CORE-BASED RESERVOIR AND GEOMECHANICAL PROPERTIES OF THE TYONEK FORMATION, HEMLOCK FORMATION, TALKEETNA FORMATION, AND MESOZOIC IGNEOUS INTRUSIVE COMPLEX (BASEMENT) IN THE COOK INLET BASIN, ALASKA

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Objectives

Core samples from the Alaska Geologic Materials Center (GMC) are used to measure the reservoir and geomechanical properties for different formations in the Cook Inlet basin. The core samples were sent to New England Research in Vermont for different reservoir and geomechanical tests.

Core Samples

The Table 1 and Figure 1 list the core samples that were taken from the GMC. Figure 1 has the location of the core samples. Table 2 lists the different properties that were measured on the core samples.

Letter	API #	Well Name	Depth ft. (MD)	Rock Type and Formation
A	50733200870000	Granite Point 18742 18	9,771.5	Sandstone, Hemlock
B	50733100650000	Granite Point 18742 03	8,221.3	Shale, Tyonek
C	50733100490100	Foreland Channel #1-A	12,926	Volcanic, Talkeetna
D	50283100070000	Stedatna Creek #1	7,139-7,159	Diorite, Mesozoic Intrusive Complex

Table 1. The information regarding the core samples, used in hydrologic and geomechanical tests. Both samples A and B are from the Granite Point field and represent the Hemlock and Tyonek formations. Sample C is from the Talkeetna Formation, and sample D is from the Mesozoic Intrusive Complex. Samples C and D represent the rock strength of different basement rocks, where large faults are present.

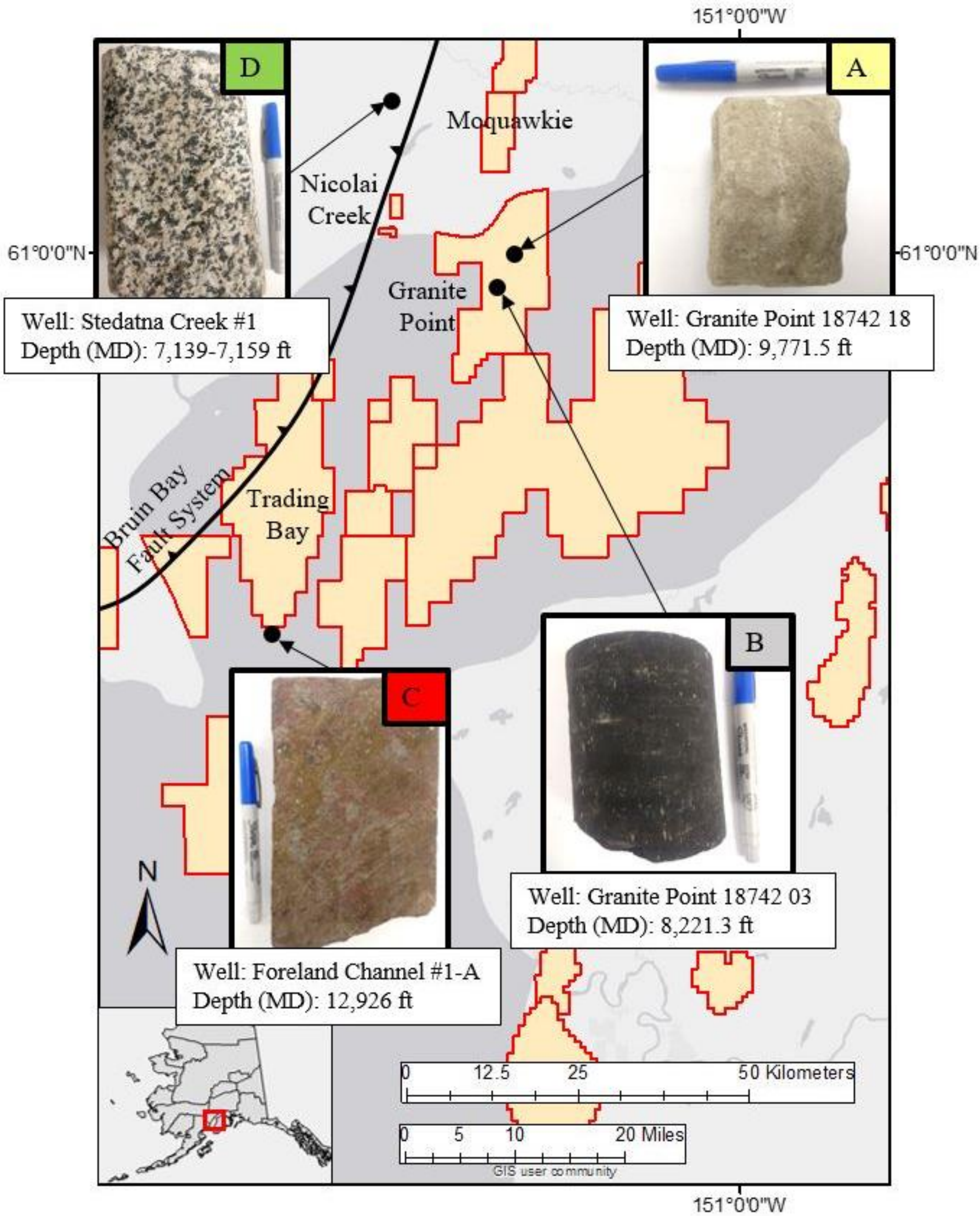

Figure 1. Photographs and well locations of the four core samples for advanced reservoir and geomechanical tests. A, B, C, and D markers correlate the core photos and locations in this figure to Table 1, which lists the well information. Sample A and B are from the Granite Point field. Sample C is just south of the Trading Bay/MacArthur field and sample D is on the west shore of the Cook Inlet basin, north of the Nicolai Creek and west of the Moquawkie field.

Properties	Units
Permeability	Millidarcy (mD)
Storage Porosity	Percent (%)
Helium Porosity	Percent (%)
Grain Density	Grams/cm^3
Stiffness Tensors	Gigapascal (GPa)
Compliances Tensors	1/Gigapascal (GPa^{-1})
Young’s Modulus and Poisson’s ratio Tensors	Gigapascal (GPa)
Linear Compressibility in the horizontal direction (1/Sgh)	Gigapascal (GPa)
Linear Compressibility in the vertical direction (1/Sgv)	Gigapascal (GPa)
Pseudo Grain Bulk Modulus	Gigapascal (GPa)
Biot-Willis effective stress tensor horizontal component	NA
Biot-Willis effective stress tensor vertical component	NA
Cohesion	Megapascal (MPa)
Friction Coefficient	Mu (μ)
Friction Angle	Degrees (ϕ)
Uniaxial Compressive Strength	MPa
Confining pressure (Pc)	Megapascal (MPa)
Differential Stress (Q)	(MPa)

Table 2. Properties from the different tests performed on the core samples.

Results

Figure 2 shows the locations of the horizontal and vertical plugs from the sandstone sample (an example). Table 3 shows the reservoir properties, and tables 4-7 list the geomechanical properties for the sandstone, shale, volcanic, and diorite samples. Through the multistage triaxial test (10, 30, 50, and 70 MPa for the confining pressures), the static elastic stiffness tensors are measured at 50 MPa under vertical transverse isotropy (VTI) conditions. During the multistage triaxial test, when the sample starts to experience a volume change (onset of dilatancy) from the confining stress then the test is stopped and repeated at a new confining stress. For the last test, the sample will goes past the onset of dilatancy and all the way to failure.

The sandstone, volcanic, and diorite samples had pore pressure-driven failure test performed. Tables 8, 9, and 10 show the results. The test procedure for each of the three samples undergoing the pore pressure driven failure test, started with the sample being triaxially loaded to a level of differential stress close to the available strength data. After the differential stress was set, the pore pressure was increased toward the failure envelope.

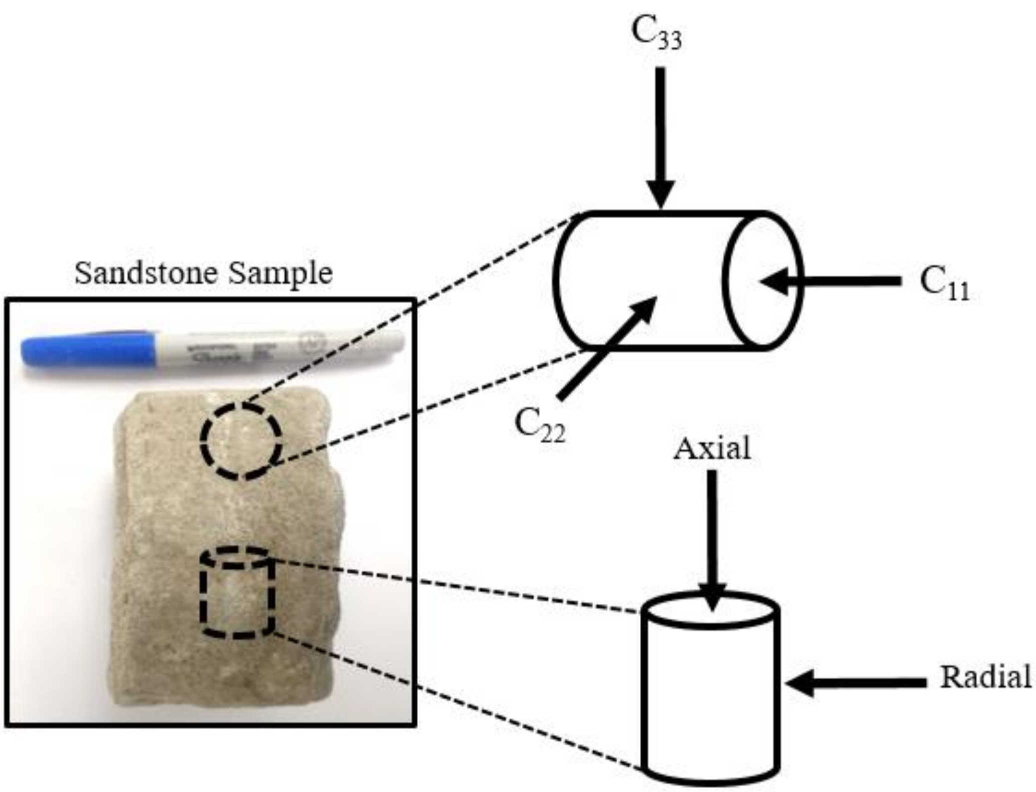

Figure 2. Diagram illustrates the horizontal and vertical plugs that were taken. The sandstone sample is shown as an example. The horizontal plug was used to measure the reservoir properties, static elastic stiffness tensors, poroelastic coefficients, and single stage triaxial test. The vertical plug was used for the multistage triaxial test, which includes the Coulomb strength parameters.

Letter	Rock Type and Formation	Storage Porosity (%)	Helium Porosity (%)	Permeability (mD)	Grain Density (g/cc)
A	Sandstone, Hemlock	NA	14.3	0.18	2.724
B	Shale, Tyonek	3.29	5.4	1.07 x 10^{-5}	2.662
C	Volcanic, Talkeetna	4.6	6.87	2.33 x 10^{-5}	2.810
D	Diorite, Mesozoic Intrusive Complex	0.1	<0.5	7.6 x 10^{-6}	2.816

Table 3. Reservoir properties from the core samples. In the table, a letter (A, B, C, and D) referring to Figure 1 and Table 1 identifies the different samples.

Sample (A) Sandstone, Hemlock Formation						
	Stiffness (GPa)		**Compliances (1/GPa)**		**Young's Modulus and Poisson's ratio (GPa)**	
Static Elastic Stiffness Tensor (VTI) at 50MPa NCS	C_{11}	32.01	S_{11}	0.0327	E_{11}	30.56
	C_{33}	33.38	S_{33}	0.0311	E_{33}	32.14
	C_{44} =C_{55}		S_{44}=S_{55}		ν_{12}	0.154
	C_{12}	5.53	S_{12}	-0.0050	ν_{31}	0.129
	C_{66}	13.24	S_{66}	0.0755	ν_{13}	0.123
	C_{13}	4.84	S_{13}	-0.0040		
Poroelastic Coefficients	**1/Sgh (GPa)**	**1/Sgv (GPa)**	**Pseudo Grain Bulk Modulus (GPa)**		**α_H**	**α_V**
	130.7	128.3	43.31		0.675	0.666
Coulomb Strength Parameters	**Cohesion (S_o) (MPa)**		**Friction Coefficient (μ)**		**Friction Angle (ϕ)(degrees)**	
	19.7		0.67		33.9	
	Uniaxial Compressive Strength (MPa)					
	73.8					

Table 4. Core geomechanical results for the sandstone sample. The coordinate system used above is a horizontal (axial for the horizontal plug), 2 horizontal (radial for the horizontal plug), and 3 is vertical (radial for the horizontal plug).

Sample (B) Shale, Tyonek Formation						
Static Elastic Stiffness Tensor (VTI) at 50MPa NCS	**Stiffness (GPa)**		**Compliances (1/GPa)**		**Young's Modulus and Poisson's ratio (GPa)**	
	C_{11}	31.38	S_{11}	0.0355	E_{11}	28.13
	C_{33}	23.60	S_{33}	0.0482	E_{33}	20.73
	$C_{44}=C_{55}$		$S_{44}=S_{55}$		ν_{12}	0.175
	C_{12}	7.44	S_{12}	-0.0062	ν_{31}	0.192
	C_{66}	11.97	S_{66}	0.0835	ν_{13}	0.261
	C_{13}	7.46	S_{13}	-0.0093		
Poroelastic Coefficients	**1/Sgh (GPa)**	**1/Sgv (GPa)**	**Pseudo Grain Bulk Modulus (GPa)**		**α_H**	**α_V**
	126.2	102.8	39.11		0.620	0.652
Coulomb Strength Parameters	**Cohesion (S_o) (MPa)**		**Friction Coefficient**		**Friction Angle (ϕ) (degree)**	
	47.5		0.30		16.6	
	Uniaxial Compressive Strength (MPa)					
	127.5					

Table 5. Core geomechanical test results for the shale sample.

Sample (C) Volcanic, Talkeetna Formation						
Static Elastic Stiffness Tensor (VTI) at 50MPa NCS	**Stiffness (GPa)**		**Compliances (1/GPa)**		**Young's Modulus and Poisson's ratio (GPa)**	
	C_{11}	37.77	S_{11}	0.0284	E_{11}	35.18
	C_{33}	34.29	S_{33}	0.0313	E_{33}	31.90
	$C_{44}=C_{55}$		$S_{44}=S_{55}$		ν_{12}	0.167
	C_{12}	7.62	S_{12}	-0.0047	ν_{31}	0.162
	C_{66}	15.08	S_{66}	0.0663	ν_{13}	0.179
	C_{13}	7.36	S_{13}	-0.0051		
Poroelastic Coefficients	**1/Sgh (GPa)**	**1/Sgv (GPa)**	**Pseudo Grain Bulk Modulus (GPa)**		**α_H**	**α_V**
	180.2	169.6	58.83		0.705	0.716
Coulomb Strength Parameters	**Cohesion (S_o) (MPa)**		**Friction Coefficient**		**Friction Angle (ϕ) (degree)**	
	42.3		0.47		24.9	
	Uniaxial Compressive Strength (MPa)					
	132.75					

Table 6. Core geomechanical test results for the volcanic sample.

Sample (D) Diorite, Basement						
	Stiffness (GPa)		**Compliances (1/GPa)**		**Young's Modulus and Poisson's ratio (GPa)**	
Static Elastic Stiffness Tensor (VTI) at 50MPa NCS	C_{11}	NA	S_{11}	NA	E_{11}	NA
	C_{33}	NA	S_{33}	NA	E_{33}	NA
	$C_{44} = C_{55}$		$S_{44} = S_{55}$		ν_{12}	NA
	C_{12}	NA	S_{12}	NA	ν_{31}	NA
	C_{66}	NA	S_{66}	NA	ν_{13}	NA
	C_{13}	NA	S_{13}	NA		
Poroelastic Coefficients	**1/Sgh (GPa)**	**1/Sgv (GPa)**	**Pseudo Grain Bulk Modulus (GPa)**		α_H	α_V
	NA	NA	NA		NA	NA
Coulomb Strength Parameters	**Cohesion (S_o) (MPa)**		**Friction Coefficient**		**Friction Angle (ϕ) (degree)**	
	88.6		0.36		19.9	
	Uniaxial Compressive Strength (MPa)					
	252.5					

Table 7. Core geomechanical test results for the diorite sample.

Sample (A) Sandstone, Hemlock Formation							
Pc (MPa)	E (GPa)	ν	TA Q (MPa)	TA σax (MPa)	Peak Q (MPa)	Peak σax (MPa)	Reload K (GPa)
10	15	0.32	54	64	99	109	
10	10	0.15	43	53			6
30	15	0.16	110	140			10
50	18	0.16	157	207			13
70	19	0.16	249	319	250	320	
Pore Pressure Driven Failure							
Pc (MPa)		Pp (MPa)		Qpp (MPa)		Pmeff (MPa)	
51.9		39.2		139		59.0	

Table 8. Sandstone results from the triaxial and pore pressure-driven test. The top six rows are measured from the triaxial test, and the bottom two rows are measured from the pore pressure driven failure test. (Pc: confining pressure, Pp: pore pressure).

Sample (C) Volcanic, Talkeetna Formation							
Pc (MPa)	E (GPa)	ν	TA Q (MPa)	TA σax (MPa)	Peak Q (MPa)	Peak σax (MPa)	Reload K (GPa)
10	23	0.15	126.5	136.5			
30	23	0.165	167	197			36
50	22	0.21	196	246			41
70	23	0.205	220	290			44
10	22	0.23	141	151	146	156	
Pore Pressure Driven Failure							
Pc (MPa)		Pp (MPa)		Qpp (MPa)		Pmeff (MPa)	
50		20.6		157		81.7	

Table 9. Volcanic sample results from the triaxial and pore pressure-driven failure test. The top six rows are measured from the triaxial test, and the bottom two rows are measured from the pore pressure-driven failure test.

Sample (D) Diorite, Basement							
Pc (MPa)	E (GPa)	ν	TA Q (MPa)	TA σax (MPa)	Peak Q (MPa)	Peak σax (MPa)	Reload K (GPa)
10	76	0.44	140	150			
30	79	0.36	155	185			32
50	80	0.36	179	229			40
70	81	0.35	207	277			46
10	77	0.42	147	157	269	279	
Pore Pressure Driven Failure							
Pc (MPa)		Pp (MPa)		Qpp (MPa)		Pmeff (MPa)	
77		72		290		101.7	

Table 10. Diorite sample results from the triaxial and pore pressure-driven failure test. The top six rows are measured from the triaxial test and the bottom two rows are measured from the pore pressure driven failure test.