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ELECTRICITY FROM GEOTHERMAL, NUCLEAR, COAL SOURCES

An Environmental Impact Comparison

R. G. Bowen
Oregon Dept. of Geology and Mineral Industries

Until recently the northwestern states of Oregon, Washington, and Idaho have been able to produce sufficient hydroelectric power for their needs. But the era of building dams across rivers for power purposes is coming to an end and the region is turning to thermal plants to provide electricity for anticipated future demands.

The use of electricity is expanding at a greater rate than the use of any other form of energy. The reasons are that electricity is easily transported, is widely available, convenient, and is clean at its end-use point. Because of the recent ecological awareness by a large segment of the population, this end-use "cleanness" of electricity has been heavily exploited by the marketers of electricity and electrical appliances. Actually, the production of electricity is not necessarily so "clean," for whenever thermal energy in a fuel is converted to electricity waste heat and waste products are produced.

In order to continue to produce electricity at the rate necessary to maintain our present living standard with anticipated population growth, certain compromises or "trade-offs" must be made. It is imperative, therefore, that the public be informed of the way the various sources of electrical energy affect the environment and be able to choose the most acceptable methods for producing electric power in any one region. To that end this paper will discuss the production of electricity from geothermal sources and compare its impact on the environment to that of producing electricity from coal and nuclear resources.

Production of Electricity from Geothermal Resources

Mexico, Italy, New Zealand, Japan, Russia, and the United States are producing electricity from natural underground reservoirs of steam and hot water. In the United States The Geysers field in Sonoma County, California, produces electricity from dry steam as do also the Larderello field in Italy and the Matsukawa field in Japan. The Wairakei field in New

Zealand and the Cerro Prieto field in Mexico utilize hot water. Since at present The Geysers is the only operating geothermal field in the United States, it is necessary to study it to understand the environmental impact of electric power production from this source.

The Geysers field has been in production since 1960, its power output increasing from 12,500 kw with the first unit to the present 192,000 kw, a more than ten-fold growth in 12 years. Presently the development at The Geysers field is sufficient to support an installation of about 800 mw (megawatt equals 1,000 kilowatts) but appears to have even greater potential. In a recent report to the State Senate by the California Geothermal Resources Board, the field was estimated to have an ultimate capacity of from 1,200 to 4,800 mw.

Another geothermal field, the Salton Sea area in Imperial County, California has received a great deal of attention and is being thoroughly studied in the hope that some of the energy known to exist in the field can be developed. The Salton Sea field produces very saline hot water whereas The Geysers produces steam. Environment restrictions on disposing of the saline hot water in the Salton Sea area have been so severe that the discoverers of the field have not as yet been able to produce any power.

Much more energy can be converted to electric power from a given quantity of steam brought to the surface than from the same quantity of hot water. For this reason it is the dry steam fields that are the ultimate goal of the exploration effort and it is this type of field that has the potential to make a significant contribution to the power needs of the West. For example, at The Geysers one kilowatt of electricity can be generated by 20 pounds of steam that is run directly from the ground into the turbogenerator. Of this 20 pounds of steam that passes through the turbine approximately 15 pounds is evaporated in cooling the condenser and the remaining 5 pounds, amounting to 2½ quarts of water, is injected back into the producing reservoir. For a hot water field to produce one kilowatt of electricity, about 80 to 100 pounds of fluid must be brought to the surface; the steam is separated in a flash chamber, then piped to the turbogenerator where it is utilized the same as dry steam. But in this case it is necessary to dispose of 65 to 85 pounds of unused water, or about 10 gallons for each kilowatt of power. Because of the larger volume of water in these fields its disposition would generally present problems. Returning it to the same reservoir would presumably lower the temperature excessively. Rejecting it at the surface could add heat and deleterious elements to surface water. These natural hot waters are usually mineralized, carrying from less than 1 percent to 30 percent dissolved solids. In the steam fields, on the other hand, the steam has been purified by the process of natural distillation deep within the earth and carries essentially no dissolved solids and less than 0.50 percent of other gases. The vast reservoirs of natural hot water that are known to exist in the West present an engineering challenge, and if in the future methods can be found to successfully harness the energy from hot water to electrical generators, this resource could supply a large part of our needed electricity. In the meantime, the dry steam field can be utilized by the present technology.

Although dry steam is known at present in only a few areas, exploration effort will increase as soon as the public lands become available for leasing under the new Federal law. Natural steam exploration in the United States is at about the same stage of development as petroleum exploration was a hundred years ago. However, geothermal exploration has the tremendous advantage of being able to utilize the well-developed exploration and drilling techniques that have been perfected in oil and gas exploration; this factor will undoubtedly greatly improve the success ratio in finding new steam fields. Experts differ widely in their opinions on how many dry steam fields will be found in the western United States, but most agree that, considering world-wide experience, 5 to 10 percent of the geothermal systems discovered will contain dry steam. If so, this resource could be of considerable magnitude, for in the western United States there are about 1200 known hot springs, many young volcanoes, and numerous recent lava flows which cover hundreds of square miles. All of this indicates widespread areas of high-heat flow and a potential source of geothermal energy.

Recently the U.S. Geological Survey has classified 1.8 million acres of land in the western states as "known geothermal resource areas" (KGRA) and another 96 million acres to have prospective value. It is not unreasonable to expect that within this 96 million acres another 10 or 20 fields the size of The Geysers will be found over the next 50 years, and for every "giant" the size of The Geysers there could be 10 fields with a capacity of 100 to 500 mw. In a recent article on geothermal energy in the Bulletin of Atomic Scientists, Dr. Robert W. Rex of the University of California, Riverside, estimated that a concerted exploration effort over the next 30 years should prove a geothermal potential of between 100,000 and 1,000,000 mw of electrical capacity. By comparison, the present power capacity of the United States is a little over 300,000 mw.

Environmental Effects of Producing Electricity from Thermal Sources

The three methods of power production presently under serious consideration in the Pacific Northwest are nuclear reactors, coal - fired generators, and geothermal plants. New and untried methods of power production, such as magnetohydrodynamics, fast breeder reactors, and fusion reactors are possible methods of producing power sometime in the future. However, they are only in the preliminary developmental stages at this time and cannot be regarded as substantial sources for at least 20 to 30 years. Power plants fueled by oil and natural gas, although used extensively in other parts of the country, are not being considered in the Pacific Northwest because of anticipated rising costs and shortages of these fuels.

To understand properly the impact of electric power production on the environment, it is necessary to evaluate more than just the power plant; the entire cycle from mining, processing, transportation, and disposal of spent wastes must also be considered. The effects of these processes on the environment will be discussed under the major headings of "Impact on the land," "Impact on the air," "Impact on the water," and "Impact on the economy."

Impact on the land

The mining of fuels, be it coal, oil, natural gas, or uranium, has developed into a major activity and dominates the extractive industry. Presently 26 percent of all energy resources are devoted to the production of electrical power, and the annual demand for electricity is increasing at a rate twice as fast as the over-all energy demand. This means that by the year 2000 half of our energy production will be used to generate electricity and the extractive activities will have to increase commensurately.

Both nuclear plants and coal plants require the mining of the fuel and both take a considerable amount of land out of service for this purpose.

The AEC reports that the uranium mining industry currently holds over 28 million acres of land for mining and exploration, most of this in two areas in the northern Rocky Mountains and the Colorado Plateau. Not all of this land is going to be devoted to mining, but any mine either underground or open pit requires a significant amount of land. Many millions of acres of land will be required to fulfill the projected uranium requirements. For example, a 1,000 mw nuclear plant would require over its 30-year expected life about 4050 tons of enriched uranium fuel. In order to produce this much fuel, 16,200 tons of natural uranium must be used. This requires the mining of about 1,620,000 tons of ore over the life of the plant. Most uranium in the United States comes from open-pit mines, which as a rule mine about 9 tons of waste rock for 1 ton of ore. For the life of the power plant a total of 16 million tons would have to be removed, requiring a considerable excavation for this one nuclear power plant. Of course, more than 90 percent of this material is returned to the excavation and the land can be rehabilitated.

In addition to mining, the other steps in the fuel cycle - milling, refining, enrichment, conversion, fabrication, reprocessing, and radioactive waste storage - require the construction of large facilities and take a great deal of land out of service. Figure 1 illustrates the steps in the supply of atomic fuel.

The transportation and handling of nuclear fuels, especially the spent fuels, loom large as a potential environmental hazard. There is currently great concern over the packaging, shipping, and storage of the radioactive fission product wastes. The isolation and storage of the high-level fission

ATOMIC FUEL CYCLE

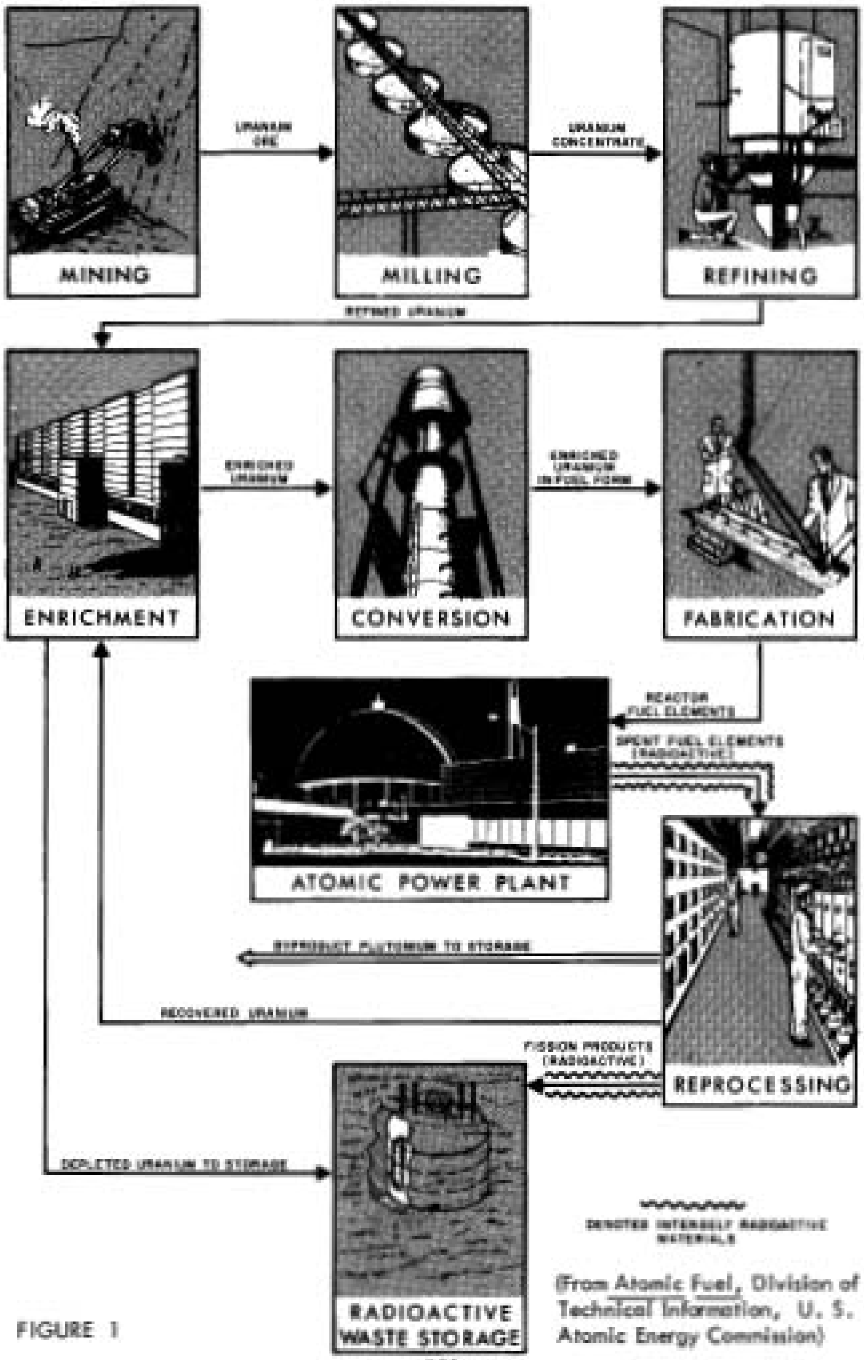

FIGURE 1

(From Atomic Fuel, Division of Technical Information, U. S. Atomic Energy Commission) product wastes, estimated by the AEC to be 60 million gallons produced by commercial reactors by the year 2000, requires large guarded disposal sites. In addition to the high-level wastes that must be isolated, there are large amounts of low-level wastes such as tailings, a waste product generated from the milling of uranium ore. These tailings contain appreciable quantities of radium and other decay products which should be isolated from human contact but are present in large piles adjacent to many of the processing mills. Each of these uses occupies land, and for the high-level wastes this may be for a period of time longer than man's recorded history. It is not possible to estimate the amount of land that may be required by each generating plant, but it appears to be many times greater than the actual power site.

Fossil fuel generating plants, particularly those fired by coal, require a large amount of land for the mine, railroad yards, and coal washing and storage facilities. A coal-fired power plant of 1,000 mw, the same size as the nuclear plant used in the previous example, would require about 100 million tons of coal over the life of the plant. With a ratio of 2:1 overburden to coal this would amount to the movement of about 300 million tons over the life of the plant. Here again the mining operation disrupts the land surface, but with rehabilitation the land returns to its natural state. Coal-fired electric plants usually require more land for the operational facilities than do nuclear plants, but because of the simplicity of the fuel cycle coal-fired electric plants do not require the multiple-step processing, nor do the waste products require guarded isolation.

Coal processing is relatively simple: the coal is separated from waste rock, washed, and then pulverized and blown directly into the boiler furnace. The fly ash from the burning is collected and used as construction material, landfill, or in some instances is put back into the coal mine as fill. This procedure is outlined in figure 2.

The production of electricity from geothermal resources does not require excavation as the natural steam is produced from well bores. Because the steam cannot be moved more than a mile without serious heat loss, the generating plant must be located near the steam wells, thereby localizing the entire environmental impact to the site where the geothermal field is located. Put in its simplest terms, the steam is taken from the ground by wells and collected in pipelines; then it flows by its own energy to the steam turbines at a distance of no more than a mile. Using The Geysers field as an example, present well-flow information indicates that sufficient steam can be produced for a 1,000 mw plant from an area between 4 and 8 square miles. The plants themselves are built among wells in the field to make the pipelines as short as possible. Figure 3 illustrates the cycle for a geothermal field.

Since only a small part of the whole field is required for the wells, pipelines, and generating plants, the rest can be utilized for other purposes such as farming or grazing. For example, at the Larderello field in Italy, where geothermal steam has been utilized for power production for

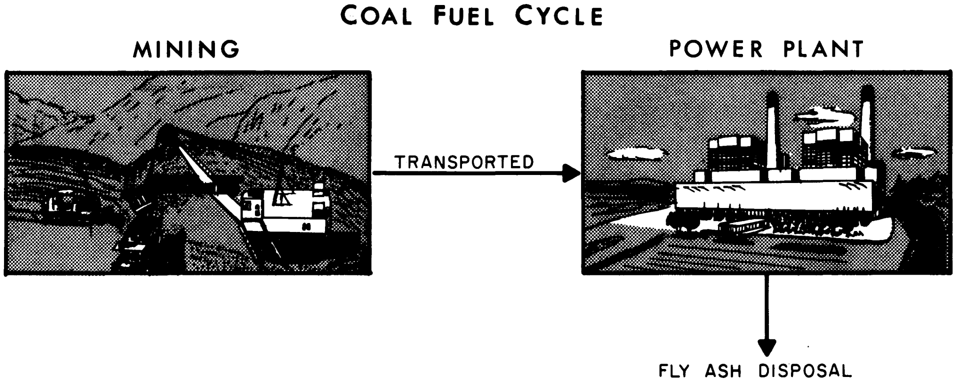

Figure 2. Fuel supply cycle for a coal-fired thermal plant.

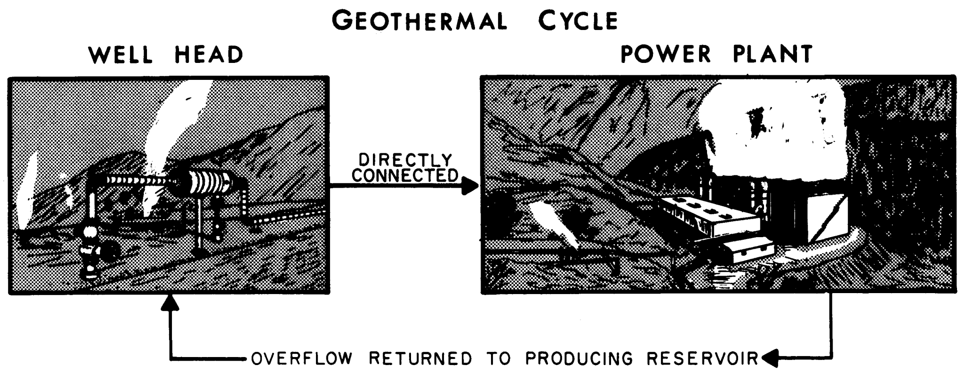

Figure 3. Energy cycle for a natural dry-steam geothermal plant.

nearly 60 years, an intensive agricultural industry is carried on within the steam field, and many vineyards and orchards are interspersed among the pipelines and wells. Figures 4 and 5 are photographs of the Larderello steam field illustrating the agricultural activities carried on within the field while production is going on.

Impact on the air

Gases are rejected into the air from each type of thermal power plant. Nuclear plants emit radioactive gases which are removed directly from the reactor vessel. This gas, mostly tritium, a radioactive isotope of hydrogen, finds its way into the atmospheric processes along with other radioactive products.

Prior to entering the reactor cycle large amounts of radioactive radon gas are released from the mining and milling operations. Radon is a daughter product produced from the natural decay of uranium. Underground mines must be well ventilated at all times to protect the miners from this dangerous gas. In the milling process the uranium is extracted, and the waste rock is sent to the tailings piles where it continues to be radioactive.

It is at the nuclear fuel reprocessing plants that most of the radioactive gases are released. Monitoring of these sites indicates that the amount of radioactivity escaping is below hazard levels, but some scientists point out that as more nuclear plants are built the over-all addition of air-borne radioactivity will increase greatly.

Fossil fuel plants utilize combustion of coal, oil, or natural gas which produce large amount of fly ash, carbon dioxide, nitrogen oxides, and sulfur oxides. This creates visible air pollution as well as other subtle effects and has been the object of most of the complaints against fossil fuel plants. A great deal of success has been achieved in cutting down the amount of fly ash from coal-fired plants by precipitators and other collection devices before the flue gas leaves the chimney. Oil- and natural gas-fired plants do not have as great a problem because the petroleum products contain little if any ash.

Environmental protection rules have caused the fossil fuel plants to cut down on their emissions of both the visible fly ash and the nitrogen and sulfur oxides. A partial solution, at least in urban regions where there is a concentration of these air pollutants, is to move the plants out into the countryside nearer to the mines.

An important point to consider in regard to the impact on the air from fossil fuel plants is that the effects are localized at the point of power production and with modern plants using low-sulfur coal the effects are short-lived. If an extreme temperature inversion occurs, causing peril to life and health, the fossil fuel plant can be shut down and all emissions stopped on very short notice.

The geothermal steam plant operates without combustion and emits no appreciable quantities of deleterious products. Using The Geysers as an example, the steam has an average content of 99.5 percent water. This leaves only 0.5 percent non-condensable gases present in the steam, of which about 90 percent is carbon dioxide with lesser amounts of methane, hydrogen sulfide, and trace amounts of other gases. Because of the remoteness of the area these gases have not been a problem. However, now that the field is being enlarged methods are being developed to eliminate the minor amount of hydrogen sulfide exhausted from the condenser.

Impact on the waters

In order for a thermal electric plant to operate at maximum efficiency the steam must be condensed after passing through the turbine. This forms a

Figure 4. Larderello steam field in Italy showing steam-gathering lines. Note the compatibility of extraction of natural steam with other types of land uses. (Photo by Ira E. Klein, U.S. Bureau of Reclamation)

Figure 5. Larderello power plant with steam-gathering lines passing through an orchard in the foreground. This site has been used for electric power generation for over 60 years with only minimal environmental impact. (Photo by Ira E. Klein, U.S. Bureau of Reclamation)

vacuum which allows further expansion of the steam passing through the turbine and greatly increases its power output. However, to produce the cold sink necessary to condense the steam all thermal plants require large amounts of cooling water. A turbine operating in a noncondensing mode will produce much less power for the same heat input.

One of the most vigorous complaints lodged against thermal plants is that when the cooling water is returned to its source - lake, river, ocean - it has been heated several degrees above its normal temperature. Warming of surface waters may cause a change in the ecological balance, often resulting in the growth of less desirable species of aquatic life.

The alternative involved here is to use cooling towers or to construct cooling lakes if sufficient land is available. Thus by evaporation of a part of the cooling water the temperature of the remainder is brought to near its former level before being returned to its source. Cooling towers or lakes add considerably to the cost of power plants and also need large quantities of water for evaporation. An efficient 1,000 mw fossil fuel plant using cooling towers evaporates 15 to 25 million gallons of water a day, whereas a nuclear power plant, because of its lower thermal efficiency, evaporates about 50 percent more water for the same power production.

The necessity for large quantities of water is becoming one of the limiting factors in the location of thermal generating plants. In the Rocky Mountains, where most of the country's coal resources lie, there is already a shortage of surface and ground water for other uses. Adding the load of several new thermal plants will cause a severe strain on this resource. So great are the requirements for cooling water that at a recent national symposium on "Power Generation and Environmental Change" held in Boston it was estimated that by 1980 one-sixth of the freshwater runoff in the United States will be used to cool power plants, increasing to one-third by the year 2000.

A possible solution to the water shortage problem, but at a greater capital cost, is to use dry cooling towers. The dry tower is based on the same principle as the automobile radiator; it is a series of tubes with air passages that transfer heat directly to the air. By this method there is no loss of water through evaporation, but at times of high ambient temperatures the plant is forced to operate at reduced efficiency, adding to the overall cost.

On the other hand, geothermal plants that utilize dry steam do not require a supplementary source of cooling water. The natural steam, after passing through the turbine, is condensed within the circulating cooling water and thus provides additional water to the cooling towers. By this process an excess of water is produced at The Geysers field and about 20 percent of the fluid brought to the surface is returned to the reservoir where it originated, thus prolonging the useful life of the field. A geothermal plant, thus, is the only type of thermal power plant that does not compete with other uses of water. Increasing competition for our diminishing supplies of water is probably the single most important reason why our geothermal resources warrant development.

No modern power plant adds any appreciable amount of chemical contaminates to the water supply. However, to get the true picture of the impact on the waters, the entire cycle of mining, milling, refining, enrichment, fabrication, reprocessing, and waste storage involved in the production of both fossil and nuclear fuels must be considered. By comparison, since the dry steam geothermal resources are utilized at the point of production the danger of adverse effects on the waters is minimal and in the case of The Geysers field there is none. But before the hot water fields can come into full production methods for handling the excess fluids will have to be perfected.

Impact on the economy

Along with the environmental impact related to the different methods of producing electrical power, we must also consider the reliability of the energy source. Today when so many diverse uses in our complex civilization depend upon electricity, power failures are damaging, causing loss of revenue and inconvenience at the least. The geothermal plant figures importantly in this respect. Because the geothermal system is self-contained, it needs no outside support to maintain the production of electricity, no railroads nor mines, no complex processing plants that can be put out of service. The reliability of nature's own boiler is paramount and has been used to advantage at The Geysers where, because of the constancy of the steam supply, the plants can be operated automatically. This requires fewer personnel and in actual practice the plant is attended by regular maintenance crews only during the 8-hour daytime shift. It is unattended the rest of the time but monitored by a contact station located several miles distant. In the event of a failure within the generating machinery the plant is shut off automatically and started later manually when the problem is located.

The economic success of power production from a dry steam field has been well proven from the 12-years operating experience at The Geysers field, and from nearly 60 years of experience from the Larderello field in Italy. Because all of the steam-generating equipment is inherent in the earth there is no need to construct it on the site. The furnace, boiler and fuel-handling equipment required in a fossil fuel plant, and the reactor-heat exchanger loop in the nuclear plant, are the most expensive parts of those operations. With the geothermal plant only gathering pipelines are needed to deliver the steam to the turbines. Actual plant construction costs are about two-thirds to three-fourths those of a fossil fuel plant and less than half that of a nuclear plant. A lower plant cost means that the "fixed charges" - that is, the part of the cost of electricity based on paying off the cost of the plant, taxes, etc. - can be lower, thus reducing the over-all cost of the electricity.

Summary

The development of geothermal resources has been delayed in the United States for several reasons: the ready availability of low-cost fossil fuels, the general remoteness from load centers of geothermal areas, and more recently the illusion that nuclear power plants would provide all our needed power at a low cost and with no environmental hazards. Significant, also, is the fact that until a leasing act was passed in 1970 all Federal lands, amounting to nearly half of the land in the Western States, were withdrawn from geothermal exploration.

A major change of values within a large segment of the population has forced the electric utilities to re-evaluate their present and planned power-plant siting criteria. This re-evaluation, along with the passage of the Federal leasing law in late 1970, combined with the demonstrated success of The Geysers field, has made geothermal resources much more economically attractive. Leasing of private and state lands is now underway in many parts of the West and plans are being made for the drilling of exploratory wells. At the same time, however, stringent zoning regulations are being proposed that would effectively ban drilling and development of geothermal wells in even the very remote regions of the states. If such regulations are adopted we will have to pay a much higher price for our electricity, both monetarily and environmentally, than if geothermal power is developed to its full potential.

Suggested Further Reading

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WORLD MONETARY SYSTEM

It is anticipated that during forthcoming talks in London regarding the world monetary system key nations will advance a simple arrangement to follow the current period of floating currency; namely, devalue the dollar against gold and make that devaluation part of a broad package of currency adjustments, mainly upward revaluations of other currencies, and lift the U.S. import surcharge. However, President Nixon's economic package was partly designed to force other nations with strong currencies to revalue their currencies upward against the U.S. dollar which would have the same effect as a dollar devaluation. It is the desire of many countries in the Common Market and elsewhere to downgrade or replace the U.S. dollar as a reserve since President Nixon suspended the exchange of each ounce of gold for $35, which had made the dollar "as good as gold." Mario Ferrari-Aggradi, Italian minister of the treasury, said, "The long-term solution that we desire is the creation of a new international standard not dominated by any currency, whatever the importance of the issuing country."

France and some other countries have long advocated increasing the price of gold and strengthening its role in international finance as a solution to the problem. Nations and international agencies hold about $41-billion in gold in their reserves and many would benefit considerably from a rise in the price of gold. The U.S. has insisted, however, it will not increase the gold price.

Experts warn that until the dollar is either strengthened or replaced as a major component of international liquidity, periodic bouts of uncertainty may well plague the world monetary system.

(Nevada Mining Assoc. News Letter, Sept. 15, 1971)

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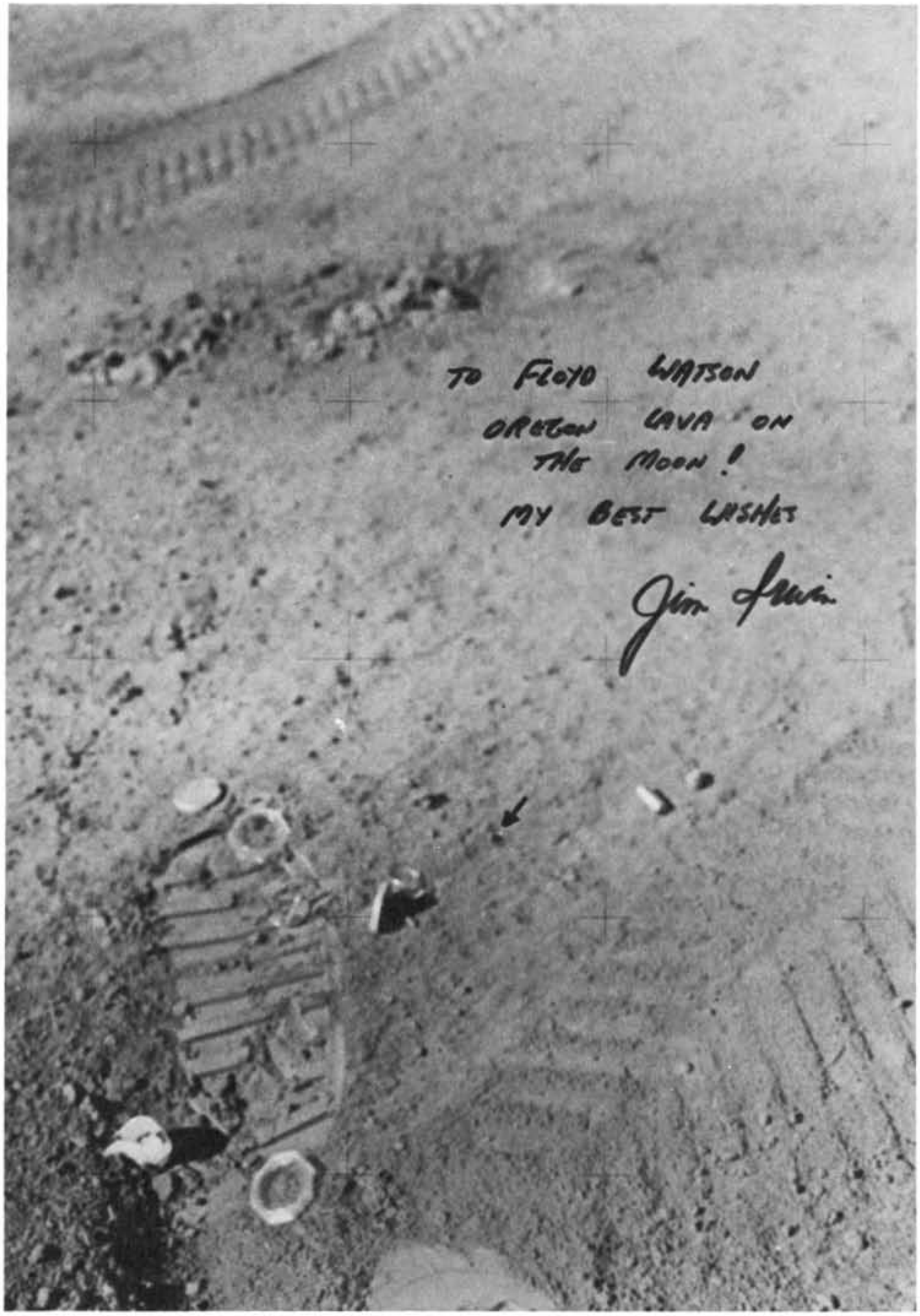

Arrow on this photo of the moon points to sliver of lava from Devil's Lake near Bend, Oregon.

CENTRAL OREGON ROCK RESTS ON THE MOON

Phil F. Brogan

There is a bit of rock from Central Oregon on the bright moon these nights as the orb circles the earth. It was placed there by NASA Astronaut James B. Irwin, who, with David R. Scott and Alfred M. Worden, was aboard Apollo 15 on the highly successful mission to the moon this past summer.

The story of how the Oregon rock, a splinter from a chunk of dacite near Devils Lake on the Cascade Lakes Highway west of Bend, found an eternal resting place on the moon starts with a dinner honoring the 16 astronauts who were guests of Bend in 1966.

Various Bend residents were hosts to the astronauts at a welcoming party at the Bend Golf Club. Floyd E. Watson, Bend building inspector, was host to Irwin and during the evening got well acquainted with him.

In time, Watson forgot the astronauts' dinner. Then in July, 1971, in the list of astronauts for the Apollo 15 mission to the moon was Irwin, graduate of the U.S. Naval Academy and University of Michigan.

Watson immediately wrote to Irwin, congratulating him on his appointment to the Apollo 15 command, adding "I am sending you a small sliver of Central Oregon lava which I hope you will be able to deliver to the moon for me. I have five grandchildren who would be eternally grateful to you." One of the grandsons hopes someday to enter the space program and fly to another planet.

Watson little expected to hear from the busy astronaut. Then came a letter from Irwin, who had toured the base of the Apennine Mountains on the moon, rode with Commander Scott over rugged moonscape, drove an $8 million "moon buggy" to the brink of an awesome rill, and studied billion-year-old rocks.

The letter was brief: "I did carry your sliver of lava to the moon and left it there. I took a picture of the location and will send it to you as soon as it has been properly mounted."

The picture, autographed by Astronaut Irwin, had an arrow pointing to a small black object on the silvery lunar dust. That object was from a tongue of lava which ages ago flowed to the edge of the Devil's Lake basin. Irwin dropped the bit of rock on the moon on July 31, 1971.

The story of the Oregon rock that found its way to the moon aboard Apollo 15 may not be at an end. The Devil's Lake area is in the Bend District of the Deschutes National Forest. Ranger Jack R. Krieger is considering marking the spot, adjacent to the highway, with a roadside sign. That sign, if approved, might read:

"A piece of rock from this site was placed on the moon in July, 1971, by Apollo 15 astronauts."

(The Bulletin, Bend, Oregon, October 2, 1971)

KLAMATH MOUNTAINS GEOLOGY AND GOLD DEPOSITS OUTLINED

"Geology of Lode Gold Districts in the Klamath Mountains, California and Oregon," by Preston E. Hotz, has been published by the U.S. Geological Survey as Bulletin 1290. The 91-page bulletin includes a multi-colored geologic map and a distribution-production map of the lode gold deposits. Bulletin 1290 is for sale by the Superintendent of Documents, U.S. Government Printing Office, Washington, D.C. 20402. Price is $1.50.

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BASALT AQUIFERS OUTLINED IN NORTHEAST OREGON

"Hydrology of Basalt Aquifers in the Hermiston-Ordnance area, Umatilla and Morrow Counties, Oregon," by J. H. Robison, has been issued by the U.S. Geological Survey as Hydrologic Investigations Atlas HA-387.

The Atlas is in two sheets: a geologic map and a hydrologic map, both at a scale of 1:125,000. It gives information on stratigraphy, structure, chemical analyses, and radiocarbon dates of the ground water, and the author's conclusions on the reason for the lowering of water levels in deep wells.

Atlas HA-387 is for sale by the U.S. Geological Survey, Denver Center, Denver, Colorado 80225 for $1.25.

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Page 1

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(Act of August 12, 1970: Section 3685, Title 39, United States Code)

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