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U.S. DEPARTMENT OF ENERGY

memorandum

DATE:

REPLY TO ATTN OF: CE-324

Program Letter ______

SUBJECT: FY 1985 OPERATING EXPENSES FOR Idaho Operations Office

TO: Idaho Operations Office
Idaho Falls, ID

Fred Glatstein,
Budget and Fiscal Management Div.
Conservation and Renewable Energy

This letter authorizes an increase of $ 72,000 in B/A and $ 72,000 in B/O for Idaho Operations Office. These funds are budgeted under the budget and reporting classification AM-10. Attachment I of this letter provides guidance for the use of these funds.

Acting Director
Office of Renewable Technology
Conservation and Renewable Energy

cc: DGHT Program Manager
M. Reed

ATTACHMENT I
Operating Expenses

Page _____ of _____
Program Letter ______

Idaho Operations Office

B & R Classification	($000) FY 1985 Increment **B/A**	**B/O**
AM-10-15-10	$ 72	$ 72

Program Guidance

Geothermal Reservoir Technology Program

FY 1985 Budget Authority and FY 1985 Cost Authority in the amount of $30,000 each is provided to fund the project, Potassium-Argon Dating of Young Volcanic Rocks, in the attached unsolicited proposal from University of Arizona. The objective of this project is to extend the dating techniques to very young volcanic rocks in active geothermal areas. This will provide valuable information for understanding the formation and lifetime of geothermal systems.

Geothermal Reservoir Technology Program

FY 1985 Budget Authority and FY 1985 Cost Authority in the amount of $42,000 each is provided as incremental funding for the project, Geothermal Map of the United States, in the attached unsolicited proposal from Southern Methodist University. The objective of this project is the compilation of all the heat flow and thermal gradient data collected under DOE funded geothermal projects and the preparation of a geothermal map of the U. S. This map is to be published by the Geological Society of America. This project is to work closely with heat flow projects funded by the State Cooperative Geothermal Resource Definition Program. Ownership of the IBM-PC computer needed for this project is to be transferred to Southern Methodist University for its use in future geothermal projects.

Program Manager

M. Reed

THE UNIVERSITY OF ARIZONA
TUCSON, ARIZONA 85721

DEPARTMENT OF GEOSCIENCES
LABORATORY OF ISOTOPE GEOCHEMISTRY
TEL. (602) 621-6014

13 March 1985

Dr. Marshall Reed
Geothermal and Hydropower Technologies Division
U.S. Department of Energy, C.E. 324
Washington, D.C., 20585

Dear Dr. Reed:

Thank you for the information that I requested in order to submit a proposal to the National Geothermal Program. Three copies of our proposal are enclosed. We would be pleased to have the oppotunity to use our expertise and experience in K-Ar dating of young volcanic rocks to further the goals of this important program.

Sincerely,

Paul E. Damon

Professor and Chief
Scientist of the Laboratory
of Isotope Geochemistry

UNSOLICATED PROPOSAL

FOR

K-AR DATING OF VOLCANIC ROCKS

from the Pacific Northwest; Cerro Prieta Area; Baja California, Mexico; Los Azufres Area; Michoacan, Mexico; and other Areas of Interest to the National Geothermal Program

Submitted by:

Paul E. Damon, Principal Investigator
Muhammad Shafiqullah, Co-Principal Investigator

To:

Geothermal and Hydropower Technologies Division,
United States Department of Energy

A. Experience in Dating Volcanic Rocks Younger Than 0.5 Million Years

The potassium-argon method determines absolute age by measuring the amount of radioactive potassium-40 and the amount of radiogenic argon-40 in a sample. Potassium-argon dating of geologically young samples, particularly late Pleistocene volcanic rocks of low potassium content, requires meticulous attention to detail because of the large amount of atmospheric argon-40 with a half life of about 1.25 billion years. The amount of radiogenic argon produced in a few hundred thousand years is minute, especially in rocks containing less than 1% potassium. Problems of this low signal to noise ratio are compounded by extraneous argon inherited from phenocrysts which did not completely degas on eruption or may have been trapped in chilled zones within the flow.

Atmospheric argon absorbed into the lava following eruption constitutes the major portion of argon-40 found in geologically young samples. It can exceed radiogenic argon by two orders of magnitude in samples less than 100,000 years old. Air argon is "tagged" by its argon-36 content and the "air correction" is made by multiplying the amount of argon-36 by the "air ratio" and subtracting this from the total measured argon-40 to leave the radiogenic argon-40. When atmospheric argon constitutes more than 95% of the total, confidence in the calculation is decreased and the reported experimental error grows to sometimes equal or exceeds the age. Since this atmospheric "noise" is highly variable from place to place within a given flow, the quality of the ages from samples collected from different places in the same flow will vary.

Experience gained by this laboratory over 23 years of dating whole rock samples less than 1 million years old has allowed us to progressively reduce the age of the "youngest datable sample". It is gratifying to note that improvements made by this laboratory are being used by other investigators to extend their capabilities.

A list of publications involving K-Ar dating work in this laboratory is presented in Appendix 1.

B. Laboratory Procedures

1. Sample Preparation

Basalt should be collected from the massive centers of lava flows by dismembering large rocks and collecting the unweathered center material. The chunks are reduced to 2 cm in a large jaw crusher and hand picked to remove discolored material and large phenocrysts. These fragments are reduced to 3mm in a roller crusher, passed through a flat-plate grinder and sieved to collect the -100+150 fraction. This fraction is washed to remove dust.

Heavy liquid of specific gravity 2.52 floats off glass, altered mineral grains and chance organic contaminants. Heavy liquid of 2.95 s.g. allows iron filings from the grinders, olivine, pyroxene, spinel and other potassium-poor minerals to sink thereby leaving a sand-sized concentrate of plagioclase and plagioclase-rich composite grains for further analysis. Pure plagioclase, which might be phenocryst fragments carrying excess or inherited argon, is removed by passage through a Frantz isodynamic seperator. This sample is finally leached in 5% HF for 10 minutes to remove the last of the adhering glass, clay and carbonate and then resieved to remove the finer grains. This culled groundmass now devoid of most problem causing constituents is the plagioclase concentrate that we date.

Felsic volcanic rock samples are collected from unweathered rock containing K-feldspars with good crystal face reflections. Biotite is sometimes used but may contain significant amounts of excess argon. Sample preparation is similar except that the heavy liquid s.g. is adjusted to discriminate against plagioclase if it is sufficiently calcic and the Frantz isodynamic separator is used to obtain a pure feldspar concentrate. The high potassium content and low affinity for excess argon makes sanidine a very useful mineral for dating late Pleistocene volcanic rocks. In general, any mineral phase in which potassium is a major component, can be used for K-Ar dating. If a problem of excess argon is suspected, two different minerals can be analyzed to evaluate the magnitude of the excess. The second mineral should contain a much lower potassium content and consequently the apparent age will be much more sensitive to excess argon.

2. Potassium Analysis

The dried sample is split and one part pulverized to -300 mesh for potassium analysis. Four subsamples of this part are weighed into teflon crucibles and taken into solution in HF and H_2SO_4. The resulting solutions are buffered with NaCl to supress ionization of the K and brought to standard volume. Potassium content of the sample solutions is compared to solutions of prepared potassium concentration for a minimum of 6 spot determinations. Each analytical run includes a rock standard, either our own laboratory standards or one of the international standards. The results are rejected if the internal statistical errors exceed 1.5% or the standard K content differs from its accepted value by more than 2%. Our preparation and analytical techniques have changed little in the past few years, except for inclusion of the rock standard in each analytical run which gives control of the accuracy of the results.

3. Argon Analysis

Argon is determined on the gas evolved when 10-30 gms of the sample is fused in a vacuum. The -100+150 mesh concentrate is weighed into molybdenum crucibles which are suspended in 9 cm fusion envelopes. A batch of 4 is mounted each week and the system baked out at 270°C for 20 hours to remove absorbed argon. One sample per day is fused by induction heating using a RF generator. The system is baked again overnight to eliminate the memory effect from the previous sample.

A precisely measured "spike" of argon-38 is introduced into the system during fusion. The spike-gas mixture is cleaned of water and other reactive components in synthetic zeolite molecular sieves, a copper oxide furnace and two titanium foil furnaces. What little reactive components remain are removed by a Sorbac appendage pump prior to argon analysis. The gas is split into three or more aliquots and the isotopic composition is measured in the static mode of a Nier-design 6-inch radius, 60° sector, gas-source mass spectrometer. A OSI 6502 micro computer changes the magnetic field to focus each ion beam, in turn, on a Faraday collector and then measures the voltages generated. Background is measured on both sides of each peak. Seven cycles from mass 36 to 38 to 40 and back constitute a run. Measurements are time regressed to T=0, the time the gas was introduced, using cubic, parabolic, and linear, least squares regression routines on each peak voltage and their ratios. Each reported argon value is the mean of 6 methods of calculation. If the analyses on the different gas aliquots do not agree within statistical limits, another fusion is carried out.

Precision of argon determinations has been determined to be within 1.5% reproduceability. The air ratio of argon-40 to argon-36 in the atmosphere is measured periodically and two argon standards are regularly analysed to monitor the precision of the system and technique.

4. Analyses by the Laboratory on Volcanic Rocks Less Than 500,000 Years Old

Analytical data on fifty volcanic rocks younger than 500,000 years that have been dated in this laboratory are given in Table 1. We have been able to obtain meaningful results consistent with the stratigraphy to latest Pleistocene time. Under favorable conditions meaningful results can be obtained for Holocene samples. For example, we were able to confirm that a basalt sample (UAKA-84-64) that contained less than $1x10^{-14}$ m/g of radiogenic ^{40}Ar was Holocene in age. We have made continuing efforts to improve the accuracy of our argon analyses. As a consequence, recent results should be more accurate than earlier results.

C. Proposed Research

We propose to make forty analyses for samples from the Cascade Mountains of the Pacific Northwest, Cerro Prieta area of Baja California, Mexico, Los Azufres area of Michoacan, Mexico and other geothermal areas of interest to the National Geothermal Program. When different phases of one sample, such as coexisting mica and feld-spar are dated, for reporting purposes they will be considered as different analyses. We will report three analyses on separate aliquots for potassium and analyses on three aliquots of argon from one fusion for each sample. In case results are required urgently, data will be reported by telephone.

D. Duration of Proposed Research

The duration of the proposed research is expected to be one year, starting at the earliest practical date with the possibility of extension if field collections are not complete.

E. Billings

Analytical data along with billings will be forwarded, as the work progresses, in batches of four to six samples. Thus, any bill will not exceed $4500.00. Checks for the completed work should be made payable to: The University of Arizona (Department of Geosciences) and mailed to the Laboratory of Isotope Geochemistry, Department of Geosciences, University of Arizona, Tucson, Arizona, 85721. Attn: Mrs. Maureen Mackey.

F. Budget

Geologically young samples are quite difficult to analyze and require great care in preparation. The added costs raise our price to $750.00 per sample. This includes all technical services except transportation and living expenses should field consultation be required. Laboratory overhead is included and University overhead is waived providing individual billings for analyses are less than $5000.00 and all negotiations are handled through The Laboratory of Isotope Geochemistry, University of Arizona. Our accounts are reviewed by both the Department of Geosciences and The University of Arizona accountants. Forty analyses at $750.00 per analyis: $30,000.

Table 1: K-Ar Dates for Fifty Volcanic Rocks
Less Than 500,000 Years Old

Sample No.*	% K	Radiogenic ^{40}Ar x 10^{-12} m/g	% Atmospheric Argon-40	K-Ar Date m.y	±σ m.y.
UAKA 73-113	2.70	2.31	80.1	0.493	0.060
UAKA 77-06	1.054	0.888	94.6	0.486	0.110
UAKA 82-184	1.480	1.247	79.9	0.486	0.029
UAKA 80-04	1.310	1.090	84.4	0.480	0.030
UAKA 77-44	1.227	1.010	80.7	0.475	0.029
UAKA 74-140	2.328	1.910	87.4	0.473	0.055
UAKA 76-121	0.693	0.558	95.8	0.465	0.065
UAKA 75-14	1.017	0.820	89.2	0.465	0.054
UAKA 74-141	1.488	1.12	83.8	0.434	0.031
UAKA 74-34	0.955	0.715	82.8	0.432	0.029
UAKA 79-116	0.935	0.702	94.1	0.430	0.060
UAKA 77-07	1.605	1.17	88.3	0.420	0.059
UAKA 75-121	1.93	1.36	96.6	0.406	0.155
UAKA 74-143	2.12	1.48	84.8	0.404	0.031
UAKA 77-43	0.794	0.509	94.3	0.370	0.040
UAKA 84-136	0.992	0.628	81.0	0.365	0.021
UAKA 84-252	0.584	0.363	91.4	0.359	0.050
UAKA 84-169	7.017	4.33	93.4	0.356	0.061

Table 1: continued

Sample No.*	% K	Radiogenic ^{40}Ar x 10^{-12} m/g	% Atmospheric Argon-40	K-Ar Date m.y.	±σ m.y.
UAKA 75-11	0.493	0.291	92.4	0.341	0.065
UAKA 79-181	1.162	0.687	95.5	0.340	0.070
UAKA 75-17	2.40	1.40	97.4	0.336	0.169
UAKA 77-13	2.402	1.37	96.1	0.330	0.087
UAKA 82-195	0.810	0.433	95.0	0.308	0.070
UAKA 75-9	0.822	0.400	95.7	0.281	0.082
UAKA 84-66	1.058	0.504	86.6	0.274	0.020
UAKA 84-65	1.082	0.503	87.6	0.268	0.031
UAKA 71-8	8.942	3.80	93.3	0.245	0.037
UAKA 75-8	0.497	0.192	94.4	0.221	0.050
PED 14-70	9.07	3.42	91.1	0.218	0.021
UAKA 84-253	3.402	1.244	75.7	0.211	0.013
UAKA 74-261	2.28	0.825	87.5	0.209	0.019
UAKA 79-100	1.091	0.376	94.6	0.199	0.050
UAKA 84-135	1.629	0.539	93.9	0.191	0.038
UAKA 84-119	7.122	2.315	97.5	0.187	0.063
UAKA 79-131	1.127	0.359	92.9	0.183	0.030
UAKA 84-118	7.189	2.238	96.7	0.180	0.050

Table 1: continued

Sample No.*	% K	Radiogenic ^{40}Ar x 10^{-12} m/g	% Atmospheric Argon-40	K-Ar Date m.y.	±σ m.y.
UAKA 75-16	2.408	0.73	94.2	0.175	0.038
UAKA 75-15	1.224	0.370	97.8	0.174	0.061
UAKA 84-137	2.136	0.635	88.3	0.171	0.016
UAKA 75-20	0.808	0.204	95.9	0.146	0.028
UAKA 75-81	0.785	0.197	95.0	0.145	0.038
UAKA 74-26a	1.20	0.250	96.2	0.120	0.038
UAKA 83-47	0.717	0.107	96.4	0.086	0.022
UAKA 83-44	0.643	0.087	96.7	0.078	0.018
UAKA 83-46	0.751	0.073	98.8	0.056	0.025
UAKA 73-120	2.22	0.210	95.6	0.055	0.014
UAKA 73-121	2.142	0.190	98.9	0.051	0.046
UAKA 84-63	1.389	0.086	96.5	0.036	0.012
UAKA 84-259	3.452	0.088	97.5	0.015	0.019
UAKA 84-64	1.180	0.0097	99.9	0.005	2 **

Table 1: continued

* first two digits in sample number is the year received in the laboratory last three digits are the order of receipt during the year

** at 2 σ confidence level

Constants used:

$\lambda_\beta = 4.963 \times 10^{-10}\ yr^{-1}$

$\lambda_e = 0.581 \times 10^{-10}\ yr^{-1}$

$\lambda = 5.544 \times 10^{-10}\ yr^{-1}$

$^{40}K/K = 1.167 \times 10^{-4}$ atom/atom

APPENDIX I

LIST OF PUBLICATIONS RELATED TO THE USE OF EXISTING GAS SOURCE MASS SPECTROMETERS AT THE LABORATORY OF ISOTOPE GEOCHEMISTRY, UNIVERSITY OF ARIZONA, TUCSON, ARIZONA. (Includes only papers coauthored by Lab researchers).

1961

Damon, P. E., and Giletti, 1961, The ages of the basement rocks of the Colorado Plateau and adjacent areas: Annals of the New York Academy of Science, v. 91, p. 443-453.

1962

Damon, P. E., Livingston, D. E., and Erickson, R. C., 1962, New K-Ar dates for the Precambrian of Pinal, Gila, Yavapai and Coconino Counties Arizona: Mogollon Rim Region Guidebook, 13th Field Conference, New Mexico Geological Society, p. 56-57.

Damon, P. E., Livingston, D. E., Mauger, R. L., Giletti, B. J., and Pantoja Alor, J., 1962, Edad del Precambrico "Anterior" y de obtras rocas del Zocalo de la region de Caborca-Altar de la pate Noroccidental del Estado de Sonora, in: Estudios Geocronologicos de Rocas Mexicanas, Fries, C., Jr. ed., Instituto de Geologia, Mexico, Boletin 64, parte 2, p. 11-44.

De Cserna, Z., Schmitter, E., Damon, P. E., Livingston, D. E., and Kulp, J. L., 1962, Edades isotopicas de rocas metamorficas del centro y sur de Guerrero y de una monzonita cuarcifera del norte de Sinaloa, in: Estudios Geocronologicos de Rocas Mexicanas, Fries, C., Jr., ed., Instituto de Geologia, Mexico, Boletin 64, parte 5, p. 71-84.

Fries, C., Jr., Schmitter, E., Damon, P. E., and Livingston, D. E., 1962, Rocos Precambricas de edad Grenvilliana de la parte Central de Oaxaca en el Sur de Mexico, in: Estudios Geocronologicos de Rocas Mexicanas, Fries, C., Jr., ed., Instituto de Geologia, Mexico: Boletin 64, parte 3, p. 45-53.

Fries, C., Jr., Schmitter, E., Damon, P. E., Livingston, D. E., and Erickson, R. C., 1962, Edad de las rocas metamoficas en los canones de la Peregrina y de Caballeros, parte Centro-Occidental de Tamaulipas, in: Estudios Geocronologicos de Rocas Mexicanas, Fries, C., Jr., ed., Instituto de Geologia, Mexico, Boletin 64, parte 4, p. 55-69.

1963

Bikerman, M., 1963, Origin of the Cat Mountain Rhyolite: Arizona Geological Society Digest, v. 6, p. 83-89.

Damon, P. E., Erickson, R. C., and Livingston, D. E., 1963, K-Ar dating of basin and range uplift, Catalina Mountains, Arizona: Nuclear Geophysics, Woods Hole Conference on Nuclear Geophysics, National Academy of Sciences/National Research Council, no. 1975, p. 113-121.

1964

Damon, P. E., 1964, The present status and future possibilities of geochemistry as applied to paleoecological research, in: The Reconstruction of Past Environments, assembled by J. J. Hester and J. Schoenwetter, Fort Burgwin Research Center, New Mexico p. 77-82.

Damon, P. E., and Bikerman, M., 1964, Potassium-argon dating of post-Laramide plutonic and volcanic rocks within the Basin and Range Province of southeastern Arizona and adjacent areas: Arizona Geological Society Digest, v. VII, p. 63-78.

Damon, P. E., Mauger, R. L., and Bikerman, M., 1964, K-Ar dating of Laramide plutonic and volcanic rocks within the Basin and Range province of Arizona and Sonora: 12th International Geological Congress, India, Part III, Proceedings of Section 3, p. 45-55.

1965

Damon, P. E., 1965, Pleistocene time scales: Science, v. 148, p. 1037.

Mauger, R. L., Damon, P. E., and Giletti, B. J., 1965, Isotopic dating of Arizona ore deposits: Transactions of Society of Mining Engineers, v. 232, p. 81-87.

1966

Bikerman, M., and Damon, P. E., 1966, K-Ar chronology of the Tucson Mountans, Pima County, Arizona: Geological Society of America Bulletin, v. 77, p. 1225-1234.

Damon, P. E., and Mauger, R. L., 1966, Epeirogeny-orogeny viewed from the Basis and Range province: Transactions of Society of Mining Engineers, v. 235, p. 99-112.

1967

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Livingston, D. E., Damon, P. E., Mauger, R. L., Bennett, R., and Laughlin, A. W., 1967, Argon 40 in cogenetic feldspar-mica mineral assemblages: Journal of Geophysical Research, v. 72, p. 1361-1375.

1968

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Damon, P. E., 1968, Radioactive dating of Quaternary tephra, in: Means of correlation of quaternary successions, v. 8, Proceedings, VII Congress of the International Association for Quaternary Research, University of Utah Press, p. 195-206.

Erickson, R. C., 1968, Geology and geochronology of the Dos Cabezas Mountains, Cochise County, Arizona: Arizona Geological Society Guidebook III, p. 193-198.

Laughlin, A. W., 1968, Excess radiogenic argon in pegmatite minerals: Journal of Geophysical Research, v. 74, no. 27, p. 6684-6689.

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Livingston, D. E., and Damon, P. E., 1968, The ages of stratified Precambrian rock sequences in central Arizona and northern Sonora: Canadian Journal of Earth Sciences, v. 5, p. 763-772.

Livingston, D. E., Mauger, R. L., and Damon, P. E., 1968, Geochronology of the emplacement, enrichment, and preservation of Arizona porphyry copper deposits: Economic Geology, v. 63, p. 30-36.

Marjaniemi, D., 1968, Tertiary volcanism in the northern Chiricahua Mountains, Cochise County, Arizona: Arizona Geological Society, Guidebook III, p. 208-214.

Mauger, R. L., Damon, P. E., and Livingston, D. E., 1968, Cenozoic argon ages on metamorphic rocks from the Basin and Range Province: American Journal of Science, v. 226, p. 579-589.

McKee, E. D., Hamblin, W. K., and Damon, P. E., 1968, K-Ar age of Lava Dam in Grand Canyon: Geological Society of America Bulletin, v. 79, p. 133-136.

Percious, J. K., 1968, Geology and geochronology of the Del Bac Hills, Pima County, Arizona: Arizona Geological Society, Guidebook III, p. 199-207.

Pushkar, P., 1968, Strontium isotope ratios in volcanic rocks of Three Island Arc areas: Journal of Geophysical Research, v. 73, p. 2701-2714.

1969

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1970

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1971

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1972

Watkinson, D. H., Thurston, P., and Shafiqullah, M., 1972, The Shawmere anorthosite of Archean Age in the Pakuskasing Belt, Ontario: The Journal of Geology, v. 80, p. 736-739.

1973

Elston, W. E., Damon, P. E., Coney, P. J., Rhodes, R. C., Smith, E. I., and Bikerman, M., 1973, Tertiary volcanic rocks, Mogollon-Datil Province, New Mexico, and surrounding region: K-Ar dates, patterns of eruption, and periods of mineralization: Geological Society of America Bulletin, v. 84, p. 2259-2274.

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1974

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Pushkar, P., and Damon, P. E., 1974, Apparent Paleozoic ages from Southern Arizona: K-Ar and Rb-Sr geochronology: Isochron/West, no. 10, p. 7-1.

Shafiqullah, M., and Damon, P. E., 1974, Evaluation of K-Ar isochron methods: Geochimica et Cosmochimica Acta, v. 38, p. 1341-1358.

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1975

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Brookins, D. G., Shafiqullah, M. 1975, K-Ar ages for pegmatitic and metamorphic muscovites, Sandia Mountans, New Mexico: Isochron/West, no. 12, p. 9-10.

Gresens, R. L., 1975, Geochronology of Precambrian metamorphic rocks, north-central New Mexico: Geological Society of America Bulletin, v. 86, p. 1444-1448.

Leventhal, J. S., 1975, An evaluation of the uranium-thorium-helium method for dating young basalts: Journal of Geophysical Research, v. 80, no. 14, p. 1911-1914.

1976

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February 8, 1985

Dr. Marshall Reed
U.S. Department of Energy
Division of Geothermal and Hydrothermal Technology
CE-324, M.S. GB-025
1000 Independence S.W.
Washington, D.C. 20585

Dear Marshall:

This letter concerns the geothermal map of North America which I discussed with you last fall. As I told you I am in charge of putting together a geothermal map as part of the DNAG series. (Some information on the program is enclosed) This map is to be submitted to a printer some time in 1986 and will be published in 1988. Also included will be geologic, tectonic, gravity, magnetic, neotectonic, etc. maps of North America, so I think that it is very important to include a geothermal map as part of this extensive series.

The Canadians are quite active in geothermal studies and are organizing a presentation for their part of the map. A number of people have been working in Mexico and that compilation is underway. Because of the number of people involved and the quantity of data, the most complex task is preparing a map for the United States. In view of the large amount of funds that DOE has put into a geothermal evaluation program in the last few years, it seems appropriate that the information that has been obtained should be displayed on a continent wide map that will be part of a much publicized and used series. Inclusion of this data set would enhance the detail of information available and also the success of the overall presentation as literally hundreds to thousands of data have been collected as part of the DOE state-coupled geothermal-evaluation program. Since geothermal maps for public consumption have been prepared for many states it would seem appropriate to fund preparation of a scientific map which will be used for many years based on this same information. A further important outcome would be to set the information up in a data base form that would be made available to exploration companies, government planners and other interested groups. The data would be prepared in computer compatible format such as 5¼" floppy disks and magnetic tapes.

After talking to a number of the people involved in heat flow and geothermal studies at the AGU meeting in December, I have a better idea of possible outlines of a program to compile the data and map. Such an undertaking could cost from $50,000 to $200,000 depending on the thoroughness to which the project is accomplished. The type of data which we would hope to display would be heat

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flow values in the western United States, aquifer temperatures or depth to isotherms in sedimentary basins (particularly in the Mid-continent and Gulf Coast regions), and possibly some ancillary information such as aquifer temperature, chemical aquifer temperatures, hot spring locations, and locations of young volcanic rocks.

An optimum way to proceed would, of course, be to fund a project for each state or region under an overall direction. Each group would prepare data compilations based on specifications from the steering group involved in this map compilation (myself, Paul Morgan and John Sass). With this sort of approach I expect most state or regional efforts would cost on the order of $25,000 to $50,000 and such an effort obviously would run to several hundred thousand dollars.

A more realistic and cost effective way to get the data compilation for a minimum amount of money might be to proceed through a single contract with parts of this contract being assigned to individual compilers. I have enclosed a preliminary budget based on such a compilation effort with this letter (Table 1). As presently outlined, at least seven people need to be actively involved in this compilation (outside of the U.S. Geological Survey personnel who have not been included). The persons involved in the compilation might be Will Gosnold, Ed Decker, John Costain, Doug Smith, Paul Morgan, Dave Chapman, and myself. An approximate area of responsibility for each of these compilers is shown in the table. If we are going to work on a minimal budget, then one way would be to contract through SMU for a student to work with each investigator for about 9 months to compile data under the direction of the individual investigator. Most of the people I have talked to seem to be willing to operate in this way.

Of course the apparent cost could be reduced if specifications to supply this information could be included in individual grants or contracts to these or other groups. An example is Will Gosnold who may be seperately funded for a specific evaluation project. Each of these investigators would prepare all the data available in the literature and unpublished in their files. An objective would be to compile an extensive data set for each site. A sheet (Table 2) which shows some of the information available on the data base that we currently use at SMU and which might serve as a starting point accompanies this letter. I have estimated the cost for us at SMU to put all this data together, to organize the compilations and to prepare the information in a form useful to GSA and for public distribution. The total overall cost, including SMU overhead, is approximately $160,000 for an 18 month project.

The compilation, if it is to be done largely by students, would have to be underway no later than the first part of the summer so we could begin to get information from the various groups by the Fall of 1985 and be well along by January of 1986. Not included in this estimate, but optimal, would be a contractors meeting or perhaps a Penrose type of meeting to discuss the geothermal studies of the United States and/or North America. Such a meeting would cost from $10,000 to $40,000 depending on how much is funded by individual investigators and how much was externally funded.

Another approach which would be less expensive but would result in a less effective compilation of data would be for us to spend approximately $50,000 to $60,000. I would hire several students to go through the literature and compile information in a form suitable for use in the data base. But the information that would be available would essentially be confined to what people would give us for free and what was in the literature. I don't think the result would be anywhere near as favorable as the one we would get from a slightly better funded compilation.

I have also been contacted by Ron Smith at NOAA about the possibility of printing this map. It would be appropriate and in line with the past DOE activities to have them put out the information in this way. There also might be some savings in compilation time as some of the information may already be in a file in a form which is useful to them and we could maintain that as we prepare compilations. The cost of this activity has not been included in the budget but a couple of months ago Ron gave me an estimate of $20,000 to $50,000 depending on the effort involved.

The areas which are most troublesome are the areas of Nevada and the Gulf Coast region. Nevada is a problem because of the quantity of data there, particularly in the UURI files bought from the companies, that has not been included in the geothermal maps which have been published by the state of Nevada. It would represent a major effort to get this data into a suitable form, but one which I think would be very useful. Exploration activity in Nevada is in high gear at the present time, not only for geothermal but also for oil and gas and minerals. All of these explorationists would be interested in the geothermal information. The Gulf Coast is very difficult to work with because of the extensive amount of bottom hole data and the paucity of reliable temperature data. Nonetheless some effort could well be placed in this area to come up with useful thermal data for the map.

In summary, I think that it is a very appropriate for DOE to fund a compilation of a geothermal map of the United States as part of a geothermal map of North America for the GSA/DNAG program. This map would form a nice complement to the state map series which has already been published by the Division of Geothermal Energy. Such a map would make available to scientists, and the general public as well, the results of these extensive studies, and the best summary of thermal information available up to the mid 1980's. The cost of such a compilation could range anywhere from $50,000 up to several hundred thousand dollars depending on the thoroughness and the manner in which it is carried out. I will call you in a week or so and we can discuss the various possibilities.

Sincerely yours,

David D. Blackwell

DDB/mw
Enclosure

GEOTHERMAL MAP OF THE UNITED STATES

This project involves a compilation of existing geothermal data for the United States. The object of this compilation will be to prepare a geothermal map which will be part of a geothermal map of North America to be published as part of the Geological Society of America's - Centennial Decade of North American Geology (DNAG) project. In addition to preparation of the geothermal data for the map presentation, the data will be assembled onto a computer data base which will be made available to those interested in geothermal energy. This comprehensive data base will be built on the voluminous data collection carried out for the past few years in large part through funding from the U.S. DOE/DGE. This data base will be of great use for academic studies, government planning, and private geothermal company exploration and evaluation activities. The expected completion date of the map compilation is October 31, 1986, with completion of the data base compilation and a final report of results on December 31, 1986. Compilation of the data will be through individual investigators familiar with particular areas. On the order of 10 to 15 investigators at different institutions will be involved by subcontract. Investigators at Southern Methodist University will be in overall charge of the direction and compilation of the final results.

Table 1

Tentative Work Plan and Budget
U. S. Geothermal Map
May 1, 1985 - October 31, 1986

General Compilation

D. D. Blackwell (1/2 month summer '85; 1 month summer '86)	9,000
J. Steele (45% effort for 18 months)	20,000
Secretary (25% effort for 18 months)	5,500
Travel	5,000
Supplies, Postage & Telephone	2,000
Computer	5,000
	$46,500
Overhead @ 40%	18,000
total	$64,500

NEW K-Ar DATES FROM THE SPRINGERVILLE VOLCANIC FIELD, CENTRAL JEMEZ ZONE, APACHE COUNTY, ARIZONA

A. WILLIAM LAUGHLIN — *Geosciences Division, Los Alamos Scientific Laboratory, Los Alamos, NM 87545*
PAUL E. DAMON, M. SHAFIQULLAH — *Laboratory of Isotope Geochemistry, Department of Geosciences, University of Arizona, Tucson, AZ 85721*

Six new K-Ar dates have been obtained on basaltic flows of the Springerville volcanic field, Apache County, Arizona. Other dates, whole rock chemistry, and $^{87}Sr/^{86}Sr$ ratios from flows in this field, which forms part of the Jemez Zone (Mayo, 1958) have recently been reported by Laughlin et al. (1979). These new dates confirm the age of an intense period of basaltic volcanism in this area between roughly 4 m.y. and 0.8 m.y.

This work was funded by the Division of Geothermal Energy, U.S. Department of Energy, the National Science Foundation Grant EAR-78-11535 to Paul E. Damon and the state of Arizona.

DISCUSSION

For several years the Los Alamos Scientific Laboratory has been investigating the geothermal potential of the central Jemez Zone or Lineament i.e. that portion of the lineament between Grants, New Mexico and Show Low, Arizona. As part of this investigation, the age and duration of the youngest basaltic volcanism are being examined. Prior work (Laughlin et al., 1979) indicated that in the Springerville area an intense period of basaltic volcanism occurred between approximately 3 m.y. and 0.8 m.y. ago. This earlier work indicated that both tholeiitic and alkalic basalts were erupted during this interval and that there was no correlation between age and basalt composition.

Potassium-argon ages have been obtained on six additional flows from the Springerville volcanic field. These ages range from 6.03 m.y. to 0.75 m.y. The new ages and those reported by Laughlin et al. (1979) are located on the index map of the volcanic field. LANDSAT imagery of the area indicates that the older dates (6.03 m.y. to 2.94 m.y.) are from flow lobes related to the White Mountains volcanic activity to the south (Merrill and Pewe, 1977). The two new dates of 0.75 and 0.84 m.y. are for flows from vents penetrating the older mesa capping basalts.

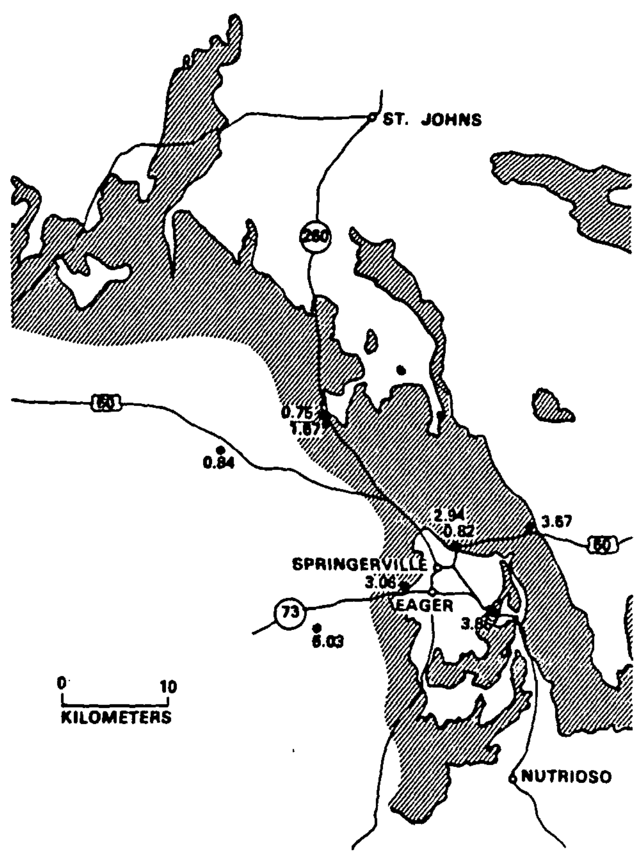
SAMPLE DESCRIPTIONS

1. *AWL-3-77*
   Basalt flow (34°08'N, 109°13'W; road cut along U. S. 60; elevation 1980 m, Apache Co., AZ). Rests on gravel and overlies oxidized top of either an older flow or the lobe of same flow which has been overrun. *Analytical data:* K = 0.596, 0.600, 0.601, 0.602, radiogenic ^{40}Ar = 3.75, 3.84, 3.88 x 10^{-12} m/g, atmospheric ^{40}Ar = 73.8, 73.1, 72.9%.
   (whole rock) 3.67 ± 0.12 m.y.

2. *AWL-4-77*
   Basalt flow lobe (34°14'N, 109°30'W; quarry in cinder cone 8175 S side of U. S. 60; elevation 2347 m; Apache Co., AZ). *Analytical data:* K = 1.194, 1.195, 1.197%, radiogenic ^{40}Ar = 1.55, 1.82, 1.84 x 10^{-12} m/g, atmospheric ^{40}Ar = 91.0, 89.6, 89.5%.
   (whole rock) 0.84 ± 0.07 m.y.

3. *AWL-5-77*
   Basalt flow (34°12'N, 109°19'W; road cut along Highway 260-666 west of Springerville; elevation 2057 m, Apache Co., AZ). Flow caps mesa. *Analytical data:* K = 0.629, 0.624, 0.623, 0.625%, radiogenic ^{40}Ar = 1.77, 1.80, 1.88 x 10^{-12} m/g, atmospheric ^{40}Ar = 83.9, 83.8, 83.0%.
   (whole rock) 1.67 ± 0.09 m.y.

4. *AWL-6-77*
   Basalt flow (34°14'N, 109°23'W; road cut along Highway 260-666; Apache Co., AZ). Overlies flow



LOCATION MAP OF DATED SAMPLES
● 3.86 - AGE (m.y.)

AWL-5-77. *Analytical data:* K = 0.857, 0.856, 0.854, 0.851, 0.851%, radiogenic ^{40}Ar = 1.04, 1.10, 1.18 x 10^{-12} m/g, atmospheric ^{40}Ar = 95.4, 95.1, 94.8%.

(whole rock) 0.75 ± 0.13 m.y.

5. *AWL-7-77*
   Basalt flow (34°03'N, 109°25'W; mesa side above South Fork campground, Apache Co., AZ). Basal flow overlying gravel beds. *Analytical data:* K = 1.124, 1.111%, radiogenic ^{40}Ar = 11.44, 11.95 x 10^{-12} m/g, atmospheric ^{40}Ar = 92.4, 92.1%.

   (whole rock) 6.03 ± 0.43 m.y.

6. *AWL-8-77*
   Basalt flow (34°05'N, 109°14'W; road cut along Highway 260-666 on road to Nutrioso, Apache Co., AZ). Overlies gravels. *Analytical data:* K = 1.326, 1.323%, radiogenic ^{40}Ar = 8.84, 8.91, 8.92 x 10^{-12} m/g, atmospheric ^{40}Ar = 62.9, 62.7, 63.4%.

   (whole rock) 3.87 ± 0.10 m.y.

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