Kemik Sandstone - petrology, physical properties, and facies of outcrop samples and of subsurface samples from the following wells:

Exxon Corp. Point Thompson Unit No. 2 cuttings (13,060 - 13,140') and core (13,124'),
Exxon Corp. Point Thompson Unit No. 3 core (13,742' - 13,904'),
Home Oil Co. Bush Federal No. 1 (11,150' - 11,220'), and
Mobil Oil Corp. Echooka Unit No. 1 core (12,797' - 12,874').

See article by Rocky R. Reifenstuhl in Short Notes on Alaska Geology 1995, State of Alaska Professional Report 117, page 53-67.

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Kemik Sandstone - petrology, physical properties, and facies of 40 outcrop and subsurface samples. Canning River to Sagavanirktok River, northeast North Slope, Alaska

Alaska Department of Natural Resources
Division of Geological and Geophysical Surveys

For

Bureau of Economic Geology
University of Texas at Austin,
Austin, Texas

For

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Kemik Sandstone - petrology, physical properties, and facies of 40 outcrop and subsurface samples, Canning River to Sagavanirktok River, northeast North Slope, Alaska

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PETROGRAPHY

Petrographic study of more than 100 thin sections of the Kemik Sandstone, and equivalent rocks indicates a predominantly very fine to fine-grained, with lesser medium and coarse-grained, moderately to well sorted, subangular to subrounded sublitharenite to litharenite (Folk classification). It is composed of 75 to 80 percent quartz, 15 to 20 percent rock fragments, and less than 5 percent feldspar (figure 6). The quartz is dominantly monocrystalline, with minor amounts of stretched metaquartz and vein quartz (table 2). Chert is the dominant rock fragment with lesser shale, siltstone, limestone, dolomite, and siliceous sandstone. Glauconite, muscovite, sericite, collophane, zircon, and tourmaline are minor constituents. Silica cementation is extensive as quartz overgrowths. Pebbly sandstone and conglomerate are locally important and clasts consist dominantly of quartz and gray to black chert. The Pt Thomson sand is dominantly dolomite-clast conglomerate.

Point counting

Detrital modal analyses were completed on a total of 36 Kemik thin sections; 17 were from drill holes, and 19 from surface exposures:

POINT COUNT SAMPLE LOCALITY	NUMBER OF THIN SECTIONS POINT COUNTED
Mobil Echooka #1	4
Bush Federal	7
Pt. Thomson #2	3
Pt. Thomson #3	3
Outcrops: Canning River to Echooka River	18

In addition to point counting, more than 60 thin sections yield information on texture, mineralogy, alteration, and diagenetic history. Point count methodology for the predominantly very fine grained sandstone, was 300 points (on 24 stained thin sections) and 100 grain counts (on 12 stained sections). Table 2 summarizes point count data; appendix 1 lists detailed point count data. Thin sections were stained for calcite (alizarin red) and ankerite (potassium ferricyanide), and some impregnated with blue epoxy resin.

Compositional differences are shown on the triangular plot of Quartz(+chert)-Lithics-Feldspar (figure 6), cumulative histogram of the same groups (figure 7), and a graph of Chert/Chert + Lithics versus Total Chert (figure 8). Modal clast analyses indicate a progressive quartz decrease and lithic (predominantly chert and carbonate) increases from southwest to northeast: Bush Federal to Echooka to Pt Thomson (figure 7).

Provenance

Framework grains of the Kemik in the Canning and Echooka River area surface and subsurface suggest a mature sedimentary provenance with a minor metamorphic source contribution. Protoliths include Sadlerochit Group sandstone (Permian to Triassic), Kekiktuk Conglomerate (Lower Mississippian), as well as other lower Paleozoic rocks which may have contributed quartz, lithics (including micaceous quartzite), and minor feldspar. Some chert clasts in the Kemik are similar to chert of the Lisburne Limestone Group (Mississippian to Pennsylvanian).

QUARTZ–FELDSPAR–LITHIC PLOT KEMIK SANDSTONE, AND EQUIVALENT SANDS

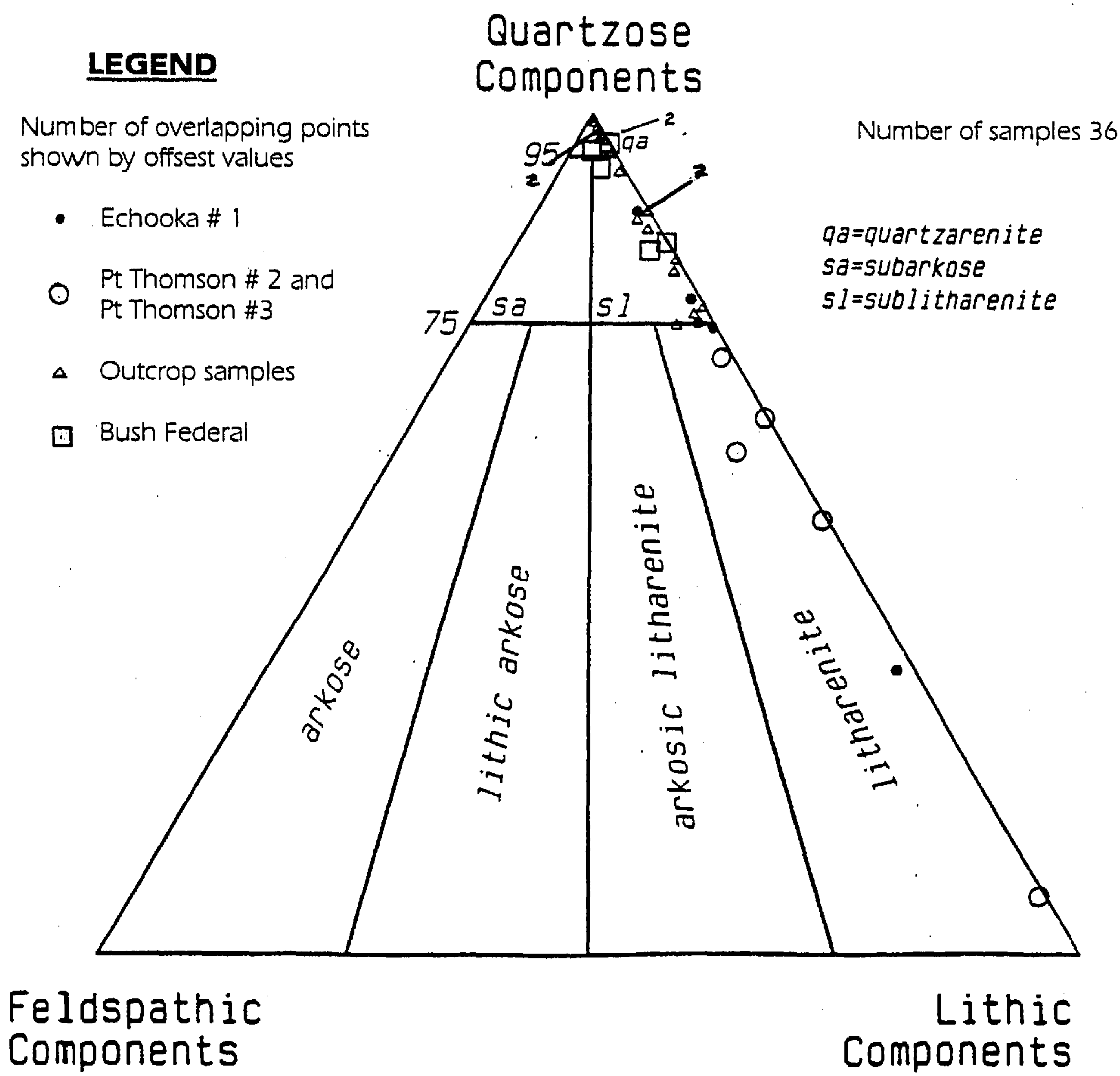

Figure 6. Quartz-Feldspar-Lithic triangular plot of petrography from 36 Kemik Sandstone and equivalent sands. 'Quartzose components' include chert. Point counts per thin section are 100 or 300 (see table 2 and appendix 1 for petrographic details). Classification is from Folk (1969).

Table 2. *Kemik Sandstone, and equivalent, point count data*

	Sample number	Total grain count	Qm	Qpe	Qpf	Kspar	Plagioclase	Chert	Phyllite	Cherty-Arg	Sandstone	Shale	Carbonate	Glauconite	White Mica	Heavy Minerals: ZrTrRtGt	Detrital Other	Mtx Arg	Mtx Undiff	Porosity	Silica Porefill	Carbonate Porefill	Clay Porefill	Other Porefill
Home	BUSH 11150	100	47	18	--	2	--	19	1	6	--	--	4	--	2	--	--	--	--	7	--	13	1	--
Oil	BUSH 11160	100	50	25	--	--	--	16	--	1	--	--	3	4	1	--	--	--	--	1	--	8	--	--
Bush	BUSH 11170	100	72	8	--	--	--	17	--	--	--	--	--	--	2	1	--	--	--	7	1	--	2	--
Federal	BUSH 11180	100	47	18	--	2	2	19	--	--	--	--	8	1	3	--	--	--	1	8	--	10	1	3
"	BUSH 11190	100	57	18	--	--	--	22	--	--	1	--	1	--	1	--	--	--	--	8	--	--	--	--
"	BUSH 11200	100	61	18	--	--	2	15	--	--	--	--	--	1	3	--	--	--	--	4	1	--	--	--
"	BUSH 11220	100	58	23	--	--	2	15	--	--	--	--	--	--	2	--	1	1	2	8	2	--	--	1
Exxon	PtTh3-13904	100	3	--	--	--	--	5	--	--	--	--	92	--	--	--	--	--	--	--	--	4	--	--
Exxon	PtTh3-13833	100	35	11	1	--	--	5	--	--	--	--	47	--	1	--	--	3	5	5	--	4	--	--
Exxon	PtTh3-13742	100	3	28	1	--	--	4	5	--	30	5	24	--	--	--	--	--	--	5	1	1	--	--
Exxon	PtTh2-13060	100	38	15	2	--	1	16	18	2	--	10	2	--	6	--	--	13	4	--	--	--	--	--
→ Exxon	PtTh2-13101	100	37	13	1	--	5	19	5	3	--	1	9	2	5	--	1	3	2	--	1	3	2	4
Exxon	PtTh2-13124	300	45	21	1	--	5	2	114	--	15	1	50	--	--	3	1	10	--	--	--	31	--	--
Mobil	Echka 12797	300	121	5	1	--	4	27	45	--	11	--	6	2	--	4	7	3	--	--	34	1	21	--
Echooka	Echka 12833	300	156	8	1	--	3	33	22	--	11	1	2	--	11	4	2	--	--	1	26	2	23	--
"	Echka 12874	300	115	4	--	--	2	18	19	--	5	--	5	2	3	7	13	93	--	--	4	--	--	5
"	Echka 12860	300	104	9	--	--	1	44	43	--	13	7	--	1	1	2	10	15	--	--	28	1	12	7
	91RR68A	300	160	6	1	--	--	26	1	--	1	--	--	2	--	6	5	--	--	1	44	31	1	15
	91RR68B	300	151	14	2	--	--	57	1	--	6	1	--	--	--	1	3	--	--	7	36	--	2	16
	91RR68C	300	95	5	--	--	--	20	2	--	3	1	--	--	--	4	4	--	--	2	37	20	2	20
	91RR68D	300	126	--	1	--	1	28	--	--	--	--	--	4	--	--	7	--	--	--	43	39	2	40
	91RR71A	300	137	3	1	--	--	53	19	--	6	--	--	1	--	--	8	--	--	3	58	1	2	7
	91RR73A	300	115	6	--	--	--	36	2	--	1	1	--	--	--	--	2	--	--	2	9	117	--	1
	91RR73B	300	157	4	--	--	3	13	2	--	--	5	--	--	2	2	13	--	--	--	56	6	8	28
	91RR76A	300	65	5	--	--	--	3	--	--	1	12	3	--	--	--	5	--	--	1	1	170	1	1
	91RR76B	300	165	8	--	--	--	23	2	--	--	--	--	1	--	--	--	--	--	30	69	--	1	--
	91RR76C	300	62	17	--	--	2	10	1		--	16	--	--	--	--	14	--	--	1	5	145	3	1
	91RR78A	300	127	7	--	--	1	47	8	--	4	--	--	5	--	--	7	--	--	9	59	--	6	20
	91RR80A	300	125	11	--	--	--	42	21	--	6	2	--	2	--	--	5	--	--	7	66	--	10	3
	91RR81B	300	46	3	--	--	--	14	1	--	--	--	--	--	--	--	1	--	--	--	21	12	1	12
	91RR81C	300	91	5	--	--	--	22	1	--	6	--	--	3	--	--	4	--	--	4	3	141	5	14
	91RR84-00	300	118	12	--	--	--	30	3	--	--	10	--	5	5	2	7	--	--	--	--	3	88	6
	91RR84-19	300	116	7	--	--	2	42	31	--	9	2	3	3	--	2	8	--	--	--	31	2	23	17
	91RR86A	300	105	9	--	--	3	36	28	--	7	4	10	3	--	5	9	--	--	--	10	4	57	6
	91RR92	300	110	6	--	--	--	30	4	--	1	--	--	1	--	1	11	--	--	--	--	134	--	1
	91RR90C	300	144	4	--	--	2	12	--	--	--	8	--	--	1	5	15	--	--	1	53	12	18	24

13110'-13140' JHP

Qm = Monocrystalline Quartz; Qpe = Polycrystalline Quartz - equigranular; Qpf = Polycrystalline Quartz - foliated; Kspar = Alkali Feldspar; Cherty-Arg = Cherty Argillite; Sandstone includes micaceous quartzite; Heavy Minerals: ZrTrRtGt = Zircon, Tourmaline, Rutile, Garnet; Detrital Other includes rare biotite (6 counts in 91RR71A) and granitic clast (1 in 91RR76c); Mtx Arg = Argillaceous/Pseudomatrix; Mtx Undiff = Matrix Undifferentiated; Silica Porfill includes quartz overgrowths; Carbonate Porefill includes siderite; Clay Porefill includes glauconitic clay; Other Porefill includes deadoil. BUSH= Bush Federal #1, and five digit number is well depth in feet; PtTh3 = Pt Thomson #3; Echka = Echooka #1; 91RR- -- = outcrop samples.

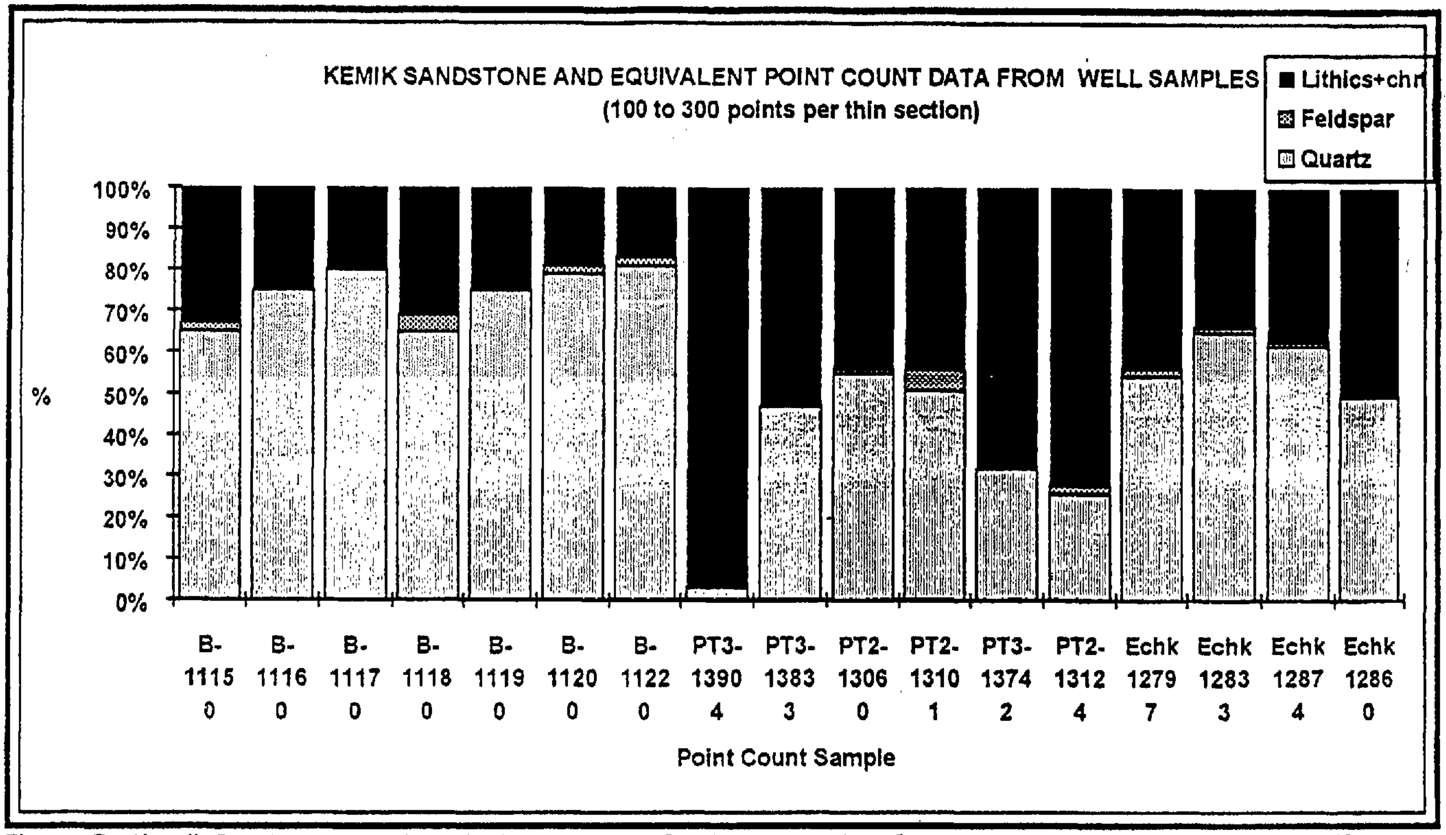

Figure 7. Kemik Sandstone, and equivalent, graph of point count data from well samples. Data show significant increase in lithic clasts (chert and carbonate) from west to northeast (Bush Federal-to Echooka- to Pt Thomson well. B = Bush Federal; PT = Pt Thomson; Echk = Echooka. Five digit number is sample depth (in feet) in well. See table 2 and appendix 1 for point count data, and plate 1 for locations.

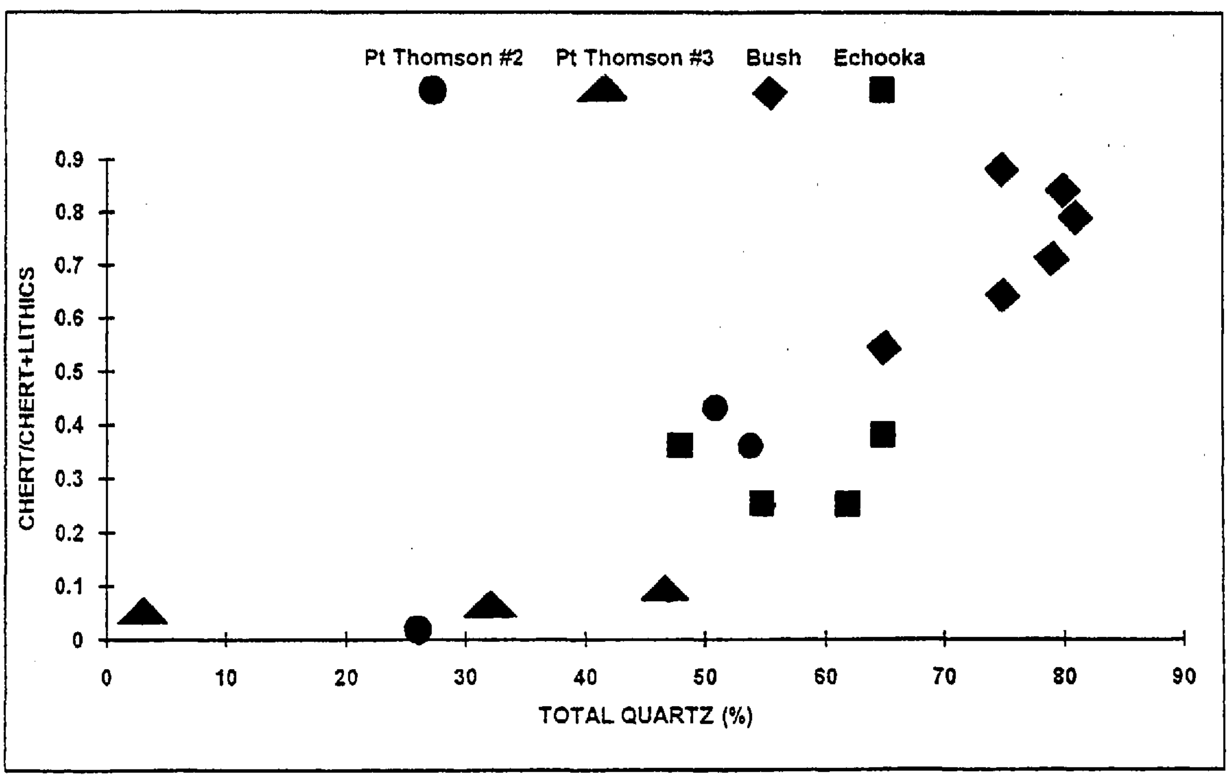

Figure 8. Kemik Sandstone, and equivalent, graph of Chert/Chert+Lithics verses Quartz; point count data from well samples. Data show significant increase in lithic clasts (chert and carbonate) from west to northeast (Bush Federal-to Echooka- to Pt Thomson well. See table 2 and appendix 1 for point count data, and plate 1 for locations.

One granitic clast was counted in an outcrop sample (91RR76A) and one locality included biotite. Pt Thomson well samples are predominantly conglomerate comprising dolomite clasts, apparently from the underlying Katakturuk Dolomite (Precambrian). Local sources for the Kemik are indicated by significant differences in framework grain abundance (figures 6, 7 and 8), as seen in the increase of chert and carbonate, from southwest to northeast, in the progression from Bush to Echooka to Pt Thomson wells.

PHYSICAL PROPERTIES

More than 60 samples were analyzed for porosity, permeability, grain density, or Thermal Alteration Index (TAI). Forty-eight of these surface and subsurface samples were analyzed for porosity, permeability, and grain density (table 3; appendix 2). Additional subsurface physical data were compiled from published well reports (table 4). Vitrinite reflectance data was part of micropaleontologic analyses (table 1; appendix 3).

Porosity

Porosity values for all samples range from 0.8 to 14.1 percent and average 5.3 percent. The maximum porosity of 14.1 is an outcrop sample of pebbly sandstone just above the LCU. Subsurface samples range from 3.9 in the Echooka well to 8.4 in the Pt Thomson #2 well, and average 6.2 percent. Comparing the average porosity of the 43 surface samples (5.3) to the average porosity of the 5 subsurface samples (6.2) shows a 17 percent higher subsurface porosity

Grain Density

Grain density values (in grams/cm^3) range from 2.57 to 3.05 and cluster in two populations, the principal cluster (74 percent of the total population) at 2.64 and a smaller cluster (26 percent) at 2.90 grams/cm^3 (appendix 2). There is no apparent correlation between grain density values and porosity (figure 1 of appendix 2). Six samples yield grain density values 10 percent greater than the average for the cluster of 17 samples. All 6 of these high-density samples are outcrop samples of medium-grained sandstone to pebble conglomerate from within one meter of the basal Kemik (LCU). These coarse-grained clastic rocks represent lag-type deposits, which, presumably, have been substantially reworked and sorted during sea level lowstands.

Permeability

Permeability was reported on 17 Kemik rock samples as Routine Air Permeability in millidarcys (md) and Insitu Klinkenberg Permeability (md; appendix 2). Insitu Klinkenberg Permeability Values range from 0.00012 md to 0.0157. One anomalously fractured sample yielded 0.271 md, and is not considered representative. Permeability and porosity values are the result of burial and thermal histories. Decreasing maximum burial and thermal exposures result in higher permeability and porosity values. Four subsurface permeability samples from the Echooka well range from 0.00253 to 0.00020 md.

Thermal Alteration Index

Thermal Alteration Index (TAI) values for 11 Kingak Shale samples range from 2.5 to 3.8 (average 3.4). One Pebble shale analysis is 3.0. One outcrop sample from the Kemik Sandstone is 2.7(?). Outcrop sample TAI values are listed with micropaleontology analysis in table 1. Kemik correlative sands from the Aurora well yield 3.2, 3.8,

Table 3. *Kemik Sandstone porosity, permeability, and density data*

Sample	Ambient Porosity (%)	Ambient Air K (md)	In-situ Klinkenberg Permeability (md)	Grain Density (g/cc)	Sample Type
91 RR68A	2.5; 3.0	0.0063; - -	0.00037, - -	2.66; 2.66	P; T.S.
91 RR68B	6.6; 6.5	0.0284; - -	0.00495; - -	2.63; 2.62	P; T.S.
91 RR68C	7.8	- -	- -	2.67	T.S.
91 RR68D	5.9; 4.0	0.0395; - -	0.00236; - -	2.62; 2.63	P.; T.S
91 RR71A	4.7; 4.8	0.0061; - -	0.00064; - -	2.64; 2.64	P; T.S.
91 RR73A	1.8	- -	- -	2.64	T.S.
91 RR73B	0.8; 1.7	0.0326; - -	0.00024; - -	2.63; 2.64	P; T.S.
91 RR76A	6.7; 14.1; 1.7	0.0189; 0.0309; - -	0.00018; 0.00283; - -	3.05; 2.93; 2.64	P; P; T.S.
91 RR76B	7.3	- -	- -	2.64	T.S.
91 RR76C	5.7	- -	- -	2.95	T.S.
91 RR78A	6.3; 6.9	0.0782; - -	0.0081; - -	2.63; 2.63	P; T.S.
91 RR80A	5.6; 8.3	0.0311; - -	0.00294; - -	2.65; 2.65	P; T.S.
91 RR80B	3.6	0.0794	0.00227	2.93	P
91 RR81B	6.7	- -	- -	2.62	T.S.
91 RR81C	6.4; 6.5	0.0057; 1.61*	0.00107; 0.271*	3.01; 3.02	P; P
91 RR84-00	3.9	- -	- -	2.66	T.S.
91 RR84-19	3.4	0.127	0.00375	2.64	P
91 RR86A	2.3; 3.3	0.0069; - -	0.0005; - -	2.67; 2.69	P; T.S.
91 RR90C	7.3; 6.7	0.0574; - -	0.0157; - -	2.64; 2.62	P; T.S
91 RR92D	3.3; 3.9	0.0344; 0.0069	0.00051; 0.00012	2.78; 2.79	P; P
84 AMu113-6	4.2	0.0146	0.0015	2.65	T.S.
80 AMu3-4	2.7; 2.1	0.0427; 0.0141	0.0012; 0.0005	2.66; 2.66	T.S.; T.S
80 AMu13-5	6.4	- -	- -	2.66	T.S.
80 AMu14-1A	3.9	0.0068	0.0003	2.79	T.S.
80 AMu14-8	5.8	0.0356	0.0021	2.66	T.S.
80 AMu14-10C	6.3	- -	- -	2.75	T.S.
80 AMu15-3	9.4	- -	- -	2.57	T.S.
80 AMu19-2	8.1	- -	- -	2.65	T.S.
80 AMu27-6	10.7	- -	- -	2.72	T.S.
76 AMu11-3	10.7; 8.7; 7.2	0.033; 0.437; - -	0.0052; 0.0971; - -	2.68; 2.65; 2.64	T.S.; T.S; T.S
76 AMu12-5	3.4	0.064	0.0046	2.66	T.S.
76 AMu15	7.0	- -	- -	2.66	T.S.
76 AMu30	1.1	- -	- -	2.72	T.S.
76 AMu31-2	6.1	0.0377	0.0028	2.65	T.S.
76 AMu32A	7.2	0.048	0.0082	2.66	T.S.
76 AMu32B	7.2	- -	- -	2.84	T.S.
76 AMu33	2.3; 4.3	0.0166; - -	0.00071; - -	2.66; 2.66	T.S.; T.S.
76 AMu69	3.3	0.0192	0.0007	2.64	T.S.
76 AMu72	3.3	0.0257	0.0016	2.65	T.S.
76 AMu108	3.0	0.00905	0.00022	2.73	T.S.
76 AMu116	8.4	0.0245	0.0028	2.64	T.S.
76 AMu117	11.0	0.0157	0.0012	2.65	T.S.
76-78 AMu12-5	2.9	- -	- -	2.63	T.S.
Echka-12797	6.3	0.0098	0.00123	2.64	P
Echka-12833	7.4	0.0079	0.00084	2.65	P
Echka-12860	4.8	0.003	0.0002	2.70	P
Echka-12874	3.9	0.0701	0.00253	2.66	P
PtTh2-13124	8.4	- -	- -	2.92	T.S.

Analyses by A.P. Byrnes, Geocore
T.S. = Thin section
P = Core plug (0.34 inch or 1.00 inch diameter)
*One split of sample 91 RR81C highly fractured, yielding anomalous values.
Multiple analyses listed on one line, with corresponding sample type listed.

3.4, and 3.6 (Banet, 1992; table 4).

Vitrinite Reflectance

Vitrinite reflectance values are from subsurface samples and range from the low of 0.6, in Pt Thomson #2 well, to 1.25 and 1.20 in the Bush well, to 1.6 in Nora, and 1.4, 1.6 and 1.8 in Aurora.

The TAI and vitrinite reflectance values for Kemik and equivalent rocks indicate a wide range, as related to the zones of petroleum generation and destruction. In the Pt Thomson #2 well, values are below the peak oil generation window. The Bush well lies within the lower oil generation window. The Nora and Aurora wells lie just below the oil window and within the wet gas generation window.

RESERVOIR POTENTIAL

Kemik framework grains consists dominantly of stable grains of quartz and chert with little matrix, characteristics of a potential reservoir for hydrocarbons, However, silica cementation is common in outcrop samples. Although the permeability analyses of the outcrop samples do not suggest reservoir potential, surface Kemik values may not be representative of subsurface Kemik. Jamison and others (1980) report that the Put River Sandstone in the Prudhoe Bay field, which is approximately correlative with the Kemik, has porosity values averaging 12 percent and measured permeability of from 10 to 404 millidarcys. In addition, the Kuparuk River Formation, the upper part of which is probably correlative with the Kemik, is oil productive in the Kuparuk River oil field (Masterson and Paris, 1987).

SUBSURFACE CORRELATION

The Kemik Sandstone correlates with several sandstone bodies that overlie the regional mid-Neocomian unconformity in the subsurface of northern Alaska: Put River Sandstone (Prudhoe Bay; Jamison and others, 1980), Cape Halkett sandstone (informal name; in NPRA), upper Kuparuk River Formation (Masterson and Paris, 1987), Point Thomson sand (sandstone and conglomerate, Point Thomson subsurface west of ANWR), and Tapkaruak sandstone and conglomerate (Aurora-# 1 well, Kaktovik area). Although all five of these sandstone units and the Kemik occupy the same stratigraphic position above the unconformity, all appear to be isolated bodies separated by areas of nondeposition in which the pebble shale unit rests directly on the unconformity (Mull, 1987).

However, a possible alternative correlation (Mull, 1987) is suggested by the reported early Hauterivian age of the *Simbirskites* sp. from the Echooka River Kemik Sandstone section. In the Mackenzie Delta area, the unconformity at the base of the Mount Goodenough Formation is underlain locally by a shale section and by the Kamik Formation of middle to late Valanginian to middle Hauterivian age (Dixon, 1982). (The Kamik Formation is also known informally as the Parsons Sandstone, a gas productive interval.) The Kemik on the Echooka River is thus apparently coeval with the upper part of the Kamik Formation of the Mackenzie Delta area. The upper Kamik consists of barrier island deposits including: offshore, shoreface, tidal channel, and lagoonal deposition (Dixon, 1982). This Kamik Formation-Kemik Sandstone correlation is plausible only if the base of the pebble shale unit rather than the base of the Kemik represents the mid-Neocomian unconformity (Mull, 1987).

Table 4. *Kemik Sandstone, and equivalent, subsurface data*

Well & Operator	Kemik or equivalent interval	TOC %[a]	Thin sections [sample interval (number of samples)] Core	Ditch	Temperature Maximum ° C	Porosity % and Permeability (md)	Vitrinite Reflectance (Ro)	Density (g/cm³)	Clasts: Q:F:L[b]	Comments
Kemik #1[c] BP	3,583' - 3,780' 4,445' - 4,650'(repeat)	1.51 0.5 - 2.0[d] 1.04	(0)	4,400' - 16,050' (89)	454 470					Moderate intergranular pores & overgrowths; minor chlorite; microporous chert and phosphate Pyrolysis: mature; G.P=1,000-3,000; P.I.=0.1-0.3; H.I.=50-400; O.I.=<400[d]
Kavik #1[c] ARCO	3,463' - 3,490'	1.0 - 4.0	(0)	(0)	465					Maturity=mature; G.P.=<4,000; P.I.=0.2-0.9
Fin Creek[c,d] McCullock	10,375' - 10,535'	2.17 1 - 2[d] 1.37	(0)	4,150 - 15,020' (22)	463					S1=0.26; S2=0.28; S3=0.81; Maturity: marginal Coaly kerogen. G.P.=1,000-10,000; P.I.=0.1-0.3; H.I.=<100; O.I.=100-200
Suzie #1 Atlantic Richfield	12,990' - 13,080'		(0)	13,020' - 13,060' (1)						- -
Echooka[c,e,i] Mobil Oil	12,736' - 12,925'	2.04 1.79	12,787' - 12,875' (10)	(0)	434	6.3 / 0.00123[g] 7.4 / 0.00084 4.8 / 0.00020 3.9 / 0.00253		2.64[g] 2.65 2.70 2.66		Moderate quartz, chlorite, illite Minor plagioclase, dolomite, pyrite. S1=0.38; S2=0.64; S3=0.69;(at 12,787'-12,875') Coaly kerogen
Nora Federal #1 Atlantic Richfield	12,460' - 12,560'	2.23	(0)	12,460' - 12,550' (7)	468		1.6 (estimated) GMC report 25			oil= 27% Saturates; S1=0.35 26% Aromatics; S2=0.25 47% Polars; S3=0.74
Bush Federal[e] Home Oil	11,147' - 11,210'	3.13 at 11,150'	(0)	11,150' - 11,350' (10)	455		1.25 (estimated) GMC report 168 1.20 GMC report 25			S1=0.75; S2=0.99; S3=1.33; Woody kerogen Seven thin sections point counted, this study.
Pt. Thompson #2[e, f] Exxon	13,013' - 13,116' Thompson sand	0.07 - 7.0 0.6 - 2.3	10,750' - 13,157'(50) 12,837' - 12,995'(10)	13,060' - 13,140' (2)		8.4 / - - - -at 13,124'[g]	0.6 at 11,500' 0.5 at 8,000' 0.4 at 3,500'	2.92[g]	55:1:44 at 13,060' 55:1:44 51:5:44	Intergranular porosity destroyed; Mica & schist grain deformation 248 barrels/day, 21° API at 11,750'
Pt. Thompson #3[e] Exxon	13,056' - 13,931' Thompson sand	0.5 - 5.0 1.0 - 7.0	13,159' - 14,008'(49) 13,673' - 13,788'(8)	(0)		5-25% typically at high end			32:0:68 at 13,742' 47:0:53 at 13,833' 3:0:97 at 13,904' 47:0:53 at 13,833' 32:0:68 at 13,742'	Three thin sections point counted, this study. Pyrolosis: immature; G.P. approx. 1,000; P.I.=0.1-0.4; H.I.=30-300
Aurora #1 OCS-Y-0943[d]	16,443' - 16,620' 'Tapkaurak sand'	1.0 -2.0; 5.0 at 15,750'	(0)	14,680' -16,630' (14)	472 at 16,400'		1.4 at 16,500' 1.6 at 16,700' 1.8 at 16,800'	2.38	85:5:10	Minor gas show at 18,200'; amorphous kerogen[h] Minor glauconite[i]. TAI = 3.2, 3.8, 3.4, 3.6. Kemik-Kalubik-Kuparuk equivalent Pyrolisis: G.P.=900; P.I.=0.1-0.3; H.I.=50; O.I.=<50

[a]TOC = Total organic carbon
[b]Q = quartz: monocrstalline & polycrystalline; F = feldspar; L = lithic clasts + chert
[c]Amstrat Log available at DGGS
[d]Banet, 1993
[e]Thin sections
[f]Petrophysical analyses of Kemik Sandstone core from this study.
[g]Analyses: Geocore, A. Byrnes, 1993
[h]Banet, 1992
[i]Mowatt and others, 1992

Subject

Twenty five sandstone samples of Kemik Sandstone, primarily from outcrops on the North Slope Alaska, were submitted for porosity, permeability, and grain density analysis. All porosity, permeability, and grain density data are presented in Table 1.

Experimental Methods

Sample Preparation

Core plugs measuring either approximately 0.75 or 1.00 inches in diameter and one to two inches in length were obtained from outcrop samples using a diamond core drill bit with tap water as bit coolant. The end faces of the core plugs were cut using a diamond saw with tap water as a coolant. The samples were dried in a vacuum oven at 70 °C to a constant weight within ± 0.003 gm. The samples were not humidity oven dried since porosities measured in this fashion do not reflect log measured porosities and are also not suitable for correlation with electrical resistivity measurements. Subsequent to porosity determination the radial surface of samples with a diameter of 0.75 inches were sealed in epoxy to provide an outer diameter of one inch for placement in the high pressure permeameter.

Porosity and Grain Density

Ambient Helium porosity was determined using a Boyle's Law technique. Dry sample weights were measured to ±0.001 gm and bulk volume was determined to an accuracy of ±0.01 cc by mercury immersion. Ambient Helium porosity was measured to an accuracy and precision of better than ± 0.1 porosity percent. Grain density values are accurate to within ± 0.01 g/cc.

Porosity values averaged 5.3±2.5% while grain density values occurred in two clusters, a principal cluster (74% of the total population) at 2.64±0.02 and lesser cluster (26%) at 2.90±0.11 g/cc. It is not known what cementing agent is responsible for the higher grain densities. Figure 1 illustrates both the general distribution of porosity and grain density and shows that there is no correlation between increased or decreased porosity with increased grain density.

Ambient and Insitu Klinkenberg Permeability

To measure routine air permeabilities and insitu Klinkenberg gas permeabilities, each core was placed in a Hassler type confining pressure cell and subjected to hydrostatic confining stresses to simulate insitu stresses. Confining pressures used were 300 psi and 3000 psi. Routine permeabilities was measured in order to provide a correction correlation for older routine data to insitu Klinkenberg values. A confining stress of 300 psi approximates the stress used by many routine laboratories especially during the time of core analysis for many earlier Alaskan wells. A confining stress of 3000 psi approximates insitu stresses at 6000 ft which is the very minimum depth of burial that these samples saw before overburden removal and the probable minimum depth of a prospective producing reservoir. Also a 3000 psi confining stress insures the closure of microfractures and represents conditions under which additional confining stress does not result in significant further permeability reduction. Ambient air permeabilities were measured at 100 psi differential pressure across the core. Klinkenberg permeabilities, which correspond to nonreactive liquid permeabilities or high pressure gas permeabilities, were determined by

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pressure pulse decay. Ambient and insitu permeability data are presented in Table 1 and Figure 2. Permeability values were not obtained on thin section samples although porosity and grain density data were measured.

The sample population was limited and represents only the lower porosity and permeability range of the Kemik Sandstone. However, based upon linear regression of the data measured here, a general correlation for conversion of lower value routine permeability data to "insitu" Klinkenberg values is:

$$K_{insitu}=10^{(0.84\pm0.21*\log_{10}K_{routine}+1.52)}$$

The standard error of prediction for this relationship is a factor of 2.8 (e.g. a predicted permeability of 1 md might be 2.8 md or 0.36 md, 1 std. dev.)

The effect of both confining stress and Klinkenberg correction decreases with increasing permeability, and by values approaching 1 to 10 md "insitu" values are generally greater than 50% of routine compared with the 1-10% values exhibited by these samples. This amount of decrease from routine air permeability values to insitu Klinkenberg values is typical of many low permeability sandstones.

Insitu Klinkenberg Permeability vs Porosity

Again, given the limitations that the data presented here represent only the lower porosity and permeability values for the Kemik Sandstone, a correlation between porosity and permeability which might be useful in the range is:

$$K_{insitu}=10^{(0.20\pm0.05*\Phi_{routine}-3.70)}$$

The standard error of prediction of this equation is a factor of 2.3. This equation was obtained by excluding the lowest three permeability samples and the two highest porosity samples which are compromised either by fracturing or are not considered representative of the Kemik Sandstone.

It is important to note that the porosity and permeability values here are largely the result of specific burial and thermal histories for the specific locations sampled. With decreasing maximum burial depth and thermal exposure porosity and permeability values increase.

Table 1
Summary of Core Analysis
Kemik Sandstone Samples
Alaska Div. Geological & Geophysical Surveys

Location I.D.	Ambient Helium Porosity (%)	Routine Air Permeability (md)	Insitu Klinkenberg Permeability (md)	Grain Density (g/cc)	Sample Type
91RR-68A	2.5	0.0063	0.00037	2.66	P
91RR-68A	3.0			2.66	TS
91RR-68B	6.6	0.0284	0.00495	2.63	P
91RR-68B	6.5			2.62	TS
91RR-68C	7.8			2.67	TS
91RR-68D	5.9	0.0395	0.00236	2.62	P
91RR-68D	4.0			2.63	TS
91RR-71A	4.7	0.0061	0.00064	2.64	P
91RR-71A	4.8			2.64	TS
91RR-73A	1.8			2.64	TS
91RR-73B	0.8	0.0326	0.00024	2.63	P
91RR-73B	1.7			2.64	TS
91RR-76A	6.7	0.0189	0.00018	3.05	P
91RR-76A	14.1	0.0309	0.00283	2.93	P
91RR-76A	1.7			2.64	TS
91RR-76B	7.3			2.64	TS
91RR-76C	5.7			2.95	TS
91RR-78A	6.3	0.0782	0.0081	2.63	P
91RR-78A	6.9			2.63	TS
91RR-80A	5.6	0.0311	0.00294	2.65	P
91RR-80A	8.3			2.65	TS
91RR-80B	3.6	0.0794	0.00227	2.93	P
91RR-81B	6.7			2.62	TS
91RR-81C	6.4	0.0057	0.00107	3.01	P
91RR-81C	6.5	1.61F	0.271F	3.02	P
91RR-84-00	3.9			2.66	TS
91RR-84-19	3.4	0.127	0.00375	2.64	P
91RR-86A	2.3	0.0069	0.00050	2.67	P
91RR-86A	3.3			2.69	TS
91RR-90C	7.3	0.0574	0.0157	2.64	P
91RR-90C	6.7			2.62	TS
91RR-92D	3.3	0.0344	0.00051	2.78	P
91RR-92D	3.9	0.0069	0.00012	2.79	P
Echka-12797	6.3	0.0098	0.00123	2.64	P
Echka-12833	7.4	0.0079	0.00084	2.65	P
Echka-12860	4.8	0.0030	0.00020	2.70	P
Echka-12874	3.9	0.0701	0.00253	2.66	P
PtTh2-13124	8.4			2.92	TS

F - Fractured sample P - Plug (0.34 or 1.00 Diam.)
TS - Thin section sample, no permeability
Note: Routine confining stress = 300 psi, Insitu = 3000 psi

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Figure 1

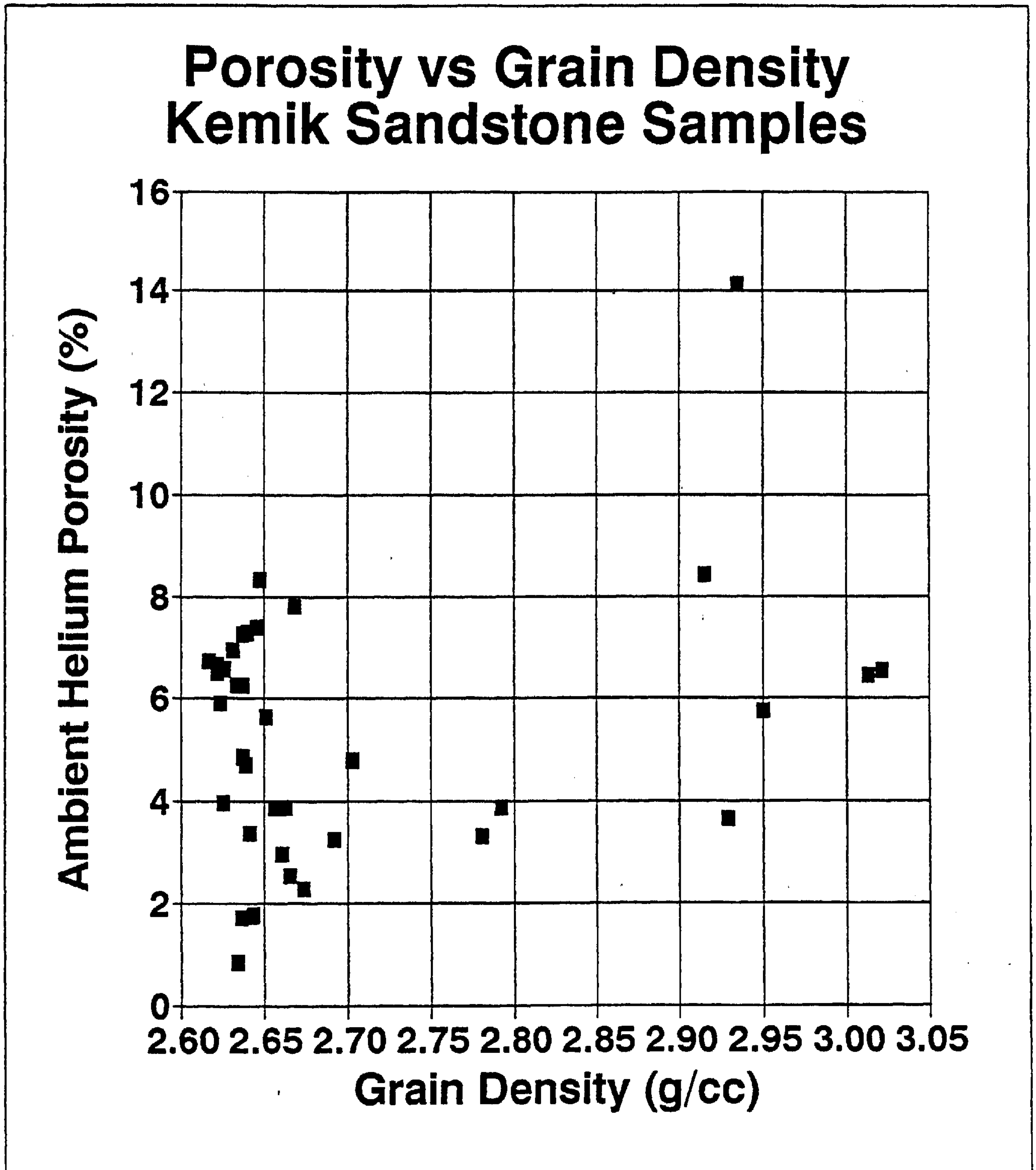

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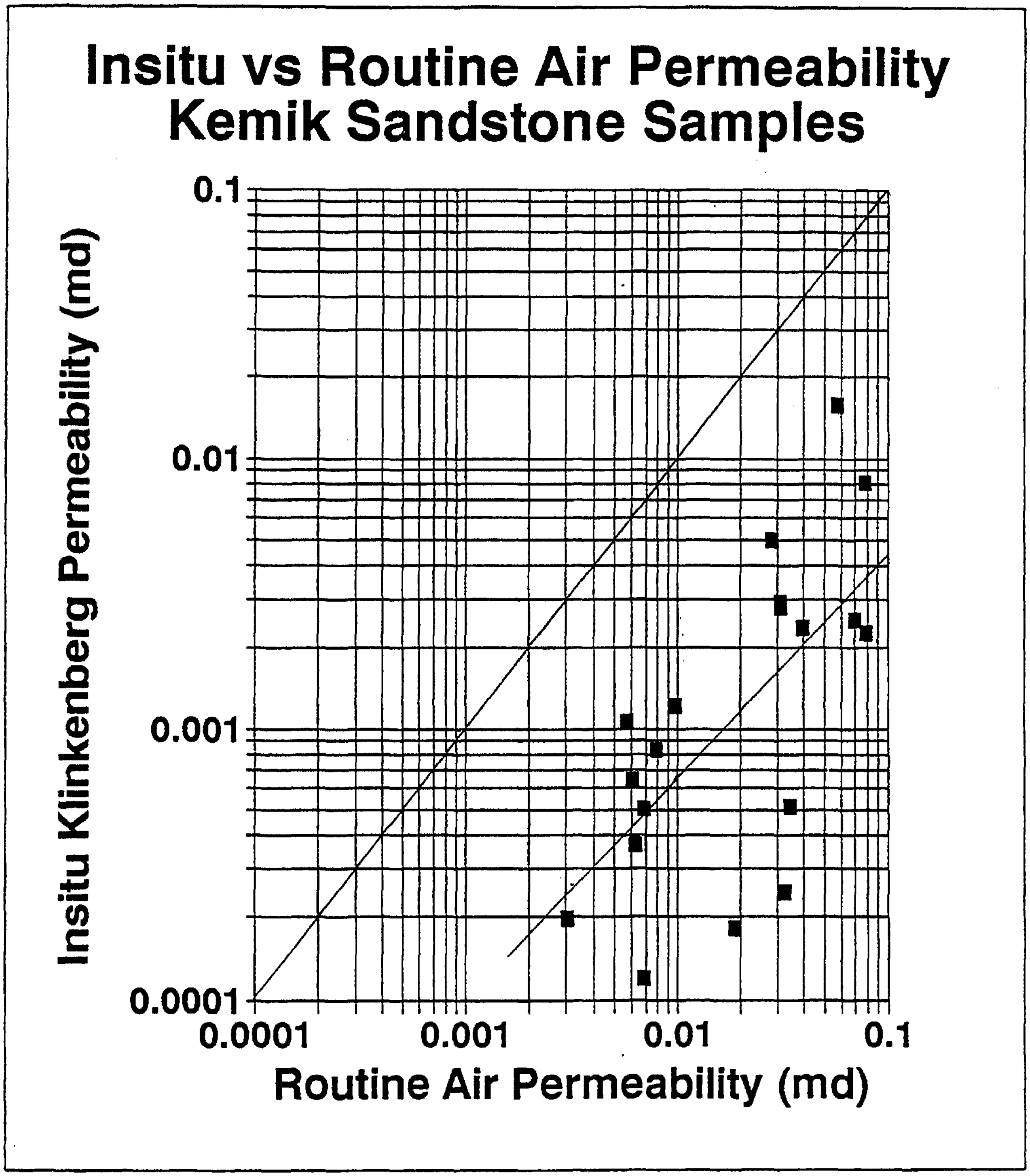
Figure 2



$$K_{insitu} = 10^{(0.84 \pm 0.21 \cdot \log_{10} K_{routine} + 1.52)}$$

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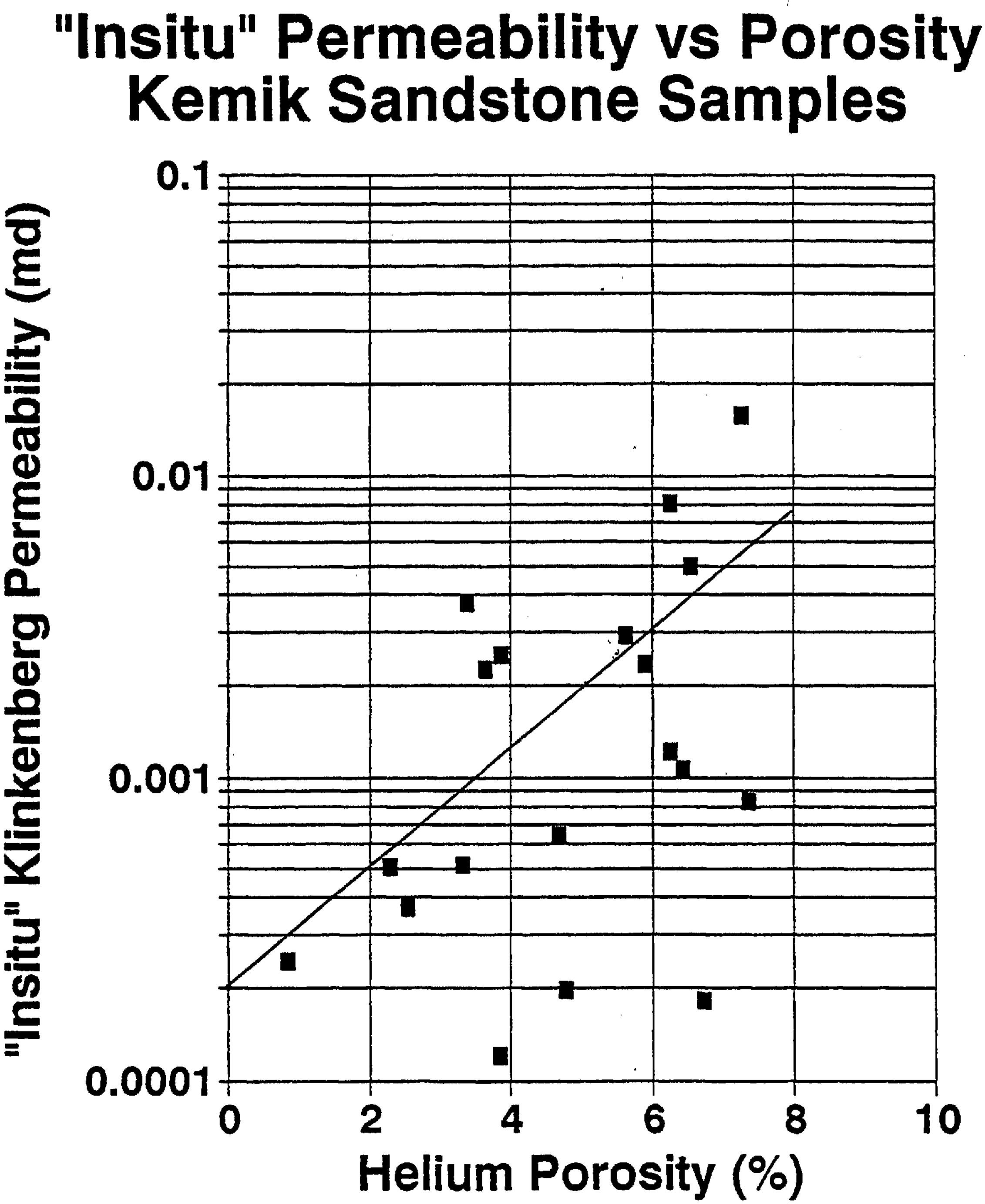
Figure 3



$$K_{insitu} = 10^{(0.20 \pm 0.05 * \Phi_{routine} - 3.70)}$$

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