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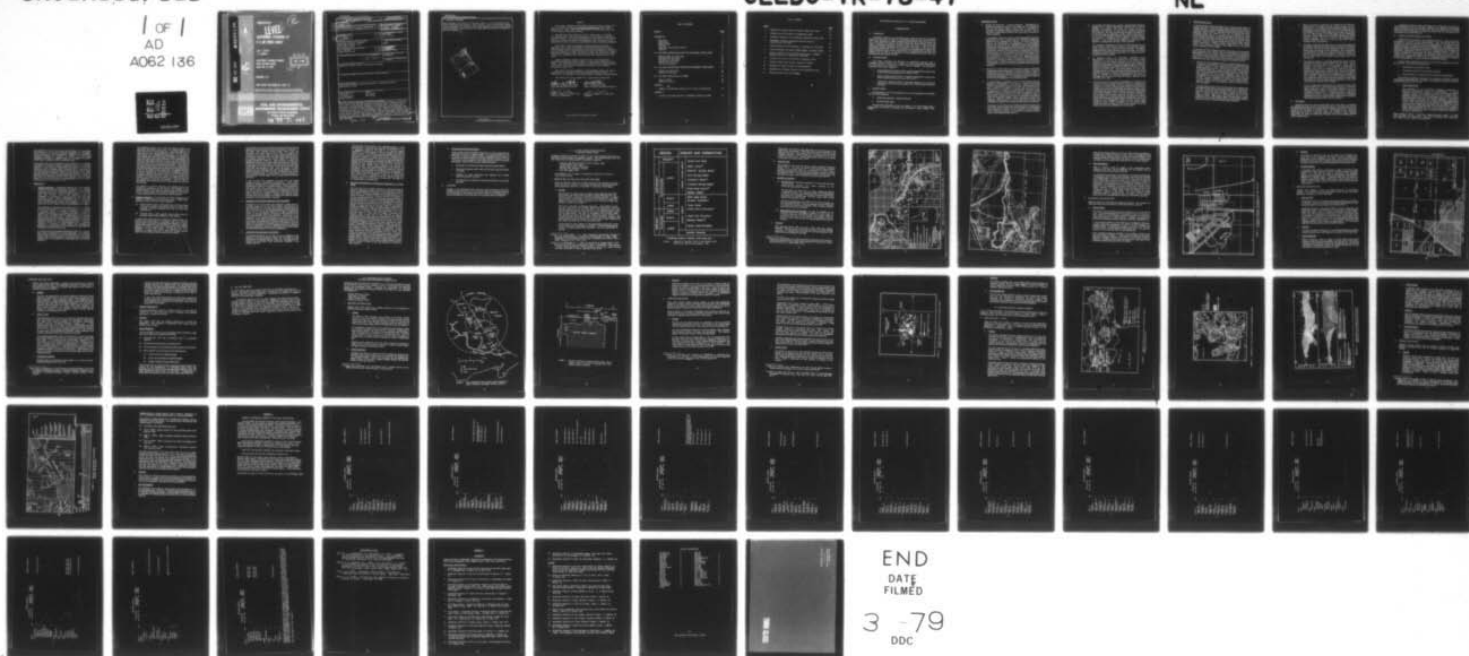
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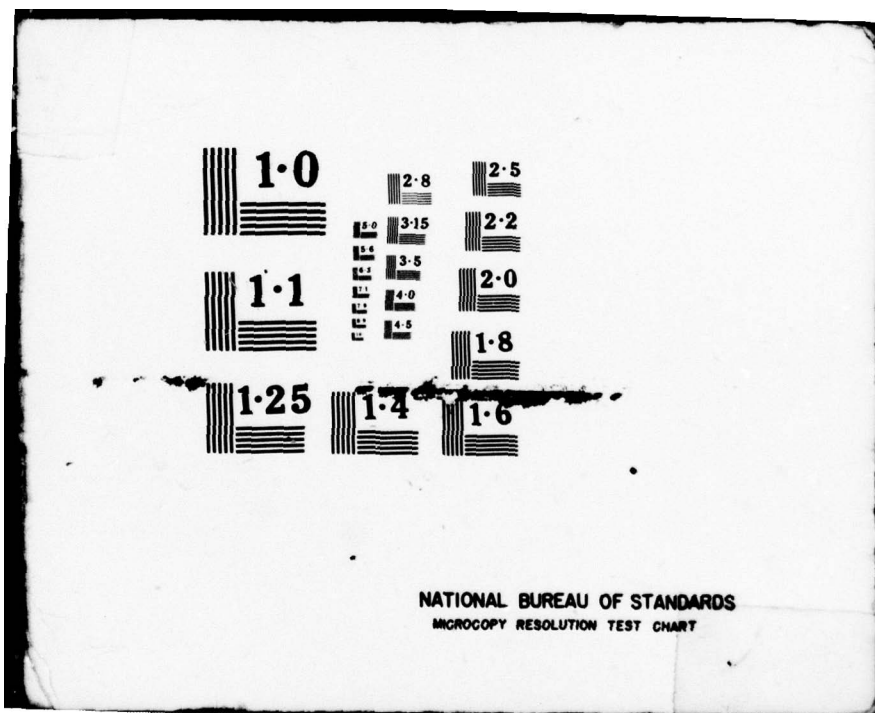
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**GEOHERMAL POTENTIAL AT
U S AIR FORCE BASES**

CARL F. AUSTIN
J. A. WHELAN

GEOHERMAL TECHNOLOGY DIVISION
NAVAL WEAPONS CENTER
CHINA LAKE, CA 93555

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FINAL REPORT FOR PERIOD JAN 77-SEPT 78

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**CIVIL AND ENVIRONMENTAL
ENGINEERING DEVELOPMENT OFFICE**

(AIR FORCE SYSTEMS COMMAND)

TYNDALL AIR FORCE BASE

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20. ABSTRACT (Continue on reverse side if necessary and identify by block number) The Air Force has completed a study of the geothermal potential of USAF bases. This report lists the power generation potential, space or industrial heating potential, and geopressure potential at each USAF base. This report also discusses in detail the data available for those USAF base which exhibit the greatest potential for use of geothermal energy. Bases with significant potential that are discussed in detail include: Mountain Home (space heating), Saylor Creek Range at Mountain Home (power), Ellsworth Air Force Bases (space heating); Keesler Air Force Base (geopressurized geothermal resource*), Hill Air Force Base		

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PREFACE

This report documents work performed during the period January 1977 through September 1978 by the Geothermal Technology Division, Naval Weapons Center (NWC), China Lake, California, and was funded under the Investigational Engineering Program.

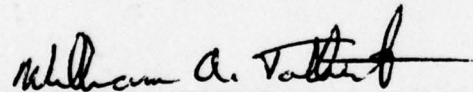
The authors of this report are Carl F. Austin and J. A. Whelan, Naval Weapons Center, who are responsible for the technical accuracy of the data reported. The opinions expressed are also those of the authors and do not reflect the view of the Department of the Air Force or the Department of Defense unless so designated by other authorizing documents.

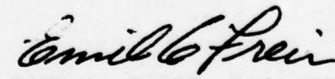
This report contains preliminary findings based on currently available data. Final evaluations of geothermal potential should be based on more detailed site specific data and field analysis. Information contained in this report dealing with legal and institutional factors should be evaluated in light of changes to public law (Title VII, Public Law 95-356, 8 September 1978) which occurred during publication of this report.

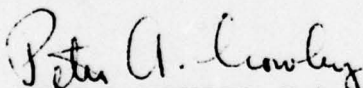
Captain William A. Tolbert, Air Force Civil and Environmental Engineering Development Office (CEEDO), is the project officer for this report. The study on which this report is based was initiated by Captain Jon M. Davis, Air Force Civil Engineering Center, prior to CEEDO's activation in April 1977.


This report has been reviewed by the Information Office (OI) and is releasable to the National Technical Information Service (NTIS). At NTIS it will be available to the general public, including foreign nations.

This report has been reviewed and is approved for publication.


WILLIAM A. TOLBERT, Capt, USAF
Chief, Energy Research Branch


EMIL C. FREIN, Maj, USAF
Chief, Env Engrg and Energy Rsch Div


PETER A. CROWLEY, Maj, USAF, BSC
Director of Environics


JOSEPH S. PIZZUTO, Col, USAF, BSC
Commander

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GEOTHERMAL POTENTIAL AT U. S. AIR FORCE BASES

INTRODUCTION

A. DEFINITION

Geothermal resources may be defined as hot water, hot dry rock, hot carbon dioxide, hot dry steam, or simply any hot geologic material within the crust of the earth, often generated by shallow magmatic materials which were forced into the crust of the earth from below, with the ultimate heat source almost always the decay of dispersed radioactive elements within the earth. These hot zones occasionally manifest themselves on the surface of the earth in the form of hot springs and natural steam vents. The presence of hot springs does not assure that there is sufficient energy to provide space heat or to generate power; however, this presence may be used as an indicator to locate geothermal sources that may potentially be economically feasible.

B. OPPORTUNITIES

This report describes and discusses the geothermal potential that is recognized to date at various sites located on or near continental United States Air Force bases and at selected Air Force facilities overseas. The potential is evaluated in three basic categories:

- o Power generation potential which is limited to geothermal sources that produce temperatures greater than 350°F (177°C).
- o Space heating potential which is limited to geothermal sources that produce temperatures greater than 130°F (54°C).
- o Geopressure utilization which is generally expected to be limited to sources that produce pressures greater than 10,000 pounds per square inch (PSI).

C. MISSION NEEDS

The rationale for Air Force development of its fee owned lands can be divided into two broad categories:

- o Mission encroachment - Mission protection
- o Secured energy supply

The following statements are not all inclusive. As in most cases, when a single subject is the focus of analysis, the statements in each category often overlap.

1. Statements of Need

- a. Mission encroachment - mission protection. Development of geothermal energy on impact or test ranges may be incompatible with the base mission unless a major effort is undertaken to reconcile the potential conflicts between the two uses. Loss of this land to uncontrolled industrial use could result in the loss of mission capability.

It is necessary for the Air Force to control development of its fee owned land in order to experiment with different management alternatives for resolving use conflicts. By directly involving itself in the development and management of the geothermal resource, the Air Force can understand exactly what problems arise and can develop solutions which encompass the requirements of both uses. The potential exists for both uses to co-exist with a minimum of conflict if Air Force pressure is sufficiently strong to force the issue. Air Force presence as an active participant in the field development is imperative if the base's future mission is to be accomplished on an equal priority with geothermal energy development. Only as an active participant in field development can the Air Force assure effective consideration of the particular base's mission. It cannot be assured by working indirectly through a second agency which is not directly affected by the results of its decisions.

- b. Since the Air Force will not be constrained to follow established leasing and royalty requirements, it has the flexibility to trade off the equivalent value of geothermal resource royalties in order to develop and implement solutions to conflicts as they are identified during field development. This management latitude is unique to the Air Force's development of its fee owned land.
- c. An added benefit is obtained if the Air Force program precedes leasing and development of the rest of a Known Geothermal Resource Area (KGRA) on Air Force lands. Where industry might balk at implementing measures to prevent use conflicts, the Air Force will be in a position to provide them with hard facts, including facts on solutions to these problems. Solutions to many problems could be well defined and ready to implement if the Air Force rapidly develops its own land. For example, the types of facilities and systems required to protect the mission environment could be explicitly defined, their operational success and mitigation effectiveness for both limited, and full scale field development evaluated, and capital and operational costs defined.

This ability to actively pursue and develop solutions to protect the Air Force's mission, rather than work through an outside agency whose interest is primarily in the resource, will be critical to future compatibility between the mission and inexorable development of this national energy resource.

- d. In a broader and longer term context, a demonstrated ability to manage the Air Force's geothermal resources and to resolve potential use conflicts will affect the future pattern of geothermal development at other military facilities containing such resources. Not only will solutions to problems developed on an Air Force base be applicable to other military activities, but the Air Force will develop manpower resources and demonstrate an expertise in developing and managing a secured energy resource. This should provide support for permitting DoD agencies to manage such resources at other locations.

The precedents established at the first Air base developed can be used to protect other activity missions, while allowing valuable energy resources to be exploited without conflict. Precedents established will primarily determine the future ability of military activities to prevent mission encroachment in a nation faced with burgeoning energy shortages.

- e. As described above, the precedents established during development of Air Force fee owned land will influence future programs at all other military activities. If the Air Force loses control of its fee owned land to another agency under pressure for geothermal development, a dangerous land management precedent could be established, specifically regarding Air Force or other military fee owned land. The loss of control over such land, especially where a strong, legitimate mission based need can be demonstrated would, in effect, implicitly classify DoD fee owned lands as available for resource exploitation during times of shortages when the need for effective military capability would probably be very high.
- f. If fee owned lands are successfully developed by a contractor, the contractor may have enough incentive to lease the withdrawn land adjacent to fee owned lands. The area could then be developed as a single unit. In such a situation, the Air Force's contractor would already be familiar with a compatible development program which would reduce the overall effort required to maintain compatibility within base boundaries. Since a strong working relationship with the contractor would already exist, the Air Force would have a better opportunity to directly influence management of adjacent withdrawn land where the lessee would be responsible only to the Bureau of Land Management (BLM), and the United States Geological Survey (USGS). Regardless of which industrial agent obtains the lease on adjacent land, proven concepts in the Air Forces contract could be applied to unit operations.

2. Secured Energy Supply

A strong rationale supports development of a secured energy supply for military activities. A secured energy supply would allow an activity to weather shortages or forced allocations of fossil fuel resources without affecting mission capability. Additional benefits include freedom from disruption during civil unrest or war, i.e., it becomes an easily protectable energy source. A nonfossil fuel based (alternative) energy source releases substantial amounts of fossil fuel to the economy which, in turn, reduces dependence on foreign oil sources and possible energy blackmail. Finally, a secured energy source releases energy capacity previously devoted to military activity supply back to the civilian sector. This, indirectly, increases energy supplies without the capital costs of building new power plants.

At this time, the Naval Weapons Center, China Lake, has the greatest known potential of any military activity for developing an alternative, self-sufficient source of energy. Based on estimated energy potentials on Air Force acquired lands and at other locations, it may be possible to wheel power to other military activities not within wheeling distance of China Lake, permitting these bases energy self sufficiency as well.

- a. Perhaps the most significant need for a secured energy source at an Air base is the freedom to continue and/or expand operational capability during a severe energy crisis or during a war where energy supplies are cut off. Not only could these bases continue to function during such a period of stress, but, thus could absorb other Air Force programs without energy constraint, if necessary. The significance of this unique capability cannot be over emphasized. In a crisis environment, the military will be only one of many interests attempting to maintain its energy supplies. With some degree of flexibility, based on a secured energy source, important research and test programs would not have to be cut back or foregone.
- b. A secured energy source at any Air base would allow sophisticated and advanced high energy consuming programs to be relocated to that base, where they could continue to function without interruption by short-term energy shortages or politically determined shifts of energy supply from the industrial sector to the residential sector. High energy projects not technically feasible today due to their large transient effects on power grids would be particularly suited to a secured energy supply situation.

- c. The cost of energy is rising and will continue to rise in the foreseeable future. As energy costs rise, a steady attrition occurs in effectiveness of the Research and Development budget. If, as is anticipated, a secured energy source at an Air Force RDT&E base will establish a flat or slowly rising cost for energy over the long term, the effectiveness of the R&D budget can be substantially increased. The net effect will be more R&D capability for a given amount of funding. This will, of course, be an inducement for locating additional research at such air bases, which further increases budget effectiveness.
- d. Utilization of geothermal resources on Air Force fee owned land to provide energy will offset the need for substantial amounts of oil and gas. The primary direct benefactor will be the civilian economy because energy will be released for their consumption. This effectively increases the energy available and reduces the need for constructing new plant capacity. A reduction in the need for new power plants also reduces overall energy costs to the public sector.
- e. One important aspect of controlling geothermal energy resource development has some unique value to the Air Force. As the search for alternative fuels to power aircraft support activity proceeds, one possibility is the collection or production of hydrogen, which can be reclaimed with geothermal CO_2 to produce hydrocarbon fuels for vehicular fuel. The non-condensable gases within a geothermal reservoir always contain CO_2 and can contain hydrogen (H_2) which could be separated and condensed for use in vehicles. Alternatively, H_2 could be produced artificially from geothermal waste fluids for the same purpose. In both cases, the energy from the field then becomes exportable in forms which can be used for powering rocket vehicles.
- f. With an energy supply belonging to the Air Force located within air base boundaries, it would be possible to effectively protect the supply during civil unrest without being requested to do so by elected government officials. In essence, Air Force ownership of the energy source makes it a "protectable" source, while maintaining a low profile. Under extreme conditions, a guaranteed, protectable source of energy increases overall military capability, while assuring supplies under extreme conditions.

D. PROBLEMS

Geothermal fluids are often contaminated with a wide variety of suspended and dissolved solids and can also contain gaseous matter. As these fluids cool and the pressures are reduced, the precipitation of dissolved solids occurs. This often results in the formation of complex scale. In addition to the solids and precipitates, the fluids can range from highly acidic to highly alkaline. Utilizing these fluids can result in interrelated corrosion, erosion, and scaling problems within a given system.

A geothermal fluid may alter appreciably over a long period of time due to gradual changes in reservoir conditions. Changes in the reinjection and recharge rates, both natural and induced, could alter the water table which can further affect the source temperature. Reinjection of waste water into the reservoir may eventually alter the fluid chemistry.

E. LEGAL AND INSTITUTIONAL FACTORS*

Geothermal steam presents a very real opportunity for a number of Air Force installations to become energy self-sufficient. This may include both the production of electric power and direct heat applications; or, the character of the resource may limit its potential to direct heat applications. Conversely, in some cases the location may permit electric power development but preclude direct heat application. Where the geothermal resource is of high quality and attractive for commercial development, there will be heavy industrial pressure to make the resource available for leasing under the Geothermal Steam Act of 1970. This coupled with the fact that Congress has historically favored development by the private sector, suggests that there would be considerable opposition to exclusive Air Force development of a major commercial geothermal resource.

In many cases a geothermal resource on an Air Force installation would not be attractive to commercial developers due to:

- o Remoteness from available market
- o The quality or quantity of the resource available
- o Physical hazards, or national defense and security considerations

The following paragraphs summarize the numerous institutional and legal considerations surrounding such development of geothermal resources located on lands administered by the Air Force.

1. Institutional Factors

The complexity of the institutional interfaces encountered in geothermal development cannot be overemphasized. A private developer must do extensive research to assure that all requirements of cognizant agencies are satisfied before he can proceed with a geothermal development. For a federal agency (e.g., the Air Force) the legal/institutional constraints are somewhat different. The federal executive agencies, generally, must comply with federal guidelines, and in some cases, with state and local substantive requirements where these are more stringent than the federal (i.e., the Clean Air Act, the Noise Control Act, the Federal Water Pollution Control Act). However, federal agencies generally are not, at the present time, required to comply with procedural matters, including the obtaining of permits at the state and local levels.

*Naval Weapons Center - Geothermal Legal/Institutional Studies, by LCDR J. M. Commander and Peggy Davis. China Lake, California, NWC, September 1977. (NWC TM 3165, publication Unclassified).

One exception to this is the recently enacted Resource Conservation and Recovery Act of 1976 which requires compliance with all federal, state, interstate, and local requirements, substantive and procedural, expressly including the obtaining of permits, for solid waste management facilities or disposal sites, or for engaging in activity which results in disposal of solid or hazardous waste.

It has been found that development of good relations with state and local agencies is essential if federal programs are to avoid controversy. Moreover, if the Resource Conservation and Recovery Act of 1976 indicates a trend in Congress' policy, extension of the requirement to other areas, particularly environmental, is a very real possibility. State and local agencies, therefore, should be kept abreast of plans and progress even where there is no legal requirement to obtain a permit. It also should be emphasized that all such contracts should be made through, or with the concurrence of, the appropriate division of the Air Force Engineering and Services Center.

2. Legal Factors

- a. Resource definition. Geothermal resources have been used for centuries for direct heat applications (hot baths, space heating). During the last century, geothermal resources were used for the production of boric acid. They also present a potential source for many other minerals. Early in the twentieth century the technology for production of electricity from dry steam was developed in Italy. Recent improvements in technology have made it possible to use hot water flashed to steam. Active research and development projects are investigating production of electricity from hot water, hot dry rock, and geopressured zones.

The importance of geothermal resources as a source for electric power was recognized in this country only after the Geysers area in California became a successful undertaking. Failure to recognize the potential of the resource at an earlier date led to a legal vacuum. Increasing interest in geothermal development has led to a rush to fill this vacuum. To date, fifteen states and the federal government have enacted statutes specifically relating to geothermal development. These statutes are neither uniform nor consistent relative to the characterization of the resource. Moreover, to a greater or lesser extent, they emphasize the production of electric power to the exclusion of comprehensive development of the entire resource.

It is clear that the laws affecting geothermal resources are in an early state of development, as is the technology. An important area for legal scholarship is the development of a definition of the resource that will serve adequately in the settlement of ownership disputes, and in the regulation of exploration, development, and production.

The Geothermal Steam Act of 1970, the federal statute, is of paramount importance to this study. Its provisions apply to all lands owned by the United States, but it authorizes disposition of resources only from certain described lands. The Act fails to state exactly what a geothermal energy system is. The description includes heat and other energy in specific formations (i.e., steam, hot water, and hot brine systems). The words "geothermal steam and associated resources" as used in the statute might, on their face, even include coal, oil, and natural gas, as well as other minerals resulting from the geothermal process. This reading of the statute would clearly be too broad in that it would lead to internal contradictions because "by-products" is defined elsewhere in the Act to exclude oil and natural gas. The legislative history of the Act indicates that it was the intent of Congress to include the types of geothermal systems known in 1970 to be useful for production of electric power (i.e., steam, hot water, and hot brine systems). This raises serious questions as to whether hot dry rock and geopressured reservoirs are included. The Act fails to characterize the resource, but implies that geothermal resources are minerals.

The question of resource definition will probably have to be clarified by Congress or by the courts. The question of the characterization of the resource will ultimately be settled in the courts. Several recent court decisions indicate a trend toward characterizing geothermal resources as a mineral resource.

b. Resource ownership. In most cases, Air Force installations are located on lands owned by the United States. These lands, generally, fall into one of two broad categories:

- (1) Public Domain Lands - lands acquired by the United States by treaty or purchase from another country and which have remained in federal ownership from the time they were acquired; and
- (2) Acquired Lands - lands acquired from private owners by purchase, condemnation, donation or other means.

In either case, where both the surface and mineral estates are owned by the United States, it is probably safe to say that the United States is also owner of the geothermal resource. On public domain lands, except for minerals located or leased under mineral leasing or mineral location laws, ownership of the minerals generally is in the United States. On acquired lands, it is necessary to research the title to determine whether mineral rights were also obtained when the lands were acquired.

At this point in time, the ownership of the resource where mineral rights have been severed from the surface estate is in question. In the latest court decision (United States versus Union Oil Company), the United States Circuit Court of Appeals (9th Circuit) has held that, when the United States granted surface ownership to a patentee under the Stock Raising Homestead Act but retained ownership of the mineral rights, this reservation included geothermal resources. Some continue to argue that geothermal resources are a water right and thus are the property of the owner of the water rights. This position has been weakened considerably by the Union Oil case, as well as the two other cases which have been decided to date. Until the question is finally decided, the only completely safe basis for developing a resource will be ownership of the full fee title, including both the surface and the mineral estates. In some cases, it may be necessary to have ownership of water rights, which is usually determined under state laws.

It must be noted that ownership is not the only water rights question involved in geothermal development. Under current technology, development of the geothermal resource necessarily includes use of water as the transfer medium. If this development uses potable water (i.e., suitable for irrigation or domestic use), the right to use the water for production of geothermal resources must be determined. If such rights are not owned by the United States, they must be obtained. Moreover, any disposal of geothermal fluids must be handled in a manner that would not damage the quality of the groundwater in the area.

c. Disposition of geothermal resources on Air Force lands.

Although the Air Force does have authority to lease lands not currently needed for the Air Force mission, this authority has been interpreted not to include water power or mineral resources. Even if this were not so, the express prohibition in the Geothermal Steam Act of 1970 against acquisition of rights to geothermal steam or associated resources, except under the provisions of the Act, would preclude use of this authority. Clearly, due to this prohibition in the Geothermal Steam Act, the Air Force cannot transfer to others, rights to geothermal resources located on Air Force lands. Parenthetically, it should be noted that, if Air Force lands should be leased by the Department of the Interior under the Steam Act, the general Air Force leasing authority may constitute the most satisfactory means for providing sites for power plants and associated facilities on Air Force installations.

d. Authority of the Secretary of the Interior

The Geothermal Steam Act of 1970 is at best ambiguous on the question of whether geothermal leases may be issued on lands administered by federal agencies other than the Department of Interior and Agriculture, those specifically mentioned in the leasing authority.

The Secretary of the Interior in his regulations appears to have assumed that he does have such authority. Interpretations of law in regulations issued by the head of an executive agency responsible for administration of the law are given considerable weight in court. It is, therefore, entirely possible that, unless at some time in the future a court should find the regulation of the Secretary of Interior in conflict with the law, his interpretation will be accepted as correct. In the case of land administered by agencies of the Department of Defense, the Engle Act provides a possible basis for arguing that, at least so far as minerals are concerned, public domain lands withdrawn and reserved for military use are, in fact, lands administered by the Secretary of the Interior. This is because the Engle Act places all "minerals" underlying such lands under the jurisdiction of the Secretary of the Interior. The argument, of course, would be strengthened by final classification of geothermal steam as a mineral-type resource. It must be remembered that this argument exists only for public domain land withdrawn for military use. The Engle Act is not applicable to acquired lands.

e. Air Force Development of Geothermal Resources on Air Force Lands.

The Air Force has no express authority to develop geothermal resources underlying its lands. The Air Force may imply authority where such development is necessary to the fulfillment of the Air Force mission. An inherent problem with implied authority is any attempt to define its limits. The first rule we must observe is that an implied authority will not overrule a specific authority or a specific prohibition. In the case of geothermal steam, Congress has provided that such resources will be developed by lease when they are located on land owned by the United States. It would be possible to argue that this is the only means of development intended by Congress and that no implied authority might be used to permit the Air Force to develop such resources for its own use. The Steam Act, however, is not clearly applicable to Air Force lands and, read as a whole, does not require a conclusion that Congress meant to deny use of such resources to agencies occupying the land where such use is important to their mission. These facts lead to the conclusion that the Air Force may develop geothermal resources on its own lands for its own use. Of course, the prohibition against transfer of the rights to geothermal steam or associated geothermal resources under any other law remains a barrier to any lease or other type transfer. This prohibition also may present a problem in the disposal of by-products. Finally, with reference to public domain lands, the Engle Act may have placed geothermal resources underlying such Air Force lands under the jurisdiction of the Secretary of the Interior. Therefore, on public domain lands it is recommended that no development be planned without concurrence by the Secretary of the Interior. An implied authority, while it may present a proper basis for a small program to meet specific needs, always presents greater hazards when an attempt is made to use such authority to institute a major program.

3. Conclusions and Recommendations

Under suitable institutional/legal conditions, Air Force development of geothermal resources is legally feasible. The implied authority of the Air Force to utilize the lands on which its installations are located to fulfill the Air Force mission may provide sufficient authority for the Air Force to use the resource. Each case, however, must be evaluated individually. Factors which must be considered include:

- o Ownership of the lands and mineral resources located thereon
- o Terms and conditions under which the Air Force controls the lands in question
- o Authority of other departments and agencies over mineral resources located on the lands
- o All other laws and regulations effecting development on the lands concerned

F. LOCATION

Distance to the geothermal source (site) can create problems of hot fluid transport, power line right-of-way, and other legal and ownership problems. For the purposes of this report, only sources within the immediate area or within the boundaries of the individual Air Force bases will be considered.

U. S. AIR FORCE INSTALLATIONS WITHIN THE
CONTINENTAL UNITED STATES

Geothermal resources available to the U. A. Air Force installations with the continental United States are somewhat limited. The following activities have been identified as having potential geothermal resources:

Mountain Home AFB and Saylor Creek AF Range, Idaho
Ellsworth AFB, South Dakota
Keesler AFB, Biloxi, Mississippi
Williams AFB, Chandler, Arizona
Hill AFB, Ogden, Utah

See Appendix A for a summary of Geothermal Potentials of other Air Force Installations.

1. MOUNTAIN HOME AIR FORCE BASE AND SAYLOR CREEK RANGE

Mountain Home AFB, Idaho has probable potential for Geothermal heating, while the Saylor Creek Air Force Range has definite heating potential. Power generating potential is possible in the Saylor Creek Range.

a. Geology

Generalized rock types found in Elmore County (Mountain Home AFB) are Pliocene and Pleistocene sediments, pleistocene basalts, and Tertiary silicic volcanics overlying Cretaceous granite. In Owyhee County (Saylor Creek Range), the rocks are primarily Pliocene sediments and basalts overlying Tertiary silicic volcanics (Young and Mitchell, 1973)¹ (see Figure 1).

The silicic volcanics are Miocene rhyolites. Data present at this time are insufficient to determine whether the rhyolites or granites have the capacity to act as a reservoir. The Idavada volcanics, present in both the Mountain Home AFB and Saylor Creek AFR areas, underlie the Idaho Group. This unit is considered to be the most important aquifer and source of hot water (Young and others, 1975)². The Idavada volcanics are lower Pliocene silicic volcanics; generally the water produced from the complex has significantly higher temperatures than those at nearby wells from overlying units.

The thickness of this complex in the Bruneau-Grand View area is believed to be 915m (3,000 feet) or greater. The underlying granite could be fractured enough from faulting to act as a significant aquifer.

¹Young, H. W., and Mitchell, J. C., 1973, Geochemical and Geologic Setting of Selected Thermal Waters, in Geothermal Investigations in Idaho, Idaho Department of Water Administration, Water Information Bull.No.30, Part 1, Boise, Idaho, pp 12-16, 19-22, 25-33

²Young, H. W., Whitehead, R. L., 1975, An Evaluation of Thermal Water in the Bruneau-Grand View Area, Southwestern Idaho, in Geothermal Investigations in Idaho, Idaho Department of Water Resources and U.S.G.S., Water Information Bull.No.30,Part 2, Boise, Idaho,pp 14-39, 43-46

SERIES			GROUPS AND FORMATIONS		
QUATERNARY	RECENT		SNAKE RIVER GROUP	Recent lava flows	
				Melon Gravel*	
	PLEISTOCENE	UPPER			Bancroft Springs Basalt
					Sand Springs Basalt
					Crowsnest Gravel*
					Thousand Springs Basalt
		Sugar Bowl Gravel*			
		Madson Basalt			
TERTIARY	PLEISTOCENE	MIDDLE	IDAHO GROUP	Black Mesa Gravel	
				Bruneau Formation*	
		LOWER		Tauna Gravel	
	PLIOCENE	UPPER		Glenns Ferry Formation*	
		MIDDLE		Chalk Hills Formation	
				Banbury Basalt*	
		LOWER		Poison Creek Formation	
Idavada Volcanics					

* Formations present in Mountain Home study area

FIGURE 1. SEQUENCE OF CENOZOIC ROCKS IN THE WESTERN SNAKE RIVER PLAIN (RALSTON AND CHAPMAN, 1968)

Structurally, the area has high angle faults on the north side of the Snake River Plain graben. These faults are located northeast of the Mountain Home area. The Bruneau-Grand View area is laced with faults trending northwest. Most of these are down-thrown on the north, toward the Snake River. Vertical displacement can be up to several hundred feet (Young and others, 1975).

b. Source of Heat

The probable source of heat in this area is deep circulation (Young and others, 1975). The area has above normal geothermal gradients. Heating of the ground water to a temperature of 83°C using a geothermal gradient of 6.5°C/100m would require circulation of water to a depth of 1140m. The high geothermal gradient may be due to the thinning of the upper crust in the Snake River Plain (see Figure 2).

c. Geothermal Gradients

- (1) Mountain Home: Geothermal gradients in the base area are on the 4.0-6.0°C/100m contours, with higher gradients of 8.9-9.0°C/100m just north of the base.

The base gets its water from six wells, tapping the general groundwater system. The average discharge is 2,231,000 gal/day. A driller's report indicates the Bruneau Formation basalts were encountered at 360-400 feet (91-122m) below land surface (Ralston and Chapman, 1968)³.

The water temperatures are 67-70°F (19.4-21.1°C) throughout the base hydrologic sub-area. Chemical analysis indicates uniformity of composition (Ralston and Chapman, 1968): however, published geochemical data is not available.

- (2) Saylor Creek Air Force Range: No data are available for the immediate area, but a geothermal gradient map (see Figure 3) indicates gradients of 8.2-20.9°C/100m on the western margin of the area in the vicinity of Hot Springs. One gradient of 34 and another of 32.8 in the area may be isolated geothermal highs for the area.

d. Summary

Both Mountain Home AFB and Saylor Creek AFR have definite potential. Mountain Home for heating, and Saylor Creek for heating and power. A definite heat source has not yet been defined in the region and data is lacking for the range.

³ Ralston, D.R., and Chapman, S.L., 1968, Ground Water Resource of the Mountain Home Area, Elmore County, Idaho, Idaho Department of Reclamation Water Information Bull. No. 4, Boise, Idaho, 63 pp

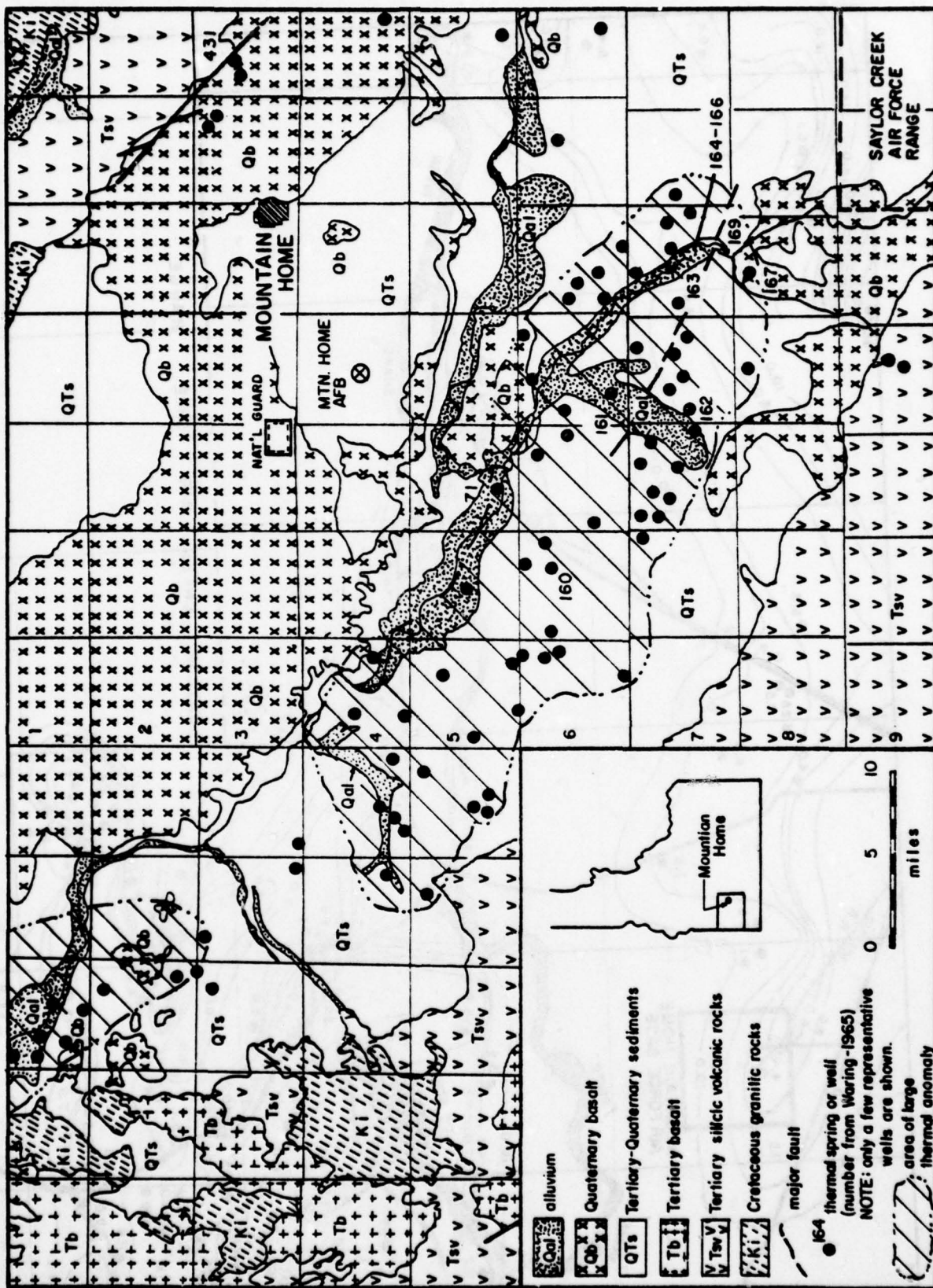


FIGURE 2. THERMAL AREAS AND GEOLOGY OF SOUTHWESTERN IDAHO (ROSS, 1971)

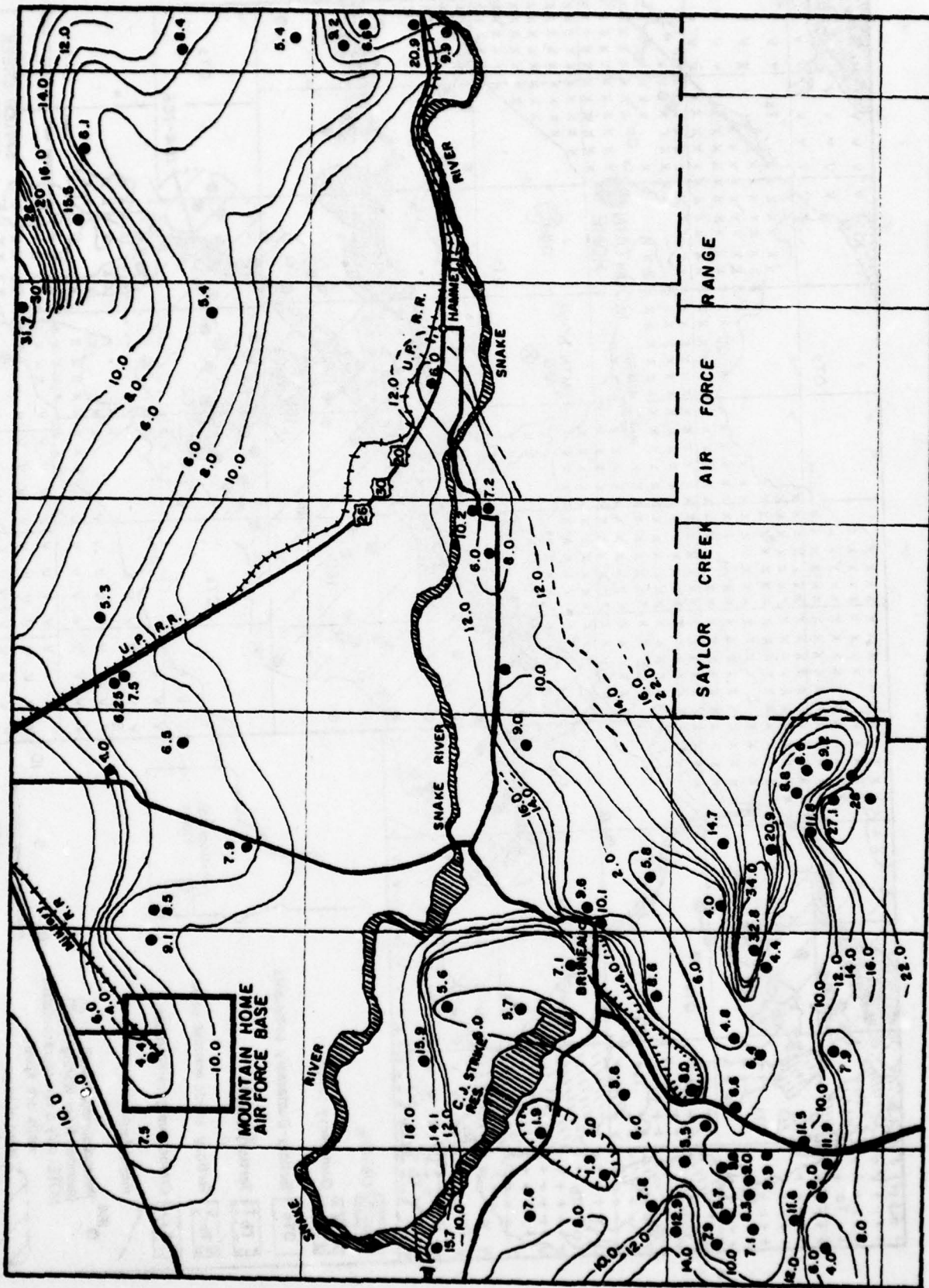


FIGURE 3. GEOTHERMAL GRADIENTS IN THE MOUNTAIN HOME/SAYLOR CREEK AREA (WHELAN, 1977)

Most data available indicate the source of high geothermal gradients is probably due to deep circulation of water which is recharged by spring run-off entering exposed volcanic outcrops in the nearby highland. The aquifers are both in sedimentary and volcanic rocks (vesicular basalts and tuffs), with the hottest water being driven from volcanic aquifers.

e. Recommendations

Wells in existence should be logged to get temperatures, water chemistry, heat flow, thermal gradients, and total depths, both on Mountain Home AFB and Saylor Creek AFR.

It is felt that the above data, in combination with published geophysical and geological data, should provide adequate information for selection of a drilling target. It should be noted that if data obtained from the Saylor Creek Range does not indicate power potential, it should be eliminated from consideration for heating alone because of the impracticality of distributing hot water of heating temperatures over a distance of this magnitude to Mountain Home, where it would be used (40km). However, if gradients and heat flow temperatures prove to be anomalously high, a drilling target should be selected for power exploratory purposes on the Range. The Naval Weapons Center geothermal staff, in conjunction with the energy staff at Mountain Home AFB have recommended a drilling site in the central base area.

2. ELLSWORTH AIR FORCE BASE

Ellsworth AFB has a potential for geothermal heating. The potential for water-dominated systems suitable for power generation is unknown.

a. Source of Heat

The source of the geothermal gradient anomalies is not known at this time. It has been postulated that the probable causes are friction, or deep circulation at the boundary of relative movement of two precambrian shield provinces in South Dakota, a boundary concordant with geothermal anomalies, causing the heating, resulting in high gradients.

A well located in Section 13, T2N, R8E near (or on) Ellsworth AFB has a recorded down-hole temperature of 49.4°C (121°F), adequate for heating purposes. The geothermal gradient for this hole is $3.1^{\circ}\text{C}/100\text{m}$ ($1.7^{\circ}\text{F}/100$ feet) with total depth of 1349m (4425 feet). This well was drilled in 1947 for water by the U. S. War Department.

Other geothermal gradients available in the immediate vicinity of the base are plotted on Figure 4. In the built-up portion of the base, geothermal gradients between $4.0^{\circ}\text{C}/100\text{m}$ and $4.5^{\circ}\text{C}/100\text{m}$ would be expected. At depths of 950m (3200 feet) and 1100m (3500 feet), water suitable for space heating should be encountered.

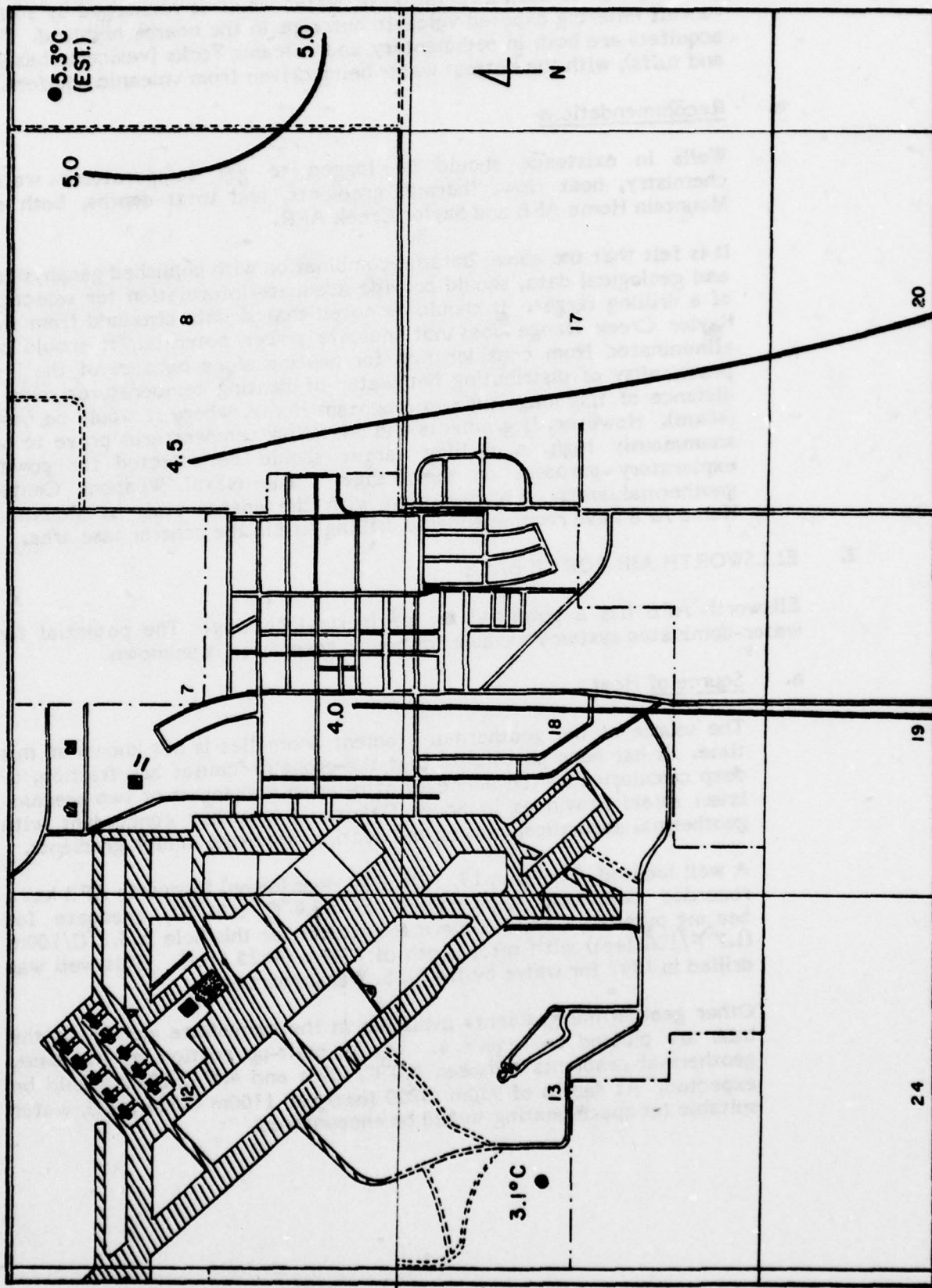


FIGURE 4. GEOTHERMAL GRADIENTS DETERMINED FROM WELL DATA ON FILLSMORTH AIR FORCE BASE (LHFI AN)

b. Summary

The location of Ellsworth AFB, and its relation to hot springs in the area, lead to the conclusion that there is definite potential for geothermal resource utilization at the base. This conclusion is further augmented by the fact that in Midland, South Dakota, some 100 miles to the east, a small school is currently being heated by geothermal water.

c. Recommendations

A thorough study should be performed of wells in the area to get temperatures, water chemistry, heat flow, thermal gradients, and total depths. It is felt that this data, in combination with published geophysical and geological data would provide adequate information for selection of a drilling target. A relatively deep test hole should be drilled to approximately 1850m (6000 feet) to study gradients at this depth as well as analyze aquifers and provide material for geochemical water analysis.

3. WILLIAMS AIR FORCE BASE

Williams AFB Chandler, Arizona, has definite potential for geothermal heating. The potential for water-dominated systems suitable for power generation is unknown, but looks interesting.

a. Source of Heat

The geologic source of the geothermal gradient anomalies is not known at this time. However, an area known as the NOMAD geothermal field is located adjacent to and probably under Williams AFB.

Geothermal Kinetics, Incorporated (GKI), a private corporation, has leased and drilled 2 wells in Section 1 of Township 2 South, Range 6 East. Well number 1 has a total depth of 9,207 with the depth to water of 421 feet. The temperature of the water is 301°F. Well number 2 has a total depth of 10,450 feet with similar findings. Well number 1 has a flow rate of 6000 gallons per minute and is considered "producible." Figure 5 illustrates the portion of the NOMAD geothermal field originally leased by GKI in relation to base property. It is on the GKI lease that two test wells have been drilled by industry.

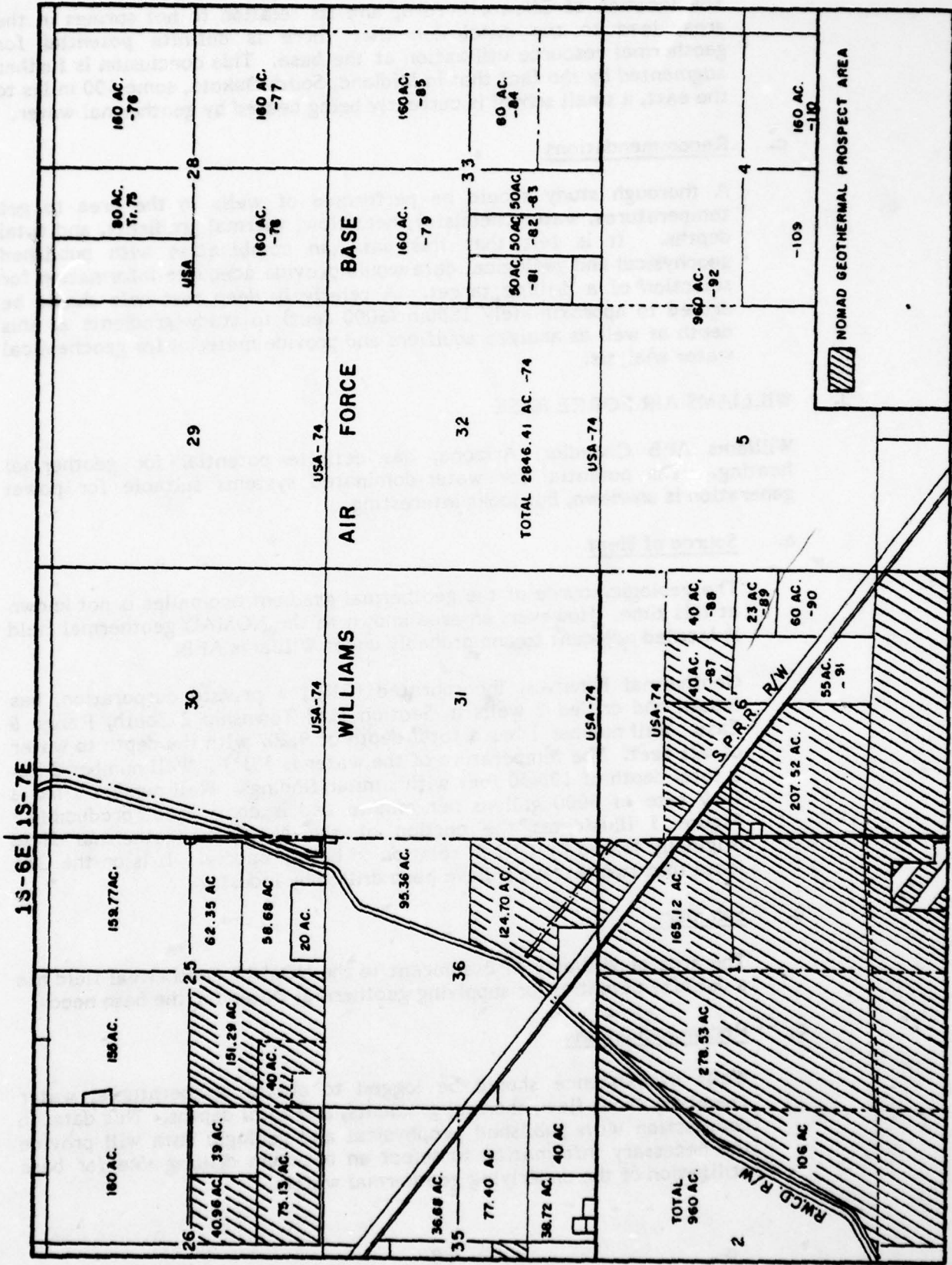
b. Summary

The area of Williams AFB adjacent to the NOMAD geothermal field has a definite potential for supplying geothermal water for the base needs.

c. Recommendations

Wells in existence should be logged to obtain temperatures, water chemistry, heat flow, thermal gradients, and total depths. This data, in conjunction with published geophysical and geologic data will provide the necessary information to select an optimum drilling site for base utilization of the underlying geothermal water.

13-6E | 1S-7E



2S-6M | 1S-6M

FIGURE 5. NOMAD GEOTHERMAL FIELD PROXIMITY TO WILLIAMS AIR FORCE BASE

4.KEESLER AIR FORCE BASE

Keesler AFB, Biloxi, Mississippi, is located in an area known as the Gulf Coast Geopressurized Zone. The geopressure potential for Keesler AFB is very good due to its proximity to known high pressure wells located in extreme southwestern Alabama.

a. Geology

The Gulf Coast geosyncline was formed during the Cenozoic by clastic sediments eroded from the central United States, particularly the Rocky Mountains. These sediments consist of interfingering marine sands and clays. In general, subsidence of the syncline into the oceanic crust has kept pace with the on going deposition, with the focus of deposition shifting gulfward with time. Major faults parallel to the basin margin accompany this subsidence vertically offsetting the bedding as deposition moved seaward, thereby forming discrete reservoirs in the sedimentary section.

b. Source of Heat

High sedimentation rates of up to 1.2 meters per thousand years in the Gulf Coast geosyncline basin coupled with intrusions of semi-molten salt diapirs have created subsurface hot (90° - 300° C), pressurized, aquatic reservoirs containing dissolved methane gas. These "geopressured" reservoirs lie under a zone of impermeable shales and clays that are within 1.5 to 3.0 km of the surface and extend to depths of 7 to 15 km. Three energy producing phases may in the future be extracted from these geopressured reservoirs: kinetic (hydraulic fluid pressure), geothermal (heat), and combustion (methane).

The potential geothermal energy is within reach of current technology and drilling techniques, but to date not even pilot plant studies have been made. It is estimated that off-the-shelf hardware for its exploitation will not be available for about ten years. Problems remain too, in detailing exact reservoir characteristics in a localized area. Serious problems exist as to: what aquifer, water can be reinjected into; power requirements for reinjection; and the possibility of land subsidence caused by extraction of the waters. Legal problems may arise as to whether the resource comes under petroleum, ground water, or geothermal law.

c. Geopressure Gradients

Detailed data on the reservoir under Keesler is not known, however, Stone and Paddison (1977)⁴ note that:

⁴ Stone, A.M., and Paddison, F.C. (1977) Status of Geothermal Energy in the State of Alabama, Operational Research, Geothermal Energy Development and Utilization, 33, Geothermal Program. Region 5 ZJOCQO, Support: ERDA DGE, 2p

"Several test wells (oil) drilled in Baldwin, Escambia, and Clark Counties (extreme S.S. Alabama) have run into geopressurized reservoirs that caused serious problems. The Watson well, drilled by Phillips Petroleum and Getty Oil encountered high pressure and after much trouble was closed off. Another well ran into calcium chloride at 16,000 feet and required a drilling mud of 21 lb/gal in order to kill the well.

A well in the Piney Wood field hit an area where pressures of 20,000 psi blew it out. Stainless steel casing had to be used; costs for completing the well were \$15 to \$18 million rather than the expected \$1 to \$2 million."

d. Pressure Requirements

Minimum geopressure required to generate power is on the order of 10,000 PSI. As noted previously, there is evidence that adequate geopressure is available in the area.

e. Summary

The Keesler AFB area has definite potential as a source for geopressure. The availability of geothermal water systems appears however to be minimal.

f. Recommendations

In the immediate vicinity of any anticipated future production a deep test well is required to establish the following:

- (1) Sustained flow rate from a particular level in a particular reservoir.
- (2) Flowing well-head pressures and temperatures.
- (3) The exact depth to the isothermal surface required for production.
- (4) Water samples from the reservoir to be used showing:
 - (a) Amount and type of dissolved solids.
 - (b) Amount and composition of dissolved gases.
 - (c) Change in salinity during constant flow.

Effort should also be directed toward understanding the chemistry and controls of the geochemistry of formation waters from the geopressurized zone and from the normally pressurized zone where the spent geothermal fluids would be reinjected. Developments in exploitation of geopressured zones should be continuously monitored.

5. HILL AIR FORCE BASE

Hill AFB, Ogden, Utah has probable potential for geothermal resource utilization. The extent of these resources is unknown at the present time since the necessary data is currently unavailable. Evaluations are however in progress, and will be provided when completed.

The geologic setting at Hill Air Base suggests that deep drilling might produce fluids suitable for space heating. Commercial test drilling in a comparable geologic setting to the north at Brigham City encountered 295°F water at 12000 feet in a marble horizon, but flows were only of the order of 50 gpm. The data in hand regarding Hill Air Base was transmitted to EG&G and is incorporated in their detailed study (Ref Donovan and others (1978)). One note of caution was demonstrated at the Brigham City test hole as the hot fluids ran 65,000 to 70,000 ppm dissolved solids, suggesting corrosion and scaling as well as disposal concerns.

U. S. AIR FORCE INSTALLATIONS OUTSIDE THE CONTINENTAL UNITED STATES

Geothermal resource information available for U. S. Air Force installations outside the Continental United States is basically limited to information from published sources and professional papers. Utilizing this information, the following installations have geothermal resources either on the base or in the immediate surrounding area.

Bellows AFB, Oahu, Hawaii
Lajes AFB, the Azores
Cigli Air Base, Turkey
Ankara Air Station, Turkey

1. BELLOWS AIR FORCE BASE

Bellows AFB, Oahu, Hawaii has probable potential for the production of geothermal power and space heating.

a. Geology

The Island of Oahu represents the remnants of two major volcanic centers in which the principle volcanism took place between two and three million years ago. Erosional remnants of these two volcanoes are represented today by the Waianae Mountains along the west coast of Oahu and the Koolau Range along the southeastern coast (see Figure 6).

It is reasonable to expect that if any subsurface heat remains in these two dormant volcanoes, the major part of it would be concentrated in these volcanic stocks. The amount of heat persisting until the present time will depend on how effective the cooling has been. That the central stock of Koolau Volcano may still be warm is indicated by resurgent activity which occurred as recently as 31,000 to 33,000 years ago.

Magnetic surveys performed across the island indicate the presence of dense rock in a stock-like mass under each of these mountain ranges. (Strange, Mockensky, and Wollard, 1965)⁵

b. Seismicity Surveys

Changes in the velocity of seismic "P" waves through the surface of the earth are widely used to locate zones with unusually high temperatures. This discrete change in travel time has been used to delineate the general outline of the stock or magma chamber beneath the remnant Koolau Volcano (see Figure 7).

⁵ Strange, W.E., Machevsky, L.F., and Wollard, G.P., A Gravity Survey of the Island of Oahu, Hawaii: Pacific Science, v. 19, pp 350-353

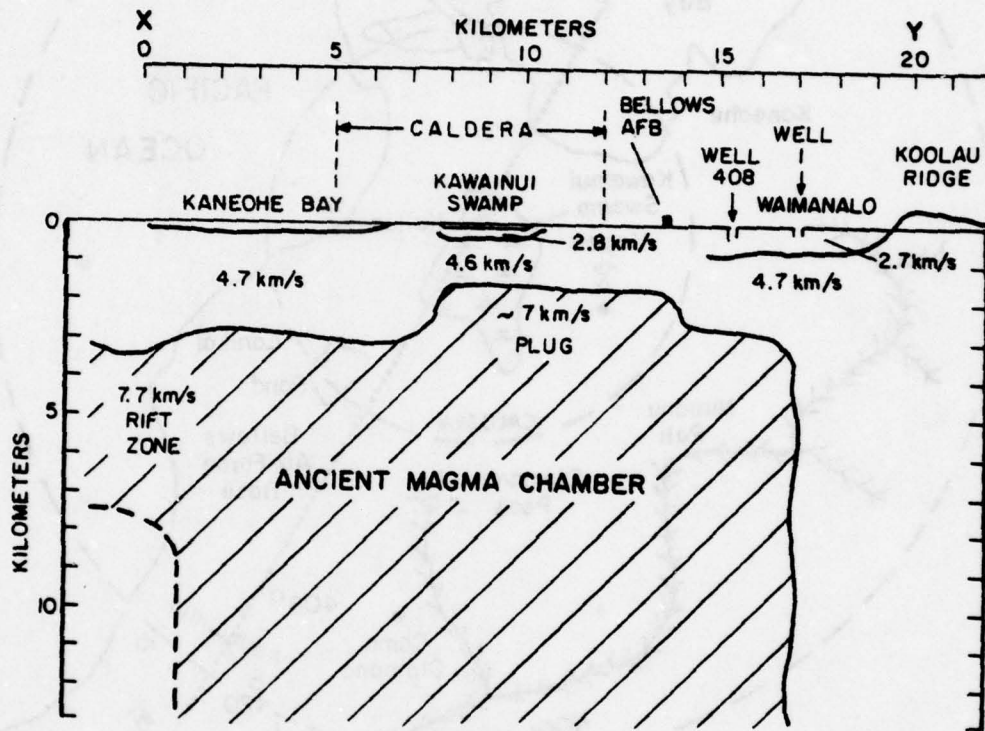


FIGURE 7. VERTICAL PROFILE OF CROSS-SECTION ALONG LINE XY SHOWING RELATIVE POSITION OF BELLOWS AFB, (GEOTHERMAL ENERGY MAGAZINE)

c. Summary

Geothermal gradients from wells in the vicinity of Bellows AFB are presently unavailable, so an accurate determination of the temperature change with depth is impossible at this time. Using the plot of the relative location of Bellows AFB to the ancient Magma Chamber (see Figure 7) it can be extrapolated that the potential for geothermal resource utilization at Bellows AFB is very good. A comprehensive program to determine thermal gradients should be pursued.

2. LAJES AIR FORCE BASE

Lajes AFB, Terceira Island, Azores, appears to have good geothermal potential. The base is also a NATO base, and is located in the northeastern portion of the Island of Terceira, three miles (4.8 km) east of the city of Praia do Victoria. Terceira is in the District of Angra do Heroismo.

Several islands in the Azores Archipelago have geothermal potential for power and/or heating. Estimates of potential power have been made as many hundreds of megawatts being available in these islands.

a. Geology

Terceira and San Miguel Islands are considered to have the greatest potential for geothermal resources. Both islands are of volcanic nature with San Miguel having three major volcanos and Terceira having two.

The basic stratigraphic sequence is a series of basaltic flows, trachytic flows, basaltic breccia, ash falls, and ignimbrites. This sequence appears to be typical of both Terceira and San Miguel.

On San Miguel Island, drilling done in 1973 by geoscientists from Dalhousie University and Lamont-Doherty Geological Observatory on the flanks of Agua de Pau, a major volcano (950m elevation above sea level) garnered down-hole temperatures of 200°C (392°F). This temperature was encountered at 550m initially and, at the time of last measurements, at 290m depth (Muecke, et al, 1974)⁶.

⁶ Muecke, G.K., Ade-Hall, J.M., Aumento, R., MacDonald, A., Reynolds, P.H., Hyndman, R.A., Quintino, J., 1974, Deep Drilling in an Active Geothermal Area in the Azores, in Nature, Vol. 252. 11/22/74, pp 281-285

The boiling point was exceeded during drilling and steam erupted from the hole when the drill rod was removed. No flow measurements were made and permeability of the core has not been measured. The eruption of steam and hot water was stopped after 20 minutes before any depletion was noted. Power potential of this hole, therefore, is not known.

The 200° water boiled when it reached the temperature-pressure boiling curve near 215m depth.

Temperatures were nearly constant to 100m (20°C - 25°C), then a sudden jump in temperature to over 100°C (212°F) occurred between 100 and 175m depths. A uniform gradient was then established of 250°C/km (25°C/100m) to 550m depth. After that, a low gradient of less than 10°C/km (1°C/100m) was established to the bottom of the hole, approximately 900m.

Terceira Island has two large calderas in the eastern and central parts of the island (see Figure 8). The volcanos are aligned on a west-north-west trend. A graben strikes northwest in the northeastern portion. The oldest rocks are ankaramites, succeeded by relatively young basalts, trachytes and olivine basalts (Ridley, et al, 1973)⁷.

Although there are no hot springs known on Terceira, the central volcano, Caldeira de Guilherme, has water vapor present and temperatures of 90°C (194°F) (Waring, 1965). There is much CO₂ and H₂S, and sulfur deposits are present. The rocks are considerably decomposed, probably indicating severe hydrothermal alteration.

Faulting is generally right lateral transform with tension normal to the axis of the Ridge (Mid-Atlantic Ridge). Normal faulting results along with crustal extension. The faulting in the Azores is directly related to Ridge activity (Arroyo and Udias, 1972)⁸.

b. Source of Heat

The source of heat has not been defined, however hot water flows, parallel to the bedding, down dip from the volcanic source. The low-bottom hole temperatures indicate that the source is not under the drill site. Impermeable beds at 102m restrict vertical circulation of the hot water. Figure 8 illustrates the base location in relation to the volcanics.

⁷ Ridley, W.I., Watkins, N.D., MacFarlane, D.J., 1973, Oceanic Islands, Azores, in Oceans, Basins and Margins, Vol. 2, North Atlantic, pp 450-457

⁸ Arroyo, A. Lopez, and Udias, A., 1972, Aftershock Data of Azores-Gibraltar Earthquake of February, 1969, in Bull. Seis. Soc. Amer., Vol. 62, June, 1972 pp 717

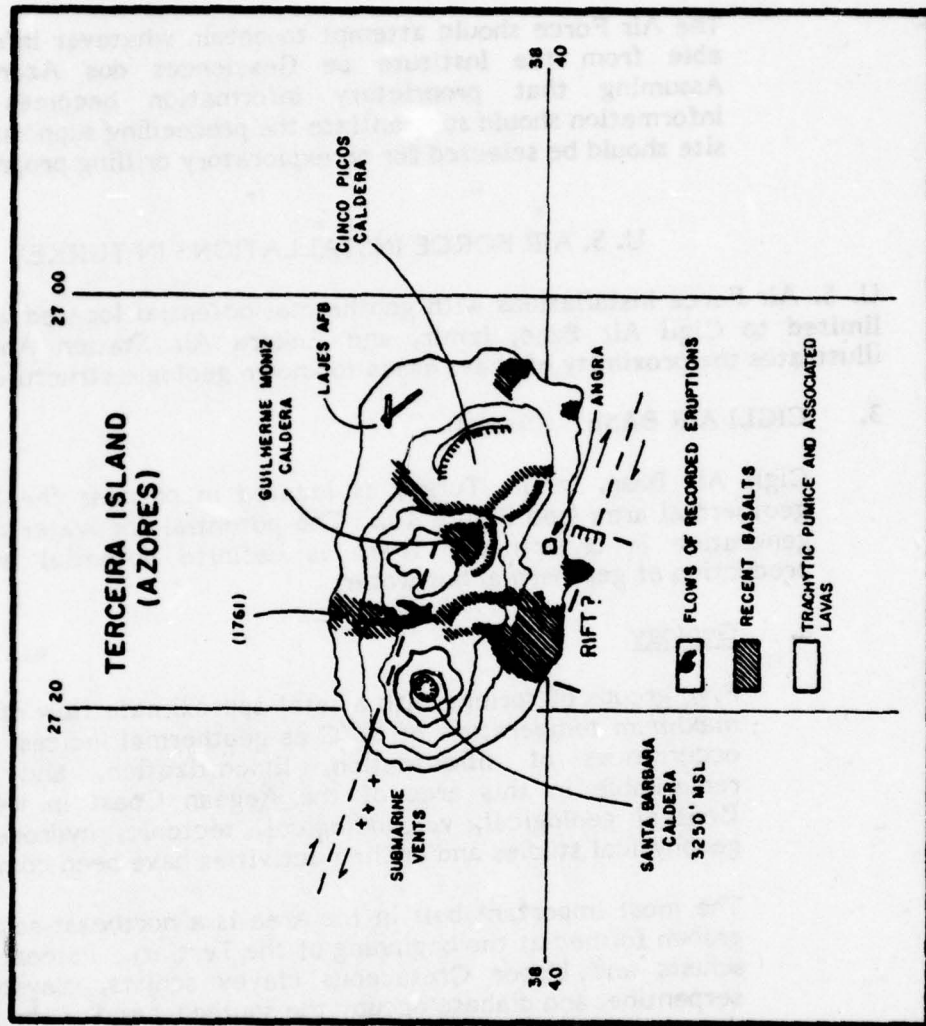


FIGURE 8. LOCATION OF LAJES AIR FORCE BASE ON TERCEIRA ISLAND (MACHADO AND QUINTEHO)

c. Summary

The results of drilling tests on San Miguel Island, and the similarity of structure between the two islands suggests a strong probability of similar geothermal resources which should provide as a minimum adequate geothermal water.

d. Recommendations

The Air Force should attempt to obtain whatever information is available from the Institute de Gesciences dos Azores, San Miguel. Assuming that proprietary information becomes available, this information should substantiate the preceding suppositions and a target site should be selected for an exploratory drilling program.

U. S. AIR FORCE INSTALLATIONS IN TURKEY

U. S. Air Force installations with geothermal potential located within Turkey are limited to Cigli Air Base, Izmir, and Ankara Air Station Ankara. Figure 9 illustrates the proximity of these areas to known geologic structures.

3. CIGLI AIR BASE (Closed)

Cigli Air Base, Izmir, Turkey is located in or near the Izmir-Seferihisar geothermal area (see Figure 10). The potential for water dominated power generation is uncertain. There is definite potential however for the production of geothermal hot water.

a. Geology

Five groups of springs with a total approximate flow of 110 l/sec and a maximum temperature of 82°C as geothermal indices; with widespread occurrences of silicification, limonitization, and travertine are remarkable in this area of the Aegean Coast in western Anatolia. General geological, volcanological, tectonic, hydrogeochemical, and geophysical studies and drilling activities have been completed.

The most important belt in the area is a northeast-southwest-trending graben formed at the beginning of the Tertiary. Paleozoic metamorphic schists and Upper Cretaceous clayey schists, claystone, limestone, serpentine, and diabase occupy the southeast end of the graben, while at the northwest end, Upper Cretaceous flysch with dominant limestone facies occurs. Figure 11 shows two characteristic sections of the Seferihisar area.

The graben has been filled with beds of sandstone, claystone, millstone, clayey limestone, limestone, and coal, which are Neogene in age. Young faults cutting these 1200m thick levels with cap rock characteristics have possibly provided the formation of perlite, tuff, agglomerate, tuffite, and ignimbrite at the top. In the later phase (probably Upper Pliocene or at the beginning of the Quaternary), young rhyolite and rhyodacite domes appeared, passing through these tuffs and agglomerates.

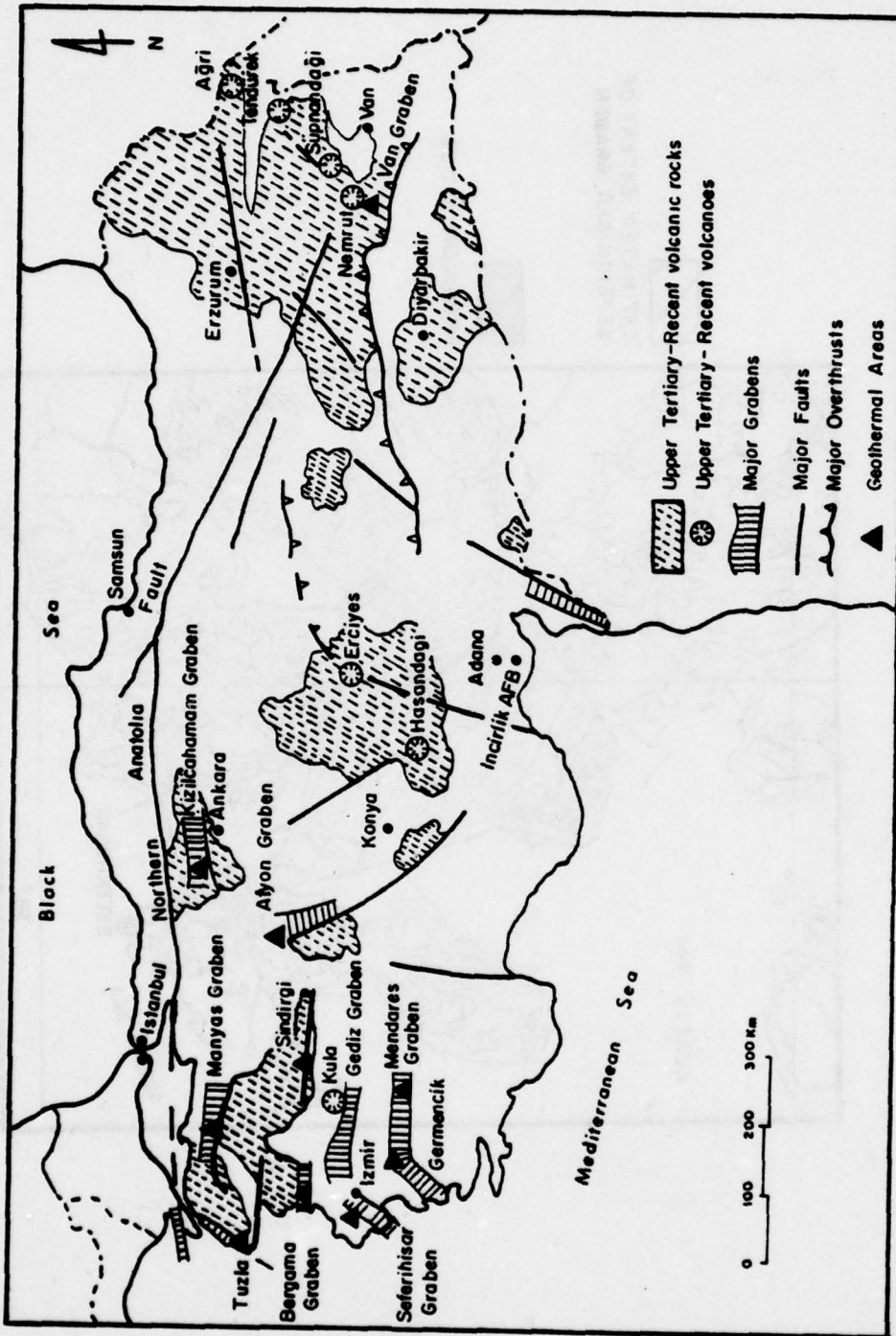


FIGURE 9. GENERAL TECTONIC AND VOLCANIC FEATURES OF TURKEY (KURTMAND AND SAMILGIL)

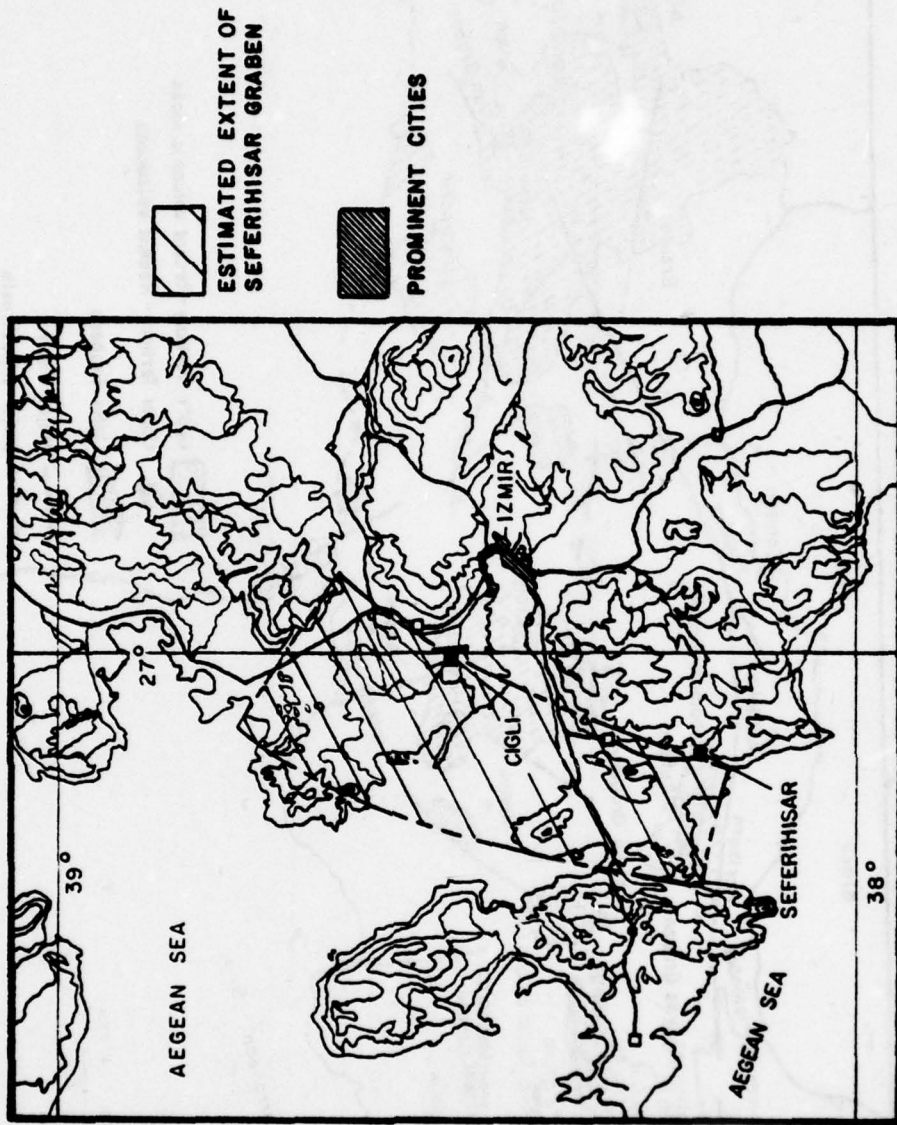


FIGURE 10. PROXIMITY OF CIGLI AIR BASE TO THE SEFERIHISAR GRABEN

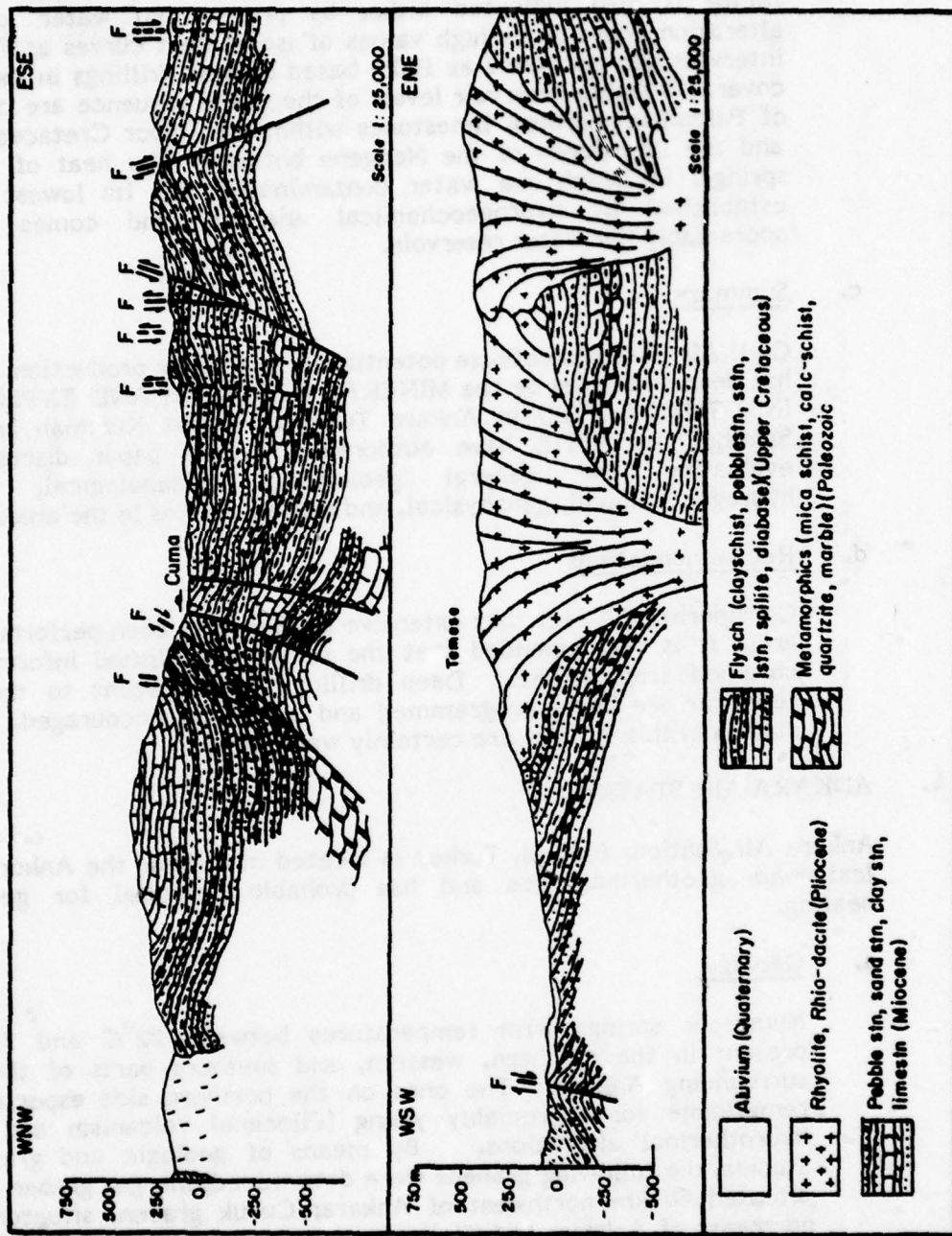


FIGURE 11. CHARACTERISTIC GEOLOGIC SECTION IN THE SEFERIHISAR AREA (KURTMAN AND SAMILGIL)

b. Source of Heat

A probable magma pocket of the young acidic volcanics, still in its cooling period, is thought to be the source. The existence of such a factor is also indicated either by present hot water springs and alteration zones or by high values of isogradients at 90 to 110m intervals and isotherms at 100m based on test drillings in the Neogene cover. Probable reservoir levels of the whole sequence are constituted of Paleozoic marbles, limestones within the Upper Cretaceous flysch, and the limestones of the Neogene bottom. The heat of the Cuma springs, in which sea water contamination has its lowest value, is established by hydrogeochemical analysis, and comes from an appreciably hot water reservoir.

c. Summary

Cigli Air Base has definite potential for hot water production. The area has been evaluated by the MINERAL RESEARCH AND EXPLORATION INSTITUTE (MTAE) in Ankara Turkey. Fikret Kurtman and Erman Samilgil⁹ of MTAE have authored a recent paper discussing and evaluating the general geological, volcanological, tectonic, hydrogeochemical, geophysical, and drilling studies in the area.

d. Recommendations

Considering the fact that extensive studies have been performed on the area, it is recommended that the recently published information be obtained from MTAE. Deep drillings with descent to the second reservoir are being programmed and should be encouraged. Further studies in this vicinity are certainly warranted.

4. ANKARA AIR STATION

Ankara Air Station, Ankara, Turkey is located in or near the Ankara - Kizilcahamam geothermal area and has probable potential for geothermal heating.

a. Geology

Numerous springs with temperatures between 22°C and 55°C are present in the northern, western, and southern parts of the region surrounding Ankara. The ones on the northern side especially, are remarkable for appreciably young (Pliocene) volcanism and related hydrothermal alterations. By means of geologic and gravimetric studies, the following grabens were determined; Murget graben which is situated 40 km northwest of Ankara; Cubuk graben, situated 30 km northeast of Ankara; and Kizilcahamam graben, situated 80 km north-northwest of Ankara. Figure 12 shows a geologic section near Kizilcahamam.

⁹ Kurtman, Fikret and Samilgil, Erman; Geothermal Energy Possibilities, Their Exploration and Evaluation in Turkey; Proceedings of the Second United Nations Symposium on the Development and Use of Geothermal Resources, San Francisco, California, 20-29 May 1975, pp 447

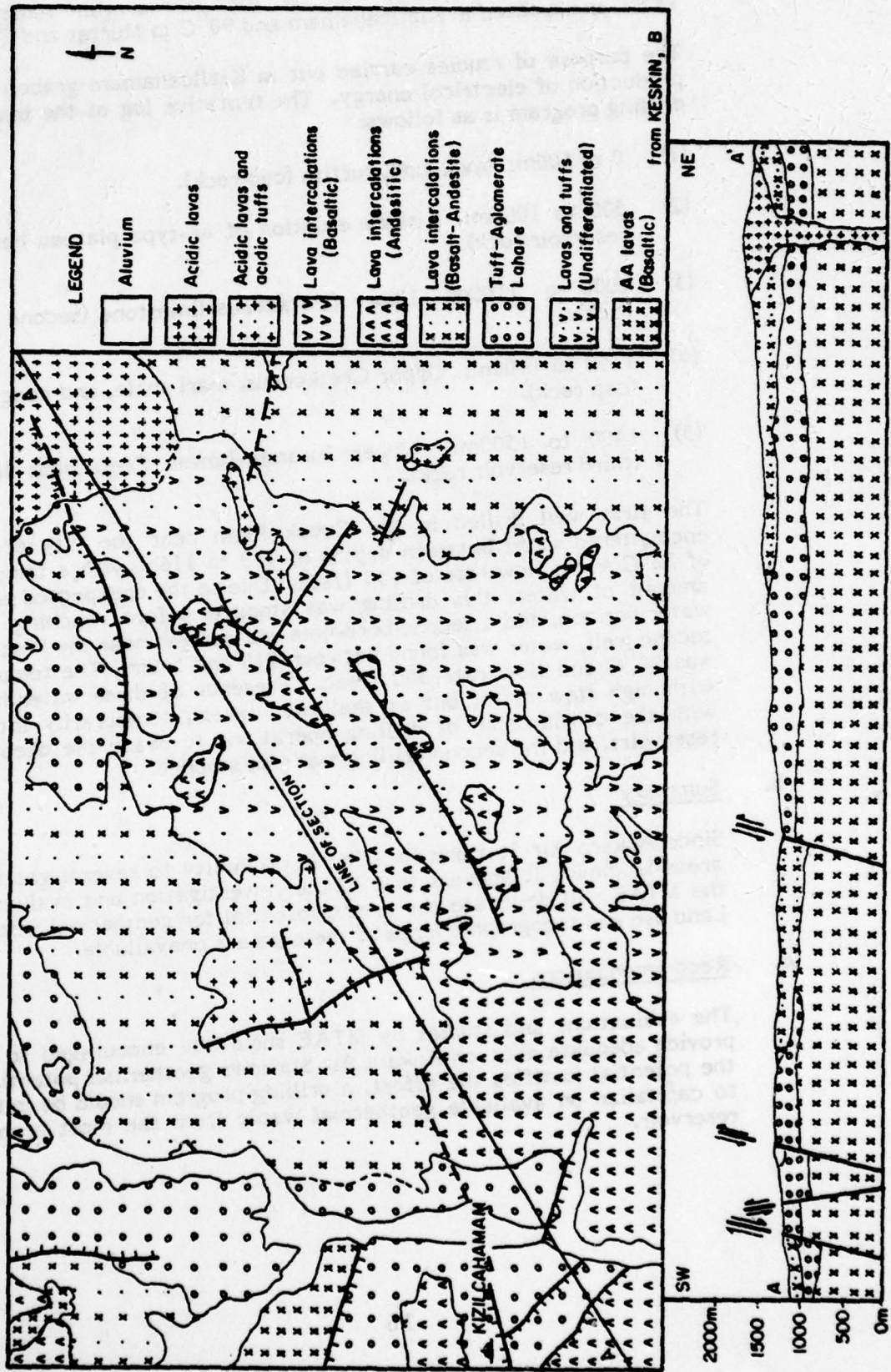


FIGURE 12. GEOLOGIC SECTION NEAR KIZILCAHAMAM (KURTMAN AND SAMILGIL)

Hydrogeochemical studies indicate that a reservoir temperature of 195°C is expected in Kizilcahamam and 90°C in Murtet and Cubuk.

The purpose of studies carried out in Kizilcahamam graben is for the production of electrical energy. The tentative log of the planned deep drilling program is as follows:

- (1) 0 to 500m: lava, tuff, tuffite (cap rock).
- (2) 500 to 1000m: Fissure eruption of aa-type plateau basalt (first reservoir rock).
- (3) 1000 to 1100m: Upper Cretaceous limestone (second reservoir rock).
- (4) 1100 to 1400m: Upper Cretaceous, marl shale, and conglomerate (cap rock).
- (5) 1400 to 1500m: Upper Jurassic-Lower Cretaceous limestone (third reservoir rock).

The first well drilled in the Cubuk Plain near the city of Ankara encountered water between depths of 113 to 116m with a temperature of 32°C and a flow rate of 150 l/sec. Due to the unexpected enormous amount of water, this drilling was stopped before reaching the hot water horizon, and a second bore-hole was started near the first. In the second well, water was found between 218 and 549m. The temperature was 40°C and flow rate 300 l/sec. Presence of these water horizons with high flow rates, but at shallower levels, temporarily interfered with the continuation of drilling operations to reach the deep-seated reservoirs, and the second drilling was also stopped.

b. Summary

Since Ankara Air Station's location in proximity to several geothermal areas is known, it appears that further investigation and evaluation by the MTAE will delineate the area's potential for geothermal resources. Land use and topographic maps of the area are unavailable.

c. Recommendations

The evaluations and studies by MTAE should be encouraged so as to provide adequate data on Ankara Air Station's geothermal potential. If the potential justifies the effort, a drilling program should be initiated to capitalize on available geothermal water from the most promising reservoir.

APPENDIX A

Summary of Geothermal Potential of Air Force Installations

The Geothermal Utilization Division, Public Works Department, Naval Weapons Center, is continuously reviewing the geothermal potential of military installations around the world. The initial phase of review is to determine the geologic setting of the installation. Such factors as known hot springs, warm or hot wells, seismic activity, mercury, arsenic, or uranium mineralization are considered. Data were taken from geologic literature and from unpublished studies available to the authors. This preliminary review is useful to determine the priority for more detailed studies and to plan such studies. Informal reports were prepared on some installations where considerable library data were utilized.

Evaluation of geothermal potential of areas is not a static process. Additional geologic studies, the drilling of good or poor wells in an area, preliminary geologic or geophysical field studies may cause the assessed potential of an area of installation to be changed.

Legal and institutional problems are discussed in the main report.

The bases with the greatest geothermal potential are:

Mountain Home Air Force Base (space heating), Saylor Creek Range at Mountain Home (power), Ellsworth Air Force Base (space heating), Keesler Air Force Base (geopressurized geothermal resource), Hill Air Force Base (space heating), and Williams Air Force Base (power) in the Continental United States; and Bellows AFB Hawaii (power), Lajes AFB Azores (power), Ankara Air Station Turkey (space heating), and Cigili Air Base Turkey (space heating) outside the Continental United States. These facilities are discussed in the basic report.

Evaluations of other Air Force facilities are given in the following Table:

FACILITY	GEOHERMAL POTENTIAL						REMARKS & REFERENCES **
	SPACE HEATING		ELECTRIC POWER PRODUCTION		GEOPRESSURIZED RESOURCE*		
	FAIR	GOOD	HIGH	FAIR			
	LOW						
Altus AFB Altus, OK.	X						
Andrews AFB, Camp Springs, MD.	X						
Barksdale AFB Bossier City, LA.					X		NMC Informal Report #1
Beale AFB, Marysville, CA.		X					NMC Informal Report #9
Bergstrom AFB, Austin, TX.	X						May have geopressurized potential
Blytheville AFB, Blytheville, AR.	X						
Bolling AFB, (N) Washington, D. C.	X						
Brooks AFB (N) San Antonio, TX.					X		NMC Informal Report #1
Cannon AFB, Clovis, NH.	X						
Carswell AFB, Fort Worth, TX.	X						May have geopressurized potential
Castle AFB, Atwater, CA.	X						

REMARKS & REFERENCES**

GEOTHERMAL POTENTIAL

SPACE HEATING
FAIR GOOD HIGH

ELECTRIC POWER
PRODUCTION
FAIR GOOD HIGH

GEOPRESS-
URIZED
RESOURCE*

FACILITY

LOW

X

Chanute AFB,
Rantoul, IL.

X

Charleston, AFB
North Charleston, SC.

X

Craig AFB,
Selma, AL.

X

Columbus AFB,
Columbus, MS.

X

Davis-Monthan AFB,
Tucson, AZ.

X

Dobbins AFB,
Marietta, GA.

X

Dover AFB,
Dover, DE.

X

Duluth International
Airport, Duluth, MN.

X

Dyess AFB,
Abilene, TX.

X

Edwards AFB, AFFTC
Rosamond, CA.

X

Eglin AF Aux. Field
No. 9, Mary Ester,
FL.

May have geopressurized potential

Possible geothermal potential
NMC Informal Report #5

NMC Informal Report #2

NMC Informal Report #16

Possible space heating potential

NMC Informal Report #12

FACILITY	GEOHERMAL POTENTIAL						REMARKS & REFERENCES**
	SPACE HEATING		ELECTRIC POWER PRODUCTION		GEOPRESSURIZED RESOURCE*		
	LOW	FAIR	GOOD	HIGH		FAIR	
Eglin AFB, Valparaiso, FL					X		NMC Informal Report #12
Eielson AFB, Fairbanks, AK	X						NMC Informal Report #1
Ellington AFB, Ellington, TX.					X		NMC Informal Report #1
Ellsworth AFB, Rapid City, SD.			X				Gries 1977 & NMC Informal Report #6
Elmendorf AFB, Anchorage, AK.	X						Miller 1973
England AFB, Alexandria, LA.					X		NMC Informal Report #1
Ent AFB, Peterson, CO	X						NMC Informal Report #4
Fairchild AFB, Spokane, WA.	X						NMC Informal Report #3
Francis E. Warren AFB, Cheyenne, WY.	X						Needs more study
George AFB, Victorville, CA.							Possibly in geopressurized zone
Goodfellow AFB, San Angelo, TX.					X		

FACILITY	GEOTHERMAL POTENTIAL						REMARKS & REFERENCES**
	LOW	SPACE HEATING		ELECTRIC POWER PRODUCTION		GEOPRESSURIZED RESOURCE*	
		FAIR	GOOD	HIGH	FAIR		
Grand Forks AFB, Grand Forks, N. D.	X						
Griffiss AFB, Rome, NY	X						
Grissom AFB, Peru, IN	X						
Hancock Field Syracuse, NY	X						
Hickam AFB Oahu, Hawaii	X						
Hill AFB, Ogden, UT.						X	Donovan and others, 1978. Little Mountain Facility has good space heating potential. Wendover Bombing Range has power potential. & NMC Informal Reports #14 & 15.
Holloman AFB, Almogordo, NM.						X	Needs More study
Homestead AFB, Homestead, FL.	X						NMC Informal Report #12
HQ AFAC, Denver, CO.	X						NMC Informal Report #4
Keesler AFB, Biloxi, MS.							NMC Informal Report #1
Kelly AFB, San Antonio, TX.							NMC Informal Report #1

REMARKS & REFERENCES**

GEOTHERMAL POTENTIAL

FACILITY	LOW	SPACE HEATING			ELECTRIC POWER PRODUCTION			GEOPRESSURIZED RESOURCE*	REMARKS & REFERENCES**
		FAIR	GOOD	HIGH	FAIR	GOOD	HIGH		
Kincheloe AFB, Kinross, MI.	X								
Kingsley Field Kingsley, OR.				X				NMC Informal Report #3	
Kirtland AFB Albuquerque, NM.		X						Needs more study	
K. I. Sawyer AFB, Gwinn, MI.	X								
Lackland AFB (N) San Antonio, TX.							X	NMC Informal Report #1	
Langley AFB Hampton, VA.	X								
Laughlin AFB, Del Rio, TX.	X								
Laurence G. Hanscom AFB, Bedford, MA.	X								
Little Rock AFB Jacksonville, AR.	X								
Loring AFB Limestone, ME.	X								
Lowry AFB, Denver, CO.	X							NMC Informal Report #4	

REMARKS & REFERENCES**

GEOTHERMAL POTENTIAL

SPACE HEATING ELECTRIC POWER GEOPRESS-
 FAIR GOOD HIGH PRODUCTION URIZED
 X X X FAIR GOOD HIGH RESOURCE*

FACILITY	LOW	FAIR	GOOD	HIGH	SPACE HEATING	FAIR	GOOD	HIGH	ELECTRIC POWER PRODUCTION	FAIR	GOOD	HIGH	GEOPRESS-URIZED RESOURCE*	REMARKS & REFERENCES**
Luke AFB, Glendale, AZ.		X												NWC Informal Report #5
MacDill AFB Tampa, FL.	X													NWC Informal Report #12
Malstrom AFB Great Falls, MT.	X													
March AFB Riverside, CA.						X								
Mather AFB Sacramento, CA.	X													
Maxwell AFB Montgomery, AL.	X													
McChord AFB Tacoma, WA.	X													NWC Informal Report #3
McClellan AFB Sacramento, CA.	X													
McConnell AFB Wichita, KS.	X													
McGuire AFB Wrightstown, NJ.	X													
Minot AFB Minot, ND	X													
Moody AFB Valdosta, GA.	X													

FACILITY	GEOTHERMAL POTENTIAL						REMARKS & REFERENCES**
	LOW	SPACE HEATING		ELECTRIC POWER PRODUCTION		GEOPRESSURIZED RESOURCE*	
		FAIR	GOOD	HIGH	FAIR		
Mountain Home AFB Mountain Home, ID.			X			X	NMC Informal Reports #7 & 8
Myrtle Beach AFB, Myrtle Beach, SC.	X						
Neills AFB Las Vegas, NV.			X				Needs more study
Newark AFS Newark, OH.	X						
Norton AFB San Bernardino, CA.			X			X	NMC Informal Report #12
Offutt AFB Omaha, NE.	X						
Patrick AFB Cocoa Beach, FL.	X						NMC Informal Report #1
Pease AFB Portsmouth, NH.	X						
Plattsburgh AFB Plattsburgh, NY.	X						
Pope AFB Fayetteville, NC.	X					X	
Randolph AFB San Antonio, TX.							

REMARKS & REFERENCES**

GEOTHERMAL POTENTIAL

GEOPRESS-
URIZED
RESOURCE*

ELECTRIC POWER
PRODUCTION
FAIR GOOD HIGH

SPACE HEATING
FAIR GOOD HIGH

LOW

FACILITY

Reese AFB
Lubbock, TX.

Richards-Gebaur AFB
Belton, MO.

Rickenbacker AFB
Columbus, OH.

Robins AFB
Warner Robins, GA.

SAMSO AFS
Los Angeles, CA.

Scott AFB
Shiloh, IL.

Seymour Johnson AFB
Goldsboro, NC.

Shaw AFB
Sumter, SC.

Sheppard AFB
Wichita Falls, TX.

Tinker AFB
Oklahoma City, OK.

Travis AFB
Fairfield, CA.

FACILITY	GEO THERMAL POTENTIAL			REMARKS & REFERENCES **
	SPACE HEATING	ELECTRIC POWER PRODUCTION	GEOPRESSURIZED RESOURCE*	
Tyndall AFB Panama City, FL.	LOW	FAIR GOOD HIGH	X	NMC Informal Report #12
USAF Academy Monument, CO.	X	FAIR GOOD HIGH		NMC Informal Report #4
Vance AFB Enid, OK	X	FAIR GOOD HIGH		
Vandenberg AFB Lompoc, CA.		FAIR GOOD HIGH		
Webb AFB Big Spring, TX.	X	FAIR GOOD HIGH		
Westover AFB Chicopee, MA.	X	FAIR GOOD HIGH		
Whiteman AFB Sedalia, MO.	X	FAIR GOOD HIGH		
Williams AFB Chandler, AZ.		FAIR GOOD HIGH		NMC Informal Report #5
Wright-Patterson AFB, Dayton, OH.	X	FAIR GOOD HIGH		
Murtsmigh AFB, Oscoda, MI.	X	FAIR GOOD HIGH		

REMARKS & REFERENCES**

GEOTHERMAL POTENTIAL

SPACE HEATING ELECTRIC POWER
 FAIR GOOD HIGH FAIR GOOD HIGH
 GEOPRESS-
 URIZED
 RESOURCE*

FACILITY	LOW	FAIR	GOOD	HIGH	FAIR	GOOD	HIGH	GEOPRESS- URIZED RESOURCE*	REMARKS & REFERENCES**
Japan:									
Misawa AB	X								
Yokota AB	X								
Tachikawa AB	X								NMC Informal Report #19
Guam:									
Anderson AFB	X								NMC Informal Report #23
Alaska:									
King Salmon	X								Miller 1973
Murphy Dome	X								Miller 1973
Ladd AFB	X								NMC Informal Report #10
Shemya	X								
Canal Zone:									
Howard AFB	X								
Atbrook AFB	X								
Labrador:									
Goose Bay	X								
Greenland:									
Sondrestrom AB	X								
Thule AB	X								
Hawaii:									
Bellows AFB					X				

FACILITY	GEOHERMAL POTENTIAL				REMARKS & REFERENCES **
	SPACE HEATING		ELECTRIC POWER PRODUCTION		
	FAIR	GOOD	FAIR	GOOD	
LOW	HIGH	HIGH	HIGH	GEOPRESSURIZED RESOURCE*	
Iceland:		X			
Keflavik Airport					On Geothermal Space Heating through USN Contract
Azores:					
Lajes Field		X			NWC Geothermal Report #20
Spain:					
Moron AB			X		
Torrejon AB			X		
Zaragoza AB					
Netherlands:					Needs more study
Camp New Amsterdam			X		
Italy:					
Aviano AB			X		
San Vito Dei Normanni AS			X		
Germany:					
Augsburg SCTYG				X	Delisle and others (1975)
Spangdahlem AB				X	"
Bitburg AB				X	"
Hahn AB				X	"

REMARKS & REFERENCES **

GEOTHERMAL POTENTIAL

GEOPRESS-
URIZED
RESOURCE*

ELECTRIC POWER
PRODUCTION
FAIR GOOD HIGH

SPACE HEATING
FAIR GOOD HIGH

LOW

FACILITY

Overseas

Philippines:

Clark A.B. X X

Taiwan:

Tianan AS X

Ching Chuan Kang X

AS X

Koahsuing AS X

Shu Lin Kou AS X

Okinawa:

Kadena AB X

Naha AB X

Korea:

Kunsan AB X

Taegu AB X

Kwangju AB X

Osan AB X

(All Areas) See NWC Informal Report #17

In an area being prospected.

Geothermal potential of S. Korea considered
LOW

REMARKS & REFERENCES**

GEOHERMAL POTENTIAL

FACILITY	SPACE HEATING		ELECTRIC POWER PRODUCTION		GEOPRESSURIZED RESOURCE*
	FAIR	GOOD	FAIR	GOOD	
LOW					

United Kingdom:					
Alconbury RAF		X			Needs more study
Bentwaters RAF		X			Needs more study
Chicksands RAF			X		Needs more study
Lakenheath RAF			X		Needs more study
Mildenhall RAF				X	Needs more study
Upper Heyford RAF				X	

Denmark:					
Copenhagen MAAG				X	
Norway:					
Oslo				X	
Iran:					
Teheran				X	
Australia:					
Woomera Aprt				X	Needs more study

*Geopressurized resources would utilize water at temperatures of 90°C to 300°C at pressure of 8000 to 16000 psi produced from depths of 12,000 to 20,000 feet. There waters contain 7 to 11 st m³/m³ methane. It is proposed to utilize the mechanical energy of the water as well as the heat energy. Natural gas would also be extracted. Geopressurized zones have been discovered and outlined by oil well drilling. To date the technology of utilizing geopressurized zones is beyond the state of the art. Economical disposal of tremendous volumes of water and subsidence are two serious problems. It is doubtful commercial application will occur before 15 years.

**NWC Informal Reports are listed in Appendix B.

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- Donovon L.E., Gertsch, W.D., Stoker, R.C. and Davis, L.P. (1978). A preliminary Assessment of the Feasibility of Developing Geothermal Energy for Space Heat and Process applications at Hill Air Force Base, Utah. Unpub. Dept. EG&G, Idaho, Inc. 47p.
- Gries, J.P. (1977). Geothermal applications on the Madison (Pahasapa) Aquifer System in South Dakota. DOB rept. 1D0/1625-2.
- Miller, T.P. (1973). Distribution and Chemical Analyses of thermal springs in Alaska. USGS Open File Map.

APPENDIX B

LISTING OF

Informal Reviews of Geothermal Potentials by Geothermal Utilization Division,
Public Works Department, Naval Weapons Center, China Lake, California:

Continental United States:

1. Geothermal Potential of the Military Facilities in the Gulf Coast Area
W. D. Brumbaugh and J. Whelan, 9p. 30 April 1977
2. Geothermal Potential of Military Installations in Georgia. W. F. Daniel
4p.
3. Geothermal Potential of Military Installations in Washington and Oregon,
W. F. Daniel, 1p.
4. Preliminary Report on the Geothermal Potential of Military Bases in
Colorado, Casey Danielson, 9/77, 12p. (USAF Academy, Fort Carson, Rocky
Mountain Arsenal, Lowery Air Force Base, Lowery Bombing Range, Buckley
Field (USN).
5. Geothermal Potential of Federal Military Reservations in Arizona. C.
Danielson, 34p.
6. Geothermal Potential of Ellsworth Air Force Base, South Dakota, J. Hyde
and J. A. Whelan, 18 April 1977, 6p.
7. Preliminary Report - Geothermal Potential of Mountain Home Air Force
Base, Mountain Home, Idaho. Joy Hyde and J. A. Whelan, 11p. 29 April
1977.
8. Final Report. Geothermal Potential of Mountain Home Air Force Base and
Saylor Creek Air Force Range, Idaho. Joy Hyde and J. A. Whelan, 9p.
9. Preliminary report on the Geothermal Possibilities of Beal Air Force
Base. R. D. Paulsen and J. A. Whelan, 6p., 19 Dec. 1977.
10. Geothermal Potential of Shemya Island, Alaska, J. Whelan, 8pp. 9/77.
11. Geothermal Potential of the Naval Ammunition Depot, Hawthorne, Nevada.
J. Whelan, 10p.
12. Geothermal Potential of Military Bases in Florida, J. A. Whelan, 3p.
13. Geothermal Potential of Military Bases in Nebraska, J. Whelan, 1p.
(Lincoln AFB, Offutt AFB, Cornhusker Ammunition Depot, Grand Island
and NAD Hastings).
14. Geothermal Potential of Hill Air Force Base, Little Mountain Facility.
J. A. Whelan, 25p.

15. Geothermal Potential of the Wendover Range, The Desert Test Center, and the Hill Air Force Range, J. A. Whelan, 15p.
16. Geothermal Potential of Dover Air Force Base, Delaware, J. A. Whelan, 6p.

Foreign

17. Geothermal Potential of Military Installations on Taiwan, Republic of China, by William F. Daniel, 2p. (Shu Lin Kau Air Station, Ching-Chuan Kang Air Station, Koosuing Air Station and various Air Force and Navy Installations in Taipei and Taiwan.
18. Report of Geothermal Resources at Cligi Air Base, Izmir, Turkey. W. Daniel, 3p.
19. Geothermal Potential of Major Military Installations in Japan. W. Daniel, 3p.
20. Preliminary Report, Geothermal Potential of Lajes Air Force Base, Terceira Island, Azores, J. Hyde and J. Whelan, 9p, 24 April 1977.
21. Geothermal Potential of NAF Sigonella, Sicily. J. A. Whelan 29 Aug 1977, 9p.
22. Geothermal Potential of Saipan, Marianas Islands, J. Whelan, 2p.
23. Geothermal Potential of Guam, Marianas Islands, J. A. Whelan, 4p.
24. Geothermal Potential of Incirlik Air Base, Turkey, J. Whelan, 1p. 31 March 1977.
25. Report of the Geothermal Energy Possibilities of the Ankara Air Station, Ankara, Turkey, By W. Daniel, 3pp.
26. Geothermal Potential of Yap Islands, Caroline Islands, J. A. Whelan, 2p.
27. Geothermal Potential of Truk Islands, Caroline Islands, J. Whelan, 2p.
28. Geothermal Potential of Tinian, Marianas Islands, J. Whelan, 1p.
29. Geothermal Potential of Naval Facility at Naples, Italy, J. Whelan 2p. 31 March 1977.
30. Geothermal Potential of Military Bases in Puerto Rico. J. Whelan, 3p. (Army: Fort Buchanan, Santo Domingo, San Juan; Navy Roosevelt Roads)

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