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ENERGY FLUX AND HYDROGEOLOGY
OF THERMAL ANOMALIES
IN THE GULF OF MEXICO BASIN

Progress Report

August 1992 - August 1993

John M. Sharp, Jr.

Department of Geological Sciences

The University of Texas at Austin

Austin, Texas 78712

September 1993

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1. **Project Title:** Energy Flux and Hydrogeology of Thermal Anomalies in the Gulf of Mexico Basin

Duration of Project: June 1992 to July 1995

Period Covered by this Report: June 1992 to August 1993

Principal Investigator: John M. Sharp, Jr.

Organization: The University of Texas at Austin

Address: Department of Geological Sciences (61130)
The University of Texas at Austin
Austin TX 78712-1101

Telephone Numbers: 512/471-3317
512/471-5172 (messages)
512/471-9425 (FAX)

2. **Principal Project Personnel**

John M. Sharp, Jr.

A. **Role in the project:** Principal investigator in charge of field, laboratory, and theoretical aspects of this project.

B. **Principal areas of research and expertise:** Hydrogeology with research expertise in sedimentary basin evolution, heat flow, regional flow systems, fractured rock, and alluvial systems.

C. **Indication of time devoted to the project:** Professor Sharp received 1 month's research funding this summer. During the past two semesters, time spent on this project varied from nothing to 20 hours/week.

D. **Education:**

Ph.D., Geology (hydrogeology), 1974; M.S., Geology (hydrogeology), 1974, both from University of Illinois, Champaign-Urbana. B. Geol. E. (geological engineering), 1967, University of Minnesota.

E. **Employment history:**

Professor (presently Chevron Centennial Professor of Geology), Department of Geological Sciences, The University of Texas at Austin, Austin, Tex., 1982-1993; Professor, Department of Geology, University of Missouri, Columbia, Mo., 1974-1982; Teaching assistant, research assistant, and research fellow, University of Illinois, 1971-1974; Civil engineering officer, U.S. Air Force, 1967-1971; Research consultant, University of Minnesota, 1966-1967.

F. **Professional honors and activities:**

Honors: Chevron Centennial Professor of Geology (1993-on); Gulf Foundation Centennial Professor of Geology (1989-1993); C. E. Yager Professor of Geology (1986-1989); Fellow, Geological Society of America; Alexander von Humboldt Fellow to West Germany (1983); Alexander von Humboldt Fellow to West Germany (1980-81); Geological Society of America's O. E. Meinzer Award (1979) for outstanding contributions to hydro-

geology; Sigma Xi; Phi Kappa Phi; University of Illinois Fellow in Geology; Distinguished graduate of: U.S. Air Force Officer Training School, U.S. Air Force Base Civil Engineer School, and U.S. Navy Fallout Shelter Analysis School; Alpha Delta Phi Literary Award; Tau Beta Pi; W. H. Ziegler Company Scholarship (2 years); University of Minnesota Freshman Scholarship

Current Professional Activities: Geological Society of America: Long-Range Planning Committee, 1993; Nominating Committee, 1992-1993; Council (Audit Committee, 1991-93; Executive Committee, 1992-93); Nominating Committee, Hydrogeology Division, 1993. American Institute of Hydrology: Chairman, Board of Registration, 1991-on; Program Committee, 1994 annual meeting, 1992-94. International Association of Hydrogeologists: U.S. National Advisory Board, 1985-92. Other miscellaneous services to profession: Local Committee, 35th U.S. Symposium on Rock Mechanics, 1992-94; Water Resources Advisory Panel, Desert Research Institute, Nevada, 1991-on.

G. Relevant Publications (not emanating from this research grant):

- Sharp, J. M., Jr., and Domenico, P. A., 1976, Energy transport in thick sequences of compacting sediments: *Bull., Geol. Soc. America*, v. 87, no. 3, p. 390-400.
- Sharp, J. M., Jr., 1976, Momentum and energy and energy balance equations for compacting sediments: *Jour. Internat. Assoc. Mathematical Geol.*, v. 8, no. 3, p. 305-322.
- Sharp, J. M., Jr., 1978, Energy and momentum transport model of the Ouachita Basin and its possible impact on the formation of economic mineral deposits: *Econ. Geology*, v. 73, no. 6, p. 1057-1068.
- Sharp, J. M., Jr., 1983, Permeability controls on aquathermal pressuring: *Am. Assoc. Petrol. Geologists Bull.*, v. 67, no. 11, p. 2057-2061.
- Blanchard, P. E., and Sharp, J. M., Jr., 1985, Possible free convection in thick Gulf Coast sandstone sequences: *in* *Trans., S.W. Section, Am. Assoc. Petrol. Geologists* (McNulty, C. L., and McPherson, J. G., eds.), Fort Worth Geol. Soc., p. 6-12.
- Bodner, D. P., Blanchard, P. E., and Sharp, J. M., Jr., 1985, Variations in Gulf Coast heat flow created by ground-water flow: *Trans., Gulf Coast Assoc. Geol. Societies*, v. 35, p. 19-27.
- Muehlberger, W. R., Galloway, W. E., Land, L. S., Sharp, J. M., Jr., Sawyer, D. S., and Light, M. P. R., 1987, Deep crustal drilling, Texas Gulf Coast, United States of America: *in* *Deep Drilling in Crystalline Bedrock* (Boden and Eriksson, eds.), v. 2, Springer-Verlag, Berlin, p. 155-171.
- Bodner, D. P., and Sharp, J. M., Jr., 1988, Heat flow in the South Texas subsurface: *Am. Assoc. Petrol. Geologists Bull.*, v. 72, p. 21-32.
- Sharp, J. M., Jr., and Kyle, J. R., 1988, The role of ground-water processes in the formation of ore deposits: *in* *Hydrogeology* (Back, W., Rosenshein, J. S., and Seaber, P. R., eds.), *The Geology of North America*, Geol. Soc. America, Boulder, Col., v. 0-2, Ch. 47, p. 461-483.
- Sharp, J. M., Jr., Galloway, W. E., Land, L. S., McBride, E. F., Blanchard, P. E., Bodner, D. P., Dutton, S. P., Farr, M. R., Gold, P. B., Jackson, T. J., Lundegard, P. D., Macpherson, G. L., and Milliken, K. L., 1988, Diagenetic Processes in Northwest Gulf of Mexico Sediments: Ch. 1 *in* *Diagenesis, II* (Chilingarian, G. V., and Wolk, K. H., eds.), Elsevier Science Publ., p. 43-113.
- Pfeiffer, D. S., and Sharp, 1989, Subsurface temperature distributions in South Texas: *Trans., Gulf Coast Assoc. Geol. Societies*, v. 39, p. 231-246.
- Sharp, J. M., Jr., and McBride, E. F., 1989, Sedimentary petrology: a guide to paleohydrogeologic analyses, example of sandstones from the northwest Gulf of Mexico: *Jour. Hydrology*, v. 108, p. 367-386.
- Sharp, J. M., Jr., and Germiot, S. J., 1990, Risk assessment and causes of subsidence along the Texas Gulf Coast: *in* (Fairbridge, R. W., Paepe, R., and Jelgersma, S., eds.),

- Greenhouse Effect, Sea Level, and Drought, Kluwer Acad. Publ., Dordrecht, NAO ASI Series, v. 325, p. 395-414.
- Sharp, J. M., Jr., Kreitler, C. E., and Lesser, J., 1991, Ground Water: in The Gulf of Mexico (Salvador, A., ed.), The Geology of North America, Boulder, Colo., v. J., Ch. 17, p. 529-543.
- Sharp, J. M., Jr., Raymond, R. H., Germiot, S. J., and Paine, J. G., 1991, Re-evaluation of the causes of subsidence along the Texas Gulf of Mexico coast and some extrapolations of future trends: in (Johnson, A. I., ed.), Land Subsidence, Internat. Assoc. Hydrological Sciences Publ. 200, p. 397-406.

Thomas E. McKenna

- A. Role in the project: Acquiring rock samples, measuring thermal properties and analyzing the results, acquiring geophysical logs and additional temperature and pressure data, building the geologic cross-section for two-dimensional modeling, setting up the geographic information system (GIS), performing the potentiometric surface mapping with the GIS, and performing the bulk of the heat transport modeling.
- B. Principal areas of research and expertise: Quantitative basin analysis and regional hydrogeology.
- C. Indication of time devoted to the project: At least 40 hours per week to the project and currently receiving funding external to DOE.
- D. Education: M.S., Geology, 1987, University of South Carolina; B.S. with High Honors and Distinction in Geology, 1984, Stockton State College, N.J.
- E. Employment history:
 Research and teaching assistant, University of Texas at Austin, 1990-present;
 Research Assistant, Texas Bureau of Economic Geology, Summer 1990; Hydrogeologist, Geraghty & Miller, Inc., 1987-1990; and Research and teaching assistant, University of South Carolina, 1985-1987.
- F. Professional honors and activities:
 Student Liaison, Austin Geological Society, 1990-on; Manuscript reviewer - *Groundwater*, *GSA Bull.*, *Jour. Geol. Res.*, 1990-on; Phi Kappa Phi; Geol. Soc. America Hydrogeology Division Outstanding Research Award, 1992.
- G. Relevant publications (not emanating from this research grant):
 Lerche, I., and McKenna, T. E., 1991, Pollen translucency as a thermal maturation indicator: *Jour. Petrol. Geology*, v. 14, no. 1, p. 19-36.

3. Additional Project Personnel

David Hill worked 20 hours/week on this project and part-time this past summer. His contribution was the analysis of basin fluid pressure, documentation of fluid-pressure declines, and the effects of petroleum production over the past five decades. He collected and analyzed well logs in the project area. Mr. Hill received a B.S. in Geology from Texas A&M University in 1976 and worked in the petroleum service industry for nearly 20 years before returning to graduate school. Mr. Hill assisted in the input of our collected data into Arc-Info GIS. He is currently finishing his M.A. thesis.

Merrie Smith is funded this fall as an RA on the project starting this summer. She has been evaluating buoyancy effects on groundwater flow in the South Texas area. Ms. Smith received a B.S. in geology in 1991 from Texas A&I University. Ms. Smith assisted in entering data into our data base and developing our GIS capability.

Carolyn Cooper worked part-time as a laboratory technician until May 1993. She helped prepare core samples for thermal conductivity and heat production analyses. She also ran the bulk density and mercury porosimetry tests. She will obtain her B.S. in Geological Sciences next August.

4. Project Overview

A. Specific project objectives are to:

1. determine whether or not the observed thermal anomalies in the Gulf of Mexico sedimentary basin can be accounted for by heat conduction only;
2. determine whether or not the present-day groundwater flow system is amenable with the heat advection hypothesis; and
3. determine fluid and heat flux histories that are consistent with the observed data.

In support of these objectives, we have collected over 25,000 data points, reflecting pressures and temperatures at depths of up to 16,000 feet in the Texas portion of the Gulf of Mexico basin. These data have been collated into a computerized data base system. In addition, we have begun collection of thermophysical data: over 90 values of radiogenic heat production for Gulf Coast shales have been obtained. These values, when input into computer models, indicate that thermal anomalies observed in earlier studies are not the result of exothermic reactions, but the heat production is significant. Currently underway are the collection of thermal conductivity data on core samples (over 60 samples have been analyzed) and a refinement of pressure/depth profiles in reservoirs as a function of time. We are entering these data into the Arc-Info GIS. Numerical analyses indicate that the above data are critical to understanding the observed thermal pattern. Also, our studies of reservoir depressurization over time are being correlated with observed rates of subsidence and relative sea-level rise. Finally, we are now mapping buoyancy gradients in the basin to test the possibility of free convection.

B. How this project relates to the DOE mission: This research provides fundamental knowledge and understanding to the geosciences and contributes to the sciences and technology base required for current and future energy technologies. Quantifying the evolution of the hydrodynamic and thermal regimes in sedimentary basins is important for predicting timing of hydrocarbon maturation and migration. The evolving subsurface temperature and hydrodynamic system also have a first-order control on sediment diagenesis, brine evolution, and the formation of ore deposits. Thermal rock properties are needed by engineers when developing both thermal methods of petroleum production and geothermal energy. In addition to these contributions to energy exploration and production technology, the fluid potential maps are valuable in evaluating the fate of energy-related waste by-products that are typically injected into the subsurface in this area.

C. How this project relates to other DOE-funded projects: The specifics of other projects are unknown by the PI, except for studies at The University of Texas. In these, Dr. Land of our Department is currently studying the diagenesis of mudrocks. We are using some of his samples for our measurements of radiogenic heat production. Results of our study could provide thermal constraints and quantitative estimates of fluid flux for diagenetic modeling. The feasibility of developing geothermal energy in the South Texas region has been the focus of a long-standing DOE-funded project at the Texas Bureau of Economic Geology and the

Department of Petroleum Engineering at the University of Texas. Thermal rock properties are needed by engineers when developing thermal methods of petroleum production and geothermal energy. Quantifying the regional hydrogeology provides constraints for estimating geothermal reserves. Surprisingly, our data will be the first published values of radiogenic heat production and thermal conductivity in the basin.

D. Project history: This project developed from research conducted by Dr. Sharp and colleagues at The University of Texas at Austin. Previous studies documented unexpectedly high geothermal gradients, geochemical and petrographic for extensive fluid flux in the Gulf of Mexico basin, potential zones of advection and also free convection, and high rates of regional subsidence (see section 2G above).

Previous and current research funding of Dr. Sharp relating to this environment and the issues addressed in the present research are:

Paleohydrogeology of the northern Gulf of Mexico: \$35,000, Amer. Chemical Society, Petrol. Research Fund, Sept. 1983 to Dec. 1987.
Analysis and prediction of regional subsidence trends along the Texas Gulf coastal plain: \$5,000, Univ. of Texas Research Institute, Jan. to June 1986.
Fluid flow and thermal anomalies in the Gulf of Mexico basin: \$37,000, Amer. Chemical Society, Petrol. Research Fund, Sept. 1988 to August 1992.
Fluid and heat flow in sedimentary basins: geologic and hydrologic constraints on a thermal anomaly in South Texas, northern Gulf of Mexico: \$39,855, Amer. Chem. Society, Petrol. Research Fund, Sept. 1992 to Aug. 1994.
Energy flux and hydrogeology of thermal anomalies in the Gulf of Mexico sedimentary basin - South Texas example: \$147,307, U.S. Dept. of Energy, Aug. 1992 to Sept. 1995.

The total funding, since 1983, for research related to the present DOE research is \$264,162, of which DOE funds total \$147,307 through 1995.

5. Scientific and Technical Content

A. Relation of this research to research being conducted by others in the field:

There are numerous other investigators who have published on related research. These include Garven, Bethke, and Harrison, among others, who have constructed theoretical models of basin flow systems. Our work builds upon these by using data and fully integrating heat flux. Hanor and others at LSU have speculated on the feasibility of free convection near salt domes. We are evaluating this on a regional basis. We are not evaluating the Powley and Hunt concept of "seals," but our data and preliminary interpretations conflict with at least portions of their model. Our energy flux calculations will be the first using regional databases and actual data. Studies by Sclater and Nagihara, among others, look at near-surface thermal patterns.

It should be noted that we are in active communication on this project with Drs. Land, Galloway, Milliken, McBride, Cloos, and their students in the Department of Geological Sciences; with Dr. Miller and students in the Department of Petroleum Engineering, Exxon Production Research, Dr. Blackwell at Southern Methodist University, and the Global Basins Research Network (GBRN).

B. Schedule of major research activities:

May - July 1993: Prepare DOE briefing materials and present briefing. Input salinity algorithms into GIS data base. Continue coding of energy transport codes.

July - August 1993: Prepare 6-month DOE report and articles (depressurization and thermophysical data) for publication. Prepare GIS maps of pressure, temperature, and buoyancy. Continue heat production and thermal conductivity measurements.

August 1993 - June 1994: Continue thermophysical measurements; code and run heat conduction and advection models. Seek additional cores, well logs, and data.

June 1994 - August 1995: Simulation of coupled fluid and heat flow; continued input of data into GIS database, and thermophysical measurements; and writing of papers and DOE reports.

C. Scientific and technical issues currently being addressed and their significance:

The prime scientific issues addressed in this research reflect the project objectives (item 4A above). We are studying these issues based upon an extensive data base and newly acquired thermophysical data as the required input to conceptual and numerical models. Specific issues can be restated as:

1. What are the thermal conductivities and radiogenic heat production of Gulf Coast sediments?
2. What is the present-day hydrogeology?
3. How much regional depressurization has been created by petroleum production?
4. What is the propensity for free convection?
5. What causes the observed thermal patterns in Gulf Coast sediments?

D. Experimental and theoretical approaches, other techniques used, and resources applied. The integrated approaches involve laboratory experiments, data collation into an extensive database utilizing GIS capability, and mathematical models of varying complexity.

E. Importance of problems addressed by research. If we are to understand the thermal evolution of a sedimentary basin, we need to know the rock thermophysical parameter, the processes transporting heat, and how they evolve over geological time. Practical considerations include the prediction of rock properties from geological and petrographic data, as well as perhaps an increase in our understanding of the processes of petroleum and ore-deposit formation. There are still strikingly few hard data available to analyze these processes.

6. Project Output

A. Major recent accomplishments with supporting data and their significance. We believe that we are directly on (and ahead of) schedule. First, we have compiled over 22,000 BHP (bottomhole-pressure) data for all counties in the study area (Brooks County was inexplicably missing from our original data set, but was added this summer courtesy of Exxon Production Research). We have also compiled BHP data for selected sites in northwest Texas. These data have been subdivided by decades and they reveal significant depressurization by petroleum production. This makes interpretation of the fluid-pressure field difficult, unless regional and temporal trends are adequately considered.

Our data base now includes over 5500 BHT (bottomhole-temperature) measurements. These data reinforce the validity of the previously inferred thermal anomalies. We note that regional temperatures are highest along and just coastward of the Wilcox Growth Fault Trend. Furthermore, zones of shallow geopressures do not correspond to the thermal anomalies.

We have entered all the subsurface fluid-chemistry data that we have been able to discover into the data base. We have about 100 analyses. Combining fluid salinity, temperature, and (to a lesser degree) pressure, we have calculated thermohaline Rayleigh numbers. Several areas along the coast have major density inversions. This implies a strong tendency for free convection in these (and perhaps other) areas.

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Our measurements of thermal properties indicate that the general range of radiogenic heat production for Gulf Coast shaley sediments is between 0.86 to 1.91 microwatts per cubic meter. We are now collecting data for Gulf Coast sandy sediments and limestone. These data were input into simple analytical models of thermal profiles and indicate that radiogenic heat production is not insignificant. It may affect thermal gradients, particularly in low thermal-conductivity units. Mr. McKenna, one of my Ph.D. students working on this project, has worked for the last 2 months as an intern at Exxon Production. he has located a number of spectral gamma well logs that we plan to integrate into our model of radiogenic heat production.

The thermal-conductivity data indicate values ranging from 2.06 to 3.14 watts per meter per degree Kelvin. The only significant correlation of factors is with the percentage of quartz in the media. Correlations with porosity (the most common relationship used in most models) are present but not strong. Unfortunately, we still lack good thermal-conductivity data for Gulf Coast shales.

The modeling aspects of the project are now taking a greater percentage of our effort. We are developing 1-D models of thermal profiles for the situations shown in Table 1.

Table 1. One-Dimensional Heat Conduction Models

Table 1.

ONE-DIMENSIONAL HEAT CONDUCTION MODELS			
RUN	BASEMENT HEAT FLUX	HEAT SOURCES	THERMAL CONDUCTIVITY
1	Constant	None	Constant
2	Constant	Constant	Constant
3	Constant	Depth dependent	Constant
4	Constant	Constant	Depth dependent
5	Constant	None	Temp. dependent
6	Constant	Constant	Temp. dependent
7	Constant	Depth dependent	Depth dependent
8	Constant	Depth dependent	Temp. dependent
9	Constant	Constant	Fluid dependent
10	Time dependent	Depth dependent	Depth dependent

We have selected BASIN2 as the 2-D (3-D) model to be used in the detailed simulations and are using TEMISPAK for generalized conduction/advection modeling of flow along Gulf Coast fault zones. Preliminary models indicate that thermal-conduction pressures cannot account for the obscured (and reconfirmed) thermal anomalies unless highly unusual thermal conductivities are present.

Our results to date should be considered preliminary, but we have produced the first data on thermal properties of sediments from the (western) Gulf of Mexico Basin. We have demonstrated that in this setting:

1. there is significant reservoir depressurization;
2. there are significant buoyancy gradients that should lead to free convection;
3. the thermal anomalies are real and do not appear to be the result of conductive heat transport alone; and
4. changes (usually increases with depth) in thermal gradients do not correspond to the top of pressure.

B. Bibliography of publications emanating from this project. Three abstracts have been presented to date, and one is in press. Their titles are listed below:

- Hill, D. W., 1993, A theoretical model for subsidence caused by petroleum production: Bill Hill Field, Jefferson County, Texas: Proceedings, A.W.R.A.-A.I.H. Texas Hydrology Roundup, Austin, April 1993.
- Hill, D. W., and Sharp, J. M., Jr., 1993, A theoretical model of subsidence caused by petroleum production: Big Hill Field, Jefferson County, Texas: Geol. Soc. America, Abs. with Programs (South-Central Section), v. 25, p. 14.
- McKenna, T., 1993, Hydrogeology of sedimentary basins: Proceedings, A.W.R.A.-A.I.H. Texas Hydrology Roundup, Austin, April 1993.
- Smith, M. J., and Sharp, J. M., Jr., 1993, Significance of free convection in saline fluid migration, Frio Formation, South Texas: Geol. Soc. America Abs. with Programs (Ann. Mtg.), v. 25, in press.

Papers are now prepared for presentation at the American Association of Petroleum Geologists Award Meeting and the Hedberg Conference.

7. Project Status

The originally proposed research schedule is attached as Table 2.

Determination of core availability

Status: 100% complete. Identified cores from 8 wells and drill cuttings from 5 wells. Petrographic data are available for 90% of the wells. Heat-flow density can be calculated using thermal conductivity measurements on cuttings from one well, along with an available precision temperature log. Proposed and actual timeframe: June 1, 1992, to December 31, 1992. Purpose: Identify cores and cuttings to sample for thermal conductivity and radiogenic heat-production analyses. Summary of work completed: Searched the core inventory of the Texas Bureau of Economic Geology's Core Research Center (TX BEG/CRC) and identified cores from four wells that met our sampling criteria; collaborated with Earl McBride and Leo Lynch in our Department to identify cores from two wells (industry-sponsored research project); collaborated with Dave Blackwell at Southern Methodist University to identify cutting available at the TX BEG/CRC (Blackwell has a precision temperature log from this well; therefore, we can measure thermal conductivity in his lab and calculate the first heat-flow density value for the onshore Texas portion of the Gulf of Mexico basin--this is a very important constraint for our modeling effort); located another source of core (in need) curated by Robert Berg at Texas A&M University. Work proposed over the next six months: none.

Table 2. Research schedule as originally proposed

June 1, 1992 to December 31, 1992

- * Determination of core availability
- * Development of optimum procedures for manipulating large temperature and pressure databases
- * Acquisition of additional temperature and pressure data to fill in and validate database
- * Development of base geologic cross-section

July 1, 1992 to May 31, 1993

- * Performance of quality control check on pressure data
- * Mapping of potentiometric surfaces
- * Coding of heat conduction model
- * Preliminary simulation of heat conduction
- * Collection of cores

January 1, 1993 to May 31, 1994

- * Thermophysical measurements
- * Final simulations of heat conduction

June 1, 1993, to May 31, 1994

- * Writing of paper on heat conduction study
- * Simulations of coupled fluid and heat flow

May 31, 1994 to May 31, 1995

- * Writing of paper on regional hydrogeology
- * Continuation of simulations of coupled fluid and heat flow

January 1, 1994 to May 31, 1995

- * Continuation of simulations of coupled fluid and heat flow
- * Writing of paper on coupled fluid and heat transport

NOTE: Preliminary collection of core data, testing of guarded ring apparatus, and procurement and evaluation of HST-3D are now underway.

Development of optimum procedures for manipulating large temperature and pressure databases

Status: 100% complete. Acquired and installed a geographic information system (ARC/INFO). Proposed and actual timeframe: June 1, 1992, to December 31, 1992. Purpose: Develop tools and procedures to analyze and map out a large database of geographic and subsurface features (temperature and pressure data points, well locations, faults, geology, etc.). GIS technology combines database management with cartographic output, thereby allowing our analyses to incorporate new data as they become available with minimal effort. Summary of work completed: Collaborated with David Maidment in the University of Texas's Civil Engineering Department and Diane Spinney in the TX BEG to evaluate tools and procedures in a pilot project using a small subset of our data; installed and configured the ARC/INFO software on a Department Silicon Graphics substation linked to a digitizer and the INTERNET communications system (many of the private, state, and federal sources of our data use this same system and this makes our results readily available to other researchers). Work proposed over the next six months: none. Work proposed through the end of the project: none.

Acquisition of temperature and pressure data to fill in and validate database

Status: 95% complete. Presently, we have over 25,000 data points of subsurface pressures and temperatures. We are augmenting these with data from the TEX BEG and Petroleum Incorporated. Proposed timeframe: June 1, 1992, to December 31, 1992; actual timeframe: June 1, 1992, to September 30, 1993. Purpose: Augment our current database of temperatures and pressures in areas where data are poor or sparse. Summary of work completed: Collaborated with Charles Kreitler and Saleem Ahkter of the TX BEG to acquire pressure database; searched the Petroleum Incorporated well database for additional pressure data and other well locations; searched the TX BEG well-log repository for additional temperature data; transformed all available data into GIS format for spatial analysis. Work proposed over the next six months: complete filling in database. Work proposed through the end of the project (after six months): none.

Development of geologic cross-section

Status: 80% complete. An interpreted geologic cross-section was acquired from Bill Galloway in our Department (Paleocene to Oligocene). Additional information was compiled to complete the section (Paleozoic basement, Mesozoic, Miocene, and younger). Proposed timeframe: June 1, 1992, to December 31, 1992; actual timeframe: June 1, 1992, to December 31, 1993. Purpose: Augment and high grade our current database of temperatures and pressures. Summary of work completed: Additional data were compiled from TX BEG and the GSA DNAG Gulf of Mexico volume edited by Amos Salvador in our Department; collaborated with Charles Kreitler and Saleem Ahkter of the TX BEG to acquire pressure database; search the Petroleum Incorporated well database for additional pressure data and other well locations; searched the TX BEG well-log repository for additional temperature data; transformed all available data into GIS format for spatial analysis. Work proposed over the next six months: complete geologic cross-section to be used in proposed mapping and modeling efforts. Work proposed through the end of the project (after six months): digitize geologic cross-section for visualization of mapping and modeling results.

Performance of quality control check on pressure data

Status: 80% complete. First pass of high grading data is complete. Pressure-depth plots completed for each county to identify spatial trends. Pressure-depth plots constructed for each county by decade to identify temporal trends (depressurization). Proposed timeframe: July 1, 1992, to May 31, 1993; actual timeframe: July 1, 1992, to December 30, 1993. Purpose: high grade the pressure data set and rank by quality. Summary of work completed: constructed pressure depth plots for all counties (except Brooks) in the area to look at differences in the shapes of the profiles and to screen the data for bogus points; constructed pressure depth plots for all counties (except Brooks) in the area by decade to look for temporal trends (depressurization is obvious and must be accounted for in our analysis); data locations mapped out to locate spurious points that are a part of any large database in its initial stages. Work proposed over the next six months: complete filling in and validating database. Work proposed through the end of the project (after six months): none.

Mapping of potentiometric surfaces

Status: 50% complete. Raw pressure, temperature, and salinity data input into GIS. Pressure-depth plots indicate general trends in fluid pressure. The temperature distribution is well known from our previous studies. Salinities are sparse but are being compiled from several sources. Proposed timeframe: July 1, 1992, to May 31, 1993; actual timeframe: July 1, 1992, to March 31, 1994. Purpose: quantitative description of flow field (potentiometric maps). Summary of work completed: purchased lease maps from GEOMAP to validate well locations; input all data into GIS; determined optimum method within GIS to calculate potentials from spatially distributed temperature, pressure, and salinity data; identified additional sources of salinity data (literature, Lynton Land, TX BEG, and the South Texas and Corpus Christi geological societies). Work proposed over the next six months: integrate the pressure, temperature, and salinity databases within GIS to map potentials. Work proposed through the end of the project (after six months): complete potentiometric maps.

Coding of heat-conduction model

Status: 20% complete. Simple one-dimensional analytical models coded; more complex models being evaluated. We now have access (through EPR) to some models that allow real-time visualization of results. Proposed timeframe: July 1, 1992, to May 31, 1993; actual timeframe: July 1, 1992, to May 31, 1994. Purpose: simple models coded (evaluating more complex models that better represent the real geologic scenario). Summary of work completed: wrote one-dimensional spreadsheet and numerical heat conduction codes; getting up to speed on more complex models that allow real-time visualization of results. Work proposed over the next six months: finish coding simple models. Work proposed through the end of the project (after six months): none.

Preliminary simulation of heat conduction

Status: 60% complete. Some simple one-dimensional analytical models run. Work is ongoing for simple one-dimensional cases. Propose to present results at next year's AAPG or AGU meeting. Proposed timeframe: July 1, 1992, to May 31, 1993; actual timeframe: July 1, 1992, to October 31, 1993. Purpose: evaluate simple one-dimensional heat-conduction models to get a handle on boundary conditions and ranges of thermal properties (sensitivity analyses). Summary of work completed: evaluated simple models of one-dimensional heat conduction with varying heat-flow density, thermal properties, and sediment thick-

nesses. Work proposed over the next six months: finish these preliminary analyses. Work proposed through the end of the project (after six months): none.

Collection of cores

Status: 100% complete. Sampled cores from 8 wells and drill cuttings from 5 wells. Petrographic data are available for 90% of the wells. Proposed and actual timeframe: July 1, 1992, to May 31, 1993. Purpose: sample cores and cuttings for thermal conductivity and radiogenic heat production analyses. Summary of work completed: sampled 4 cores at TX BEG/CRC and 2 from our Department; acquired shale cutting samples from Lynton Land and Kitty Milliken in our Department (DOE-funded mudrock project). Work proposed over the next six months: sample on well to measure thermal conductivity for heat-flow density calculation (not originally proposed). Work proposed through the end of the project: none.

Thermophysical measurements

Status: 100% (160%!) complete. Thermal conductivity was measured on over 100 samples in conjunction with Dave Blackwell at SMU. Radiogenic heat measured on over 75 samples on an alpha scintillation counter installed in our lab. These are the first data for this part of the GOM. Proposed timeframe: January 1, 1993, to May 31, 1994; actual timeframe: January 1, 1993, to June 30, 1993. Purpose: measure the thermal conductivity and radiogenic heat production of typical Gulf of Mexico basin sediments. Summary of work completed: thermal conductivity was measured on over 75 samples on an alpha scintillation counter installed in our lab (these are the first data for the GOM); porosity measured on each thermal conductivity sample in a saturation vessel (methodology validated with mercury porosimeter measurements). Work proposed over the next six months: measure thermal conductivity for about 20 samples from one well for heat-flow density calculation (not originally proposed). Work proposed through the end of the project: none.

Final simulation of heat conduction

Status: 20% complete. Model cross-section is partially completed. Conceptual model derived. Proposed and actual timeframe: January 1, 1993, to May 31, 1994. Purpose: conclude whether the thermal anomaly can be quantitatively described by heat conduction. Work proposed over the next six months: complete building model cross-section; begin more complex modeling effort at this scale. Work proposed through the end of the project: conclude whether the thermal anomaly can be quantitatively described by heat conduction.

Writing of paper on heat conduction study

Status: 0% complete. Summary of work completed: a preliminary paper will be produced detailing simple models and thermophysical measurements.

Simulations of coupled heat and fluid flow

Status: 5% complete. Proposed timeframe: June 1, 1993, to May 31, 1994; actual timeframe: October 1, 1993, to October 31, 1994.

Writing of paper on regional hydrogeology

Status: 0% complete. Proposed and actual timeframe: May 31, 1994, to May 31, 1995.

Continuation of simulation of coupled fluid and heat flow

Status: 0% complete. Proposed and actual timeframe: May 31, 1994, to May 31, 1995.

Writing of paper on couple fluid and heat transport

Status: 0% complete. Proposed and actual timeframe: January 1, 1994, to May 31, 1995.

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