Appendix K

Cooney (2016): Vitrinite reflectance report: Antero Hill Unit 2H and Antero Hill Unit 3H wells, Washington County, Pennsylvania

Vitrinite Reflectance Report

Antero Hill Unit 2H and Antero Hill Unit 3H Wells
Washington County, Pennsylvania

Prepared for:

Midwest Regional Carbon Sequestration Partnership

(MRCSP) Phase III

July 2016

Vitrinite Reflectance Report

Antero 2H and 3H Wells
Washington County, Pennsylvania

Prepared for:

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(MRCSP) Phase III

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Geologic Contractor

Date: July 31, 2016

1.0 Introduction

This task builds on previous work conducted by the Pennsylvania Geological Survey as part of the Midwest Regional Carbon Sequestration Partnership Phase III Study. This report also investigates thermal maturity trends identified by Opsitnick (2015) as part of an undergraduate senior thesis. This study focused on two wells completed in the "heart" of Pennsylvania's Marcellus country, Washington County. Not only has this area been prolific for oil and natural gas production, but historic oil and gas production in the region has depleted many of the reservoirs that could potentially be viable for carbon capture, storage, and utilization projects. Marcellus shale reservoirs, along with others, are being examined for their storage characteristics.

Recently, the Antero Resources Hill Unit 2H (API# 37-125-23880) and Hill Unit 3H (API# 37-125-23879) wells were completed in Washington County. A geophysical log was only available for the Hill Unit 3H well and is presented in **Figure 1.**

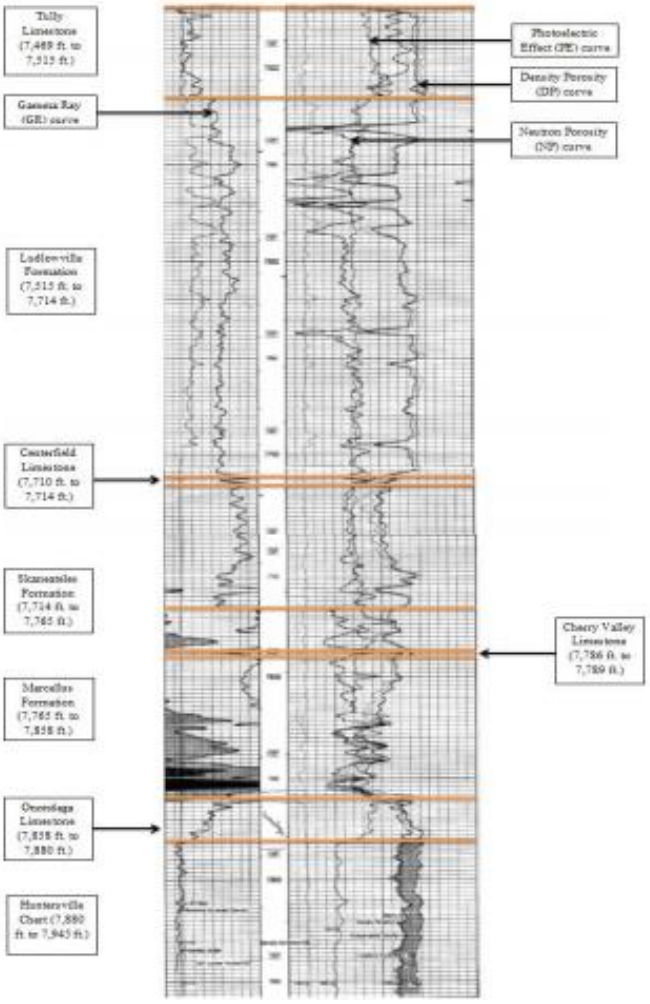


Figure 1. Well log of the Hill Unit 3H well from Opstinick (2015).

The purpose of this study is to examine the thermal maturity trends of these wells by vitrinite and bitumen reflectance, and compare trends to the study by Opsitnick (2015) to characterize this part of the Marcellus reservoir for possible sequestration and storage use.

2.0 Materials and Methods

Rock cuttings from the Antero Resources Hill Unit 2H and Hill Unit 3H wells were collected from the PAGS repository for this work. The 2H well was sampled from 7530 feet (ft) to 7830 ft in the vertical portion of the well from the Ludlowville Formation through the Marcellus Shale at (roughly) 30-foot intervals and from 7600 feet to 11,624 feet in the lateral portion of the well at various intervals (Table 1). The 3H well was sampled from 7490 ft to 7850 ft in the vertical portion of the well at varying 30-foot and 10-foot intervals and from 11,010 ft to 12,990 ft in the lateral portion of the well at various intervals. The Centerfield Limestone was not sampled in either well for the lack of organic material found in the formation.

Each sample was ground with a mortar and pestle and sieved through a #16 sieve. At the Pennsylvania Geological Survey Headquarters in Middletown, Pennsylvania, approximately 2 grams (g) of sample were combined with roughly 3 g of Beuhler TransOptic power (20-3400-080) and mixed. The mixture was then placed into a Beuhler Simplimet 3000 Automatic Mounting Press and run for 15.5 minutes at 4000 pounds per square inch (psi) to form solid sample plugs for reflectance analysis. The samples were cured overnight in a dessicator and then polished using a Beuhler Ecomet 300 and six polishing pads of varying coarseness. The 42 plugs were examined using a Leica DMRX microscope calibrated with a (GGG) [1.719] standard with MSP200V4.3 and AxioVision software. Using immersion oil and an oil objective, samples were visually assessed for bitumen and/or vitrinite using the American Society for Testing and Materials (ASTM) standard D2797. As many measurements were mad as possible on macerals of sufficient size and data was placed into a histogram using the ASTM 7708 template in either the bitumen or vitrinite category (Appendix A). Since the Devonian-age Marcellus Formation has many types of organic macerals present, measurements were taken on both bitumen and vitrinite macerals and the data was analyzed separately. A maceral containing both bitumen and vitrinite is shown in **Figure 2.** The histograms for each depth interval were examined and anonymously high and low reflectance values were removed if they were believed to be measured on macerals other than bitumen or vitrinite. The resulting reports for each depth interval are presented in **Appendix A.**

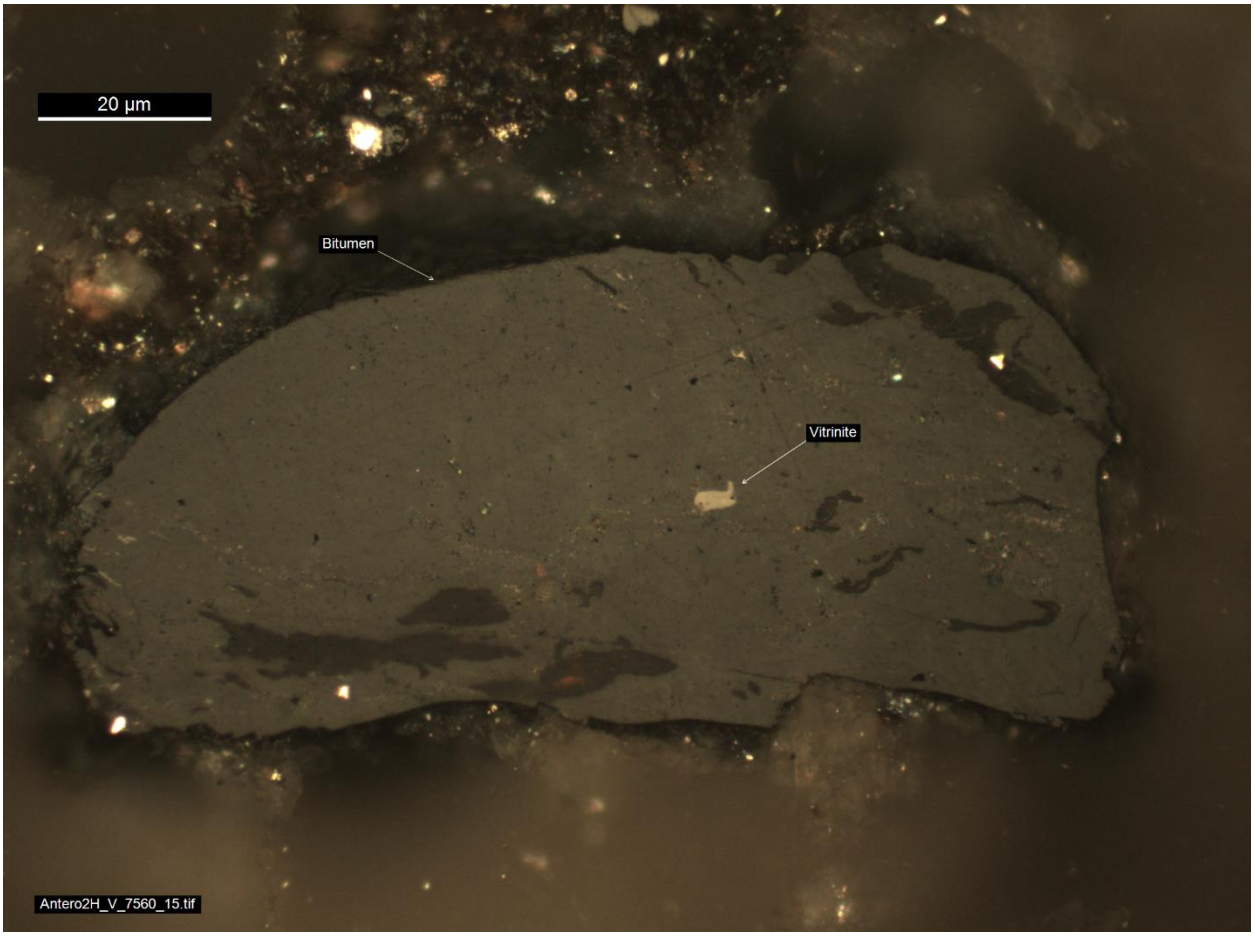


Figure 2. Maceral showing both bitumen, vitrinite, and other types of organic macerals from Hill Unit 2H at 7560 ft deep.

3.0 Results

3.1 Hill Unit 2H

Table 1 shows the bitumen reflectance values as well as mineralogical data from the vertical portion of the Hill Unit 2H well. Mean $\%Ro_{eq}$ values ranged between 0.74 and 0.89 with a mean $\%Ro_{eq}$ of 0.81 for the well. The mean %Ro values ranged from 1.55 to 1.88 with a mean %Ro of 1.68 for the well.

Table 1. Mean reflectance values and mineralogy data for the vertical section of the Hill Unit 2H Well (API# 37-125-23880)

Bitumen Reflectance			Mineralogy		
Depth	**N**	**Mean %Ro_{eq}**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7560	23	0.89	11	17	73
7590	22	0.79	25	29	46
7620	11	0.74	27	30	44
Vitrinite Reflectance			**Mineralogy**		
Depth	**N**	**Mean %Ro**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7530	54	1.55	25	18	57
7560	26	1.56	11	17	73
7590	15	1.57	25	29	46
7620	18	1.55	27	30	44
7650	22	1.73	39	44	18
7680	27	1.88	44	53	4
7710	34	1.79	39	57	4
7740	9	1.69	43	50	7
7800	21	1.73	50	44	6
7830	45	1.75	43	50	7

While the Hill Unit 3H %Ro_{eq} values slightly decrease with depth, the %Ro values increase almost uniformly with depth. A spike in higher reflectance occurs between 7650 ft and 7750 ft (**Figure 3)** This spike in higher %Ro values coincides with a change in mineralogy as carbonate content decreases and clay content increases **(Table 1).**

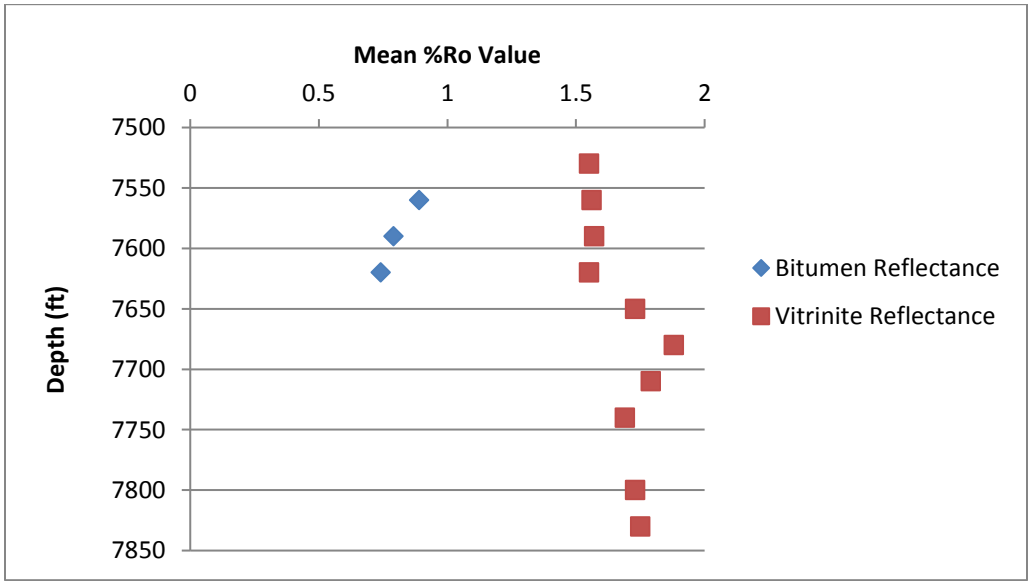


Figure 3. Bitumen reflectance values for the Hill Unit 2H well (API# 37-125-23880)

This change in mineralogy is also evidence in Opstinick (2015) between the Ludlowville Formation and Centerfield Limestone and is shown here as **Figure 4.**

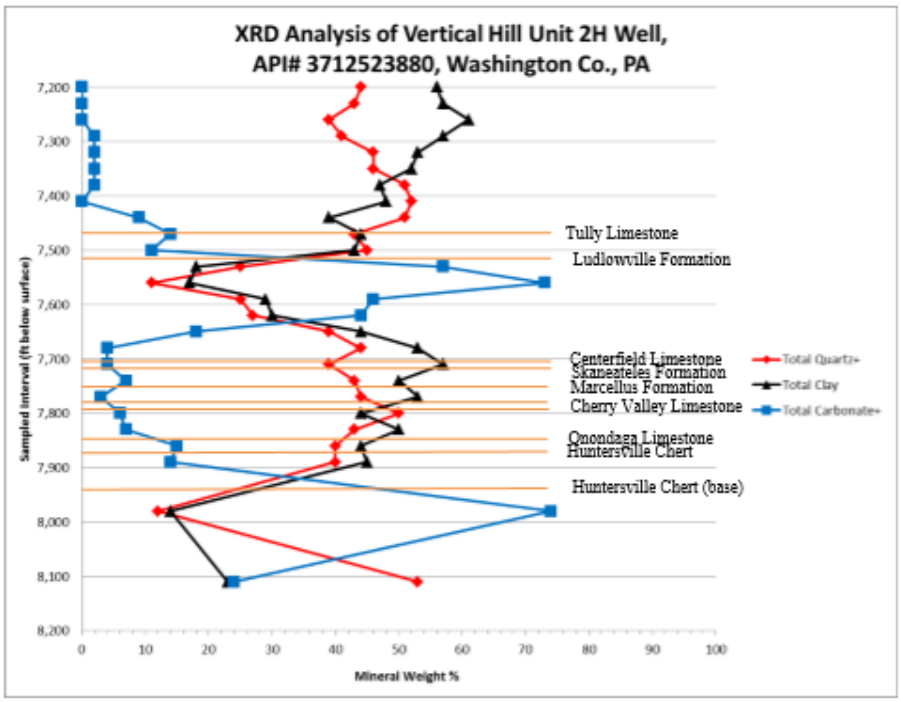


Figure 4 . Mineralogical trends for the vertical portion of the Hill Unit 2H Well (API# 37-125-23880) (Opsitnick, 2015).

The lateral section of the 2H well is represented by **Table 2**. Mean $\%Ro_{eq}$ values range from 0.39 to 0.78 with a mean value of 0.59 for the well. %Ro values ranged from 1.13 to 1.77 with a mean value of 1.62 for the well. The mineralogy in the lateral portion of the well changes from decreased quartz with high clay and carbonate near the landing zone of the lateral to gradually more quartz and clay, and almost no carbonate at the farthest extent of the lateral **(Table 2).**

Table 2. Mean reflectance values and mineralogy data for the lateral section of the Hill Unit 2H Well (API# 37-125-23880)

Bitumen Reflectance			Mineralogy		
Depth	**N**	**Mean %Ro_{eq}**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7600	1	0.78	5	20	74
11624	46	0.39	49	50	1
Vitrinite Reflectance			**Mineralogy**		
Depth	**N**	**Mean %Ro**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7600	108	1.56	5	20	74
7990	44	1.68			
8620	38	1.76	39	33	27
9010	35	1.77			
9490	18	1.72			
9610	55	1.67	45	52	2
10000	32	1.68			
10600	28	1.73	40	60	0
10990	33	1.13			
11624	54	1.54	49	50	1

This trend is evident in Opstinick (2015) and is shown in **Figure 5**. The change in mineralogy occurs relatively uniformly along the length of the lateral.

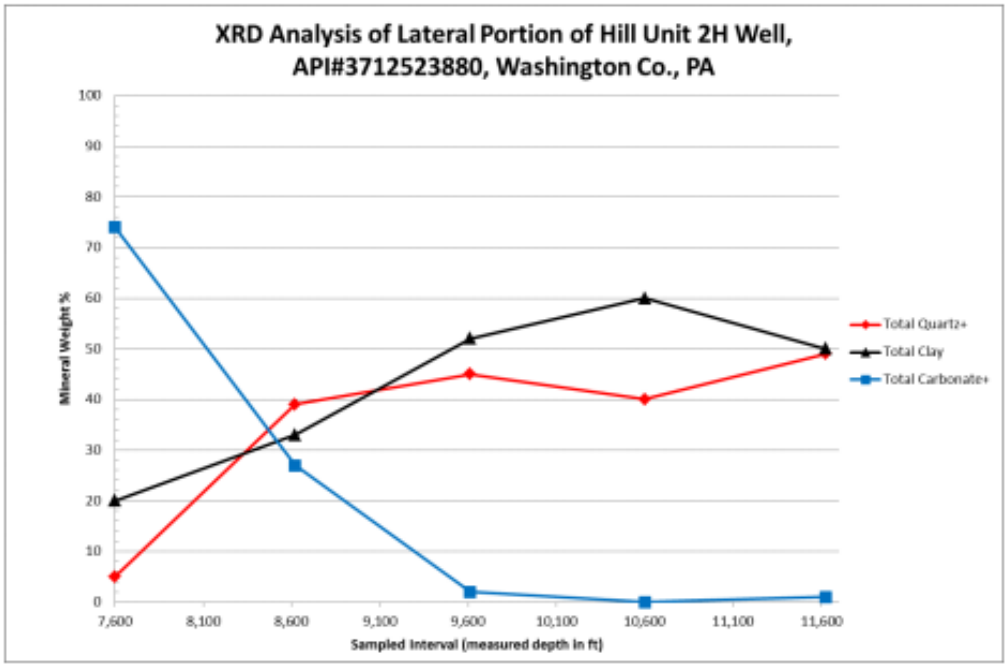


Figure 5. Mineralogical trends for the lateral portion of the Hill Unit 2H Well (API# 37-125-23880).

3.2 Hill Unit 3H

Table 3 shows the reflectance and mineralogical data in the vertical portion of the Hill Unit 3H well. The $\%Ro_{eq}$ values range from 0.74 to 0.98 with a mean value of 0.82 for the well. Mean %Ro values range from 1.40 to 2.11 with a mean value of 1.79 for the well.

Table 3. Mean reflectance values and mineralogy data for the vertical section of the Hill Unit 3H Well (API# 37-125-23879)

Bitumen Reflectance			Mineralogy		
Depth	**N**	**Mean $\%Ro_{eq}$**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7490	166	0.78	52	35	13
7550	212	0.82	29	24	48
7580	2	0.83	40	49	11
7610	19	0.79	47	51	2
7690	11	0.74	49	49	2
7720	20	0.78	58	40	1
7730	16	0.85	56	42	2
7740	52	0.98	40	48	12
7810	7	0.81	55	37	8
Vitrinite Reflectance			**Mineralogy**		
Depth	**N**	**Mean %Ro**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
7490	7	1.58	52	35	13
7520	44	2.11	45	55	0
7550	37	1.65	29	24	48
7580	51	1.95	40	49	11
7610	18	2.06	47	51	2
7640	26	1.95	49	51	0
7690	7	1.61	49	49	2
7700	50	1.50	51	47	1
7720	44	1.72	58	40	1
7730	29	1.88	56	42	2
7740	9	2.06	40	48	12
7760	69	1.40			
7770	39	1.78	39	41	20
7790	40	1.84	39	27	24
7810	11	1.81	55	37	8
7830	60	1.62	30	16	55
7850	42	1.89	30	16	55

There is no uniform trend in either the $\%Ro_{eq}$ or %Ro values. Generally, $\%Ro_{eq}$ values remain uniform until a sharp increase occurs near 7750 ft. There is no identifiable trend in %Ro values, as illustrated in **Figure 6.**

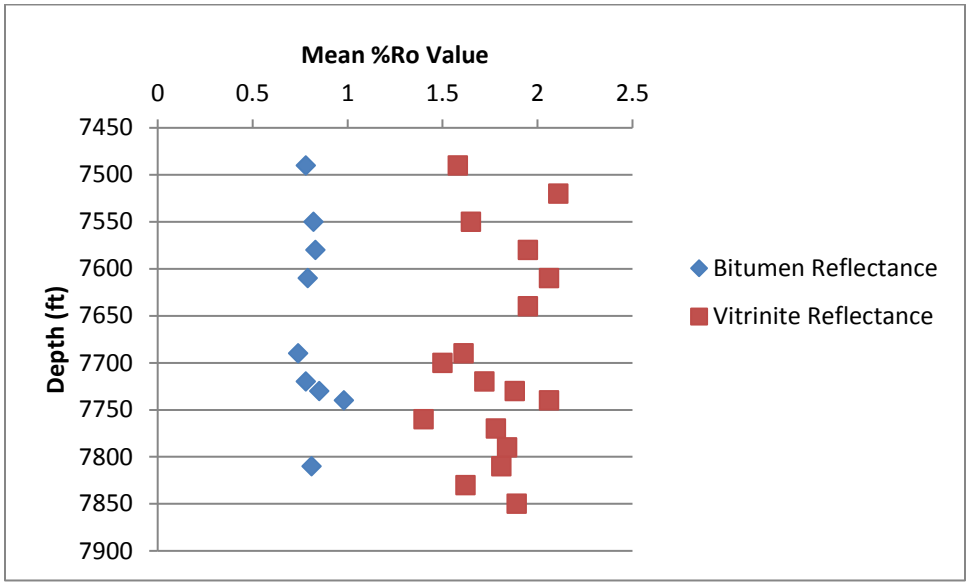


Figure 6. Reflectance value trends for the Hill Unit 3H Well (API# 37-125-23879)

Mineralogy varies along the vertical portion of the 3H well. Generally, the well exhibits low carbonate, with high clay and quartz, with a narrow reversal of mineralogy in the Ludlowville Formation and below the Onondaga Limestone, where high carbonate is encountered. This relationship was examined in Opstinick (2015) and is presented in **Figure 7.**

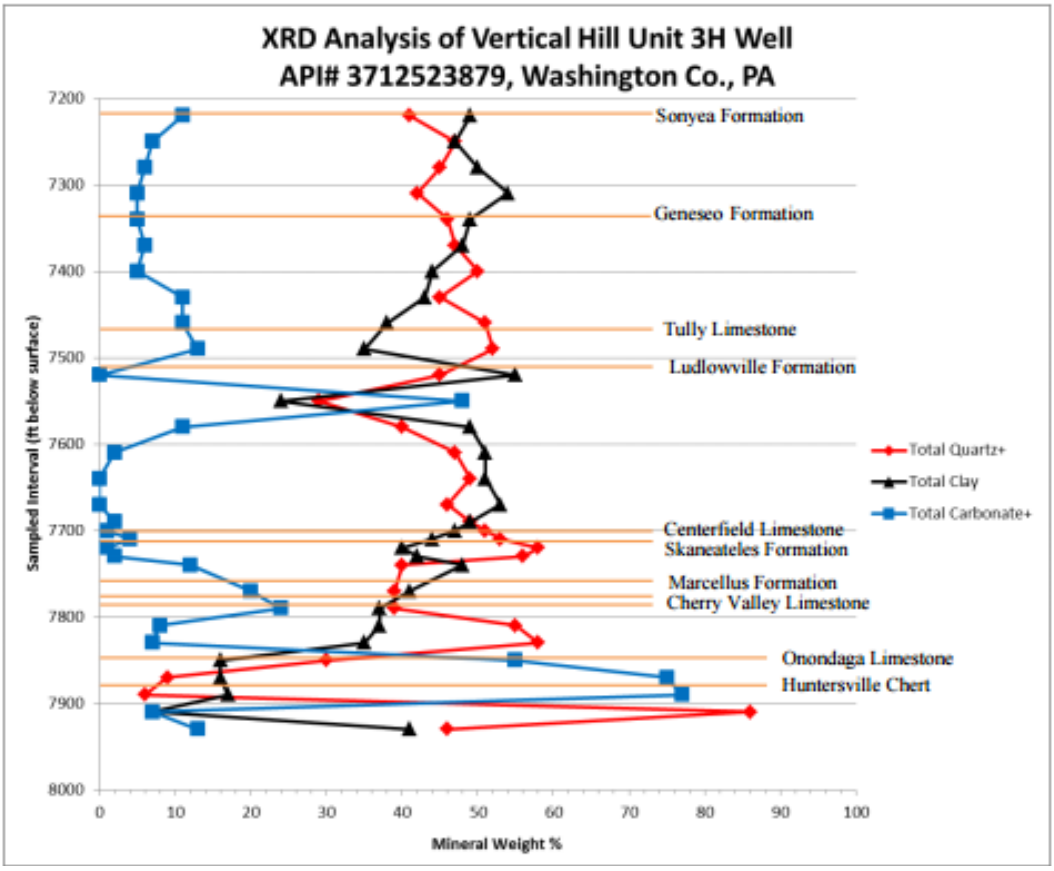


Figure 7. Mineralogical trends for the vertical portion of the Hill Unit 3H Well (API# 37-125-23879) (Opsitnick, 2015).

Table 4 shows the reflectance and mineralogical data from the lateral portion of the Hill Unit 3H well. The $\%Ro_{eq}$ values range from 0.78 to 1.16 with a mean value of 0.97 for the well. The %Ro values range from 1.76 to 2.22 with a mean value of 1.95 for the well. The mineralogy of the well transitions from high quartz and clay content with low carbonate at the landing point of the lateral to high quartz and carbonate with low clay at the farthest extent of the lateral (Table 4).

Table 4. Mean reflectance values and mineralogy data for the lateral section of the Hill Unit 3H Well (API# 37-125-23879).

Bitumen Reflectance			Mineralogy		
Depth	**N**	**Mean %Ro$_{eq}$**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
11010	6	1.16	63	30	6
11900	4	0.78			
Vitrinite Reflectance			**Mineralogy**		
Depth	**N**	**Mean %Ro**	**Quartz (%)**	**Clay (%)**	**Carbonate (%)**
11010	46	1.93	63	30	6
11900	6	1.76			
11910	100	2.06			
12000			57	29	14
12030	55	1.77			
12990	127	2.22	43	16	42

As in the 2H well, this change in mineralogy occurs gradually over the length of the lateral. This trend is evident in Opstinick (2015) and is shown in **Figure 8.**

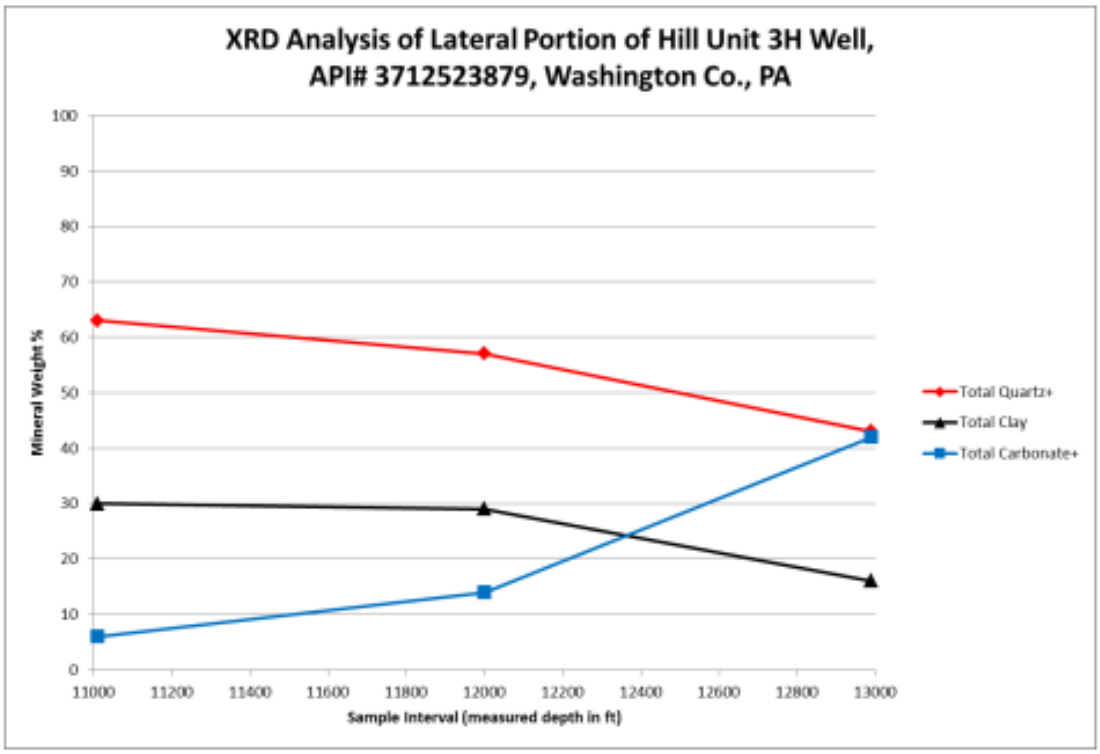


Figure 8. Mineralogical trends for the lateral portion of the Hill Unit 3H Well (API# 37-125-23879).

4.0 Discussion and Conclusions

The Hill Unit 2H well shows relatively uniform trends mineralogy and predictable changes in mineralogy. Changes in mineralogy and thermal maturity occur simultaneously near 7650 ft deep in the well. The %Ro values in the Hill Unit 2H well places it in the middle of the dry gas window (1.35 to 2.0), shown in Figure 9, which coincides with production from this well.

The Hill Unit 3H well presents a similar mineralogical signature as the Hill Unit 2H well but almost no discernible trend in the %Ro values. Like the 2H well, the %Ro values in the 3H well place it in the dry gas window, and just out of the wet gas floor, fitting with production from this well.

While changes in mineralogy and thermal maturity seem to coincide in the 2H well, there is no obvious pattern of variaton in the 3H well.

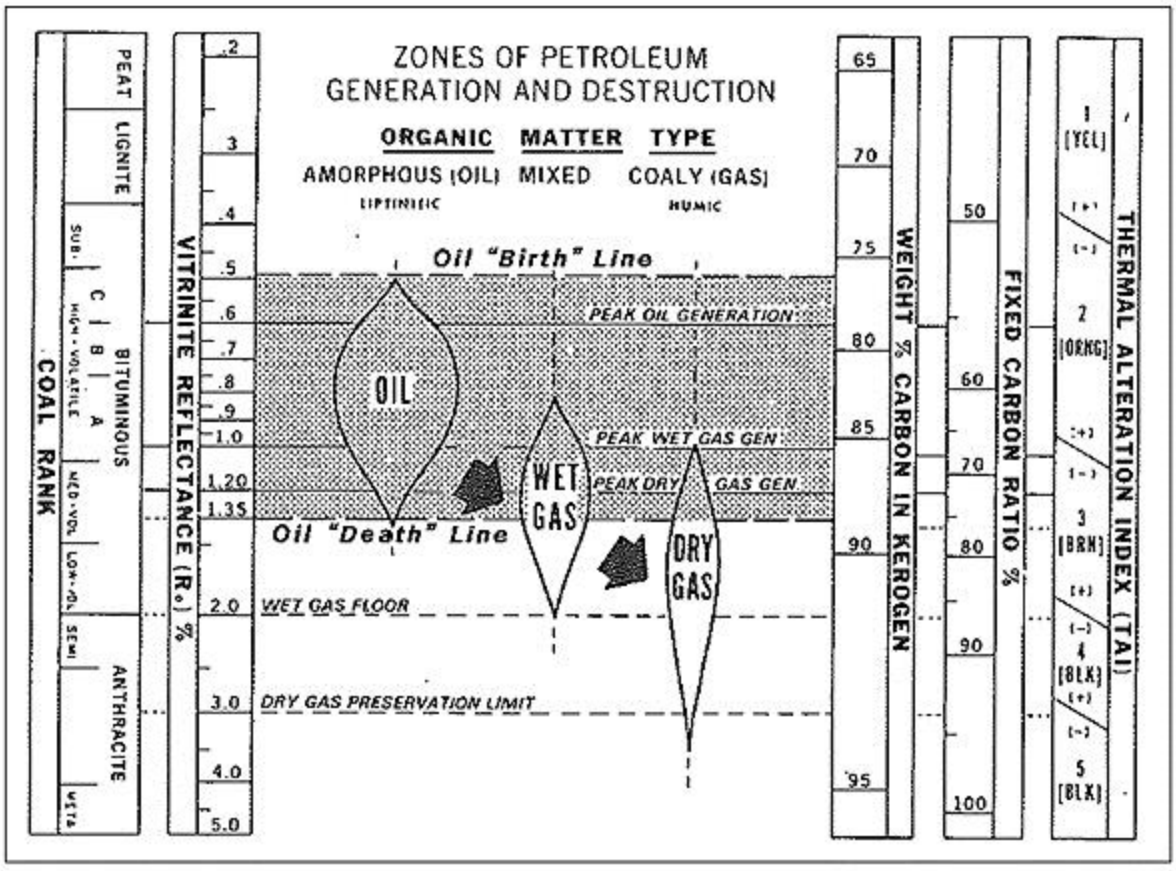


Figure 9. Petroleum generation chart (Patchen and Carter, 2015).

5.0 Resources

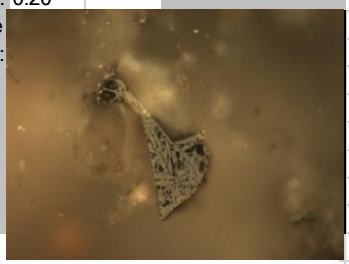
Opsitnick, Alexandra, 2015, Reservoir Quality of the Marcellus Shale Play in the Hill Unit 2H and 3H Wells: Determining Mineralogical and Lithological Properties, Allegheny College Undergraduate Thesis, 99 p.

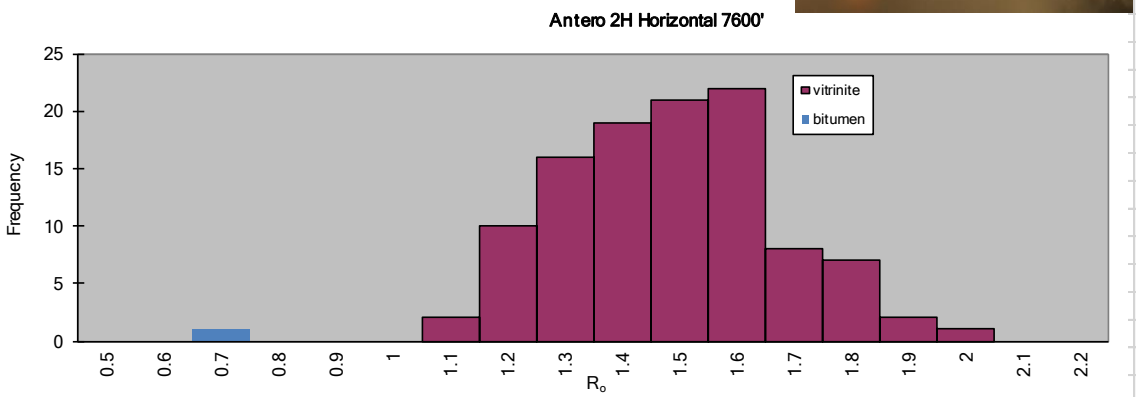
Patchen, D.G. and Carter, K.M., eds., 2015, A geologic play book for Utica Shale Appalachian basin exploration, Final report of the Utica Shale Appalachian basin exploration consortium, 187 p. Available from: http://www.wvgs.wvnet.edu/utica.

Appendix A

Antero Hill Unit 2H and Antero Hill Unit 3H Well Data
Washington County, Pennsylvania

Submitted by:	Michele Cooney	No. measurements:	109
Date Submitted:	12/4/2015	maceral type:	Bitumen
Project:	MRCSP	R_o:	1.53
		s.d.:	0.20
Sample ID:	**Antero 2H Horizontal 7600**	Example Photograph:	
Lab ID:	Antero2H_H_7600		
Sample Type:	Shale plug		
Date Analyzed:	2/10/2016		
Operator:	Antero Resources		
Standard:	ASTM D2798 7708		





DATA

0.781	1.294	1.370	1.403	1.446	1.505	1.568	1.604	1.652	1.695	1.822
1.101	1.294	1.371	1.404	1.447	1.509	1.573	1.605	1.659	1.721	1.849
1.159	1.298	1.374	1.415	1.447	1.513	1.578	1.605	1.663	1.739	1.854
1.203	1.328	1.377	1.417	1.464	1.513	1.582	1.606	1.668	1.756	1.869
1.216	1.328	1.384	1.423	1.467	1.517	1.584	1.611	1.670	1.762	1.882
1.225	1.359	1.386	1.424	1.471	1.533	1.591	1.635	1.670	1.764	1.883
1.244	1.360	1.392	1.429	1.480	1.541	1.591	1.636	1.674	1.765	1.964
1.253	1.362	1.392	1.431	1.480	1.549	1.596	1.643	1.684	1.772	1.988
1.264	1.366	1.399	1.435	1.501	1.553	1.599	1.650	1.687	1.782	2.009
1.27	1.369	1.401	1.436	1.505	1.558	1.601	1.651	1.692	1.815	

All Data: **min:** 0.781 **max:** 2.009

Vitrinite Only: **min:** 0.781 **max:** 2.009 **V-types:** 14

COMMENT

GGG standard 1.719

DISPERSED VITRINITE REFLECTANCE REPORT

Run

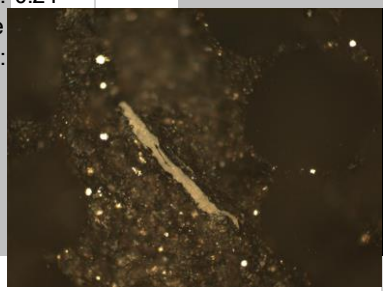
SAMPLE INFORMATION

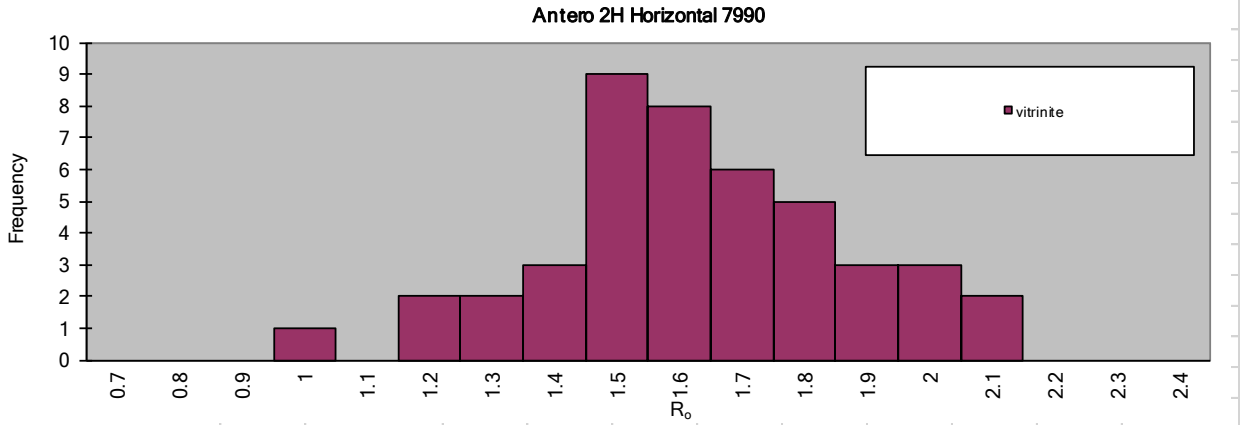
Submitted by:	Michele Cooney
Date Submitted:	12/9/2015
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 7990**
Lab ID:	Antero2H_H_7990
Sample Type:	shale plug
Date Analyzed:	2/10/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	44
maceral type:	bitumen
R_o:	1.68
s.d.:	0.24

Example Photograph:





DATA

0.349	1.453	1.603	1.762	1.978
0.351	1.500	1.611	1.776	1.988
0.354	1.514	1.630	1.790	2.010
1.080	1.549	1.636	1.797	2.011
1.218	1.560	1.637	1.830	2.015
1.281	1.561	1.638	1.855	2.105
1.301	1.565	1.662	1.877	2.155
1.348	1.565	1.671	1.879	2.430
1.439	1.577	1.707	1.891	2.489
1.452	1.589	1.756	1.954	

All Data: **min:** 0.349 **max:** 2.489

Vitrinite Only: **min:** 1.080 **max:** 2.155 **V-types:** 12

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

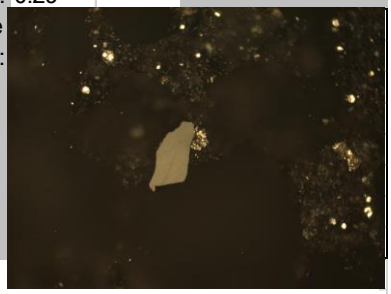
SAMPLE INFORMATION

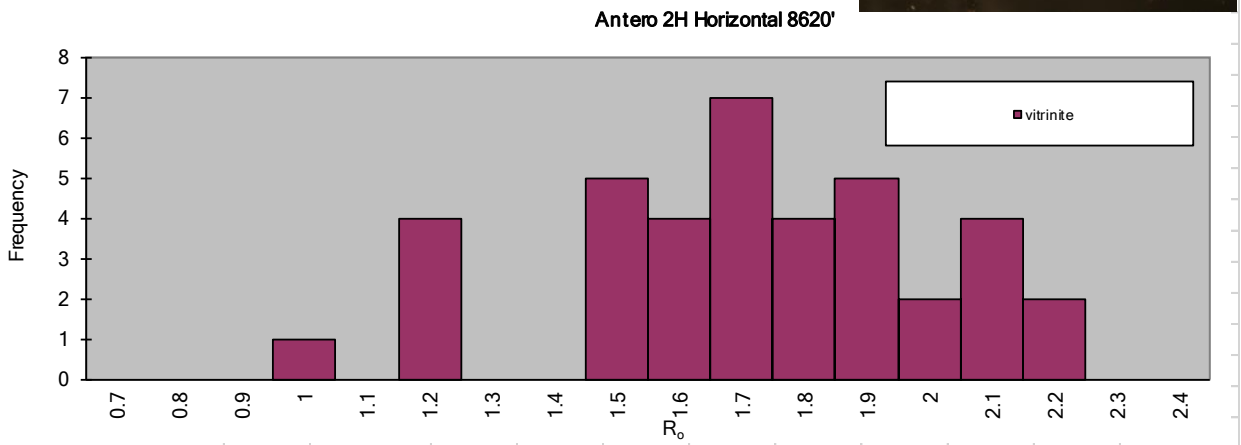
Submitted by:	Michele Cooney
Date Submitted:	12/17/2015
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 8620'**
Lab ID:	Antero2H_H_8620
Sample Type:	shale plug
Date Analyzed:	2/10/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	38
maceral type:	bitumen
R_o:	1.76
s.d.:	0.29

Example Photograph:





DATA

1.046	1.605	1.766	2.008
1.220	1.640	1.827	2.075
1.241	1.673	1.844	2.111
1.269	1.676	1.852	2.136
1.283	1.701	1.872	2.168
1.543	1.714	1.901	2.180
1.553	1.716	1.915	2.213
1.588	1.730	1.929	2.282
1.591	1.750	1.935	2.600
1.594	1.750	1.941	

All Data: **min:** 1.046 **max:** 2.600

Vitrinite Only: **min:** 1.046 **max:** 2.282 **V-types:** 13

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

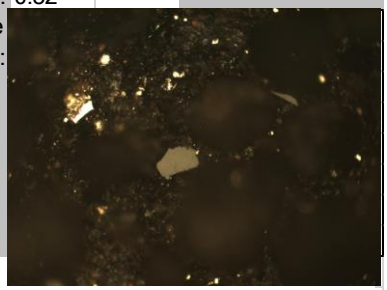
SAMPLE INFORMATION

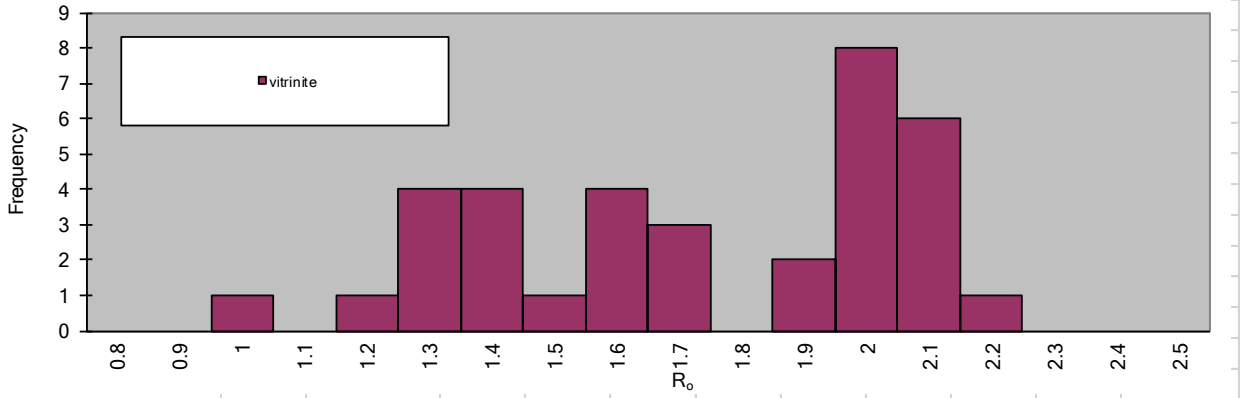
Submitted by:	Michele Cooney
Date Submitted:	12/22/2015
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 9010'**
Lab ID:	Antero2H_H_9010
Sample Type:	shale plug
Date Analyzed:	2/10/2015
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	35
maceral type:	bitumen
R_o:	1.77
s.d.:	0.32

Example Photograph:





DATA

1.096	1.528	2.003	2.118
1.270	1.603	2.035	2.130
1.301	1.611	2.035	2.136
1.341	1.623	2.043	2.170
1.344	1.671	2.051	2.213
1.358	1.741	2.056	2.603
1.409	1.752	2.066	
1.436	1.781	2.078	
1.461	1.934	2.107	
1.497	1.948	2.117	

All Data: **min:** 1.096 **max:** 2.603

Vitrinite Only: **min:** 1.096 **max:** 2.213 **V-types:** 13

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

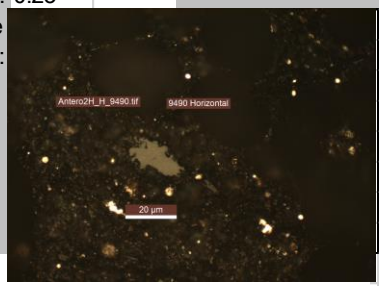
SAMPLE INFORMATION

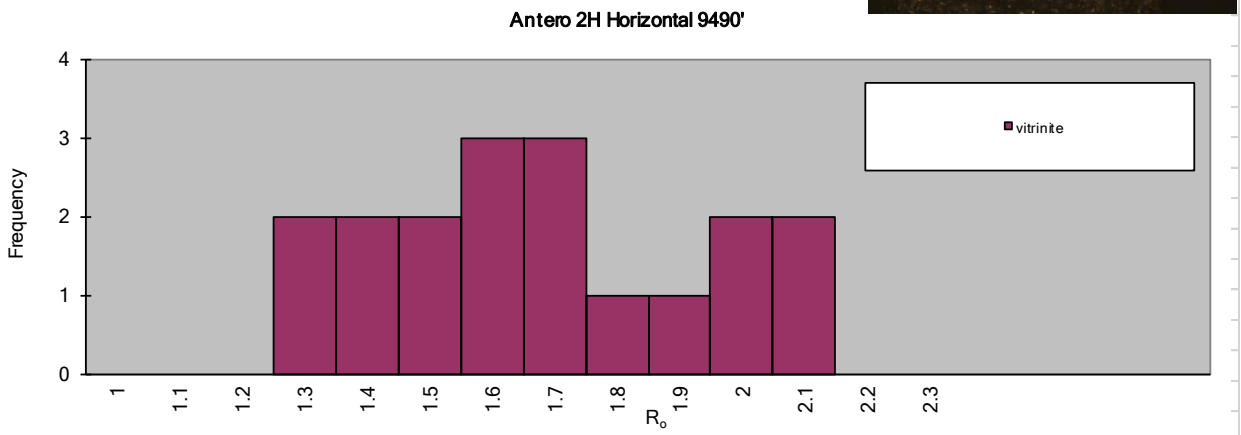
Submitted by:	Michele Cooney
Date Submitted:	1/8/2016
Project:	MRCSP
Sample ID:	**Antero2H Horizontal 9490'**
Lab ID:	Antero2H_H_9490
Sample Type:	shale plug
Date Analyzed:	2/10/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	18
maceral type:	bitumen
R_o:	1.72
s.d.:	0.25

Example Photograph:





DATA

1.311	1.736
1.323	1.755
1.447	1.885
1.481	1.950
1.514	2.012
1.546	2.040
1.640	2.100
1.642	2.130
1.680	
1.719	

All Data: **min:** 1.311 **max:** 2.130

Vitrinite Only: **min:** 1.311 **max:** 2.130 **V-types:** 9

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

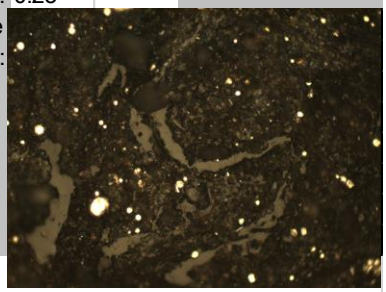
SAMPLE INFORMATION

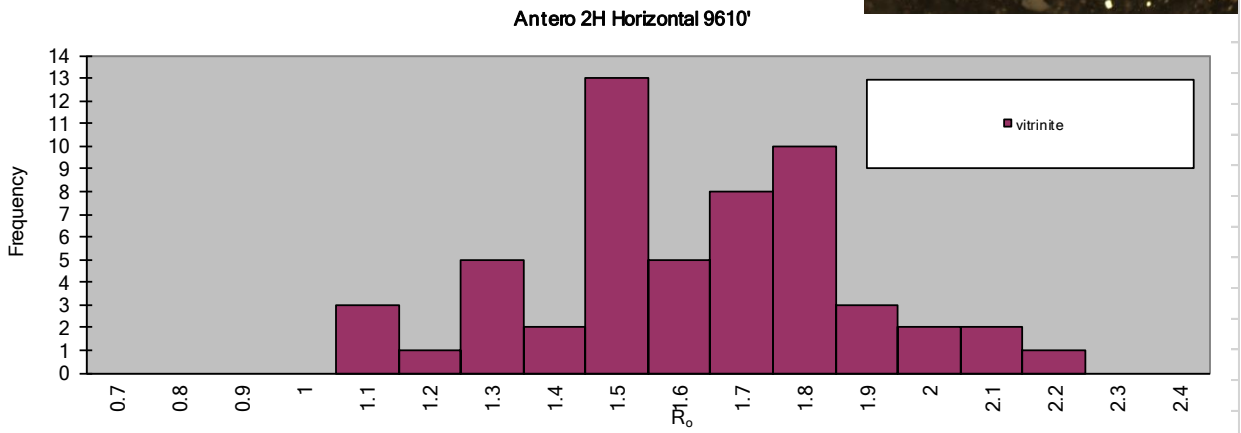
Submitted by:	Michele Cooney
Date Submitted:	12/28/2015
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 9610'**
Lab ID:	Antero2H_H_9610
Sample Type:	shale plug
Date Analyzed:	2/10/2015
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	55
maceral type:	bitumen
R_o:	1.67
s.d.:	0.25

Example Photograph:





DATA

1.143	1.470	1.579	1.734	1.824	2.023
1.149	1.500	1.581	1.739	1.846	2.059
1.172	1.501	1.582	1.749	1.862	2.111
1.241	1.518	1.590	1.764	1.864	2.163
1.319	1.520	1.626	1.772	1.864	2.233
1.344	1.521	1.634	1.788	1.876	
1.346	1.535	1.669	1.791	1.898	
1.378	1.552	1.680	1.805	1.936	
1.388	1.559	1.698	1.810	1.941	
1.424	1.560	1.724	1.821	1.993	

All Data: **min:** 1.143 **max:** 2.233

Vitrinite Only: **min:** 1.143 **max:** 2.233 **V-types:** 12

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

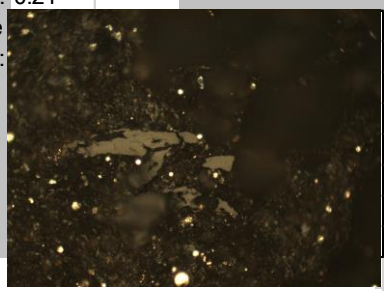
SAMPLE INFORMATION

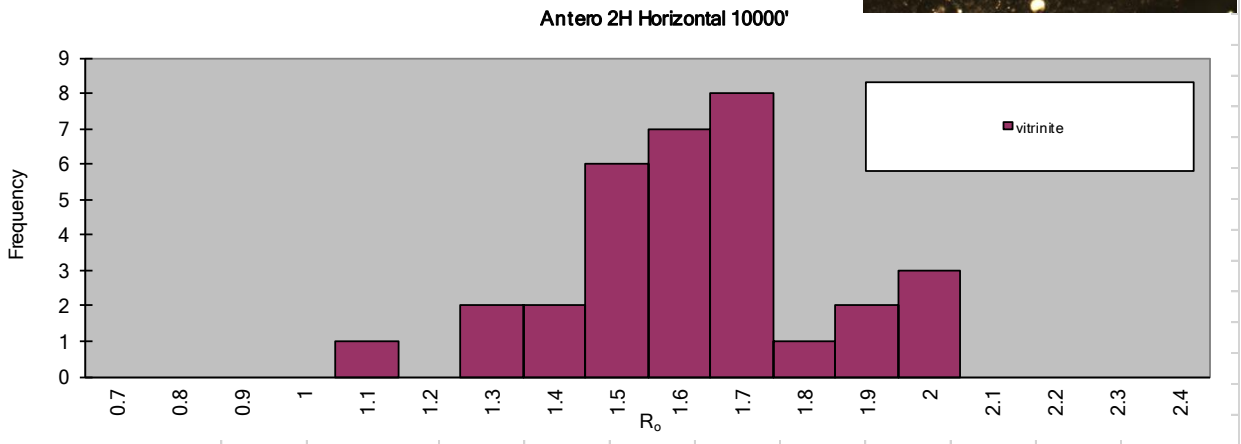
Submitted by:	Michele Cooney
Date Submitted:	1/5/2016
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 10000**
Lab ID:	Antero2H_H_10000
Sample Type:	shale plug
Date Analyzed:	2/11/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	32
maceral type:	bitumen
R_o:	1.68
s.d.:	0.21

Example Photograph:





DATA

1.127	1.596	1.714	2.049
1.351	1.602	1.740	2.066
1.356	1.603	1.769	2.323
1.458	1.634	1.775	
1.463	1.662	1.778	
1.517	1.688	1.782	
1.552	1.696	1.880	
1.560	1.696	1.991	
1.565	1.706	1.999	
1.584	1.707	2.032	

All Data: **min:** 1.127 **max:** 2.323

Vitrinite Only: **min:** 1.127 **max:** 2.066 **V-types:** 10

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

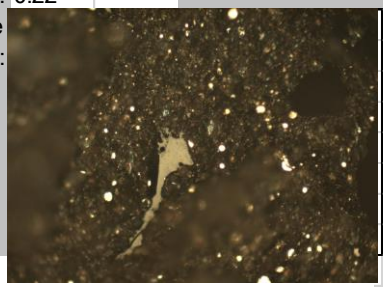
SAMPLE INFORMATION

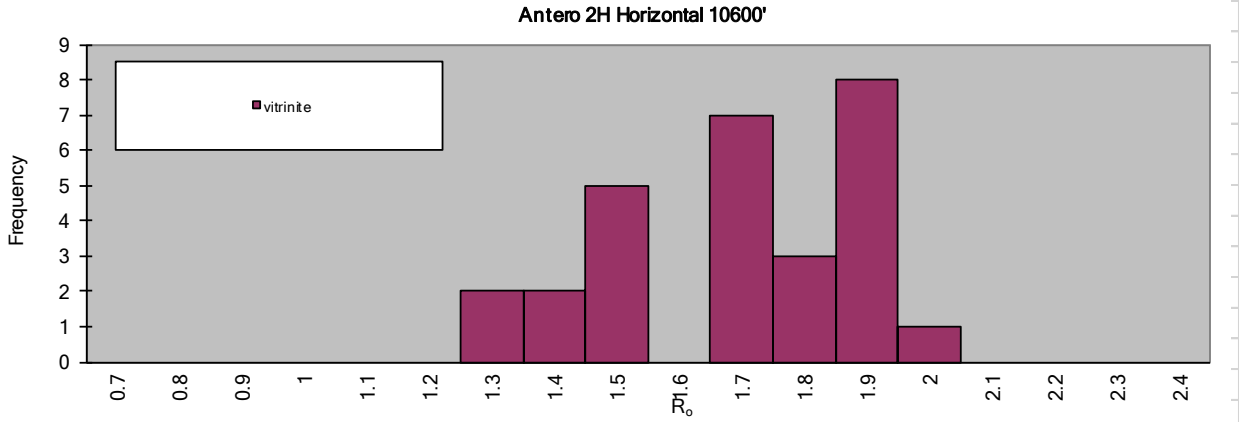
Submitted by:	Michele Cooney
Date Submitted:	1/20/2016
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 10600**
Lab ID:	Antero2H_H_10600
Sample Type:	shale plug
Date Analyzed:	2/11/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	28
maceral type:	bitumen
R_o:	1.73
s.d.:	0.22

Example Photograph:





DATA

1.319	1.711	1.922
1.341	1.718	1.951
1.423	1.724	1.984
1.425	1.729	1.987
1.504	1.755	1.991
1.504	1.787	1.995
1.507	1.803	1.996
1.508	1.811	2.020
1.576	1.823	
1.705	1.909	

All Data: **min:** 1.319 **max:** 2.020

Vitrinite Only: **min:** 1.319 **max:** 2.020 **V-types:** 8

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

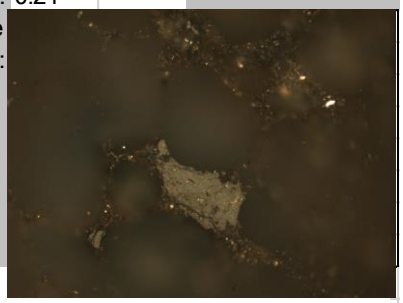
SAMPLE INFORMATION

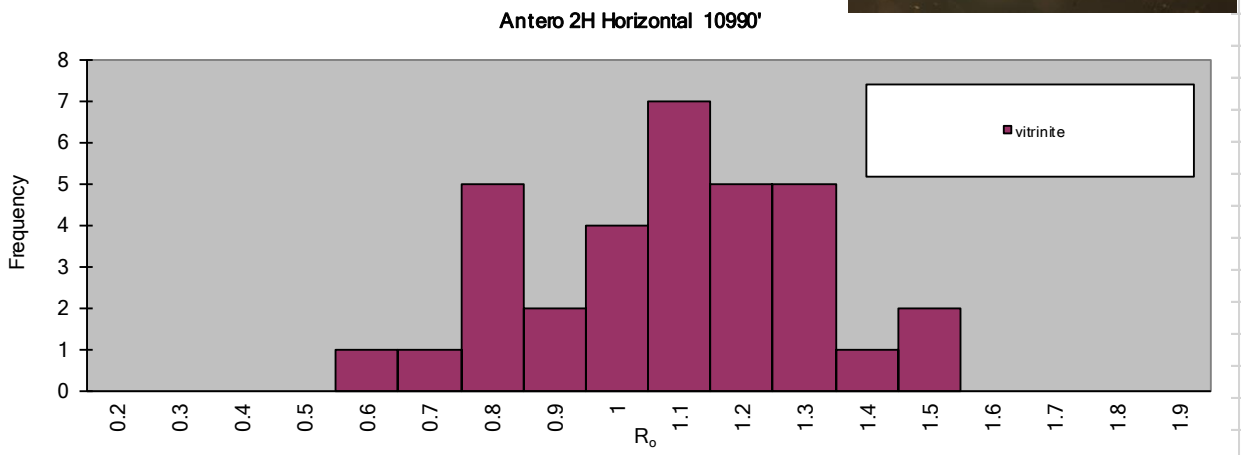
Submitted by:	Michele Cooney
Date Submitted:	1/22/2016
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 10990'**
Lab ID:	Antero2H_H_10
Sample Type:	shale plug
Date Analyzed:	2/11/2015
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	33
maceral type:	bitumen
R_o:	1.13
s.d.:	0.21

Example Photograph:





DATA

0.688	1.060	1.217	1.404
0.762	1.067	1.221	1.516
0.817	1.074	1.244	1.551
0.855	1.111	1.257	2.002
0.856	1.118	1.292	
0.867	1.123	1.308	
0.890	1.143	1.326	
0.900	1.143	1.337	
0.982	1.149	1.362	
1.045	1.170	1.375	

All Data: **min:** 0.688 **max:** 2.002

Vitrinite Only: **min:** 0.688 **max:** 1.551 **V-types:** 10

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

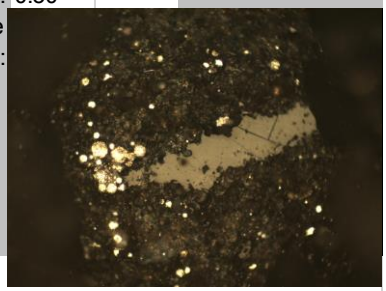
SAMPLE INFORMATION

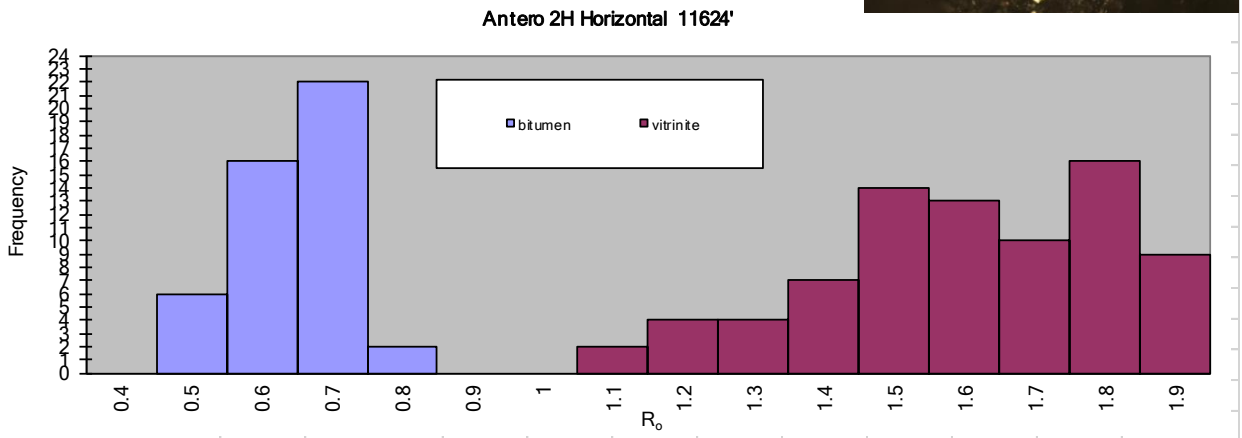
Submitted by:	Michele Cooney
Date Submitted:	1/25/2016
Project:	MRCSP
Sample ID:	**Antero 2H Horizontal 11624'**
Lab ID:	Antero2H_H_11624
Sample Type:	shale plug
Date Analyzed:	1/25/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	138
maceral type:	bitumen
R_o:	1.35
s.d.:	0.50

Example Photograph:





DATA

0.525	0.634	0.679	0.726	0.776	1.287	1.440	1.540	1.628	1.701
0.545	0.639	0.690	0.732	0.780	1.293	1.476	1.543	1.633	1.726
0.558	0.646	0.700	0.733	0.784	1.315	1.499	1.548	1.640	1.726
0.562	0.653	0.701	0.735	0.790	1.353	1.506	1.554	1.642	1.726
0.570	0.655	0.707	0.746	0.800	1.365	1.509	1.558	1.643	1.730
0.591	0.656	0.708	0.763	0.819	1.395	1.511	1.583	1.660	1.745
0.602	0.659	0.712	0.766	1.156	1.400	1.517	1.585	1.666	1.751
0.616	0.663	0.715	0.766	1.195	1.411	1.524	1.620	1.683	1.754
0.628	0.663	0.716	0.769	1.244	1.429	1.531	1.621	1.690	1.756
0.630	0.679	0.722	0.775	1.260	1.435	1.533	1.624	1.694	1.766

All Data: **min:** 0.525 **max:** 1.766

Vitrinite Only: **min:** 0.525 **max:** 1.766 **V-types:** 13

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

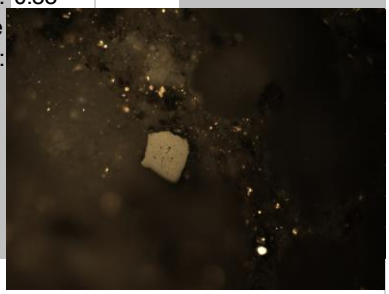
SAMPLE INFORMATION

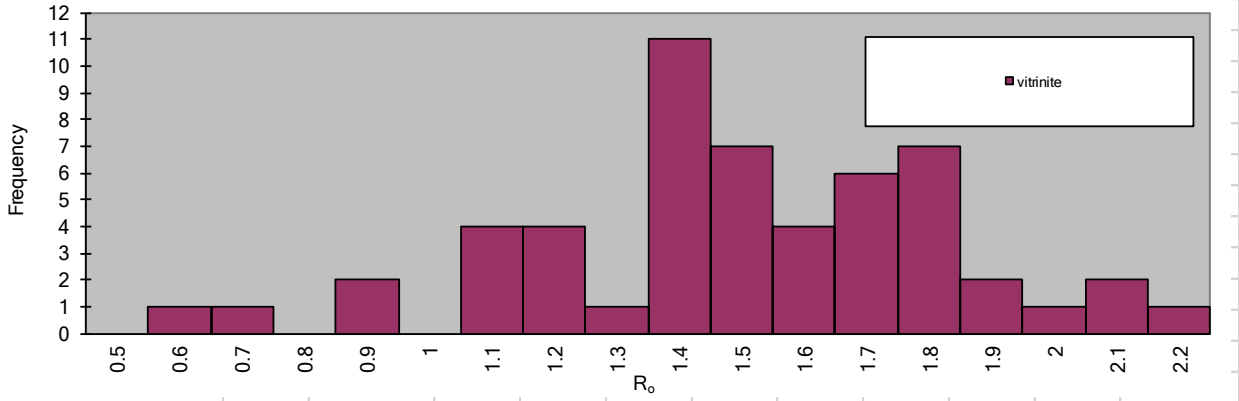
Submitted by:	Michele Cooney
Date Submitted:	9/28/2015
Project:	MRCSP
Sample ID:	**Antero 2H Veritcal 7530**
Lab ID:	Antero2H_V_7530
Sample Type:	shale plug
Date Analyzed:	2/11/2015
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	54
maceral type:	bitumen
R_o:	1.55
s.d.:	0.33

Example Photograph:





DATA

0.679	1.225	1.481	1.595	1.784	2.063	2.668	3.252	3.393
0.794	1.260	1.487	1.620	1.829	2.164	2.720	3.328	3.393
0.988	1.327	1.490	1.637	1.836	2.175	2.757	3.328	
0.992	1.411	1.499	1.665	1.846	2.286	2.822	3.328	
1.134	1.418	1.524	1.690	1.852	2.372	2.913	3.387	
1.168	1.426	1.537	1.702	1.863	2.475	3.034	3.388	
1.187	1.445	1.537	1.709	1.876	2.534	3.044	3.393	
1.189	1.456	1.541	1.710	1.882	2.559	3.171	3.393	
1.200	1.462	1.571	1.716	1.923	2.607	3.192	3.393	
1.200	1.479	1.589	1.748	1.997	2.650	3.207	3.393	

All Data: **min:** 0.679 **max:** 3.393

Vitrinite Only: **min:** 0.679 **max:** 2.286 **V-types:** 17

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

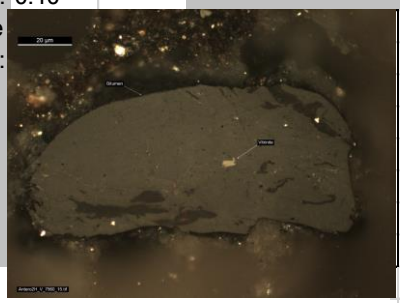
SAMPLE INFORMATION

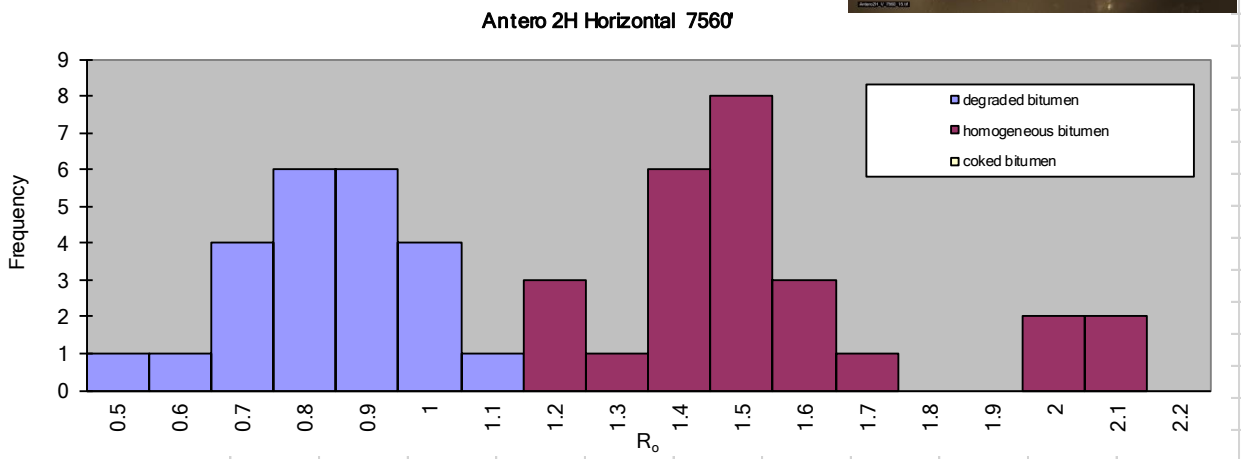
Submitted by:	Michele Cooney
Date Submitted:	9/30/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7560**
Lab ID:	Antero2H_V_75
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	49
maceral type:	bitumen
R_o:	1.26
s.d.:	0.40

Example Photograph:





DATA

	0.854	1.013	1.448	1.592
0.591	0.879	1.042	1.453	1.597
0.676	0.880	1.060	1.487	1.631
0.770	0.923	1.144	1.491	1.685
0.782	0.929	1.224	1.507	1.697
0.791	0.942	1.265	1.507	1.713
0.792	0.948	1.281	1.558	2.024
0.814	0.966	1.317	1.562	2.030
0.828	0.986	1.413	1.564	2.122
0.852	1.006	1.443	1.585	2.137

All Data: **min:** 0.591 **max:** 2.137

Vitrinite Only: **min:** 0.591 **max:** 2.137 **V-types:** 17

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

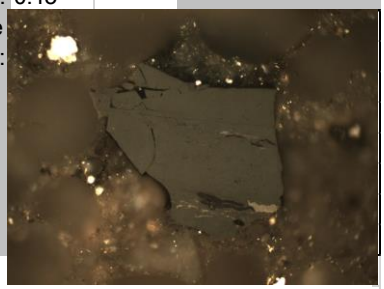
SAMPLE INFORMATION

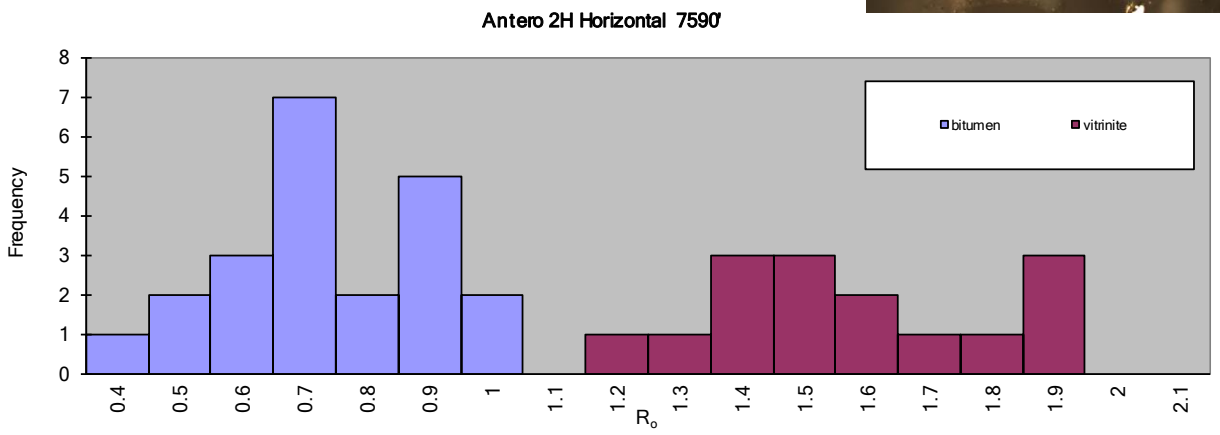
Submitted by:	Michele Cooney
Date Submitted:	10/1/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7590'**
Lab ID:	Antero2H_VV_7590
Sample Type:	shale plug
Date Analyzed:	2/12/2015
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	37
maceral type:	bitumen
R_o:	1.13
s.d.:	0.45

Example Photograph:





DATA

0.497	0.764	1.003	1.633	2.486
0.521	0.765	1.069	1.636	2.532
0.595	0.789	1.288	1.704	2.550
0.644	0.808	1.336	1.844	2.736
0.675	0.895	1.430	1.903	2.751
0.679	0.900	1.478	1.994	3.076
0.700	0.905	1.499	1.994	
0.705	0.970	1.547	2.232	
0.720	0.970	1.555	2.297	
0.753	0.987	1.575	2.470	

All Data: **min:** 0.497 **max:** 3.076

Vitrinite Only: **min:** 0.497 **max:** 1.994 **V-types:** 16

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

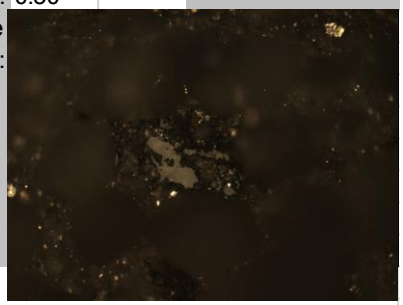
SAMPLE INFORMATION

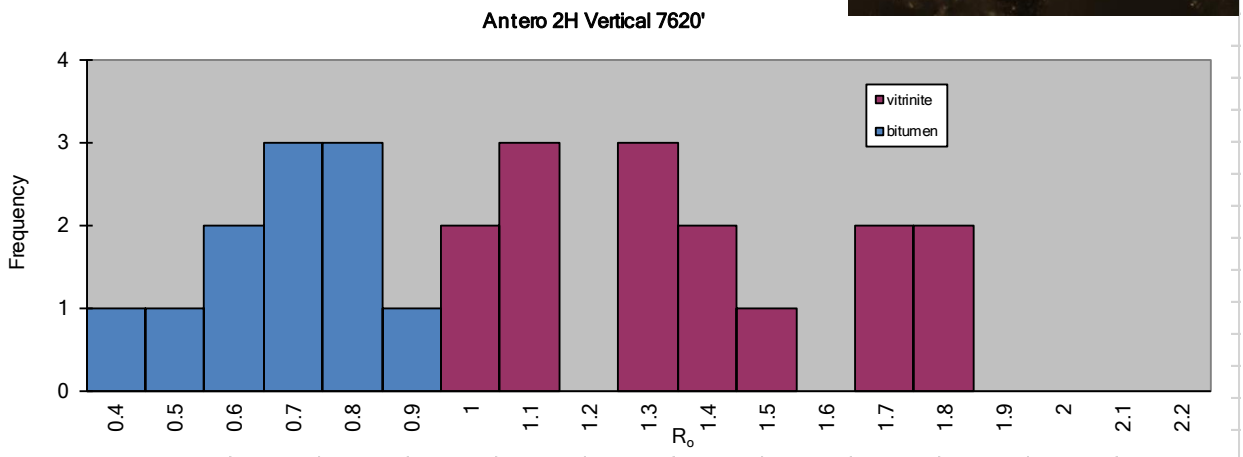
Submitted by:	Michele Cooney
Date Submitted:	10/2/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7620'**
Lab ID:	Antero2H_V_76
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	29
maceral type:	bitumen
R_o:	1.24
s.d.:	0.50

Example Photograph:





DATA

0.454	0.962	1.466
0.538	1.018	1.554
0.634	1.076	1.719
0.689	1.172	1.752
0.724	1.177	1.842
0.771	1.185	1.852
0.799	1.349	2.148
0.863	1.366	2.151
0.865	1.379	2.222
0.888	1.461	

All Data: min: 0.454 max: 2.222

Vitrinite Only: min: 0.454 max: 2.222 V-types: 19

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

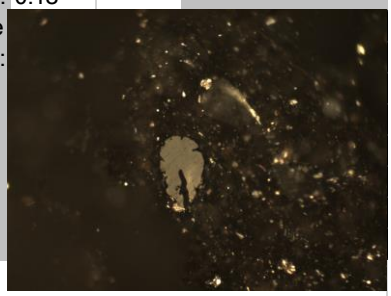
SAMPLE INFORMATION

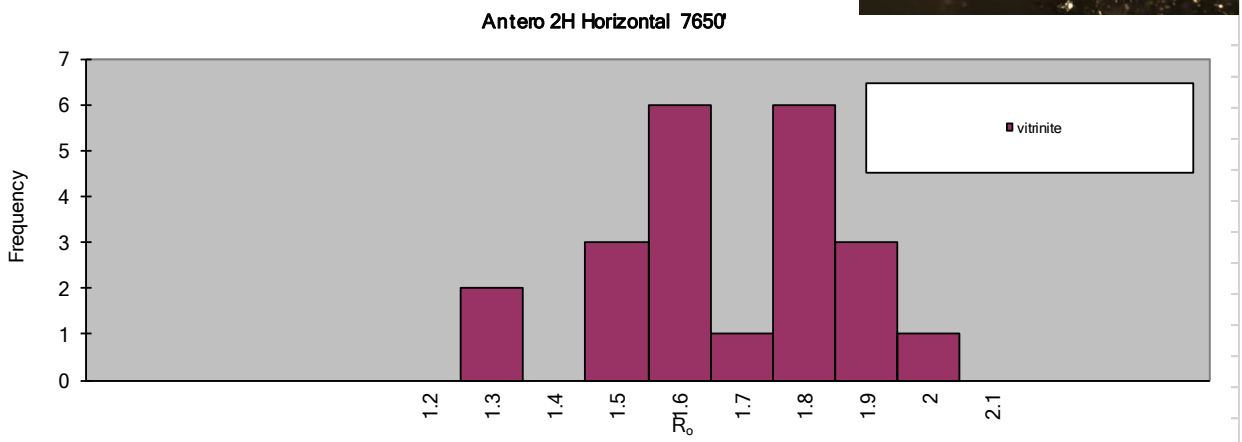
Submitted by:	Michele Cooney
Date Submitted:	11/16/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7650'**
Lab ID:	Antero2H_V_7650
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	22
maceral type:	bitumen
R_o:	1.73
s.d.:	0.18

Example Photograph:





DATA

1.312	1.694	1.981
1.391	1.721	2.034
1.537	1.808	
1.577	1.808	
1.582	1.833	
1.602	1.857	
1.631	1.868	
1.642	1.897	
1.666	1.908	
1.689	1.927	

All Data: **min:** 1.312 **max:** 2.034

Vitrinite Only: **min:** 1.312 **max:** 2.034 **V-types:** 8

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

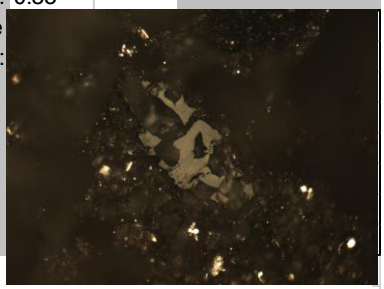
SAMPLE INFORMATION

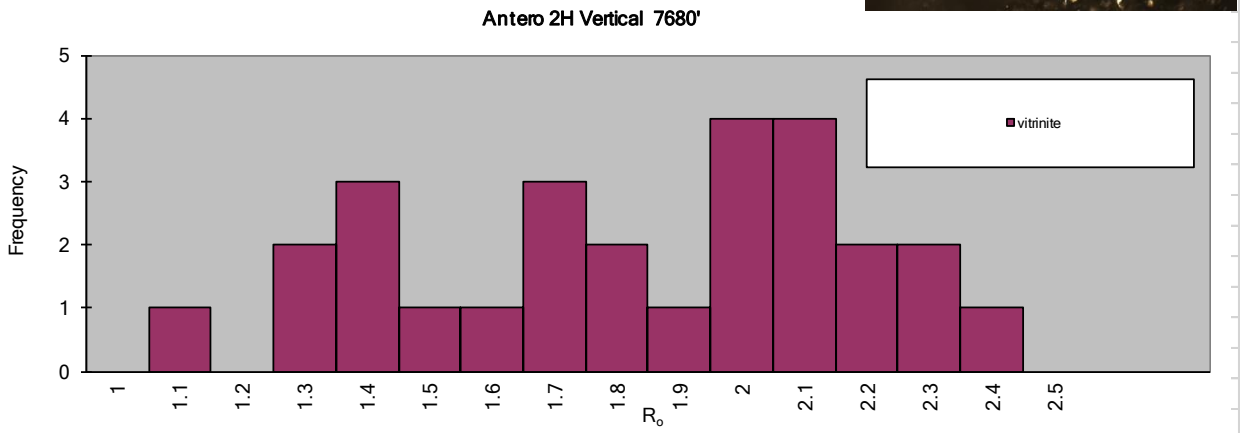
Submitted by:	Michele Cooney
Date Submitted:	11/19/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7680'**
Lab ID:	Antero2H_V_7680
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	27
maceral type:	bitumen
R_o:	1.88
s.d.:	0.35

Example Photograph:





DATA

1.186	1.780	2.180
1.302	1.809	2.187
1.329	1.885	2.233
1.438	1.976	2.278
1.478	2.016	2.353
1.480	2.041	2.355
1.591	2.043	2.420
1.686	2.061	
1.711	2.100	
1.763	2.146	

All Data: **min:** 1.186 **max:** 2.420

Vitrinite Only: **min:** 1.186 **max:** 2.420 **V-types:** 14

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

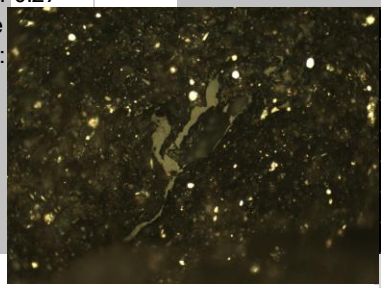
SAMPLE INFORMATION

Submitted by:	Michele Cooney
Date Submitted:	12/2/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7710'**
Lab ID:	Antero2H_V_7710
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

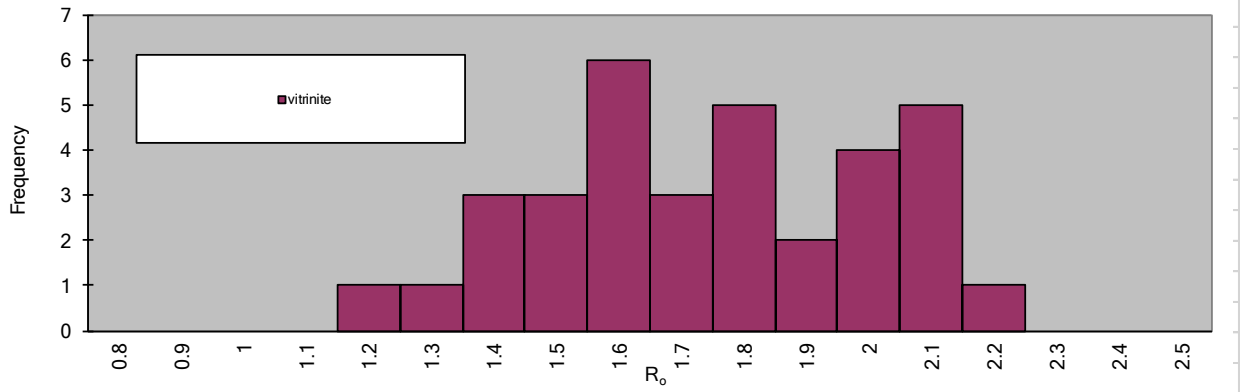
RESULTS

No. measurements:	34
maceral type:	bitumen
R_o:	1.79
s.d.:	0.27

Example Photograph:



Antero 2H Vertical 7710"



DATA

1.201	1.636	1.865	2.162
1.355	1.644	1.872	2.179
1.424	1.663	1.933	2.195
1.448	1.691	1.960	2.263
1.478	1.723	2.003	2.798
1.523	1.729	2.026	
1.542	1.781	2.070	
1.570	1.803	2.083	
1.606	1.817	2.105	
1.626	1.852	2.108	

All Data: **min:** 1.201 **max:** 2.798

Vitrinite Only: **min:** 1.201 **max:** 2.263 **V-types:** 11

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

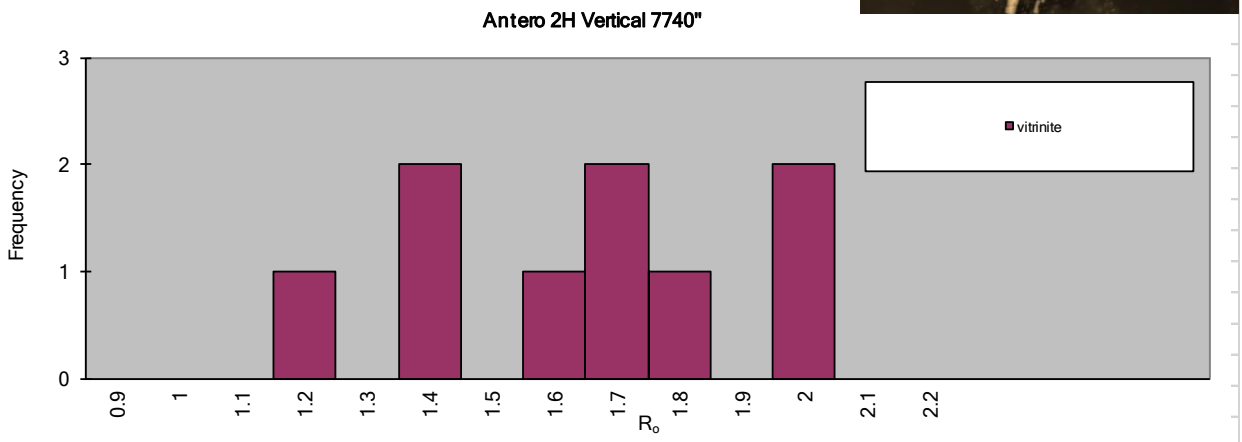
SAMPLE INFORMATION

Submitted by:	Michele Cooney
Date Submitted:	10/28/2018
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7740'**
Lab ID:	Antero2H_V_7740
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	9
maceral type:	bitumen
R_o:	1.69
s.d.:	0.27

Example Photograph:



DATA

1.238
1.407
1.477
1.636
1.705
1.740
1.846
2.042
2.099

All Data: **min:** 1.238 **max:** 2.099

Vitrinite Only: **min:** 1.238 **max:** 2.099 **V-types:** 9

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

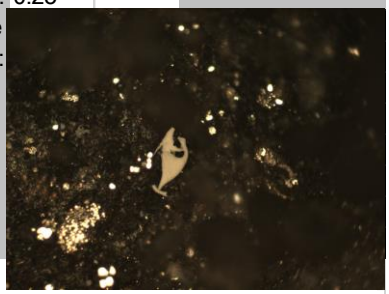
SAMPLE INFORMATION

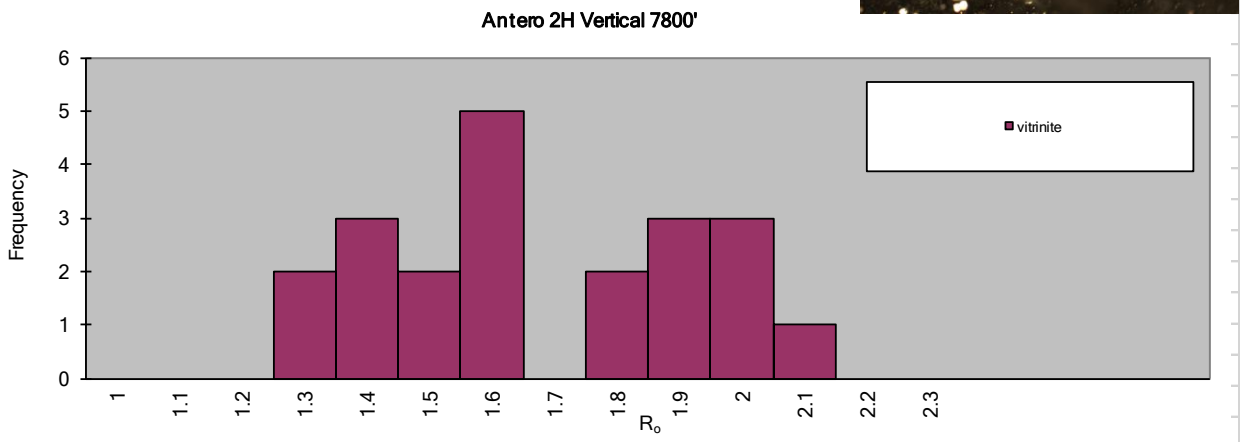
Submitted by:	Michele Cooney
Date Submitted:	10/27/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7800'**
Lab ID:	Antero2H_V_7800
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	21
maceral type:	bitumen
R_o:	1.73
s.d.:	0.25

Example Photograph:





DATA

1.344	1.659	2.195
1.390	1.686	
1.416	1.812	
1.461	1.843	
1.494	1.938	
1.506	1.977	
1.568	1.987	
1.641	2.024	
1.655	2.054	
1.655	2.077	

All Data: **min:** 1.344 **max:** 2.195

Vitrinite Only: **min:** 1.344 **max:** 2.195 **V-types:** 9

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

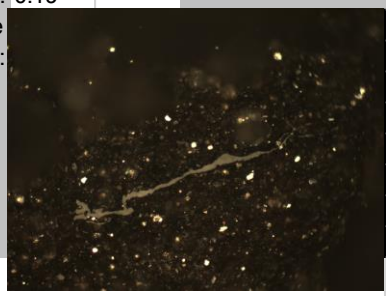
SAMPLE INFORMATION

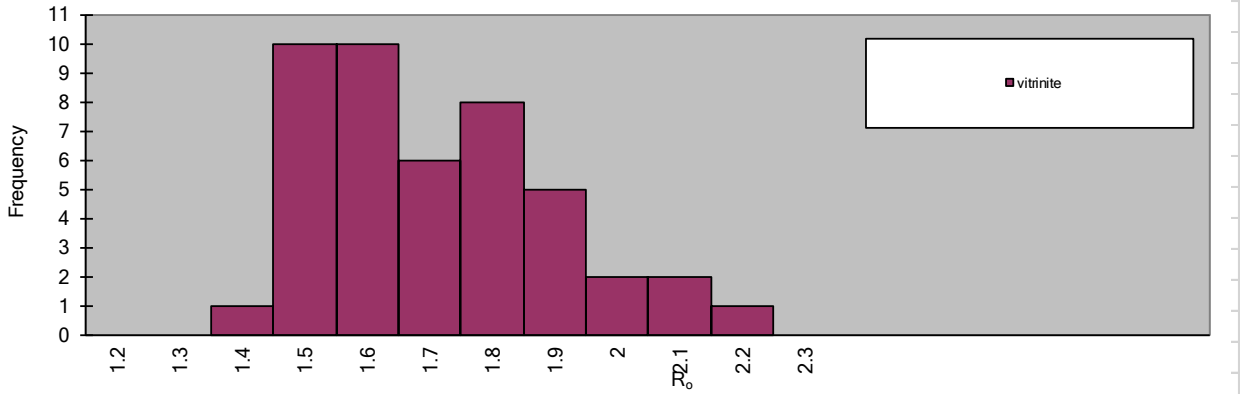
Submitted by:	Michele Cooney
Date Submitted:	11/6/2015
Project:	MRCSP
Sample ID:	**Antero 2H Vertical 7830'**
Lab ID:	Antero2H_V_7830
Sample Type:	shale plug
Date Analyzed:	2/12/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	45
maceral type:	bitumen
R_o:	1.75
s.d.:	0.19

Example Photograph:





DATA

1.497	1.592	1.699	1.840	2.021
1.507	1.601	1.703	1.863	2.024
1.507	1.611	1.717	1.866	2.121
1.517	1.619	1.726	1.870	2.146
1.524	1.622	1.745	1.898	2.201
1.528	1.622	1.763	1.908	
1.529	1.623	1.784	1.924	
1.544	1.624	1.808	1.952	
1.546	1.690	1.819	1.957	
1.591	1.696	1.821	1.971	

All Data: **min:** 1.497 **max:** 2.201

Vitrinite Only: **min:** 1.497 **max:** 2.201 **V-types:** 9

COMMENT

DIS+A1:L44PERSED VITRINITE REFLECTANCE REPORT

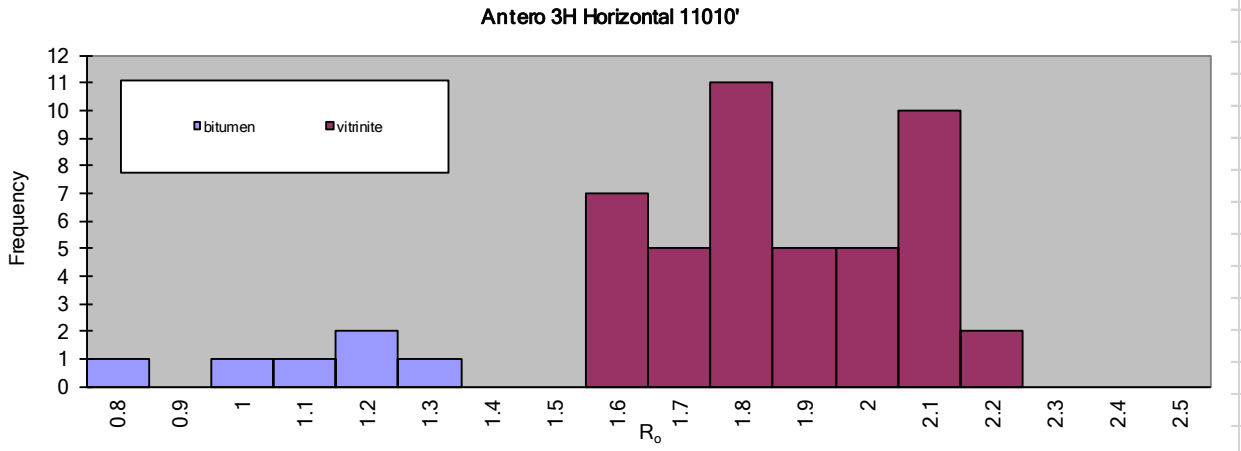
Run

SAMPLE INFORMATION

Submitted by:	Michele Cooney
Date Submitted:	2/5/2016
Project:	MRCSP
Sample ID:	**Antero 3H Horizontal 11010**
Lab ID:	Antero3H_H_11
Sample Type:	shale plug
Date Analyzed:	2/16/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	51
maceral type:	bitumen
R_o:	1.84
s.d.:	0.31
Example Photograph:	N/A



DATA

0.577	1.649	1.804	1.914	2.100	2.265
0.859	1.679	1.819	1.925	2.138	2.280
1.076	1.685	1.827	1.928	2.162	2.438
1.169	1.692	1.829	1.957	2.165	2.464
1.214	1.748	1.839	1.964	2.173	
1.264	1.781	1.867	2.013	2.176	
1.364	1.782	1.873	2.025	2.176	
1.613	1.793	1.876	2.041	2.177	
1.621	1.795	1.876	2.044	2.183	
1.646	1.801	1.891	2.061	2.196	

All Data: **min:** 0.577 **max:** 2.464

Vitrinite Only: **min:** 0.859 **max:** 2.280 **V-types:** 15

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

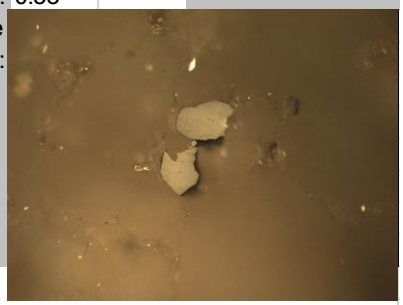
SAMPLE INFORMATION

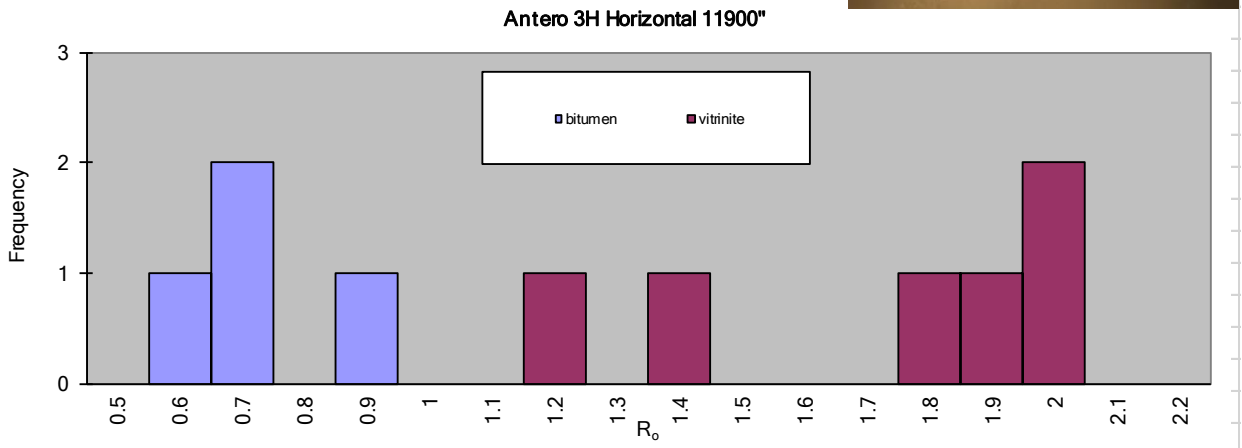
Submitted by:	Michele Cooney
Date Submitted:	2/8/2016
Project:	MRCSP
Sample ID:	**Antero 3H Horizontal 11900'**
Lab ID:	Antero3H_H_11
Sample Type:	shale plug
Date Analyzed:	2/16/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	10
maceral type:	bitumen
R_o:	1.37
s.d.:	0.55

Example Photograph:





DATA

0.611	2.724
0.735	2.815
0.782	2.829
0.974	2.881
1.208	
1.443	
1.838	
1.980	
2.042	
2.046	

All Data: **min:** 0.611 **max:** 2.881

Vitrinite Only: **min:** 0.611 **max:** 2.046 **V-types:** 15

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

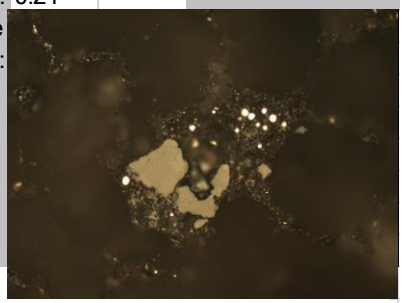
SAMPLE INFORMATION

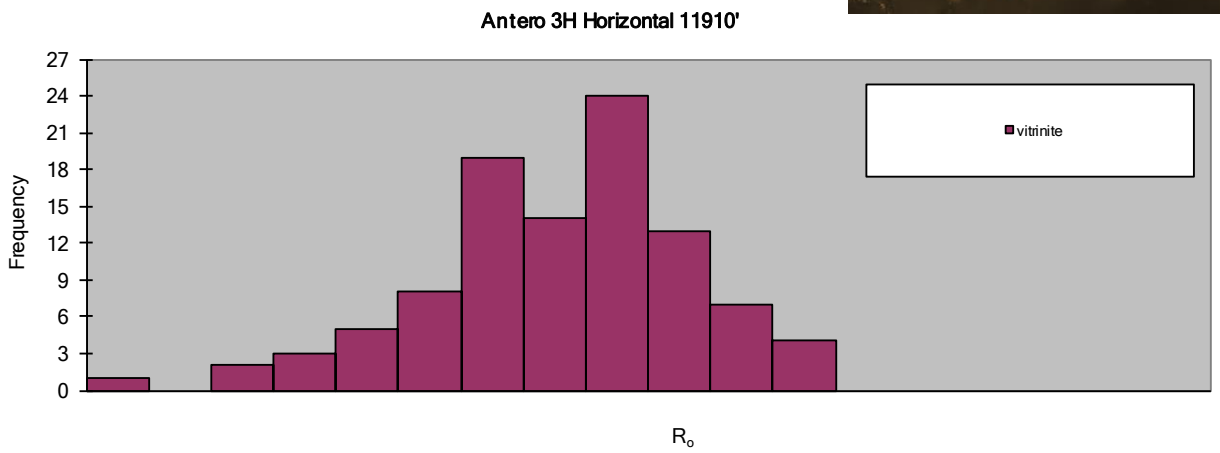
Submitted by:	Michele Cooney
Date Submitted:	2/9/2016
Project:	MRCSP
Sample ID:	**Antero 3H Horizontal 11910'**
Lab ID:	Antero 3H_H_1
Sample Type:	shale plug
Date Analyzed:	2/16/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	100
maceral type:	bitumen
R_o:	2.06
s.d.:	0.21

Example Photograph:





DATA

0.503	1.773	1.900	1.953	2.009	2.093	2.141	2.167	2.216	2.302
1.397	1.792	1.904	1.954	2.015	2.096	2.142	2.174	2.229	2.322
1.546	1.803	1.922	1.959	2.021	2.099	2.145	2.176	2.231	2.328
1.572	1.809	1.932	1.963	2.031	2.101	2.156	2.178	2.232	2.371
1.614	1.848	1.935	1.979	2.048	2.110	2.156	2.186	2.232	2.373
1.652	1.859	1.935	1.980	2.051	2.112	2.159	2.187	2.240	2.389
1.697	1.863	1.936	1.983	2.056	2.128	2.159	2.198	2.243	2.391
1.750	1.876	1.940	1.996	2.061	2.132	2.160	2.201	2.249	2.405
1.756	1.885	1.945	1.997	2.062	2.134	2.164	2.203	2.253	2.415
1.766	1.893	1.948	2.003	2.078	2.135	2.166	2.204	2.289	2.432

All Data: **min:** 0.503 **max:** 2.432

Vitrinite Only: **min:** 1.397 **max:** 2.466 **V-types:** 12

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

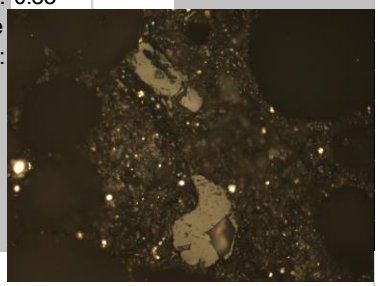
SAMPLE INFORMATION

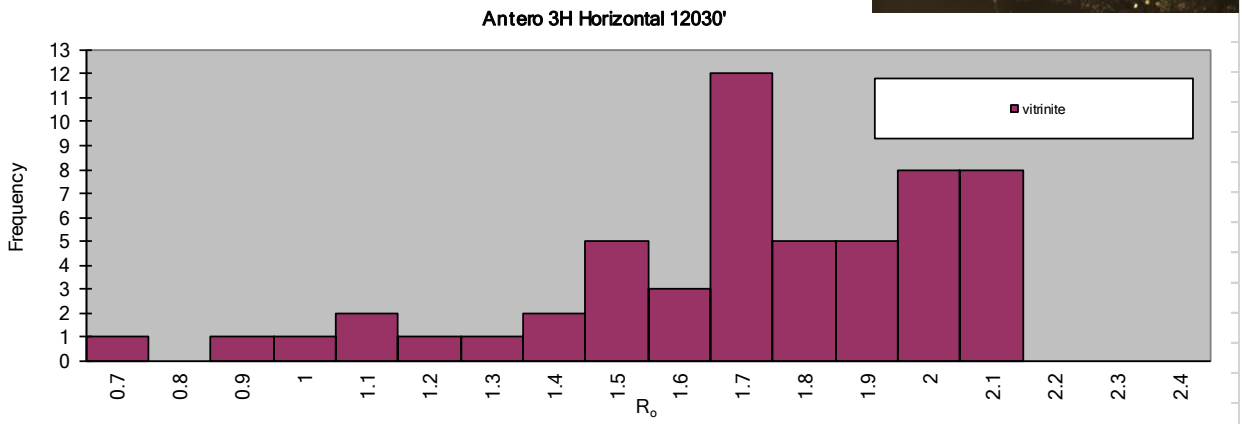
Submitted by:	Michele Cooney
Date Submitted:	2/9/2016
Project:	MRCSP
Sample ID:	**Antero 3H Horizontal 12030'**
Lab ID:	Antero3H_H_12030
Sample Type:	shale plug
Date Analyzed:	2/16/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	55
maceral type:	bitumen
R_o:	1.77
s.d.:	0.33

Example Photograph:





DATA

0.789	1.527	1.739	1.844	2.014	2.158
0.924	1.557	1.752	1.873	2.026	2.160
1.049	1.558	1.761	1.886	2.037	2.161
1.140	1.581	1.764	1.898	2.087	2.186
1.160	1.603	1.774	1.904	2.089	2.190
1.299	1.641	1.774	1.928	2.089	2.430
1.374	1.664	1.775	1.976	2.096	
1.433	1.704	1.786	1.979	2.104	
1.462	1.722	1.798	1.980	2.117	
1.517	1.735	1.809	2.005	2.118	

All Data: **min:** 0.789 **max:** 2.430

Vitrinite Only: **min:** 0.789 **max:** 2.190 **V-types:** 15

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

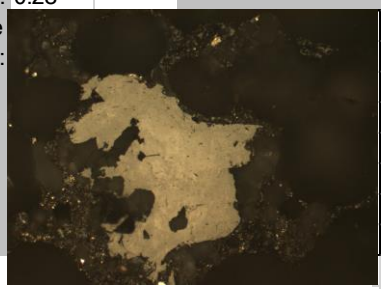
SAMPLE INFORMATION

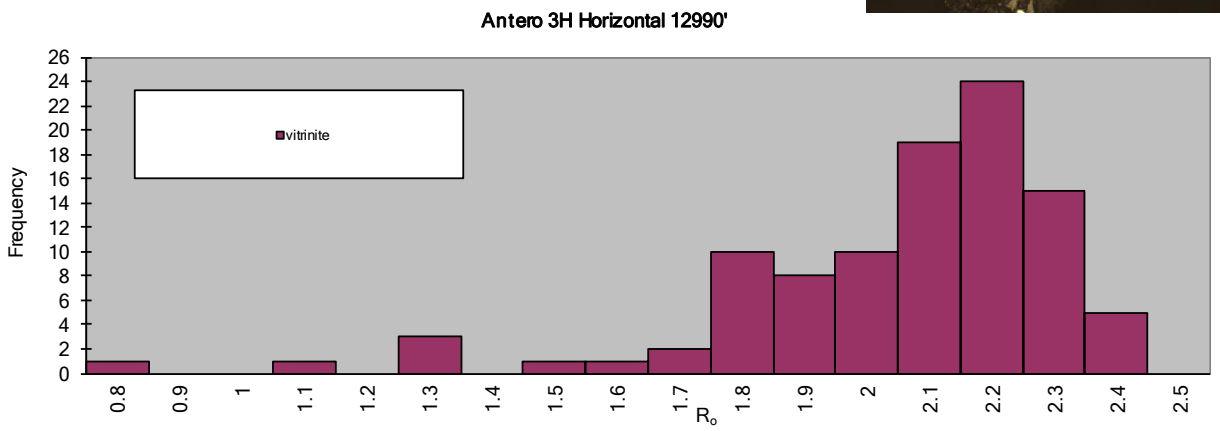
Submitted by:	Michele Cooney
Date Submitted:	2/9/2016
Project:	MRCSP
Sample ID:	**Antero 3H Horizontal 12990'**
Lab ID:	Antero3H_H_12990
Sample Type:	shale plug
Date Analyzed:	2/16/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	127
maceral type:	bitumen
R_o:	2.22
s.d.:	0.28

Example Photograph:





DATA

0.886	1.838	1.924	2.048	2.123	2.177	2.225	2.274	2.303	2.381
1.193	1.872	1.924	2.056	2.133	2.187	2.226	2.276	2.306	2.382
1.310	1.876	1.929	2.063	2.135	2.190	2.235	2.278	2.309	2.392
1.378	1.881	1.975	2.065	2.138	2.195	2.242	2.280	2.318	2.394
1.389	1.883	1.980	2.070	2.150	2.197	2.245	2.281	2.326	2.398
1.526	1.883	1.980	2.075	2.156	2.199	2.245	2.286	2.337	2.437
1.681	1.895	1.991	2.079	2.161	2.210	2.248	2.286	2.343	2.451
1.708	1.897	2.037	2.101	2.166	2.213	2.251	2.287	2.361	2.458
1.784	1.897	2.038	2.109	2.170	2.215	2.254	2.292	2.377	2.462
1.832	1.914	2.042	2.116	2.173	2.221	2.257	2.296	2.381	2.466

All Data: **min:** 0.886 **max:** 2.466

Vitrinite Only: **min:** 0.886 **max:** 2.466 **V-types:** 17

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

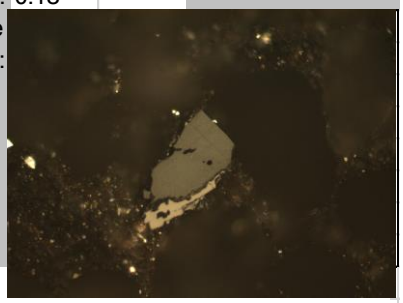
SAMPLE INFORMATION

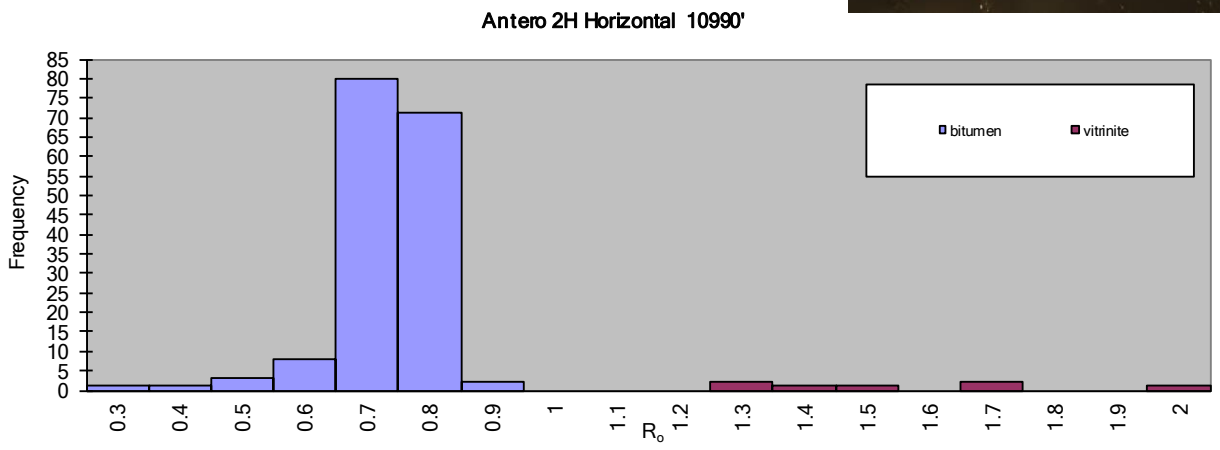
Submitted by:	Michele Cooney
Date Submitted:	1/25/2016
Project:	MRCSP
Sample ID:	**Antero 3H Verticla 7490'**
Lab ID:	Antero3H_V_74
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	173
maceral type:	bitumen
R_o:	0.81
s.d.:	0.18

Example Photograph:





DATA

0.363	0.695	0.720	0.732	0.747	0.759	0.771	0.786	0.791	0.798
0.451	0.696	0.722	0.733	0.748	0.760	0.772	0.787	0.792	0.798
0.511	0.698	0.723	0.736	0.749	0.763	0.772	0.787	0.792	0.798
0.548	0.702	0.725	0.737	0.751	0.763	0.772	0.788	0.792	0.801
0.555	0.712	0.726	0.737	0.753	0.766	0.775	0.788	0.795	0.801
0.613	0.715	0.728	0.738	0.755	0.767	0.778	0.788	0.795	0.801
0.616	0.717	0.728	0.740	0.756	0.769	0.779	0.789	0.796	0.802
0.645	0.719	0.730	0.740	0.757	0.769	0.780	0.790	0.796	0.804
0.692	0.720	0.730	0.740	0.757	0.769	0.782	0.790	0.797	0.805
0.694	0.720	0.732	0.742	0.757	0.769	0.785	0.790	0.798	0.807

All Data: **min:** 0.363 **max:** 0.807

Vitrinite Only: **min:** 0.363 **max:** 0.807 **V-types:** 6

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

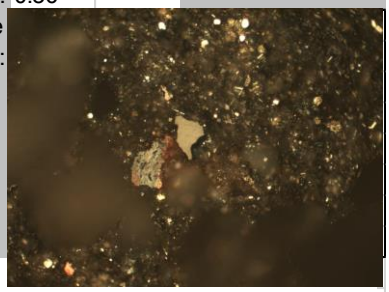
SAMPLE INFORMATION

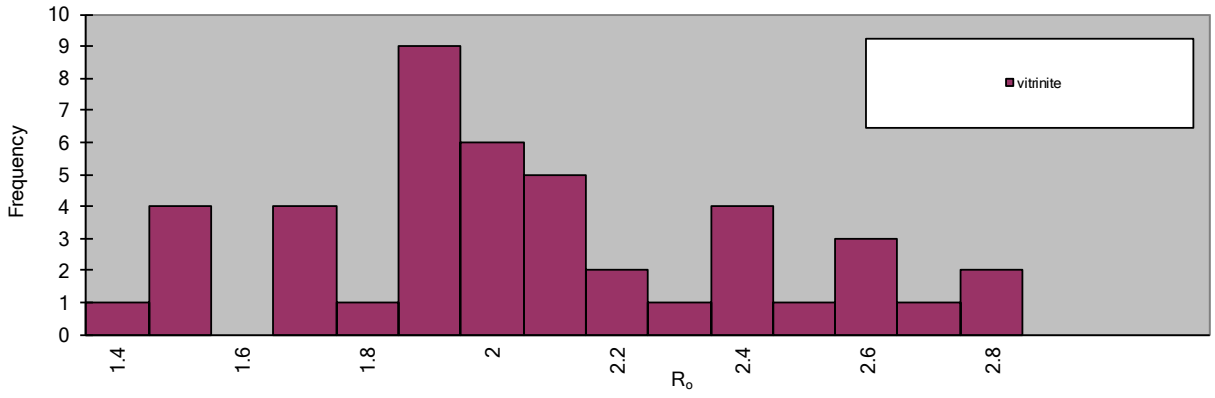
Submitted by:	Michele Cooney
Date Submitted:	1/26/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7520'**
Lab ID:	Antero3H_V_7520'
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	44
maceral type:	bitumen
R_o:	2.11
s.d.:	0.36

Example Photograph:





DATA

1.417	1.928	2.014	2.235	2.696
1.503	1.930	2.032	2.293	2.723
1.534	1.930	2.036	2.385	2.827
1.559	1.943	2.060	2.417	2.861
1.598	1.951	2.094	2.449	
1.740	1.961	2.137	2.469	
1.771	1.962	2.138	2.480	
1.785	1.966	2.147	2.507	
1.798	1.981	2.179	2.614	
1.829	2.003	2.190	2.676	

All Data: **min:** 1.417 **max:** 2.861

Vitrinite Only: **min:** 1.417 **max:** 2.861 **V-types:** 15

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

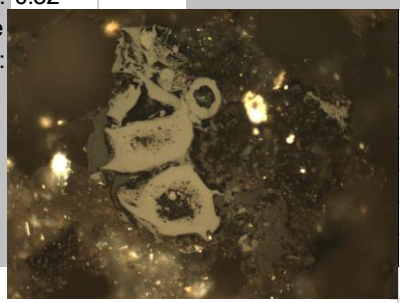
SAMPLE INFORMATION

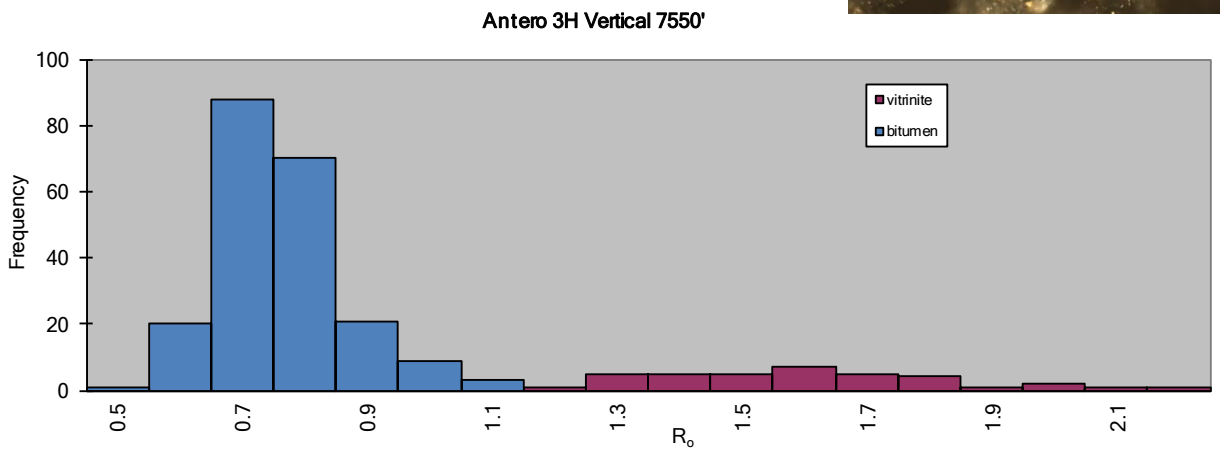
Submitted by:	Michele Cooney
Date Submitted:	1/27/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7550'**
Lab ID:	Antero2H_V_75
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	249
maceral type:	bitumen
R_o:	0.94
s.d.:	0.32

Example Photograph:





DATA

0.590	0.681	0.696	0.720	0.738	0.752	0.766	0.774	0.780	0.786
0.639	0.690	0.702	0.722	0.741	0.754	0.767	0.774	0.781	0.787
0.641	0.691	0.703	0.724	0.742	0.754	0.768	0.775	0.782	0.787
0.651	0.691	0.708	0.727	0.744	0.755	0.770	0.777	0.783	0.788
0.664	0.692	0.709	0.729	0.745	0.757	0.771	0.777	0.783	0.788
0.664	0.694	0.711	0.730	0.747	0.760	0.772	0.777	0.784	0.788
0.672	0.695	0.711	0.731	0.748	0.761	0.773	0.777	0.784	0.790
0.674	0.696	0.716	0.731	0.749	0.762	0.773	0.778	0.785	0.790
0.675	0.696	0.718	0.734	0.750	0.763	0.773	0.780	0.785	0.790
0.679	0.696	0.719	0.735	0.750	0.765	0.774	0.780	0.785	0.790

All Data: **min:** 0.590 **max:** 0.790

Vitrinite Only: **min:** 0.590 **max:** 0.790 **V-types:** 3

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

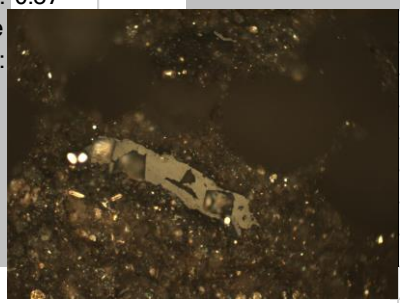
SAMPLE INFORMATION

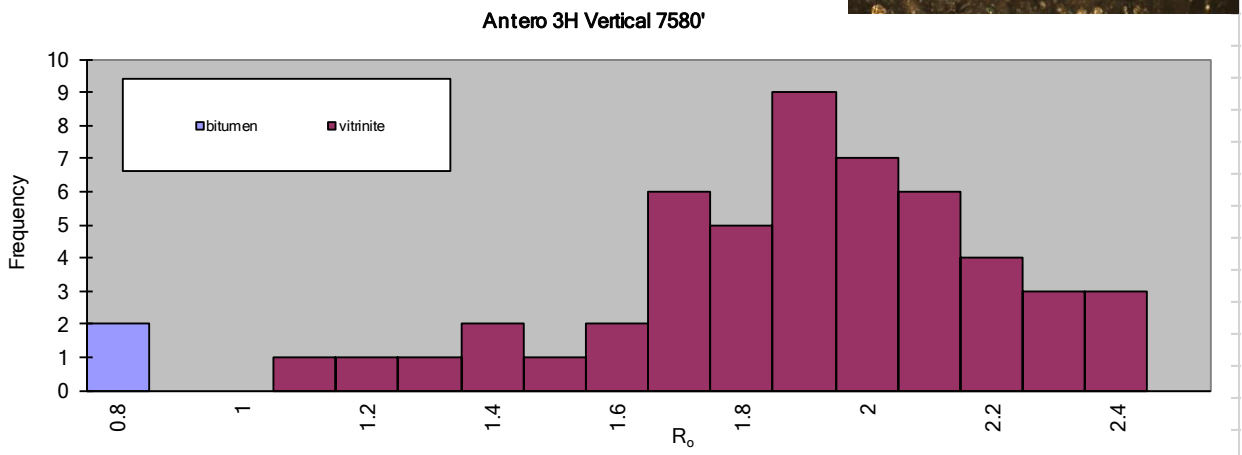
Submitted by:	Michele Cooney
Date Submitted:	1/27/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7580'**
Lab ID:	Antero3H_V_75
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	53
maceral type:	bitumen
R_o:	1.91
s.d.:	0.37

Example Photograph:





DATA

0.819	1.728	1.882	2.007	2.123	2.469
0.845	1.733	1.915	2.025	2.123	2.477
1.170	1.742	1.931	2.037	2.165	2.486
1.210	1.751	1.941	2.054	2.201	
1.316	1.760	1.957	2.070	2.202	
1.417	1.786	1.959	2.090	2.265	
1.420	1.834	1.972	2.090	2.282	
1.595	1.853	1.982	2.101	2.364	
1.636	1.861	1.982	2.101	2.368	
1.695	1.878	1.995	2.110	2.394	

All Data: **min:** 0.819 **max:** 2.486

Vitrinite Only: **min:** 0.819 **max:** 2.486 **V-types:** 17

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

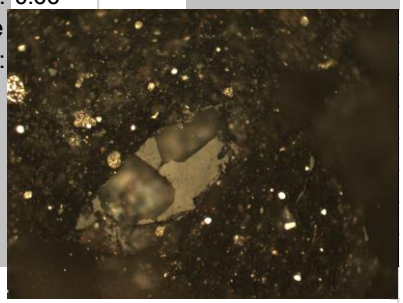
SAMPLE INFORMATION

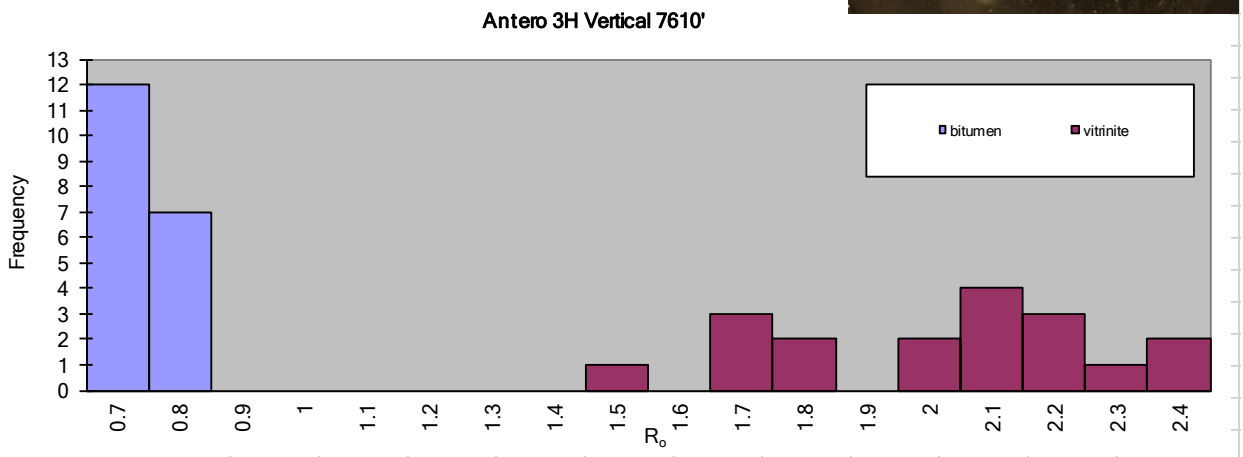
Submitted by:	Michele Cooney
Date Submitted:	1/29/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7610'**
Lab ID:	Antero3H_V_76
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	37
maceral type:	vitrinite
R_o:	1.41
s.d.:	0.66

Example Photograph:





DATA

0.723	0.793	1.706	2.168
0.730	0.795	1.760	2.216
0.737	0.807	1.764	2.235
0.738	0.824	1.852	2.241
0.756	0.833	1.878	2.381
0.770	0.838	2.044	2.429
0.773	0.849	2.094	2.487
0.778	0.877	2.104	2.727
0.785	0.882	2.109	
0.787	1.502	2.166	

All Data: min: 0.723 max: 2.727

Vitrinite Only: min: 0.723 max: 2.487 V-types: 18

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

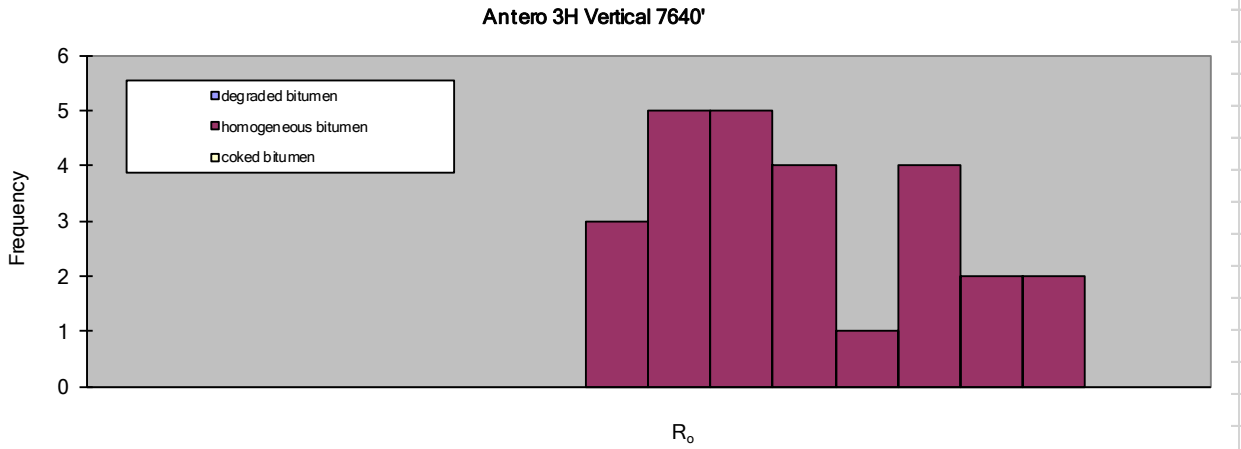
Run

SAMPLE INFORMATION

Submitted by:	Michele Cooney
Date Submitted:	1/29/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7640'**
Lab ID:	Antero3H_V_76
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	26
maceral type:	bitumen
R_o:	1.95
s.d.:	0.21
Example Photograph:	N/A



DATA

1.626	1.866	2.161
1.644	1.873	2.185
1.683	1.888	2.229
1.740	1.923	2.280
1.764	1.949	2.348
1.775	1.951	2.377
1.782	1.983	2.547
1.794	2.031	2.623
1.837	2.125	
1.853	2.130	

All Data: min: 1.626 max: 2.623

Vitrinite Only: min: 1.626 max: 2.377 V-types: 8

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

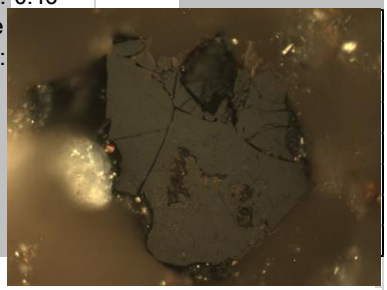
SAMPLE INFORMATION

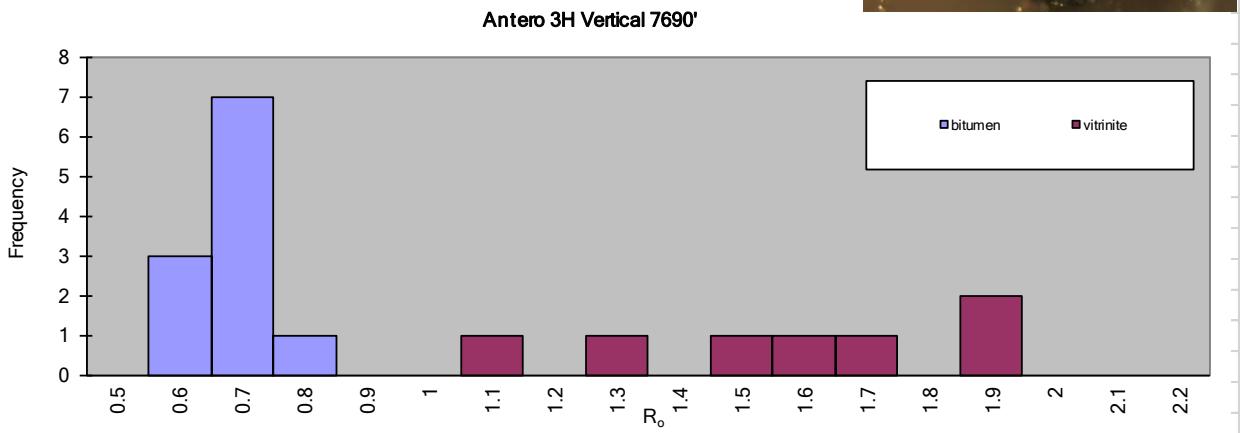
Submitted by:	Michele Cooney
Date Submitted:	2/2/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7690**
Lab ID:	Antero3H_V_7690
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	18
maceral type:	bitumen
R_o:	1.08
s.d.:	0.46

Example Photograph:





DATA

0.681	0.800
0.695	1.146
0.696	1.383
0.725	1.516
0.741	1.622
0.742	1.716
0.744	1.959
0.754	1.962
0.765	
0.788	

All Data: **min:** 0.681 **max:** 1.962

Vitrinite Only: **min:** 0.681 **max:** 1.962 **V-types:** 14

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

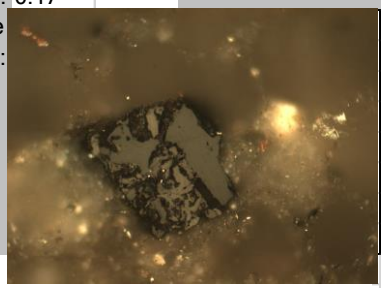
SAMPLE INFORMATION

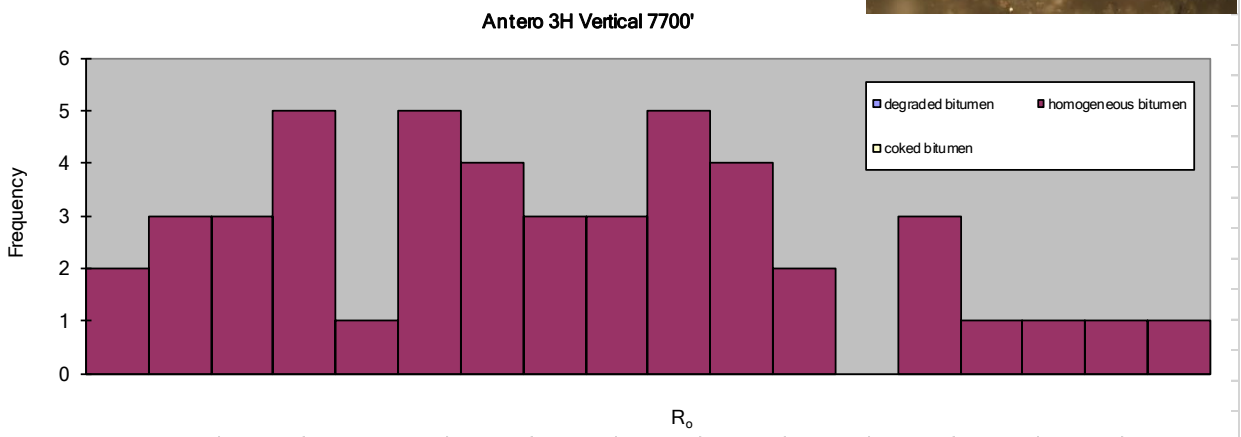
Submitted by:	Michele Cooney
Date Submitted:	2/2/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7700'**
Lab ID:	Antero3H_V_7700
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	50
maceral type:	bitumen
R_o:	1.50
s.d.:	0.47

Example Photograph:





DATA

0.759	1.067	1.351	1.648	1.880	2.851					
0.785	1.082	1.388	1.653	2.059						
0.820	1.082	1.391	1.658	2.074						
0.836	1.115	1.413	1.663	2.076						
0.850	1.215	1.428	1.722	2.192						
0.903	1.254	1.462	1.727	2.283						
0.946	1.259	1.555	1.762	2.305						
0.959	1.265	1.559	1.779	2.321						
1.046	1.270	1.576	1.817	2.405						
1.058	1.337	1.628	1.824	2.534						

All Data: **min:** 0.759 **max:** 2.851

Vitrinite Only: **min:** 0.759 **max:** 2.534 **V-types:** 19

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

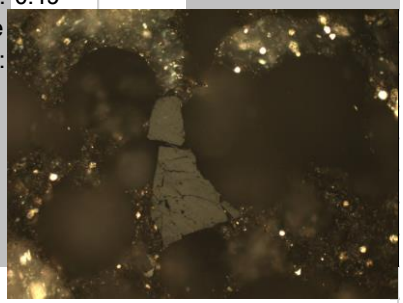
SAMPLE INFORMATION

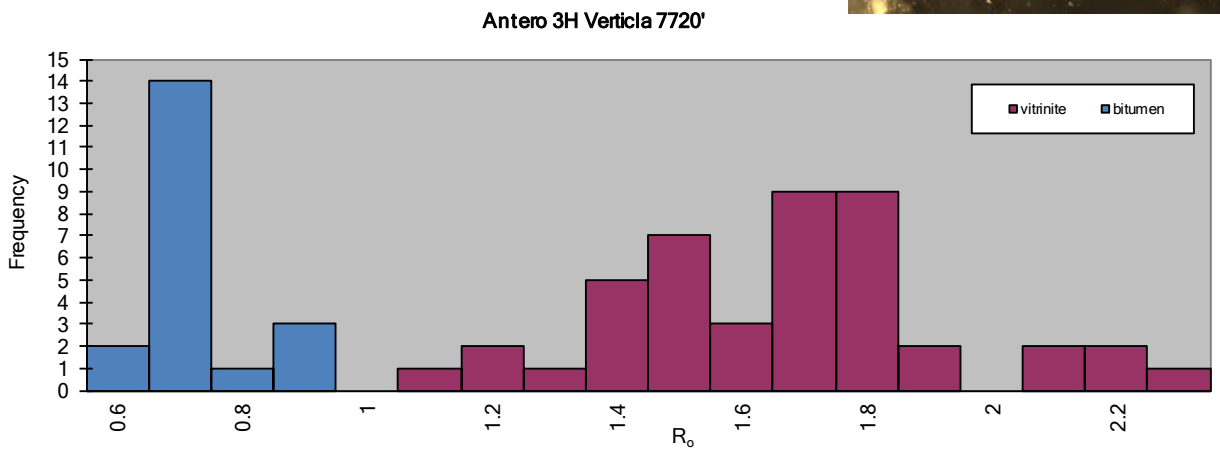
Submitted by:	Michele Cooney
Date Submitted:	2/2/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7720'**
Lab ID:	Antero3H_V_77
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	64
maceral type:	bitumen
R_o:	1.43
s.d.:	0.49

Example Photograph:





DATA

0.388	0.760	0.976	1.503	1.712	1.810	2.108
0.648	0.769	1.130	1.531	1.716	1.812	2.140
0.668	0.772	1.248	1.548	1.743	1.841	2.235
0.700	0.777	1.256	1.549	1.767	1.851	2.281
0.702	0.778	1.366	1.558	1.767	1.856	2.313
0.726	0.780	1.430	1.584	1.784	1.874	
0.733	0.795	1.474	1.592	1.786	1.882	
0.741	0.819	1.484	1.614	1.792	1.890	
0.747	0.922	1.487	1.694	1.797	1.946	
0.757	0.943	1.493	1.696	1.802	1.976	

All Data: **min:** 0.388 **max:** 2.313

Vitrinite Only: **min:** 0.648 **max:** 2.313 **V-types:** 18

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

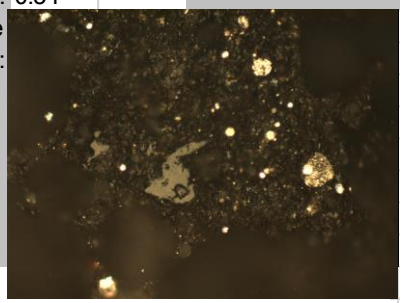
SAMPLE INFORMATION

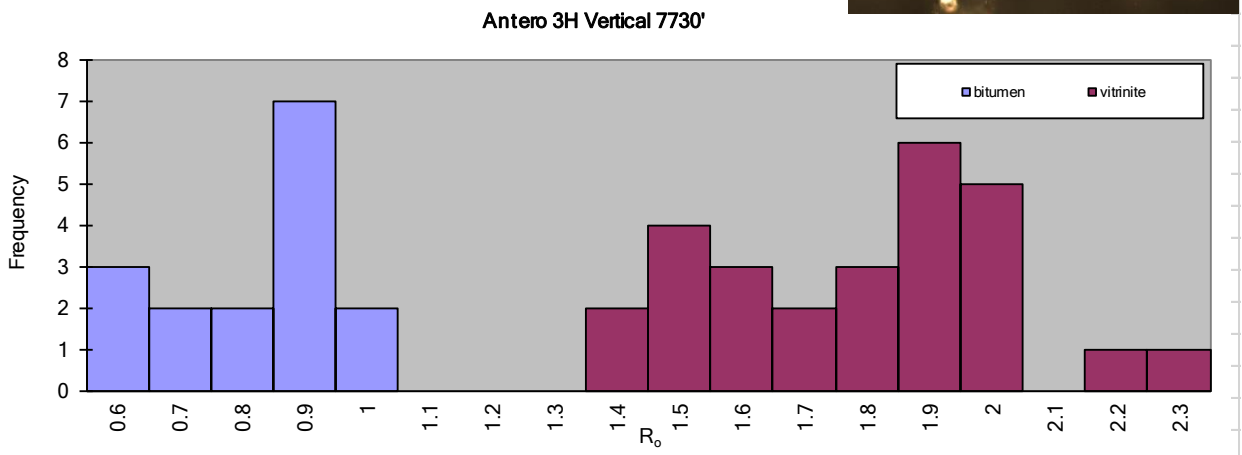
Submitted by:	Michele Cooney
Date Submitted:	2/3/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7730'**
Lab ID:	Antero3H_V_77
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	45
maceral type:	bitumen
R_o:	1.51
s.d.:	0.54

Example Photograph:





DATA

0.660	0.910	1.589	1.917	2.067
0.668	0.920	1.594	1.935	2.263
0.669	0.943	1.627	1.936	2.303
0.709	0.945	1.676	1.946	2.424
0.751	1.004	1.681	1.968	2.436
0.868	1.005	1.716	1.969	2.652
0.888	1.408	1.777	2.003	
0.905	1.497	1.843	2.036	
0.905	1.537	1.854	2.042	
0.907	1.540	1.857	2.043	

All Data: **min:** 0.660 **max:** 2.652

Vitrinite Only: **min:** 0.660 **max:** 2.436 **V-types:** 19

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

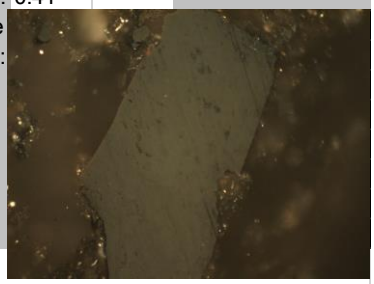
SAMPLE INFORMATION

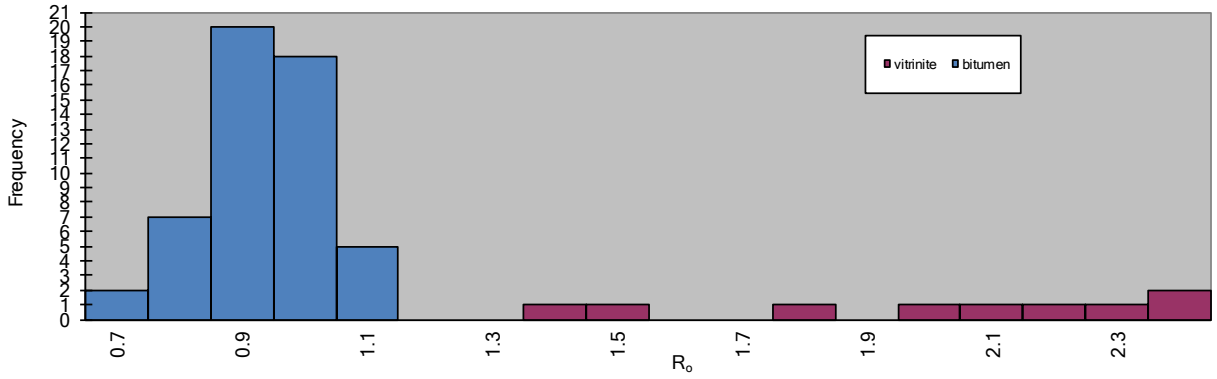
Submitted by:	Michele Cooney
Date Submitted:	2//2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7740'**
Lab ID:	Antero3H_V_7740
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	61
maceral type:	bitumen
R_o:	1.14
s.d.:	0.41

Example Photograph:





DATA

0.763	0.908	0.964	1.007	1.061	1.114	2.495
0.790	0.913	0.971	1.008	1.062	1.117	
0.807	0.915	0.972	1.008	1.070	1.480	
0.833	0.929	0.982	1.018	1.076	1.509	
0.884	0.939	0.986	1.019	1.084	1.841	
0.886	0.949	0.994	1.026	1.085	2.092	
0.890	0.951	0.997	1.037	1.091	2.128	
0.891	0.951	0.997	1.041	1.104	2.210	
0.892	0.951	0.998	1.048	1.108	2.338	
0.907	0.953	1.002	1.059	1.109	2.442	

All Data: **min:** 0.763 **max:** 2.495

Vitrinite Only: **min:** 0.763 **max:** 2.495 **V-types:** 18

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

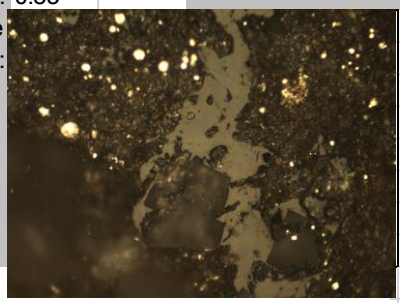
SAMPLE INFORMATION

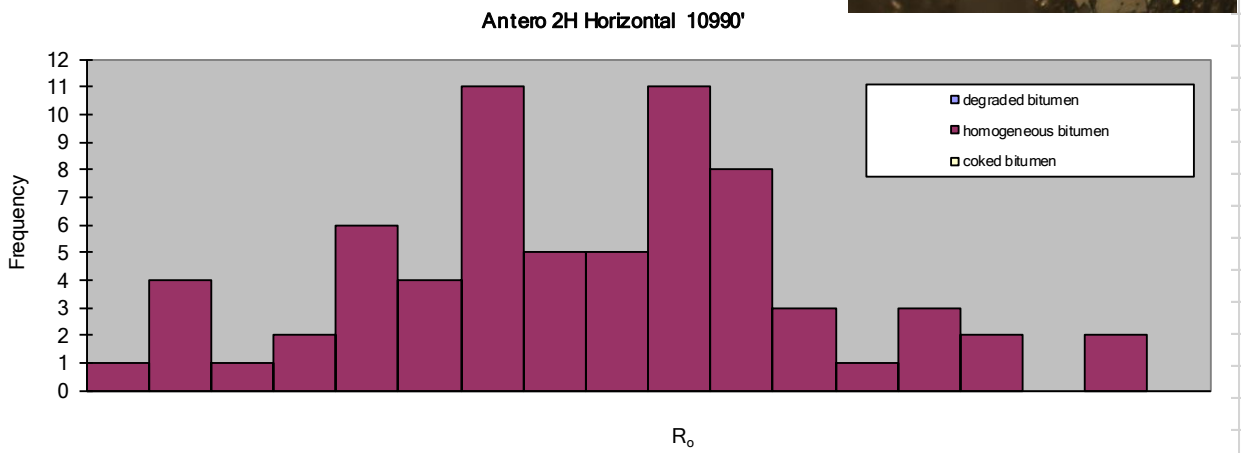
Submitted by:	Michele Cooney
Date Submitted:	2/3/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7760**
Lab ID:	Antero3H_V_77
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	69
maceral type:	bitumen
R_o:	1.40
s.d.:	0.35

Example Photograph:





DATA

0.661	1.038	1.238	1.376	1.526	1.611	1.760
0.733	1.050	1.241	1.388	1.527	1.620	1.809
0.745	1.058	1.244	1.390	1.535	1.634	1.952
0.746	1.061	1.255	1.392	1.545	1.636	1.968
0.794	1.125	1.270	1.401	1.545	1.643	1.977
0.807	1.126	1.277	1.416	1.550	1.665	2.044
0.959	1.148	1.281	1.419	1.559	1.674	2.056
0.988	1.174	1.288	1.440	1.575	1.680	2.209
1.021	1.207	1.297	1.456	1.592	1.705	2.209
1.033	1.230	1.344	1.508	1.593	1.707	

All Data: **min:** 0.661 **max:** 2.209

Vitrinite Only: **min:** 0.661 **max:** 2.209 **V-types:** 17

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

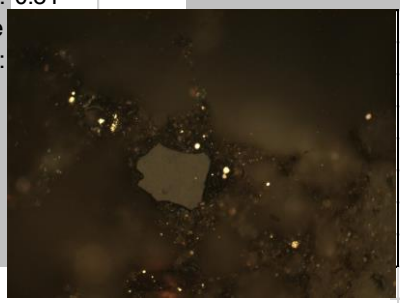
SAMPLE INFORMATION

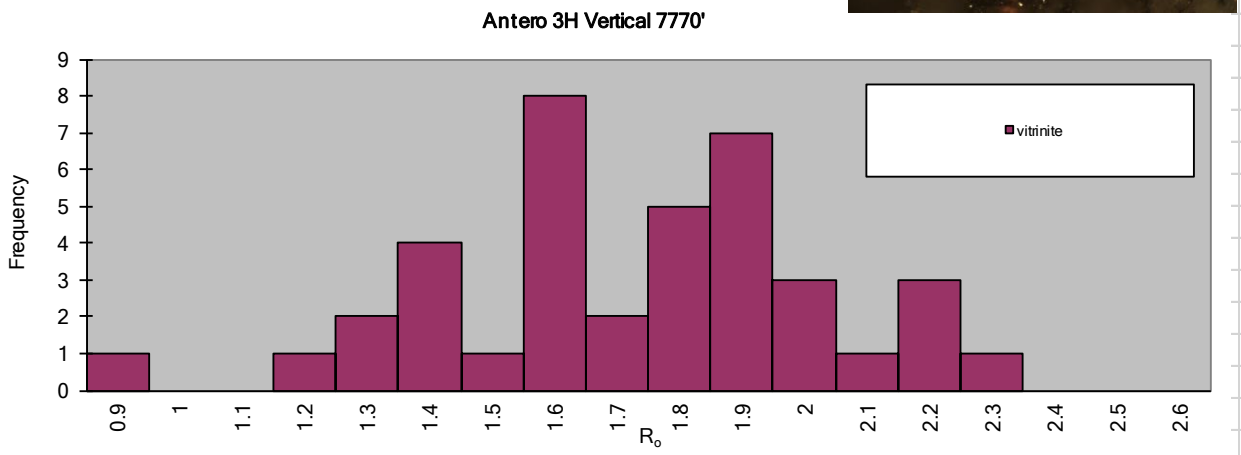
Submitted by:	Michele Cooney
Date Submitted:	2/3/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vetical 7770'**
Lab ID:	Antero3H_V_77
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	39
maceral type:	bitumen
R_o:	1.78
s.d.:	0.31

Example Photograph:





DATA

0.978	1.606	1.849	1.997
1.260	1.607	1.864	2.060
1.347	1.643	1.891	2.093
1.360	1.662	1.897	2.098
1.405	1.678	1.908	2.186
1.417	1.689	1.934	2.220
1.426	1.694	1.947	2.256
1.471	1.702	1.961	2.265
1.582	1.727	1.985	2.315
1.600	1.805	1.995	

All Data: **min:** 0.978 **max:** 2.315

Vitrinite Only: **min:** 0.978 **max:** 2.315 **V-types:** 15

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

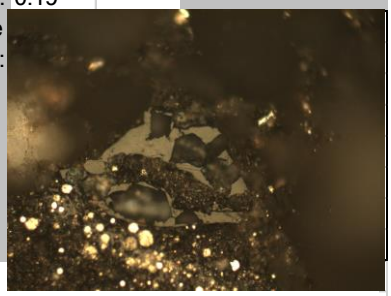
SAMPLE INFORMATION

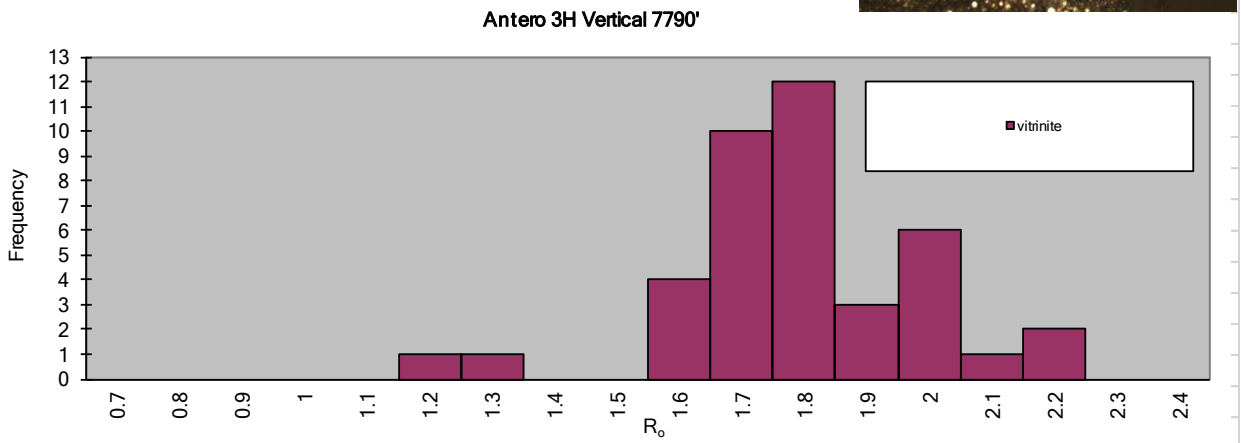
Submitted by:	Michele Cooney
Date Submitted:	2/4/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7790'**
Lab ID:	Antero3H_V_7790
Sample Type:	shale plug
Date Analyzed:	3/17/2016
Operator:	Antero Resources
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	40
maceral type:	bitumen
R_o:	1.84
s.d.:	0.19

Example Photograph:





DATA

0.700	1.726	1.830	1.891	2.128
0.886	1.737	1.844	1.900	2.203
0.962	1.746	1.850	1.932	2.213
1.272	1.752	1.853	1.964	2.623
1.334	1.753	1.854	2.003	
1.608	1.754	1.865	2.018	
1.666	1.758	1.868	2.039	
1.691	1.785	1.868	2.041	
1.694	1.786	1.872	2.088	
1.710	1.825	1.889	2.096	

All Data: **min:** 0.700 **max:** 2.623

Vitrinite Only: **min:** 1.272 **max:** 2.213 **V-types:** 11

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

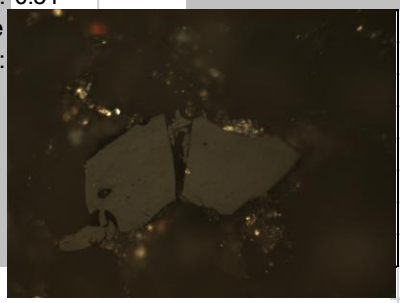
SAMPLE INFORMATION

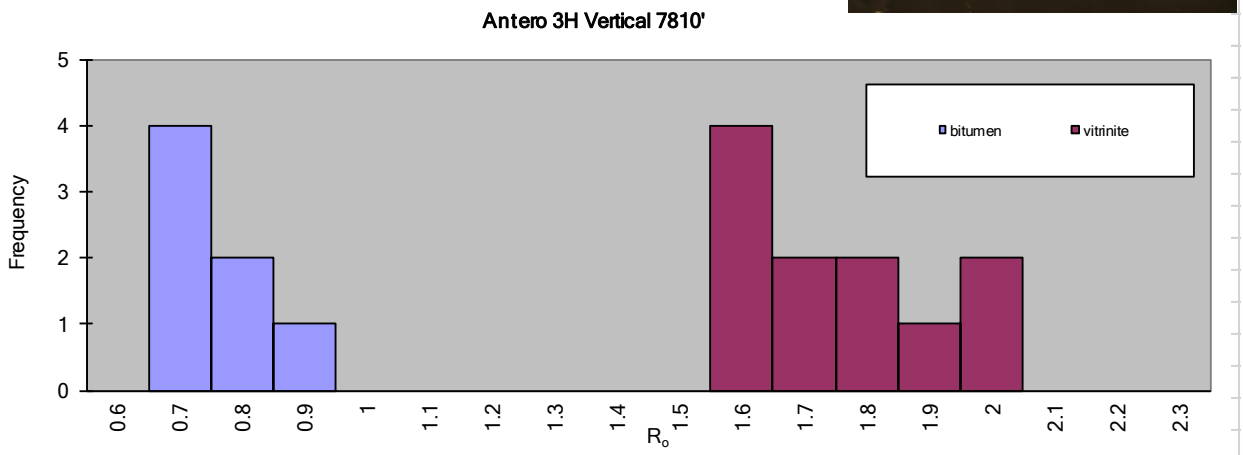
Submitted by:	Michele Cooney
Date Submitted:	2/5/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7810'**
Lab ID:	Antero3H_V_78
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	18
maceral type:	bitumen
R_o:	1.42
s.d.:	0.51

Example Photograph:





DATA

0.731	1.689
0.740	1.743
0.761	1.775
0.776	1.861
0.824	1.876
0.897	1.930
0.906	2.017
1.604	2.094
1.653	
1.657	

All Data: **min:** 0.731 **max:** 2.094

Vitrinite Only: **min:** 0.731 **max:** 2.094 **V-types:** 14

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

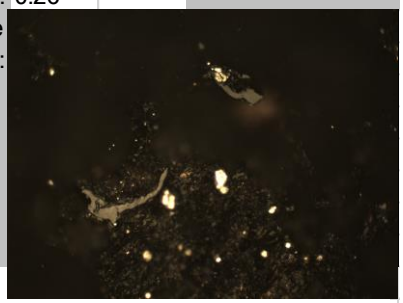
SAMPLE INFORMATION

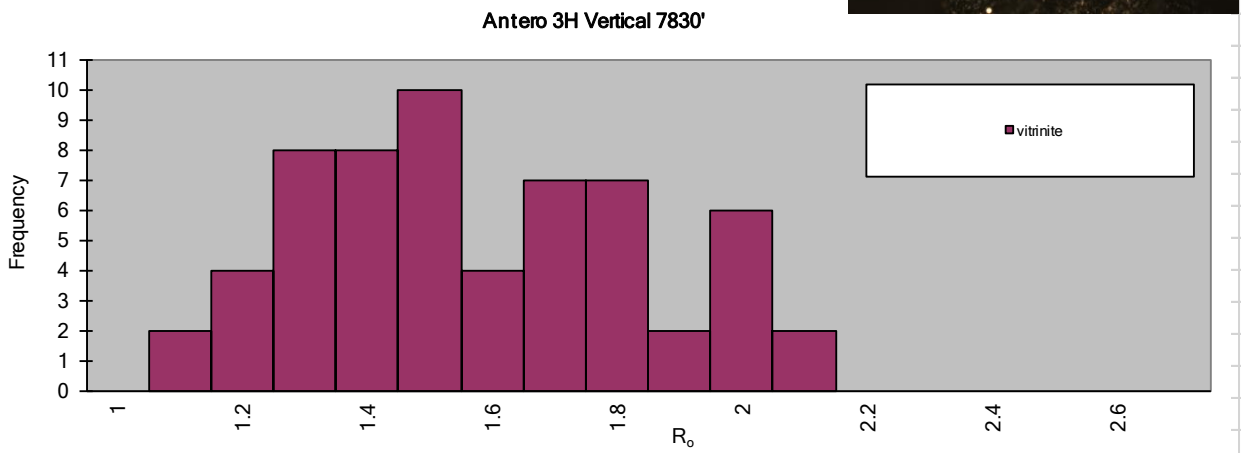
Submitted by:	Michele Cooney
Date Submitted:	10/19/2015
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7830'**
Lab ID:	Antero3H_V_78
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	60
maceral type:	bitumen
R_o:	1.62
s.d.:	0.26

Example Photograph:





DATA

1.168	1.338	1.484	1.577	1.783	1.918
1.198	1.348	1.494	1.591	1.794	1.989
1.224	1.351	1.502	1.630	1.799	2.001
1.243	1.395	1.506	1.630	1.808	2.001
1.265	1.414	1.510	1.653	1.813	2.002
1.286	1.421	1.513	1.671	1.837	2.006
1.309	1.423	1.517	1.708	1.845	2.029
1.316	1.425	1.542	1.740	1.869	2.048
1.333	1.428	1.553	1.774	1.886	2.152
1.337	1.473	1.557	1.776	1.895	2.164

All Data: **min:** 1.168 **max:** 2.164

Vitrinite Only: **min:** 1.168 **max:** 2.164 **V-types:** 11

COMMENT

DISPERSED VITRINITE REFLECTANCE REPORT

Run

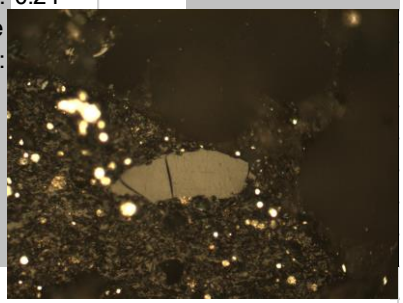
SAMPLE INFORMATION

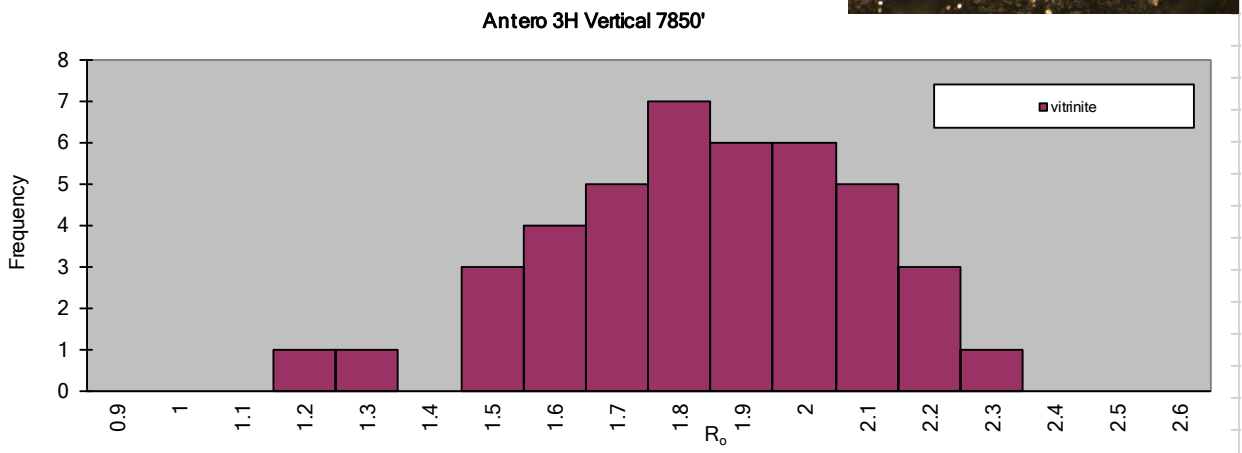
Submitted by:	Michele Cooney
Date Submitted:	2/5/2016
Project:	MRCSP
Sample ID:	**Antero 3H Vertical 7850'**
Lab ID:	Antero3H_V_78
Sample Type:	shale plug
Date Analyzed:	2/17/2016
Operator:	Antero Resourc
Standard:	ASTM D2798 7708

RESULTS

No. measurements:	42
maceral type:	bitumen
R_o:	1.89
s.d.:	0.24

Example Photograph:





DATA

1.220	1.732	1.891	2.054	2.261						
1.345	1.787	1.903	2.059	2.309						
1.524	1.789	1.907	2.095	2.554						
1.581	1.791	1.928	2.117	2.668						
1.588	1.815	1.959	2.141							
1.632	1.821	1.972	2.144							
1.633	1.842	1.999	2.165							
1.688	1.845	2.007	2.183							
1.690	1.853	2.010	2.210							
1.703	1.870	2.022	2.251							

All Data: **min:** 1.220 **max:** 2.668

Vitrinite Only: **min:** 1.220 **max:** 2.309 **V-types:** 12

COMMENT