Finding Geothermal Energy In Texas

Maria Richards

SMU Department of Earth Sciences
Geothermal Laboratory
Dallas, Texas
214-768-1975
mrichard@smu.edu
http://smu.edu/geothermal - see online Teacher's Materials

Goal: Give teachers the history behind the Texas geothermal maps and various methods to work with Texas geothermal data.

SMU | GEOTHERMAL LABORATORY

November 2008

Thank you for the funding!

SMU | HUFFINGTON DEPARTMENT OF EARTH SCIENCES

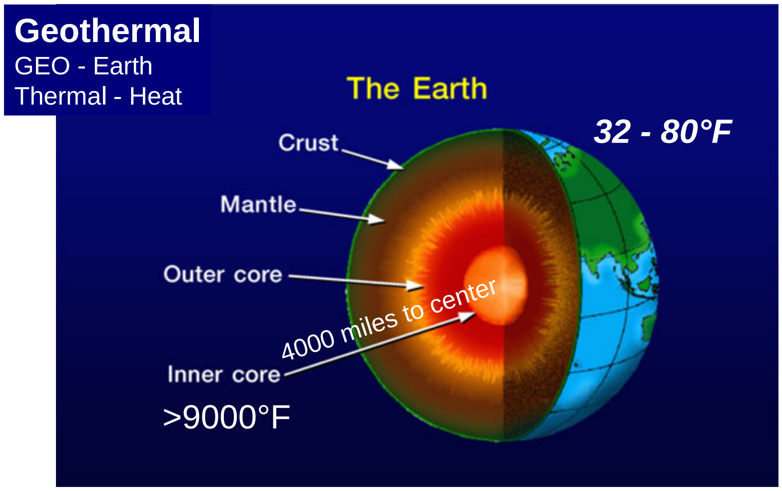
GEOPOWERING THE WEST

SECO State Energy Conservation Office

SMU | GEOTHERMAL LABORATORY

November 2008

Heat flows outward from the Earth's interior core.

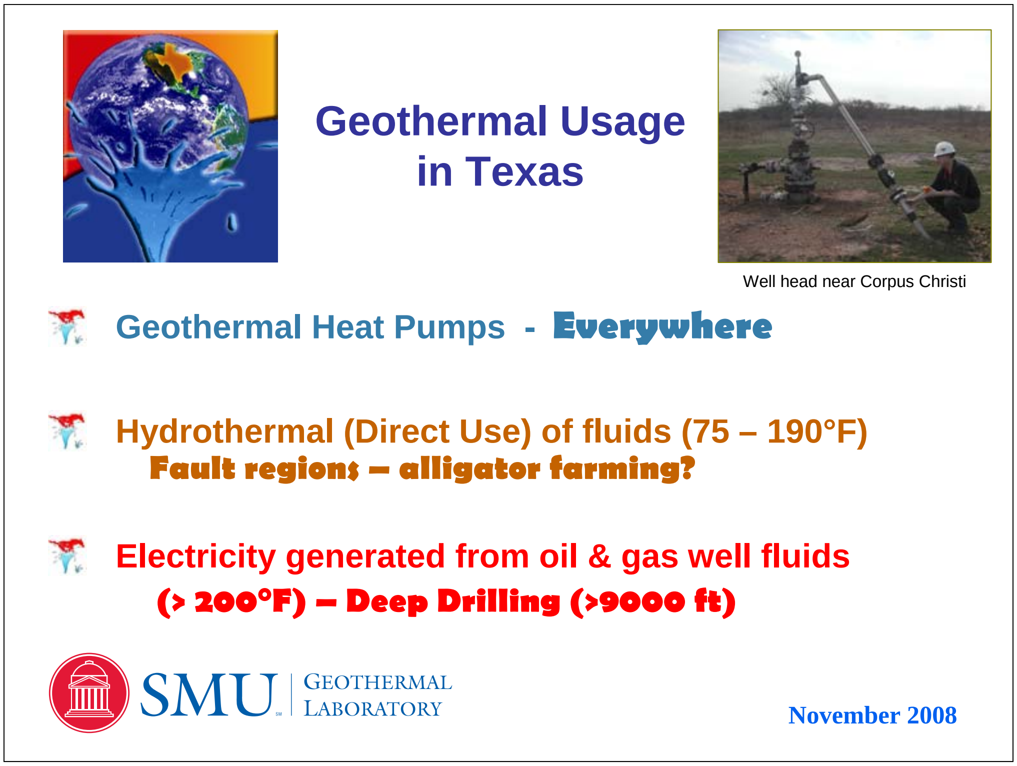


Graphic from the US Geothermal Education Office, California, http://geothermal.marin.org/

SMU | GEOTHERMAL LABORATORY

November 2008

Geothermal energy can be defined by splitting it into its components, *geo* meaning ‘Earth’ and *thermal* meaning ‘heat’, making geothermal the heat within the Earth. Geothermal energy represents the natural, internal heat of the Earth that is stored within the rock and fluid.



There are many different ways to use the geothermal resources in the Earth. The temperature of the Earth is a constant temperature beneath the zone of seasonal change. In much of Texas, this constant temperature depth is below 10 feet. Think about being at the beach. In the summer, the surface of the sand is very hot, but if you dig into the sand it gets cooler. Just like the sand a few inches down, the temperature of the Earth reaches equilibrium and stays the same year round regardless of the temperature of the air. Oh, and don't forget that the Earth does get warmer the deeper you go below the constant temperature depth, just like the slide of the Earth showed earlier.

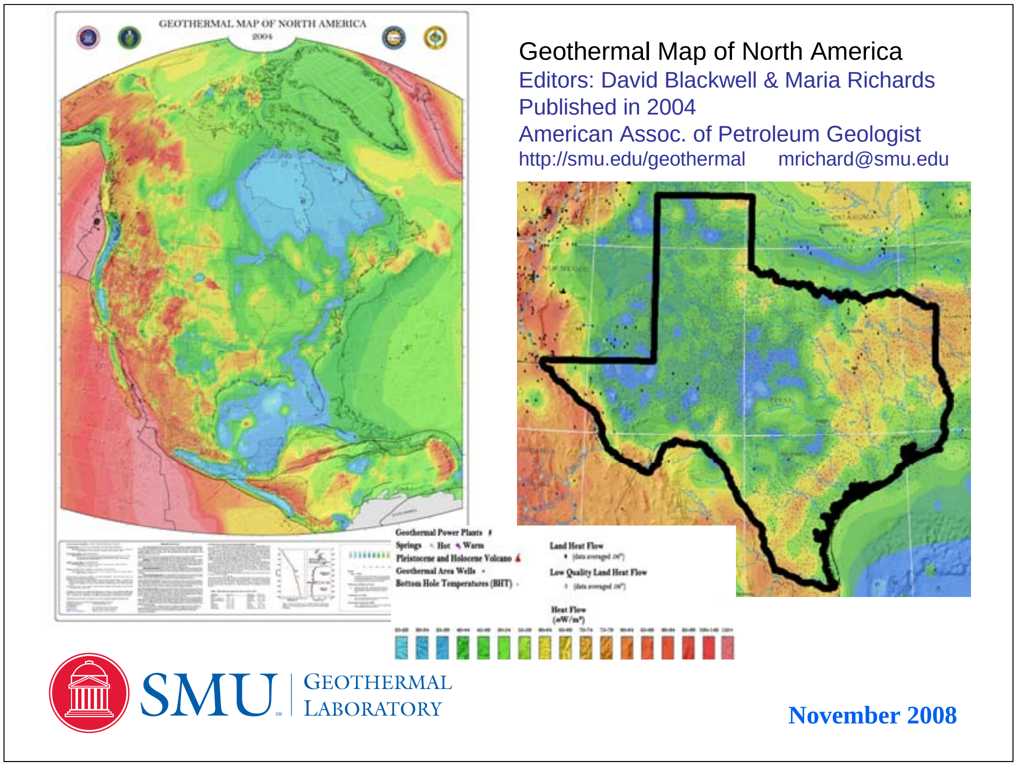
Here are just some quick ideas for Texas in how to use the constant temperature at various depths. The next slide has many different ways to use the different temperatures.

Ways to use the Earth's Geothermal Resource

RESOURCE TEMPERATURE	BEST APPLICATIONS FOR GEOTHERMAL HEAT*
Surface Temperature (40°F to 80°F)	Geothermal HVAC systems for homes and buildings
Low Temperature (70°F to 165°F)	Direct Use: agriculture and greenhouses, aquaculture (fish farming), mineral water spas and bath facilities, district water heating, soil warming, fruit & vegetable drying, concrete curing, food processing
Moderate Temperature (165°F to 300°F)	Binary fluid generators for electrical production; Direct Use: absorption chillers, fabric dyeing, pulp and paper processing, lumber and cement drying, sugar evaporation
High Temperature (>300°F)	Electricity production, minerals recovery, hydrogen production, ethanol and biofuels production

SMU Geothermal Laboratory

November 2008

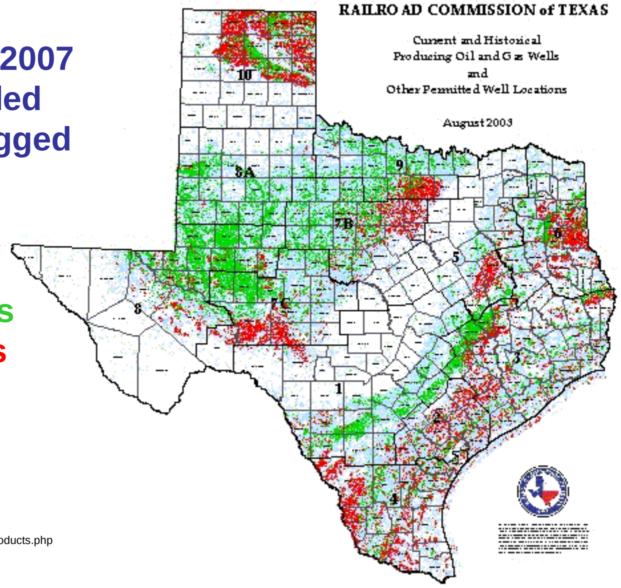


In the production of the Geothermal Map of North America, Dr. David Blackwell incorporated the data from oil and gas wells. Reviewing the temperature data from 10,000s of oil and gas wells, it became apparent that they reemphasized the existing heat flow data base. Where the heat flow is higher than expected, temperatures from the oil and gas wells were higher as well, and vice versa for colder locations.

In studying the data for Texas, it became clear that Texas had more geothermal resources than expected along the eastern - southern portion of the state. The research focus had always been on Western United States for most of the geothermal development in the United States. The 2004 Geothermal Map of North America, with its higher resolution, showed the potential waiting to be unleashed right below Texas.

Between 1960 and 2007
- 534,000 wells drilled
- 355,000 wells plugged

Green = oil wells
Red = gas wells



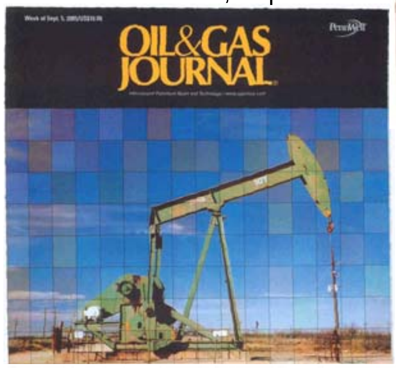
http://www.rrc.state.tx.us/forms/maps/specialmaps/mapproducts.php
http://www.rrc.state.tx.us/data/drilling/txdrillingstat.pdf

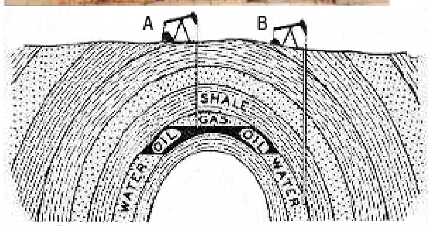
SMU | GEOTHERMAL LABORATORY

November 2008

Oil and gas wells are like a window into the geology of the Earth. From the well logs taken after drilling, a person can “see” what the Earth looks like inside.

McKenna et al., Sept. 2005





SMU | GEOTHERMAL LABORATORY

Geothermal electric power supply possible from Gulf Coast, Midcontinent oil field waters

State	2004 Total Produced Fluids (bbl)	Electricity (MW) if 210°F Fluid
Alabama	203,223,404	7
Arkansas	258,095,372	9
Louisiana	2,136,572,640	74
Mississippi	592,517,602	21
Oklahoma	12,423,264,300	447
Texas	**12,097,990,120**	**423**

In converting to geothermal energy production, hot water can be pumped up from Well B and the used water reinjected into Well A to keep the reservoir productive.

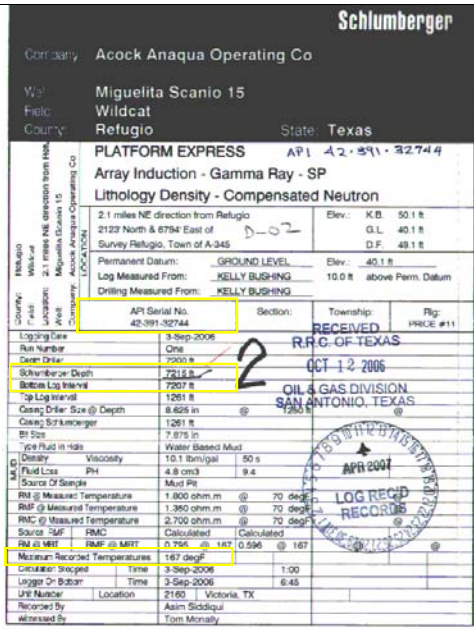
November 2008

The primary needs for geothermal power development are high fluid flow rates and hot temperatures. To better understand the potential that Texas has for geothermal energy projects, Jason McKenna and David Blackwell did a review of the amount of fluids being produced with oil and gas production.

The Texas Railroad Commission does not keep track of the amount of water (brine) produced from an individual well. Instead it has records from the wells that are used for reinjecting the fluid back into the ground. Because the oil and gas well fluids have many different elements, including salt, it is not able to be put into rivers or ponds on the surface.

Just like a salad dressing that needs to be shaken to mix the water, oil, and vinegar, in a geologic setting, gas will float to the top, then oil, then water. Therefore, it is generally at the end of a well’s production life that water is produced, which consequently ceases production and the well is abandoned. Rather than stopping production, the water could be used for geothermal energy projects.

Texas has one of the highest amounts of produced fluids (water, brine) with oil and gas in the country … over 12,000,000,000 barrels in 2004. This was exciting for geothermal potential since fluids are needed to produce energy.


Schlumberger

Company: Acock Anaqua Operating Co

Well: Miguelita Scanio 15

Field: Wildcat

County: Refugio State: Texas

PLATFORM EXPRESS API 42-391-32744

Array Induction - Gamma Ray - SP

Lithology Density - Compensated Neutron

LOCATION: 2.1 miles NE direction from Refugio; 2123' North & 6794' East of; Survey Refugio, Town of A-345 D-02

Elev.: K.B. 50.1 ft; G.L. 40.1 ft; D.F. 49.1 ft

Permanent Datum: GROUND LEVEL Elev.: 40.1 ft

Log Measured From: KELLY BUSHING 10.0 ft above Perm. Datum

Drilling Measured From: KELLY BUSHING

API Serial No. 42-391-32744 | Section: | Township: | Rig: PRICE #11

RECEIVED R.R.C. OF TEXAS OCT 12 2006 OIL & GAS DIVISION SAN ANTONIO, TEXAS

2

Logging Date	3-Sep-2006		
Run Number	One		
Depth Driller	7200 ft		
Schlumberger Depth	7215 ft		
Bottom Log Interval	7207 ft		
Top Log Interval	1261 ft		
Casing Driller Size @ Depth	8.625 in	@	1260 ft
Casing Schlumberger	1261 ft		
Bit Size	7.875 in		
Type Fluid in Hole	Water Based Mud		
MUD: Density / Viscosity	10.1 lbm/gal	50 s	
Fluid Loss / PH	4.8 cm3	9.4	
Source Of Sample	Mud Pit		
RM @ Measured Temperature	1.800 ohm.m	@	70 degF
RMF @ Measured Temperature	1.350 ohm.m	@	70 degF
RMC @ Measured Temperature	2.700 ohm.m	@	70 degF
Source RMF / RMC	Calculated	Calculated	
RM @ MRT / RMF @ MRT	0.796 @ 167	0.596	@ 167
Maximum Recorded Temperatures	167 degF		
Circulation Stopped / Time	3-Sep-2006	1:00	
Logger On Bottom / Time	3-Sep-2006	6:45	
Unit Number / Location	2160	Victoria, TX	
Recorded By	Asim Siddiqui		
Witnessed By	Tom Mcnally		

APR 2007 LOG REC'D RECORDS

Example Well Log Header

Data gathered:

API Number

Drill depth (can be multiple)

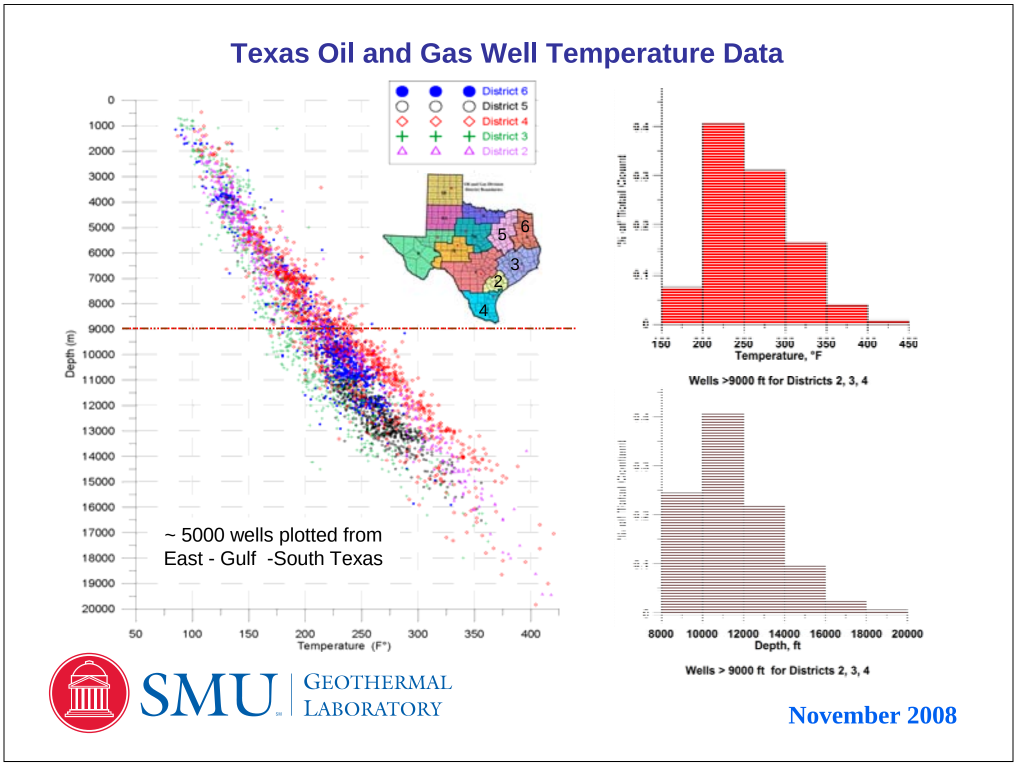
Bottom logged interval

Maximum Temperature

SMU Geothermal Laboratory

November 2008

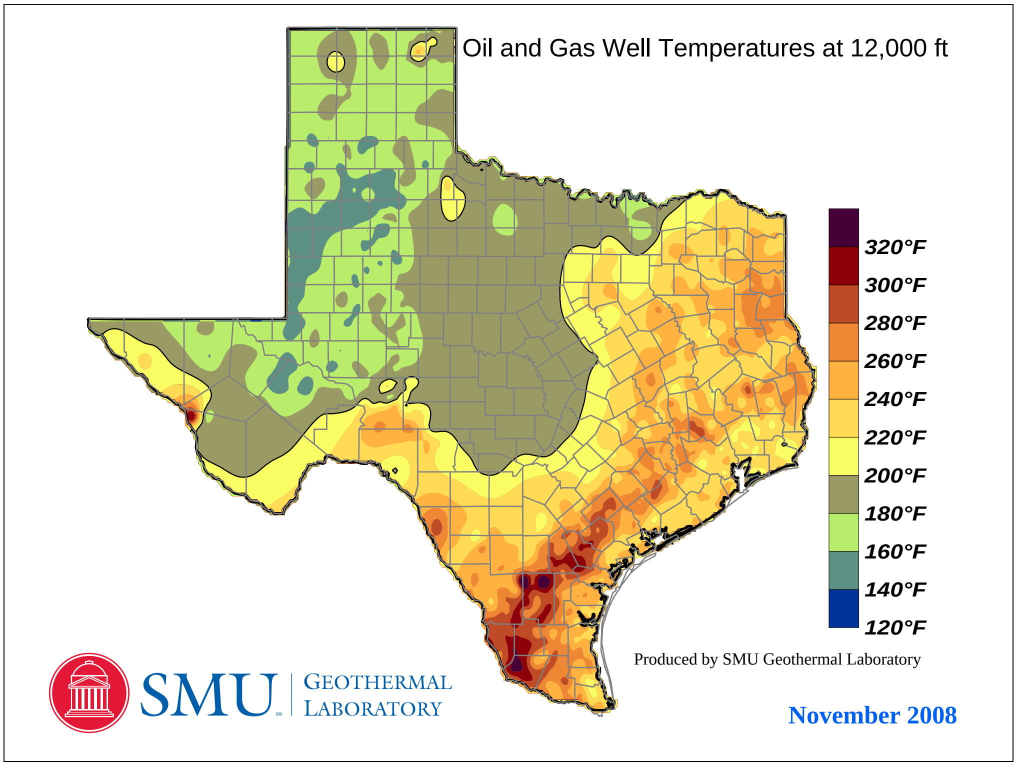
From the Texas Railroad Commission, oil and gas well logs can be downloaded, or copies can be made through the UT Austin Bureau of Economic Geology Well Log Library. The top page of a well log is named a header. From the header it gives basic information about drilling the well and the parameters of the new well.



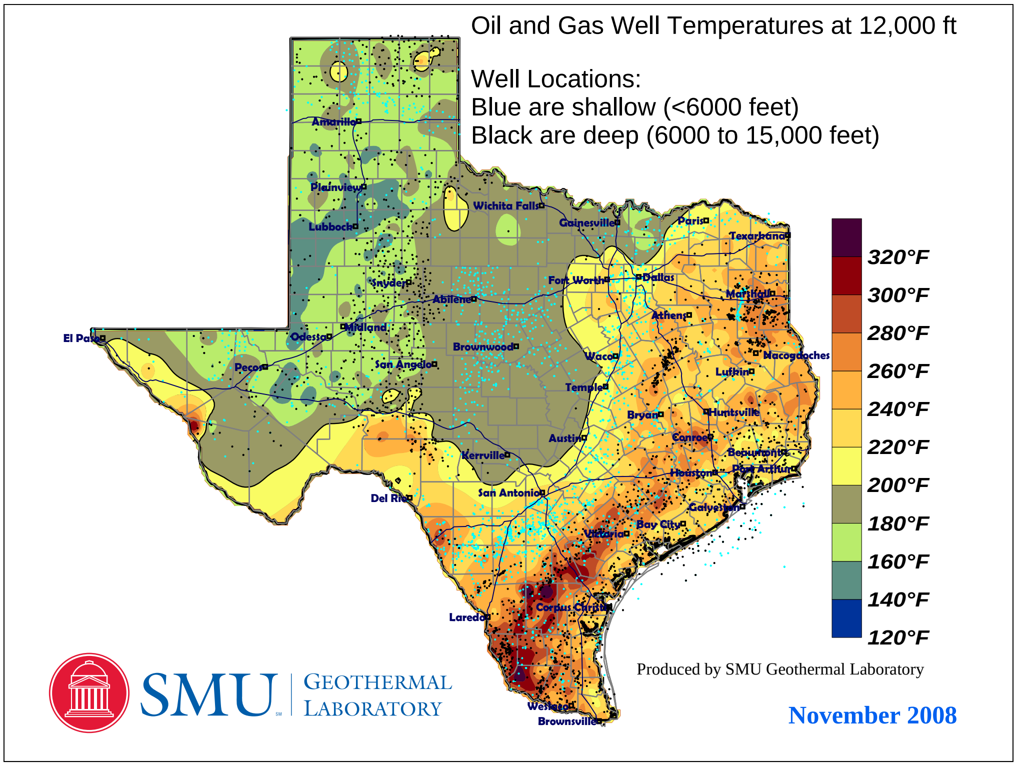
To develop geothermal energy in Texas, the fluid temperatures need to be at least 200°F. Remember that the hotter the better so the wells with temperatures over 300°F are the first locations to look into for a geothermal power project. As you can see, below about 9000 feet in eastern - southern Texas the temperatures are usually above the 200°F starting point. Most of the wells are located between 10,000 and 13,000 feet that are above 200°F.

If we use 5000 wells as our total number, then from the red bar chart, we can read that about 16% of the wells have temperatures between 300 and 350°F. That means that about 800 wells are really hot.

Question for you: What temperature does water boil at if it is near sea level?



It is important to know that there are many wells that meet the temperature criteria for geothermal projects in Texas. Plotting the temperature data, we can make maps to help us understand where the temperatures vary. This map of the temperatures at 12,000 feet was created from oil and gas well temperatures. Although there are wells from all different depths, in making a map such as this, the data is limited to those values are between 10,000 to 14,000 feet for more accuracy.



With the county boundaries, city names, and major roadways, hopefully you can determine what the temperature is where you live at 12,000 feet. If it is over 200°F then there is enough heat to generate electricity from geothermal resources right below your feet.

Gradient, Thermal Conductivity, Heat Flow

Gradient = change in temperature over change in depth. Represents the slope of the temperature line.

Thermal Conductivity = the amount of heat able to transfer through a rock or layer. Varies because of:

1. Mineral content (quartz is high, clay minerals are low)
2. Fluid content (more water = higher value)
3. Pressure (pressure connects surfaces for increase)
4. Isotropy (how similar rock is in all directions)


Quartzite


Clay minerals

Heat Flow = The amount of heat that moves through a layer of rock. Heat Flow = Gradient x Thermal Conductivity

***m*W/m² = °C/km x W/m/K**

m = milli	W = Watts
m = meters	km = kilometers
K = Kelvin	°C = Celsius

SMU Geothermal Laboratory

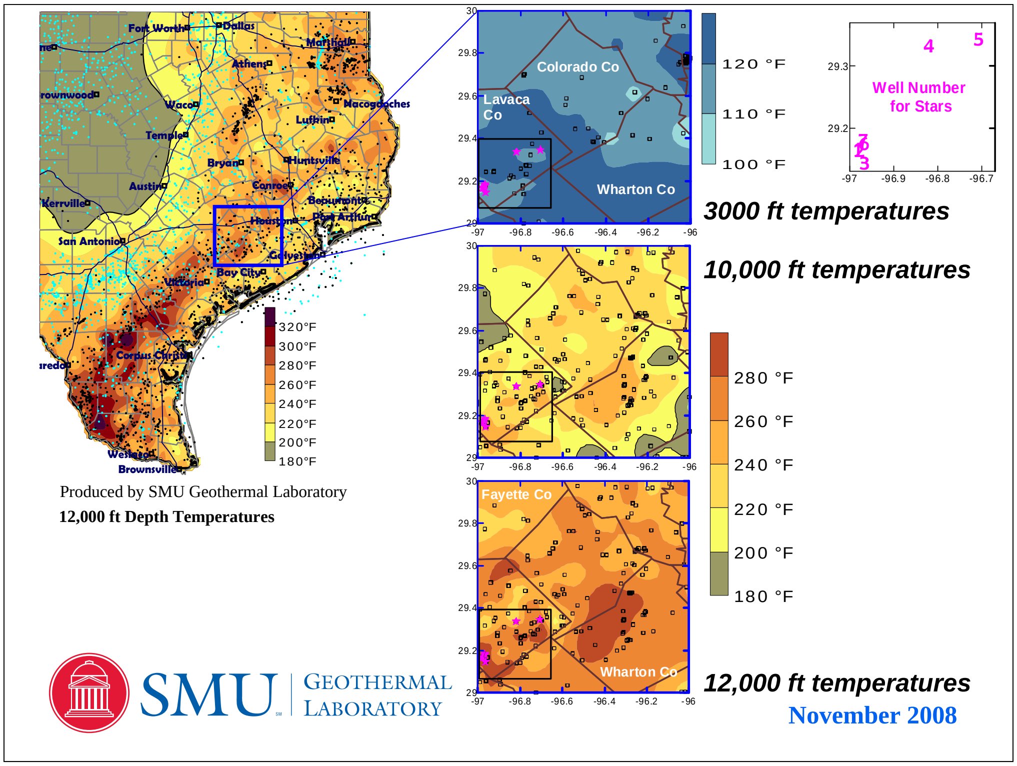
November 2008

Science is filled with terminology related to the specific field of research. Here are three basic terms that are used daily in the SMU Geothermal Laboratory: gradient, thermal conductivity, and heat flow. Without realizing it, these are words that you use daily as well.

When you walk up a stairway or hill, the “gradient” is what determines how steep the stairs are or how difficult it is to climb the hill. In Math gradient is also referred to as the slope. For instance, the “slope of a line” is m in this equation. $y = mx + b$

On a hot day you quickly become aware of the thermal conductivity of the ground. Grass is not very conductive, so it stays cool, whereas the black pavement is very conductive and becomes very hot to touch. Another example related to thermal conductivity is when you use a microwave to heat something. Have you ever noticed that if you add water or another liquid to the leftovers, they heat faster? Water is able to absorb the microwave energy and then transfer it to the other food items. By connecting the pieces of food being heated, they get hot more quickly.

Luckily heat flow is slow in air so the hot oven feels warm when you put your hand into it, but does not burn you. Whereas metal has high heat flow and will transfer the heat from your stove through your pan and heat your food.



In doing research on geothermal resources, it is helpful to look at the gradient, the thermal conductivity and the heat flow of an area. The rock type, the fluid within the rock layers, and the pressure all are important parameters to determine the geothermal resources.

Although the 2004 Geothermal Map of North America helped determine that there were geothermal resources available, the details of where geothermal resources are accessible were not necessarily easy to depict except for generalizing that the eastern and southern portion of Texas have the most resource potential.

By looking more closely at a specific area, we can have a better resolution of the resources available. From data at different depths, the changes in the gradients between the wells help to show which wells to focus on.

Using Data from Railroad Commission Well Log Headers

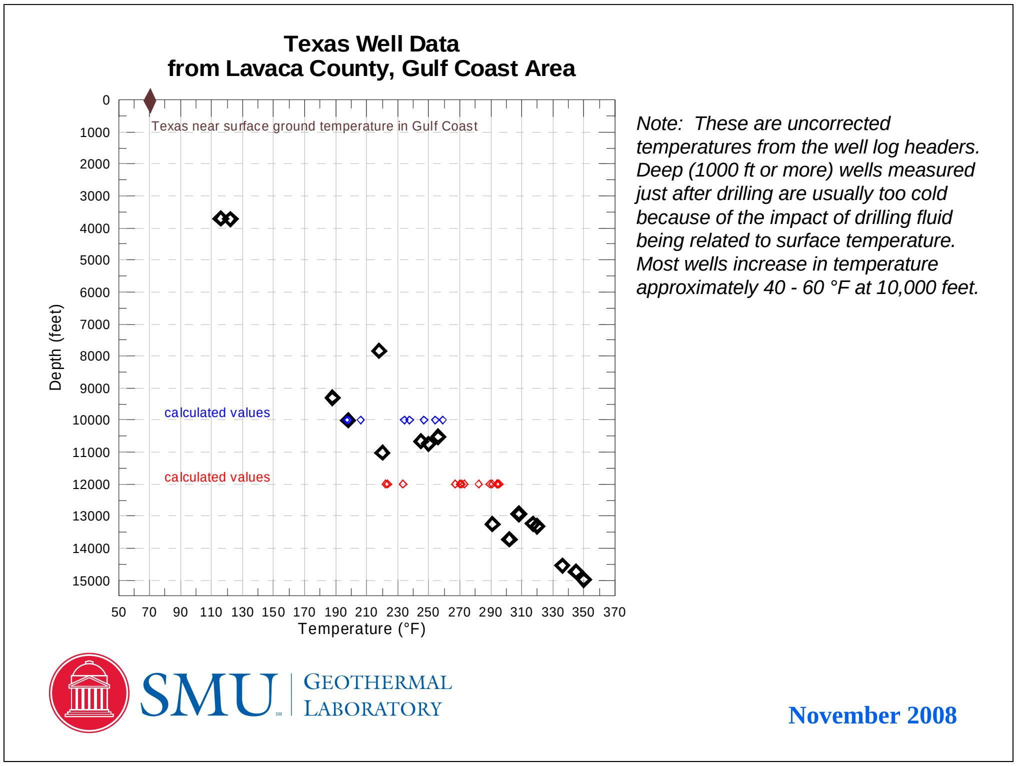
A	B	C	D	E	F	G	H	I
Well	**Longitude**	**Latitude**	**Depth (ft)**	**BHT Temp (°F)**	**Gradient (°F/ 1000 ft)**	**Interval Gradient**	**Temp @ 10,000 ft**	**Temp @ 12000 ft**
1	-96.9806	29.1681	10656	245	16.4		234	267
	-96.9806	29.1681	12925	308	18.4	27.8	254	291
	-96.9806	29.1681	14547	336	18.3	17.3		289
2	-96.9784	29.1645	7830	218	18.9		259	
	-96.9784	29.1645	13315	320	18.8	18.6		295
	-96.9784	29.1645	14981	350	18.7	18.0		294
3	-96.9652	29.1453	10518	256	17.7		247	282
	-96.9652	29.1453	13236	317	18.7	22.4		294
	-96.9652	29.1453	14734	345	18.7	18.7		294
4	-96.8200	29.3350	9300	188	12.7		197	222
	-96.8200	29.3350	10005	198	12.8	14.2	198	224
	-96.8200	29.3350	11019	220	13.6	21.7	206	233
5	-96.7062	29.3454	10739	250	16.8		238	271
	-96.7062	29.3454	13246	291	16.7	16.4		270
	-96.7062	29.3454	13720	302	16.9	23.2		273
6	-96.9661	29.1768	3703	116	12.4			
7	-96.9688	29.1827	3719	122	14.0			
example	-96.9806	29.1681	12925	308	=(E3-70)/D3*1000	=(E3-E2)/(D3-D2)*1000	=F3*((10000-D3)/1000)+E3	

BHT = Bottom Hole Temperature
Gradient = [(Total max temp. - surface temp. {70°F}) ÷ by total depth] * 1000 ft.
Interval Gradient = Difference between two segments of one well
Temp @ 10,000 ft = interpolated temperature using gradient

SMU | GEOTHERMAL LABORATORY

November 2008

This spreadsheet gives you the equations to calculate gradient and temperatures at a specific depth that you can used to make detailed maps for your own area. There is data available on the Railroad Commission website and the SMU Geothermal Laboratory website: http://smu.edu/geothermal. If you need help finding it, give Maria Richards a call or email.



This is an example of the plotted data for you to look at. looking at the whole graph, where would you draw a line to show the average gradient for the points above 10,000 feet? What about from 11,000 to the bottom? Are the gradients different for these two lines?

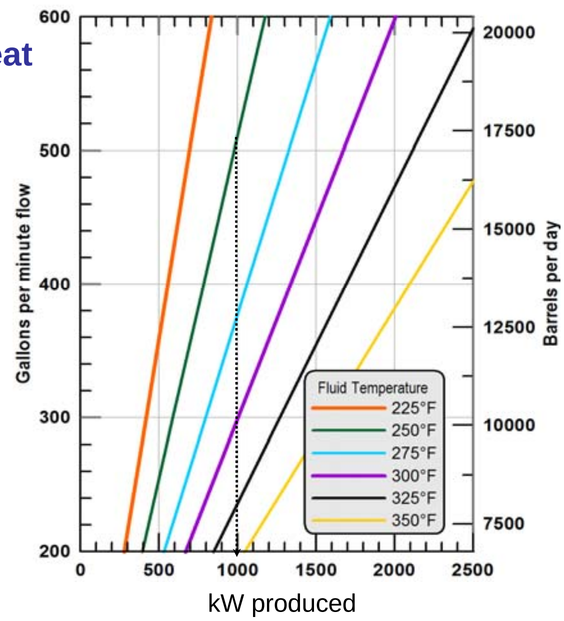
Converting Thermal Heat to Electrical Energy

Step one:

Determine the well(s)
fluid flow and
fluid temperature.

Note - one gallon fills about 2/3 a cubic foot, thus a space 10' x 10' x 3' is filled every minute for 500 gpm.

1000 kW = 1 MW
= electricity for
~ 1000 people
~ 225 homes



SMU | GEOTHERMAL LABORATORY

November 2008

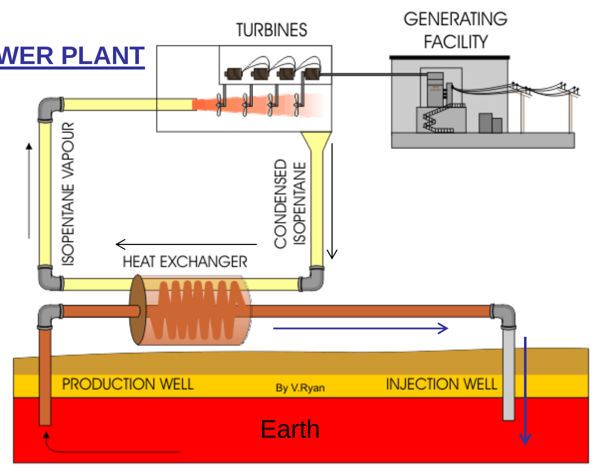
If you can find the temperature of a well in your community, then you can predict how much energy maybe produced depending on the fluid flow for the well. Oil and gas wells typically produce less than 200 gallons per minute of fluid. The well would most likely have to be worked again to open up the rock layers with the most water. Therefore, the fluid flow is a parameter that you can adjust depending on your needs and resources. Try to calculate how much fluid you would need to generate enough electricity from a geothermal power plant for your school electrical consumption.

If the water that reaches the surface is not hot enough to produce steam directly, it can still produce electricity by feeding it into a Binary Power Plant. The hot water is fed into a heat exchanger. The heat from the water is absorbed by a liquid such as isopentane which boils at a lower temperature. The isopentane steam is used to drive turbines, producing electricity. The isopentane then condenses back to its liquid state and is used again.

Temperatures under 300°F use binary cycle technology.

BINARY CYCLE POWER PLANT

V. Ryan © 2005



Shown with moving parts at http://www.technologystudent.com/energy1/geo3.htm

SMU | GEOTHERMAL LABORATORY

November 2008

There are different types of geothermal power plants. For places where the water is less than 300°F, a binary power plant is used. Most small geothermal power plants (less than 10 MW) are binary geothermal power plants.

Converting Thermal Heat to Electrical Energy

Step two:

Choose a power plant for fluid to run through to extract the heat.

UTC Power PureCycle (250 kW)

These systems are designed to run on temperatures as low as 200 °F in Texas. The hotter the well fluids the more efficient. They need both a hot source of fluid and a cold source (or air cooled).

ElectraTherm INC. Green Machine (80 kW)

ORMAT Technology Organic Rankine Cycle ORC unit (250 kW)

SMU | GEOTHERMAL LABORATORY

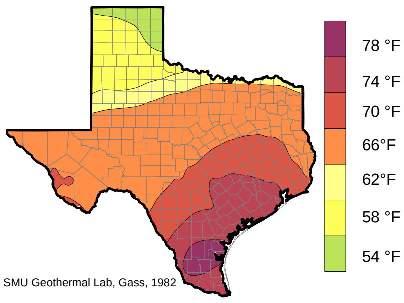
November 2008

What is exciting about this slide, is that there are more and more binary technologies being developed. In 2004, when the Geothermal Map of North America was being produced, no one was making small (less than 1 MW) power plants. ORMAT Technologies had made some in the past, but were not focusing on making them at the time.

The development of the UTC Power PureCycle is what seemed to get the geothermal community excited about small-scale projects and using them with oil and gas wells. The PureCycle is based on the Carrier air conditioning unit, only running it backwards. Rather than using electricity to take the heat out of the air, it uses the heat to generate electricity.

How to Determine Your Area's Geothermal Resources

Surface ground water temperatures



Map from SMU Geothermal Lab, Gass, 1982

Note: Students can calculate the ground temperature by using the outside home water tap. Measure the water temperature every 15 seconds until it levels off and reaches a constant temperature. The city water main pipes are at 5 - 15 feet below ground. The water in them equilibrates with the ground and represents the constant geothermal temperature for the ground in your area.

SMU | GEOTHERMAL LABORATORY

Deep water temperatures

1. Use area oil/gas wells from Railroad Commission for bottom hole temperatures.

2. Use local water wells from residential and public sources.

Geothermal Potential in Texas

Texas is estimated to have
910,000 EJ of Thermal Energy
… enough to power the state of Texas
for the next 100 years.

November 2008

Send Maria Richards a note about what temperatures you find. I can use this information when making other maps for Texas.

Build Your Own Data Base for Classroom Projects

http://www.rrc.state.tx.us/data/online/oilgasrecords.php

Click on *Oil and Gas Well Records* to get the *Key Field Search* for well logs. The Well Log headers give you temperature and depth.

Use the *GIS Map Viewer* to find individual wells close to your school.

http://www.rrc.state.tx.us/data/online/gis/index.php

SMU | GEOTHERMAL LABORATORY

November 2008

Benefits of Geothermal Power

Provides clean, safe, renewable power

Uses little surface land area

Generates continuous, reliable “baseloa

Extends the life of oil & gas extraction from a field

Note: There are over 18,000 active wells in the Texas Gulf Coast
Over 11,000 wells are deeper than 10,000 feet

SMU | Geothermal Laboratory

November 2008

Comparison of Alternative Electrical Energy Sources

	Load Factor
Geothermal Power Plant	90-95%
Wind Turbine Fields	20-30%

25 MW Geothermal Plant = 100 MW Wind Plant

Geothermal = ~5 - 8 cents/kWh

Wind = ~5 cents/kWh

1 MW = Energy for 250 homes or 1000 people

SMU | Geothermal Laboratory

November 2008

Jobs in Geothermal Energy

Geothermal Power - geologists, chemists, geophysicists, hydrologists, reservoir engineers, hydraulic engineers, power plant designers, and drillers

Environmental scientists - impact studies, permits, and leasing

Direct-Use - heating engineers for agricultural/aquaculture industries

Geothermal Heat Pumps - Mechanical engineers, drillers, and HVAC contractors for Home, School, and Office building systems – LEED Certification

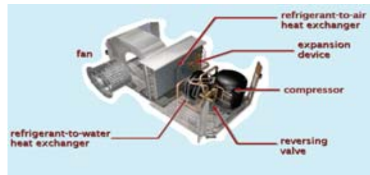
Research Positions - engineers, geologists, chemists, and materials scientists for government, university, and company projects.

SMU | GEOTHERMAL LABORATORY

November 2008

Geothermal Activity Suggestions

- **Visit a cave and compare the outside temperature with the inside temperature.**
- **Visit a school or building installing geothermal heat pumps to see how they work (Heat pump part diagram is shown.)**



- **Measure the groundwater temperature in your community**
- **Research if there were previously flowing wells or spas in your community**
- **What is the temperature of your city water when it comes out of the well? Do they have to cool it?**

SMU | Geothermal Laboratory

November 2008