Porosimeter. Grain density was calculated by the equation:

$$Dg = Mg/Vg$$

Where:
Dg = Grain Density
Vg = Grain Volume
Mg = Grain Mass

Atmospheric porosity

The samples were measured for bulk volume by mercury displacement at ambient conditions. Porosity was calculated by the equation:

$$P = [(Vb - Vg / Vb)] \times 100$$

Where:
P = Porosity, Percent
Vb = Bulk Volume
Cg = Grain Volume

Atmospheric Permeability to Air

Samples were loaded into a Hassler-type core holder at a confining pressure of 200 psig. Permeability calculations were performed as defined by Darcy's Equation for compressible fluids:

$$K = \frac{Pa \times v \times 1000}{(P1 - P2)\frac{(P1 + P2)}{2}} \times \frac{Qa \times L \times L}{Vb}$$

Where:
K = Permeability
v = Gas Viscosity
P1 - P2 = Differential Pressure
$\frac{P1 + P2}{2}$ = Mean Pressure
Pa = Atmospheric Pressure
Qa = Flow Rate
L = Length
Vb = Bulk Volume

ANALYTICAL RESULTS

The porosity of the Katakturuk Dolomite samples tested range from 0.5% to 8.6% (table 2) with a mean value of 3.3%. The highest value of 8.6% was obtained for sample 87JC2-13 from the Silicified oolite (SO) member. Five samples broke during initial testing due to their small size and were not usable for permeability analysis. Permeability for the remaining fifteen samples was extremely low. Seven samples had less than the measurable limit of 0.01 millidarcies (md) of permeability. The highest value was 1.19 md for sample 87JC1-35 from the Lower gray craggy dolomite (LGC) member. Grain density values average 2.84 gm/cc.

Table 2. Porosity, permeability and grain density analyses for 20 outcrop samples of the Katakturuk Dolomite. Analyses performed by Core Laboratories, Anchorage, Alaska. CL File No. BP-3-1349

SAMPLE NO.	MEMBER[1]	LOCATION MAP	PERMEABILITY[2] (HORIZONTAL) Kair md	POROSITY (HELIUM) %	GRAIN DENSITY gm/cc
86JC1-35	LGC	Fig. 2	1.19	3.3	2.84
86JC1-36	LGC	Fig. 2	•	3.7	2.86
86JC2-4	ZEBRA	Fig. 3	•	1.5	2.71
86JC2-9	ZEBRA	Fig. 3	<0.01	0.5	2.74
86JC2-20	SO	Fig. 3	0.02	2.1	2.86
86JC2-24	SO	Fig. 3	0.11	2.5	2.87
86JC2-61	WHITE	Fig. 3	0.16	5.9	2.86
86JC6-2	TL	Fig. 4	•	2.0	2.87
86JC6-3	VRG	Fig. 4	•	1.0	2.85
86JC6-7	TL	Fig. 4	•	2.5	2.83
86JC8-52	UGC	Fig. 4	0.06	2.7	2.85
86JC8-56	UGC	Fig. 4	0.18	1.3	2.85
86JC8-58	UGC	Fig. 4	<0.01	4.3	2.86
86JC10-49	PINK	Fig. 3	<0.01	7.9	2.86
86JC10-67	BRECCIA	Fig. 4	<0.01	2.4	2.85
87JC1-4	TL	Fig. 4	<0.01	1.7	2.89
87JC2-13	SO	Fig. 4	0.04	8.6	2.85
87JC11-1	SPIRE	Fig. 3	0.01	5.0	2.86
88JC1-14	SPIRE	Fig. 3	<0.01	1.2	2.76
88JC1-17	SPIRE	Fig. 3	<0.01	6.5	2.85

[1] Informal member names abbreviated. Full names are given in table 1.

[2] Permeability analyses not performed on samples (indicated by •) which broke during testing.

The main visible porosity types in the samples tested are moldic, intraparticle, interparticle, and fenestral (porosity classification of Choquette and Pray, 1970). Visible fracture porosity is secondary in occurrence. Laminated mudstone from the tidal flat depositional setting (samples from the VRG, WHITE and BRECCIA members) have fenestral porosity almost exclusively. Grainstone from the shallow lagoon to shoal depositional setting (samples from the SO, LGC, UGC, PINK and SPIRE members) commonly have interparticle, moldic and intraparticle porosity. Deep-water mid-ramp (samples from the ZEBRA member) and outer-ramp slope settings (samples from the TL) have very low porosity values (table 2) and no visible porosity.

The percent porosity values given in table 2 are higher than the values for the Katakturuk Dolomite reported in Dutro (1970), which range from 1.2% to 4.1%. The low permeability values in table 2 are similar to those reported in Dutro (1970).

Table 3. Brief description of samples tested for porosity, permeability and grain density. Rock classification scheme of Dunham (1962) and porosity classification of Choquette and Pray (1970) are used in descriptions.

SAMPLE NO.	MEMBER[1]	HAND SAMPLE DESCRIPTION
86JC1-35	LGC	Medium light gray dolomite, peloidal-oolitic-intraclastic grainstone. Visible interparticle, vuggy and moldic porosity.
86JC1-36	LGC	Light gray dolomite, intraclastic-peloidal grainstone, crossbedded. Contains stromatolitic intraclasts. Visible porosity is interparticle, fracture porosity also visible along larger intraclast boundaries.
86JC2-4	ZEBRA	Medium gray dolomite, highly silicified, packstone. Contains minor chert grains to 0.5 mm. No visible porosity.
86JC2-9	ZEBRA	Light gray dolomite, silicified, grainstone. Grains are altered and are faintly oolitic. No visible porosity.
86JC2-20	SO	Medium light gray dolomite, oolitic grainstone. Visible interparticle porosity.
86JC2-24	SO	Light gray dolomite, oolitic-intraclastic grainstone. Intraclasts are aggregate ooids and peritidal laminite clasts. Minor visible moldic porosity.
86JC2-61	WHITE	Very light gray dolomite, peritidal mudstone. Visible laminoid fenestral porosity. Up to 50% of visible fenestral vugs are filled with reddish-tan weathering carbonate.
86JC6-2	TL	Medium light gray lime mudstone. No visible porosity.
86JC6-3	VRG	Medium light gray dolomite, peritidal mudstone. Visible fenestral and non-fabric selective vuggy porosity.
86JC6-7	TL	Medium light gray lime mudstone. No visible porosity. Thin calcite cemented fractures.
86JC8-52	UGC	Medium light gray dolomite, peloidal-intraclastic grainstone. Visible porosity is moldic after peloidal grains.
86JC8-56	UGC	Medium gray dolomite, oolitic-peloidal grainstone, crossbedded. Minor visible moldic to intraparticle porosity visible in hand specimen.
86JC8-58	UGC	Medium light gray dolomite, oolitic-peloidal grainstone. Visible porosity is minor, appears to be moldic to intraparticle.
86JC 10-49	PINK	Light gray, very fine-grained dolomite, oolitic grainstone, crossbedded. Very finely crystalline in hand specimen. No visible porosity.
86JC10-67	BRECCIA	Very light gray dolomite, peritidal mudstone. Visible laminoid fenestral porosity.
87JC1-4	TL	Light gray dolomite, very fine-crystalline mudstone. No visible porosity.
87JC2-13	SO	Light gray dolomite, pisolitic grainstone. Pisoids to 3 mm in diameter. Visible moldic porosity.
87JC11-1	SPIRE	Very light gray dolomite, pisolitic grainstone. Visible moldic porosity
88JC1-14	SPIRE	Very light gray dolomite, pisolitic grainstone. Pisoids to 4 mm in diameter. No visible porosity.
88JC1-17	SPIRE	Very light gray dolomite, pisolitic grainstone, silicified pisoids to 4 mm in diameter. No visible porosity.

[1] Informal member names abbreviated. Full names are given in table 1.

[2] Permeability analyses not performed on samples (indicated by •) which broke during testing due to their small size.

ACKNOWLEDGMENTS

This report is part of the author's dissertation research at the University of Alaska Fairbanks, Department of Geology and Geophysics and is also part of his work with the Alaska Division of Geological and Geophysical Surveys (ADGGS). Funding for the porosity, permeability and grain density analyses was provided by the Tectonics and Sedimentation Research Group, Department of Geology and Geophysics, University of Alaska Fairbanks through grants from Amoco Production Company, ARCO Alaska, Inc., BP Exploration (Alaska) Inc., Chevron USA, Inc., Conoco Inc., Elf Exploration, Inc., Exxon Company, USA, Japan National Oil Corporation, Mobil Exploration and Producing U.S. Inc., Murphy Exploration and Production Company, Phillips Petroleum Company, Shell Western Exploration & Production Inc., Texaco Inc., and Union Oil Company of California. The author gratefully acknowledges the advice and support of Dr. John Decker, formerly with ADGGS and currently with ARCO Alaska, and Mark Robinson, formerly with ADGGS, and Drs. Keith Watts, Keith Crowder, and Wes Wallace, Tectonics and Sedimentation Research Group, Department of Geology and Geophysics, University of Alaska Fairbanks.

REFERENCES

Blodgett, R.B., Clough, J.G., Dutro, J.T., Jr., Ormiston, A.R., Palmer, A.R., and Taylor, M.E., 1986, Age revisions of the Nanook Limestone and Katakturuk Dolomite, northeastern Brooks Range, Alaska, *in* Bartsch-Winkler, S., and Reed, K.M., (eds.), Geologic studies in Alaska by the U.S. Geological Survey during 1985: U.S. Geological Survey Circular 978, p. 5-10.

Choquette, P.W., and Pray, L.C., 1970, Geologic nomenclature and classification of porosity in sedimentary carbonates: American Association of Petroleum Geologists Bulletin, v. 54, p. 107-250.

Clough, J.G., 1986, Peritidal sedimentary facies and stromatolites of the Katakturuk Dolomite (Proterozoic), northeastern Alaska [abs]: 12th International Sedimentological Congress, Abstracts, Canberra, Australia, p. 64.

Clough, J.G., 1989, General stratigraphy of the Katakturuk Dolomite in the Sadlerochit and Shublik Mountains, Arctic National Wildlife Refuge, northeastern Alaska: Alaska Division of Geological and Geophysical Surveys PDF 89-4a, 11 p., 1 in.= 100 m, 1 sheet.

Clough, J.G., and Goldhammer, R.K., 1992, Third-order vertical variations in parasequence character of the lower gray craggy member, Katakturuk Dolomite (Proterozoic), northeastern Brooks Range, Alaska [abs.]: American Association of Petroleum Geologists 1992 Annual Convention, Official Program, Calgary, Alberta, p. 21.

Clough, J.G., Robinson, M.S., Pessel, G.H., Imm, T.A., Blodgett, R.B., Harris, A.G., Bergman, S.C., and Foland, K.A., 1990, Geology and age of Franklinian and older rocks in the Sadlerochit and Shublik Mountains, Arctic National Wildlife Refuge, Alaska [abs]: Geological Association of Canada and Mineralogical Association of Canada Annual Meeting, Program with Abstracts, v. 15, p. A25.

Dunham, R.J., 1962, Classification of carbonate rocks according to depositional texture: American Association of Petroleum Geologists Memoir 1, p. 108-121.

Dutro, J.T., Jr., 1970, Pre-Carboniferous carbonate rocks, northeastern Alaska, *in* Adkison, W.L., and Brosge, M.M., (eds.), Proceedings of the geological seminar on the North Slope of Alaska: Los Angeles, Calif.: American Association of Petroleum Geologists, Pacific Section, p. M1-M8.

Robinson, M.S., Decker, J., Clough, J.G., Reifenstuhl, R.R., Bakke, A., Dillon, J.T., Combellick, R.A., and Rawlinson, S.E., 1989, Geology of the Sadlerochit and Shublik Mountains, Arctic National Wildlife Refuge, northeastern Alaska: Alaska Division of Geological and Geophysical Surveys Professional Report 100, 1:63,360-scale map.

Wallace, W.K., 1993, Detachment folds and a passive-roof duplex: examples from the northeastern Brooks Range, Alaska, in Solie, D.N., and Tannian, F., (eds.), Short notes on Alaskan Geology 1993: Alaska Division of Geological and Geophysical Surveys Professional Report 113, p. 81-99.