

60094E



DIVISION OF EARTH SCIENCES  
ENVIRONMENTAL RESEARCH CENTER  
UNIVERSITY OF NEVADA, LAS VEGAS  
100 WASHINGTON ST., SUITE 201  
RENO, NEVADA 89503 • (702) 784-6151  
FAX (702) 784-1300

April 25, 1990

Ms. Elizabeth Bowhan, Contracts Director  
U.S. Department of Energy  
Idaho Operations Office  
785 DOE Place  
Idaho Falls, ID 83402

Dear Ms. Bowhan:

The Division of Earth Sciences is completing work on DOE contract DE-FG07-88ID12784, entitled "Geothermal Fluid Genesis in the Great Basin" (see attached). The scheduled completion date for submission of the final report is May 1, 1990. All of the research and field work have been completed and a draft report was submitted for technical review to Dr. Marshall Reed (DOE Headquarters in Washington, D.C.), Dr. Howard Ross (University of Utah Research Institute), and others, in March, 1990. All comments and suggestions have been incorporated into a revised draft (see attached). The purpose of this letter is to request additional time for review of the draft by the U.S. Geological Survey, in Menlo Park, California.

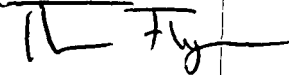
Earlier this month, Dr. Reed suggested that I forward a copy of the draft to Dr. Robert Mariner, a geologist with the USGS who is a recognized authority in geothermal science. Dr. Ross agreed that the report findings were significant and warranted the expertise of an outside agency for review. I contacted Dr. Mariner by telephone and, although he agreed to review the report, he explained that his schedule would keep him from the review until May 1, 1990. I contacted Dr. Ross and, after discussion with Dr. Reed, they recommended that I contact your office with the following proposal.

The Division of Earth Sciences, University of Nevada, Las Vegas, proposes to grant itself a one month no-cost extension of time on contract DE-FG07-88ID12784 for the purposes of obtaining and incorporating addition input to the draft copy of the final report from the U.S. Geological Survey. This request will change the Budget and Project Termination Date from May 1, 1990 to June 1, 1990. It is the understanding of the Division of Earth Sciences that this request is provided for in 10 CFR Part 600, section 600.31d, as amended by FR doc. 89-24243, filed 10/12/89. No additional Federal funds are requested for this extension.

Note  
Citation

On behalf of the Division and the University, I appreciate your cooperation in this matter and regret any inconveniences that may arise. If you have any questions, please contact me at 702 784-6151. Thank You.

Sincerely,



Thomas Flynn, Deputy Director  
Principal Investigator

enclosure:

copies to:

Dr. Marshall Reed, DOE Washington  
✓ Dr. Howard Ross, UURI  
Kenneth J. Taylor, DOE Idaho  
Pattie Baldwin, UNLV

U.S. DEPARTMENT OF ENERGY  
 NOTICE OF FINANCIAL ASSISTANCE AWARD  
 (See Instructions on Reverse)

ACC  
 9-2-343-4752-217

Public Law PL 93-410

on, regulations and policies applicable to (cite legislative program title):

Geothermal Energy Research, Development, and Demonstration Act of 1974

<p>1. PROJECT TITLE <b>Geothermal Fluid Genesis in the Great Basin</b></p> <p>3. RECIPIENT (Name, address, zip code, area code and telephone no.)          University of Nevada, Las Vegas          Division of Earth Sciences          255 Bell Street, Suite 200 Reno, NV 89503</p> <p>8. RECIPIENT PROJECT DIRECTOR (Name and telephone No.)          Thomas Flynn (702) 784-6151</p> <p>9. RECIPIENT BUSINESS OFFICER (Name and telephone No.)          Patty Baldwin (702) 739-3745</p> <p>11. DOE PROJECT OFFICER (Name, address, zip code, telephone No.)          Kenneth J. Taylor [(208) 526-9063]          U.S. DCE, Idaho Operations Office          785 DOE Place, Idaho Falls, ID 83402</p>	<p>2. INSTRUMENT TYPE  <input checked="" type="checkbox"/> GRANT      <input type="checkbox"/> COOPERATIVE AGREEMENT</p> <p>4. INSTRUMENT NO. DE-FG07-88ID12784</p> <p>5. AMENDMENT NO. AC00</p> <p>6. BUDGET PERIOD FROM: 8/1/88 THRU: 8/1/89</p> <p>7. PROJECT PERIOD FROM: 8/1/88 THRU: 8/1/89</p> <p>10. TYPE OF AWARD  <input checked="" type="checkbox"/> NEW      <input type="checkbox"/> CONTINUATION      <input type="checkbox"/> RENEWAL  <input type="checkbox"/> REVISION      <input type="checkbox"/> SUPPLEMENT</p> <p>12. ADMINISTERED FOR DOE BY (Name, address, zip code, telephone No.)          Trudy A. Thorne (208) 526-9519          U.S. Department of Energy          Idaho Operations Office          785 DOE Place          Idaho Falls, ID 83402</p>
<p>13. RECIPIENT TYPE</p> <p><input type="checkbox"/> STATE GOVT      <input type="checkbox"/> INDIAN TRIBAL GOVT      <input type="checkbox"/> HOSPITAL      <input type="checkbox"/> FOR PROFIT ORGANIZATION      <input type="checkbox"/> INDIVIDUAL  <input type="checkbox"/> LOCAL GOVT      <input checked="" type="checkbox"/> INSTITUTION OF HIGHER EDUCATION      <input type="checkbox"/> OTHER NONPROFIT ORGANIZATION      <input type="checkbox"/> C    <input type="checkbox"/> P    <input type="checkbox"/> SP      <input type="checkbox"/> OTHER (Specify)</p>	

<p>14. ACCOUNTING AND APPROPRIATIONS DATA</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td style="width:25%;">a. Appropriation Symbol 89X0224.91</td> <td style="width:25%;">b. B &amp; R Number AM1510000</td> <td style="width:25%;">c. FTA/FP/OC YA410</td> <td style="width:25%;">d. CFA Number</td> </tr> </table>	a. Appropriation Symbol 89X0224.91	b. B & R Number AM1510000	c. FTA/FP/OC YA410	d. CFA Number	<p>15. EMPLOYER I.D. NUMBER/SSN</p>
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<p>BUDGET AND FUNDING INFORMATION</p>																			
<p>a. CURRENT BUDGET PERIOD INFORMATION</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>(1) DOE Funds Obligated This Action</td> <td>\$ 157,114</td> </tr> <tr> <td>(2) DOE Funds Authorized for Carry Over</td> <td>\$ -0-</td> </tr> <tr> <td>(3) DOE Funds Previously Obligated in this Budget Period</td> <td>\$ -0-</td> </tr> <tr> <td>(4) DOE Share of Total Approved Budget</td> <td>\$ 157,114</td> </tr> <tr> <td>(5) Recipient Share of Total Approved Budget</td> <td>\$ 20,300</td> </tr> <tr> <td>(6) Total Approved Budget</td> <td>\$ 177,414</td> </tr> </table>	(1) DOE Funds Obligated This Action	\$ 157,114	(2) DOE Funds Authorized for Carry Over	\$ -0-	(3) DOE Funds Previously Obligated in this Budget Period	\$ -0-	(4) DOE Share of Total Approved Budget	\$ 157,114	(5) Recipient Share of Total Approved Budget	\$ 20,300	(6) Total Approved Budget	\$ 177,414	<p>b. CUMULATIVE DOE OBLIGATIONS</p> <table border="1" style="width:100%; border-collapse: collapse;"> <tr> <td>(1) This Budget Period [Total of lines a.(1) and a.(3)]</td> <td>\$ 157,114</td> </tr> <tr> <td>(2) Prior Budget Periods</td> <td>\$ -0-</td> </tr> <tr> <td>(3) Project Period to Date [Total of lines b. (1) and b. (2)]</td> <td>\$ 157,114</td> </tr> </table>	(1) This Budget Period [Total of lines a.(1) and a.(3)]	\$ 157,114	(2) Prior Budget Periods	\$ -0-	(3) Project Period to Date [Total of lines b. (1) and b. (2)]	\$ 157,114
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17. TOTAL ESTIMATED COST OF PROJECT \$ 177,414  
 (This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations (specify) \_\_\_\_\_ (Date) \_\_\_\_\_

c. DOE Assistance Regulations, 10 CFR Part 600, as amended, Subparts A and  B (Grants) or  C (Cooperative Agreements)

d. Application/proposal dated June 19, 1987  as submitted  with changes as negotiated REvised Proposal Dated 10/16/87

19. REMARKS This Grant consists of this NFAA (DOE Form 4600.1), Part I - Budget Plan; Part II - Special Conditions; Part III - General Conditions; Part IV - Statement of Work; Part V - Reporting Requirements. DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110 and OMB Circular A-21 are hereby incorporated by reference.

<p>20. EVIDENCE OF RECIPIENT ACCEPTANCE</p> <p><i>William E. Schultz</i>          Signature of Authorized Recipient Official (Date)</p> <p>WILLIAM E. SCHULTZ          (Name)          DIRECTOR, GEOTHERMAL RESEARCH &amp; DEVELOPMENT</p>	<p>21. AWARDED BY</p> <p><i>J. P. Anderson</i>          (Signature) _____ (Date) _____</p> <p>J. P. Anderson          (Name)          Contracting Officer</p>
--	---

UNIVERSITY OF UTAH RESEARCH INSTITUTE

# UURI

391 CHIPETA WAY, SUITE C  
SALT LAKE CITY, UTAH 84108-1295  
TELEPHONE 801-524-3422

April 10, 1990

Mr. Thomas Flynn  
Division of Earth Sciences  
Environmental Research Center  
University of Nevada, Las Vegas  
100 Washington Street, Suite 201  
Reno, NV 89503

Dear Tom:

Thanks for the opportunity to review the draft final report "Geothermal Fluid Genesis in the Great Basin" by Flynn and Buchanan. It has been a pleasure to read as well as a good education for this geophysicist, especially on the geochemistry of the resources and paleoclimatology of the Great Basin. Appendix 2 on isotope theory reads like a good textbook on the topic. The report is well written and each of the data sets are supported by well organized, detailed data. The data integration is good and certainly supports your conclusions.

About the only technical material I can disagree with is the discussion of Figure 3.17 on page 29, Chapter 3, paragraph 3. Although Fig. 3.17 shows a more even distribution than Fig. 3.15 and 3.16, the range of variation would appear to be more like 100 to 800+ ppm, and the high ppm anomalies do not appear coincident with the locations of the Pleistocene Lakes. And a thought more for a future publication than this DOE report- is there any easy way to summarize most of the paleoclimate data, isotope depletion,  $^{14}\text{C}$  dates and Pleistocene lake levels on one time chart?

I did note a number of missing words, punctuation problems, etc which I have attached to help out in the final clean up. The main problem in the report is referencing, and this is a common problem at a Draft stage. Most of the problems which I noted are on the attached list. These are small problems which you may already have addressed. If not, please make any appropriate corrections and go ahead with preparations for the final report. Call me if you wish to discuss anything.

Tom, you and Paul have done a great job on this study and on this report. I encourage you to publish the results in one of the major journals.

Best regards,

*Howard Ross*

UNIVERSITY OF UTAH RESEARCH INSTITUTE

# UURI

391 CHIPETA WAY, SUITE C  
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TELEPHONE 801-524-3422

April 10, 1990

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Tom, you and Paul have done a great job on this study and on this report. I encourage you to publish the results in one of the major journals.

Best regards,

*Howard Ross*

REVIEW COMMENTS  
UNLV-DES FINAL REPORT

Geothermal Fluid Genesis In The Great Basin

1. Please include page number in Contents, List of Figures, List of Tables.
2. Acknowledgments- in Contents but not in text; please include ...Funded by U. S. DOE Grant No. \_\_\_\_\_.
3. Bibliography- several missing references and several present but not cited in the text. Some dates or references are incorrect.

Specific problems noted: C=chapter, p.=page, #=paragraph, l.=line

List of Figures, A2.8 - <sup>UC</sup> ~~Suess~~ effect

C 1, p. 1, 1.2 - electrical power production

C 2, p. 3, 1.5 - rocks units

p. 5 -Fig 2.2 -Stewart (1979) not in refs (NIR)

p. 6 -Fig 2.3 -Stewart (1978) NIR

p. 7, #2 -Steam Act, first

p. 8, #1 -Sass et al. (1971) NIR

p. 9, #2 -Wollenberg et al (1975) or Wollenberg (1975) ?

p. 9, #3 -Muffler (1979) in refs

p.10, #2 -Lachenbruch et al, 1976 or Lachenbruch & Sass, 1977?

p.10, #2 -review of the Long Valley area

p.10, 1. b-4 -missing part of sentence

p.10, 1. b-3 -Trexler et al., 1979 - not in refs.

p.11, 1.17 - Desert Peak, Soda Lake

p.11, 1.25 - Desert Peak power plant or geothermal resource?

p.12, 1.2 - for the field

p.12, 1.5 - GRC, 1983 - not in refs

p.12, 1.8 - Edmiston and Benoit (1985) - not in refs

*not corr* → p.12, 1.14 - and Roosevelt fields in southwestern Utah

p.12, 1.18 - Goode, 1978 - not in refs

p.12, 1.20 - Mabey and Budding (1987) - not in refs

p.13, 1.10 - steam, not stream

C 3, p. 1, #2 - Theses and Dissertations

p.3 - move next page of text before Fig 3.1 and Table 3.1

p.3 - center Fig. 3.1; samples 32 - 49 not located on fig. 3.1; Table 3.1 lists 48 samples, not 49

Table 3.1, p.2 - 47, 48 -no data; which was broken?

p.8, 1. 1 - .. 1200 entries; most

p.10, 1.b-8 - investigation *g* was

p.10, 1.b-6 - in part *g* on

p.18, 1.4 - Dansgaard, 1969 - not in ref, or 1964?

p.18, 1.6 - Craig (1961) not in refs

Fig. 3.12 - why no state outlines on this fig?

Fig. 3.13 - as above

p.29, #3 - Carbonate *g* bicarbonate; above two types *g*

- C 3, p.29, #3 - review discussion  
 p.40, #2 - Claassen 1986 not in refs  
 p.41, 1.1 - Glancy (1986) used ~~a~~ stable  
 p.41, 1.8 - Flynn ~~et al~~ and Ghusn, 1984 ?  
 p.41, 1.14 - in the appendix- which one?
- C 4, p. 2, #2 - Wigand, Siegel - is this a ref?  
 Fig. 4.1 - (x) = no. of samples  
 Table 4.2 comes after Table 4.1 - switch  
 Table 4.1 (first pg.- and 4.2 (pg.2-4)  
 No discussion of midden results after tables? discussed later?
- C 5, p.4, #3 - Trexler et al.(1979) not in refs  
 p.4, #3 - Flynn et al, 1983 - not in refs  
 p.4, #3 -Nehring, 1980? Fournier and Thompson, 1980?  
 Cole,1983? check dates of refs.
- C 6, p.1, 1.1 -that assume ~~that~~  
 p.2, 1.2 - 400 and 24,000 years  
 p.6, #1 - Porter et al.,1983 ?  
 p.7, 1.b-4 - the term "nivation"  
 p.8, #3 - earliest efforts in paleoclimatology ?  
 p.11, 1.2 - Yapp and Epstien (1976 or 1977) check ref.  
 p.11, 1.10 - Spaulding 1983 or 1981 as in refs?  
 p.14, Fig 6.5 - missing 3rd line of caption on copy  
 p.15, 1.b-4 - Houghton et al., 1975 - not in refs  
 p.16, #3 - Benson, 1988 or Benson & Thompson, 1987?  
 p.19, Fig. 6.7 - Benson et al in press? 1 line to caption
- C 7, p.15, Table 7.1 -not in refs - White et al., 1987; Lyles et al., 1989 - NIR  
 p.16. Table 7.1 - not in refs - Flynn et al., 1983; Nehring, 1983  
 p.19, 1.2 - Flynn et al., not in refs  
 p.21, #1 - would be nice to underline key statement!
- C 7 Time variant analysis  
 p.1, #3 -Winograd and Pearson (1976); Winograd and Friedman (1972)  
 p.1, #5 - Lyles (1985) not in refs  
 p.2, Table 7.3 - Lyles, 1988 - not in refs  
 p.3, Fig. 7.12 - YEAR 198  ;  
 p.6, Fig. 7.13, 7.14 - YEAR 198   not 19??
- C 8, p.5, Fig. 8.3 - Fetter, 1981? check refs  
 p.6, 1.3 - Fetter, 1980? check refs  
 p.6 to 8 - NICE STATEMENT OF CONCLUSIONS!!
- C 9, p.1, 1.b-2 -Greenland ~~and~~  
 EXCELLENT SUMMARY AND CONCLUSIONS
- App. 1, p. A4, eq 5.1 SrCO<sub>3</sub>  
 App. 2, p. 3, 1.8 - standards  
 App. 2, p.9, Fig. A2.2 - x-axis -Temp, deg C  
 p.11.Fig.A2.3 - Faure, 1985 or 1986?  
 p.14, #2 - and becomes more enriched  
 p.22, #2, - Ralph and Michael, 1970 - not in refs  
 p.22, #2, - Stuiver, 1970a,b ?  
 p.24, Fig A2.8 -Stuiver, 1981 - not in refs.



DIVISION OF EARTH SCIENCES  
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100 WASHINGTON ST., SUITE 201  
RENO, NEVADA 89503 • (702) 784-6151  
FAX (702) 784-1300

June 1, 1990

*Rec 6/04/90  
JPR*

Howard Ross  
University of Utah Research Institute  
Earth Sciences Laboratory  
391 Chipeta Way, Suite C  
Salt Lake City, UT 84108-1295

Dear Dr. <sup>Howard</sup> Ross:

Well, it took a little longer than I thought it would, but it's over. I've enclosed a copy the Final Technical Report for grant number DE-FG07-88ID12784, "Geothermal Fluid Genesis in the Great Basin", for the period 1 August 1988 through 1 June 1990. I have also enclosed a copy of the Federal Assistance Management Summary Report for the period 1/1/90 through 3/31/90. The final FAMSR will be completed within one month. We must wait for all the paperwork to settle.

All of the pertinent comments from the review team were incorporated or addressed. By all accounts, the people with whom I've discussed the results believe we produced some worthwhile data. I must agree.

Let me know if DOE shakes loose any more state-coupled money. It would be a shame to miss-out on all of these research opportunities just because we can't afford them!!

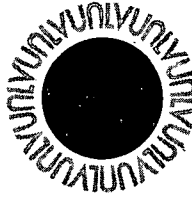
Thanks for all your help and I'll see you in Hawaii.

Sincerely,

Thomas Flynn  
Research Associate/Geologist

enclosures: Final Technical Report  
Fed. Assist. Man. Sum. Rpt.





DIVISION OF EARTH SCIENCES  
ENVIRONMENTAL RESEARCH CENTER  
UNIVERSITY OF NEVADA, LAS VEGAS  
100 WASHINGTON ST., SUITE 201  
RENO, NEVADA 89503 • (702) 784-6151  
FAX (702) 784-1300

January 19, 1990

Dr. Howard Ross  
University of Utah Research Institute  
Earth Sciences Laboratory  
391 Chipeta Way, Suite C  
Salt Lake City, UT 84108-1295

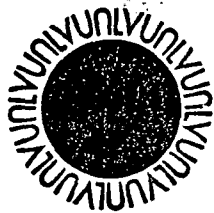
Dear Howard:

As we discussed, I've enclosed a copy of the request for extension of time that I sent to Ken Taylor. I pointed out the items we discussed that brought about the situation, including my misinterpretation of the performance period. Thanks for your help and your patience. I'll be in touch.

Sincerely,

Thomas Flynn  
Research Associate/Geologist

enclosure:



MUSEUM OF NATURAL HISTORY  
ENVIRONMENTAL RESEARCH CENTER  
DIVISION OF EARTH SCIENCES  
UNIVERSITY OF NEVADA, LAS VEGAS  
255 BELL ST., SUITE 200 • RENO, NEVADA 89503 • (702) 784-6151

January 19, 1990

Mr. Kenneth J. Taylor  
U.S. Department of Energy  
Idaho Operations Office  
785 DOE Place  
Idaho Falls, ID, 83402

Dear Mr. Taylor:

I spoke to Dr. Howard Ross earlier this week regarding the scheduled submittal date for the draft of the final report for grant number DE-FG07-88-ID-12784, "Geothermal Fluid Genesis in the Great Basin." My understanding was that the draft was due 45 days after the period of performance, which I misinterpreted as being the end of the contract period. Howard pointed out that the period of performance was defined as the date 90 PRIOR to the end of the contract. After I re-read the contract reporting requirements, I reluctantly agreed that he was right and that I was quite overdue.

Howard and I discussed several options and, based on several factors, not the least of which is my misunderstanding, the best available option is to request a three-month, no-cost extension in order to complete the final report in an orderly manner. There are several significant data sets that have been held-up for various reasons, as I explain below:

1. The University of Nevada, Las Vegas and Chevron signed a cooperative agreement in February, 1989 that allowed the University access to Chevron's geothermal power plant in Nevada for the purposes of sampling and analysis of geothermal fluids. Several months ago, Chevron announced plans to sell-off its geothermal properties in Nevada; they are now negotiating with California Energy Company for said sale. This put a small dent in the schedule; I only recently acquired data that is needed to complete the study and a bit more data is due. I've been very happy with their cooperation, but corporate needs obviously come first.

2. Packrat middens were to have been analyzed at the University of Arizona. The initial date was June, 1989. Regrettably, the Lab could not get the personnel and rescheduled the contract for September. That date had to be moved to and the samples were finally shipped in December with the delivery date set for mid-January, 1990. It is January 19, and my understanding is that the deuterium analyses will be completed by next week.

3. I am still waiting for deuterium analyses that were

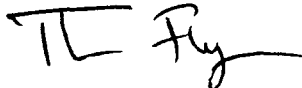
submitted to the University of Waterloo, Ontario last October. It seems that the lab had a 700 sample backlog. I had to request special handling to be bumped to the front of the pack.

The remainder of the program is doing well. We are completing sections for report, but it won't be complete without the data that is still in the pipes. I realize that this is a late request, and I sincerely regret the inconvenience. Howard pointed out that a complete report would be in the best interests of all; I can't help but agree.

I haven't included a "revised" budget in this request because there is no significant change in expenditures. If you have questions, or if you need additional information, please contact me at 702-784-6151 during working hours. Our FAX number, should you need a document signed quickly, is 702-784-1300.

Once again, I regret this inconvenience and I can guarantee that it won't happen in the future. I look forward to hearing from you.

Sincerely,

A handwritten signature in black ink, appearing to read "TL Flynn". The signature is written in a cursive style with a horizontal line above the first few letters.

Thomas Flynn  
Research Associate/Geologist

copies: Kenny K. Osborne DOE, Idaho Operations Office  
Howard Ross, UURI

U.S. DEPARTMENT OF ENERGY  
NOTICE OF FINANCIAL ASSISTANCE AWARD  
(See Instructions on Reverse)

PL 93-410

Under the authority of Public Law \_\_\_\_\_ and  
subject to legislation, regulations and policies applicable to (cite legislative program title):  
Geothermal Energy Research, Development, and Demonstration Act of 1974

1. PROJECT TITLE  Geothermal Fluid Genesis in the Great Basin		2. INSTRUMENT TYPE <input checked="" type="checkbox"/> GRANT <input type="checkbox"/> COOPERATIVE AGREEMENT	
3. RECIPIENT (Name, address, zip code, area code and telephone no.) University of Nevada, Las Vegas Division of Earth Sciences 255 Bell Street, Suite 200 Reno, NV 89503		4. INSTRUMENT NO. DE-FG07-881D12784	5. AMENDMENT NO. A000
8. RECIPIENT PROJECT DIRECTOR (Name and telephone No.)  Thomas Flynn                      (702) 784-6151		6. BUDGET PERIOD FROM: 8/1/88 THRU: 8/1/89	7. PROJECT PERIOD FROM: 8/1/88 THRU: 8/1/89
9. RECIPIENT BUSINESS OFFICER (Name and telephone No.)  Patty Baldwin                      (702) 739-3745		10. TYPE OF AWARD <input checked="" type="checkbox"/> NEW <input type="checkbox"/> CONTINUATION <input type="checkbox"/> RENEWAL <input type="checkbox"/> REVISION <input type="checkbox"/> SUPPLEMENT	
11. DOE PROJECT OFFICER (Name, address, zip code, telephone No.) Kenneth J. Taylor                      (208) 526-9063 U.S. DOE, Idaho Operations Office 785 DOE Place, Idaho Falls, ID 83402		12. ADMINISTERED FOR DOE BY (Name, address, zip code, telephone No.) Trudy A. Thorne                      (208) 526-9519 U.S. Department of Energy Idaho Operations Office 785 DOE Place Idaho Falls, ID 83402	

13. RECIPIENT TYPE

<input type="checkbox"/> STATE GOV'T	<input type="checkbox"/> INDIAN TRIBAL GOV'T	<input type="checkbox"/> HOSPITAL	<input type="checkbox"/> FOR PROFIT ORGANIZATION	<input type="checkbox"/> INDIVIDUAL
<input type="checkbox"/> LOCAL GOV'T	<input checked="" type="checkbox"/> INSTITUTION OF HIGHER EDUCATION	<input type="checkbox"/> OTHER NONPROFIT ORGANIZATION	<input type="checkbox"/> C <input type="checkbox"/> P <input type="checkbox"/> SP	<input type="checkbox"/> OTHER (Specify)

14. ACCOUNTING AND APPROPRIATIONS DATA				15. EMPLOYER I.D. NUMBER/SSN
a. Appropriation Symbol 89X0224.91	b. B & R Number AM1510000	c. FT/AFP/OC YA410	d. CFA Number	

16. BUDGET AND FUNDING INFORMATION	
a. CURRENT BUDGET PERIOD INFORMATION	b. CUMULATIVE DOE OBLIGATIONS
(1) DOE Funds Obligated This Action                      \$ 157,114	(1) This Budget Period                      \$ 157,114 [Total of lines a. (1) and a. (3)]
(2) DOE Funds Authorized for Carry Over                      \$ -0-	(2) Prior Budget Periods                      \$ -0-
(3) DOE Funds Previously Obligated in this Budget Period                      \$ -0-	(3) Project Period to Date                      \$ 157,114 [Total of lines b. (1) and b. (2)]
(4) DOE Share of Total Approved Budget                      \$ 157,114	
(5) Recipient Share of Total Approved Budget                      \$ 20,300	
(6) Total Approved Budget                      \$ 177,414	

17. TOTAL ESTIMATED COST OF PROJECT \$ 177,414  
(This is the current estimated cost of the project. It is not a promise to award nor an authorization to expend funds in this amount.)

18. AWARD/AGREEMENT TERMS AND CONDITIONS

This award/agreement consists of this form plus the following:

a. Special terms and conditions (if grant) or schedule, general provisions, special provisions (if cooperative agreement)

b. Applicable program regulations (specify) \_\_\_\_\_ (Date) \_\_\_\_\_

c. DOE Assistance Regulations, 10 CFR Part-600, as amended, Subparts A and  B (Grants) or  C (Cooperative Agreements)

d. Application/proposal dated June 19, 1987,  as submitted  with changes as negotiated Revised Proposal Dated 10/16/87

19. REMARKS This Grant consists of this NFAA (DOE Form 4600.1), Part I - Budget Plan; Part II - Special Conditions; Part III - General Conditions; Part IV - Statement of Work; Part V - Reporting Requirements. DOE Financial Assistance Rules (10 CFR Part 600), OMB Circular A-110 and OMB Circular A-21 are hereby incorporated by reference.

20. EVIDENCE OF RECIPIENT ACCEPTANCE  <u>William E. Schulze</u> 1 Aug 88 (Signature of Authorized Recipient Official) (Date)  WILLIAM E. SCHULZE (Name) DIRECTOR, GRANTS & RESEARCH DEVELOPMENT (Title)	21. AWARDED BY  <u>J. P. Anderson</u> 7/22/87 (Signature) (Date)  J. P. Anderson (Name) Contracting Officer (Title)
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FEDERAL ASSISTANCE BUDGET INFORMATION FORM

FORM EIA-459C  
(10/80)

FORM APPROVED  
OMB No. 1900-0127

1. Program/Project Identification No. <b>DE-FG07-88ID12784</b>	2. Program/Project Title <b>Geothermal Fluid Genesis in the Great Basin</b>
3. University of Nevada, Las Vegas Division of Earth Sciences 255 Bell Street, Suite 200 Reno, NV 89503	4. Program/Project Start Date <b>August 1, 1988</b>
	5. Completion Date <b>August 1, 1989</b>

SECTION A - BUDGET SUMMARY						
Grant Program, Function or Activity (a)	Federal Catalog No. (b)	Estimated Unobligated Funds		New or Revised Budget		
		Federal (c)	Non-Federal (d)	Federal (e)	Non-Federal (f)	Total (g)
1. 12693	81.087	\$	\$	\$ 157,114	\$ 20,300	\$ 177,414
2.						
3.						
4.						
5. TOTALS		\$	\$	\$ 157,114	\$ 20,300	\$ 177,414

SECTION B - BUDGET CATEGORIES						
6. Object Class Categories	Grant Program, Function or Activity				Total (5)	
	(1) DOE	(2)	(3) Nevada	(4)		
a. Personnel	\$ 72,054	\$	\$ 11,103	\$	\$ 83,157	
b. Fringe Benefits	10,177		1,721		11,898	
c. Travel	6,276		-0-		6,276	
d. Equipment	-0-		-0-		-0-	
e. Supplies	3,768		-0-		3,768	
f. Contractual	16,898		-0-		16,898	
g. Construction	-0-		-0-		-0-	
h. Other	-0-		-0-		-0-	
i. Total Direct Charges	109,173		12,824		121,997	
j. Indirect Charges	47,941		7,476		55,417	
k. TOTALS	\$ 157,114	\$	\$ 20,300	\$	\$ 177,414	
7. Program Income	\$	\$	\$	\$	\$	

Special Terms and Conditions for Research Grants

The requirements of this attachment take precedence over all other requirements of this grant found in regulations, the general terms and conditions, DOE orders, etc. except requirements of statutory law. Any apparent contradiction of statutory law stated herein should be presumed to be in error until the Grantee has sought and received clarification from the Contracting Officer, whose signature appears on the face page of this award.

1. Payments and Cost-Share

- a. The Grantee may request advance payment of cost to be incurred. Such requests should not exceed the expected outlays by the Grantee in the succeeding 30-day period.
- b. Cost-Share Arrangement - The cost-share will be in accordance with Part I - Budget Plan. Invoices must include in-kind contributions and DOE's reimbursed costs. To be an invoiced cost, a cash or in-kind contribution must be allowable under the terms and conditions of the award and meet the applicable cost principle tests of allowability in 10 CFR 600.103.

The University of Nevada, Las Vegas will pay for all salary, fringe benefits, and indirect charges associated with these for Dennis Trexler, Senior Geologist, in the amounts shown on Part I - Budget Plan. All other costs will be paid by the Department of Energy.

- c. Payments to the Grantee shall equal the Federal share of actual allowable costs of performance of this grant, provided however, and notwithstanding any other provision of this grant, that the Government's monetary liability under this grant shall not exceed the Government share of the total approved budget or an amount equal to the Federal share of actual allowable costs, whichever is less. The Grantee shall be obligated to perform under this grant throughout the agreed-upon period of performance, and to bear all costs which DOE has not agreed to pay. However, the Grantee shall have the right to cease to perform when or after the Federal share of actual allowable costs equals or exceeds the Government share of the total approved budget and if prior written notice to that effect has been provided to DOE.
- d. The Government obligations may be increased unilaterally by DOE by written notice to the Grantee and may be increased or decreased by written agreement of the parties.
- e. Upon termination or expiration of the total period of performance, the Grantee shall promptly refund to DOE (or make such disposition as DOE may in writing direct) any sums paid by DOE to the Grantee under this grant in excess of the cumulative Government allowable cost incurred in performance under the grant.

- f. Method of Payment - Payments due for amounts properly invoiced in accordance with the terms and conditions specified elsewhere in the grant shall be made either by Treasury check(s) payable to the Grantee or designee or by electronic funds transfer(s) to a financial institution designated by the Grantee for that purpose. The method of payment shall be determined by the Government at the time of payment in accordance with applicable Treasury Department requirements.

After award but no later than fourteen (14) days before an invoice or bill is submitted for payment, the Grantee shall designate a financial institution for the receipt of electronic funds transfer payments hereunder; and provide the appropriate Government representative (contracting officer or finance official as determined by the Government) with the name of the designated financial institution, financial institution's or correspondent financial institution's 9-digit American Bankers Association identifying number, telegraphic abbreviation of such financial institution, and account number at the designated financial institution to be credited with funds.

In the event the Grantee during the performance of this grant elects to designate a different financial institution for the receipt of any payment made using electronic funds transfer procedures, notification of such change and the information as specified in paragraph (b) above must be received by the appropriate Government representative thirty (30) days prior to the date such change is to become effective.

The document furnishing the information required above must be dated and contain the signature, title, and telephone number of the Grantee official authorized to provide it, as well as the Grantee's name and grant number.

Grantee failure to properly designate a financial institution or to provide appropriate payee bank account information may delay payments of amounts otherwise properly due.

- g. Applicable Credits. The Grantee agrees that any refunds, rebates, credits, or other amounts (including any interest thereon) accruing to or received by the Grantee or any assignee under this grant shall be paid by the Grantee to the Government, to the extent that they are properly allocable to costs for which the Grantee has been reimbursed by the Government under this grant. Reasonable expenses incurred by the Grantee for the purpose of securing such refund, rebates, credits, or other amounts shall be allowable costs hereunder when approved by the Contracting Officer.
- h. Audit Adjustments. The Contracting Officer may have invoices or vouchers and statements of cost submitted under this grant audited

at any time prior to the end of the required retention period for the grant records. Each payment made shall be subject to reduction for amounts included in the related invoice or voucher which are found by the Contracting Officer, on the basis of audit, not to constitute allowable cost. If a final audit of costs has not been performed prior to closeout of the grant, DOE or its successor agency, shall have the right to recover an appropriate amount after fully considering the recommendations on disallowed costs resulting from the final audit when conducted.

- i. Cognizant Office. Invoices should be sent to the individual designated in Block 12. of the Notice of Financial Assistance Award Form (NFAA). In addition to the initial supply of forms made available with this award, appropriate payment forms and instructions will be provided by this office upon request.

2. Reporting Program Technical Performance

- a. Copies. Copies of reports and all other related data and information generated under this grant shall be submitted in accordance with the attached Federal Assistance Reporting Checklist (DOE Form EIA-459A).
- b. Publication of Results. The Grantee may publish the results of its work. However, publications and reports prepared under this grant shall contain the following acknowledgment statement, "This (material) was prepared with the support of the U.S. Department of Energy (DOE) Grant No. DE-FG07-88ID12784. However, any opinions, findings, conclusions, or recommendations expressed herein are those of the author(s) and do not necessarily reflect the views of DOE."
- c. Reporting Requirements. The Federal assistance recipient shall prepare and submit (postage prepaid) the plans and reports indicated on the Federal Assistance Reporting Distribution List. Preparation of the specified plans and reports shall be in accordance with DOE Order 1332.2. The level of detail the recipient provides in the plans and reports shall be commensurate with the scope and complexity of the task and shall be as delineated in Block 4 - Reporting Requirements and Block 5 - Special Instructions.

All reports delivered to DOE shall be the sole property of the DOE. The Grantee shall not claim that any report contains any trade secrets or commercial or financial information deemed by the Grantee to be privileged or confidential, or that the Grantee has any proprietary interest in any report.

3. Designated Key Personnel

The following individual is designated key personnel in accordance with General Condition No. 14:

Thomas Flynn



4. Project Completion Date

The project completion date identified in Block 7. of the Notice of Financial Assistance Award includes an additional 90 days for completion of the final report. All R&D effort must be completed 90 days prior to the project completion date. Only costs associated with preparation of the final report will be allowed during the 90 days prior to the project completion date.

5. Technical Data

Except for technical data contained in pages N/A of the recipient's application, dated N/A, which are asserted by the Grantee as being proprietary data, it is agreed that as a condition of this award, and notwithstanding the provisions of any notice appearing on the application, the Government shall have the right to use, duplicate, disclose and have others do so for any purpose whatsoever the technical data not identified in the above blanks contained in the application upon which this award is based.

6. Prior Approval

The following actions or costs specified in the application require prior approval of DOE and are specifically disapproved in accordance with General Condition No. 3:

None

7. General Procurement Prior Approval

Article 17 of the General Terms and Conditions for Research Grants is hereby revoked. The Grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received, when the value of the contract in the aggregate is expected to exceed \$25,000.

8. Patent Clauses

The following patent clauses and technical data requirements are applicable to this grant award:

600.118(b)(1) "Patent Rights (Small Business Firm or Nonprofit Organization)"

600.118(b)(3) "Rights in Technical Data (Short Form)"

600.118(b)(5) "Authorization and Consent"

600.118(b)(6) "Notice and Assistance"

600.118(c) "Reporting of Royalties"

9. Title to Equipment

- a. Title to the following items of equipment shall vest with the Grantee upon completion of this grant:

None

- b. Title to the following items of equipment shall vest with the Government at the end of the grant project period:

None

10. Advance Travel Agreement

It has been agreed by both parties that payment for a privately-owned conveyance used for official purposes shall be made on the basis of the actual travel performed computed at the mileage rate not to exceed \$.21/mile.

General Terms and Conditions for Research Grants

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General Terms and Conditions for Research Grants

1. Explanation

These general terms and conditions do not restate all the provisions of applicable statutes and regulations nor do they represent an exhaustive listing of all requirements applicable to this grant. Rather they highlight and are consistent with those requirements which are especially pertinent to research grants in general. They are being emphasized by inclusion here either because they are invoked with high frequency, their violation is a matter of especially serious concern (e.g., use of human subjects), and/or they have been restated in the research context to be more easily understood by the research community.

In addition to these general terms and conditions, the grantee must comply with all governing requirements, including those identified in Block 18 of the Notice of Financial Assistance Award and those included in the Special Terms and Conditions attached to this grant award.

2. Grantee Adherence to Grant Terms and Conditions

The grantee's signature on the application and on the Notice of Financial Assistance Award signifies the grantee's agreement to the terms and conditions of award. Should the grantee believe modification of any of the terms and conditions of this award is necessary, an authorized official of the grantee organization or, in the case of an individual, the grantee, must submit a written request on its own behalf or on behalf of any subgrant recipient or applicant to the Contracting Officer named on the face page of this award.

Following this procedure is very important because many of the terms and conditions of this grant are required by statute and must be enforced by the Department of Energy.

3. Definitions

Principal Investigator

As used herein, the scientist or other programmatic expert named in Block 8 of the Notice of Financial Assistance Award designated by the grantee organization to direct the scientific/technical efforts being supported (also called program director or project director/leader).

Prior Approval

A statement in writing, signed by the DOE Contracting Officer, that a cost may be incurred or an action may be taken. The approval may take the form of a letter or of a revision to the grant. If actions or costs requiring prior approval are specified in the application and are not expressly disapproved by DOE in the attached Special Terms and Conditions, the award of the grant constitutes such prior approval.

4. Authorized Grantee Signatures for Prior Approval Requests

All requests for prior approval must be signed by an individual who is authorized to act for the grantee organization. The signature of the Principal Investigator (unless also a corporate officer or otherwise authorized) is insufficient to obtain action on a prior approval request, although countersignature by the Principal Investigator is not discouraged. Requests for budget revisions shall be made on the same budget format as used in applying for this grant and must be supported by a narrative justification. Other prior approval requests may be made by letter. Prior approval requests should be addressed to the Contracting Officer named on the face page of this award.

5. Allowable Costs/Applicable Cost Principles

In accordance with the applicable cost principles cited below and up to the amount shown on the face page of this award for the total approved budget for the current budget period (line 16.a.(6)), the allowable costs of this grant shall consist of the actual allowable direct costs incident to performance of this project plus the allocable portion of the allowable indirect costs, if any, of the organization less applicable credits.

The allowability of costs for work performed under this grant and any subsequent subaward will be determined in accordance with the Federal cost principles applicable to the grantee or subrecipient in effect on the date of award or, for any subaward, in effect as of the date of that subaward, except as modified by other provisions of this grant or the subaward.

The Federal cost principles applicable to specific types of grantees and subrecipients are:

1. Institutions of Higher Education. OMB Circular A-21, Cost Principles Applicable to Grants, Contracts and Other Agreements with Institutions of Higher Education, is applicable to both public and private colleges and universities.
2. State and local governments and Indian tribal governments. OMB Circular A-87, Cost Principles Applicable to Grants, Contracts and other Agreements With State and Local Governments, is applicable to state, local, and Indian tribal governments (and shall also be used to the extent appropriate for foreign governments).
3. Hospitals. 48 CFR Part 74, Appendix E, Principles for Determining Costs Applicable to Research and Development under Grants and Contracts with Hospitals, applies to nonprofit and for-profit hospitals.

4. Other nonprofit organizations and individuals. OMB Circular A-122, Cost Principles Applicable to Grants, Contracts, and other Agreements with Nonprofit Organizations, applies to nonprofit organizations and individuals except for nonprofits specifically exempted by the terms of the circular or those nonprofits covered by the cost principles cited in items 1.- 3. above.
5. Commercial firms and certain nonprofit organizations. 48 CFR Subpart 31.2, Contracts with Commercial Organizations, as supplemented by 48 CFR Subpart 931.2, applies to those nonprofit organizations not covered by OMB Circular A-122, as specified by the terms of that circular, and to all commercial organizations other than those covered by the cost principles in item 3. above.

6. Payment

Payments under this award will be made by an advance payment method unless DOE determines that the grantee's financial management system does not meet the requirements of 10 CFR 600.109 or the grantee has not maintained, or demonstrated the willingness and ability to maintain, procedures that will minimize the time elapsing between transfer of funds from the U.S. Treasury and their disbursement for grant-related purposes.

The appropriate advance payment method or the reimbursement method and the cognizant finance office are specified in the attached Special Terms and Conditions.

Advances by the grantee to subgrantee and contractor organizations must conform substantially to the same standards of timing and amount that govern advances made by the Federal Government to the grantee. Excess cash advances erroneously withdrawn from the U.S. Treasury shall be promptly refunded to DOE unless the funds will be disbursed within seven calendar days or the amount is less than \$10,000 and will be disbursed within 30 calendar days.

Interest earned on advance payments to other than state governments or their subgrantees shall be reported on the Report of Federal Cash Transactions (SF-272) and promptly remitted to the cognizant finance office (unless otherwise specified in the attached Special Terms and Conditions) by check payable to the Department of Energy.

7. Preaward Costs

Costs incurred prior to the beginning date of a new or renewal award are allowable only if they were approved in writing, prior to incurrence, by a DOE Contracting Officer. (Note - this provision does not apply to such bid and proposal costs as may be recovered through an indirect cost rate negotiated in accordance with the applicable Federal cost principles.)

8. Reporting Requirements

Attached to this grant award is EIA 459A, a checklist of the reports required under this grant.

The grantee shall submit a technical progress report (also called a performance report) as part of any application for continuation or renewal of DOE grant support. This report shall be in lieu of a separate annual performance report. Upon completion or termination of the project, the final technical report shall be prepared in accordance with the applicable program rule cited on the face page of this award or, in the absence of such program rule coverage, with the technical reporting format specified in the Uniform Reporting System for Federal Assistance (Grants and Cooperative Agreements) (DOE/MA-001).

The grantee shall submit an annual Financial Status Report (SF-269) within 90 days after the close of the budget period shown on the face page of this award. The grantee shall submit a final Financial Status Report within 90 days after the completion or termination of the project period shown on the face page of this award unless the project period is extended. In the latter case, the report for the last budget period of the existing project period shall be considered an annual report.

Instructions concerning reports to be submitted in conjunction with payment under this award are specified in the attached Special Terms and Conditions.

9. Cost-Sharing

Any cost-sharing as shown on the face page of this award shall defray allowable costs of the project only. Allowability of such costs shall be determined in accordance with the statutes, regulations, applicable cost principles, and other terms and conditions governing this award.

Cost-sharing contributions may be in the form of direct or indirect costs, including cash or in-kind contributions, incurred by the grantee, its subgrantees, or contractors. The cost sharing may be in any allowable budget category or combination of categories. When a direct cost item represents some or all of the non-Federal contribution, any associated indirect costs may not be charged to Federal funds but may be counted as part of the cost-sharing. The treatment of a contributed cost as direct or indirect must be consistent with the classification of similar items charged to DOE funds.

Valuation of in-kind contributions and documentation of cost-sharing shall be in accordance with 10 CFR 600.107.

10. Continuations, Renewals, and Extensions

Grantees are responsible for assuring that properly completed applications for continuation awards are received no later than 4 months prior to the expiration date of the current budget period shown on the Notice of Financial Assistance Award.

If a grantee wishes to apply for a renewal award in order to receive funding beyond the scheduled expiration of the existing project period, a properly completed application must be submitted to DOE no later than four months prior to the scheduled expiration date of the project period as shown on the Notice of Financial Assistance Award.

Grantee requests for extensions (modifications extending an existing project period by 18 months or less in order to complete a project) must be submitted prior to the expiration date of the project period as shown on the face page of this award, and must include a budget for the use of any remaining funds or any additional funds requested. Any request for an extension, which includes a request for additional funds and any request for an extension of more than 90 days, should be submitted to DOE no later than four months prior to the scheduled expiration date of the project period.

11. Maximum DOE Obligation

This grant is subject to the requirement that the maximum DOE obligation to the recipient is the amount shown on the Notice of Financial Assistance Award as the amount of DOE funds obligated. DOE shall not be obligated to make any additional, supplemental, continuation, renewal or other award for the same or any other purpose.

12. Transfers of Funds Between Grants

Transfers of funds between DOE grants, and transfers of funds from a DOE grant to a project (or portion of a project) not supported by that grant require the prior approval of DOE. Transfer of funds into a DOE grant-supported project from a grant awarded by another Federal agency does not require DOE prior approval but may, of course, require the approval of the other Federal agency. Funds so transferred from the grant of another Federal agency may not be used to satisfy any cost-sharing requirement on a DOE grant.

13. Property

Real and Tangible Personal Property

No real property may be acquired under this award.

Title to any equipment (an article of tangible personal property that has a useful life of more than 2 years and an acquisition cost of \$500 or more) or supplies acquired by a nonprofit institution of higher education or a nonprofit organization whose primary purpose is the conduct of scientific research shall vest in the grantee and such equipment shall be exempt from accountability except that DOE has the right to transfer ownership of any item of equipment having a unit acquisition cost of \$1,000 or more under the conditions specified in 10 CFR 600.117(d)(2). This exemption is derived from Public Law 95-224. The Federal Grant and Cooperative Agreement Act of 1977, as amended.



Title to equipment and supplies acquired by all other grantees shall vest in the grantee. However, such grantees shall be accountable for equipment with a unit acquisition cost of \$1,000 or more acquired under this grant as specified in 10 CFR 600.117(d)(2), (3) and (4). For such grantees, supplies need only be accounted for at closeout and then only if they are unused and exceed \$1,000 in total aggregate current fair market value. In this case accountability requires that DOE be compensated in an amount computed in accordance with Section 600.117(e) if the supplies are retained for use on non-Federal activities.

All grantees shall follow property management policies and procedures which provide for adequate control of the acquisition and use of assets acquired under the grant.

#### Intangible Property

Treatment, including reporting, of patent and data rights and copyrights shall be as specified in the Special Terms and Conditions of this grant.

#### 14. Change or Absence of the Principal Investigator or Designated Key Personnel

Since the DOE decision to fund a project is based, to a significant extent, on the qualifications and level of participation of the Principal Investigator, a change of Principal Investigator or of the level of effort of the Principal Investigator is considered a change in the approved project. The approval of DOE must be obtained prior to any change of the Principal Investigator or, in certain cases, other key personnel who have been identified as key personnel in the Special Terms and Conditions of this grant. In addition, any continuous absence of the Principal Investigator in excess of three months or plans for the Principal Investigator to become substantially less involved in the project than was indicated in the approved grant application requires DOE prior approval. Grantee is encouraged to contact DOE immediately upon becoming aware that any of these changes are likely to be proposed, but in any event must do so and receive DOE prior approval before effecting any such change.

#### 15. Changes in Objectives or Scope

Any change in the objectives or scope of a grant-supported project requires the prior approval of DOE. Such changes include changes in the phenomenon or phenomena under study and in the methodology or experiment if they are a specific objective of the research work as stated in the application approved by DOE.

#### 16. Transfer of Substantive Programmatic Effort

None of the substantive effort of this project may be transferred by contract or subgrant to another organization or person without the prior approval of DOE. This provision does not apply to the procurement of

equipment, supplies, materials, or general support services which may, however, be subject to other prior approval requirements as found, for example, in the applicable cost principles or procurement standards.

17. General Procurement Prior Approval Requirements

A grantee must receive prior approval from DOE before entering into any sole source contract or a contract where only one bid or proposal is received when the value of the contract in the aggregate is expected to exceed 1) \$10,000 and the grantee is a state, local, or Indian tribal government or 2) \$5,000 for all other grantees.

18. Equipment and Other Capital Expenditures

Expenditures for equipment and other capital assets having a unit acquisition cost of \$500 or more require the prior approval of DOE with one exception. For special purpose equipment, prior approval is required only when the unit acquisition cost is \$1,000 or more. (Special purpose equipment means equipment which is used only for research, medical, scientific, or other technical activities.)

19. Travel

Foreign Travel - DOE prior approval is required for each separate foreign trip. Foreign travel must be directly related to the project objectives. Foreign travel is any travel outside Canada and the United States and its territories and possessions or, for grantees located in another country, travel outside that country.

Domestic Travel - Such costs are allowable to the extent provided in the approved budget. In addition, grantees may exceed the approved budget amount for domestic travel by up to 25% or \$500 whichever is greater, without DOE prior approval. All other expenditures for domestic travel beyond these limits require prior approval.

20. Consultant Services

Costs of consultant services are allowable subject to satisfaction of the requirements of the applicable cost principles, including the requirement that the consultant not be an employee of the grantee organization. There is one exception to the requirement that the consultant not be an employee of the grantee organization which applies to colleges and universities only. For colleges and universities, in unusual cases, and only with the prior approval of DOE, intra-organizational consultation may be permitted where consultation is across departmental lines or involves a separate or remote operation.

21. Paperwork Reduction

This award is subject to the requirements of the Paperwork Reduction Act of 1980 as implemented by the Office of Management and Budget rules,

"Controlling Paperwork Burdens on the Public," published at 5 CFR 1320 (48 FR 13666, 3/31/83) if the grantee will collect information from ten or more respondents either:

- A. At the specific request of DOE, or
- B. If the award requires specific DOE approval of the information collection or the collection procedures.

Any proposed sponsored information collection under item 21 B. above shall be submitted by the grantee to the Contracting Officer named on the face page of this award at least 90 days prior to the intended date of information collection. DOE will seek the requisite approval from the Office of Management and Budget and will promptly notify the grantee of the disposition of the request.

## 22. Generally Applicable Requirements

In accordance with 10 CFR 600.12, this grant is subject to a number of statutory and other generally applicable requirements. Those requirements most pertinent to research projects are highlighted below:

### Animal Welfare

Any grantee performing research on warm-blooded animals shall comply with the Laboratory Animal Welfare Act of 1966 (Public Law 89-544, as amended) and the regulations promulgated thereunder by the Secretary of Agriculture at 9 CFR Chapter 1, Subchapter A, pertaining to the care, handling, and treatment of warm-blooded animals held or used for research, teaching, or other activities supported by Federal awards. The grantee is expected to ensure that the guidelines described in Department of Health and Human Services (DHHS) Publication No. [NIH] 78-23, "Guide for the Care and Use of Laboratory Animals," are followed (Copies are available from the Superintendent of Documents, Government Printing Office, Washington, DC 20024, Stock No. 017-040-00427-3).

### Research Involving Recombinant DNA Molecules

Any grantee performing research involving recombinant DNA molecules and/or organisms and viruses containing recombinant DNA molecules agrees by acceptance of this grant to comply with the National Institutes of Health "Guidelines for Research Involving Recombinant DNA Molecules," June 1983 (48 FR 24556) or such later revision of those guidelines as may be published in the Federal Register.

### Use of Human Subjects in Research, Development, and Related Activities

Any DOE grantee performing research, development, or related activities involving any use of human subjects must comply with DOE regulations

found at 10 CFR Part 74S "Protection of Human Subjects" and any additional Provisions which may be included in the Special Terms and Conditions of this grant. Such provisions are intended to safeguard the rights and welfare of human subjects at risk of possible physical, psychological, or social injury as a consequence of their participation.

23. Nondiscrimination

This grant is subject to the provisions of 10 CFR Part 1040 "Nondiscrimination in Federally Assisted Programs."

24. Public Access to Information

The Freedom of Information Act, as amended, and the DOE implementing regulations (10 CFR Part 1004) require the release by DOE of certain documents and records regarding grants upon written request by any member of the public. The intended use of the information will not be a criterion for release. These requirements apply to information held by DOE, and do not require grantees, their subgrantees, or their contractors to permit public access to their records.

Records maintained by DOE with respect to grants are subject to the provisions of the Privacy Act and the DOE implementing regulations (10 CFR Part 1008) if those records constitute a "system of records" as defined in the Act and the regulations. Generally, records maintained by grantees, their subgrantees, or their contractors are not subject to these requirements.

25. Acknowledgement of Support

Publication of the results of this grant, subject to any applicable restrictions in 10 CFR 600.118 ("Patents, data, and copyrights"), is encouraged. Any article which is published shall include an acknowledgement that the research was supported, in whole or in part, by a DOE grant (including the grant number), but that such support does not constitute an endorsement by DOE of the views expressed in the article.

26. National Security

It is not expected that activities under this grant will generate or otherwise involve classified information (i.e., Restricted Data, Formerly Restricted Data, National Security Information).

However, if in the opinion of the grantee or DOE such involvement becomes expected prior to the closeout of the grant, the grantee or DOE shall notify the other in writing immediately. If the grantee believes any information developed or acquired may be classifiable, the grantee shall not provide the potentially classifiable information to anyone, including the DOE officials with whom the grantee normally communicates, except the Director of Classification, and shall protect such information

as if it were classified until notified by DOE that a determination has been made that it does not require such handling. Correspondence which includes the specific information in question shall be sent by registered mail to U.S. Department of Energy, Attn: Director of Classification, DP-32, Washington, DC 20545. If the information is determined to be classified the grantee may wish to discontinue the project, in which case the grantee and DOE shall terminate the grant by mutual agreement. If the grant is to be terminated, all material deemed by DOE to be classified shall be forwarded to DOE, in a manner specified by DOE, for proper disposition. If the grantee and DOE wish to continue the grant, even though classified information is involved, the grantee shall be required to obtain both personnel and facility security clearances through the Office of Safeguards and Security. Costs associated with handling and protecting any such classified information shall be negotiated at the time the determination to proceed is made.

27. Liabilities and Losses

DOE assumes no liability with respect to any damages or loss arising out of any activities undertaken with the financial support of this grant.

28. Contracting Officer's Technical Representative (COTR)

The individual identified in Block 11. of the Notice of Financial Assistance Award as the DOE Project Officer is the Contracting Officer's Technical Representative (COTR). The COTR is responsible for 1) monitoring the research efforts being conducted by the Grantee under the scope of this award; 2) advising the Contracting Officer on technical matters related to administration of the grant, including progress and status of the Grantee's research; and 3) providing technical advice and guidance to the Grantee in order to assist both the research efforts of the Grantee and the Grantee's adherence to the grant terms and conditions.

The COTR does not have the authority to:

Cause an increase or decrease in the total estimated cost of, or the time required for, the research effort being supported;

Cause any change in the express terms and conditions of the grant;

Cause any change in the objectives or scope of the effort being supported;

Act in the capacity of the Contracting Officer by issuing any approval or disapproval required by the terms and conditions of the grant;

Interfere with the Grantee's right to perform under the terms and conditions of the grant.

29. Interest

(a) Notwithstanding any other term or conditions of this grant, all amounts that become payable by the recipient to the Government under this grant shall bear simple interest from the date due until paid unless paid within 30 days of becoming due. The interest rate shall be the interest rate established by the Secretary of Treasury (Secretary) as provided in Section 11 of the Debt Collection Act of 1982 (31 U.S.C. 3717), which is applicable to the period in which the amount becomes due, as provided in paragraph (b) of this provision, and then at the rate applicable for each three-month period as fixed by the Secretary until the amount is paid.

(b) Amounts shall be due at the earliest of the following dates:

- (1) The date fixed under this grant.
- (2) The date of the first written demand for payment consistent with this grant, including any demand resulting from a termination.
- (3) The date the Government transmits to the recipient a proposed agreement to confirm completed negotiations establishing the amount of debt.

(c) The interest charge made under this provision may be reduced in accordance with the procedures prescribed in 4 CFR 102.13 or in accordance with agency regulations in effect on the date of original award of this grant.

## STATEMENT OF WORK

### 1.0 Introduction

The goal of this grant is to support cost-shared research on geothermal resources of the Great Basin region of Nevada. Nevada has extensive geothermal resources, with more than 300 known hot springs and wells, and several electric power plants or other industrial developments on line or in progress. Earlier resource assessment activities have focused on the location and basic characteristics of the resources. Fluid genesis, and longevity of the geothermal resources have not been adequately addressed in these earlier studies. The principal objectives of this study are to determine the recharge areas, flow rates and paths, and provinces of geothermal fluids that occur at the surface today. These objectives will be achieved by integrating and interpreting a variety of fluid geochemical, archaeological, and paleontological data. The ultimate goal is to develop a model of geothermal fluid genesis within the Great Basin. Such a model will provide significant benefits to the geothermal industry and to state agencies responsible for regulating geothermal energy and water rights issues.

### 2.0 Scope

The technical objectives of this grant are to develop a model of geothermal fluid genesis within the Great Basin. The research program will delineate hydrothermal convection systems in Nevada on the basis of geothermal fluid chemistry, stable light-isotope composition, trace element geochemistry, and other data sets. Recharge areas will be resolved by analyzing paleo-fluid composition from three potential sources: artifact data resulting from American Indian habitation in Nevada from 10,000 years ago to historic time; existing ice core data; and fluid age-determinations. Carbon-14, deuterium, oxygen-18, and stable light-isotope data will be utilized in these studies. An integrated interpretation of the various data sets will be completed. All tasks including the writing of a comprehensive final report will be completed in a 12 month period.

### 3.0 Applicable Documents

The research described herein is abstracted from a proposal titled "Geothermal Fluid Genesis in the Great Basin", dated June 19, 1987 as amended October 16, 1987. This proposal was submitted by the University of Nevada, Las Vegas, Division of

Earth Sciences, in response to a DOE/ID Program Research and Development Announcement (PRDA) for State Geothermal Research and Development - PRDA No. DE-PR07-87ID12662.

#### 4.0 Technical Tasks

The following tasks will be accomplished under this grant.

#### 4.1 Collect and evaluate existing data obtained through an extensive literature search.

4.1.1 Collect fluid chemistry data for thermal and non-thermal fluids throughout the Great Basin with emphasis on isotopic ratios, apparent ages, and tritium values, to form a baseline for subsequent work. Potential data sources include the geothermal literature; data from the Nevada Test Site and High-Level Nuclear Waste Isolation Program; and the NURE program.

4.1.2 Collect corresponding data for major geothermal reservoir rocks or rock types with emphasis on stable light-isotope ratios. These data are essential for establishing model resolution limits.

4.1.3 Collect existing glacial ice data from sites in western North America, Greenland, and Antarctica and compare to snow/ice packs in the Sierra Nevada, White Mountains, Wheeler Peak, and Ruby Mountains. Existing ice core data, tephra deposits, and glacial till material with corresponding stable isotope ratios will be used to reconstruct paleoclimatic conditions within the Great Basin.

4.1.4 Acquire and describe preserved organic archaeological material from prehistoric habitation sites and from packrat middens and other natural organic deposits throughout the Great Basin. Analyze appropriate materials for stable light isotopes and date by radiometric carbon-dating techniques. Compare to present isotope ratios in geothermal fluids and project the isotopic composition of paleo fluids precipitated at various elevations throughout the Great Basin.

4.2 Format the technical data base. Produce maps and tables that differentiate data sources, establish spatial, temporal, and elevation relationships for principal geothermal systems. Identify data voids and mitigate where possible. Determine preliminary model parameters for



chemical data, temporal and spatial constraints, and regional geologic setting. Submit technical resource data to GEOTHERM for archiving.

#### 4.3 Sampling and Analysis

4.3.1 Systematically sample, record, and submit for chemical analyses geothermal fluids from selected large geothermal springs and large geothermal systems presently under development. Chemical analyses will include major, minor, and trace elements, stable light isotopes, Tritium, and Carbon-14. Integrate with baseline data from Task 4.1 and produce graphs that illustrate various parameters with respect to time at both idle hot springs and geothermal developments.

4.3.2 Complete precision isotopic analyses of selected archaeological material (plant material from caves, charcoal, reed baskets, coprolites, middens food caches) from representative sites throughout the Great Basin. Include data in data base maps of Task 4.2.

4.4 Develop conceptual geothermal fluid genesis and recharge models based on geology, inferred paleoclimatic conditions, geothermal fluid chemical and isotopic composition. Compare to existing regional models. Interpret the various data in terms of the contemporary fluid recharge model and the paleo recharge model. Identify and discuss conflicting data and evaluate those data that influence the models. Integrate detailed geochemical data with overall reservoir performance data where appropriate. Provide geothermal utilities, developers, and State legislative committees and regulatory agencies with timely progress reports. Consider performance characteristics with respect to geothermal provinces.

4.5 Complete the documentation for all new data, including geochemical data, age dates, isotope ratios, and final interpretations and present with appropriate discussion in a final technical report. Detailed geochemical sampling data on geothermal systems and developments will be presented on large scale maps.

#### 5.0 Reports, Data, and Other Deliverables.

##### 5.1 Management Records

Reports will be due as indicated on the Federal Assistance Reporting Checklist and the Report Distribution List.

## 5.2 Final Report

A detailed final technical report will be prepared which will describe all new geochemical data, data tables, age dates, isotope ratios, data synthesis, and interpretation. A draft final report will be submitted for review and comment not less than 45 days prior to the scheduled delivery of the final report.

## 6.0 Special Considerations

None

REPORT DISTRIBUTION LIST

Grant No. DE-FG07-88ID12784

Report/Plan	Form No.	Frequency	No. of Copies	Address
Federal Assistance Management Summary Report	EIA-459E	Q	1,1,1,1,1	a,b,c,d,e
Notice of Energy RD&D	DOE 538	O	1,1	a,f
Technical Progress Report	N/A	Q	1,1,1,1	a,b,d,e
Topical Report	N/A	A	1,4,1,1	a,b,d,e
Final Technical Report	N/A	F	1,4,1,1	a,b,d,e
Financial Status Report	SF-269	A	1,1,1	a,b,c

LIST OF ADDRESSEES

a. U.S. Department of Energy 785 DOE Place Idaho Falls, ID 83402 Attn: Trudy A. Thorne	f. U.S. Department of Energy Technical Information Center P.O. Box 62 Oak Ridge, TN 37830
b. Same as above Attn: Kenneth J. Taylor	
c. Same as above Attn: Earl Jones	
d. U.S. Department of Energy Forrestal Bldg., CE-342 1000 Independence Ave, SW Washington, DC 20585 Attn: Marshall Reed	
e. University of Utah Research Institute Earth Science Laboratory 391 Chipeta Way, Suite C Salt Lake City, UT 84108-1295 Attn: Howard Ross	

U.S. DEPARTMENT OF ENERGY  
**FEDERAL ASSISTANCE REPORTING CHECKLIST**

FORM EIA-453A  
(10/80)

FORM APPROVED  
OMB NO 1800-0127

1. Identification Number: DE-FG07-88ID12784		2. Program/Project Title: Geothermal Fluid Genesis in the Great Basin		
3. Recipient: University of Nevada, Las Vegas, Division of Earth Sciences				
4. Reporting Requirements:		Frequency	No. of Copies	Addressees
PROGRAM/PROJECT MANAGEMENT REPORTING				
<input type="checkbox"/>	Federal Assistance Milestone Plan			
<input type="checkbox"/>	Federal Assistance Budget Information Form			
<input checked="" type="checkbox"/>	Federal Assistance Management Summary Report	Q	1,1,1,1,1	a,b,c,d,e
<input type="checkbox"/>	Federal Assistance Program/Project Status Report			
<input checked="" type="checkbox"/>	Financial Status Report, OMB Form 269	A	1,1,1	a,b,c
TECHNICAL INFORMATION REPORTING				
<input checked="" type="checkbox"/>	Notice of Energy RD&D	O	1,1	a,f
<input checked="" type="checkbox"/>	Technical Progress Report	Q	1,1,1,1	a,b,d,e
<input checked="" type="checkbox"/>	Topical Report	A	1,4*,1,1	a,b*,d,e
<input checked="" type="checkbox"/>	Final Technical Report	F	1,4*,1,1	a,b*,d,e
<p>FREQUENCY CODES AND DUE DATES:</p> <p>A - As Necessary; within 5 calendar days after events.  F - Final; 90 calendar days after the performance of the effort ends.  Q - Quarterly; within 30 days after end of calendar quarter or portion thereof.  O - One time after project starts; within 30 days after award.  X - Required with proposals or with the application or with significant planning changes.  Y - Yearly; 30 days after the end of program year. (Financial Status Reports 90 days).  S - Semiannually; within 30 days after end of program fiscal half year.</p>				
5. Special Instructions: *3 copies plus a camera-ready copy.				
6. Prepared by: (Signature and Date) <i>Ken Taylor 5-20-88</i>		7. Reviewed by: (Signature and Date) <i>Rudy Thorne 6/3/88</i>		

RECHARGE OF GEOTHERMAL FLUIDS IN THE GREAT BASIN

Paul K. Buchanan

University of Nevada Las Vegas, Division of Earth Sciences  
255 Bell St Suite 200, Reno, Nv, 89503

ABSTRACT

In August 1988, the Division of Earth Sciences, University of Nevada Las Vegas, began an investigation of geothermal fluid genesis in the Great Basin, Western United States. Currently, there are two theories that attempt to explain the nature and occurrence of geothermal fluids. Both theories rely on interpretation of stable light-isotope ratios of geothermal fluids and meteoric waters. The school of "contemporary recharge" argues that precipitation from elevations in excess of 2,500 meters have stable light-isotope ratios that are identical to those of geothermal springs and wells. This group concludes that geothermal resources are recharged by modern, high elevation precipitation.

An alternative theory is proposed by the school of "paleo-fluid recharge". This theory is based, in part, on pioneering paleo-climate studies by Dansgaard et. al. (1969) who, using continuous core from the Greenland Ice Sheet, identified a transition from modern, isotopically enriched meteoric water to paleo-, isotopically depleted water between 12,000 and 8,000 years BP.

The purpose of this paper is to describe the elements of an investigation that is designed to assess the geologic and temporal framework required to support the hypothesis of paleo-fluid recharge of geothermal fluids. The investigation relies on interpretation of chemical and isotopic data from geothermal fluids, meteoric waters, and paleo-climate proxies such as glacial ice core and packrat midden studies. Interpretations are based on regional and systematic variations of stable light-isotopes within the Great Basin.

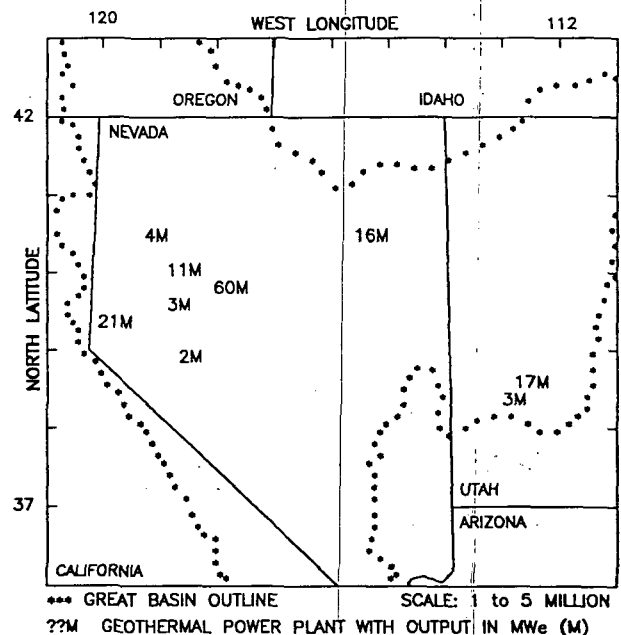
INTRODUCTION

The geothermal energy-producing potential of the Great Basin, Western United States, was long overlooked.

White (1965) saw potential for development at only three sites in Nevada. The potential has today been upgraded dramatically. In 1979, high temperature (>150°C) hydrothermal systems were identified as having a potential to generate 3,000 MWe (megawatts of electricity) for 30 years, while moderate temperature (90°C to 150°C) heat content was estimated at  $2.08 \times 10^{18}$  Joules (Muffler, 1979). In addition, low temperature (<90°C) systems were estimated to hold a potential for 2,400 MWT (megawatts thermal energy) of beneficial heat for a period of thirty years (Reed, 1983).

Geothermal resources within the Great Basin currently supply about 150 MWE of electric power (Figure 1) and have vast potential for further development. Lack of understanding of the source, rate

FIGURE 1: GENERAL LOCATION MAP FOR THE GREAT BASIN, WESTERN UNITED STATES SHOWING LOCATION OF GEOTHERMAL POWER PLANTS



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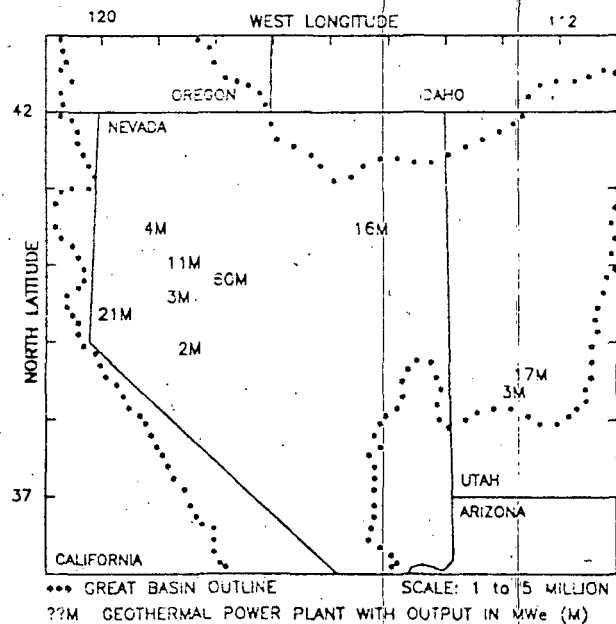
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and path of geothermal fluid recharge remains a risk to geothermal development and raises legal and institutional questions on development of geothermal (mineral) rights and water rights. The purpose of this research is to develop a conceptual, working and plausible model for paleo-recharge of geothermal systems and, eventually, to apply this information to the existing laws on water and mineral resource development in the State of Nevada.

The research program incorporates the Great Basin, emphasizing Nevada. Regional and systematic variations in stable light-isotopes of geothermal, non-thermal, and paleoclimate proxies are used to identify potential recharge area and mechanisms.

#### DATA COLLECTION

Data collection consisted of a compilation and assessment of existing data, and a fluid sampling program designed to fill data voids and incorporate data from newly completed geothermal wells.

#### *Existing Data*

An initial base of stable light-isotope data from the Great Basin was assembled through an extensive literature search. A computer search of GEOREF, CHEM ABSTRACTS AND POLLUTION ABSTRACTS used the following combination of key words: "Nevada" or "Utah" or "Great Basin" and "stable light-isotopes" or "deuterium" or "tritium" or "oxygen-18" and "geothermal" or "water". This data base was augmented by searching the publication lists of the Utah Geological and Mineral Survey, Nevada Bureau of Mines and Geology, Desert Research Institute (Reno, Nevada), California Division of Oil and Gas and the thesis collection of the University of Nevada Reno. To date, 40 references have been used to create a 1000+ point data base of stable light-isotope and geochemical values for thermal and non-thermal springs and wells from throughout the Great Basin. Unfortunately, some of the points are of limited use due to lack of supporting data such as sample temperature, collection date, or precise location.

#### *Fluid Sampling Program*

The focus of the fluid sampling program for this study was three-fold.

- 1) Fill voids in the assembled data base. Where a void was present, the hottest water available was sampled.

- 2) Duplicate samples for time-variant analysis. Hot springs with an extensive history of investigation were chosen for resampling.
- 3) Deep geothermal production wells through the industry-cooperative program. Deep geothermal fluids will be compared to nearby hot springs.

Distribution of the samples analysis budget was 16 for tritium, 48 each for bulk chemical, deuterium and oxygen-18, and 10 for  $d^{14}C/d^{13}C$  age dating. The bulk of these analyses have not yet been received and hence are not considered in this report.

#### PALEOCLIMATE WORK AND HISTORICAL RECHARGE SCHEMES

Initial hypotheses concerning geothermal recharge in the Great Basin demonstrated the similarity between the stable light-isotope content of geothermal fluids and the modern stable light isotope content of range-top precipitation. The findings supported the contention of recharge by modern precipitation through immediate infiltration at elevations in excess of 2,500 meters. The questions of infiltration mechanism and the unrealistically high fluid flow rates required (meters to tens of meters per day) that are necessary to circulate fluids to a depth of six to seven kilometers (Lockenbrook and Sass, 1977) were never adequately addressed (Welch, 1981).

In an unrelated study, Dansgaard (1969) analyzed Greenland ice cores and showed a major enrichment occurred in stable light-isotopes of precipitation at the end of the Pleistocene ice ages, approximately 10,000 years BP. The study revealed a depletion in oxygen-18 of 10 to 12‰ (per mil) and of deuterium by approximately 100‰ relative to modern values. Dansgaard (1969) also demonstrated that the depletion was a worldwide phenomenon related to the colder, wetter climate. Applying the depletion to precipitation in the Great Basin, the elevation of Pleistocene precipitation with stable light-isotope content similar to that of modern range-top precipitation would have been considerably lower, probably near the basin floors (1,500 to 2,000 meters).

#### FLUID AGE AND STABLE LIGHT-ISOTOPE RATIOS

Paleo-carbon age dates and stable light-isotope data from three sources, non-thermal fluids, geothermal fluids and packrat middens, are utilized in this study.

### Carbon Age Dates

Two types of samples were collected for dating; water and carbonate scale. The water samples were treated with NaOH and SrCl to form a SrCO<sub>3</sub> precipitate, which was submitted for analysis. Carbonate scale was collected from geothermal production wells at Dixie Valley and Desert Peak. The scale precipitates at the flash point in the well and must be periodically removed to prevent well closure. Though the scale is a modern feature, it should represent the age of the fluids from which it precipitated. Carbonate scale dates will provide a good cross-check on the SrCO<sub>3</sub> precipitate dates.

Plots of radio-carbon age vs. deuterium for sites in northern and southern Nevada (Figure 2A) both indicate a direct correlation between deuterium depletion and age of fluid. The southern Nevada data (Figure 2B) is largely from shallow wells with moderate temperature (~30°C) waters. The three data sets are geographically close and show similar plots. The northern Nevada data (Figure 2C) are from three widely separated basins and demonstrate that thermal fluids (Dixie Valley and some Moana) tend to be much older than non-thermal fluids (Fallon). Moderate temperature fluids (some Moana) are of intermediate age and are likely a product of mixing.

### Precipitation and Groundwater

Two principal storm tracks provide contemporary precipitation to the Great Basin. The first is a storm track with a northern latitude isotope signature, that originates in the eastern Pacific and travels to the region via the Gulf of Alaska. The second storm track is from the South Pacific. It has a tropical origin and isotopic signature and tracks into the region from the southwest.

Stable light-isotope values of precipitation vary systematically on the basis of latitude, distance inland, elevation, temperature and season (Faure, 1986). The multi-variate nature of the changes in stable light-isotope concentrations makes meaningful monitoring of precipitation content difficult without a regionally extensive sampling network. However, non-thermal (<20°C) shallow groundwater should provide a representative sampling of mean local precipitation, mitigating seasonal and single-storm effects. Mifflin (1968) described an extensive system of interbasin flow in Nevada, mixing waters from different basins and concealing individual basin signatures. This undesired effect can be avoided by sampling only non-thermal springs discharging in the ranges above the basins, prior to mixing. The samples

should then represent contemporary local mean meteoric water.

A contoured plot of deuterium content of non-thermal springs in the Great Basin is provided as Figure 3A. The northern Great Basin displays a west to east deuterium depletion reflecting precipitation from the northern storm track, while the southern Great Basin shows a south to north depletion reflecting precipitation from the southern storm track. The northern region is clearly more depleted in deuterium than the southern region owing to the increased depletion of stable light-isotopes with increasing latitude. A plot of deuterium content of thermal (>75°C) springs and wells (Figure 3B) shows a similar depletion pattern.

Subtracting the plot of non-thermal springs from thermal waters (Figure 3C) allows easy comparison of the two populations. Areas where the non-thermal water is more depleted than the thermal water (positive values) are rare and limited to western Nevada. This area appears to coincide with the persistent location of Pleistocene Lake Lahontan, suggesting isotopically enriched lake waters entered the geothermal recharge system. Alternatively, this could be a result of an orographic effect of the Sierra Nevada Mountain Range. In general, the thermal waters show a depletion of approximately 6‰ to 10‰ throughout the Great Basin. Assuming the non-thermal springs represent contemporary precipitation and the thermal fluids represent Pleistocene meteoric waters, this supports the contention of a depletion in stable light-isotope content of Pleistocene precipitation. In a few areas, particularly the extreme east and south, the plots are adversely influenced by a sparsity of data points and should be viewed accordingly.

### Packrat Middens

Middens are stratified deposits of organic material collected by generations of packrats and preserved with dried, semi-crystalline urine. Twigs, leaves or fecal pellets removed from a midden provide a proxy for the meteoric fluids that supported the plants gathered and consumed by packrats. Since the packrat scavenging range is very limited (10 to 20 meters), the middens can be used to establish an elevation scale against which stable light-isotope content of Pleistocene precipitation can be calibrated. Deuterium vs. age plots of middens from Siegel (1983) show excellent correlation with the oxygen-18 vs. age plots of Dansgaard (1969) (Figure 4). A researcher at the Desert Research Institute has agreed to provide dated packrat midden samples from northern Nevada to further this study.



2A LOCATIONS FOR FIGURES 1B, 1C AND 3

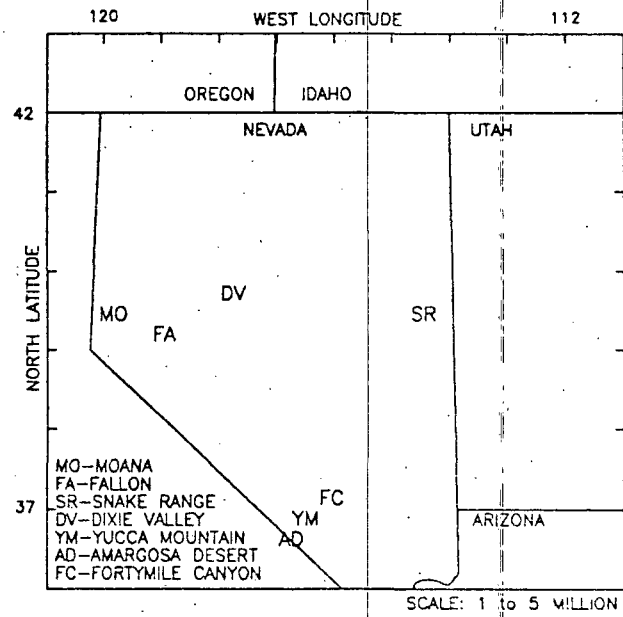
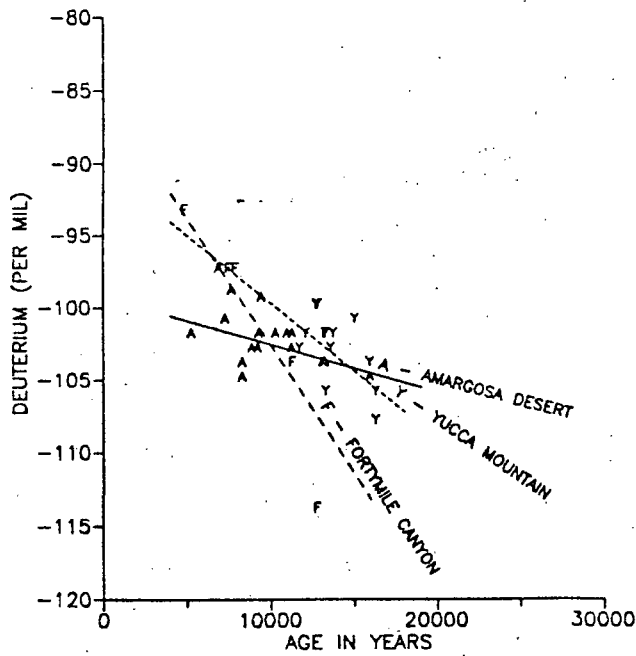


FIGURE 2:

- A) RADIOCARBON AGE VS DEUTERIUM, DATA LOCATIONS
- B) RADIOCARBON-AGE VS DEUTERIUM, SOUTHERN NEVADA
- C) RADIOCARBON-AGE VS DEUTERIUM, NORTHERN NEVADA

2B LOCATIONS IN SOUTHERN NEVADA AT 38.5 DEGREES LATITUDE



2C LOCATIONS IN NORTHERN NEVADA AT 39.5 DEGREES LATITUDE

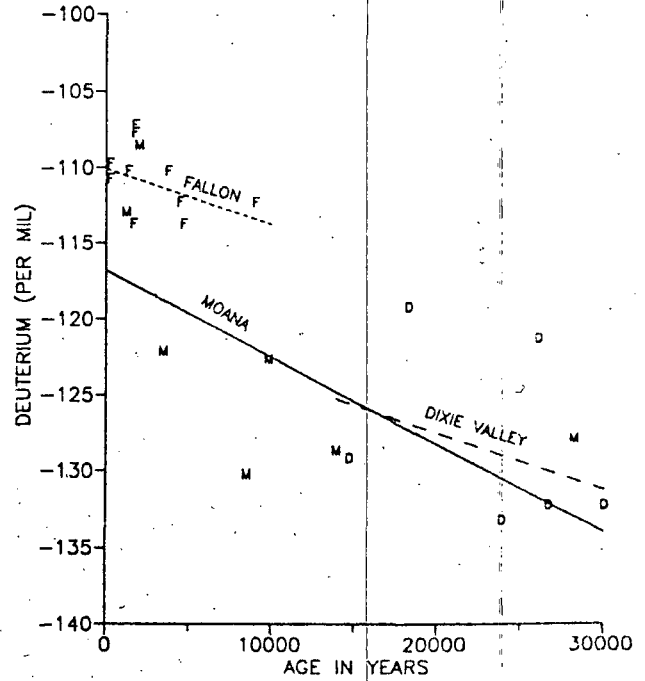
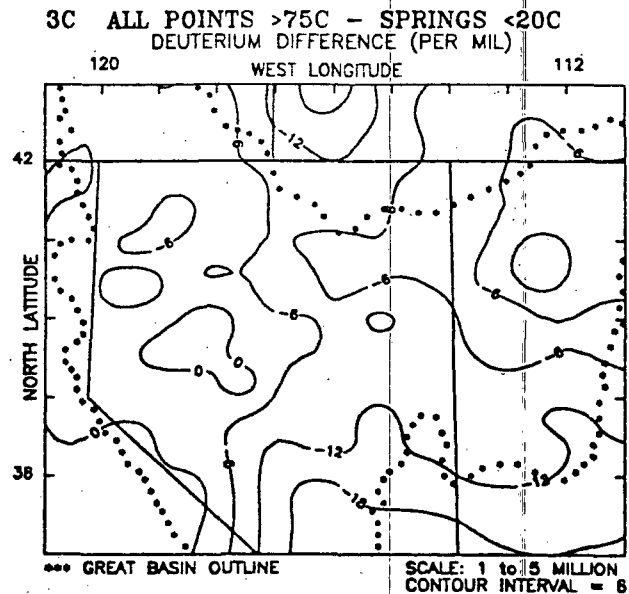
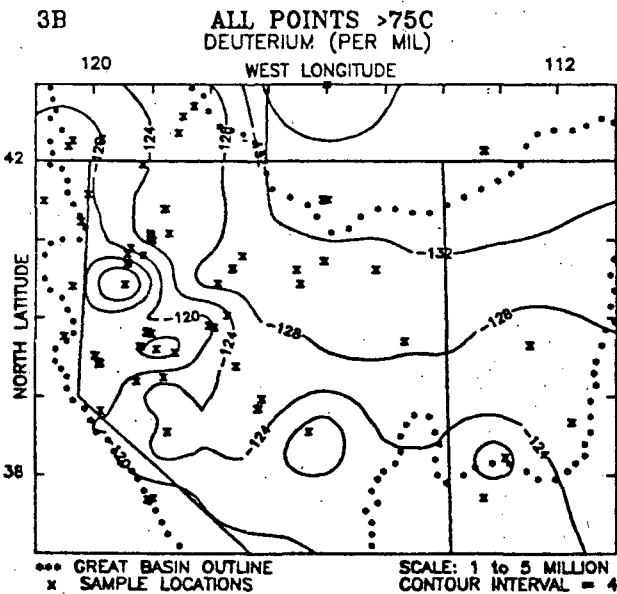
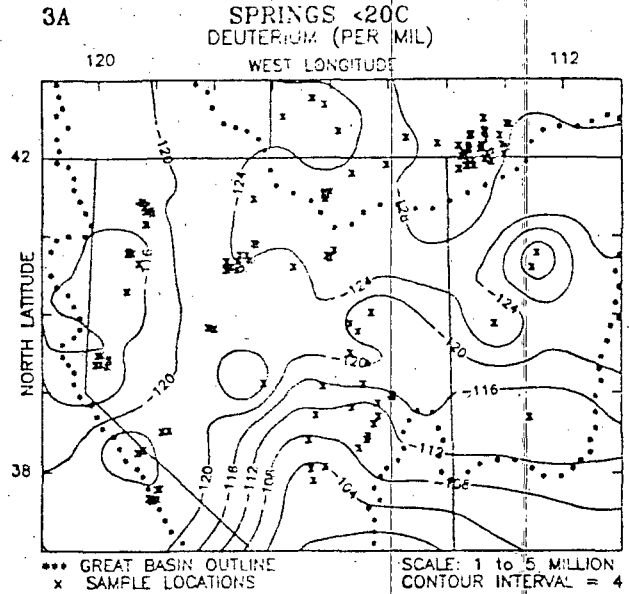


FIGURE 3:

- A) CONTOUR MAP OF DEUTERIUM CONTENT OF NON-THERMAL SPRINGS
- B) CONTOUR MAP OF DEUTERIUM CONTENT OF THERMAL SPRINGS AND WELLS
- C) DIFFERENCE BETWEEN A) AND B)



LAKE LAHONTAN HIGH-STANDS  
AND  
NEW RECHARGE SCHEMES

Geothermal fluids from the Great Basin have apparent ages that date from the late Pleistocene, 40,000 to 10,000 years BP. It is well documented that the basins of western Nevada were submerged beneath Lake Lahontan from 25,000 to 10,000 years BP (Benson and Thompson, 1987, Thompson et al, 1986 ). A chart showing the variations in the level of Lake Lahontan is provided as Figure 5. The basins of western Nevada have minimum elevations around 1000 to 1200 meters.

A lake surrounded by a high water table and supplied by a homogeneous, anisotropic aquifer system will experience inflow from all sides. The presence of a high-conductivity zone beneath the lake will significantly change the potentiometric field (Fetter, 1980) and alter the hydraulic gradient allowing leakage to occur through the lake bottom. Applying the latter scenario to the Great Basin, shattered rock along range-bounding faults could provide a high-conductivity zone for fluid flow. Leakage from the lakes into the submerged alluvial fans would mix with groundwater supplied by run-off from the ranges. This mixture would then migrate vertically through the high-conductivity zone provided by the range-bounding faults. The range-front faults therefore act as conduits for deep

recharge of geothermal fluids. The presence of the pluvial/glacial lakes almost certainly had a positive effect on recharge of deep geothermal systems.

Certain thermodynamic properties of molecules, including vapor pressure, are dependent upon the mass of their constituent atoms (Faure, 1986). Since surface water is constantly evaporating it becomes more enriched in the heavier isotopes of oxygen and hydrogen. The lighter molecules, having a lower vapor pressure, are preferentially evaporated. Lakes therefore are normally isotopically more enriched than their inflow. The similarity in the stable light-isotope values between contemporary and Pleistocene fluids in western Nevada could thus be explained by assigning a substantial portion of the recharge to lake water. A mixture of isotopically enriched lake water and depleted meteoric water could resemble contemporary precipitation.

Geothermal fluids from eastern Nevada are isotopically depleted compared to those from western Nevada and to contemporary precipitation. Since late Pleistocene lakes were not as prevalent in eastern Nevada, the bulk of geothermal fluid recharge was derived from the meteoric waters of the colder, wetter Pleistocene climate. Range-bounding faults remain the likely conduit for deep geothermal recharge.

FIGURE 4: PALEO-CLIMATE DATA FROM GREENLAND AND THE SNAKE RANGE

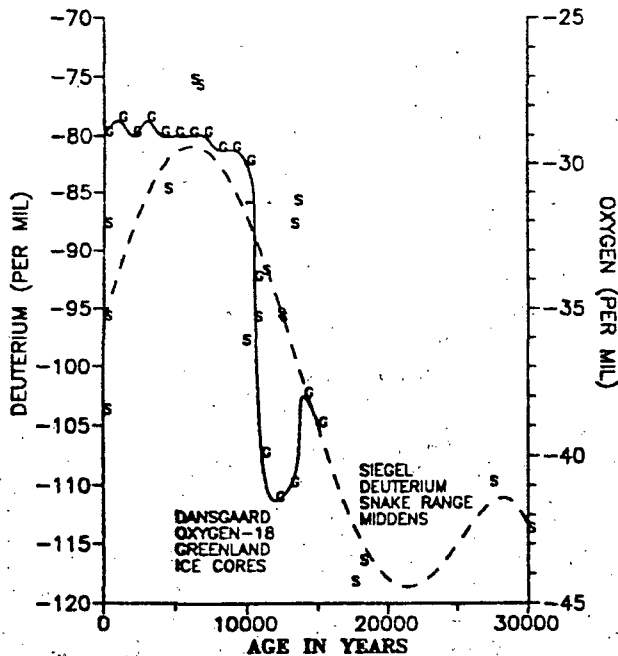
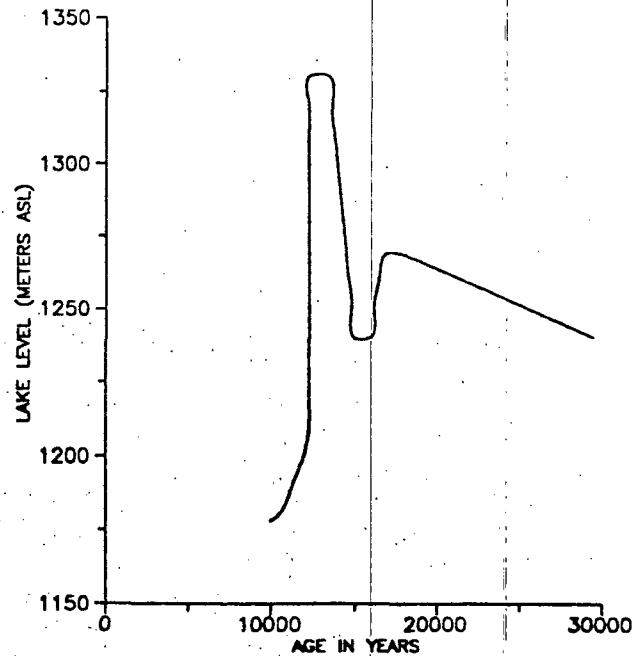


FIGURE 5: PLEISTOCENE HIGHSTANDS OF LAKE LAHONTAN, WESTERN NEVADA FROM BENSON AND THOMPSON (1987)



CONCLUSION

Isotope ratios of non-thermal (contemporary) fluids and thermal (older) fluids vary systematically throughout the Great Basin. Contemporary precipitation falling at elevations in excess of 2,500 meters has isotopic signatures similar to geothermal resources, but would require unrealistically high flow rates to complete the cycle from range-top to resource to basin.

The apparent late Pleistocene age of nearly all geothermal fluids strongly supports a paleo-recharge scheme. This contention is supported by the isotopically depleted nature of the geothermal fluids compared to contemporary meteoric water. Range-bounding faults provide a plausible conduit for recharge of deep geothermal systems. In western Nevada, Pleistocene lakes appear to have made a substantial contribution to the recharge, isotopically enriching the geothermal fluids. The influence of Pleistocene lakes on recharge in eastern Nevada is not evident, suggesting recharge is a local phenomena.

ACKNOWLEDGEMENTS

This work is funded by the United States Department of Energy, Idaho Operations Office, grant #DE-FG07-88ID 12784. Additional support for this paper was received from the Nevada Section of the Geothermal Resources Council and the Nevada geothermal industry.

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