FIELDNOTES

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GEOTHERMAL SPACE HEATING / COOLING

a direct use of naturally occurring hot water in southern arizona

by JAMES C. WITCHER

Hot water derived from geothermal sources may be used directly to heat buildings and homes using conventional wall radiators; therefore, geothermal resources in cold climates are potentially very useful and valuable.

In southern Arizona, significant geothermal reserves are believed to exist; but maximum efficient use of geothermal space heating may only be accomplished for a few days during the winter due to the warm climate. This limited application hardly makes these potential resources viable in southern Arizona. However, this is not the whole story. In fact, given the proper circumstances, natural hot water may be used to space cool, too!

The apparent paradox of using heat to make "cold" is possible by implementing a "not so new" technology called absorption refrigeration. Absorption refrigeration is a cooling process that is efficiently employed to cool areas of human occupancy. Absorption refrigeration may also be used to freeze or preserve food. Conventional absorption units utilize a gas flame or an electric heating coil to heat a boiler or generator within the unit. A geothermal absorption system simply substitutes hot water for the gas or electrically produced heat. Geothermal water that is 80°C to 150°C (175°F to 300°F) is sufficiently hot for absorption refrigeration applications.

Geothermal absorption refrigeration units create "cold" without magic and make use of well known physical phenomena: the boiling temperature of a liquid depends on pressure; and heat is "robbed" from the environment when a liquid boils. It is useful to remember that heat *always* travels from a hot material toward a cold material and not vice versa. In other words, "coldness" may be thought of as the absence of heat.

Figure 1 illustrates how a geothermal absorption process works. Hot water is piped from a geothermal well to the generator (A) where the geothermal heat is used to boil ammonia dissolved in water (the water remains a liquid because its boiling temperature is much higher than that of ammonia). The ammonia gas is funneled over to a condenser (B) which cools the ammonia gas. The cooling gas condenses into pure liquid ammonia. Cooling water for the condenser may be provided by an evaporative (swamp) cooler. The liquid ammonia leaves the condenser and travels through an expansion valve (C). This is where actual refrigeration begins. While passing through the expansion valve, the pressure of the liquid ammonia is reduced and as a result, the boiling temperature of ammonia is lowered drastically. The ammonia, entering the evaporator coils (D), begins to boil vigorously because of the decreased boiling temperature. In boiling, heat is "robbed" from the refrigerated space (E) and taken up by the ammonia in the evaporator coils. A cold temperature results in the

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refrigerated space. The evolved ammonia gas, containing the heat it "robbed" from the refrigerated space, continues its journey into the absorber (F). In the absorber, the ammonia gas gives up its heat and is dissolved (absorbed) in a weak solution of ammonia and water. Again, cooling water for the absorber may be provided by an evaporative cooler. The solution in the absorber becomes very concentrated in ammonia and is pumped to the generator (A) using a small electric pump to begin the process anew.

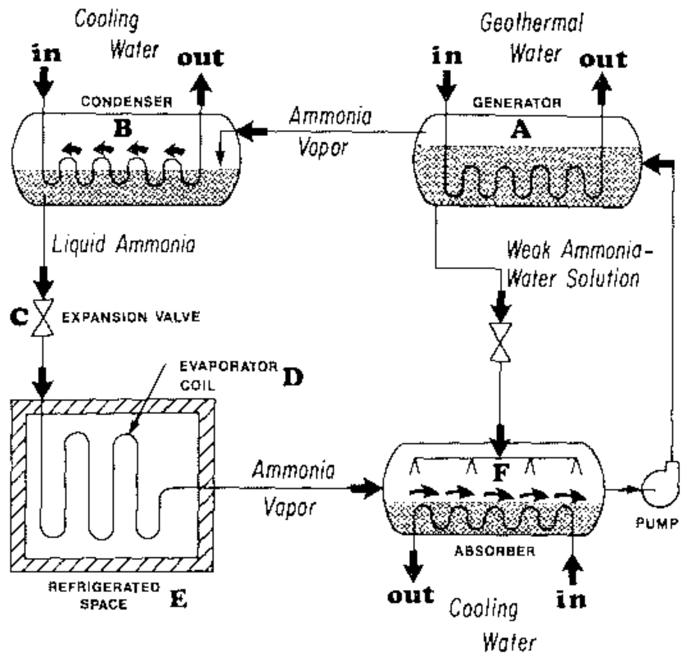

Figure 1, *Geothermal.* Absorption Refrigeration Process (modified from Briendel and others, 1978).

The process just described is an ammonia and water absorption refrigeration system. Water and lithium bromide may also be used in a low pressured absorption refrigeration process. Water is the refrigerant instead of ammonia, and lithium bromide acts as the absorbing medium. A lithium bromide system cannot be used to cool below 0°C (32°F) because the refrigerant (water) would freeze in the evaporative coils.

The 100 room Rotorua International Hotel, Rotorua, New Zealand, is air conditioned (space cooled) by a geothermal lithium bromide absorption refrigeration system. In operation since the late 1960s, the system uses 170 gpm of 117°C (243°F) hot water.

Very hot summers like those of southern Arizona necessitate space cooling of homes and buildings for the comfort requirements of the occupants and due to this, the Arizona utilities experience their peak power loads during the summer. Most areas in the United States experience their peak loads in the winter. In addition to conserving oil and gas, geothermal space cooling of schools, factories, office buildings and shopping centers could partially relieve the utilities of maintaining expensive peak power generating facilities. As a result, consumers' energy costs would be kept to a minimum.

The use of geothermal space cooling in Arizona will depend upon the location, temperature, production (flow) rates and chemical quality of hot water in Arizona's potential geothermal reservoirs. In general, the smallest, simplest, most efficient absorption units (least expensive) require temperatures over 120°C (250°F). An absorption unit in Arizona using 115°C (240°F) hot water is not as efficient as one in New Zealand because of higher summer temperatures in Arizona. The cost of a geothermal absorption system will vary depending mostly on the drilling depth of the geothermal wells, well head temperature, size of the space to be cooled, scope of retrofitting that might be required, and the method of financing. In any case, the initial costs (drilling, retrofitting, financing) are likely to be high. However, there are advantages to using geothermal cooling if a suitable geothermal resource exists: fuel costs are kept minimal; and the used geothermal water still has heat which may be utilized in a cascading fashion in numerous industrial, agricultural or domestic uses requiring low grade heat.

If the geothermal water quality is good, the water may be added to domestic and agricultural water supplies; if not, the water may be reinjected into the earth to be heated again. Hot water space cooling of individual homes is too expensive; but cities or new housing developments could possibly construct "district" space cooling systems integrating neighborhood homes in a cost effective manner. This might be financed in a manner similar to water and sewer utilities. The bottom line in any geothermal space cooling system is the availability of the geothermal resource and the cost of constructing and maintaining the system.

The Arizona Bureau of Geology and Mineral Technology is studying geothermal potential in Arizona for use in space heating and cooling. The studies are a part of an ongoing effort by the U.S. Department of Energy to evaluate Arizona's geothermal resources.

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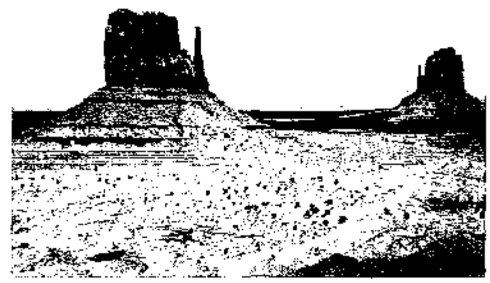
Colorado Plateau Field Trip

by Jan Carol Wilt

Field Trip: Grand Canyon. The top of the cliff is Kaibab Limestone (Permian) underlain by Toroweap Formation. The white band is Coconino Sandstone underlain by sloping redbeds of Hermit Shale and Supai Formation (Permian and Pennsylvanian). The underlying cliff is Redwall Limestone (Mississippian) underlain by the Tonto Group of Muav Limestone, Bright Angel Shale, and Tapeats Sandstone (Cambrian), just above the Great Unconformity on Precambrian schists. Photo by J.C. Wilt.

Field Trip: Oak Creek Canyon near Midgley Bridge. Controversy centers on how this section of sedimentary rocks correlates with Grand Canyon to the north and the closer Mogollon Rim to the south. Is the Hermit Shale of Grand Canyon in this section? Is the Naco Formation of the Mogollon Rim represented? Opinions differ on these questions. Photo by H.W. Peirce.



Field Trip: Monument Valley. Cliffs of massive red DeChelly Sandstone overlie slopes of thin-bedded Organ Rock Shale, both of Permian age. Photo by J.C. Wilt.

Some of the most spectacular scenery on Arizona's Colorado Plateau is cut into the Permian section as canyons or as erosional remnants or buttes, but they are as enigmatic as they are beautiful. The lack of fossils or ash beds frustrates any attempt to establish time lines for regional correlations. The intertonguing and gradational lateral and vertical contacts or facies changes between the various redbed units further confuse any efforts to trace formations for more than a hundred miles.

The Four Corners Geological Society sponsored a field symposium to southeastern Utah and northern Arizona on September 27-30, 1979 to highlight complexities of the Permian section and to publish recent research. More than 100 geologists met at Moab, Utah, for a four-day field trip led by the following persons: Don Baars of Ft. Lewis College, Durango, Colorado; Jack Campbell of the U.S. Geological Survey, Denver; and Dick Rawson and Ron Blakey of Northern Arizona University, Flagstaff.

The first day of the field trip was spent in the vicinity of Moab, Utah. During the morning, the group looked at the redbeds of the Permian Cutler Formation, the breached Onion Creek salt anticline, and the truncation of an aeolian Permian sandstone by Triassic Moenkopi Formation in Castle Valley. From a lunch stop at the spectacular Dead Horse Point overlook, the caravan descended the Shafer Trail on tight, hairpin turns in a nearly vertical cliff through Jurassic and Triassic rocks, down to the Permian and Pennsylvanian formations in the valley 2,000 feet below.

The second day's excursion ranged from Moab, Utah to Kayenta, Arizona, with side trips to uranium and oil areas and to scenic Permian outcrops at Needles, Cedar Mesa and Monument Valley. At the first stop in Lisbon Valley, uranium was being mined from the Salt Wash member of the Morrison Formation (Jurassic), the Moss Back member of the Chinle Formation (Triassic) and the fluvial redbeds of the Cutler Formation (Permian). The uranium in the Cutler was deposited from groundwater without obvious reductants, perhaps by sorption by hematite (see article by Campbell and Steel-Mallory in the Guidebook).

The Permian Cedar Mesa Sandstone was the object of the afternoon's sidetrips to the Needles district in Canyonlands near the Colorado River and to Cedar Mesa, the type section of the formation. The caravan ascended a steep, one way, dirt road called the Mokee Dugway, built to bring uranium from the White Canyon area to a processing mill at Mexican Hat. The road climbs nearly 1,100 feet in 2½ miles through the Permian Halgaito Shale and Cedar Mesa Sandstone. The afternoon ended with stops at the Goosenecks of the San Juan River and Monument Valley. At the Goosenecks, deeply entrenched meanders were incised into thin-bedded limestones, sandstones and shales of the Hermosa Group (Pennsylvanian). The buttes in Monument Valley are erosional remnants of an upwarp that are preserved in some cases by a thin capping of Shinarump Conglomerate member of Chinle Formation (Triassic), underlain by a thin slope of Moenkopi Shale (Triassic). The tall, red cliffs are of DeChelly Sandstone (Permian), overlying lower red slopes of Organ Rock Shale.

The third day's travels extended from Kayenta to Flagstaff, Arizona via Page, the Echo Cliffs, the Navajo Bridge across Marble Canyon of the Colorado River, the Vermilion Cliffs, and the south rim of the Grand Canyon. South of Kayenta, beyond Marsh Pass, the highway follows tracks of the fully automatic electric train that carries coal from the Cretaceous section at Black Mesa to the Navajo generating plant at Page. The highway to Page from Black Mesa for the most part traverses the white, aeolian, crossbedded Navajo Sandstone (Jurassic) with mesas of Carmel Formation and Entrada Sandstone, overlain by Dakota Sandstone (Cretaceous).

The caravan retraced its route along the base of the Vermilion Cliffs and Echo Cliffs (composed of Triassic and Jurassic red sands and shales of Moenkopi, Chinle, Moenave, Kayenta and Navajo formations). A stop at the Little Colorado overlook demonstrated the Toroweap Formation had changed facies so much that it is now nearly indistinguishable from underlying

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GRANTS

Several new cooperative projects between the Bureau of Geology and Mineral Technology and federal agencies have been initiated. These projects, conducted by the Bureau with financial support from the federal agencies, are summarized below:

Assessment of Geologic Hazards in Arizona

Cooperating Federal agency: U.S. Geological Survey, Geologic Division.
Amount of Grant: $30,000.
Tenure of Project: October 1, 1979 to September 30, 1980.
Principal Investigator: Susan M. DuBois.
Objectives: To conduct a statewide inventory of geologic hazards, prepare a map showing areas affected and assess the extent of damages caused.

Historical Seismicity and Late Cenozoic Faulting in Arizona

Cooperating Federal agency: Nuclear Regulatory Commission (The U.S. Geological Survey, Geologic Division, will also be providing financial support for this project).
Amount of Grant: $10,146.
Tenure of Project: October 1, 1979 to September 30, 1980.
Principal Investigator: Susan M. DuBois.
Objectives: To review, analyze and document earthquakes of historic record in Arizona.

Radioactive Mineral Occurrences in Arizona

Cooperating Federal agency: U.S. Department of Energy.
Amount of Grant: $53,442.
Tenure of Project: September 1, 1979 to November 30, 1980.
Principal Investigator: Robert B. Scarborough.
Objectives: To prepare a comprehensive compendium of data regarding radioactive mineral occurrences in Arizona, including location, geology, production, development status and references.

Quaternary Map of Arizona

Cooperating Federal agency: U.S. Geological Survey, Geologic Division.
Amount of Grant: $5,000.
Tenure of Project: August 27, 1979 to June 1980.
Principal Investigator: Dr. Roger Morrison.
Objectives: To prepare a map at a scale of 1:1,000,000 that depicts surficial materials in Arizona.

Mineral Resources Recovery

Cooperating Federal Agency: U.S. Bureau of Mines.
Amount of Grant: $25,000.
Tenure of Project: July 1, 1979 to October 1, 1980
Principal Investigators: David Raab and Dr. Douglas Robinson.
Objective: To recover valuable metals from mine tailings in Mohave County.

McDowell Folio

Two maps, *Waste Disposal* and *Construction Conditions* will be available for purchase from the Bureau of Geology in January 1980, thereby completing the "Environmental Geology of the McDowell Mountains area, Maricopa County, Arizona" Folio.

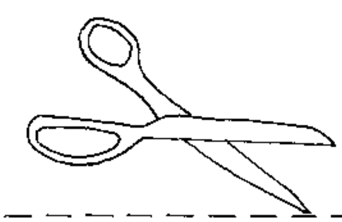
Waste Disposal will cover the suitability of land for septic tank systems, sanitary landfills and sewage treatment plants relative to permeability of sediments, rock structure, ease of excavation and flood hazard. *Construction Conditions* will evaluate land for general construction suitability. Other maps in this folio are: *Geology, Landforms, Land Slopes, Caliche, Ground Water, Material Resources, Geologic Hazards* and *Excavation Conditions.*

Each of the 10 maps sells for $1.25, with the exception of maps #1 and #2 which are presented as a unit for $2.50. The entire set sells for $10.00. The Bureau requests that a 10% (25¢ minimum) handling charge accompany full payment (check or money order) when ordering by mail.

The McDowell Mountain study was prepared by Arizona State University, in cooperation with the City of Scottsdale, with drafting and editorial assistance from the Bureau of Geology.

New Publication

Early in 1980, the Bureau of Geology will be publishing its first edition of *Graduate Theses on Arizona Geology, 1891 to 1978.* This compilation will include the authors' names, theses titles and dates, as well as a subject index. The cost of this publication will be announced in the next issue of Fieldnotes.



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THE MOHAVE PROJECT: Reclamation of Precious Metals

by David Rabb

The Arizona Bureau of Geology & Mineral Technology was awarded a contract by the U.S. Bureau of Mines to determine the feasibility of scavenging valuable metals or minerals from the dumps or mill tailing piles at abandoned or inactive mines in Mohave County. This study, entitled, "The Recovery of Metal Values Prior to Reclamation of Mine Areas in the Southwest", will emphasize site restoration and will be concerned with mines in the predominately gold and silver-producing areas in the southern and western part of the county.

The Federal Civilian Employment Training Agency (CETA) funded a similarly titled project three years ago. The CETA project covered the lead-zinc mines in the Cerbat Mountains north of Kingman.

The Bureau proposes to sample selected mine dump and mill tailings to obtain a set of reasonably representative samples. Mineralogical analyses will be made to determine the values of the ore. Particular emphasis will be placed on the oxidation, the presence of cyanicides and fine clays, and the quantification of locked minerals. If possible, metallurgical testing will be performed on each type of ore to determine the best method of treatment.

Some of the ore in the district may lend itself to a modified heap leach. The gold ores at Congress and Octave, like the Tom Reed ore, had to be ground very fine to effect a reasonable extraction by a cyanide agitation leach. However, the recent success of a large scale dump leach by D.W. Jaquay at the Congress site may have pointed the way to a low cost but feasible leach of the Oatman-Goldroads-Katherine area material.

Two trips to the Kingman area by Bureau personnel have resulted in the following: 1) Contacts with the Mohave County Board of Supervisors, with various mining exploration companies and with individual mine owners; 2) Location and verification of the samples, mine data files and maps acquired by the CETA project. These items are being stored in Kingman. Microfilm records of the maps are now available at the Arizona Bureau of Geology & Mineral Technology in Tucson; and 3) Acquisition of 19 additional samples from dumps and mill tails from five selected properties in the Oatman-Goldroads-Katherine area. These samples are now being processed at the Mineral Technology Branch of the Bureau of Geology. After assay results are available and mineralogical examinations are completed, a decision will be made as to the logical method of processing the individual samples.

Other samples will be obtained after this first batch has been evaluated. Also, careful consideration will be given to the findings of private companies conducting geological exploration work in southern Mohave County. In addition the search for a suitable and available site for a small scale pilot leach operation will continue.

The Bureau intends to develop recommendations for the safe, efficient and most economical processing of the subject waste materials. These recommendations will be presented to the Mohave County Board of Supervisors as a guide to design a plant which will recycle ores from mining dumps in their area.

Dr. Douglas Robinson, Metallurgist, and David Rabb, Mining Engineer, of the Bureau of Geology are the Principal Investigators of this project. Roman Malach, Historian, and the Mohave County Board of Supervisors are the contacts for Mohave County.

Field Trip continued.

Coconino Sandstone. A final stop at the Desert View overlook revealed the classic Grand Canyon section from Permian Kaibab Formation down through Precambrian redbeds and schists.

During the fourth day, which began at Flagstaff, the field symposium concentrated on the controversial redbeds of Oak Creek Canyon and Sedona. The area is isolated from other well-known Permian sections, such as the Grand Canyon, Monument Valley and the Mogollon Rim. This lack of continuous outcrop from which to trace formation boundaries is aggravated by facies changes within the Permian near Oak Creek to more sandy and nonmarine facies, rather than the open shelf or marine facies of the western Grand Canyon, the Holbrook basin or the Pedregosa basin to the southeast.

It is no wonder that so many different formation names and correlations abound at Oak Creek. And it appears that the Permian correlative problem is not much closer to being solved, in spite of the attention focused on it by this field trip.

The Guidebook, *Permianland 1979*, was edited by Don Baars and includes 17 articles on Permian depositional environments, regional correlations, and economic geology (breccia pipes, uranium, gas fields and groundwater). The Guidebook is available for $25.00 in hardbound from the Four Corners Geological Society, P.O. Box 1501, Durango, Colorado, 81301.

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