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An Evaluation of Hydrothermal

Resources of North Dakota - Phase II

Submitted by

The Engineering Experiment Station

University of North Dakota

Grand Forks, North Dakota

In Cooperation with the North Dakota

Geological Survey

Grand Forks, N.D. and

The Dept of Physics

University of North Dakota

Grand Forks, N.D.

to

Department of Energy - Division of Geothermal Energy

Roy Mink

January 21, 1980

Amount Requested	100000.00
UND, NDGS Cost Share 1	20171.01
Total	120171.01

Funding Period - June 1, 1980 - June 1, 1981

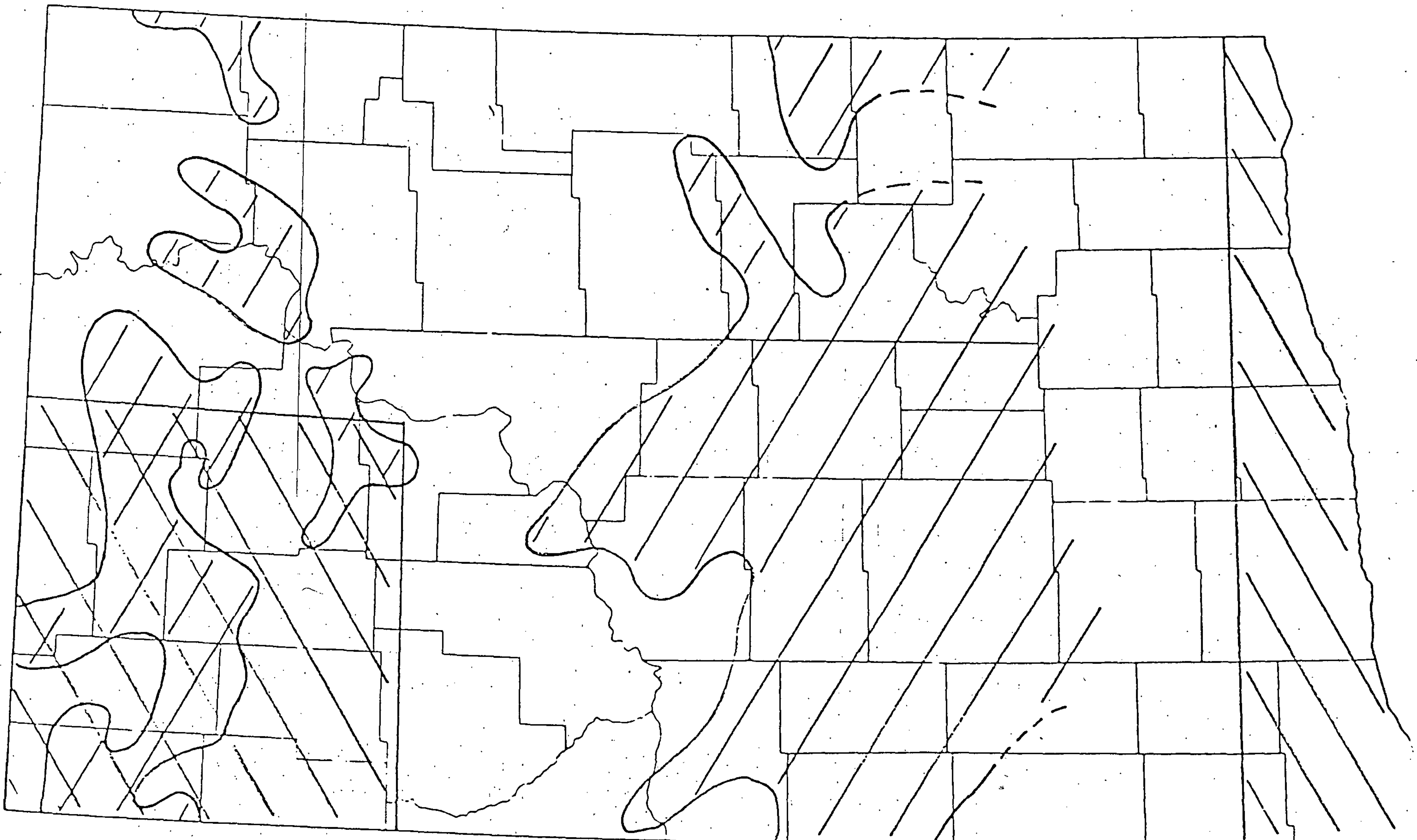
INTRODUCTION

The proposed study will consist of a detailed analysis based on results of the preliminary evaluation, Phase I, of the geothermal resources of North Dakota (ref. 1) carried out under cooperative agreement DOE-FCØ 7-79ID12Ø3Ø.

The phase I study is providing a preliminary geothermal resource evaluation based on all bottom-hole-temperature, depth, and stratigraphic data stored in the North Dakota Geological Survey oil and gas well files. The information will be displayed on a North Dakota base map to show the areal changes in the apparent geothermal gradient, observed temperature and water quality of potential hydrothermal reservoirs.

Since 1973 the terrestrial heat-flow has been measured at some 35 sites in North Dakota (ref. 2, 3, 4, 5,). The results of these measurements characterize the heat-flow in two main areas of the state (fig. I).

AAPG geothermal gradient data (ref. 6) and preliminary results of the Phase I study (fig.2) indicate that higher than average geothermal gradients are presented west of 102°W, between about 98°30'W and about 101°W, and north of 48°30'N from about 98°30'W west to the Montana border (fig I).

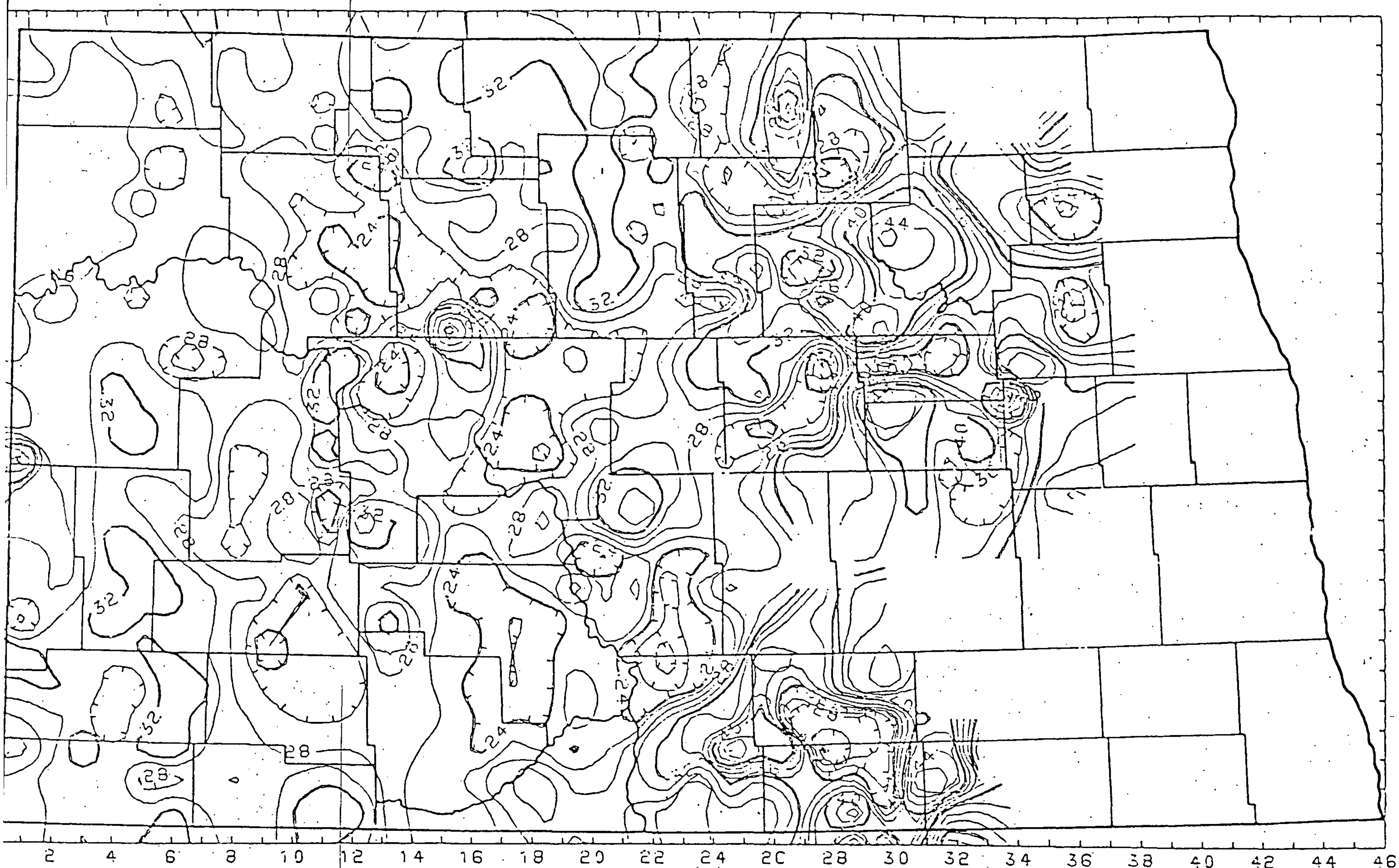


SCALE IN MILES

Areas of reliable heat-flow data

Areas of higher than average geothermal gradients

Figure 1



GEOTHERMAL GRADIENT - CONTOUR (HRU#1)

PLOT NO. 1 DATE 1/17/80 TIME 23:12:27

Figure 2

A phase II study is proposed in the area indicated in Figure 3, which includes all areas of above average geothermal gradient for which reliable heat-flow data is not available.

The phase II activities would be directed at a detailed evaluation of potential geothermal resource areas, which would include heat-flow measurements, detailed stratigraphy, and further characterization of the aquifer water quality.

OBJECTIVES AND METHODS

There are three main objectives to be met in the areas of potential geothermal resources identified by phase I.

Objective:

Develop a comprehensive survey of the terrestrial heat flow in North Dakota. Fig. 4 includes measurements completed at this time. In much of the region of the state where a higher than average gradient (see fig. 1) is observed no measurements of the heat flow have been completed.

Method:

Heat flow determinations will be made employing sites as they are available from two primary sources:

1. Oil Industry holes (abandoned or shut in wells).
2. Holes drilled as a part of the North Dakota State Water Commission Survey and U.S.G.S. Water Resources Branch.

Two basic considerations apply in the selection of sites from these sources. First is accessibility. The primary concern is the

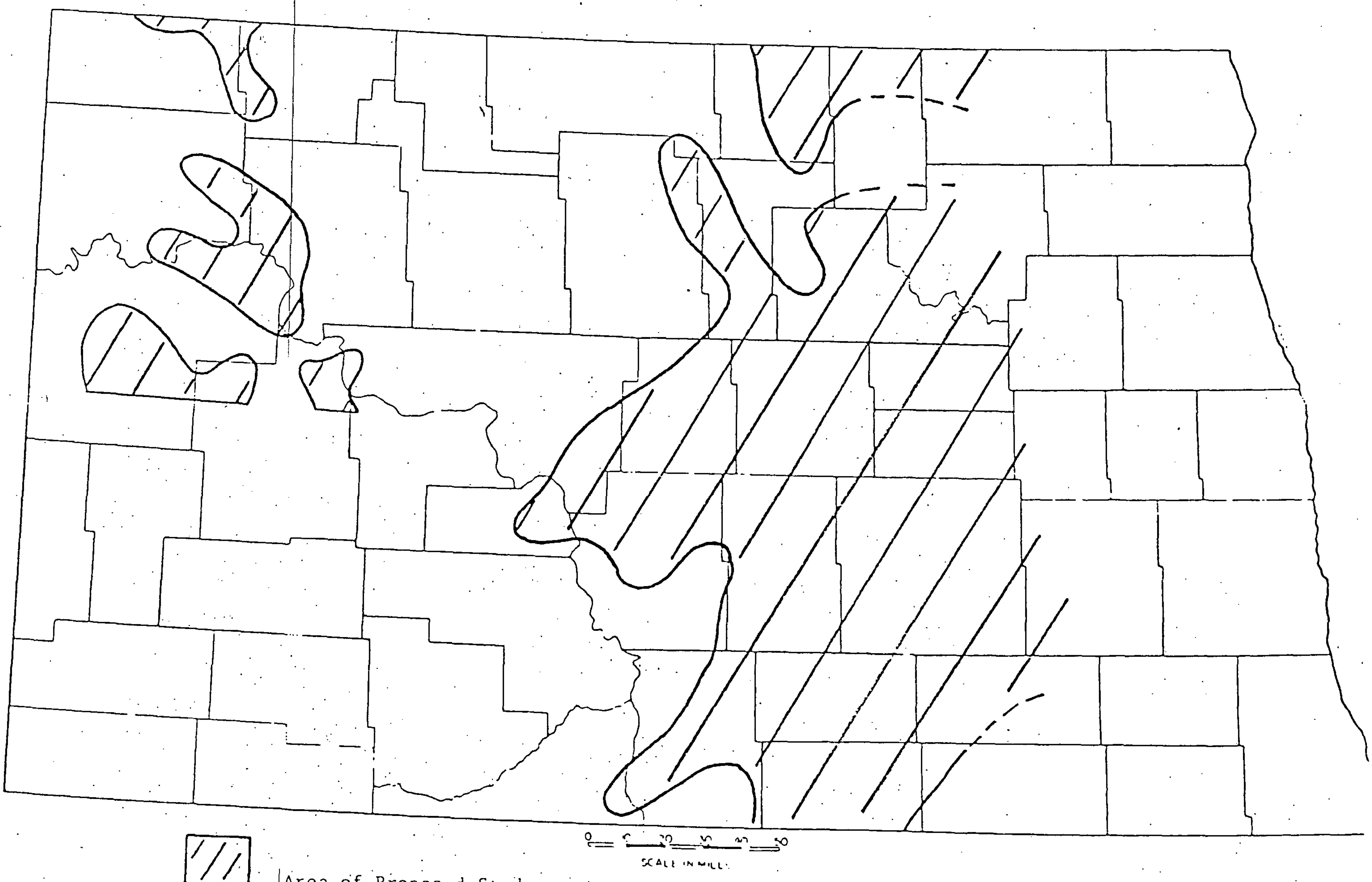
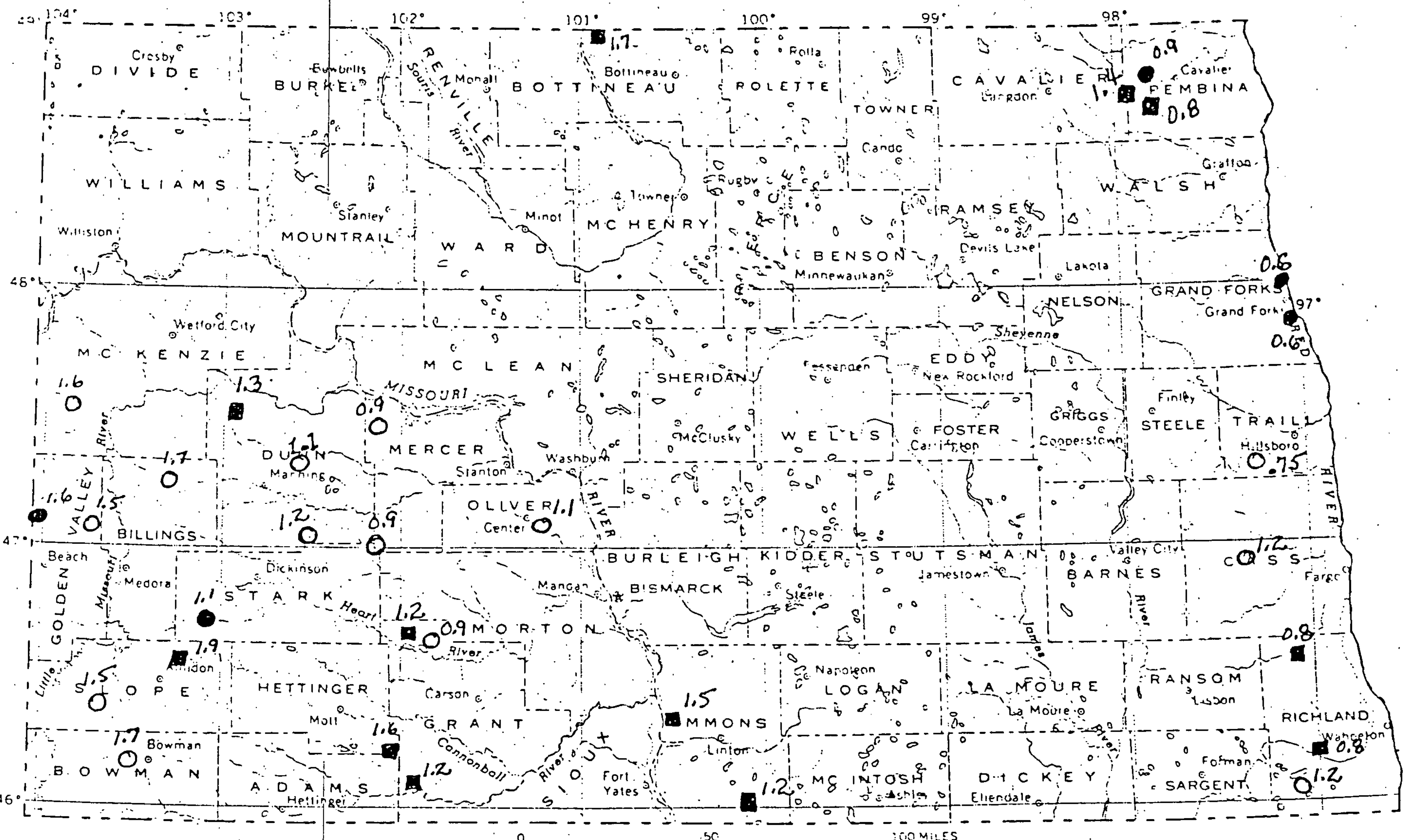


Figure 3



Measured Heat Flow values in No. Dak. (ref. 2, 3, 4, 5)

Figure 4

to opening the hole, or logging, the second consideration is whether the temperature measured in the borehole represents the equilibrium temperature in the surrounding earth. The information which enables one to evaluate this concern is usually evident from drilling records, or may be inferred from inspection of the temperature log. Repeated logging of a hole at periods of several months sometimes proves useful in revealing this information.

An attempt will be made to recover holes drilled in a region of interest which by casing and cementing may provide a suitable heat flow determination site. This process of going piggyback on someone elses drilling has provided us three good heat flow values in southeastern North Dakota. Although not inexpensive, since we must provide casing, cement, and rig time for setting the casing and cementing, the greater cost of drilling the hole is avoided.

A heat flow determination requires knowledge of the thermal conductivity of earth materials at the site as well as a temperature profile. Samples of material from the hole are necessary. Such samples, usually in the form of drill cuttings, are available from the N.D.G.S. Core and Sample Library for most holes of interest.

Determination of thermal conductivity will be made using well known techniques (ref. 7, 8) applicable to the available sample type.

In addition to determining thermal conductivities from each heat-flow site studied, the thermal conductivity of material from important formations will be catalogued. This will enable us to make reasonable estimates of heat-flow from a temperature profile through the formation even though samples of material from the formation site may be unavailable.

Information gained from these heat flow determinations will be used with phase I date to substantiate areas of possible commercialization. From this information it may be possible to better identify the mechanisms responsible for the generation, and transfer of heat into regions of commercial interst, thus providing additional basis for development guidelines.

Objective:

Construct geologic maps of potential hydrothermal aquifers in areas of interest.

Methods:

Preliminary results of our Phase I study have identified a general area of above average geothermal gradients (>30°C/km) in the easter one third of North Dakota (Fig. 2). The basal Cretaceous sand, the Inyan Kara group, is a particularly interesting, widespread potential hydrothermal aquifer in this area. Our present data suggests the possibility that warm water from Paleozoic aquifers is being introduced into the basal Cretaceous sands in areas where truncated Paleozoic rocks underly the preCretaceous errosional surface. (Figure 5). We propose constructing detailed structural and sand-shale ratio maps of the Inyan Kara group to indicate expected temperatures, the probability of encountering productive sands, and proximity of potentially useful areas to population centers.

Maps of the Inyan Kara group and other potential hydrothermal aquifers can be generated by incorporating additional stratigraphic information into the computer well file developed during Phase I.

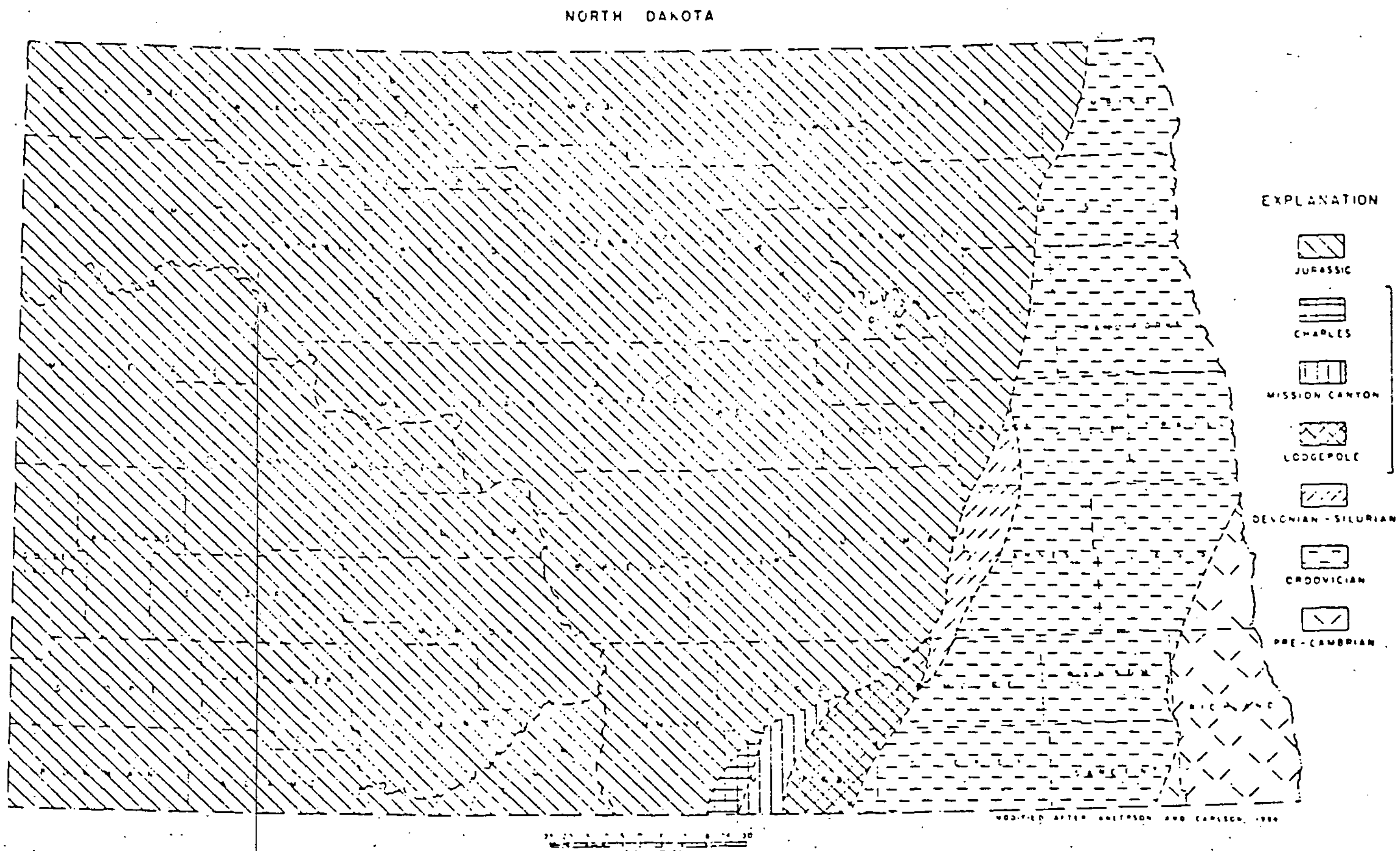


Figure 3

PRE-CRETACEOUS PALEOGEOLOGICAL MAP

From: Dan E. Hansen, 1955, Bulletin 29, NDGS

Figure 5

Objective:

Summarize existing water quality for specific areas of interest.

Methods:

Phase I has collected water quality information in a general statewide attempt to characterizing the water quality of major aquifer systems. Phase I has also localized the areas of interest by delineating areas of potentially useful hydrothermal resources. We will now concentrate our efforts in these localized areas of interest. Water quality data will be collected from county, city and local sources as well as other state and federal agencies. This water quality data will supplement the data gathered during Phase I.

APPROXIMATE SCHEDULE OF INDIVIDUAL EFFORTS

RINCIPAL INVESTIGATOR PHYSICS	SITE SELECTION FIELDWORK (March–May); THERMAL CONDUCTIVITY MEASUREMENT, HEAT FLOW ANALYSIS (May–Jan.); FINAL ANALYSIS, FINAL REPORT (Jan.–March)
RINCIPAL INVESTIGATOR GEOLOGY	SITE SELECTION FIELDWORK (March–May); REFINE STRATIGRAPHIC FRAMEWORK, STRUCTURAL STRATIGRAPHIC MAPPING (May–Jan.); FINAL ANALYSIS, FINAL REPORT (Jan.–March)
EOLOGIST STRATIGRAPHY	STRATIGRAPHIC CONSULTATION (March 1980–March 1981)
OMPUTER PROGRAMER	INSERTION OF STRATIGRAPHIC DATA IN COMPUTER WELL FILE; SUPERVISE CODING; DEVELOP BASE MAPS. (March–Jan.); FINAL MAPS (Jan.–March)
IELD TECHNICIAN	MEASURE TEMP. PROFILES FIELDWORK (June–Aug.)
RADUATE RESEARCH ASS'T. PHYSICS GEOLOGY	(March–June); THERMAL CONDUCTIVITY MEASUREMENTS, HEAT FLOW ANALYSIS, GEOLOGIC MAPPING (June–Aug.); (Aug.–March)
UDENT ASS'T.	ASSIST FIELD TECH (June–Aug.)
UDENT ASS'T.	(March–May); SELECT AND SORT SAMPLES FOR T.C. MEASUREMENT (Aug.–March)
UDENT ASS'T.	(March–May); CODING DEBUGGING STRAT DATA (Aug.–March)

7 MARCH 1980 — MAY — JULY — SEPT. — NOV. — JAN — 6 MARCH 1981

PROPOSED BUDGET

PERSONNEL	NDGS or UND	DOE	TOTAL
Co-Principal Investigator-Physics (2 man-mos @ 2380=4760) (0.2x9-mos=4250)	4250	4760	9010
Co-Principal Investigator-Geology Geologist (stratigraphy-computer App.) (3 man-mos. @ 1730/mo.)	5190		5190
Geologist (stratigraphy) (1 man-mo. @ 2000/mo.)	2000		2000
Computer Programmer (6 man-mo. @ 1800/mo.)		5400	5400
Research Ass't (Field Tech.) (2 man-mo. @ 1800/mo.)		3600	3600
Graduate Research Ass'ts (Geology and Physics) (20 man-mo. @ 550/mo) ~~(4 man-mo. @ 1100/mo.)~~		11000	11000
Student Ass'ts (11 wks @ 40 hr/wk) (18 wks @ 8 hr/wk) (36 wks @ 20 hr/wk) (1304 Hr @ 4/hr.)		5216	5216
Clerical-Sect. (1.5 Man-mo. @ 850/mo.)		1275	1275
Draftsman (150 hr @ 6.80/hr)		1020	1020
TOTAL SALARIES	11440	32271	43711
BENEFITS (16% of Tot. Sal.)	1830.40	5163.36	6993.76
SUBTOTAL (Total Sal. Benefits)	13270.40	37434.36	50704.76
INDIRECT COSTS (52% of subtotal)	6900.61	19465.87	26366.48
TOTAL SALARIES, BENEFITS & INDIR. CST.	20171.01	56900.23	77071.24
	(26)	(74)	(100)

PROPOSED BUDGET

Services/Equipment	NDGS/UND	DOE	TOTAL
- Computer Services			
- CPU Time (5 hr/mo. for 6 mo.=30 hr. @ 360/hr)		10800	10800
- VSPC Terminal Port (140/mo for 6 mo.)		840	840
- Plotter Time (100 hr @ 10/hr		1000	1000
- Key Punch Time (62.5 Hr @ 16/hr)		1000	1000
- Supplies (Paper, Pencils (Computer expendables)		500	500
- Publication Expenses		500	500
- Travel			
- Fieldwork			
-5000 mi @ .2/mi		1000	1000
-support (2 people x (13+20/dy x 50 dys)		3300	3300
-Vehicle (6 mo. @ 400/mo)		2400	2400
- Well Access and Testing (5000 mi @ .2/mi)		1000	1000
- Meetings			
-Salt Lk. City (4 people, 1 trip @ 500/person)		2700	2700
-Geoth. Res. Counc. Mtg. ($700)			
- Equipment (Casing, cement and rig time 2656 @ 5/ft)		13281.77	13281.77
- Thermister Temperature Probe		263	263
- Gamma Ray Logging Tool		1350	1350
- Constant Temperature Bath.		965	965
- Four-Conductor Bore Hole Cable (2000 ft)		2000	2000
- Equipment Maintenance		200	200
TOTAL (EQUIP./SERVICES)		43099.77	43099.77
TOTAL (SALARIES, BENEFITS & IND. CST.)	20171.01	56900.23	77071.24
GRAND TOTAL	20171.01	100000.00	120171.01
	(17)	(83)	(100)

Proposed Budget broken down by TASKS

	NDGS/UND	DOE	TOTAL
I Heat Flow Measurements & Related Activities			
A) People			
- PI (PHYSICS) (1)	4250	4760	9010
- Computer Programer (.2)		1080	1080
- Research Ass't. (Field tech) (1.0)		3600	3600
- Grad. Research Ass't. (5)		5500	5500
- Student Ass't. (5)		2608	2608
- Clerical-Sect. (5)		637.50	637.50
- Draftsman (.5)		510	510
SubTotal I (Salaries)	4250	18695.50	22945.50
- benefits, .16 of Sub tot. I	680	2991.28	3671.28
SubTotal II (Sal. + benef.)	4930	21686.78	26616.78
- indirect cst., .52 of Sub.Tot. II	2563.60	11277.13	13840.73
Total Salaries	7493.60	32963.91	40457.51
B) Services And Equipment			
- Computer Services (.2)		2728	2728
- Supplies (.5)		250	250
- Publication (5)		250	250
- Travel			
- Field Work (1.0)		6700	6700
- Well Access & Tstg (1.0)		1000	1000
- Meetings (5)		1350	1350
- Equipment			
- casing (1.0)		13281.77	13281.77
- thermister probe (1.0)		263	263
- gamma Ray tool (5)		675	675
- Const. Temp. Bath (1.0)		965	965
- 4-conductor Cable (5)		1000	1000
- Maint. (.5)		100	100
- Total		28562.77	28562.77
C) Summary for Heat Flow & Related Activities			
- People	7493.60	32963.91	40457.51
- Services & Equip.		28562.77	28562.77
- Total For Task	7493.60	61526.68	69020.28
	(11)	(89)	(100)

	NDGS/UND	DOE	TOTAL
II Potential Aquifer Mapping And Water Chemistry Data Summary			
A) People			
-PI (Geology) (1.0)	5190		5190
-geologist Stratigraphy (1.0)	2000		2000
-Computer Programer (.8)		4320	4320
-Graduate Research Ass't. (.5)		5500	5500
-Student Ass't. (.5)		2608	2608
-Clerical-Sect. (.5)		637.50	637.50
-Draftsman (.5)		510.	510
-Sub Total I (Salaries)	7190	13575.50	20765.50
-benefits (.16 of SubTot. I)	1150.40	2172.08	3322.48
-Sub Total II (Sal. + benef.)	8340.40	15747.58	24087.98
- indirect costs (.52 of SubTot II)	4337.00	8188.74	12525.75
-Total Salaries	12677.40	23936.32	36613.73
B) Services And Equipment			
- Computer Services (.8)		10912	10912
- Supplies (.5)		250	250
- Publication (.5)		250	250
- Travel			
- Meetings (.5)		1350	1350
- Equipment			
- gamma Ray Tool (.5)		675	675
- 4-Conductor Cable (.5)		1000	1000
- Maint. (.5)		100	100
- TOTAL Services And Equip.		14537	14537
c) Summary for Potential Aquifer Mapping and Water Chemistry Data Summary			
- People	12677.40	23936.32	36613.73
- Services and Equip.		14537.-	14537.-
- Total for Task	12677.40	38473.32	51150.73
	(25)	(75)	(100)

III Budget Summary for Proposed Tasks

	NDGS/UND	DOE	TOTAL
A) Heat Flow Measurements and related Activities	7493.60 (11)	61526.68 (89)	69020.28 (100)
B) Potential Aquifer Mapping and Water Chemistry Data Summary	12677.40 (25)	38473.32 (75)	51150.73 (100)
c) GRAND TOTAL	20171	100,000	120,171.01

LIST OF REFERENCES

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Co-Principal Investigator

Francis L. Howell, Associate Professor, Physics Department, University of North Dakota.

Date and Place of Birth: November 25, 1932, Mitchell, South Dakota.

Education: Montana State University - Ph. D. (Physics) - 1969
Thesis: Hydrogen Bonding in Lithium Hydrazinium Sulfate.

University of South Dakota - M.A. (Physics) - 1963
Thesis: Temperature Dependence of the Nuclear Quadrupule Resonance Frequency of Cl^{35} in Barium Chlorate.

Yankton College - B.A. (Math-Chem) - 1959

Research Interests and Experience: Study of solids using techniques of N.M.R., N.Q.R., electrical conductivity and dielectric constant measurements. Study of terrestrial heat flow, thermal conductivity of earth materials.

Academic Experience: 1969-present - Department of Physics, University of North Dakota. 1963-1965 - Instructor, Dept. of Physics, University of South Dakota. 1959-1962 - Instructor of Math., Chem., Physics, Public High School at Yankton, South Dakota and Marshall, Minnesota

Non-Academic Experience: 1973, summer - Visiting Assoc. Prof., Macromolecular Science, Case Western Reserve Univ. 1953-1957 - Electronics Technician, U.S.A.F.

Professional Affiliations: American Association of Physics Teachers, American Geophysical Union, North Dakota Academy of Science.

Kenneth L. Harris

CO-PRINCIPA INVESTIGATOR

EDUCATION:

University of North Dakota, Ph.D. (Geology), 1975
Dissertation: Pleistocene Geology of the Grand Forks-Bemidji Area, Northwestern Minnesota.
University of North Dakota, M.S. (Geology), 1973
Thesis: Pleistocene Stratigraphy of the Red Lake Falls Area, Minnesota.
North Dakota State University, B.S., 1969
Major: Electrical Engineering Minor: Geology

WORK HISTORY:

July 21, 1977 to Present
North Dakota Geological Survey
University of North Dakota
University Station
Grand Forks, North Dakota 58202

Title: Geologist III
Supervisor: Lee Gerhard, State Geologist
Responsibilities: Conduct and participate in geologic investigations in the following, main areas: Pleistocene stratigraphy, geologic surface mapping, land use, coal reclamation, energy resources.

June 1975 to July 15, 1977
Cities Service Oil Company
Southeast Region
Exploration and Production Office
4785 I-55 North
Jackson, Mississippi 39206

Title: Exploration Geologist
Supervisor: Jim Stripling, Geological Manager
Responsibilities: Developing wildcat prospects for hydrocarbon recovery in the lower Cretaceous of East Texas.

May 1972 to August 1972 (Summer Employment)
Exxon Company
Minerals Division
Energy Bldg. 1
107 Werner Ct.
Casper, Wyoming 82601

Title: Field Geologist
Supervisor: Ladd Hagmaier
Responsibilities: Reconnaissance mapping of Tertiary rocks in central and southwestern Wyoming.

July 1969 to July 1970
Schlumberger Well Services
P. O. Box 2175
Houston, Texas 77001

Title: Field Engineer
Supervisor: Glen Campbell, Location Manager, Miles City, Montana
Responsibilities: Performing and interpreting wire-line well logging services for clients in southeastern Montana.

MISCELLANEOUS INFORMATION:

Professional Society Memberships:
The American Association for the Advancement of Science
The American Association of Petroleum Geologists

MILITARY EXPERIENCE:

U.S. Navy, August 1961 to August 1965
Training: Airborne electronics maintenance schools
Service: West Pacific
Rank: Petty Officer Second Class (E-5)
Discharge: Honorable

PERSONAL DATA:

Age: 36 (born 1/17/42, Bismarck, North Dakota)
Marital status: Married, 1 child
Hobbies: Photography and canoeing

PUBLICATIONS:

Harris, K. L., 1972, Glacial stratigraphy complicated by subglacial thrusting (abs): Abstracts with Programs, v. 4, no. 5, Geol. Soc. America, p. 325.

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Moran, S. R., Arndt, M., Bluemle, J. P., Camara, M., Clayton, L., Fenton, M. W., Harris, K. L., Hobbs, H. C., Keatinge, R., Sackreiter, D. K., Salomon, N. L., and Teller, J., 1976, Quaternary stratigraphy and history of North Dakota, Southern Manitoba, and Northwestern Minnesota: in W. C. Mahaney, editor, Quaternary stratigraphy of North America, Stroudsburg, Pennsylvania, Dowden, Hutchinson and Ross, Inc., pp. 133-158.

Bluemle, J. P., Kehew, A. E., Brostuen, E. A., Harris, K. L., 1978, Alfalfa and the occurrence of fissures on the North Dakota prairies: North Dakota Natural Science Soc., Grand Forks, North Dakota, The Prairie Naturalist, v. 10, no. 2, pp. 53-59.