To: Appalachian Basin Geothermal Play Fairway Analysis Group

From: Zachary Frone

Date: April 30, 2015

Subject: Anadarko Basin Thermal Conductivity Measurements

The Appalachian Basin Geothermal Play Fairway Analysis (AB-GPFA) team must determine which thermal conductivity values (K) to use for each formation in the thermal model. Data from Carter et al. (1998) from the Anadarko Basin (Oklahoma) is used due to the large number of measurements (n=275) and the similar ages and burial histories of the basins. The raw data from Carter shows large variations in K of sandstone, and generally smaller variations for other lithologies (Figure 1). Variations in sandstone samples do not show any systematic change with density or porosity (Figure 1).

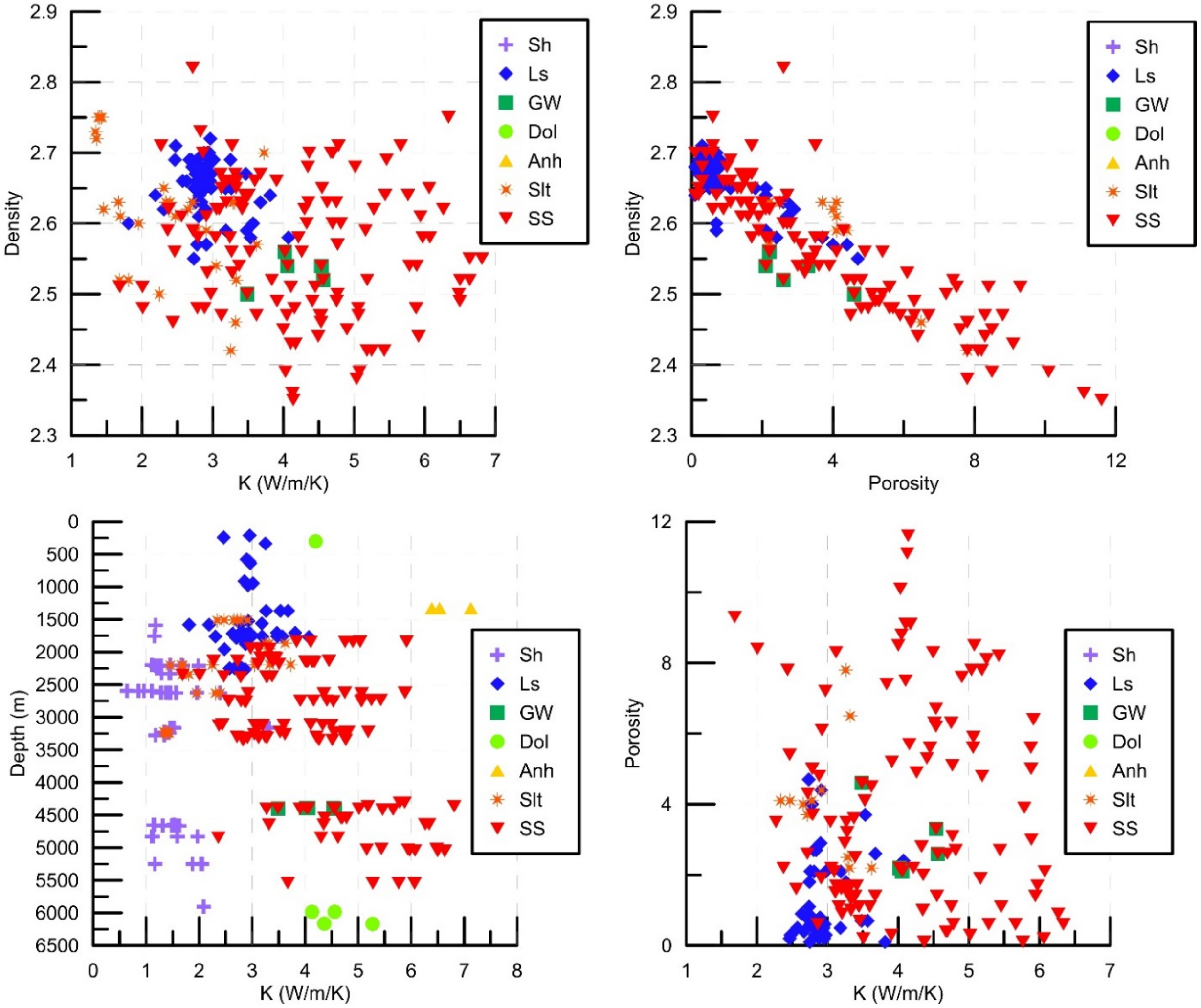

Figure 1: Original data from Carter et al. (1998).Sh: Shale, Ls: Limestone, GW: Greywacke, Dol: Dolomite, Anh: Anhydrite, Slt: Siltstone, SS: Sandstone.

Data from Carter et al. (1998) included measured K, density, and porosity values, along with core descriptions and grain size data. The original sampling methodology seems to have been to collect 3 samples over narrow 3-10 foot intervals. In order to see if the variability in the original K data is valid, a sub set of 18 samples were measured again. The 18 samples are from 6 wells, with 3 samples from each well. The 3 samples from each well are generally within 1-2 feet of each other, with two exceptions. All were selected to test whether the small scale variation in thermal conductivity that was measured was real. See table 1 for sample names, depth, lithology, and K.

All samples were prepared following the same procedure as Carter et al. (1998). The samples are weighed and measured dry, and a dry density is determined. The samples are then loaded into a vacuum/pressure cylinder where they are placed under vacuum for several hours to days to draw air out of the pores, followed by high pressure (~3000 psi) H_2O for up to 24 hours to saturate the cores. The samples are removed from the cylinder and then reweighted to determine a wet mass. The porosity, a parameter needed to calculate the thermal conductivity, is then calculated from the difference in the wet and dry masses and the volume of the core.

Once prepared, samples were run on a divided bar for 25 minutes each, with a temperature reading collected every 15 seconds. Each sample was run twice (once on each side of the bar) and the last 5 minutes of data were used. Thermal conductivity values are then calculated for the cores. 2 of the 18 cores were not run due to fractures and chipping of the cores. The results from the rest of the cores are shown on Table 1. All but two samples have values that are within ±6% of the values reported by Carter et al. (1998).

This data show that in general, the values from Carter et al. (1998) can be trusted and that there can be small scale (sub-meter) changes in thermal conductivity within a single lithology. Also, the range in values for sandstone appears to be real. The cause of this variation is unknown currently, but is likely caused by changes in mineralogy. Two methods to test this would be XRD or XRF analysis of the cores. XRD requires powdered samples so the cores would have to be destroyed. XRF analysis can be completed on cores and allows for multiple measurements along the length of the core. Changes in elemental composition measured by XRF could provide insight into why there are variations in thermal conductivity in cores from the same formation.

Table 1: Samples selected for re-measurement

Sample Name	Depth (ft)	Lithology	Carter K Value (W/m/K)	K1	K2	% difference
Dannehl 8609	8609	SH	1.38	1.46	1.43	4.71
Dannehl 8610	8610	SH	2.39	2.38	2.45	1.05
Dannehl 8611	8611	SH	1.46	1.53	1.51	4.11
Smallwood 8646	8646	SS	2.92	BROKEN		
Smallwood 8647	8647	SS	5.06	4.64	4.87	6.03
Smallwood 8648	8648	SS	4.35	3.9	3.72	12.41
Lloyd 5195	5195	LS	1.81	BROKEN		
Lloyd 5196	5196	LS	2.19	2.5	2.47	13.47
Lloyd 6157	6157	LS	2.88	2.84	2.9	0.35
Nightingale 10217	10217	SS	4.10	4.31	4.31	5.12
Nightingale 10219	10219	SS	2.43	2.54	2.45	2.67
Nightingale 10235	10235	SS	4.33	4.08	4.28	3.46
Brewer 7015	7015	SS	4.45	4.15	4.23	5.84
Brewer 7016	7016	SS	2.72	2.65	2.6	3.49
Brewer 7017	7017	SS	2.27	2.15	2.14	5.51
Scott 10834	10834	SS	2.71	2.56	2.57	5.35
Scott 10835	10835	SS	3.24	3.28	3.17	0.46
Scott 10836	10836	SS	4.21	4	4.13	3.44