The Ways and Means of Geothermal Energy

Christopher B. Purvis

Abstract

This article discusses the geological nature of geothermal energy while applying it to geothermal power. Geothermal power is applied energy from superheated ground or groundwater. Hydrothermal reservoirs, geopressured brines, hot dry rock, magma, and ambient ground heat are a few of the geothermal resources that humans have successfully tapped or plan on harnessing in the future. There are two types of technology available for superheated groundwater: flash steam technology and a system that encompasses the flash steam method (a binary system). There are geological features that standout out to developers interested in using the earth's heat for production. It is also important to note the side effects of such systems, whether it be environmental or economical. The final statements of this article tell the reader where global society is headed in terms of geothermal power. At present, the only resource able to be tapped is hydrothermal reservoirs. Fossil fuels are being depleted and nations of every economic status will need to yield to the natural power of the wind, the water, the sun, or of the earth.

WHAT IS GEOTHERMAL ENERGY?

Geothermal power according to the *McGraw-Hill Encyclopedia of Science and Technology* is thermal or electric power produced from thermal energy contained in the earth or otherwise known as geothermal energy. To environmentalists, it could be defined as a means to a cleaner and healthier biosphere. To conservationists, it could be defined as clean renewable energy that has yet to be tapped to its furthest potential. The explanation of the natural forces that allow us to capture this power is crucial to the development and creation of geothermal power plants.

HEATING OF GROUND WATER

The earth holds power that seems incomprehensible to the human mind. Geothermal energy comes directly from the Earth's vast subsurface expanse of heat (Deudney, 218). Like the sun's energy, that heat is the product of gravitational collisions, atomic reactions, and radioactive decay (Deudney, 218). Geothermal heat is derived from earth's inner molten rock, magma. This makes up the 40 kilometer thick crust. With each kilometer of depth the temperature increases twenty-five degrees centigrade (Deudney, 219) (Fig.1). This translates to 400 degrees to 1800 degrees Fahrenheit at the base of the earth's crust (McGraw-Hill, 88). Geothermal activity has been observed to occur where two plates of

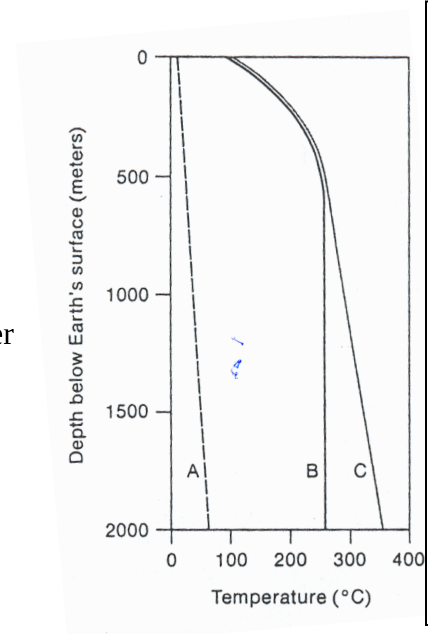


Fig. 1 (Volcanoes of the Eastern Sierra Nevada) Curve A is the temperature below hot springs and geysers. Curve B represents temperature in a geothermal steam field. Curve C is the

the earth's crust meet. These geothermal niches are found at the mid-Atlantic ridge, around the Mediterranean, the Rift Valley in Africa, and the "Ring of Fire." Here in the states, a famous example is the Basin and Range of American's West. The Juan De Fuca plate is subducting under the North American pate (Fig. 2), and the Pacific Plate is moving against the North American Plate. The force of friction and pressure causes the rock to heat up, and as it travels deeper below the North-American plate, the rock begins to melt. The molten rock becomes less dense than the solid rock surrounding it so it "floats" near the surface to a magma chamber. Massive areas of groundwater, commonly known as aquifers, are approached by these voluminous chambers of magma and begin to heat up. This convection of heat is not only produced by magma.

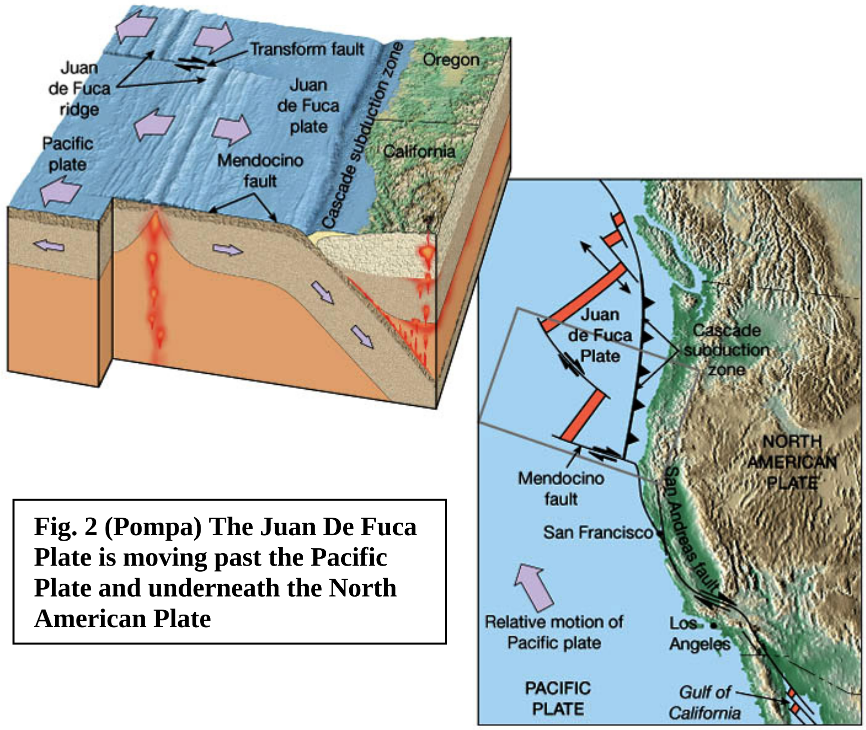


Fig. 2 (Pompa) The Juan De Fuca Plate is moving past the Pacific Plate and underneath the North American Plate

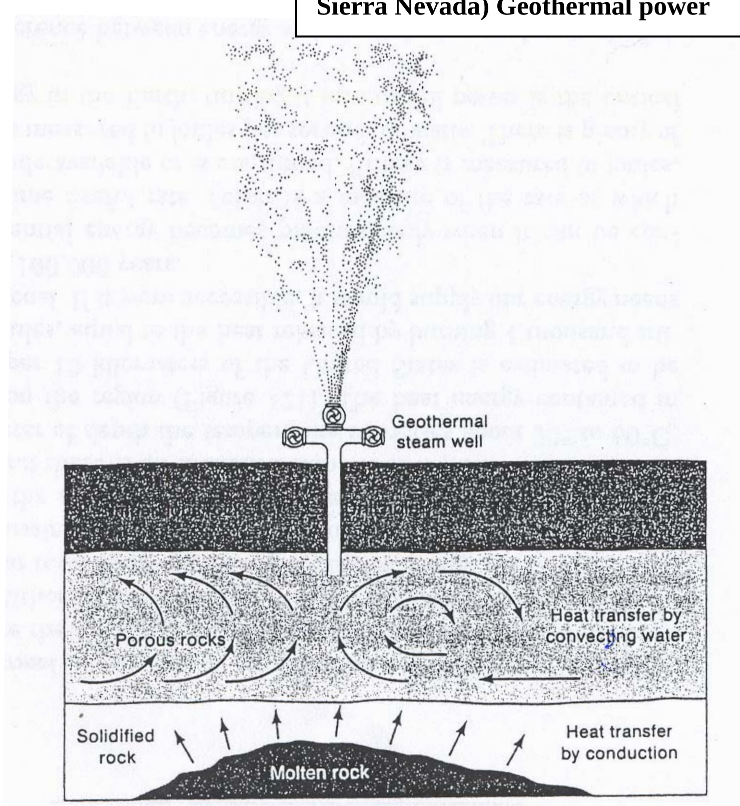
Five Flavors of Geothermal Energy

There are five variations of geothermal resources: hot dry rock, hydrothermal reservoirs, ambient ground heat, geopressured brines, and magma. Hydrothermal reservoirs (Fig. 3) consist of fluids found in permeable rock, which sits upon a very hot, impermeable rock. As the water heats up it rises to the surface, but then cools. As the loss of heat continues it flows outward and becomes dense again, thus it sinks creating a gyre. Eventually the water will reach a median. The next type of resource is geopressured brine. These types of reservoirs are created when decomposing vegetation is trapped in sedimentary basins and produce methane. As the material builds upon itself the pressure increases on the bottom layers and heat also begins to increase (Duffield 17). Geopressured brines are not as conventional or widespread but where they do occur the energy is in high abundance. The corporation, Johnson & Johnson, apply the same principle to power one of their manufacturing plants. They power their plant with the natural gas that is released by a nearby landfill. Hot dry rock and magma contain the highest degree of heat and considering magma and hot dry rock are found perpetually underground, makes it the most abundant of all the resources. Finally, ambient ground heat is the surrounding heat extruding from the ground. All of these geologic features create interesting phenomena.

Natural Features

Such phenomenon includes steam vents, fumaroles, geysers, boiling pots of mud, and hot springs (Duffield 2). Harnessing the earth's heat is not a contemporary field. For thousands of years people have been bathing in hot springs. Romans would relax in a geothermal baths, Vikings would use geothermal heat for cooking, and medieval Europeans would use the heat from the earth to warm their homes

Fig. 3 (Volcanoes of the Eastern Sierra Nevada) Geothermal power



(Duedney 221). Fumaroles are entropic geological features that can be found along fissures. They emit sulfuric gasses along with steam powered by a chamber of magma heating up a chamber of water. Fumaroles have little power output and can be very dangerous (Encyclopedia Britannica Online). The plumbing of geysers and hot springs are essentially identical except for one component. The water that comes up from a geyser is restricted by a narrow space, but with a hot spring, the boiling water comes up to a well (Krystek). Steam resources are the easiest to use, that's why geysers were one of the first geothermal resources tapped (Chambers 132). Northern California's Geysers, the frontier of geothermal power forty-eight years ago, is "the largest source of geothermal energy in the world" (Volcanic Power 126).

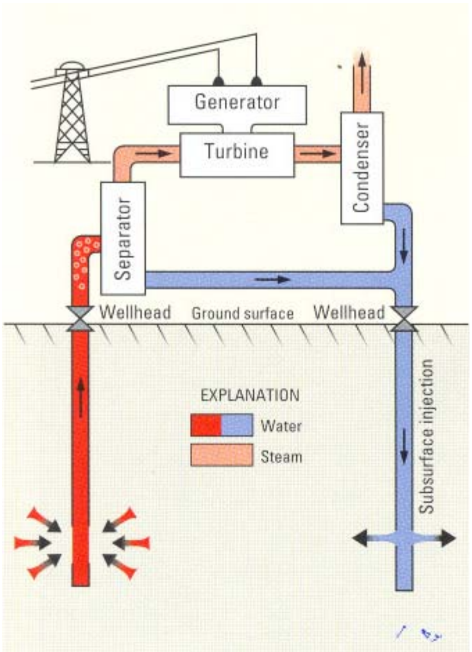


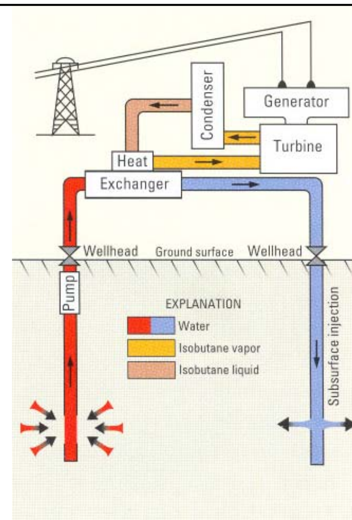
Fig. 4 (Duffield) Water that is above 400 degrees Fahrenheit is pumped so quickly that it turns to steam to drive a turbine.

Potential Side Effects These locations do not go by without problems. The reason there is heat is because current tectonic activity is taking place. That is, there is potential for earthquakes and eruptions. However, it is difficult to say when any of them could go off and to what degree. That is why, politicians, researchers, scientists, engineers, and citizens must collaborate to asses the risk involved. To what extent will they go and what price are they willing to pay when a catastrophic event does occur? The city of Mammoth in California had one escape route; they began to reassess the severity of the geology in their location and thought it best to add another route heading citizens in the other direction. They believed that adding another route outweighed the cost of abandoning the city, for example. On another note, tapping this massive energy source has become another economic savior to the region.

WATER MINING

Extracting Water

Fig. 5 (Duffield) Binary technology uses the hot water to vaporize another fluid which also drives a turbine. This method is efficient for moderate-temperature hydrothermal systems.



How does the hot water power the frying pan in one's home kilometers away from its source? The technology is very simple, yet the key to mastering the efficiency is timing. Seeing as steam is the easiest form of geothermal energy to tap, technology has evolved very well with it. To put it simply, the hydrothermal fluids use to produce steam function to power steam turbines. The steam traverses through a set of pipes directly to a turbine. Just as with hydrological systems, such as dams, these turbines drive electrical generators. This eliminates the need for fossil fuels, such as coal, to heat the water that runs the turbine (Chambers 131). For *high-temperature* water, that is fluids above 400 degrees Fahrenheit, flash steam technology (Fig. 4) is used. The part of the hydrothermal water that flashes to steam is separated and used to drive a turbine generator. The water quickly cools and then is injected back into the ground so that it may prolong the life of the hydrothermal system. (Duffield 11). For *moderate-temperature* water, fluids less than 400 degrees Fahrenheit, a binary system (Fig. 5) is generally most cost effective. Casa Diablo, Mammoth, California's geothermal power plant, uses this type of technology.

Binary System

The initial set up of a binary system is the same: engineers drill one kilometer below the bed rock to encounter water at 300 degrees Celsius and pump it quickly to create steam, which is driven through steam turbines. These turbines move at 1800 rotations per minute. The binary aspect comes into play when they have water that is too cool to produce sufficient energy but too hot to inject back into the ground. The heat of the cooling water is used to vaporize a tank of liquid isobutane, which also runs through turbines (Duffield 17). Now that the water is finally cool it can be used to cool the tank of vapor isobutane, turning it back to a liquid state so that it may be used again. The water has no more purpose so it is flushed back into the subsurface so that it may be used once again. Timing is everything. If the steam is pumped too quiescently then it turns into water, which will damage the turbines. Also if the water is not dumped back into the subsurface before its use, then it begins to loose its ability to act as a solvent. The minerals that were dissolved in solution begin to precipitate. This causes pipes to clog. As with the case of Casa Diablo, their pipes have been clogged with gold. However, developers cannot simply pick a plot of land and begin drilling. Many factors go into consideration before a geothermal plant becomes economically viable.

Hot Spots

Areas of special interest for future development of a geothermal plant are generally known in the business as “hot spots.” The clearest evidence of hydrothermal wells is the presence of hot springs. In the 1980’s, drilling wells would cost close to a millions dollars, and in most cases it was the only means of knowing whether or not that location was acceptable to harbor a geothermal plant (Deudney 225). Today, obtaining an accurate depiction of the volume of a well is rather simple, when using an ultrasonic tool.

The temperature of the heated groundwater can be easily quantified with today's technology. It would not be wise to build a plant upon a well with a temperature close to that of surface water. Only a few hydrothermal deposits have sufficient temperature and pressure to yield dry steam, the most valued geothermal resource (Deudney 220). Another agent in determining plant development is the porosity of the rock. It would be grand if all the hydrothermal wells were lakes which could be tapped with ease, unfortunately this is not always the case. Superheated water can be found in rock, but in the pores of the rock. If a potential hydrothermal system planned on building at a location with geology such as this, they would need to grind up the rock in order to release the water like a miner searching for precious metal.

Rock-Heat Chemistry

The composition and structure of the rock also plays an important role. If hydrothermal alteration (Fig. 6) is evident, then circulation of hot water is the culprit. Superheated groundwater moving through volcanic magma greatly affects the outcome of the rock type. Also, the texture and mineralogy of the rocks varies greatly depending on its interaction with groundwater. Circulating water is highly feasible in mining. Active or young volcanic regions are primary targets, because magma chambers are the

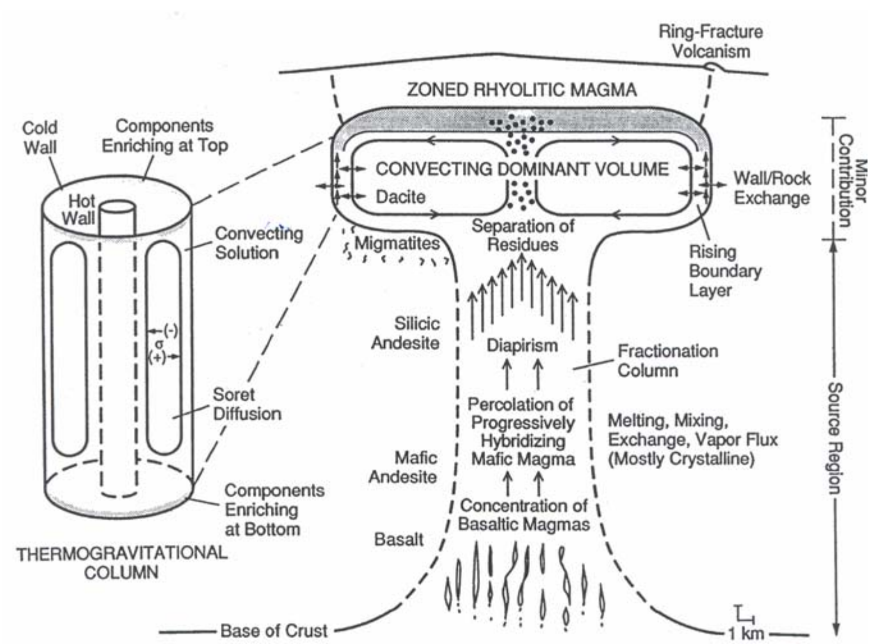


Fig. 6 (Volcanoes of the Eastern Sierra Nevada) The process that affects this kind of geochemical force varies with temperature, pressure, and silica content (among other factors). This process may take up to a million years

instigators in hydrothermal dynamics. They cause the water to heat up and move, thus causing everything else to fall in place. These regions are the primary reason someone would be looking in the area to begin with. Thermal energy generated in the upper crust by radioactive decay of isotopes of uranium, thorium, and potassium are produced at varying gradients of the earth's lithosphere (McGraw-Hill 88). Granitic rock in the upper mantle is a specials source of geothermal heat because it generally contains high amounts of uranium and thorium. At what cost are agencies wiling to pay for the output of potential energy? For Mammoth, it took the area of two football fields for the physical plant, and a well several miles away before gain was to be seen. Once again, mining the water for its power has not been its only use in the past as well as the now.

Direct uses

Hot water has found many direct uses in contemporary society as well as ancient ones. The most common use would be for recreational bathing. People have been gathering at natural pools since words have been scripted. It has been used by the ancient Greeks, Romans, Japanese, and Icelanders (Duffield 2). The uses for this 100 degree water are basic, but nonetheless fundamental. These are the current uses of geothermal energy but are not limited to: washing clothes, boiling vegetables, cooking, brewing tea, drying crops, aquaculture, greenhouse heating, removing moisture from the ground, and onion-dehydration (Deudney 221). Another use for geothermal water is to heat and cool homes (McGraw-Hill 89). Of course, all of this production does not occur without modest discrepancy. There a severe consequences that can result in the death of wildlife to minute problems that can be fixed right away.

ENVIRONMENTAL AND ECONOMICAL COMPLICATIONS

Cost-Benefit Analysis and Hydrothermal Energy as a Renewable Resource

The environmental and economic cost-benefit analysis is crucial to the development of geothermal resources. Foremost, answering the question of whether or not hydrothermal energy is a renewable resource is necessary for further discussion. According to Daniel Deudney's and Christopher Flavin's book *Renewable Energy: The Power to Choose*, all geothermal resources, including hydrothermal energy, are part of the title's concept. However, the argument has been made that "geothermal energy is not strictly speaking, a 'renewable energy source.'" This claim has been made because at certain times, the cooled water used in hydrothermal systems is not pumped back into the subsurface; therefore it allows it to have a lifespan shorter than its counterpart. For the sake of argument, if the resource has potential, if the resource has the option of being renewed, than all other antithesis are irrelevant. For example, petroleum does not have the option of being used again; therefore, it is not renewable.

Environmental and Economical Pitfalls and Benefits of Hydrothermal Power

The only geothermal resource that has been successfully developed for commercial power generation are hydrothermal fluids. This makes geothermal steam an attractive power generation alternative because of environmental benefits and because the unit sizes are small (less than 100 MW) (Chambers 132). However, the negative aspect of this feature is that geothermal power could never be harnessed (with current technology) to power the city of Las Angeles. Contemporary hydrothermal power plants produce little waste, which in turn support a healthy environment. The plants release little or no carbon dioxide. Geothermal power plants are more reliable in comparison to less eco-friendly plants, e.g. new steam plants at the Geysers in California are operable more than 99% of the time (Duffield). However, efficiency levels are a cause for concern. In the same region, Casa Diablo, in Mammoth, only manages to operate at a 50% efficiency level. The good news is that in a few “parts of the world, geothermal systems are cost competitive with conventional energy sources” (Duffield). The philosophy of technology holds true still: as it improves, the cost will decrease.

Production and Pollution Problems

Principle problems arise, creating an imbalance in the cost-benefit analysis. Such primary issues include mineral deposition (some areas are more prone than others), changes in hydrological conditions, and corrosion of equipment. High water temperature and pressure allow water to hold minerals quite well, but events can lead this to do terrible things to a geothermal power plant. Silica deposition is common in California. This occurs when wastewater is not disposed of properly. When unwanted water is dumped on the surface of the ground minerals precipitate out of solution rapidly, creating problems for the machines (McGraw-Hill 90). Hydrological changes occur for a number of reasons. One of them happens when water is extracted from an aquifer causing the chamber to decrease in pressure. As cooler water enters the arena, the whole dynamics change. As temperature changes, so does the availability of steam. Corrosion is not common except in areas of highly acidic waters. Stainless steel, copper-based alloys, and other principle metals corrode as the pH levels in the superheated water decrease. Other inputs include noise pollution, thermal pollution, and water vapor containing ammonia, sulfide, and boron. Casa Diablo is located in a resort town in Mammoth, California. Seeing as it is located miles from a well and even farther from the city, it is safe to presume that a council decided it was best to neutralize the noise pollution by putting the plant as far away as possible. Earnestly, this could not have been the deciding factor in the location, but high rates of tourism can lead politicians to use odd measures.

What *is* the deciding factor? And to what means? Humans have been wading in natural baths for thousands of year and the final frontier of geothermal energy is harnessing all of its resources, from the hot dry rock to its molten cousin.

CASE STUDY: THE FUTURE OF GEOTHERMAL POWER

Ann Chambers

In Ann Chamber's case study "The Future of Geothermal Power," she examines hydrothermal energy, hot dry rock energy, and geopressured brine energy. Chambers defines these resources for the reader and their potential to be harnessed for future consumption. It seems that harnessing these resources is a simple carefree solution because of its benefits, but two important factors remain: the technology to tap these resources is a work in progress, and the competition that gives it an edge against "traditional forms of energy" does not yet exist (Chambers 135). However, according to Chambers, the DOE is working to achieve a geothermal-energy life-cycle cost of electricity of $0.03/kWh. With this new goal in mind, 15,000 MW could be installed during the next ten years (135).

The Three Energies: Hydrothermal, Hot Dry Rock, and Geopressured Brines

Deposit of hydrothermal energy are abundant but undiscovered because their surficial features are difficult to trace and it is also tricky to map regions of the earth that are miles below the surface. There could be five times the number of undiscovered reserves available according to the USGS (135).

The earth's crust of made of rock and much of this rock is hot. One possible technique used in extracting the energy from this hot rock is to create fractures in the rock then circulate water to through the fracture to heat up the water. Then the creation of electricity is possible at the surface with this hot water. The cooled water can go back through the system to be recycled (136). Once again, the problem lies within the lack of existence of such technologies.

Fifteen thousand feet below the surface of the earth rest seas of methane water solutions that have the potential to produce electricity. However, "current technology has not advanced to the point where geopressured brines and magma can be most effectively used for energy production" (135).

The grand hope that all of these resources, when used simultaneously, can produce cast amounts of power for families all across the globe. The United States alone holds 1.5 million quads of energy through ambient ground heat in conjunction with heat pumps (136). The geothermal power harnessed from hydrothermal reservoirs, which is the only one of the resources being used to produce electricity today, marks a mere one-tenth of all the potential resources (136).

Bibliography

Chambers, Ann. *Renewable Energy in Nontechnical Language.* Penwell. Tulsa. 2004.

Deudney, Daniel and Flavin, Christopher. *Renewable Energy: The Power to Choose.* W. W. Norton & Company. New York. 1983.

Duffield, Wendell A. and Sass, John H. United States Geological Survey-*Geothermal Energy- Clean Power From the Earth's Heat*. Circular 1249. 2003

"Geothermal Power." Encyclopedia of Science and Technology. 2002. McGraw-Hill. 9th edition.

"geyser and fumarole." Student's Encyclopædia. 2008. Britannica Student Encyclopædia. 12 June 2008 <http://student.britannica.com/comptons/article-9274544>.

Krystek, Lee. UnMuseum. *Weird Geology: Geysers*. 2000. 11 Jun 2008. \ <http://www.unmuseum.org/geysers.htm>.

Pompa. *Plate Tectonics Mini Lecture*. 10 Jun 2008. <http://www.gasd.k12.pa.us/~dpompa/Mini%20Lecture.html>.

Volcanoes of the Eastern Sierra Nevada: Geology of and Natural Heritage of the Long Valley Caldera. Prof Michael Hamburger. Indiana University Department of Geological Sciences. First Summer Session May 13-27, 2008. *Hydrothermal Systems. Volcanic Power.*