

**Department of Energy  
Idaho Operations Office**

**Federal Building Program and  
Alternative Energy Development**

**Technical Assistance to the  
Department of Defense**

# **Purpose**

- **Reduce expenditures for energy**
- **Make bases more self-sufficient with noninterruptible energy sources**

# Geothermal Team

- **DOE — Idaho Operations Office**
  - **Lead office federal buildings program**
  - **Geothermal support contractors**
    - **EG&G, Idaho, Inc.**
    - **University of Utah Research Institute (UURI)**
- **UURI**
  - **Exploration and resource evaluation**
  - **Drilling supervision**
- **EG&G**
  - **Drilling supervision**
  - **Reservoir engineering**
  - **System design and construction supervision**

# **University of Utah Research Institute, Earth Science Laboratory Division Geothermal Experience**

**Contractor to DOE-ID**

**Provides primary technical support for:**

- **Industry Coupled Program - Nevada and Utah**
- **State Coupled Program - Western U.S.**
- **Exploration Technology Program - Nationwide**
- **User Coupled Confirmation Drilling Program - Nationwide**

**Provides technical support for:**

- **Technology Transfer - Western U.S.**
- **Induced Seismicity - Roosevelt Hot Springs, Raft River**
- **Program Planning**

# ***DOE/DGE INDUSTRY COUPLED PROGRAM***

## **DELIVERABLES FROM INDUSTRY**

- *Drill cuttings, core, fluids*
- *Drilling summaries \$500,000 - \$1,000,000 holes*
- *Lithologic, temperature, pressure, geophysical logs*
- *Surface studies - geology, geochemistry, geophysics*
- *Reservoir tests*

## **UURI - ESL STUDIES**

- *Lithology, petrology*
- *Geochemical, alteration zoning*
- *Geologic mapping*
- *Geophysical interpretation*
- *Data integration ➤ Case studies*
- *Critical evaluation - techniques & methods*

## INDUSTRY COUPLED PROGRAM DATA PACKAGES

AREA	BALTAZOR	TUSCARORA	MC COY	LEACH H.S.	COLADO	BEOVAWE	BEOVAWE	SAN EMIDIO	SODA LAKE	STILLWATER	DIXIE VALLEY	DESERT PEAK	HUMBOLDT H.	COVE FORT - SULPHURDALE UTAH	ROOSEVELT HOT SPRINGS UTAH
COMPANY DATA	EPP	AM	AM	AO	G	G	C	C	C	U	SR	P	P	U	*
GRAVITY	E	X	X	E	E	X		E		E		E	E	E	
GROUND MAG.					E	X						E			
AERO MAG.	E	X	X				E				E			E	E
ELEC. RES.					E	X	E	E	E	E				E	X
MAGNETO-TELLURIC		X	X	X	E		E		E	E	E	E	E		
AUDIO MAGNETO-TELLURIC					E										
SELF POTENTIAL		X	X				E	E							
SEISMIC EMISSIONS							E	E						E	X
MICRO-EARTHQUAKE	E	X	X				E								
SEISMIC REFL. (weight drop)							E		E					E	
SEISMIC REFL. (CDPI2 or 24 fold)			X	X			X	E	E						X
GEOLOGY	E			E				E			X	E	E	E	X
GEOCHEMISTRY	E			E							E			E	
SHALLOW TEMPERATURE											X				
SHALLOW THERMAL GRADIENT	E	E	E	X	E	X		E	E	E	E			E	E
DEEP THERMAL GRADIENT	X	X	X	X	X	X			X		X	E		E	X
EXPLORATION WELL †	X	X	X	X	X	X	E	E	E	E	X	X	X	X	X
FLOW TEST (if appropriate)	X	X	X	X	X	X	X			X	X	X	X	X	X

### COMPANY EXPLANATION

EPP - Earth Power Production

AM - Amax Exploration Inc.

AO - Aminoil USA, Inc.

G - Getty Oil Co.

C - Chevron Resources Co.

U - Union Oil Co. of Ca.

SR - Southland Royalty Co.

P - Phillips Petroleum Co.

E = EXISTING DATA

X = NEW PROGRAM

† Companies at Roosevelt Hot Springs:

Getty Oil Co.

Thermal Power Co.

Geothermal Power Co.

Seismic Exploration Inc.

Geophysical Services Inc.

University of Denver (DRI)

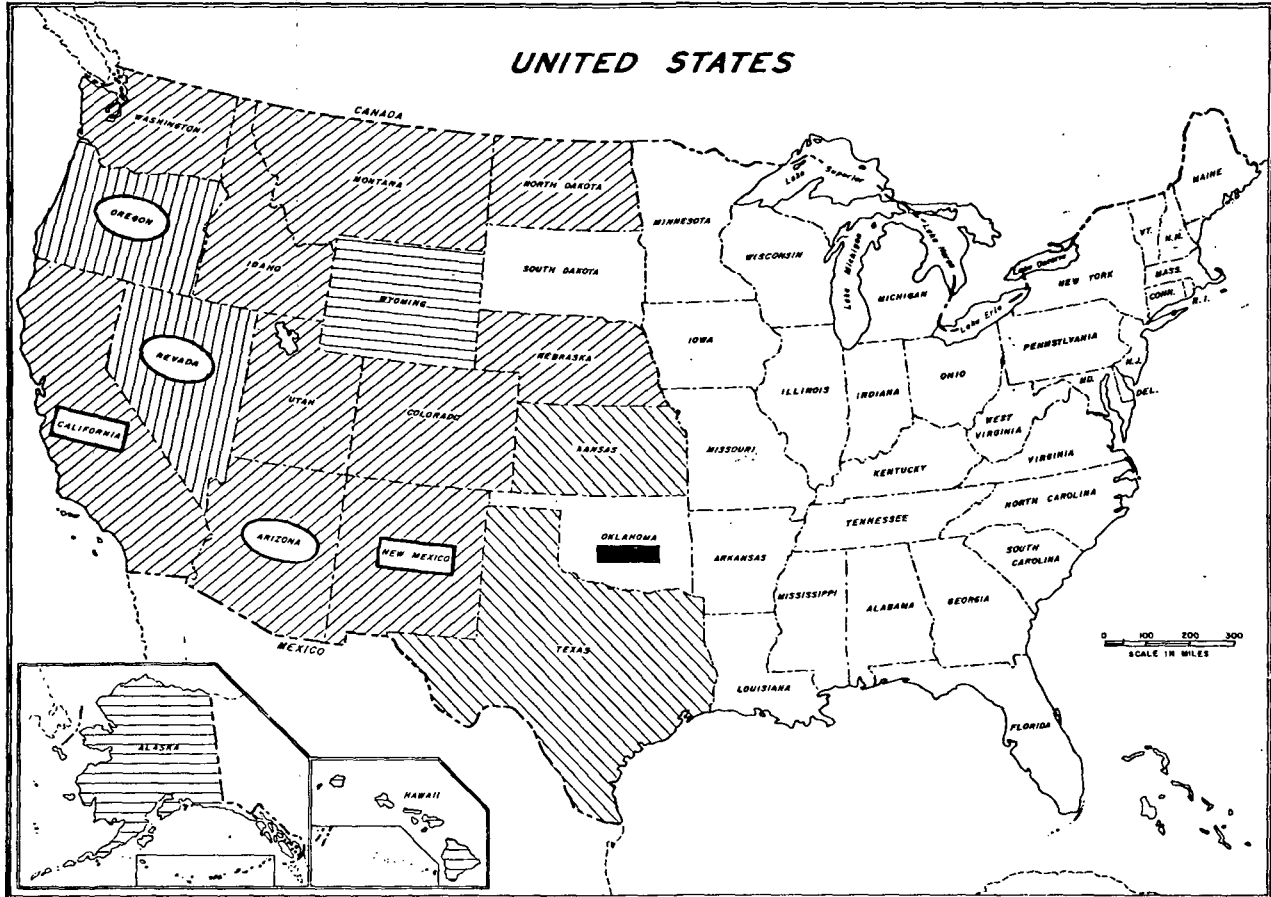
† Exploration Wells --








Drill cuttings and geophysical well logs provided



# STATE COUPLED PROGRAM MAP STATUS

APRIL 1982



-  User Map Published or in press (NOAA)
-  State Printed Map
-  User Proof in Review
-  User Map Planned by September 1982
-  Update Planned by September 1982 (NOAA)
-  Technical Map in Production
-  Other Map Through State Program

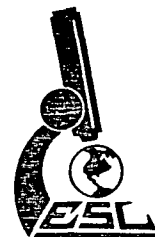




**CURRENT PROGRAMS-GEOCHEMICAL  
TECHNIQUE DEVELOPMENT**

- ***Refinement of Subsurface Trace Element Distribution Models***
- ***Isotope Systematics of High Temperature Systems***
- ***Test and Develop New Techniques for Predicting Permeability, Fluid Residence Time and Water/Rock Ratios***
- ***Develop Dynamic Mineralogic and Chemical Models of Geothermal Systems in the Basin and Range***
- ***Geochemistry of Low Temperature Resources***

EAT/GC-051



# **USER COUPLED CONFIRMATION DRILLING PROGRAM**

**GEOPRODUCTS CORP., Honey Lake, CA.**

- successful well drilled
- will be used to dehydrate wood chips to burn in electric generation plant

**CITY OF ALAMOSA,**

- well drilled to 7112 ft. CO.
- well testing incomplete
- would be used in barley malting and space heating

**WINE VALLEY INN, Calistoga, CA**

- project not underway yet
- would be used for space conditioning and spas

**UURI**  
**MILITARY GEOTHERMAL PROJECTS**  
**(to April 1982)**

**COSO HOT SPRINGS, CA - China Lake Naval Weapons Test Center**

- geological mapping
- geophysical surveys
- well geology - DOE well site, 1977
- STATUS - successful well recently drilled by California Energy

**HILL AFB, UT**

- geological mapping
- geochemical surveys
- gravity and seismic surveys
- test well siting and drilling
- STATUS - inactive - no thermal water found

**WILLIAMS AFB, AZ**

- review of existing resource data
- review of proposal to USAF RFP
- STATUS - inactive - recommended USAF drop project

**M-X/RES, NV and UT**

- lead contractor for M-X/RES geothermal assessment
- program plan and presentation
- STATUS - inactive

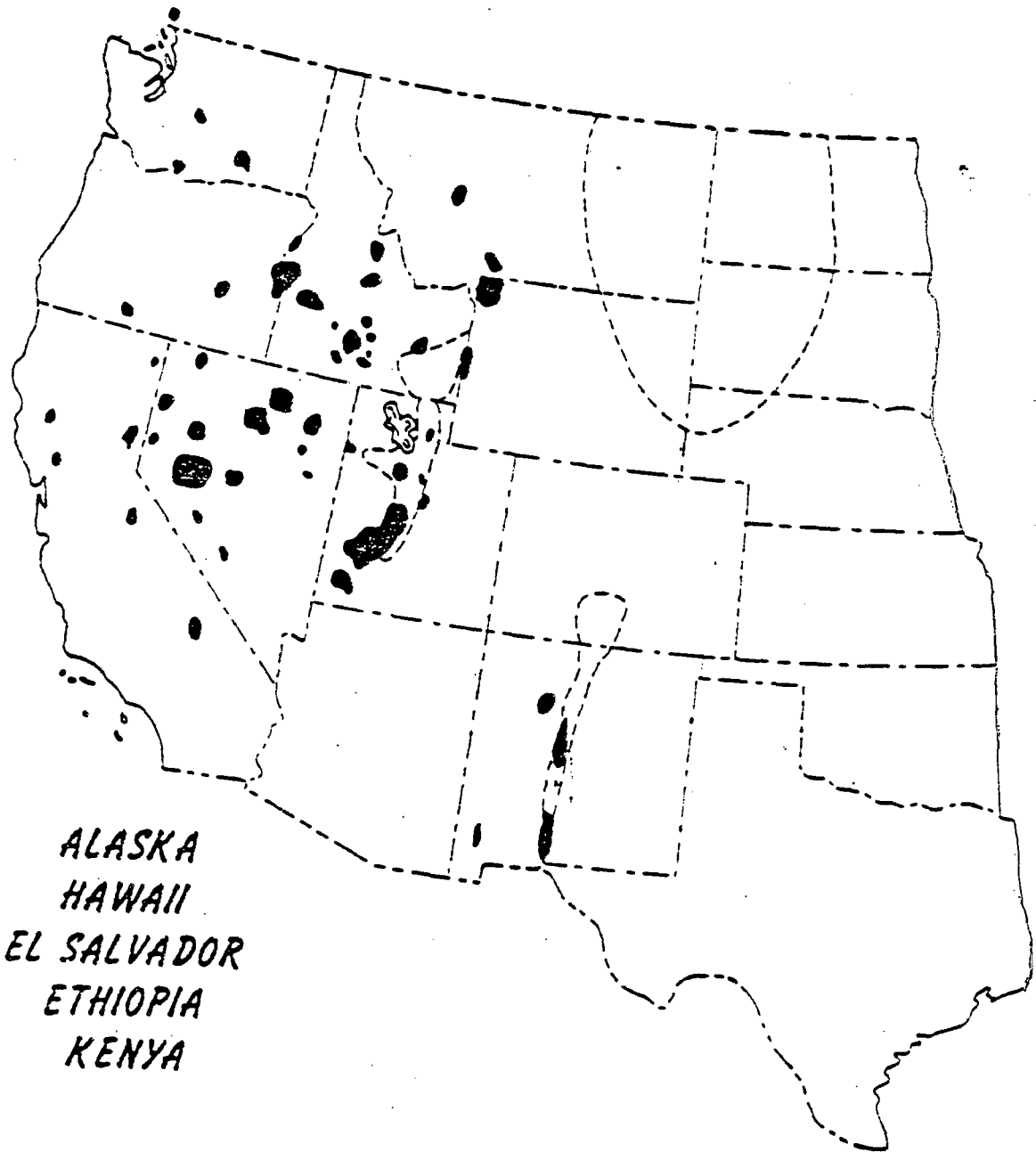
**LACKLAND AFB, TX**

- site and drill production well
- STATUS - workscope now being negotiated

**ASCENSION ISLAND**

- geological mapping
- geochemical surveys
- design Phase II exploration program
- STATUS - awaiting Falkland Island resolution

# UURI GEOTHERMAL EXPERIENCE



ALASKA  
HAWAII  
EL SALVADOR  
ETHIOPIA  
KENYA

# ESL Staff

- Most earth science problems require interdisciplinary work for solution
- ESL has a balanced interdisciplinary staff

	<u>PhD</u>	<u>MS</u>	<u>BS</u>	<u>Total</u>
Geology	4	3	4	11
Geochemistry	2	1	1	4
Geophysics	5	0	1	6
Computer	0	3	1	4
Electronics	0	0	2	2
	<u>11</u>	<u>7</u>	<u>9</u>	<u>27</u>

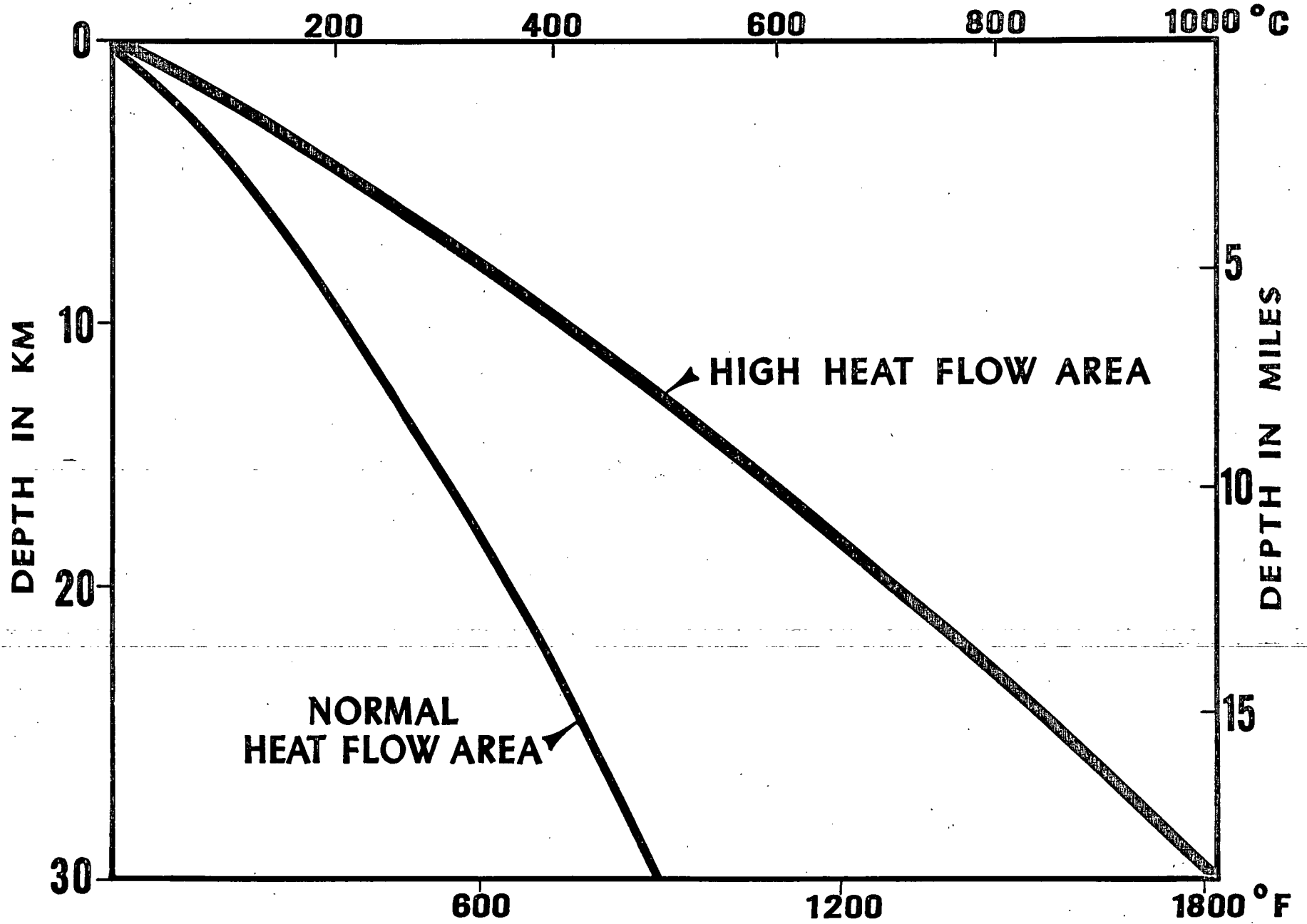
# **Nature of Geothermal Resources**

**S2 0368**

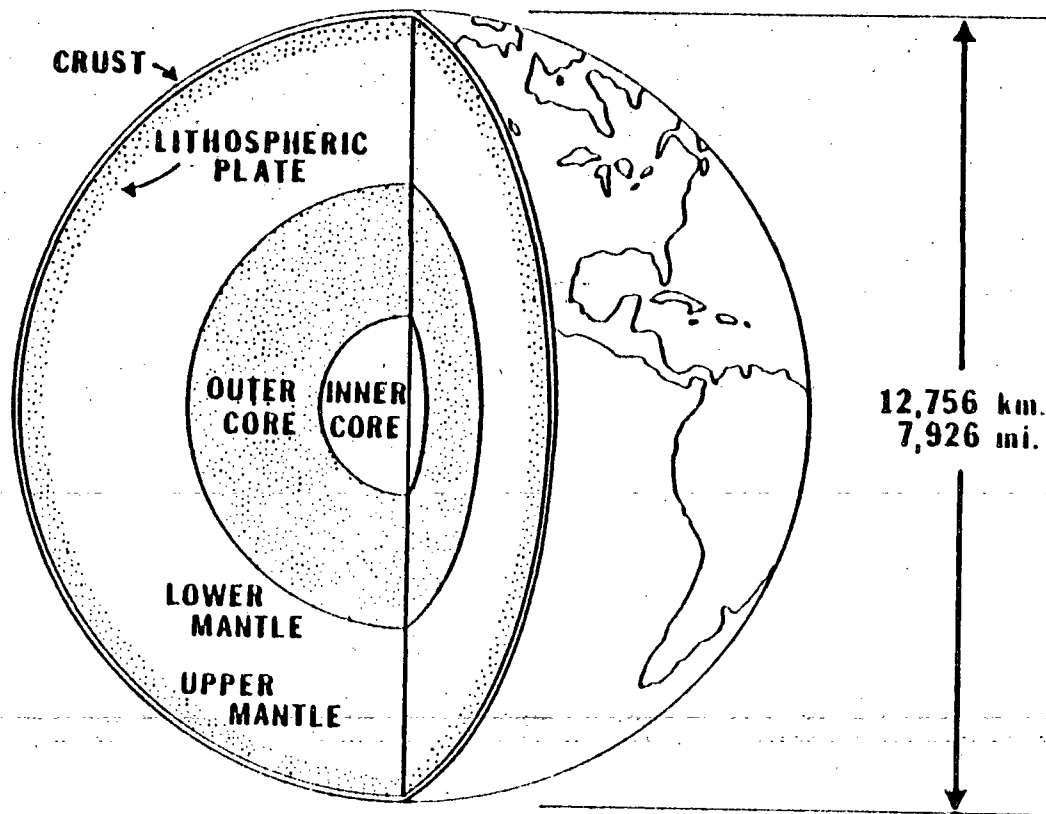
# Characteristics of Geothermal Resources

- **Source of heat**
  - **Volcanic activity**
  - **Igneous intrusion**
- **Water to transfer heat**
- **Permeable rocks**

# TEMPERATURE VS DEPTH IN EARTH

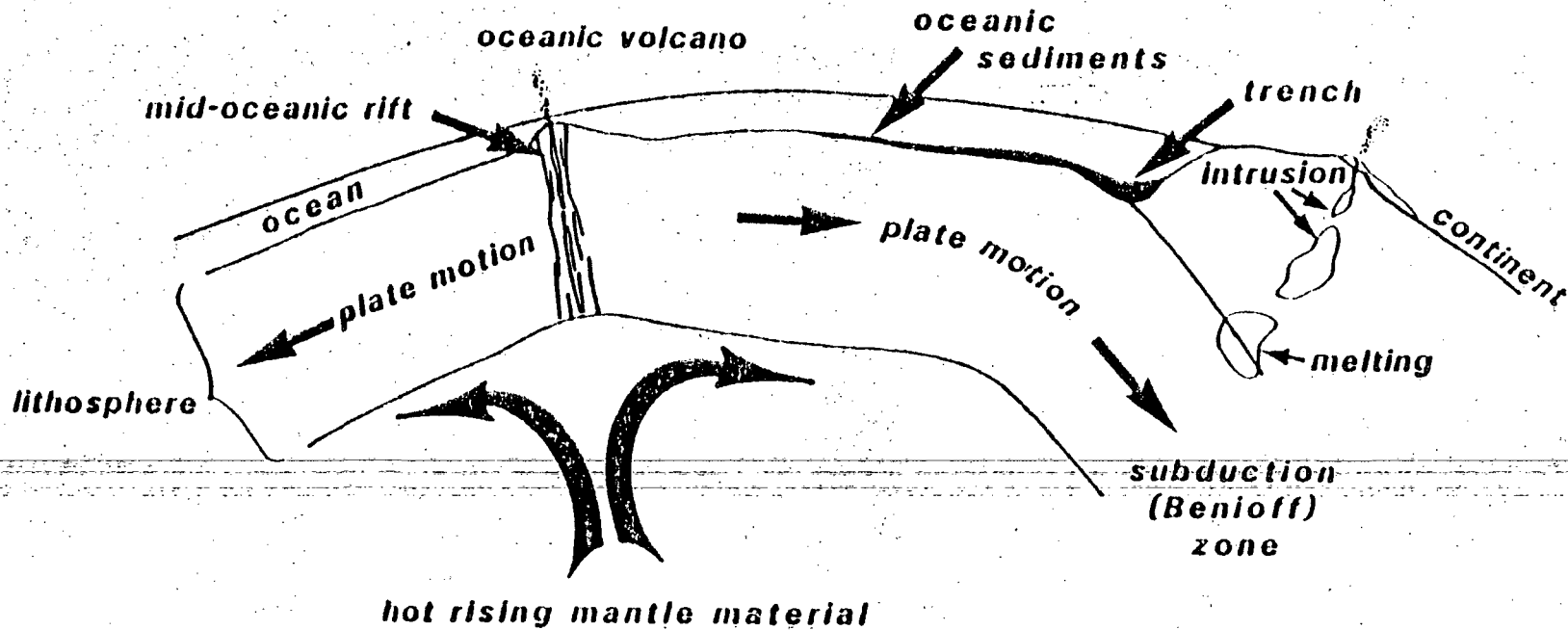




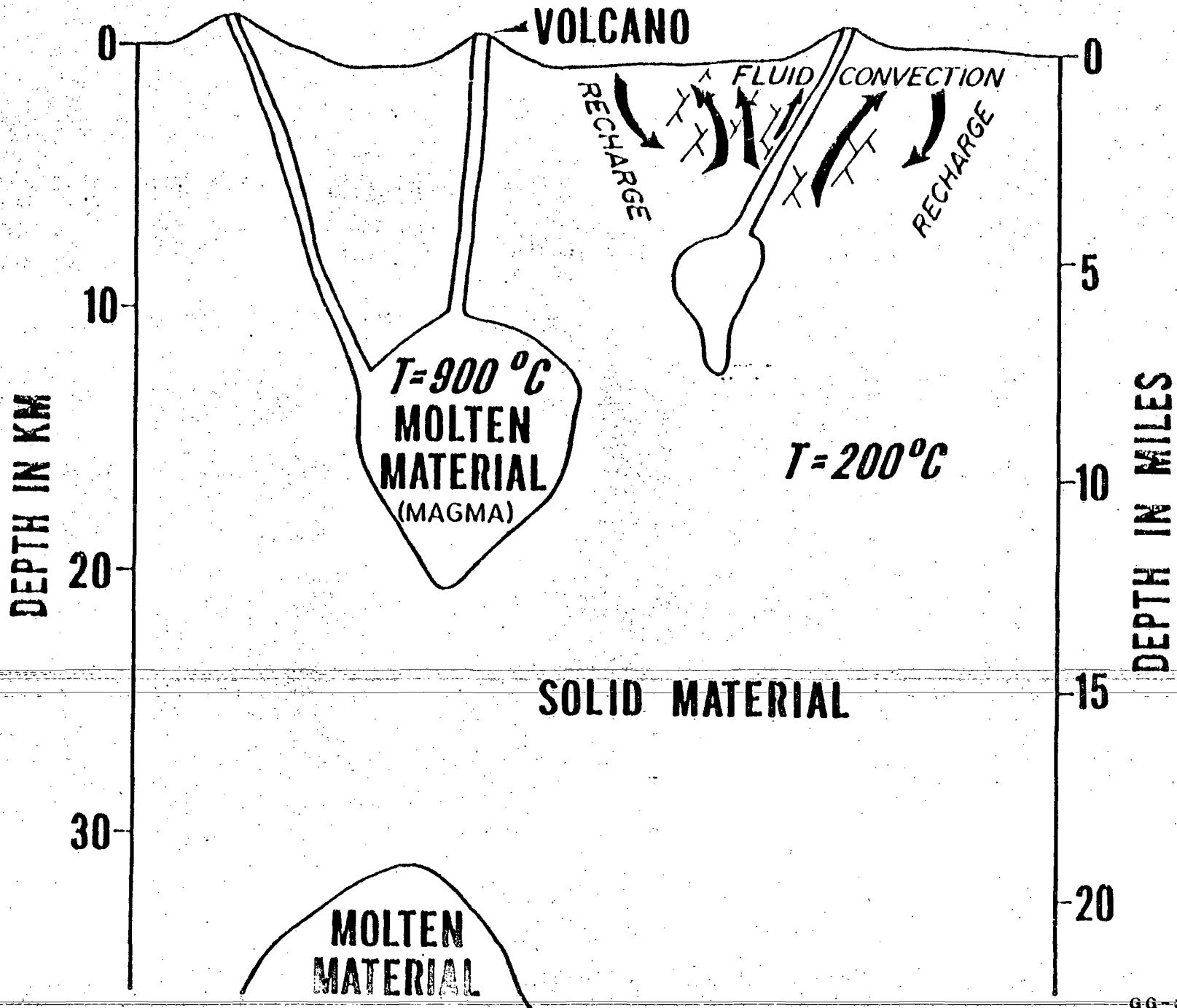


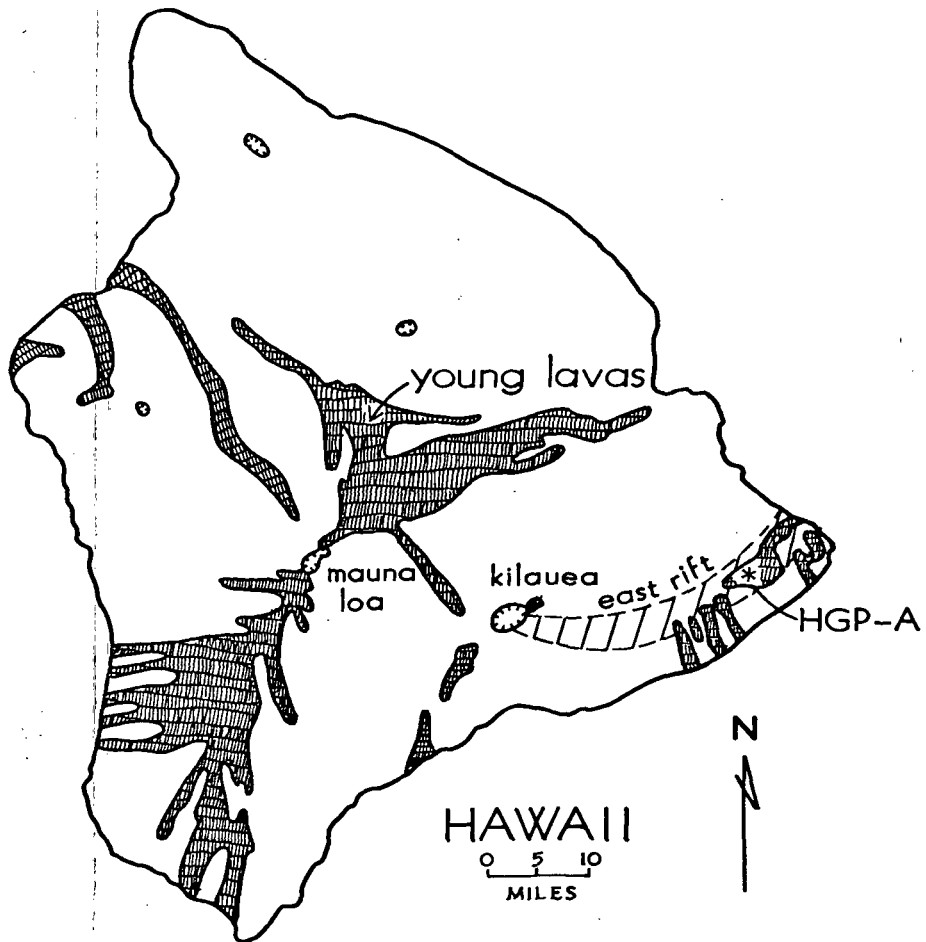
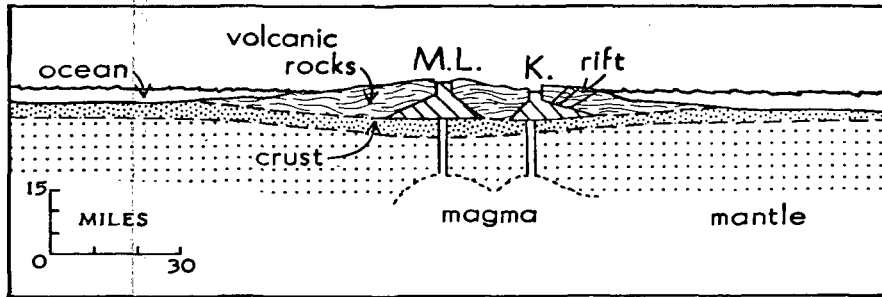
# CONCEPT OF PLATE TECTONICS

(not to scale)



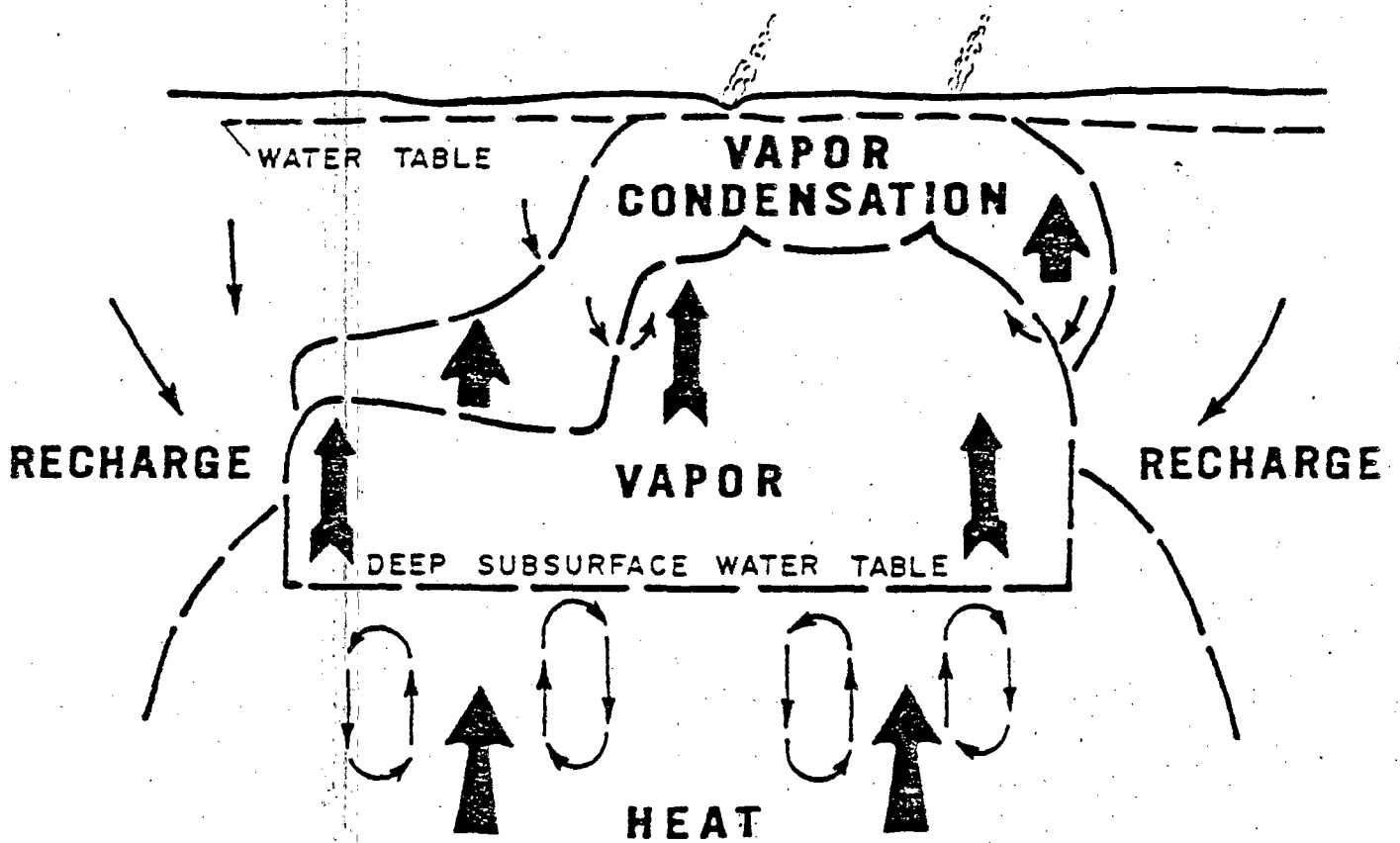
# CRUSTAL INTRUSION



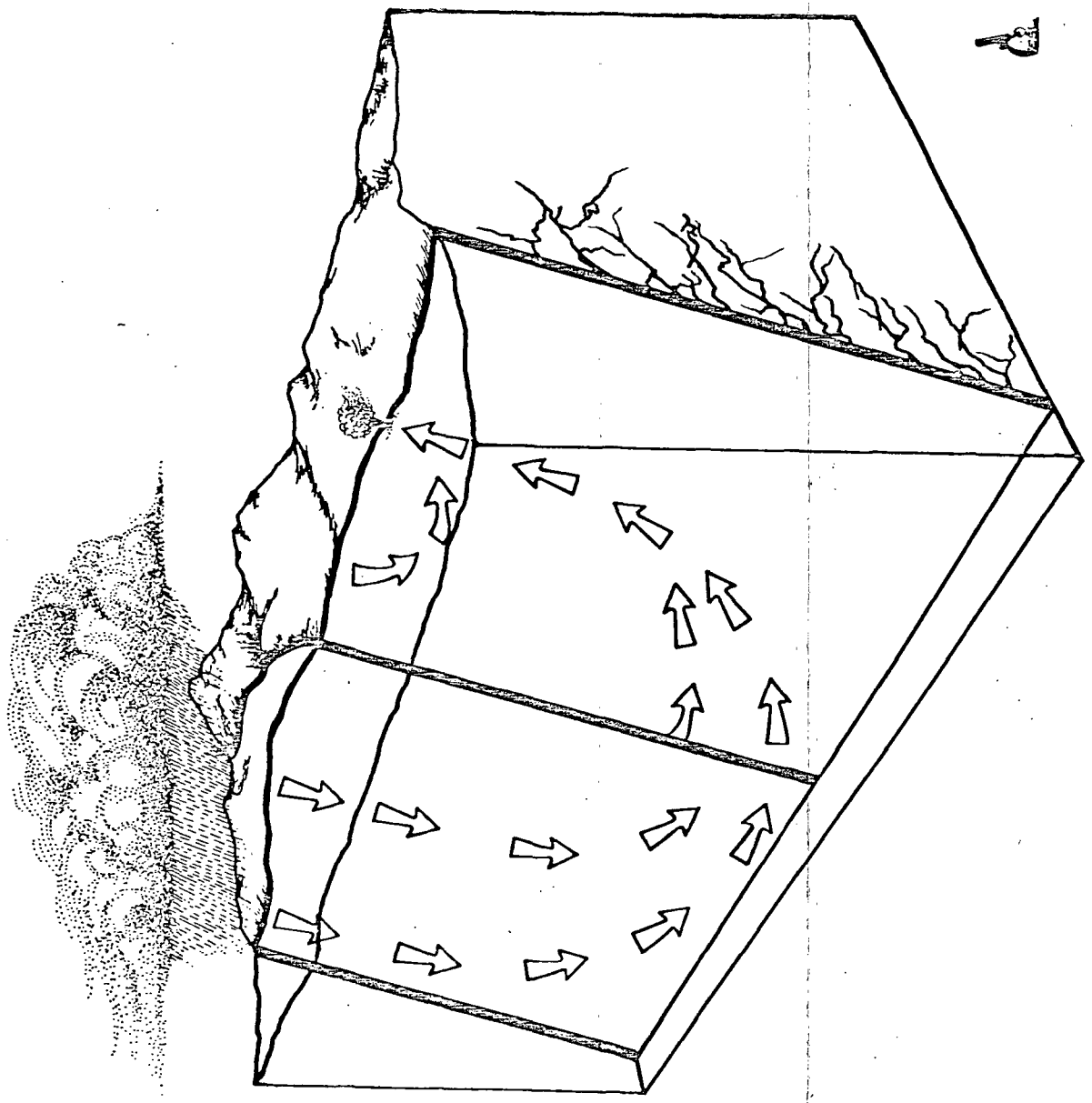


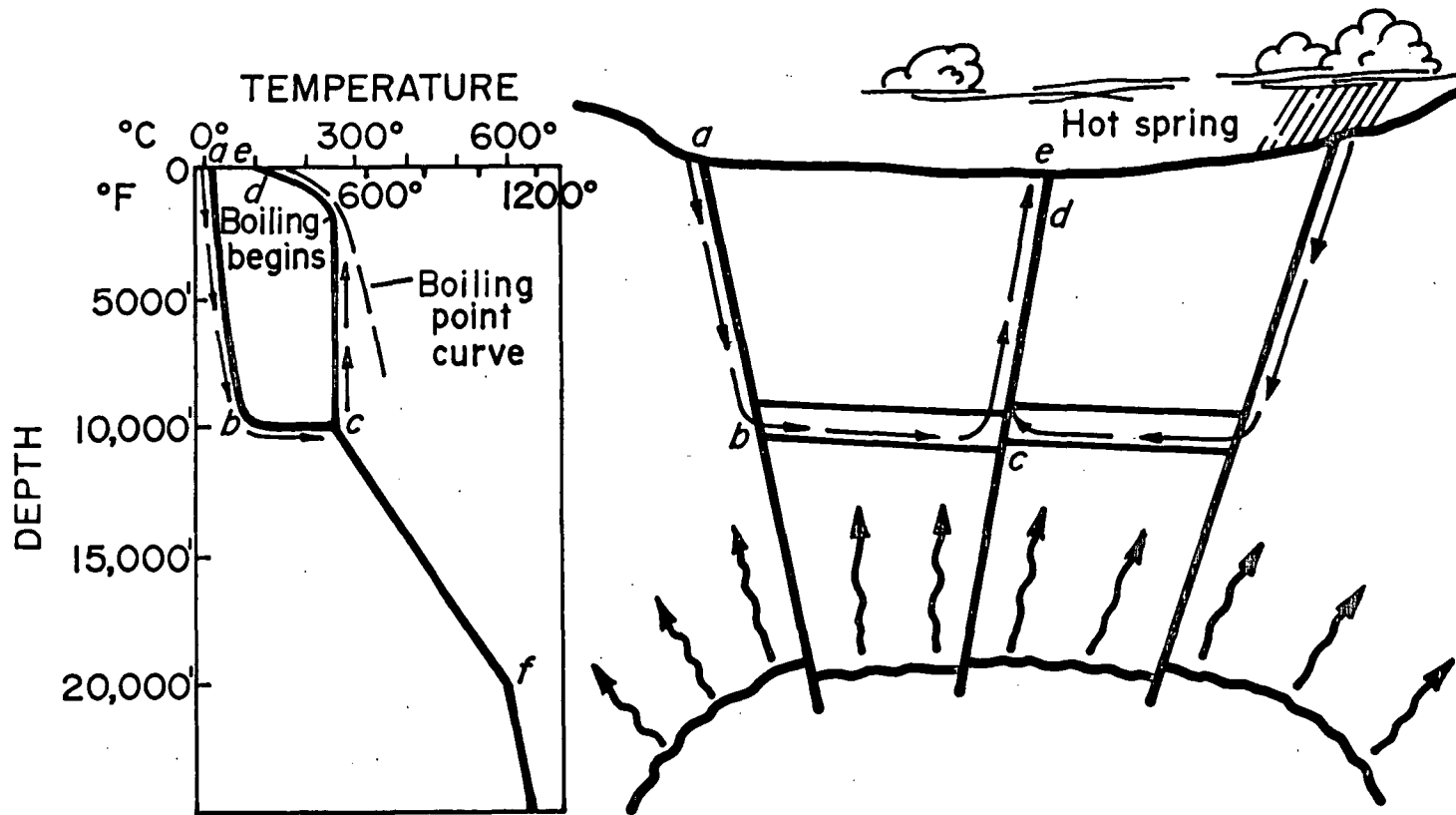
# HAWAIIAN GEOTHERMAL SETTING

# VAPOR DOMINATED GEOTHERMAL RESERVOIR

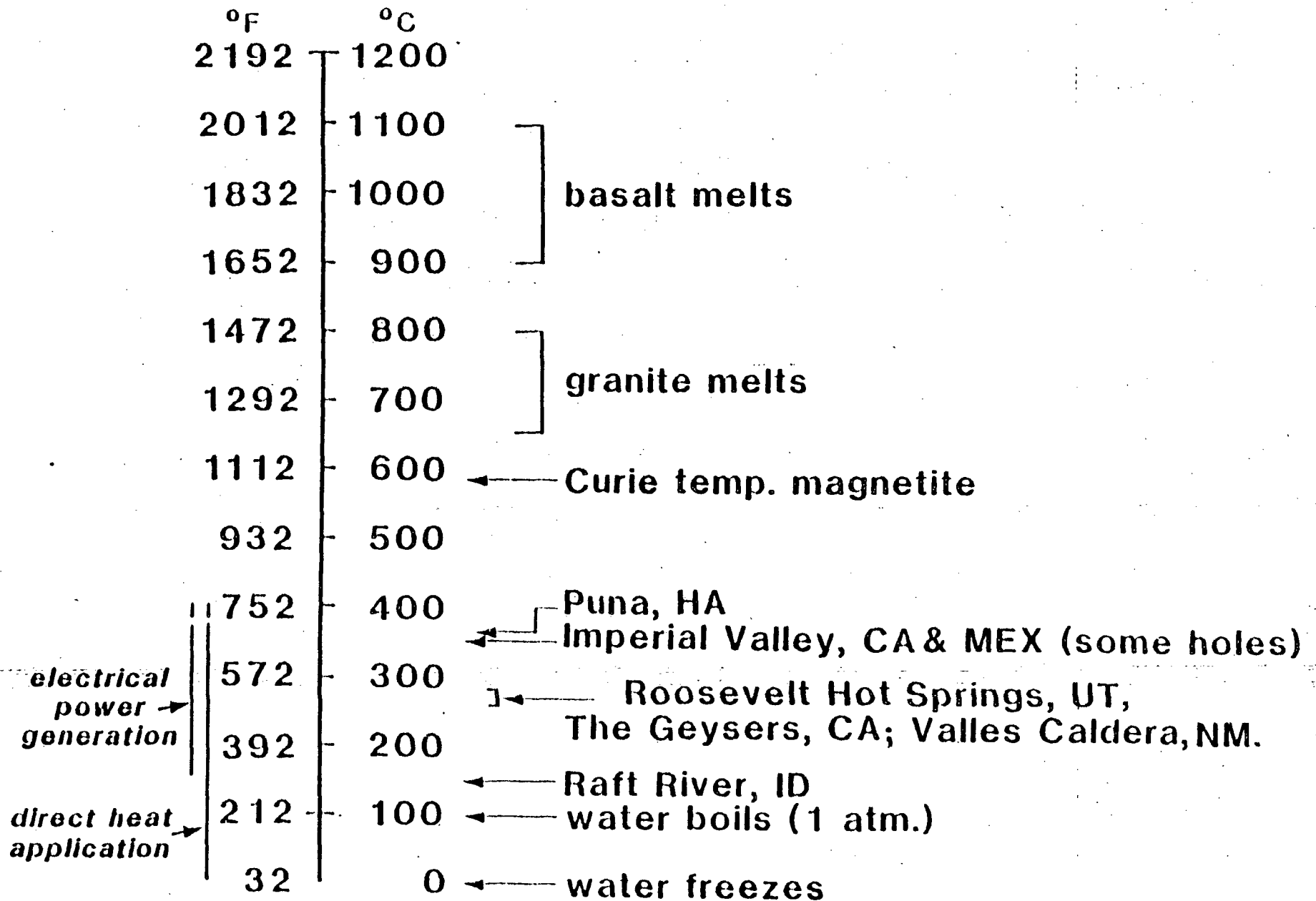


GG-011





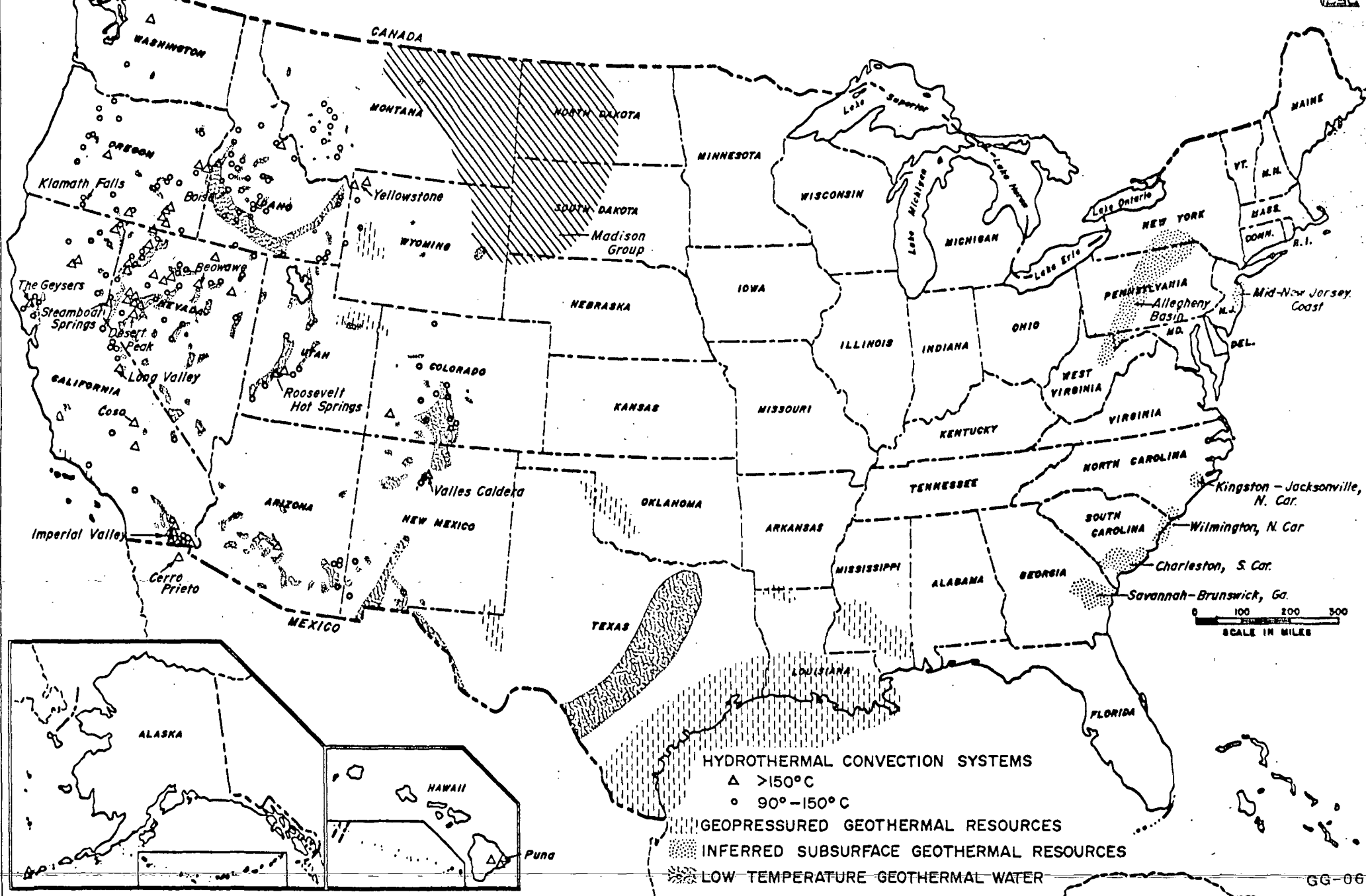
# GEOHERMAL TEMPERATURES





# GEOTHERMAL RESOURCES

modified from USGS Circular 790



- HYDROTHERMAL CONVECTION SYSTEMS
  - △ >150°C
  - 90°-150°C
- GEOPRESSURED GEOTHERMAL RESOURCES
- INFERRED SUBSURFACE GEOTHERMAL RESOURCES
- LOW TEMPERATURE GEOTHERMAL WATER

# **EG&G Idaho Geothermal Experience**

**Provides primary technical support for:**

- **Raft River, ID, Geothermal Binary Electric Demonstration Plant**
- **User Coupled Confirmation Drilling Program**
- **Program Planning**
- **Direct Heat Feasibility and Field Demonstration Programs  
(PRDA's, PON's)**

**Provides technical support for:**

- **Reservoir Engineering**
- **Technology Transfer**
- **Geothermal Loan Guaranty Program**
- **Electric Conversion Technology**

# **User Coupled Confirmation Drilling Program EG&G/UURI Support**

- **Evaluation of proposals — Resource/Reservoir  
Drilling  
Utilization/Economics  
Institutional/Environmental  
Management/Business**
- **Negotiation — Technical support to DOE**
- **Monitoring — Environmental evaluation  
Exploration program  
Drilling  
Testing**

# **User Coupled Confirmation Drilling Program**

## **Cost Sharing of Wells with Industry to Confirm a Geothermal Reservoir**

**GeoProducts - Susanville, CA — 50MW Hybrid Wood  
Chips Power Plant**

**City of Alamosa - Alamosa, CO — Barley Malting Plant**

**Wine Valley Inn - Calistoga, CA — Space Heating**

**Vale GeoPark - Vale, OR — Fuel Alcohol Plant**

**Hydrothermal Energy-Reno, NV — Space Heating Hotel  
Complex**

**State of Delaware, Lewes, DEL — Process Heat**

# **Geothermal Loan Guaranty Program EG&G Idaho Responsibilities**

- **Evaluate applicant design for technical feasibility**
- **Evaluate applicant project cost estimate**
- **In some cases, suggest alternate design because of feasibility problems or improvements in cost effectiveness**
- **Monitor project management and construction**

# **Geothermal Loan Guaranty Applications Evaluated by EG&G Idaho**

- **Electric projects**

- 54 MW(e) power plant at East Mesa, CA
- 45 MW(e) power plant at Westmoreland, CA
- 45 MW(e) power plant at Brawley, CA
- 50 MW(e) power plant at Roosevelt H.S., UT
- 110 MW(e) power plant at the Geysers, CA
- 20 MW(e) power plant at Coso, CA

- **Direct heat projects**

- Onion dehydrating plant at Brady H.S., NV
- Greenhouses at Susanville, CA
- Space conditioning for mushroom growing at Vale, OR
- Ethanol plant at Cove Fort, UT
- Ethanol-livestock facility at Beowawe, NV
- Ethanol plant at East Mesa, CA
- District heating at Boise, ID

# **SAC Geothermal Assessments INEL Administered Direct Use Projects**

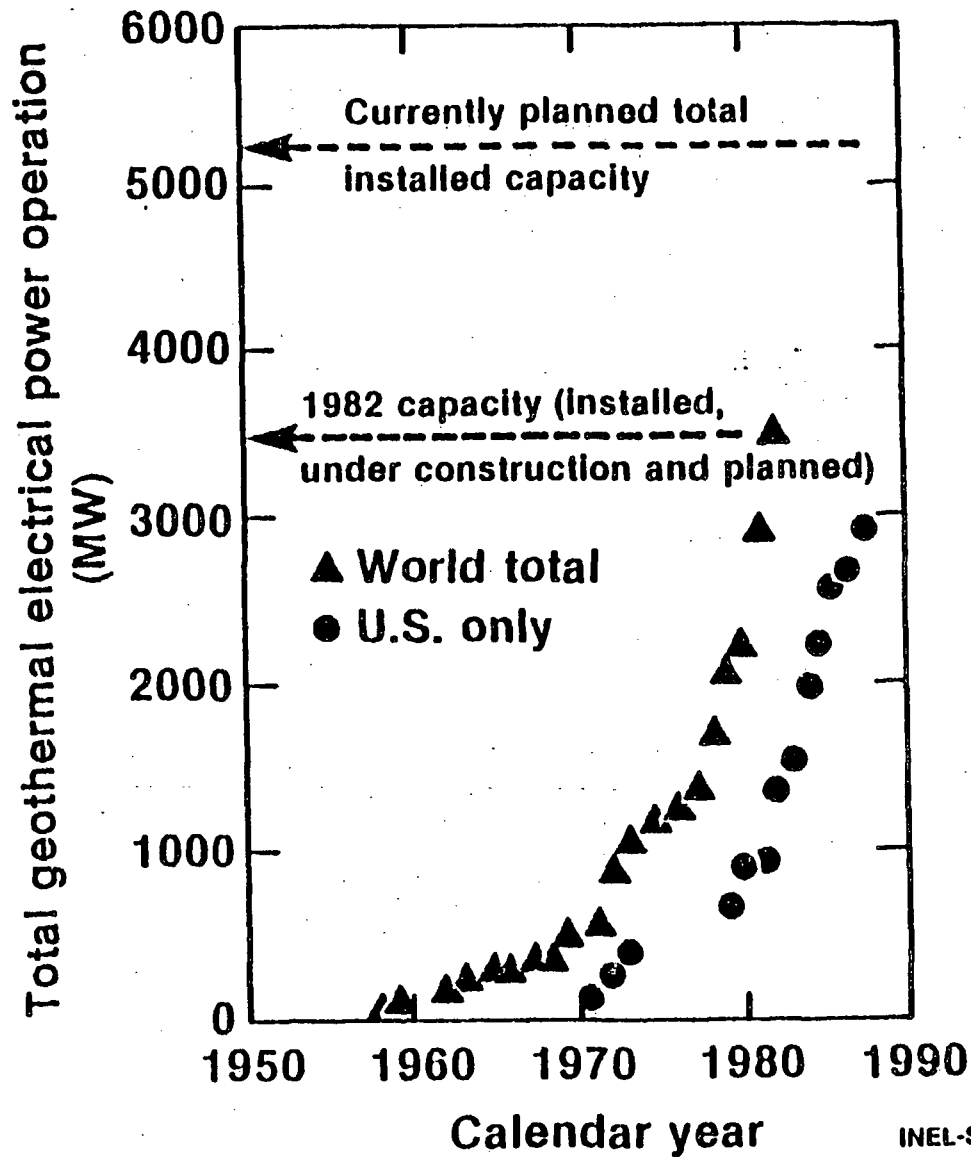
<b>Number of projects</b>	<b>12</b>
<b>Applications</b>	<b>Space heating, industrial processing and domestic water heating</b>
<b>Peak heating size</b>	<b>1-100 million Btu/hr</b>
<b>Wells drilled</b>	<b>17</b>
<b>Wells successful</b>	<b>10</b>
<b>Projects terminated</b>	<b>3 (Inadequate resource)</b>
<b>Capital cost</b>	<b>\$0.7 - 7.2 million</b>
<b>Energy cost</b>	<b>\$2.50 - 10.00/million Btu</b>

# Background

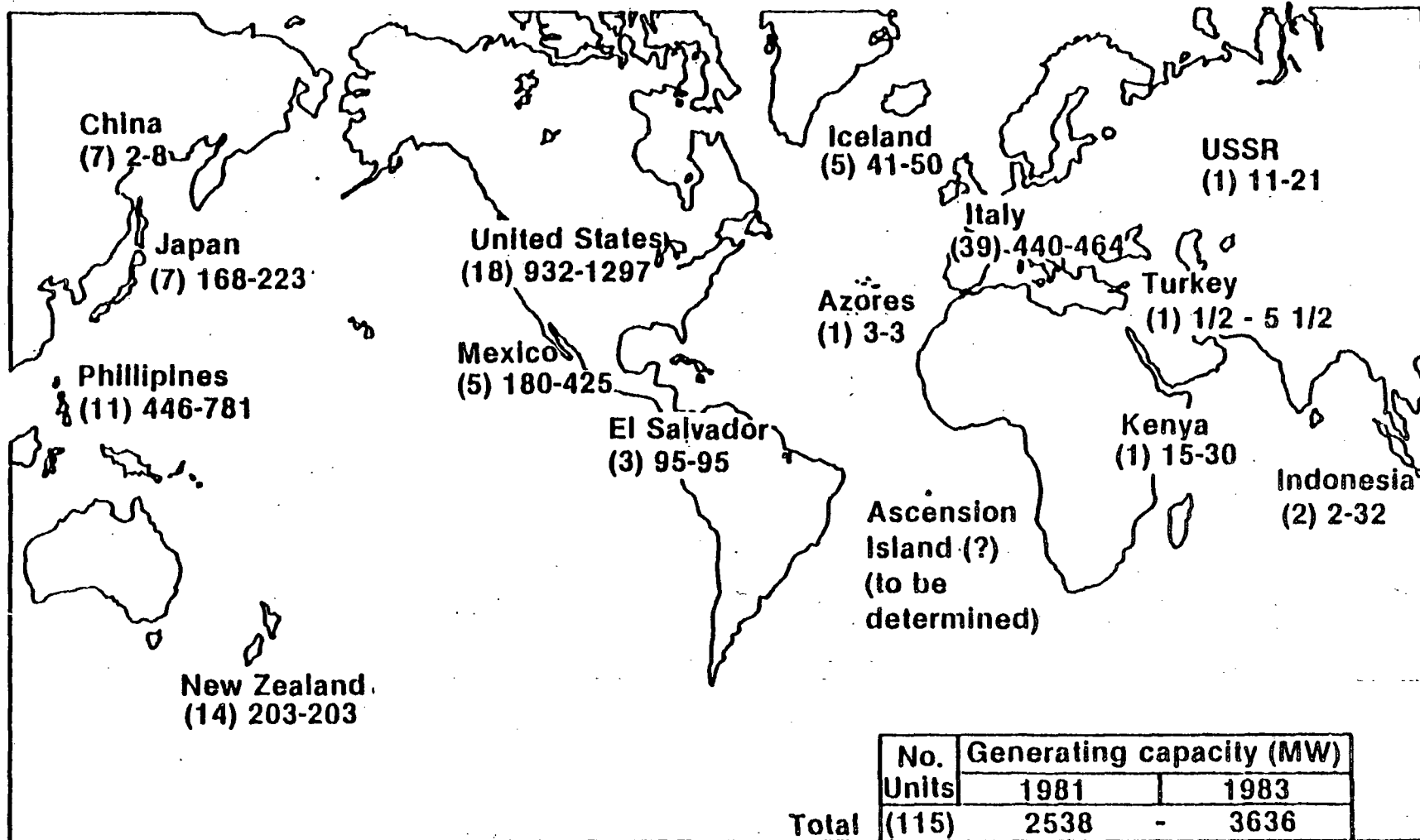
S2 0308



# Growth of Geothermal Electrical Capacity



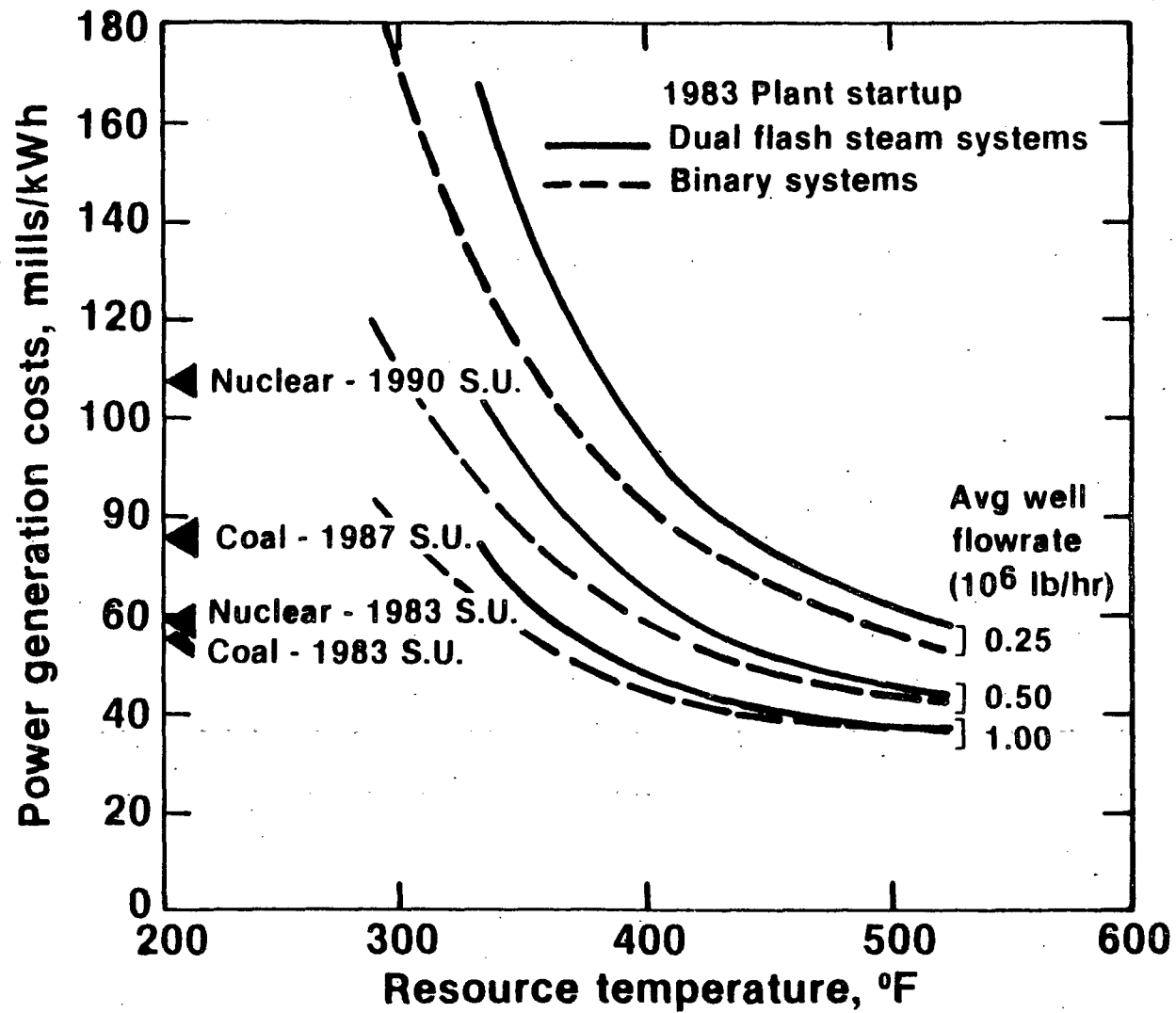
# Geothermal Power Plants in the World



## Electrical Production with Geothermal Energy Commercial Power (MWe)

	<u>On Line</u>	<u>Planned</u>
<b>The Geysers, CA</b>	902	18 plants, 55 to 110 MWe each, 1982-1990.
<b>Brawley, CA</b>	10	47 in 1984.
<b>Niland, CA</b>		10 in 1982, 26 in 1985, increasing to 100 in 1988.
<b>Heber, CA</b>	10	46 in 1985, 100 in 1986.
<b>East Mesa, CA</b>	10	
<b>Wendell Amedee, CA</b>		50 in 1985, geothermal and wood.
<b>Westmoreland, CA</b>		48 in 1984.
<b>Puna, HI</b>	3	Drilling fifth well.
<b>Nevada</b>		10 MWe unit ordered, Nornev looking at 5 sites in Nevada.
<b>Roosevelt Hot Springs, UT 1600 KW</b>		20 in 1984.
<b>Raft River, ID</b>		5, being tested.

# Geothermal Power Generation Costs



# Geothermal Energy Direct Applications

## Applications (some)

Space conditioning  
Food processing  
Ethanol Production

Greenhousing  
Mining  
Drying

	<u>Projects</u>	<u>States</u>	<u>Energy</u>
Installed (1980)	213	14	13 trillion BTU/yr
Developing	42	11	4 trillion BTU/yr
Planned	197	18	17.5 trillion BTU/yr

x

# **Exploration and Resource Assessment**

S2 0314

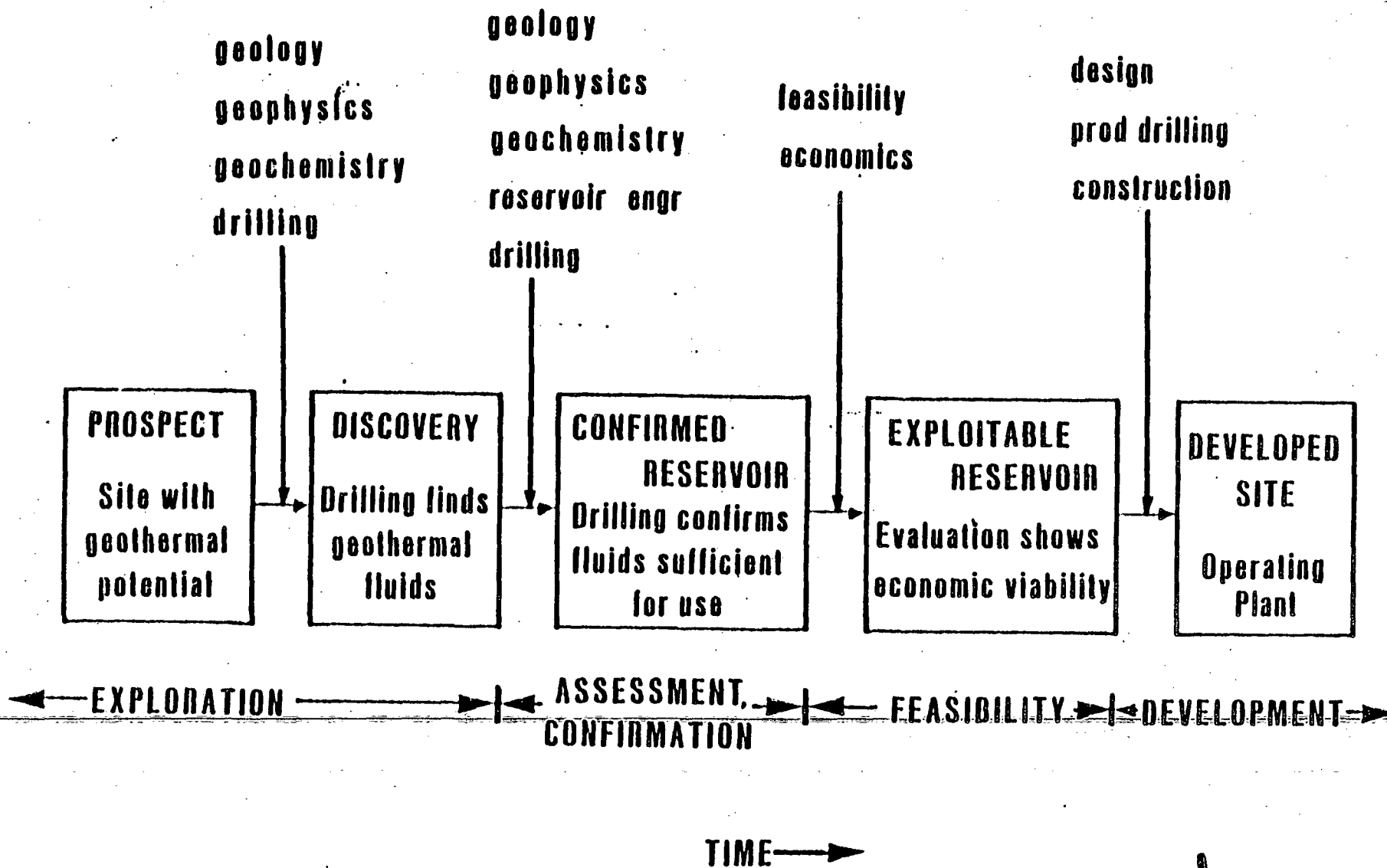
## **Some geothermal systems have surface manifestation**

- **The Geysers, CA**
- **Roosevelt Hot Springs, UT**
- **Iceland**
- **New Zealand**
- **Italy**

**Others have none — geology, geophysics, geochemistry lead to discovery**

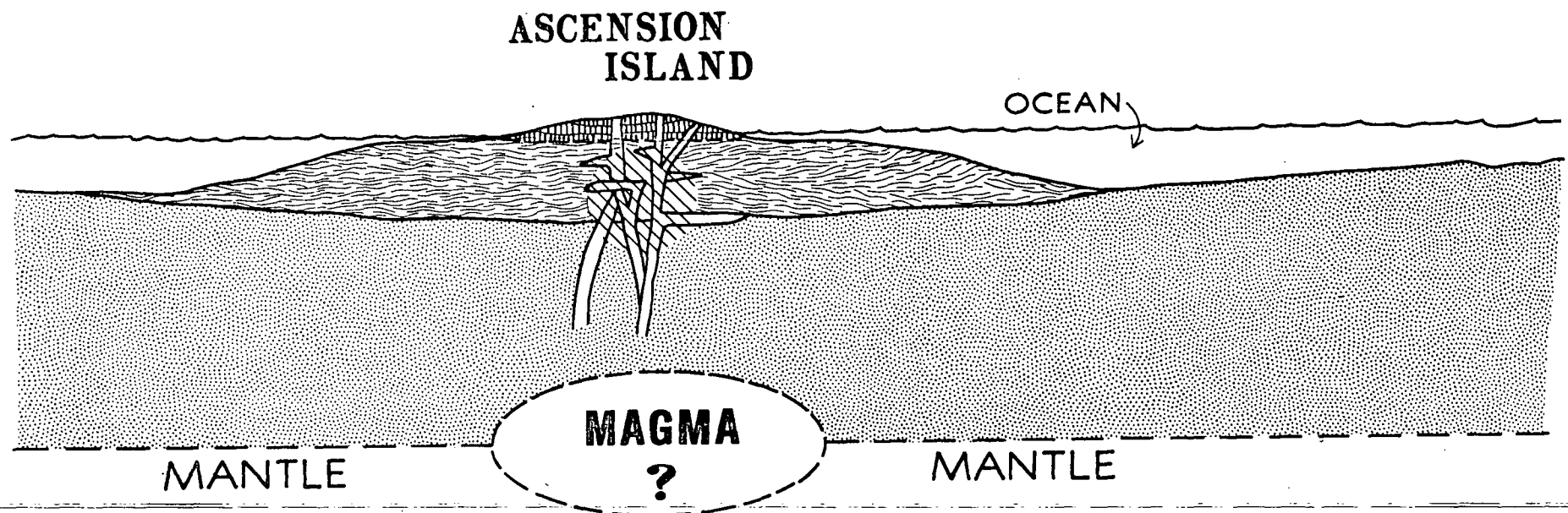
- **Imperial Valley, CA**
- **Humboldt House, NV**
- **Newberry, OR**

# GEOHERMAL DEVELOPMENT





# CONCEPTUAL THERMAL AND GEOLOGIC MODEL



FEEDER INTRUSIONS



SUBAERIAL EXTRUSIVE ROCKS



SUBAQUEOUS EXTRUSIVE ROCKS  
(PILLOW LAVAS)

5km.



0 5km.

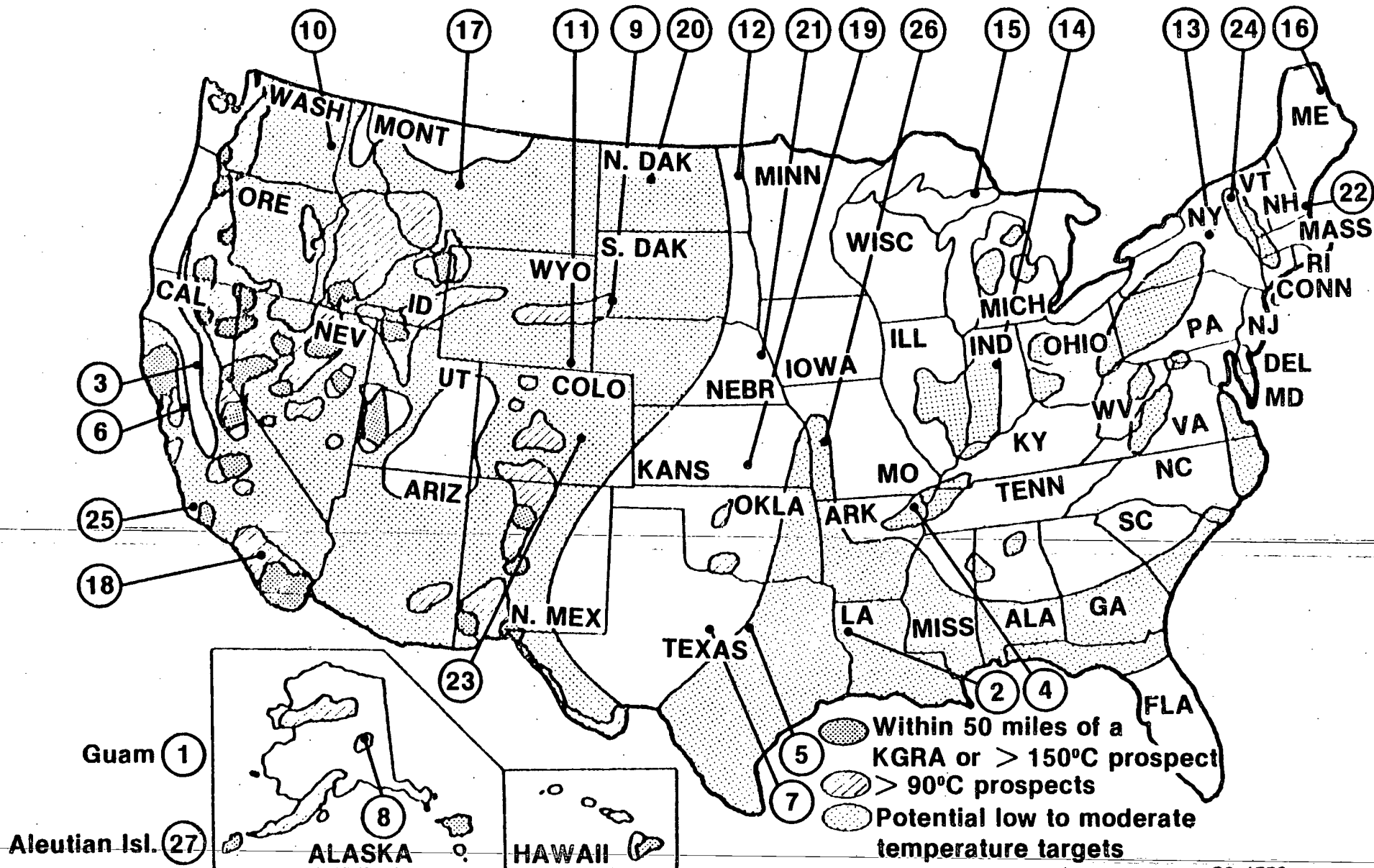


OCEANIC CRUST



THERMAL RESERVOIR

# USAF SAC Base Locations Relative to Geothermal Resources



# USAF SAC Bases

- |                           |                  |
|---------------------------|------------------|
| 1. Andersen AFB           | Agana, Guam      |
| 2. Barksdale AFB          | Bossier City, LA |
| 3. Beale AFB              | Marysville, CA   |
| 4. Blytheville AFB        | Blytheville, ARK |
| 5. Carswell AFB           | Fort Worth, TX   |
| 6. Castle AFB             | Merced, CA       |
| 7. Dyess AFB              | Abilene, TX      |
| 8. Eielson AFB            | Fairbanks, AK    |
| 9. Ellsworth AFB          | Rapid City, SD   |
| 10. Fairchild AFB         | Spokane, WA      |
| 11. Francis E. Warren AFB | Cheyenne, WYO    |
| 12. Grand Forks AFB       | Grand Forks, ND  |
| 13. Griffiss AFB          | Rome, NY         |

## **USAF SAC Bases (cont'd)**

- |                            |                               |
|----------------------------|-------------------------------|
| <b>14. Grissom AFB</b>     | <b>Peru, IND</b>              |
| <b>15. K.I. Sawyer AFB</b> | <b>Marquette, MICH</b>        |
| <b>16. Loring AFB</b>      | <b>Caribou, ME</b>            |
| <b>17. Malmstrom AFB</b>   | <b>Great Falls, MONT</b>      |
| <b>18. March AFB</b>       | <b>Riverside, CA</b>          |
| <b>19. McConnell AFB</b>   | <b>Wichita, KAN</b>           |
| <b>20. Minot AFB</b>       | <b>Minot, ND</b>              |
| <b>21. Offutt AFB</b>      | <b>Omaha, NEB</b>             |
| <b>22. Pease AFB</b>       | <b>Portsmouth, NH</b>         |
| <b>23. Peterson AFB</b>    | <b>Colorado Springs, COLO</b> |
| <b>24. Plattsburgh AFB</b> | <b>Plattsburgh, NY</b>        |
| <b>25. Vandenberg AFB</b>  | <b>Lompoc, CA</b>             |
| <b>26. Whiteman AFB</b>    | <b>Knob Noster, MO</b>        |
| <b>27. Shemya AFB</b>      | <b>Aleutian Islands, AK</b>   |

**PRELIMINARY\* GEOTHERMAL  
ASSESSMENT  
SAC BASES**

(not in order of priority)

• **PRIME GEOTHERMAL POTENTIAL**

Sondrestrom AB, Greenland  
Ellsworth AFB, SD  
Vandenberg AFB, CA  
March AFB, CA

• **POSSIBLE GEOTHERMAL POTENTIAL**

Shemya AFB, AK  
Thule AB, Greenland  
Carswell AFB, TX  
Minot AFB, ND  
Fairchild AFB, WA

**\* MUCH MORE DETAILED ANALYSIS NEEDED**

# **SAC BASES**

**with**

## **PRIME GEOTHERMAL POTENTIAL**

- **SONDRESTROM AB, Greenland**
  - hot springs reported on site
  - near major geologic province boundaries
- **ELLSWORTH AFB, SD**
  - on Madison formation thermal aquifer
  - expect 40°C water at 1000-2000m
- **VANDERBERG AFB, CA**
  - well on site with 42°C water
- **MARCH AFB, CA**
  - between Elsinore (12mi SW) and Lakeview (6mi E) geothermal areas

# **SAC BASES**

**with**

## **POSSIBLE GEOTHERMAL POTENTIAL**

- **SHEMYA AFB, AK**

- volcanic island, but volcanics are old

- **THULE AB, Greenland**

- potential unknown

- **CARSWELL AFB, TX**

- along Balcones fault zone

- possible production 40°C from 300-600m

- **MINOT AFB, ND**

- possibly over Madison formation aquifer

- **FAIRCHILD AFB, WA**

- two known warm wells 15 mi distant

- 30°C at 500m

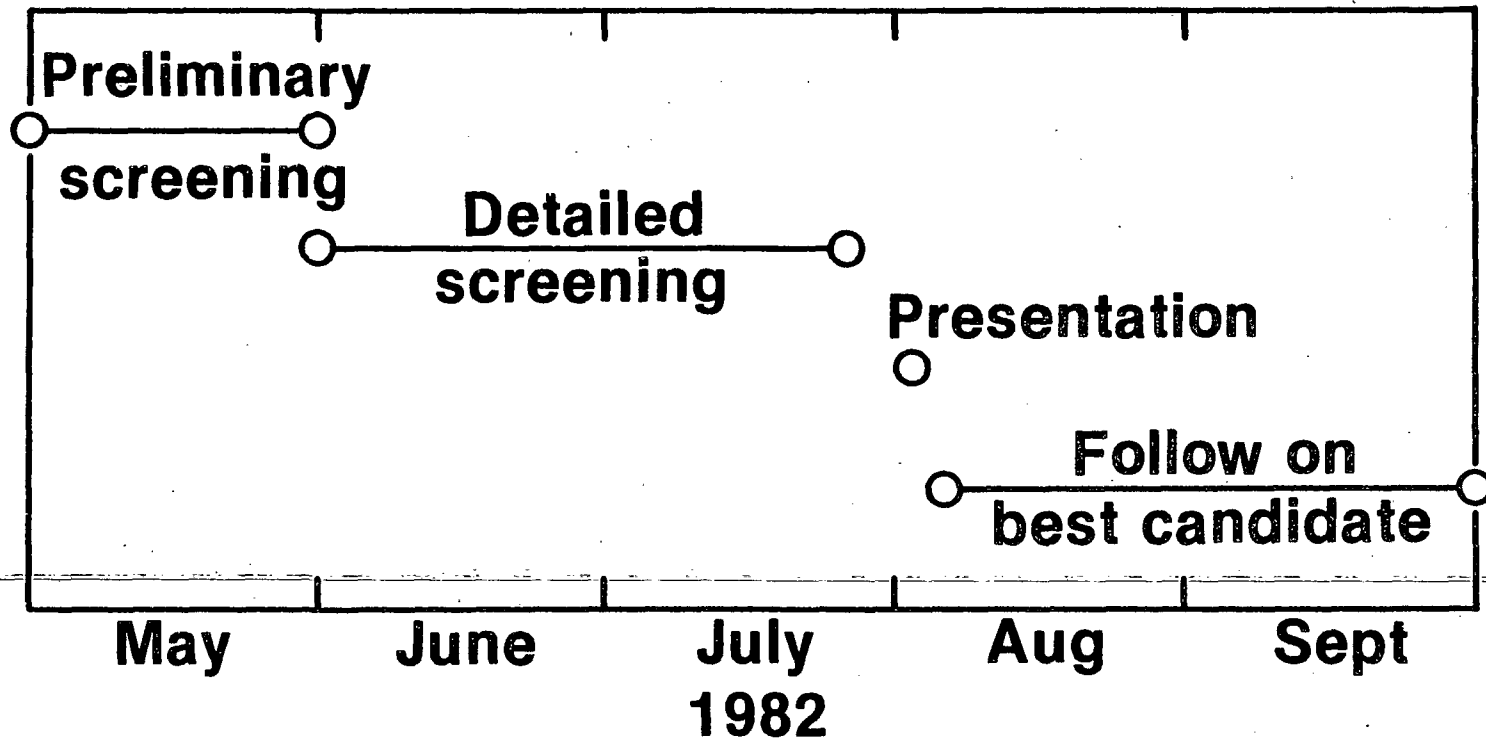
# **Golden Rules of Geothermal Development**

- **A commercial resource can be a cheap source of power**
- **Not all land has a commercial resource**
- **Commercial resources will not move**



# Schedule

## Assessment & Development of Geothermal Power at U.S. Air Force SAC Bases



# **Geothermal Assessment U.S. Air Force SAC Bases Task Description Preliminary Screening**

- **Get complete list of bases**
- **Get listing of base energy uses**
- **Gather available resource data**
- **Develop preliminary prioritization**
  - **Resource quality**
  - **Resource location**
  - **Qualitative economic potential**

# **SAC Geothermal Assessment Detailed Screening**

- **For bases with positive potential**
  - **Assess physical location energy use**
  - **Assess types of energy use**
  - **Assess resource quality**
  - **Identify potential well sites**
  - **Qualitatively layout geothermal system**
  - **Qualitatively assess economics**

# **SAC Geothermal Assessment Detailed Screening Greenland Study**

- **Sondrestrom**
  - **Locate geothermal manifestations**
  - **Prepare geologic map**
  - **Perform chemical geothermometry**
  - **Prepare conceptual reservoir model**
  - **Study energy requirements**
  - **Layout conceptual geothermal system**
  - **Conduct preliminary economic analysis**

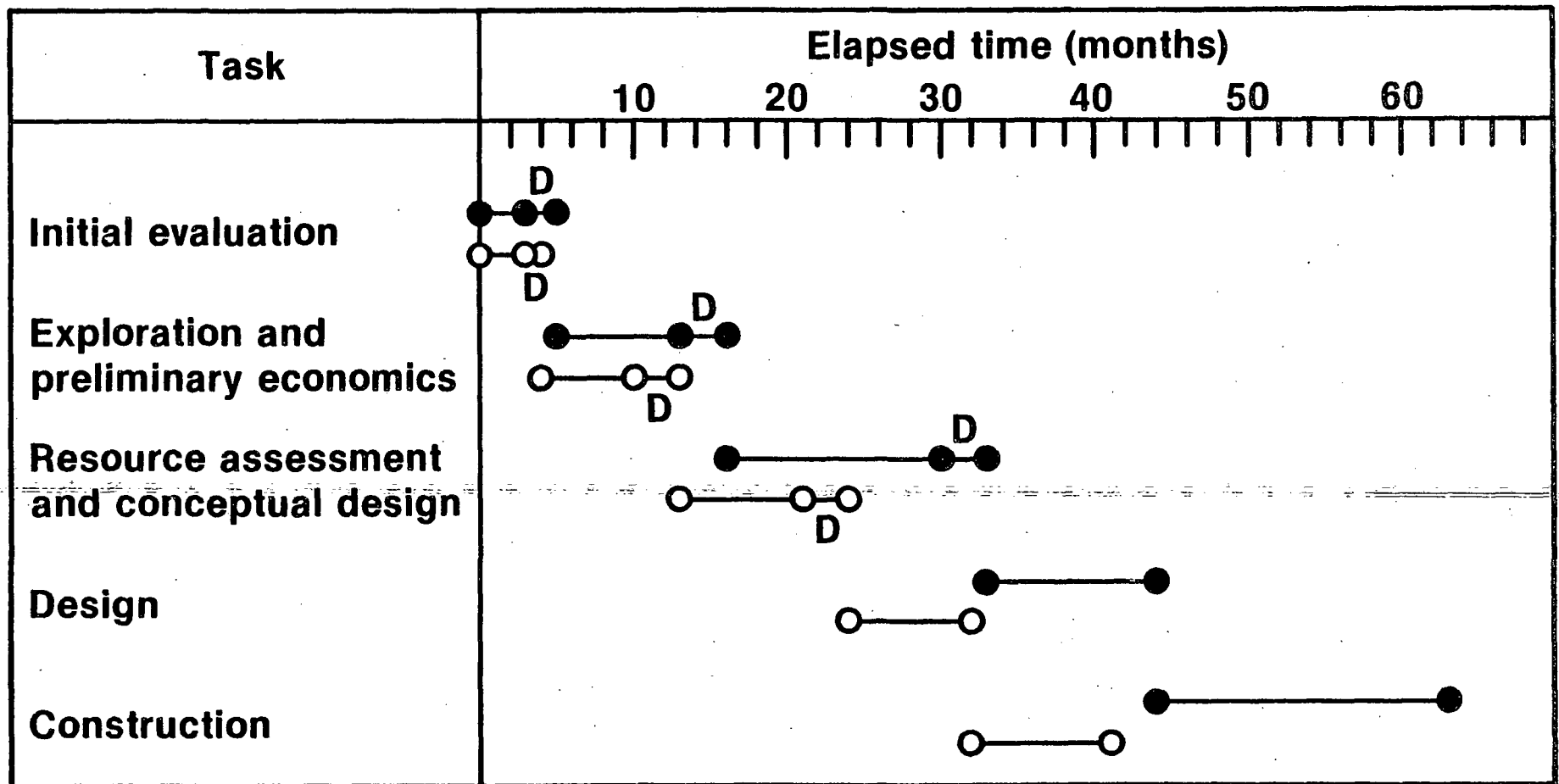
# **SAC Geothermal Assessment 9 Aug 82 Presentation**

- **Prioritized list of candidate sites**
  - **Resource evaluation**
  - **Potential application**
  - **Qualitative economics**
- **FY 83 recommended programs**
  - **Sites recommended**
  - **Tasks**
  - **Cost**
  - **Schedule**

# **SAC Geothermal Assessment Follow on Work**

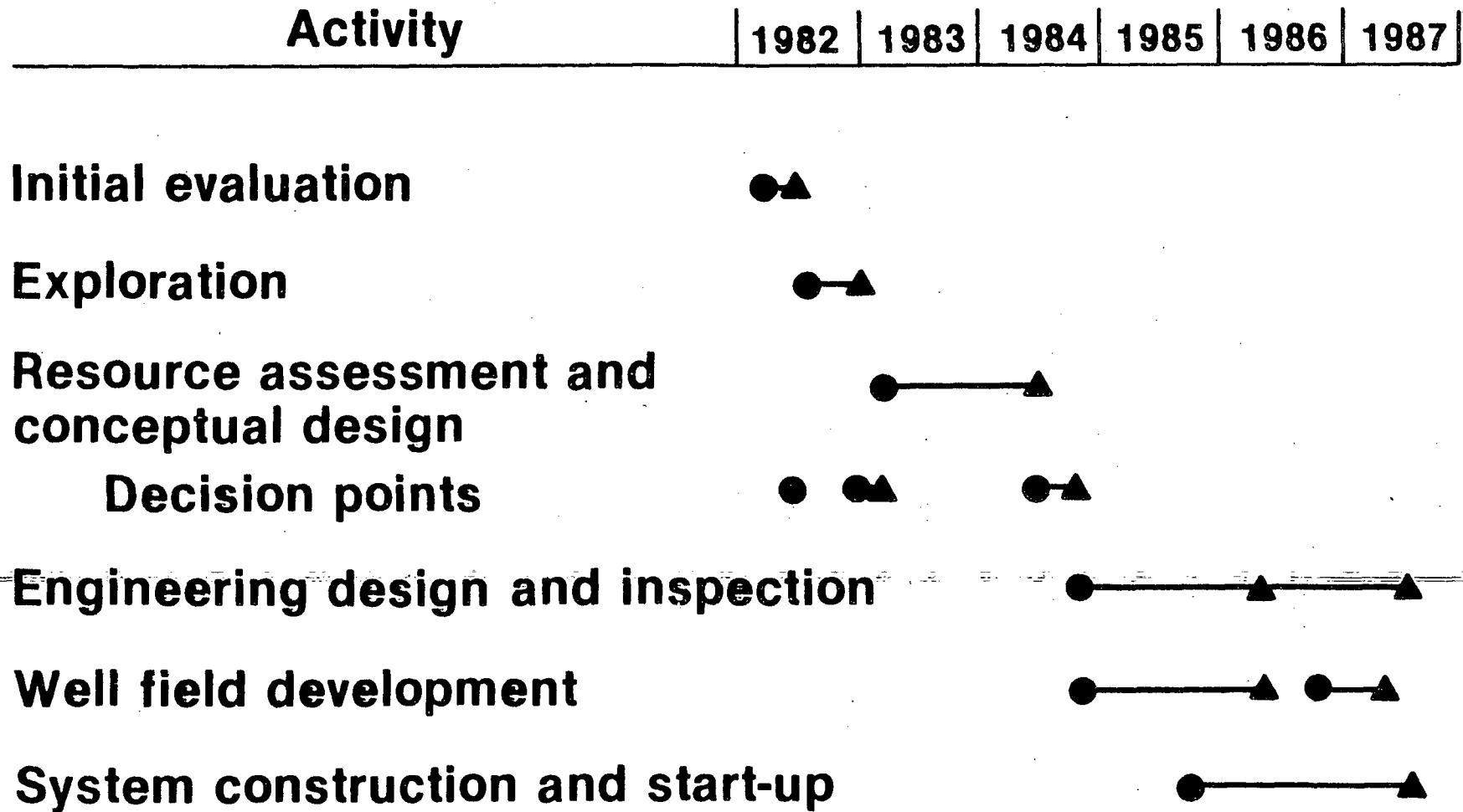
- **Option 1**
  - **Level of effort**
    - **Respond to Air Force questions**
    - **Acquire detailed information where needed**
    - **Start detailed study of prime prospect**
  
- **Option 2**
  - **Initiate prime candidate project**
    - **Perform geochemical survey**
    - **Perform electrical resistivity survey**
    - **Perform laboratory analysis of rocks and water**
    - **Prepare detailed geological map**
    - **Get detailed energy use data for conceptual system design**
    - **Respond to Air Force questions**

# SAC Geothermal Assessment Typical Schedules for Geothermal Direct Application Projects



D = Decision points

# Dual Flash Plant Schedule





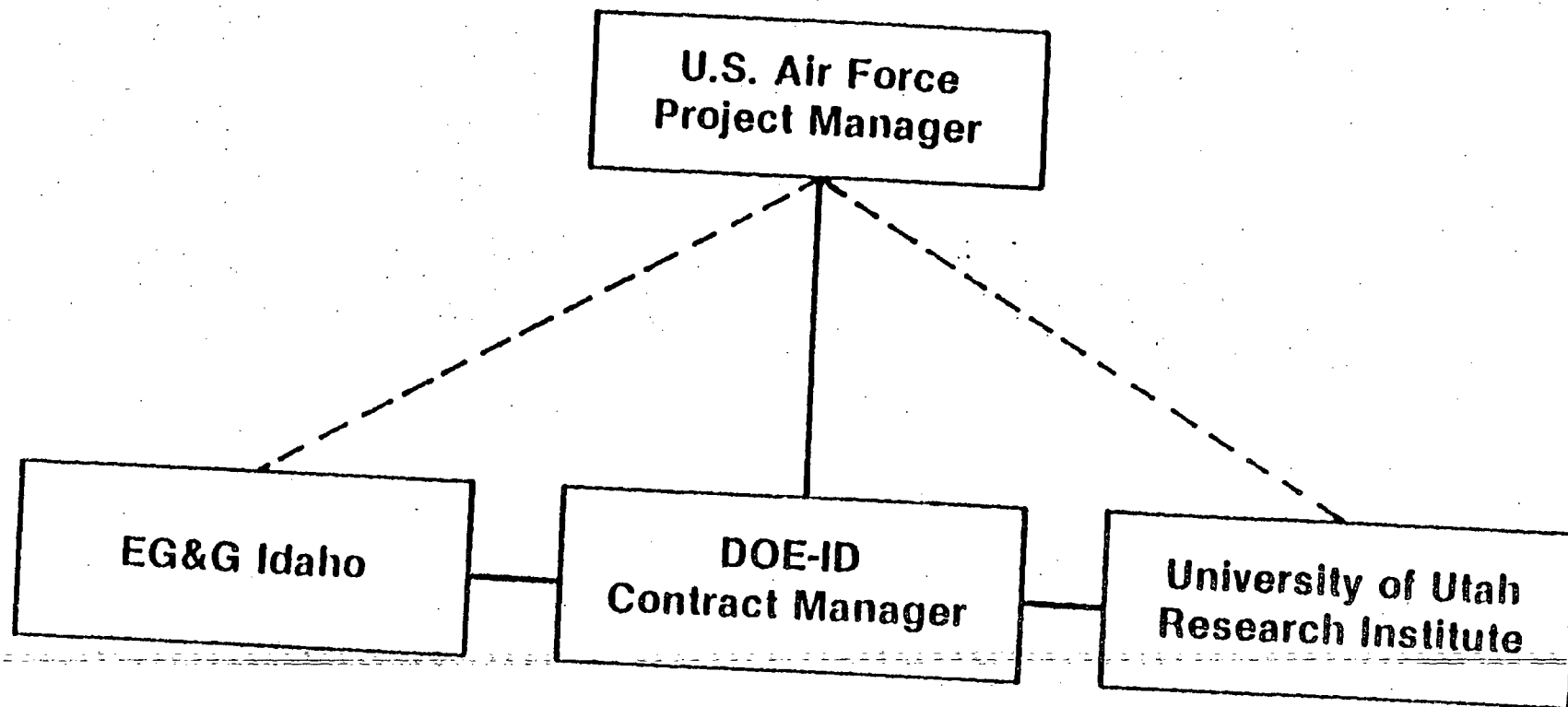
# SAC Geothermal Development FY 1982 Proposed Budget

<u>Tasks</u>	<u>Cost (\$1000)</u>	
Preliminary screening	0	0
Detailed screening	32	32
Greenland study	18	18
Report & presentation	10	10
Follow on work for best candidate	20	—
Full exploration for Greenland	—	67
	<u>80</u>	<u>127</u>

# Proposed Project Organization

S2 0365

# Organizational Structure



--- Technical interface  
— Contractual interface