On The Cover

Figure 12 from Mustafa’s technical article on geophysical methods for locating caves

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STGS Lunch Meeting Notice

Date: Wednesday, April 12th, 2017
Time: 11:30 am
Location: Petroleum Club, 7th Floor
8620 N. New Braunfels,
San Antonio, Texas
Speaker: Kitty L. Milliken,
Bureau of Economic Geology
Topic: Mudrocks (shales, mudstones) at the Scale of Grains and Pores: Current Understanding

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The Million Dollar Question: Which Geophysical Methods Locate Caves Best Over the Edwards Aquifer?

A Potpourri of Case Studies from San Antonio and Austin, Texas, USA
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President’s Message

This month I submitted the following text to the GCAGS as the mid-year report on the STGS.

The South Texas Geological Society is currently in good shape. We look forward to hosting the GCAGS/GCSSEPM Annual Convention on November 1-3, 2017 in San Antonio. An excellent Convention Committee, led by General Chair Gene Ames, III and Co-Chair David Clay have planning in place for venue, exhibits, technical program, field trips, short courses, sponsorship, GCAGS Journal/Transactions, entertainment, publicity, luncheon/speaker, spouse activities and more.

The STGS remains committed to both print and online publication of our monthly (September-May) STGS Bulletin. This publication had long been about the largest single item in our budget. This year, in the face of declining advertising revenues, we managed to substantially cut our publication costs and boost the color content through a process of competitive bidding. The STGS Board feels that with the current cost structure the STGS can continue print and online publication for the foreseeable future, and move towards an all-color format. In addition this approach of cost management we have focused on adding value through, 1) the work of our Editor, Joe McGovern, who is amping up the technical content; and 2) focus on delivering value to our advertisers, such as interleaving advertising throughout the Bulletin (rather than the prior practice of confining ads to one advertising section), and projecting a continuous loop of the ad copy during the social and meal portion of our monthly meetings.

Our Scholarship Committee has been quite active, successfully participating in the all-industry ‘Coalition Blowout’ fundraiser last January (thanks to the work of Ken Helm), and awarding Field Camp scholarships and Jones-Amsbury research grants in support of Master’s level thesis work.

We have a local one-day field trip scheduled next month to examine several outcrops of the Austin Chalk and related strata. Of course we continue to hold monthly luncheon meetings (September-April), and our Annual All-Industry Christmas Party at the San Antonio Petroleum Club. We will hold our Annual Dinner Meeting in May at Trinity University, featuring a general interest speaker and the awarding of scholarships and also middle- and high school science fair prizes.

Finally, I’m very happy to report continuing success in recruitment of young members into the Society and onto its Board. Currently five of the nine voting members for the STGS Board are under 35 years of age.

Best regards,

Ted Flanigan
STGS President 2016-2017
Sage Energy Company

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Editor’s Message

It’s that time of year again in which we are nearing the end of another great Volume of the STGS Bulletin. Although I will be glad to have a nice summer break, I’m already thinking about next year’s Volume. One of the more difficult tasks when kicking off a new Volume is deciding what color to use for the cover, so I was hoping to get some feedback from the readers.

Please email your color of choice to: Joe.McGovern@blackbrushenergy.com

As of right now deco pink is in the lead with the most votes.

Looking forward to some feedback.

Joe McGovern
STGS Editor 2016-2017
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- **April Fools Day**

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- **STGS Field Trip**
  - **8:30 AM**
  - Petroleum Club

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SPEAKER:  Kitty L. Milliken, Bureau of Economic Geology

TOPIC:  Mudrocks (shales, mudstones) at the Scale of Grains and Pores: Current Understanding

LOCATION:  San Antonio Petroleum Club, 8620 N. New Braunfels, 7th Floor

TIME:  11:30 AM to 1:00 PM, Wednesday, April 12th, 2017

*Always the second Wednesday of the month*

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Abstract

The fine-grained sediments and rocks that constitute most of the sedimentary record have received tremendous research attention in the past decade. This talk reviews some of the technologies that have supported these advances and summarizes current knowledge of the diagenetic processes that drive the evolution of bulk rock properties of mud in the subsurface. Electron microbeam instrumentation has been central to improving our understanding of fine-grained materials. In particular, improvements in resolution offered by field-emission electron guns and advances in sample preparation by various ion-milling techniques have allowed researchers to see tiny grains and pores in unprecedented detail. Grain assemblages in mudrocks vary across a very broad compositional range and the beginning compositions in muds have significant implications for the evolution of properties relevant to reservoir quality in mudrocks. It is now clear that the principal diagenetic processes of sandstones and limestones, compaction and cementation, also operate in mudrocks. Research efforts to quantify the roles of compaction and cementation are central in the quest to refine a predictive understanding of the evolution of mudrock properties in the subsurface.
Biography

Kitty L. Milliken received a B.A. in geology (1975) from Vanderbilt University and M.A. (1977) and Ph.D. (1985) degrees from the University of Texas at Austin. She is now Senior Research Scientist at the Bureau of Economic Geology. Her research focuses on the diagenesis of siliciclastic sediments and the evolution of rock properties in the subsurface. She has authored and co-authored around 90 peer-reviewed papers, over 100 abstracts, and also digital resources for teaching petrography. She served as Associate Editor of the *Journal of Sedimentary Research* (1993-2000) and as Co-Editor (2004-2008). She was elected a Fellow of the Geological Society of America (2008) and President of SEPM (2014-2015). She has been recognized by the AAPG with the J. Ben Carsey Distinguished Lectureship (2005-2006), the Robert Berg Outstanding Research Award (2015), the Pratt Award (with co-authors) for best paper in the Bulletin (2015), and a distinguished lectureship in 2016-2017. Her current work is focused on the application of electron microbeam imaging and analysis to interpret chemical and mechanical histories of mudrocks (oil and gas shales).

Figure 1. Dolomitic and siliceous Eagle Ford sample.
SPEAKER: Dr. Tim Collett, AAPG Distinguished Lecturer

TOPIC: Integrated Seismic and Well Log Analysis of Gas Hydrate Prospects

LOCATION: San Antonio Petroleum Club, 8620 N. New Braunfels, San Antonio, Texas 78217

TIME: 11:30 AM to 1:00 PM, Tuesday, April 25, 2017

COST: $25.00 for SAGS members with reservations
$30.00 for non-members or without reservations
$10.00 for Student members ($20.00 for first time includes membership)

RESERVATIONS: Please email rsvpsags@gmail.com no later than Noon on Monday, April 24, 2017.

Abstract

This lecture presents the findings of recent international gas hydrate exploration efforts that are using new advanced technologies to identify and characterize the properties of gas hydrate prospects. Case studies from the Alaska North Slope, Gulf of Mexico, Japan and India demonstrate how standard oilfield technologies are helping to identify and evaluate gas hydrate accumulations.

In numerous geophysical studies from around the world, high gas hydrate concentrations have been shown to be associated with increases in host-sediment acoustic velocities. Furthermore, the amplitude of the seismic response to a hydrate-bearing sand reservoir is sensitive to the range of gas hydrate saturations. Geophysical inversion techniques have been developed that use full-waveform prestack inversion processing in combination with conventional linear prestack inversions to produce P-wave and S-wave impedance 3D volumes, which are converted to “gas hydrate saturation cubes.” As a result, seismic-derived maps of gas hydrate saturation can be generated with some degree of confidence in areas with suitable reference data. These types of studies have led to the discovery and characterization of highly concentrated gas hydrates in sand-rich marine reservoirs in the Nankai Trough off the southeastern coast of Japan, the Gulf of Mexico, and in the Krishna-Godavari Basin off the eastern coast of India.

In the last 25 years there have been significant advancements in the use of well logging tools to acquire detailed information on the occurrence of gas hydrate in nature. Whereas wireline electrical resistivity and acoustic logs were formerly used to only identify gas-hydrate occurrences in wells drilled in Arctic permafrost environments, more advanced wireline deployed and logging while drilling (LWD) tools are now routinely used to examine the petrophysical nature of gas-hydrate reservoirs and the distribution and
concentration of gas hydrates within various complex reservoir systems. Advancements in nuclear magnetic resonance (NMR) logging and wireline formation testing has also allowed for the characterization of gas hydrate at the pore scale. Integrated NMR and formation testing studies have yielded valuable insight into how gas hydrate is physically distributed in sediments and the occurrence and nature of pore fluids in gas hydrate-bearing reservoirs. Information on the distribution of gas hydrate at the pore scale has provided invaluable insight on the mechanisms controlling the formation and occurrence of gas hydrate in nature along with data on gas hydrate reservoir properties (i.e., porosities and permeabilities) needed to accurately predict gas production rates for various gas-hydrate production concepts.

Biography

Dr. Tim Collett has been a research geologist in the U.S. Geological Survey (USGS) since 1983. Tim is the Project Chief of the Energy Resources Program funded gas hydrate research efforts in the USGS. He has received the Department of the Interior Meritorious Service Award and the Golomb-Chilinger Medal from the Russian Academy of Natural Sciences and the Natural Resources of Canada Public Service Award. Tim has been the Chief and Co-Chief Scientist of numerous domestic and international gas hydrate scientific and industrial drilling expeditions and programs. He has been the Co-Chief Scientists and Operational Coordinator for the India NGHP Expedition 01 and 02 gas hydrate drilling and testing projects. Tim was a Co-Chief Scientist of the international cooperative gas hydrate research project that was responsible for drilling dedicated gas hydrate production research wells in the Mackenzie Delta of Canada under the Mallik 1998 and 2002 efforts. Tim was the logging scientist on the Gulf of Mexico JIP Gas Hydrate Research Expedition in 2005 and is the Co-Chief Scientist of the Integrated Ocean Drilling Program (IODP) Expedition 311, and the Gulf of Mexico JIP Leg II drilling project in 2009. He sailed as a science advisor on the Korean UBGH2 Expedition in 2010. Tim was also the Principal Investigator responsible for organizing and conducting the 1995 and 2008 USGS National Oil and Gas Assessment of natural gas hydrates. Tim is an Adjunct Professor in the Department of Geophysics at the Colorado School of Mines. Tim’s current research efforts in the USGS deal mostly with domestic and international gas hydrate energy resource characterization studies. His ongoing gas hydrate assessment activities in Alaska are focused on assessing the energy resource potential of gas hydrates on the North Slope and supporting the domestic marine gas hydrate assessments being led by the U.S. Bureau of Ocean Energy Management. Tim’s international gas hydrate activities include cooperative projects with research partners in India, Korea, Japan, China, Taiwan, and Canada. Tim has published more than 200 research papers along with 10 books and treatises on gas hydrates and other unconventional resources.
SPEAKER: Charles Goebel, Banner Resources

TOPIC: Margham Field—Dubai, United Arab Emirates: An Exploration Success Story

LOCATION: San Antonio Petroleum Club, 8620 N. New Braunfels, San Antonio, Texas 78217

TIME: 11:30 AM to 1:00 PM, Thursday, April 20th, 2017

*Always the third Thursday of the month*

COST: Free for paying dues members
$25.00 for guests (Includes Lunch)

RESERVATIONS: Please call Doreen at 210-822-9092 or email doreenbrooner@hotmail.com

ABSTRACT

Margham Field, located in the Emirate of Dubai, lies within the Oman Mountain Fold and Thrust Belt of the North Eastern Arabian Plate. The field was discovered in 1982 by ARCO International Oil & Gas Company as Operator for the East Dubai Onshore Concession Area. An exploratory mindset and new 2-D seismic data were key to locating the discovery well, which tested approximately 50 MMCFGD and 2500 BPD of condensate from Early Cretaceous Thamama Group shelf carbonates. Development drilling quickly demonstrated the limits of the seismic data; a shallow syncline formed by a decollement thrust zone was found to overly the productive anticline, and 40 degree dips were measured within the reservoir in flank wells. Fortunately, the Thamama and Wasia Group sediments were deposited prior to the compressional events, and their relatively consistent and cyclic stratigraphy made it possible to detect faults, fractures, and other important structural phenomena. At discovery, reservoir hydrocarbons were a retrograde gas-condensate, and produced gas was re-injected into the reservoir after liquids were extracted. This process maximized liquid recovery, and over 100 MMBbls of condensate were produced from the field.

BIOGRAPHY

Mr. Goebel has been the Chief Geologist for Banner Resources since 2011. From 2000 through 2011, Mr. Goebel worked and consulted for several companies in the Dallas–Ft. Worth area. In 2001, Mr. Goebel formed Santa Rita Energy, LLC. Activities include prospect generation, participation in development drilling and production (small scale), and consulting. From 1981 to 2000, Mr. Goebel was a Geologist with ARCO International Oil & Gas Co. (Atlantic Richfield Co., now part of BP plc), where he was involved in evaluation, discovery and development worldwide. Specific focus areas were the Middle East and Latin America. Mr. Goebel began his career with in 1980 as Geologist for Humbard & Associates in Midland, TX (Permian Basin). Mr. Goebel received a BS in Geological Sciences from the University of Texas at Austin in 1980. Mr. Goebel is an AAPG (American Association of Petroleum Geologists) Certified Petroleum Geologist, and is a Licensed Professional Geologist in the State of Texas.
STGS NEOGEOS/
AAPG Gulf Coast YP Happy Hour
SPONSORED BY: SOUTH TEXAS GEOLOGICAL SOCIETY
Tuesday, April 18th @ 5:30 PM
FREETAIL BREWING CO. (1604)
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Don’t forget to join STGS at stgs.org

The NeoGeos of South Texas are trying to build membership. We are looking for Young Professionals in the Geology community. This group is intended to provide networking and mentoring opportunities for people new to the geology field. It doesn't matter if you are into oil, environmental, or hydro, we know everyone will have something to contribute. All STGS members are more than welcome to come have fun and share your experiences in the industry. If you or your company would be interested in sponsoring an event please contact: barnett@gulftexenergy.com
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November 1-3

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South Texas Geological Society
Spring 2017 Field Trip

“The Austin Chalk in San Antonio: Tying outcrop to subsurface”

Saturday, April 8, 2017

Depart from the Petroleum Club at 8:30 AM
We will carpool
Trip will finish around 4:30 PM

We will explore the stratigraphy of the Austin Chalk Group in Bexar County from lower to upper contact and integrate geophysical logs to make ties to the subsurface.

Cost: $40 (Students: $20)
(includes lunch and guidebook)

Trip Leader: John Cooper, UTSA

TO REGISTER:
Email Tom Fett, medinalake@msn.com
ENDOWED DISTINGUISHED PROFESSORSHIP IN HYDROGEOLOGY

The University of Texas at San Antonio (UTSA) invites applications from senior scholars in the field of Hydrology to fill a tenured position at the Professor or Associate Professor level, subject to qualifications, to begin Fall 2017. The successful candidate will be awarded the Dr. Weldon W. Hammond, Jr. Endowed Distinguished Professorship in Hydrogeology. Read more about the endowed chair at:


Information on the geoscience program and details on what to include in an application can be viewed at www.utsa.edu/geosci/positions.html. Review of completed applications will begin November 18, 2016 and continue until the position is filled.

STGS “GUIDEBOOKS IN SCHOOLS” PROJECT

Sponsored by Frank Morrill

In 2008, the South Texas Geological Society published the guidebook “Landscapes, Water, and Man: Geology and History in the San Antonio Area of Texas”, written by Tom Ewing and based on earlier versions of his work. Although this guidebook had been sold primarily through the Society’s regular publication sales, it had never been directly distributed to schools in the San Antonio area. Last year, STGS member Frank Morrill recognized that this guidebook would indeed be a great resource for local teachers to use for their Earth science and environmental science classes. So Frank proposed that the STGS embark on a project to deliver complimentary copies to the local high schools, and he very generously provided the funding to cover the cost of those books.
STGS NOMINEES FOR OFFICE 2017-2018

PRESIDENT-ELECT

CANDIDATES: Alex Godet, Tom Fett

Alex Godet

Assistant Professor, The University of Texas at San Antonio
B.S. Earth Sciences, University of Montpellier 2, France
M.S. Sedimentology, University of Lille 1, France
Ph.D. Sciences, University of Neuchâtel, Switzerland

Professional Organizations:
GSA, AGU, STGS, AAPG, IAS

Professional Experience:
Neftex Petroleum Consultants ltd., Abingdon, Oxfordshire, United Kingdom
Postdoctoral fellow, University of Lausanne, Switzerland

Tom Fett

Geological Consultant
B.S. Engineering Science, Trinity University

Professional Organizations:
STGS – Field Trip Chair
AAPG- Emeritus Member
SIPES – Chairman
HGS
CCGS
WTGS

Professional Experience:
Schlumberger Wireline 1966 – 2000
Geological Consultant  2000 - present
VICE PRESIDENT

CANDIDATES: John Cooper, Jose Rodriguez

John Cooper

Graduate Student, University of Texas at San Antonio
B.S. Geology, Texas A&M University, 2015
M.S. Geology, University of Texas at San Antonio, expected 2017

Professional Organizations:
AAPG Student Chapter at UTSA, President, 2015-2017
STGS
GSA

Professional Experience:
AAPG Imperial Barrel Award Competition, Participant
University of Texas at San Antonio, Teaching Assistant
Dawson Geophysical, Geomerge Operator

Jose Rodriguez

Consultant/Owner, JRODS Energy Management, LLC
B.S. Geology, Texas A&M University-College Station

Professional Experience:
Independent/Consulting Geologist
Ricochet Energy Inc., Exploration Geologist
Killam Oil Co., Geologist
Halliburton Energy Services, Wireline Engineer

Professional Organizations:
STGS
AAPG
SECRETARY

CANDIDATES: Mary Hughes, Kathryn Branley

Mary Hughes

Senior Geologist, Lilis Energy
B.S. Geology, Sam Houston State University
M.S. Geology, University of Texas at San Antonio

Professional Organizations:
STGS—Secretary 2016-2017
AAPG

Professional Experience:
Lilis Energy, Senior Geologist
Mid-World Exploration, Consulting Geologist
Apache Corporation, Geologist
Activa Resources, Geologist

Kathryn Branley

Senior Geologist, Portage, Inc.
B. S. Geology, Lamar University
M. S. Geology, Southern Illinois University - Carbondale

Professional Organizations:
IAS
SEPM
STGS
PG – TX and WY

Professional Experience:
Senior Geologist, Portage, Inc. /AGEISS, Inc.
Project Manager/Sr. Geologist, Portage, Inc.
Associate/Sr. Geologist, Booz Allen Hamilton
TREASURER

CANDIDATES: Bradley Arnett, Nick Quante

**Bradley K. Arnett**

Geologist, GulfTex Energy, LLC  
*B.S. Geology, University of North Alabama  
M.S. Geology, University of Texas at San Antonio*

**Professional Organizations:**
STGS—Treasurer, 2016-17, AAPG, HGS

**Professional Experience:**
GulfTex Energy, LLC; Geologist  
UTSA; Geology Teaching Assistant  
Dal-Tile Corporation; Geologist

**Nick Quante**

Graduate Student and Teaching Assistant, University of Texas at San Antonio  
*B.A. Economics, University of Texas at Austin  
M.S. Geology, University of Texas at San Antonio, May 2017*

**Professional Organizations:**
SAGS: Secretary, 2016-2017  
STGS: Active member 2016 - present

**Professional Experience:**
Balcones Energy Library, Geological Technician  
The New Office Inc., Technology Consultant  
Ranger Environmental Services, Environmental Scientist
EDITOR

CANDIDATES: Joe McGovern

Joe McGovern

Geologist, BlackBrush Oil & Gas, L.P.

B.S. Geology, University of Texas at San Antonio
M.S. Geology, University of Texas at San Antonio

Professional Organizations:
STGS - Editor: 2016—2017
AAPG
STGS NeoGeos

Professional Experience:
Geologist, BlackBrush Oil & Gas, L.P., 2011-Current
EXECUTIVE COMMITTEE

CANDIDATES: Bud Holzman, Tim McGovern, John Waugh, Kim Wright

Bud Holzman
Geologist Thunder Exploration
B.A. Geology, Trinity University 1974

Professional Organizations
STGS-Past President 2014-2015
AAPG CPG # 3000
DGS
HGS
Vietnam Helicopter Pilots Association
Combat Helicopter Pilots Association

Professional Experience
Geologist Thunder Exploration-Present
President Geomap Corporation 1992-2000
Geologist Geomap Corporation 1975-1992
Counterintelligence Agent US Army 1994-2008

Tim McGovern
Geological Consultant, McGovern Geological Consulting
B.S. Geology Texas A&M University, 2007

Professional Organizations:
STGS, SAGS, SIPES, AADE, AAPG, SEG, GCAGS

Professional Experience:
McGovern Geological Consulting 2015-Present
JL Resources, LLC 2010-2015
Ameritex Minerals, Ltd 2007-2010
John Waugh
Senior Hydrogeologist
San Antonio Water System
*B.S. Geology, SMU, 1974*
*M.S. Geology, SMU, 1977*

Professional Organizations:
STGS – Former President
AAPG
TGWA – Past-President – GW Science Division

Professional Experience:
Nova Petroleum Corp. – Exploration Geologist
AMR Energy Corp. – Senior Exploration Geologist
Edwards Underground Wtr. District/Edwards Aquifer Authority – Geologist III
San Antonio Water System – Senior Hydrogeologist

Kim Wright
Geologist, KTW Consulting
*B.S. Geology, Ball State University*

Professional Organizations
American Association of Petroleum Geologists
Society of Independent Professional Earth Scientists, #3102
South Texas Geological Society
  STGS Past President 2014-15
  STGS President 2013-14
  STGS President-Elect 2012-13
  STGS Treasurer 2001-02
  Editor STGS Bulletin 1998-2001
  Assistant Editor STGS Bulletin 1997-98
Houston Geological Society
San Antonio Geophysical Society
Gulf Coast Association of Geological Societies
  Comptroller & Audio/Visual Co-Chair for 2004 San Antonio GCAGS

Professional Experience
KTW Consulting 1999 to present
Frontera Exploration Consultants 1995
South Texas Geological Society 2017 Jones-Amsbury Research Grant

The San Antonio based South Texas Geological Society (STGS) offers a financial assistance research grant of $1,000 to graduate students currently enrolled in a Texas university who are pursuing the Masters Degree in Geology or Earth Science. The subject of the research, usually being a thesis undertaken as part of the requirement for earning the Masters Degree, must pertain to some aspect of the geology of south, or south-central Texas.

Each applicant for the research grant must have an estimated completion date of one and one-half years or less from the time of funding. Therefore, the ideal candidate would be completing his/her first year of graduate work at the time of submittal of the application, and would be in a position to finish the proposed research by the spring or fall of the following year.

Application Procedure
Submit the following to the Chairman of the STGS Jones-Amsbury Research Grant Committee no later than April 1, 2017.
1. The one page Application Form for the 2017 Jones-Amsbury Research Grant which is listed on the STGS web site at www.stgs.org
2. A research proposal, limited to three pages in length. The submittal may be a copy of the thesis proposal or other research proposal previously submitted to and approved by academic supervisors. The proposal must clearly state: a) how the research relates to the geology of south Texas, either directly or indirectly, b) research purpose/objectives, c) methods of investigation, and d) projected uses of the research grant funds.
3. A letter of endorsement from the applicant's academic advisor either included with the application and proposal or sent directly by the advisor. The letter should verify the qualifications of the student to conduct the proposed research and the attainability of the one and one-half year time limit to complete the research.

Obligation of Student Candidate and Academic Advisor
In addition to encouraging geological research in south Texas, the STGS also desires to disseminate information to its members. Toward this goal, the STGS requires that all recipients of the Jones-Amsbury Research Grant submit their research upon its completion to the STGS for publication in the Bulletin of the South Texas Geological Society. Being that most completed research will be in the form of a formal thesis presented to the candidate's university, a summary of the research or some other format compatible with publication in the STGS Bulletin will be deemed acceptable for this requirement. At the time of funding, all recipients and the recipient’s academic advisor will sign an acknowledgement of this publication requirement.

All applicants will be notified of the results by May 15, 2017. Funding will be awarded by May 31, 2017.

Return all research proposal material either by mail or email to:

Chairman, Jones-Amsbury Research Grant Committee
South Texas Geological Society
P.O. Box 17805
San Antonio, Texas 78217

Mark E. Thompson
Chairman, Jones-Amsbury Research Grant Committee
oilmanmet@yahoo.com
Instructions For The STGS Field Camp Scholarship

The South Texas Geological Society Scholarship Fund provides scholarships to assist students with the expense to attend a summer geology field camp that is required in the pursuit of a degree in the geological sciences. These Field Camp Scholarship awards are limited to those students that are enrolled at either Trinity University or the University of Texas at San Antonio.

All applicants for the Field Camp Scholarship award should complete the two page Application for STGS 2017 Field Camp Scholarship and return it to the address listed on the application form by the April 1, 2017 deadline date.
Using professional career experiences to strengthen pathways into the geoscience workforce

The Department of Geological Sciences at the University of Texas at San Antonio (UTSA), with support from the National Science Foundation, is commencing a three-year program for geoscience undergraduate students to improve academic and career preparedness and stimulate interest in specific types of geoscience careers. One key component of this program will be a work internship. Specifically, this program will place promising geoscience students in three successive, semester-long internships that begin with an internal academic internship at UTSA, followed by two external placements at private companies or governmental organizations linked to careers in energy resources, geo-environmental assessment, and water resources. We invite your organization’s participation in this initiative.

Organizations who partner with UTSA in this initiative will receive the following benefits:

- Increased staffing to work on priorities of the organization: A gain of 10 hours per week for 28 weeks will result from accepting two student interns per academic year. There is no salary cost because student interns will receive sufficient stipends from the project.
- Preview and train future employees: Interacting with student interns will provide insights into their competencies and in-house training will make them wise investments as future employees.
- Mentor the next generation of geoscientists: Personnel at the organization will reap the rewards and satisfaction of preparing more well-trained geoscientists.
- Influence the education of future geoscientists: Your evaluation of student interns will inform the content and approach of coursework and other opportunities in the geology majors degree program.

Organizations are expected to provide student interns with:

- Realistic and meaningful work experiences: Work tasks should involve knowledge and skill based activities that are of mutual benefit to employers and student interns.
- Opportunities for professional and personal development: Working along side student interns should lead to continued development and reinforcement of the intern’s individual capacities.
- Expanded professional networks: Maximizing introductions to other professionals will help promote the intern’s future success through established personal relationships.

A UTSA faculty member will serve as liaison between the student and employer. Students will enter external internships with the following preparation:

- Geoscience knowledge and analytical skills: Completion of introductory and advanced geoscience courses appropriate for the career trajectory will build their baseline competencies.
- Experience in a work environment: Student interns will have gained experience in a geoscience work place prior to placement, which will involve applying knowledge and skills to accomplish assigned research-related work tasks in a team environment at UTSA.
- Professional development skills: A set of workshops will train student interns in the areas of scientific communication, professional ethics, and work safety.

For more information, contact Dr. Judy Haschenburger
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The Million Dollar Question: Which Geophysical Methods Locate Caves Best Over the Edwards Aquifer? A Potpourri of Case Studies from San Antonio and Austin, Texas, USA

Mustafa Saribudak

Environmental Geophysics Associates
2000 Cullen Avenue, Number 7
Austin, TX, 78757, USA, ega@pdq.net

*First published in the NCKRI Symposium 5, 14th Sinkhole Conference, and reprinted here by the kind permission of the NCKRI, whose permission is required for further use.

Abstract

This article describes resistivity imaging and natural potential data (NP) collected over six caves between the years of 2000 and 2014, which are air filled and are located in the northern part of Bexar County, San Antonio, and in the south and north of Travis County, Austin, Texas. All caves were encountered through drilling and/or excavation for construction and utility lines or power pole reconstructions. The study area falls into the part of the Recharge Zone of the Edwards Aquifer region and it represents a well-developed karstified and faulted limestone (Stein and Ozuna, 1996).

The resistivity and NP data over these 6 caves suggest that the resistivity data does not specifically determine where karstic features are located in the subsurface. However, it provides significant information on the near-surface geology and geological structure. The NP data, on the other hand, notably defines the location of cave features. Thus the merits of integrating the NP method along with the resistivity imaging over the Edwards Aquifer, in order to reduce the ambiguity in the interpretation, are evident.

Introduction

Currently, several geophysical methods exist to locate subsurface voids. These geophysical methods are resistivity (2D and 3D), natural potential (NP), ground penetrating radar (GPR), gravimetry, magnetics, electromagnetics, and seismic (refraction, reflection and shear waves). Natural potential method is also called as self-potential.

Detecting incipient sinkholes, bedrock cavities, rock pinnacles, and other karst-related features using these geophysical methods has been proven over the years (Ahmed and Carpenter, 2003, Dobecki and Church, 2006). But each method has limitations in depth and resolution accuracy based on geological factors and void size, shape, and orientation. In addition, some methods, such as gravity, and seismic, take longer and they may be cost-inhibitive.

We have collected geophysical data over the Edwards Aquifer in the San Antonio and Austin areas for the last 15 years. We have used almost all methods mentioned above. Based on these results, we conclude that the best methods have been the combination of NP and resistivity techniques (Saribudak, M., 2010, Saribudak, 2011, Saribudak et. al., 2012a; Saribudak et. al, 2012b, Saribudak et al, 2013).

The 2D resistivity method images the subsurface by applying a constant current in the ground through two current electrodes and measuring the resulting voltage differences at two potential electrodes some distance away. An apparent resistivity value is the product of the measured resistance and a geometric correction for a given electrode array. The geometric factor incorporates the geometric arrangement of the electrodes and contributes a unit length, giving apparent resistivity values in units of ohm-meters ($\Omega\text{-m}$). Resistivity values are highly affected by several variables, including the presence of water or moisture, and the amount and distribution of poor space in the material, and temperature.
Based on our experience on the Edwards Aquifer, the expected resistivity for weathered limestone varies between 50 to 300 $\Omega$-m, while fresh limestone is expected to produce a range of values between 350–10,000 $\Omega$-m and more. The presence of moisture or groundwater reduces resistivity values. The presence of air-filled caves causes the highest resistivity values. But it is rare that caves are purely filled with air. A variety of sediments accumulates in caves and can be preserved more or less intact for long periods of time (Palmer, 2007). The presence of sand and gravel and clay deposits, mineralization, faults and fractures, perched water in caves are the rules rather than the exception. Clay-filled caves cause low resistivity values.

We acquired the resistivity data using an Advance Geosciences, Inc. (AGI) SuperStingR1 and R8 resistivity systems. We processed the data using AGI’s 2D EarthImager software.

Natural electrical currents occur everywhere in the subsurface. In seepage or cave investigations, we are concerned with the unchanging or slowly varying direct currents (D.C.) that give rise to a surface distribution of natural potentials due to the flow of groundwater within permeable materials. Differences of potential are most common in the millivolts range and can be detected using a pair of non-polarizing copper sulfate electrodes and a sensitive measuring device (i.e. a voltmeter or potentiometer). It should be noted that water movement should be present within or surrounding a cave in order to determine a void or cave location. Positive and negative natural potential (NP) values are attributed to changes in the flow conditions and the resistivity distribution of the subsurface. The source of NP anomalies can be also due to changes in topography, soils and rock conditions. It should be noted that NP measurements made on the surface are the product of electrical current due to groundwater flow and the subsurface resistivity structure. NP anomalies do not provide information on the depth of their sources.

There is no commercially available NP geophysical instrument in the geophysical market. For this reason, we developed a NP system to locate karstic features. We processed the NP data using Geosoft Oasis Montaj Mapping software.

Two Case Studies from San Antonio Area

The location of two caves from the San Antonio area is shown with a red square in Figure 1.

Figure 1. Locations of study area. The red and yellow squares indicate the approximate location of caves in the San Antonio and Austin areas, respectively (The figure is taken from the Edwards Aquifer Authority website, www.edwardsaquifer.net).

Cave 1

A series of voids (cave 1) was encountered during the installations of piers into the Person Formation of Edwards Aquifer limestone (Stein and Ozuna, 1996) for a construction project. These voids had a depth of about 4 meter (15 feet) and appear to be connected. Combination of lowering a tape and a video camera indicated that the cave extended as deep as 50 feet. The cave was wet and air-filled. Following the discovery of the voids, geophysical surveys were conducted to evaluate the extent of the cave and the voids. Geophysical surveys included, resistivity, natural potential and ground penetrating radar methods.

Four resistivity profiles, with a profile spacing of 6 m (20 feet) were acquired across the pier locations and adjacent areas. Figure 2 displays one of the resistivity imaging profiles along with 4 borehole locations, three of which encountered the cave. The resistivity data show that the cave encompasses high resistivity (10000 $\Omega$-m), medium (750 $\Omega$-m) and as well as low resistivity values (200 $\Omega$-m).
Figure 2. Resistivity data across cave 1 along with pier locations drilled into the limestone. Black lines indicate the geometry of the cave.

Four resistivity profiles were combined to create a 3-D block diagram and is shown in Figure 3.

Figure 3. A map view of 3D resistivity block diagram showing the cave geometry. Note that cave location corresponds to low resistivity values (light blue color).

A 3-D top-view of the cave area is shown in Figure 3. The known void locations encountered by borehole drilling are shown with red circles. Three borehole locations that did not encounter the cave are shown with yellow circles. Note that the boundaries of the cave defined by the borehole data include the low and medium resistivity values as in the 2-D resistivity profile. The 3-D image of the resistivity data appear to define the geometry of the cave much better than the 2-D resistivity data.

Figure 4 shows a NP profile along the same resistivity profile shown in Figure 2.

Figure 4. NP data across cave 1 along with pier locations drilled into the limestone.

The NP data indicates a significant low anomaly where the cave is located. Correlation of the both data sets suggest that it would have been difficult to determine the precise location of the cave with only the resistivity data without either having boreholes or the NP data.

Cave 2

Cave 2 was observed along a utility trench in the north of San Antonio (Figures 1 and 5). The trench was about 4 meter (15 feet) deep and 35 meter (112 feet) long. The cave was air-filled and its width along the trench was about 4 meter (15 feet). A measuring tape was lowered into the cave and its apparent depth was determined to be 9 meter (30 feet).

Figure 5. A picture showing the cave location along the trench. The cave is located 3.5 meter below the
Figure 6 displays the resistivity data along the utility trench. The cave’s dimensions are also superimposed on the resistivity data. The resistivity profile indicates medium range resistivity values (300 to 800 Ohm-m), not high resistivity values, across the air-filled cave. The cave’s geometry defined by the resistivity data is quite correlative with the observed dimensions of the cave.

**Figure 6. The resistivity profile along the trench cave.**

The resistivity data also indicate a well-defined high resistivity anomaly between stations 49 and 55 meter (160 and 180 feet), which could be interpreted as an air-filled cave by a novice interpreter based on the resistivity data only.

The NP data provided in Figure 7 shows a significant low NP anomaly across the cave. However, the NP data does not indicate any anomaly over the high resistivity anomaly that was located to the north of the cave.

**Figure 7. The NP data across the Trench cave.**

### Three Case Studies from the Austin Area

Three case studies were performed over the Edwards Aquifer in the Austin area (see Figure 1 for general location). A cave location was determined during the geophysical field work and borehole drilling in the year of 2008. The purpose of the study was to locate potential karstic features along a transmission line, which consisted of 25 transmission poles with 300 meter (1000 feet) spacing.

### Cave 3

A resistivity survey was conducted across the location of transmission number 15, and is shown in Figure 8.

**Figure 8. The resistivity data across a proposed transmission pole location. The black line indicates a borehole drilling location.**

The resistivity values across the profile range between 10 and 10,000 Ohm-m. The resistivity data did not indicate any significant karstic features beneath the proposed transmission pole location.

However, the NP data collected along the same profile shows a high NP anomaly where the proposed pole is located (Figure 9). This is a typical NP anomaly indicating presence of a cave.

**Figure 9. NP data across the proposed transmission pole.**
A borehole was drilled at the proposed location, down to 25 feet depth and a 2.5-inch downhole camera was lowered into it. A cave passage at 5.2 meter (17 feet) depth was encountered and it blew moist air. Another karstic feature (a minor void and a fracture) was observed at 7.2 meter (24 feet) (Pete Sprouse of Zara Environmental, LLC, Pers. Comm., 2010).

In the light of the borehole data, the resistivity data did not show any specific anomaly indicating the potential presence of the cave; however, the NP data did display a unique M-shaped anomaly where the cave is located. The pole location was relocated to 20 feet to the north of the proposed location and did not have voids or caves.

### Caves 4 and 5

The City of Austin (City) Watershed Protection performed a hydrogeologic investigation related to the design and construction of the Martin Hill Transmission Main (TM) on the Northern Edwards Aquifer Recharge Zone. Several karst features have been identified by the City of Austin in the vicinity of the Recharge Zone. These features include a sinkhole/cave opening located behind McNeil High School; the McNeil Bat Cave, located on the east side of the high school; and 3 caves (Weldon Cave, No Rent Cave) located west of the high school and McNeil Bat Cave. To acquire such information and address these concerns multiple geophysical surveys (resistivity, NP, GPR, magnetic and conductivity) were performed across the site (Figure 10). The GPR, magnetic and conductivity data did not provide useful subsurface information due to the presence of cultural features and the conductive soil along the geophysical profile. In this paper only the resistivity and NP results along the McNeil Road profile will be discussed.

![Figure 10. Location of a geophysical profile-a mile long-along the McNeill Road and McNeil High School in north Austin, Texas. Two stars shown with red and white colors (A and B) are locations where significant NP anomalies are observed.](image)

Another combination of resistivity and NP data from the west side of the study area is provided in Figure 11.

![Figure 11. Resistivity and NP data from the west side of the study area. Note that a significant NP anomaly is detected across the creek and is shown with the letter A.](image)

The resistivity data shows a high resistive layer undulating under a low resistive layer along the profile. There is no striking resistivity anomaly due to a karstic feature across the Creek. However, the NP data displays a significant anomaly, in terms horizontal coverage of 60 meter (~200 feet) and a magnitude of 50 mV.

Another combination of resistivity and NP data from the east side of the study area, where the McNeil High School is located, is shown in Figure 12.
Figure 12. Resistivity and NP data from the east side of the study area. The letter B indicates a significant NP anomaly.

The resistivity data shows a high resistive unit (red and yellow in color) in the middle of the profile and it is enclosed by two low resistivity layers below and above. The high resistivity unit appears to thicken to the east of the letter B. This observation would signal a clue to an experienced interpreter that there could be a karstic feature in this area.

The NP data, however, clearly displays a major anomaly between the stations 121 meter (400 feet) and 168 meter (400 and 550 feet), and is annotated with the letter B. The maximum magnitude of this anomaly is about 40 mV.

During the months of summer and fall of 2014, a major construction activity started along the geophysical profile. Bulldozers excavated the water transmission line down to a depth of 6 meter (20 feet) on the McNeill Road. Two caves (Cave 4 and Cave 5) were encountered at a depth of 5 meter (17 feet) where the NP anomalies A and B are located. Picture of Cave 4 and Cave 5 are provided in Figures 13 and 14.

Figure 14. A void was encountered where the NP anomaly B is observed (see Figure 11). This void is enlarged to the north towards the McNeill High School and became a cave (Cave 5).

Cave 6
A cave feature (Cave 6) was confirmed in the sidewalls and floor of a wastewater line (WWL) trench and manhole excavation located on the Northern Edwards Aquifer Recharge located on the Northern Edwards Aquifer Recharge Zone, a few miles to the north of McNeil Road (Figure 15).

Figure 15. Site map showing the location of the geophysical profile, and the geometry of the cave, which was defined by trenching. The length of the geophysical profile is about 122 meter (400 feet).

Figure 13. Cave 4 was observed where the NP anomaly A is observed (see Figure 10).
The cave 6 represents a bedding plane cave that has developed into a groundwater flow channel. The feature lies at approximately 6 meter (20 feet) below ground surface, and has exposed openings along approximately 22 meter (71 feet) of the trench and manhole excavation sidewalls. The visible length of the cave is about 35 meter (115.0 feet) in length, 3.5 meter (12.0 feet) average width, and about 1.5 meter (5 feet) in average height (see Figure 16).

**Figure 16.** A picture showing the part of the cave which was encountered during the excavation.

After the discovery of the cave, geophysical surveys (resistivity and NP) were performed to map the karstic features. The purpose of the work was to define geology along the Wastewater line and map potential karstic features. The length of the profile was extended. 200 feet further north from the northern end of the trench.

The resistivity data is given in Figure 17. The cave locations on the western sidewall of the trench are exposed on the southern and northern ends, and are superimposed on the resistivity profile. A groundwater flow channel is observed from the northern cave to the southern cave. Resistivity values in the vicinity of the caves vary between 50 to 5000 Ohm-m. It is difficult to determine the cave locations based on the resistivity data.

**Figure 17.** Resistivity data along the trenched wastewater line. Locations of caves encountered on the western sidewall of the caves are indicated as dashed red lines filled with white color. There is a groundwater flow from the northern cave to the southern cave.

Note that the high resistive pinnacle shown with a red color between the two caves on the resistivity section, based on the trenching, is not defined as a karstic feature.

The NP data is provided in Figure 18, which indicates a strong but linear NP gradient towards to the north. It is not possible to detect small NP anomalies along the profile with the superimposition of such a high gradient. The source of the high NP gradient could be due to the significant ground water flow from the north to the south.

**Figure 18.** NP data along the trenched wastewater line. Note that there is a strong NP gradient towards to the north.

The majority of the high gradient NP data was clipped out (a sort of regional removal) between stations 76 meter (250 feet) to (121) 400 feet, and the rest of the profile is provided in Figure 19.

**Figure 19.** Residual NP data collected along the wastewater line. Note that there are three NP anomalies (A, B and C) are defined now after taking out the majority of the strong gradient.
The NP data indicates three NP anomalies as shown with letters A, B and C. The locations of these anomalies are correlative with the two cave locations exposed on the side wall of the trench.

The resistivity data did not show the presence of the air-filled caves along the trench; however, the NP data did locate them with a good accuracy.

The trench was completed up to the northern end of the geophysical profile without encountering any void as the NP data predicted.

**Conclusion**

It is clear from the ongoing discussion above that the 2-D resistivity data does not specifically determine where karstic features are located in the subsurface. However, it provides significant information on the near-surface geology and geological structure. In addition, the combination of 2D and 3D resistivity measurements illustrates the subsurface conditions in a sufficiently accurate manner as shown in Cave 1 case study.

The NP data, on the other hand, notably defines the location of karstic features. Thus the merits of integrating NP method along with the resistivity imaging, in order to reduce the ambiguity in the interpretation, are evident. Thus the best methods are chosen to be the natural potential and resistivity techniques over the Edwards Aquifer.

**Acknowledgments**

A research paper like this is a journey from the past, and I am grateful to the many people who helped me along the way. Thanks to Art Lange, my mentor on natural potential method, who has been instrumental for me to understand the NP technique and apply it correctly in the field. I dedicate this paper to him.

Special thanks to Alfred Hawkins, who has been my associate since late 1990s, for his help all those years and sharing the load of the fieldwork with me, and having a good time most of the time.

I would like to thank Nico Hauwert, Sylvia Pope of City of Austin, for providing information on some of the data that is presented in this paper.

I thank to Janet Atkinson City of Austin Water Utility for giving permission to publish the geophysical data on McNeil Road.

Finally, but not the least, I thank Aaron Googins for allowing me to present some of the geophysical data on Cave 6.

**References**


Find the South Texas Geological Society on Facebook
Objectives: The South Texas Geological Society, founded in 1929, is a non-profit organization whose purposes are:

- To advance the science of geology;
- To promote the technology of exploring for, finding and producing raw material from the earth, their conservation and propitious use;
- To foster the spirit of scientific research;
- To disseminate facts relating to geological science;
- To inspire and maintain a high standard of professional conduct on the part of its members; and
- To provide the public with means of recognition of adequately trained and professionally responsible geologists.

Membership: Membership includes individuals who are concerned with the professional application of geological sciences and have been judged qualified by the Board of Directors.

Membership class and related qualifications are detailed in the South Texas Geological Society By-Laws, Article III, and are summarized in the membership requirements section of this application.


Activities: Activities of the Society include monthly meetings from September through May. Guest speakers provide the foundation for the monthly meetings. Business of the Society is also transacted. Speaker topics and meeting location, times, and dates are announced in the Bulletin and by mail and email notices sent to members. Additional activities include short courses, field trips, seminars and social events.

Classes of Membership and Requirements:

Active: Any person engaged in the practice or teaching of geological science may apply for Active membership, provided the applicant holds a degree in geological science from an acceptable college. The degree requirement may be waived by the Board of Directors if the applicant has adequate geological experience.

Associate: Associate members are those not eligible for other classes of membership.

Student: Student members must be enrolled in a college, majoring in geological science.

Corporate: A corporate member may be any corporation or organization whose activities and/or interests, at least in part, concern the science of geology and the advancement of geological study within their industry and community. The member will be awarded two (2) designated representatives, both of which must qualify as Active members established under the By-Laws of the Society and both shall be in the employ of the company. The two (2) designated representatives of the corporation shall be exempt from paying individual dues but will have all rights established for individual Active members under Article III, Section 1A. The corporation shall have no voting rights. Membership eligibility, dues and certain rights and privileges of the corporate members require a majority vote of the Board of Directors.

Honorary: Honorary membership is the highest honor which the Society may confer on a member. Nominees for Honorary membership must be voting members of the Society who have distinguished themselves in their services to the Society and to their profession. They must be sponsored by three (3) voting members in good standing in a written recommendation to the Board of Directors. On approval of such recommendation by the Board, nominees will be presented to the voting membership. Election to this high honor shall be by an affirmative vote of two-thirds (2/3) of the voting members of the Society who cast written ballots. Honorary members are not required to pay dues.

Active and Honorary members comprise the voting membership. Associate and Student members are non-voting.
Instructions to Applicants:

Application for membership admissions, reinstatement, or change in status should be made on this form. It is necessary that all relevant parts of this application be filled out completely so that the Board of Directors may judge the eligibility and adequacy of qualifications. Normal processing time is 45 days. Upon election, the Secretary will notify you of your instatement.

Note: Application for Corporate Membership should be made on the separate Corporate Membership Application Form, which can be obtained from the Society Secretary or the website (www.stgs.org).

Reinstatement: Former members who have allowed their memberships to lapse will be reinstated upon payment of their membership dues for one full year, and upon completion and return of this membership application. The signature of three voting members is not required.

Change in Class: Members who wish to change their membership class should complete and return this application and remit the appropriate dues.

Dues: Payment must be included with application. Dues are not refundable after applicant is approved by the Board of Directors. A dues summary is scheduled below.

Dues Summary: Memberships are annual and dues payments are due June 1st each year.

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Complete all parts of this form, obtain proper sponsors’ signatures, if available, and return with a check to:

South Texas Geological Society
P.O. Box 17805
San Antonio, Texas 78217

I am applying for: □ Admission □ Reinstatement □ Change of Status

Type of Membership: □ Active □ Associate □ Student

The Board of Directors, after reviewing this application, may change your membership application status in order to insure proper membership classification.

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Business Fax: ___________________________ Home Fax: ___________________________

Home Address: ___________________________________________________________

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Preferred Mailing Address: □ Business □ Home

Email Address: ___________________________________________________________

Professional Affiliations: □ Active AAPG □ SIPES □ SAGS

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Record of Experience

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Professional Experience: (If additional space is required use a separate sheet)

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Company’s Address: __________________________
Responsibilities: ________________________________________________________________
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Total years of professional geological experience: _____________

Endorsement:
Applicant is required to try and secure signatures of three voting members of the South Texas Geological Society. Please sign and date your application for membership in the appropriate space at the bottom of this application. If you do not know any current members, please check the box below and forward your application for membership along with the appropriate fees to the address given on this form.

☐ I do not know three (3) voting members of the South Texas Geological Society.

We, the undersigned, judge the applicant to be qualified for the class of membership in the South Texas Geological Society indicated on this application.

Sponsor’s Name (print or type)  Sponsor’s Signature

________________________________________________________________________

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Signature of Applicant: ______________________________________________________

Date of Application: _________________________________________________________