TEMPERATURE AND WATER RESISTIVITY

For shale-free formations, the conduction of electrical current is almost entirely carried by ions in the formation water. Quantitative calculations of oil or gas saturation are therefore predicated on a knowledge of the formation water resistivity. For any given brine, this value is not constant, but decreases with increasing temperature. A common source of formation water resistivity data is a catalog of laboratory measurements made of samples from drill-stem tests, etc.

For example, if you had drilled a well in Stafford County, Kansas and one of your target formations was the Viola Limestone, this is the information that you would see in the KGS Brine Catalog (along with chemical composition of the dissolved solids). Water resistivity catalogs are available in a number of areas that have oil and gas development. Data for samples that are obviously contaminated by acid treatment, excessive mud invasion, etc. are screened out of the catalog, but there is usually some variability left, and the catalog reader should look for a "typical" value. Some of the log analysis techniques described later (the Rwa method, the Pickett plot, and estimation from the SP log) provide additional checks on these values. Once a representative value of Rw has been chosen, its value must be corrected from that of its laboratory measurement to that at the temperature of the formation in the well.

FORMATION WATER **RESISTIVITIES**		
laboratory measurements of produced samples		
Stafford County, Kansas		
VIOLA		
Location	**Rw**	**RwT**
Sec-T-R	**ohm-m**	**deg F**
27-21-13W	0.127	100
9-21-14W	0.210	70
10-24-11W	0.048	100
12-24-11W	0.082	100
22-24-11W	0.055	100
2-24-12W	0.077	100
10-24-12W	0.062	100
11-24-12W	0.072	100
15-25-11W	0.088	100
2-25-14W	0.075	60
2-25-14W	0.070	60
		kgs

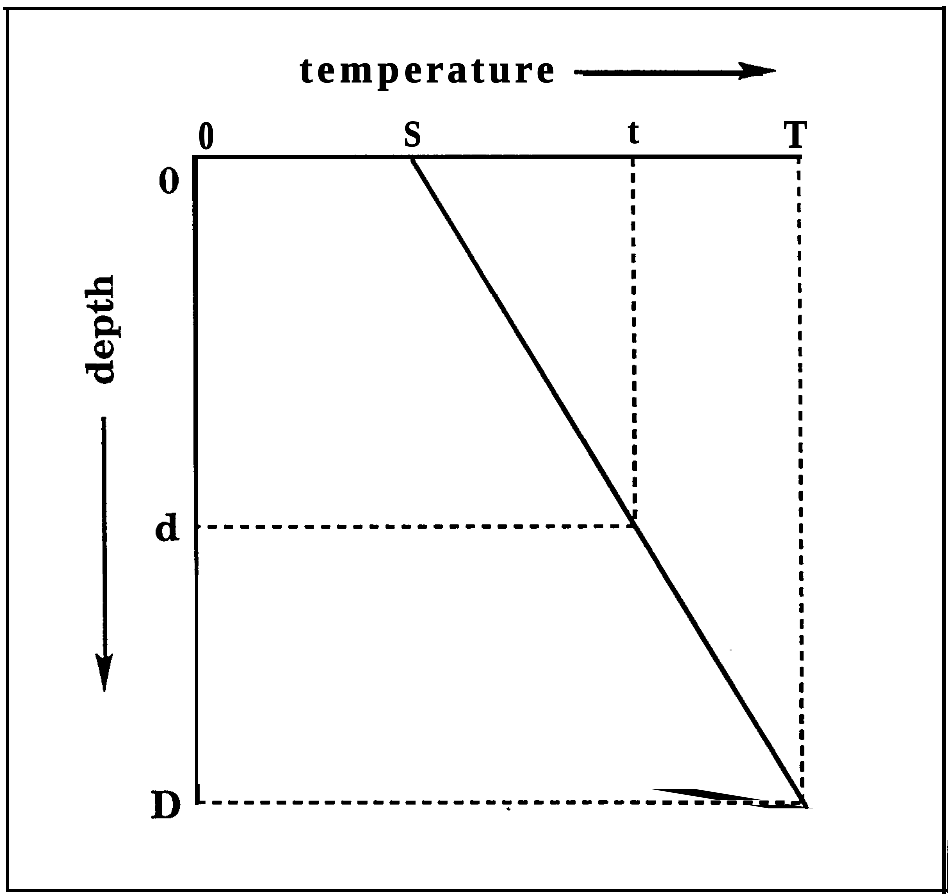
Estimation of formation temperature

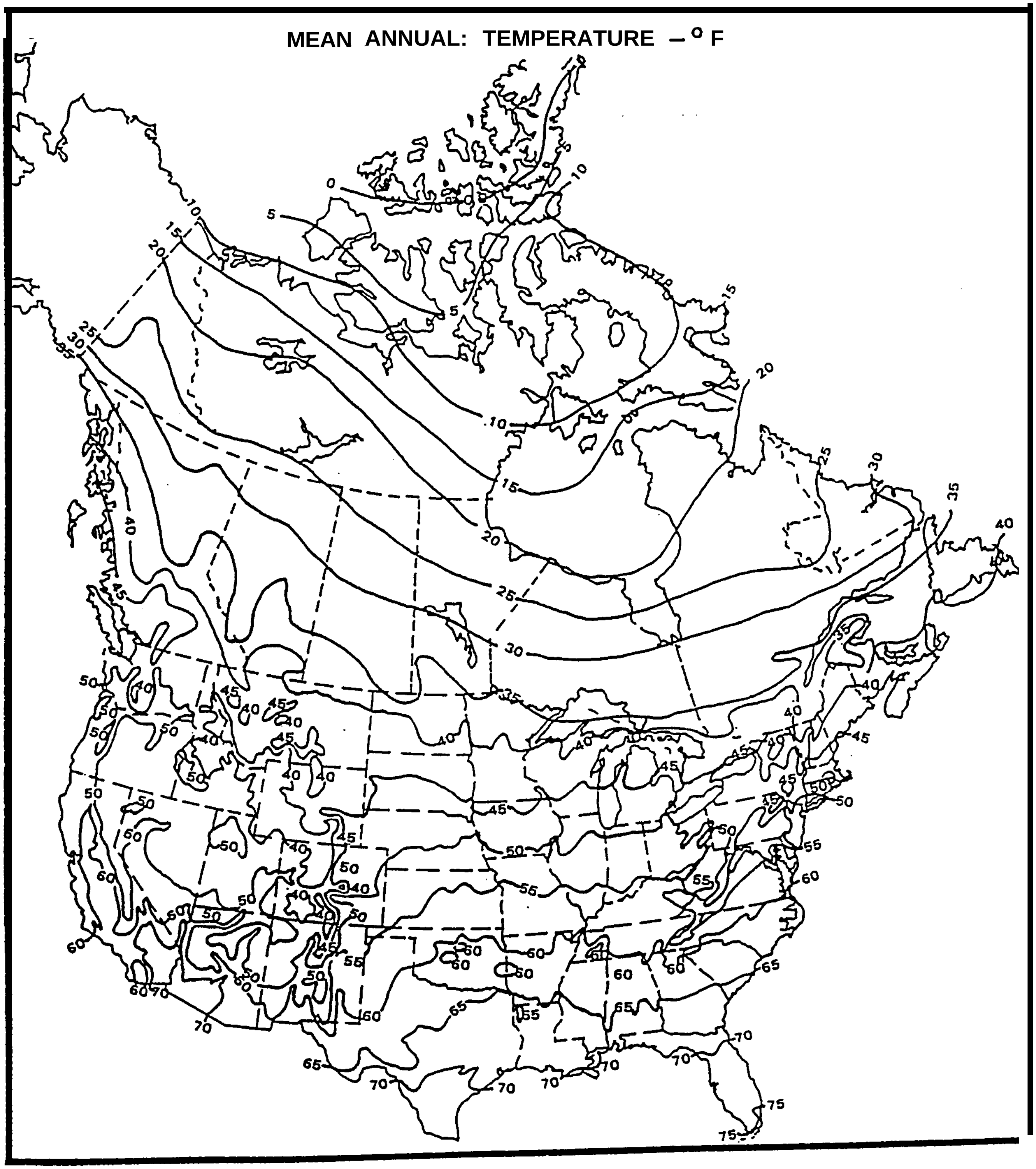
All conventional logging runs carry a maximum temperature recording device whose value, T, is recorded on the log heading and corresponds to the temperature at the deepest point of the log run, D (generally bottom hole). A linear temperature gradient is assumed as a first approximation between the bottom of the hole and the topographic surface.

The mean annual surface temperature, S, is used to establish the temperature at approximately zero depth. Then the temperature of the formation:

$$t = S + d\left(\frac{T - S}{D}\right)$$

The procedure is a simple linear interpolation where the quantity in parentheses represents an estimate of the temperature gradient. A map of mean surface temperature enables the selection of an appropriate value for any well location.





Mean annual surface temperatures in North America (after Connolly and U.S. Dept. of Agiculture)

Conversion of formation water resistivity to that at formation temperature

The formation water resistivity may be corrected from its value at laboratory temperature to formation temperature either by use of a chart found in most logging manuals or by Arp's empirical formula,

for Fahrenheit:

$$R_{w2} = R_{w1} \frac{(T_1 + 6.77)}{(T_2 + 6.77)}$$

and for Centigrade:

$$R_{w2} = R_{w1} \frac{(T_1 + 21.5)}{(T_2 + 21.5)}$$

where R_{w1} and R_{w2} are formation water resistivities at temperatures T_1 and T_2

Example of formation temperature calculation and correction of a laboratory measured water resistivity to its value at formation temperature

A Mississippi "chat" well is located in Kiowa County, south Kansas.
The log header reports a BHT (bottom-hole temperature) of 118°F at a TD (total depth) of 5398 feet.
The "Chat" zone to be evaluated is at a depth of 4838 feet. What is the zone's formation temperature?

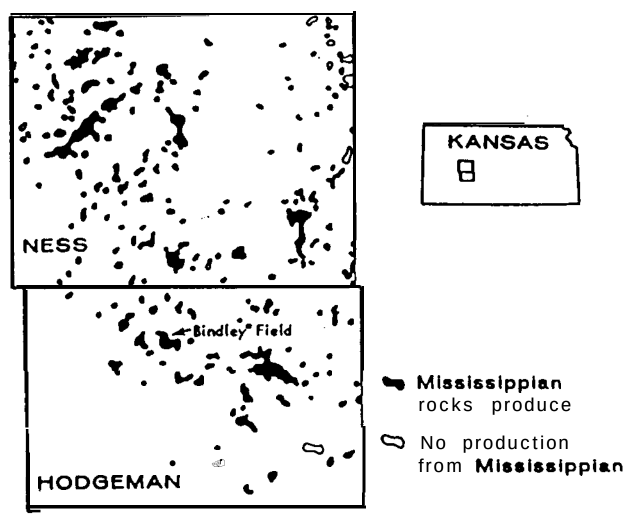
Answer:
Mean annual surface temperature in south Kansas = 57 degrees Fahrenheit
"Chat" zone formation temperature = 57 + 4838 * ((118 - 57) /5398)
= 112 degrees F

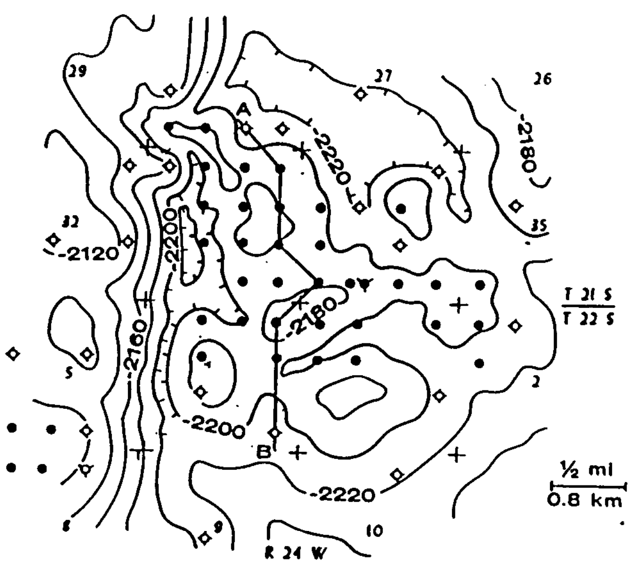
The resistivity of a Mississippi "Chat" water sample was measured to be 0.05 ohm-m at a laboratory temperature of 75°F.
What would be its resistivity in the subsurface zone at the well?

Answer: Rw = 0.05 * (75 +7) / (112 + 7)
= 0.0345 ohm-m

AN EXAMPLE OF ESTIMATION OF WATER SATURATION FROM LOG ANALYSIS OF RESISTMTY AND NEUTRON POROSITY LOGS

Bindley oil field is located in Hodgeman County in south Kansas, and was interpreted by Ebanks and others (1977) to be a combination paleogeomorphic and facies trap formed by the exhumation of a lower Mississippian bryozoan mound. Deutsch #1 is a well in the Bindley field that produces from the Mississippian “Warsaw” Formation section of (from top to bottom) dolomite breccia, bryozoan dolomite, spicule dolomite, and cherty dolomite. The well was perforated in the depth interval of 4616 - 36 feet and had an initial production of 205 BOPD with no water.





Bindley Field

Lib

Welex

SEP 18 1972

RADIATION-GUARD LOG

COMPANY	OASIS PETROLEUM, INCORPORATED
WELL	DEUTSCH # 1
FIELD	
COUNTY	HODGEMAN
STATE	KANSAS

COMPANY OASIS PETROLEUM INCORPORATED
WELL DEUTSCH # 1
FIELD
County HODGEMAN State KANS

COMPANY OASIS PETROLEUM, INCORPORATED

WELL DEUTSCH # 1 jeesr COPY AVAILABLE

FIELD

COUNTY HODGEMAN STATE KANSAS

Location C-NE-SE (9)

Sec. 33 Twp 21S Rge 24W

Other Services: COMP. A.V.

Permanent Datum GROUND LEVEL Elev. 2418'
Log Measure From KELLY BUSHING Ft. Above Perm. Datum
Drilling Measured From KELLY BUSHING

Elev.: K.B. 2423'
D.F. 2421'
G.L. 2418'

Date	8-16-72	8-16-72	8-16-72	REVISED COPY
Run No. ONE	GAMMA	NEUTRON	GUARD	
Depth—Driller	4724'	4724'	4724'	Date 8-28-72
Depth—Welex	4723'	4723'	4723'	Revision
Btm. Log Inter.	4715'	4723'	4715'	
Top Log Inter.	0'	0'	3510'	
Casing—Driller	@	@	8-5/8" @ 561'	@
Casing—Welex			8-5/8" 561'	
Bit Size			7-7/8"	
Type Fluid in Hole			WATER BASE SALT MUD	
Dens. | Visc.	|	|	9.2 | 57	|
pH | Fluid Loss	| ml	| ml	6.6 | 10.4 ml	| ml
Source of Sample			FLO LINE	
R_m @ Meas. Temp.	@ °F	@ °F	.15 @ 80 °F	@ °F
R_{mf} @ Meas. Temp.	@ °F	@ °F	.105 @ 80 °F	@ °F
R_{mc} @ Meas. Temp.	@ °F	@ °F	.225 @ 80 °F	@ °F
Source R_{mf} R_{mc}	|	|	MEAS. |	|
R_m @ BHT	@ °F	@ °F	.10 @ 117°F	@ °F
Time Since Circ.			2 HOURS	
Max. Rec. Temp.	°F @	°F @	117°F @ TD	°F @
Equip. | Location	8766 | GT. BEND	|	|	|
Recorded By	C. PEBLEY & K. STUEVE			
Witnessed By	MR. EUWER			

	FORMATION WATER RESISTIVITIES			
	laboratory measurements of produced samples			
	MISSISSIPPIAN			
	Hodgeman County, Kansas			
	Location	**Rw**	**RwT**	
	Sec-T-R	**ohm-m**	**deg F**	
	24-22-24W	0.136	100	
	24-22-24W	0.180	77	
	25-22-24W	0.170	77	
	25-22-24W	0.168	77	
	25-22-24W	0.170	77	
	25-22-24W	0.166	77	
	3-24-24W	0.094	100	
				kgs

A KGS Water Resistivity Catalog of laboratory measurements of Hodgeman County Mississippian formation brines.

Rw = 0.17 ohm-m @ 77^{o}F.

Well location:

Mean annual surface temperature (ST) of Hodgeman County (south-central Kansas) from the North American temperature map:
ST = 57 degrees Fahrenheit

From Header:

Total depth (TD) = 4723 feet
Bottom-Hole Temperature (BHT) = 117 degrees F

Formation :

Formation depth (FormD) = 4650 feet
Formation temperature of the Mississippian section (FormT) = 116 degrees F
Expected value of Rw in the Mississippian, using Arps' Formula: Rw = 0.116

Oasis Deutsch #1 C-NE-SE 33-21S-24W Hodgeman County, Kansas