ROUTINE CORE ANALYSIS FINAL REPORT

of

EAST PILCHARD-1

for

ESSO AUSTRALIA PTY LTD

by

ACS LABORATORIES PTY LTD

9 October, 2001

Esso Australia Pty Ltd
12 Riverside Quay
SOUTHBANK VIC 3006

Attention: Mr. Kumar Kuttan

FINAL REPORT: 0325-02
EAST PILCHARD-1

CLIENT REFERENCE:	Contract No. 382084/01 Cost Centre No. 61-497
MATERIAL:	Rotary Sidewall Cores
WORK REQUIRED:	Routine Core Analysis

Please direct technical enquiries regarding this work to the signatories below under whose supervision the work was carried out.

KEVIN H FLYNN
General Manager

Head Office: 8 Cox Road, Windsor Qld 4030, Australia
☎: 61 7 3357 1133 Facsimile: 61 7 3357 1100
E-mail: acs.bris@acslabs.com.au
ACS Laboratories Pty Ltd
ABN: 81 008 273 005

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CHAPTER 1

INTRODUCTION

1. INTRODUCTION

This Final Report presents the results from a routine core analysis study on Rotary Sidewall Cores (MSCT's) from East Pilchard-1. The study was undertaken as per instructions received from Esso Australia Pty Ltd on 27August 2001.

The following report includes tabular data of permeability to air and helium injection porosity at ambient and overburden conditions and density determinations.

Data presented graphically includes porosity versus permeability to air.

CHAPTER 2

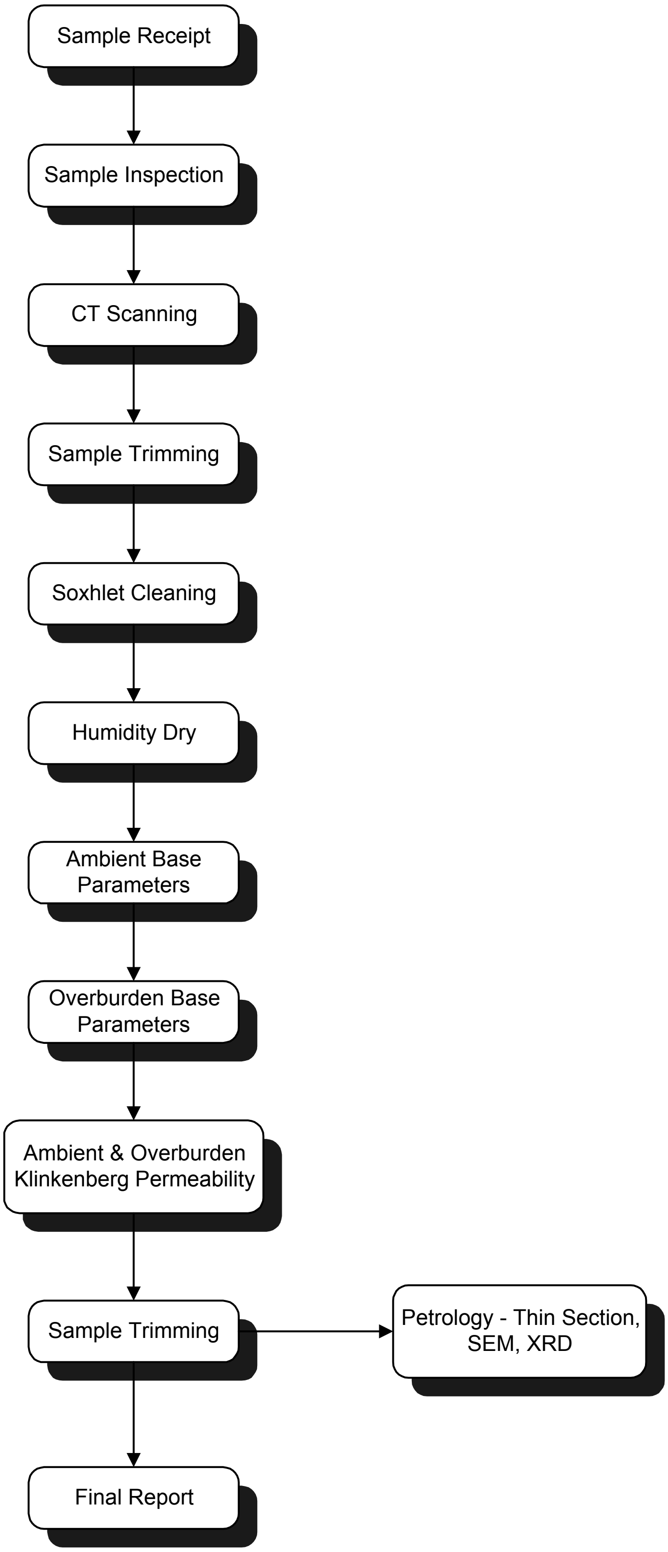
STUDY AIMS

2. STUDY AIMS

The analyses were performed with the following aims:

1. To provide ambient and overburden permeability to air, helium injection porosity and density data.

STUDY OUTLINE



CHAPTER 3

SAMPLE PREPARATION

3. SAMPLE PREPARATION

3.1 CT Scanning

CT Scanning was undertaken in order that internal inhomogeneities and/or drilling fluid invasion zones may be noted. Typical inhomogeneities may be clasts, bedding sedimentary structures, cementation, fractures and any other discontinuities that may not be readily visible to the naked eye.

The principle of CT Scanning and its applications is presented by Hove et al, 1987 and Wellington and Vinegar, 1987.

CT Scanners generate cross-sectional image slices through the sample by revolving an X-ray tube around the sample and obtaining projections at many different angles. From these image slices, a cross-sectional image was reconstructed by a back projection algorithm in the scanner's computer.

Prior to analysis, arbitrary orientation lines were inscribed onto the sample using a marker to facilitate subsequent re-orientation. The sample was placed vertically within the scanner, with the orientation arrow left to right, and a longitudinal section image obtained. The sample was then rotated through exactly 90^o to the initial orientation, and another section image recorded. These two images are labelled '0' and '90' on the prints.

As per instructions, all images have only been reported electronically.

3.2 Sample Trimming

The samples were trimmed to right cylinders of maximum possible length using a diamond impregnated cutting blade.

3.3 Sample Extraction

Cleaning was performed in a modified soxhlet system using a refluxing solvent of 3:1 chloroform:methanol azeotrope. Cleaning continued until tests for oil (fluorescence under UV light) and salt (silver nitrate precipitation) showed negative.

3.4 Sample Drying

After cleaning, all plugs were oven dried to constant weight in a humidity oven at 60^oC and 40% relative humidity. Once dried, the plugs were stored in individual airtight containers and allowed to cool to room temperature before analysis.

CHAPTER 4

SAMPLE TEST PROCEDURES

4. SAMPLE TEST PROCEDURES

4.1 Helium Injection Porosity

The plugs were sealed in a matrix cup and a known volume of helium at 100 psi reference pressure was introduced to the cup. From the resultant pressure the unknown volume, i.e. the grain volume, was calculated using Boyles Law.

The bulk volume of each plug was determined by mercury immersion. The difference between the grain volume and the bulk volume is the pore volume. The porosity is calculated as the volume percentage of pore space with respect to the bulk volume.

$$P_1 V_1 = P_2 V_2$$

$$\Rightarrow \quad P_1 Vr = P_2 (Vr + Vc - Vg)$$

$$Vp = Vb - Vg$$

$$\text{Ambient Porosity \%} = \frac{Vp}{Vb} \times 100\%$$

where
P_1 = *initial pressure (psig)*
P_2 = *final pressure (psig)*
Vr = *reference cell volume* (cm^3)
Vc = *matrix cup volume* (cm^3)
Vg = *grain volume* (cm^3)
Vp = *pore volume* (cm^3)
Vb = *bulk volume* (cm^3)

The samples were then placed into individual thick walled rubber sleeves and the assembly loaded into a hydrostatic cell. With an ambient pressure (400 psi) applied to the sample, helium held at 100 psi reference pressure was released into the samples pore volume. The resultant pressure drop was used to determine pore volume at ambient. The confining pressure was then increased to the respective overburden pressure and the resultant change in internal pore pressure was monitored and used to determine pore volume at overburden conditions.

$$Vb = Vp + Vg$$

$$\text{Ambient Porosity \%} = \frac{Vp}{Vb} x\,100$$

$$\text{Overburden Porosity \%} = \frac{Vp - \Delta Vp}{Vb - \Delta Vp} x\,100$$

where
Vp = *ambient pore volume* (cm^3)
Vb = *ambient bulk volume* (cm^3)
Vg = *grain volume* (cm^3)
ΔVp = *change in pore volume* (cm^3)

4.2 Air Permeability

The plugs were placed in a Hydrostatic cell at a confining pressure of 400 psig. This pressure is used to prevent bypassing of air around the sample when the measurement is made.

During the measurement a known air pressure is applied to the upstream face of the sample, creating a flow of air through the sample. Permeability for each sample is then calculated using Darcy's Law, through knowledge of the upstream pressure and flow rate during the test, the viscosity of air and the plug dimensions.

$$Ka = \frac{2000.BP.\mu.q.L}{(P_1^2 - P_2^2).A}$$

where	Ka	=	*air permeability (milliDarcy's)*
	BP	=	*barometric pressure (atmospheres)*
	μ	=	*gas viscosity (cP)*
	q	=	*flow rate (cm^3/s) at barometric pressure*
	L	=	*sample length (cm)*
	P_1	=	*upstream pressure (atmospheres)*
	P_2	=	*downstream pressure (atmospheres)*
	A	=	*sample cross sectional area (cm^2)*

The confining pressure was then increased to overburden conditions and the above procedure repeated to give permeability at overburden conditions.

4.3 Klinkenberg Permeability

To determine Klinkenberg permeability, the samples were placed in a thick walled rubber sleeve. This assembly was loaded into a hydrostatic cell @ ambient where a regulated supply of oxygen-free nitrogen was attached to one of the upstream pressure ports on the core holder. A known upstream pressure (measured by an electronic transducer) was introduced to the sample. A back pressure regulator placed at the core outlet created an elevated differential pressure within the core. The differential pressure, monitored by a transducer, was adjusted to a pressure at which laminar flow occurred. When the flow of gas through the sample was stable, a reading was taken with flow meters connected to the gas outflow line. Several readings were made for each sample, successively increasing the upstream pressure while maintaining a constant differential pressure. All flow rates were sufficiently low to maintain laminar flow.

The EPS program GASPERM was used to calculate the Klinkenberg permeability. The following variables were entered into the program:

- Upstream pressure
- Differential pressure
- Flow rate
- Gas temperature
- Atmospheric pressure
- Overburden pressure

For each set of pressure and flow data acquired on the sample plug, GASPERM calculated the gas permeability and the inverse mean pressure. Linear regression analysis was then performed on the calculated data set to determine the coefficients of the best fit line (of the form $y = mx + c$) where

y = *gas permeability*
x = *inverse mean pressure*
m = *bKl*
c = *Kl*

Klinkenberg permeability at zero inverse mean pressure is intercept c.

On completion the confining pressure was increased to the respective overburden pressure and the procedure repeated.

4.4 Calculated Grain Density

The apparent grain density was calculated by dividing the weight of the plug by the grain volume, determined from the helium injection porosity measurement.

$$P = \frac{Wt}{Vg}$$

where P = *grain density (g/cm^3)*
Wt = *weight of sample (g)*
Vg = *grain volume (cm^3)*

APPENDIX I

ROUTINE CORE ANALYSIS RESULTS

ROUTINE CORE ANALYSIS FINAL REPORT

Client : Esso Australia Pty Ltd
Well : East Pilchard-1
Field :

Date : 04-09-2001
File : 0325-02
Location
Analysts : kw, cw

		Ambient			Overburden					
Sample Number	**Depth** *(m)*	**Porosity Helium** *(percent)*	**Permeability to Air** *(mD)*	**Klinkenberg Permeability** *(mD)*	**Overburden Pressure** *(psi)*	**Porosity Helium** *(percent)*	**Permeability to Air** *(mD)*	**Klinkenberg Permeability** *(mD)*	**Grain Density** *(g/cm^3)*	**Remarks**
3	2594.0	20.6	3750	3630	4400	18.2	3470	2890	2.64	
4	2598.0	19.5	3280	2870	4400	15.9	2630	2600	2.64	
5	2602.0	19.2	1570	1460	4400	14.7	1290	1190	2.64	
7	2620.0	6.0	0.004	< 0.001	4450	5.5	< 0.001	< 0.001	2.68	
8	2627.5	17.2	135	131	4450	14.8	117	112	2.64	
9	2633.5	5.2	19.2	5.8	4500	2.2	0.41	0.17	2.36	Frac
11	2644.0	1.9	0.001	< 0.001	4500	1.5	< 0.001	< 0.001	2.64	
12	2652.0	7.9	0.018	< 0.001	4550	6.9	< 0.001	< 0.001	2.63	
13	2663.0	16.0	30.8	26.3	4550	14.1	24.2	20.4	2.65	

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		Ambient			Overburden					
Sample Number	**Depth** *(m)*	**Porosity Helium** *(percent)*	**Permeability to Air** *(mD)*	**Klinkenberg Permeability** *(mD)*	**Overburden Pressure** *(psi)*	**Porosity Helium** *(percent)*	**Permeability to Air** *(mD)*	**Klinkenberg Permeability** *(mD)*	**Grain Density** *(g/cm^3)*	**Remarks**
15	2700.5	13.9	0.73	0.47	4650	11.9	0.32	0.15	2.64	
17	2721.5	17.9	61.8	55.5	4700	16.0	53.3	48.3	2.65	
18	2728.5	17.6	573	531	4700	14.0	463	444	2.64	
19	2751.0	19.5	57.9	47.7	4750	16.6	41.7	31.8	2.66	
21	2759.0	4.2	0.010	< 0.001	4750	3.7	< 0.001	< 0.001	2.60	
22	2763.0	14.4	13.1	10.2	4800	10.1	6.1	4.66	2.66	
23	2764.5	17.0	118	113	4800	14.7	94.8	83.2	2.65	

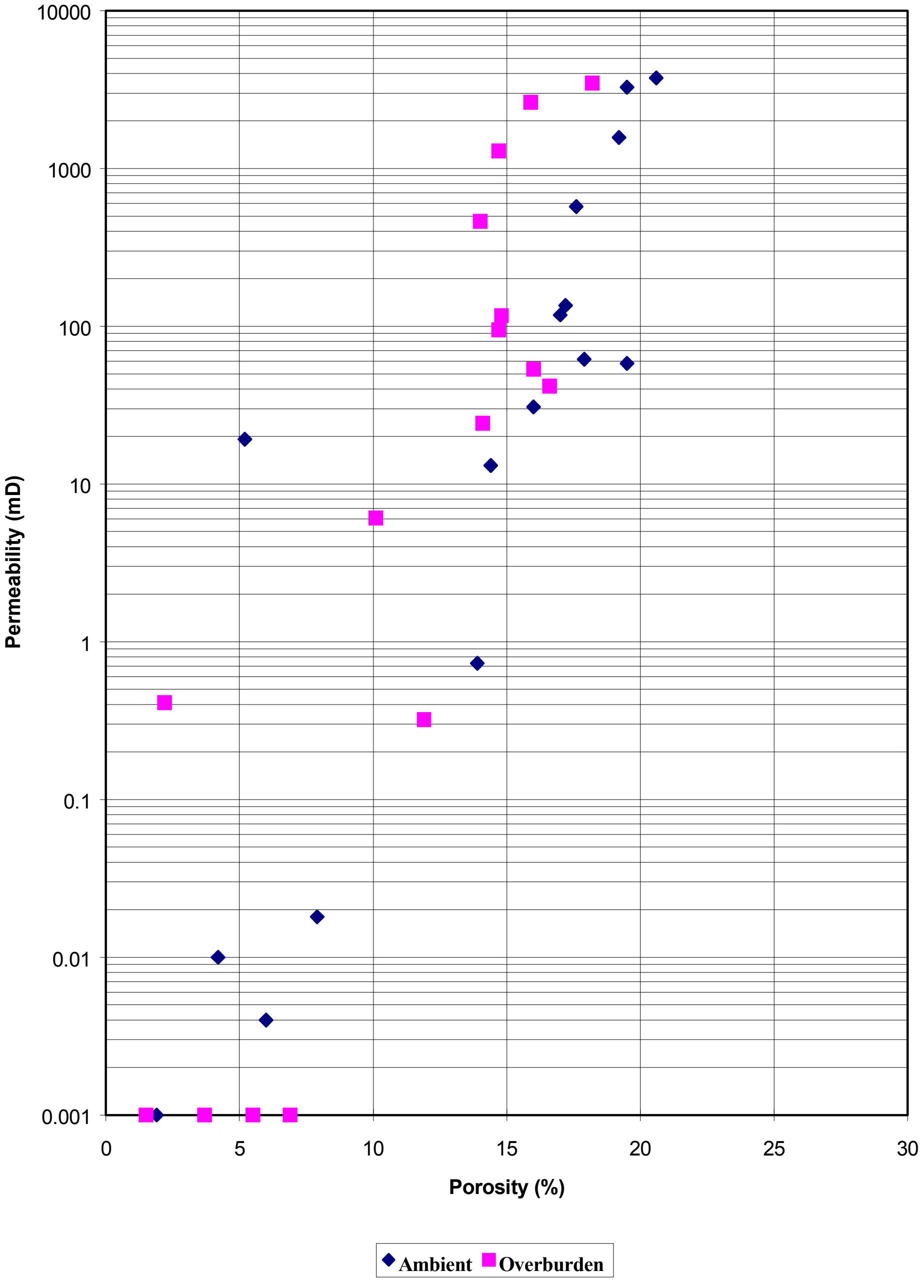
APPENDIX II

POROSITY vs PERMEABILITY CROSS PLOT

POROSITY vs PERMEABILITY
Ambient & Overburden

Client: Esso Australia Pty Ltd

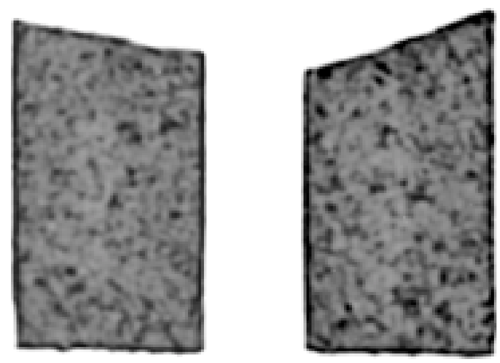
Well: East Pilchard-1



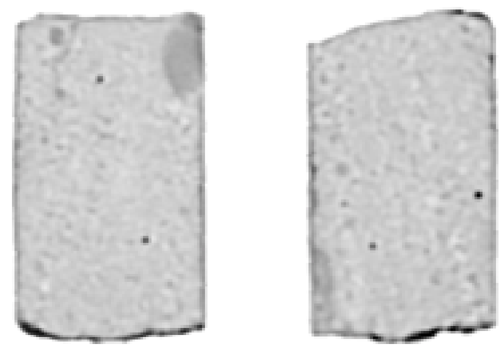
APPENDIX III

CT SCANNING IMAGES

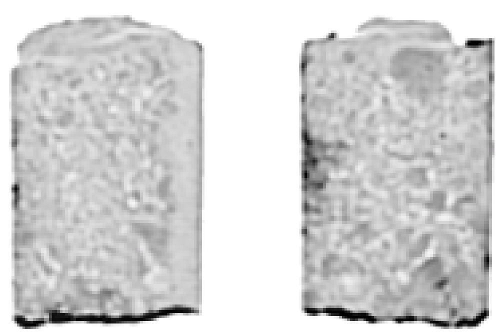
East Pilchard-1
C.T. Scans



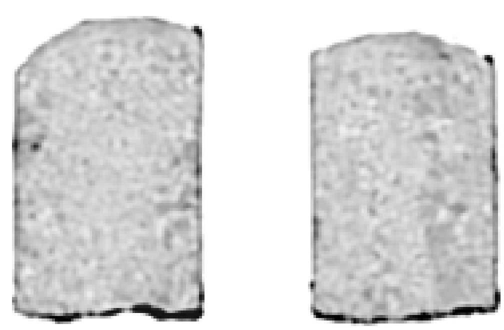
Sample No: 2
Depth: 2586.0 m



Sample No: 3
Depth: 2594.0 m

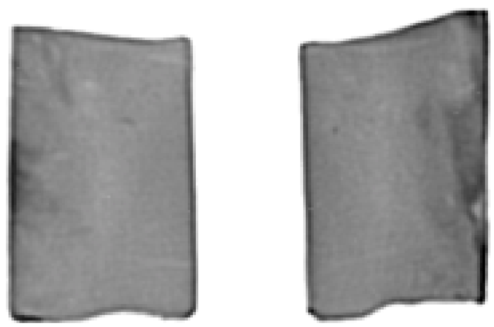


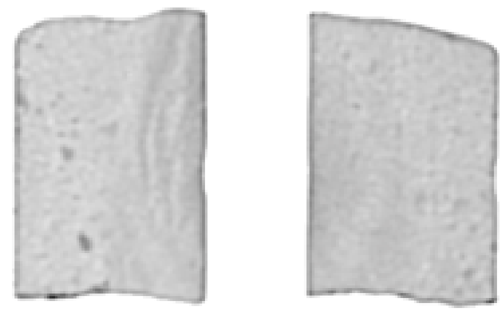
Sample No: 4
Depth: 2598.0 m



Sample No: 5
Depth: 2602.0 m

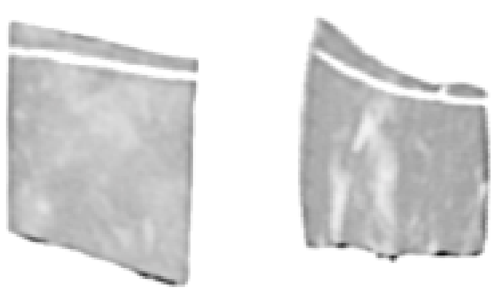
East Pilchard-1
C.T. Scans

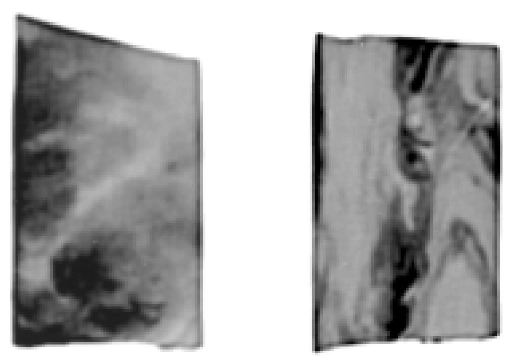




Sample No: 7
Depth: 2620.0 m

Sample No: 8
Depth: 2627.5 m

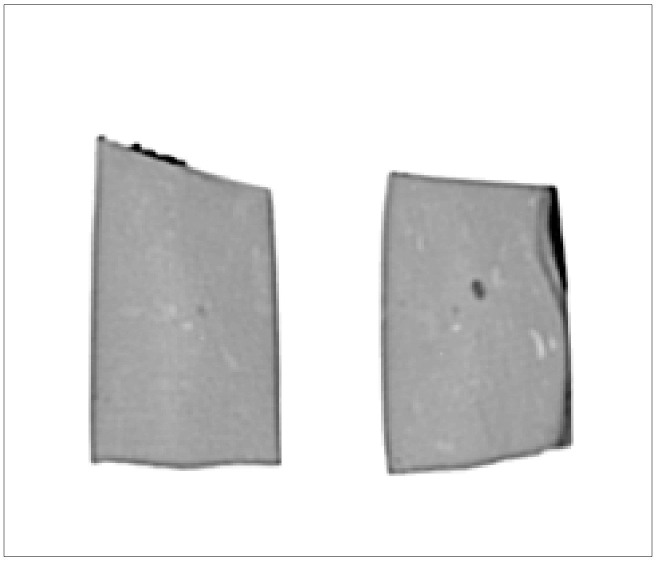




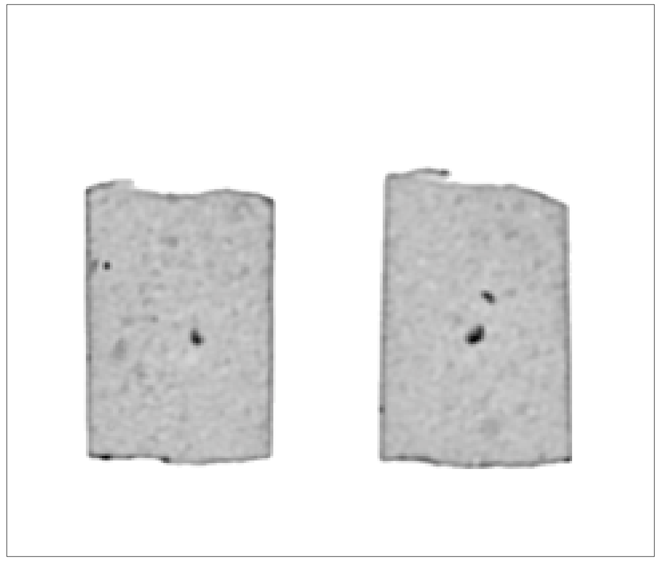
Sample No: 9
Depth: 2633.5 m

Sample No: 11
Depth: 2644.0 m

East Pilchard-1
C.T. Scans



Sample No: 12
Depth: 2652.0 m



Sample No: 13
Depth: 2663.0 m

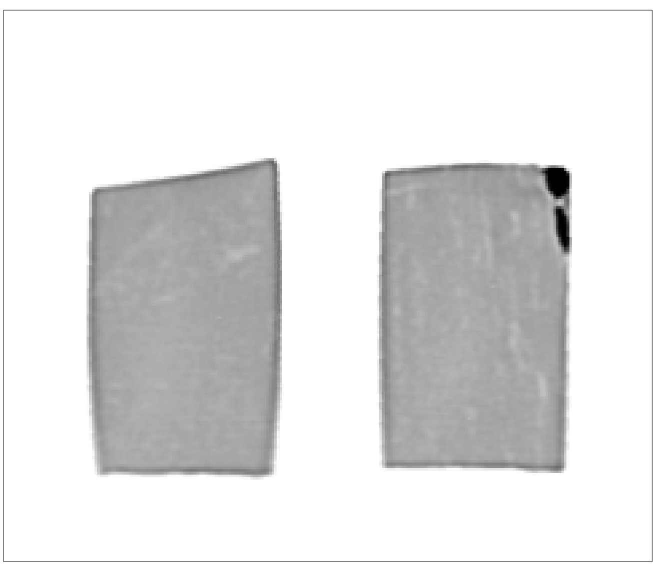
Sample No: 15
Depth: 2700.5 m

Sample No: 17
Depth: 2721.5 m

East Pilchard-1
C.T. Scans

Sample No: 18
Depth: 2728.5 m

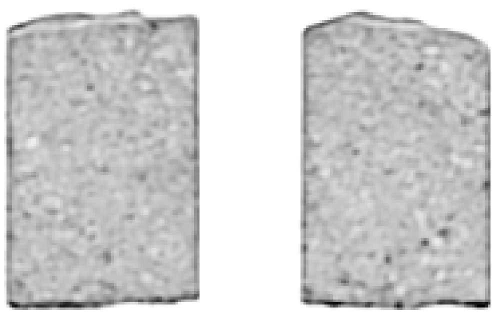
Sample No: 19
Depth: 2751.0 m



Sample No: 21
Depth: 2759.0 m

Sample No: 22
Depth: 2763.0 m

East Pilchard-1
C.T. Scans



Sample No: 23
Depth: 2764.5 m