austin geological society

bulletin

volume 7
2010-2011

Cover photograph: During the Spring 2011 field trip to Enchanted Rock Dr. Robert Reed (white hat) reviews the geologic map from the top of the batholith.

note from the president

As president of an organization like the Austin Geological Society there are two key benefits that stand above the rest, first of which are the rich and dynamic interactions with the membership. Over the past two years, I have had the honor of working with some truly gifted geoscientists coming from a range of backgrounds and specialties. This diversity has made the AGS the strong society it is today, all the while continuing to grow to over 175 members this year of which 28% are new to AGS! But, just as importantly are the close relationships I've been fortunate to have with the leadership team. AGS exemplifies dedication and service across all of the committee chairs and officers. The persistence and effort of the volunteers keeps AGS flourishing year after year.

The most important aspect to a successful scientific society is the strength of the technical program. This year was no different. Pat Dickerson handed the reins over to long time contributor and Vice-President Linda McCall. She did a fabulous job coordinating speakers for this year's meetings. Our ethics talk In August was giving by AAPG Past-President Pete Rose to a large crowd at the UT Commons Auditorium. More than 130 people attended making it one of our biggest in recent memory. Guest speakers such as Mustafa Sarabudak (urban geophysics), Glenn Longley (subsurface biota), and AGS's Robert Mace (policy and the Legislature), and a packed March poster session lent to a very diverse slate of presentations that had a little something for everyone at AGS. We were also fortunate this year to have Dr. Carl Sondergeld (SEG distinguished Lecturer) who made a stop in Austin for our December meeting. We hope to build relationships with AAPG and SEG for inclusion of their visiting speaker's program in future years.

In addition to the meeting presentations, Chock Woodruff put together another great fieldtrip program for 2011! Rob Reed and Jim Peterson led a climb up Enchanted Rock on the beautiful March morning. Nearly 45 members listened to the lectures on the geologic origin and cultural history of Enchanted Rock State Park. I believe everyone walked away with a renewed appreciation of one of our Texas true gems. Doug Wierman (Treasurer), James Samson (Membership), and others helped make it a success.

The "Hydrogeologic Atlas of the Hill Country Trinity Aquifer" edited by AGS members Doug Wierman, Alex Broun, and Brian Hunt was released this year to very positive reviews. The effort was partially supported by the AGS and is going to be a lasting legacy of our philanthropy and outreach commitment. John Mikels headed up the educational committee and gave several lectures at K-12 schools, coordinated science fair involvement, and the AGS efforts at Earth Science Week. Thanks team!

Amanda Masterson (BEG), Stephen Ruppel (AGS Publications), and Dennis Trombatore (AGS Historian) continued to develop our print and online publications, which helped generate additional revenue for all of the AGS endeavors. Thanks to Brian Hunt and Eddie Ficker for all the efforts on the Website. The addition of a dynamic calendar and blog site greatly helped to keep the membership informed and up-to-date. Laura Zahm was key in our correspondence with AAPG and Linda McCall did double duty as Finance Chair and is working on our change to a non-profit.

I must also give a big thanks to our officers who tirelessly every meeting to make them a success. Doug Wierman kept giving out reimbursements with just enough suspicion and Katrina Patterson was diligent on producing the monthly newsletter even though everyone else was late delivering the content. Thanks again Doug, Katrina, and Linda, and also Ann for all of the great advice.

I'm excited to see what John Bumgarner and the new officers have planned for 2012. I know that we are in good hands going forward! It's been a true pleasure serving AGS this year and I hope to contribute for many years to come.

All the best,
Dallas Dunlap

austin geological society

mission: The mission of the *Austin Geological Society Bulletin* is to (1) summarize the previous year's activities of the Society and (2) publish technical papers, comments, and notes concerning the natural sciences of Central Texas.

editors: Brian Hunt, Barton Springs/Edwards Aquifer Conservation District
John Mikels, GEOS Consulting
Dennis Trombatore, University of Texas at Austin

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austin geological society

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Linda McCall—Texas Water Development Board
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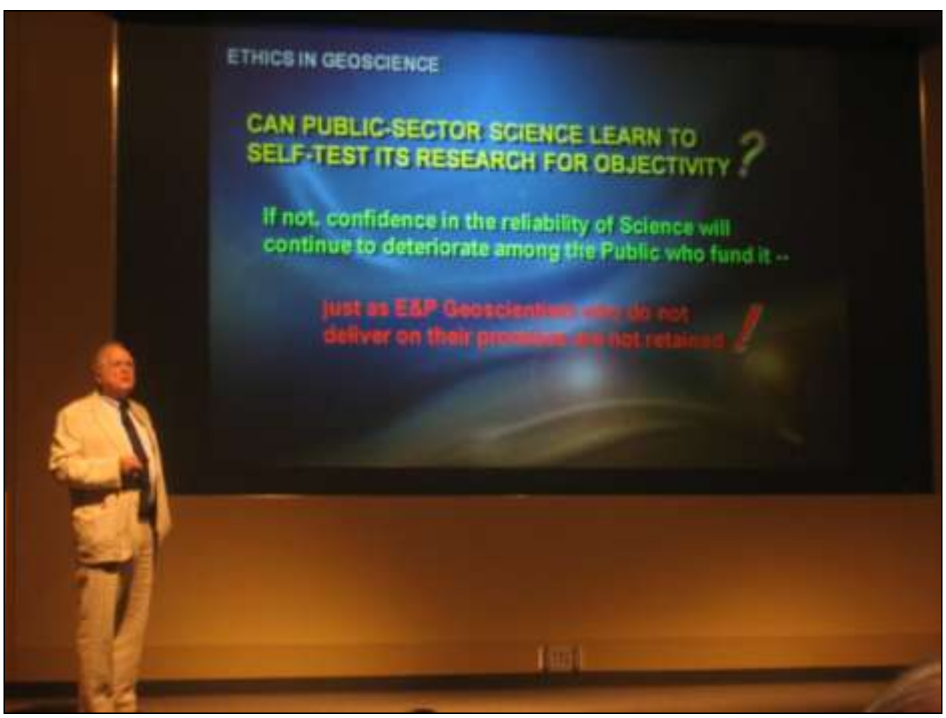
vacant—The University of Texas at Austin
Student Liaison—Undergraduate:
Steve Gohlke —The University of Texas at Austin
vacant—Austin Community College
Website:
Edwards Ficker

news from the society

First AGS Meeting a big success

Our first meeting this year drew over 120 geologists including many new members and students. AGS greatly appreciates UT and the BEG for their continued support of AGS meetings with their facilities.

AGS members register and were treated to pizza and drinks at the Pickle Research Center's Commons.



Dr. Rose addressing a full house at the first AGS meeting of 2010-11.

Distinguished Service Award to Raymond Slade

October 5, 2010

Raymond Slade received the AGS Distinguished Service award for his many years of contributions to the society, including numerous AGS Guidebooks.

Chock Woodruff and Linda McCall present Raymond Slade with the AGS Distinguished Service Award.

AGS helps publish regional study: Hydrogeologic Atlas of the Trinity Hill Country Aquifer

October 4, 2010

A recent publication that AGS partially funded was presented by AGS member, and lead editor, Douglas Wierman.

AGS Education and Outreach

Sept. 2010 – May 2011

AGS members (Sigrid Clift, Linda McCall, Raymond Slade, Dallas Dunlap, Allen Standen, Pat Foster, Aubri Jensen, and John Mikels) shared their time, talents, and experience by presenting at various Earthscience, Education & Outreach events over the 2010-2011 year. These events included:

- Brushy Creek fieldtrip for Pflugerville ISD 4th & 5th grade Science Camp (6/23/10).

- Earthscience Week Career Fair (10/1/10); several presentations on various earthscience & environmental topics was made many students from Austin-area Middle Schools.

- *"Rock Your World"* (aka, rocks & minerals and their use in your everyday world) hands-on presentations were done at: Doss ES (Austin ISD, 1/20/11), Bridge Point ES (Eanes ISD,1/28/11), Eanes ES (Eanes ISD, 3/11/11), Clayton ES (Austin ISD, 3/22/11), El Buen Samaritano Science Festival (Austin, 4/15/11), and Houston ES (Austin ISD, 4/29/11).

- Aquifer Model demonstrations of groundwater recharge, flow, & discharge and effects of groundwater pollution were presented at the Austin Cave Festival (3/5/11) and Fulmore MS (Austin ISD, 4/13/11 & 4/14/11).

- Judging the Earth & Space Science and Environmental Science categories at the annual Austin Regional Science Festival (2/24/11).

- Science Night, Geoscience Careers presentation (Murchison ES, Pflugerville ISD, 1/20/11).

- Aquifer Model & other hydrogeologic/speleologic exhibits at the Annual Cave Festival (Village of Western Oaks Karst Preserve, 3/5/11).

status report to GCAGS

austin geological society

P.O. Box 1302
Austin, Texas 78767-1302

April 9, 2011

Current Report to the Gulf Coast Association of Geological Societies (GCAGS)

Meetings:
AGS meets once each month September through May at 7PM at the Bureau of Economic Geology (BEG), part of the Jackson School of Geosciences at the University Texas at Austin. The BEG is located on the J.J. Pickle Research Campus. Lunch meetings have been rare during the last few years. Meetings attendance runs about 60-70. Our first meeting this year drew over 120 geologists including many new members and students.
Three meetings have traditional components:

1. August 30th was our ethics meeting and this year Dr. Pete Rose, presented an excellent talk, 'Ethics for Geoscientists'.
2. March is a poster session where professional and students can present their work. This year we had over twenty posters presented from environmental, Energy, to shrapnel grains left in the sands of Omaha Beach. Along with the AGS and guest presenters were the winning presentations from local Science Fair students.
3. Elections are to be held 5/2/2011 at the final meeting of the year. New officers will take over July 15th.

All meetings are posted on the AGS website.
http://www.austingeosoc.org/

Membership:
The AGS membership continues to grow. At the close of last year there were over 190 members, 7 of whom were honorary and 35 (18%) were new members. Big thanks to Jim Sansom who continues to handle the membership roster. Very few are student members but a new undergraduate liaison was nominated with hope of strengthening that relationship. Student membership is now free while Professional membership is $20 per year. We continue to document meeting attendance and provide certificates for Professional Geologist development hours. We have introduced a new digital signup system this past year to reduce the time required to track attendance for the PG certificates of attendance thanks to Sigrid Clift. Sigrid sends a digital report to all members with their attendance and PDH credits.

Publications:
The monthly newsletter is almost entirely dispersed via email with very few members requesting mailed paper copies. Thanks go to Katrina Patterson who produces this vital document with such effectiveness. The Society has published about 28 guide books, originally created for field trips. These are available from the BEG or the UT libraries digital resources where the guides are now out-of-print. Steve Ruppel continues to monitor sales and stock of these publications and we appreciate his work. We reprinted 4 commonly requested guidebooks ahead on the San Antonio GCAGS meeting and 4 more currently being reprinted ahead of next Fall. Volumes 5 of our Bulletin was published this past Fall and Volume 6 compiled by Robert Mace and Brian Hunt will be distributed this Spring.

http://www.austingeosoc.org/publications.html
http://www.lib.utexas.edu/books/landscapes/miscellaneous1.php

Scholarships:
Two new undergraduate scholarships ($500) were presented in the May meeting along with the AGS distinguished service awards presented to Chock Woodruff and Raymond Slade for there herculean efforts to produce consistently amazing field trips. We are currently taking nominations from the University of Texas for undergraduate scholarships this May

Sponsorship:
AGS joined with several other groups to sponsor ($3000 from AGS) the publication of a much needed Hydrologic Atlas of the Hill Country Trinity Aquifer, by editors Al Broun, Brian Hunt, and Doug Wierman. Expanded development into the Hill Country is stressing ground water supplies, this past summer has seen many reports of dry wells and it is imperative that we publish what is known about the aquifer systems in this area. We are excited to be able to help this project. The project was completed with the Atlas being donated to many libraries and resources, including the AGS. This book with countless multipage illustrations and plates was revealed to AGS on October 4th to very positive reviews. AGS is a sponsor of the University of Texas Earth Science week which brings schools students together on campus to promote the Earth sciences. Many Members also contribute greatly to the award winning "GeoForce" program to expose disadvantaged, but talented students to the Geological Sciences in a highly competitive environment. The AGS will sponsor a 3D Photo exhibit Lechuguilla Cave (NM) on loan from the Witte Museum in San Antonio in 2012 at the University of Texas Pari-Castinilla Library.

Education:
AGS continues to help educators with their geological curriculum requests. John Mikels spearheads this activity. Many School science fair and elementary school request come in monthly. We have contributed to 7 school fairs and career days this spring alone.

Website:
AGS website continues to develop with the great help of new committee chairman Eddie Ficker. This summer we instituted a new graphical mapping tool that illustrates the locations of past field trips and the local geography/geology. This tool also has links to the BEG Bookstore for online purchasing of guidebooks. More is planned over the next year with online membership renewals and member info.

Tax Exempt Status:
Linda McCall continues to pursue the attempt to gain 5013C status for AGS. We are updating the current State of Texas status at this moment and making the final change of Federal status later this year.

Fieldtrip:
The fall field trip on the "Geology of Enchanted Rock" was to be lead by Dr. Robert Reed and Dr. Chock Woodruff on October 9th. During that field trip the bus experienced mechanical problems and the trip had to be canceled. March 26th was the rerun of that trip with 50 AGS members and guests visiting Enchanted Rock with Geologic field stops along the way.

GCAGS 2012:
AGS is the host for this meeting and much progress has already been achieved. Dallas Dunlap, current AGS President, is serving as the General Chair of this meeting. Scott Tinker is the Chair of GCAGS in 2012. With Allan Standan (Treasurer), Angela Ludolph (Secretary), Lesli Wood (Technical Program) and Tucker Hentz (Editor) the steering Committee is complete. Plans for the meeting are developing and Dallas Dunlap will present more details in his General Chairman Report.

Respectfully,

Dallas B. Dunlap
AGS President 2010-2011

about the technical content

The technical content in the Bulletin consists of abstracts or extended abstracts for presentations, summaries of the field trips, technical papers, and notes.

presentation

The Austin Geological Society hosts technical presentations from invited speakers concerning the natural sciences. We publish an abstract in the Society's newsletter and allow for an extended abstract in the Bulletin.

posters

The Austin Geological Society hosts a poster session each spring. Presenters can submit an abstract concerning their poster topic. Local middle and high school students, whose earth science projects were recognized by AGS at the Austin Regional Science Festival, are invited to present their projects at the AGS poster session. Student abstracts are published herein.

field trip

The Austin Geological Society tries to have at least one field trip per year. The summary included here provides an overview of this year's trip. Interested readers are encouraged to purchase the guide book for additional information and details.

technical paper

The Bulletin accepts technical papers for publication provided that the papers meet technical and editorial requirements.

note

The Bulletin also accepts notes, which may be technical or anecdotal.

presentation

august 30, 2010, bureau of economic geology

Ethics in Geoscience: Can Public-sector Science Learn from Proven Private-sector Techniques?

Peter R. Rose, Ph.D., P.G.

The practice of modern, publicly-funded Science faces increasingly apparent problems having to do with 1) bias; 2) failure to address uncertainty; 3) transparency; and 4) objective, diligent peer-review. Funding, career advancement, personal philosophy and arrogance have all been cited as drivers of bias and unethical scientific behavior.

The conduct of modern E&P corporations in assessing and selecting exploration and development projects provides examples that could be employed usefully by scientists working outside the E & P sector. Multidisciplinary teams practice collaborative teamwork, drawing on diversity of knowledge and perspective to develop “group wisdom” as it applies to uncertain projects. They routinely employ T. C. Chamberlin’s principle of Multiple Working Hypotheses. They routinely assess the ranges of uncertainty that attend key variables. They routinely estimate the probabilities that critical subsurface geological attributes are present around plays and prospects. They routinely assess the cost-effectiveness of additional data acquisition that might reduce the risks associated with premature drilling.

Before wells are drilled, they utilize stringent methods of peer-review in pro-active exercises designed to identify and eliminate bias. After wells are drilled, they routinely measure their accuracy in predicting the presence and magnitude of geologic attributes, through rigorous post-audits of completed projects. Most successful E & P corporations can show steady improvement in their ability to make objective predictions of key geologic parameters.

Development of such methodologies in corporations stemmed from concerns about wasting money provided by private investors. Perhaps the adoption of equally stringent measures by public-sector scientists might help restore confidence among those who ultimately provide the funding for public-sector science.

Urban Geophysics: A Mapping of Mount Bonnell Fault and its Karstic Features in Austin, Tx

Mustafa Saribudak

Environmental Geophysics Associates - Austin, TX

Although most karstic regions are characterized by caves, collapsed features, and sinkholes, such features often do not have surface expressions, and their presence may go unrecorded. Central Texas and the Greater Austin metropolitan area have been built on the karstic limestone (Lower Cretaceous of Glen Rose Formation and Edwards Aquifer) in the Balcones Fault Zone (BFZ), and urban growth is expanding. Near-surface karst features in the Austin area have a profound effect upon geotechnical engineering studies, such as structural foundations (residential buildings, shopping malls), utility excavations, tunnels, pavements and cut slopes. Thus the practice of geotechnical engineering is and has been a challenging proposition in the Austin area. Geophysical methods are sporadically used to estimate the locations and parameters of these karst features prior to any of these above-mentioned geotechnical studies. Opinions concerning the effectiveness of these geophysical surveys are mixed, and geophysical techniques are not generally recognized as primary tools in engineering-scale studies. However, remarkable advances in the manufacturing of geophysical instruments over the last ten years have made geophysics a viable tool for geotechnical studies of these karstic features. Data quality has been increased by the advent of continuous data collection. The data are better processed and interpreted by new and improved software packages, which produce improved sub-surface imaging and mapping. Thus integrated geophysical surveys can provide new insight into the near-surface karstic features in the Glen Rose Formation and Edwards Aquifer. I have conducted geophysical surveys (ground penetrating radar [GPR], resistivity imaging, magnetic [G-858], conductivity [EM-31] and natural potential [NP]) at three locations where the Mount Bonnell fault (MBF) is present, along the northern limiting boundary of the BFZ. Results indicate that all methods successfully imaged significant karst anomalies across the known fault locations. Integration of all these anomalies provides a much better understanding of near-surface geology defined by the caves, voids, collapsed materials, sinkholes and the fault itself.

presentation

November 1, 2010, bureau of economic geology

"What might happen water-wise in the next Legislative session?"

Robert Mace, Ph.D., P.G.
Texas Water Development Board

I often get asked "What's the Legislature going to do next session?" And my stock answer is "If I could predict what the Legislature was going to do, I would own a small island in the Caribbean with a large margarita maker." However, there are some tea leaves out there (various legislative reports, hearings, and public statements by legislators), so I will try to read a few of them for you.

First off, there are a lot of other issues out there besides water. Budget, and the expected budget shortfall, comes to mind. Depending how budget cuts manifest themselves, there could be impacts to water and water issues. For example, the Texas Water Development Board has placed some groundwater grant money on the potential cut list. Next, there's redistricting, and redistricting is often controversial and time consuming. Anybody remember the exodus to Ardmore, Oklahoma? I've heard several legislators state publicly that budget and redistricting are already more than enough to keep the Legislature busy. And then there's the possibility of school finance and immigration also being on the docket.

Nonetheless, legislators will almost surely file water bills this session. One reason is that several water agencies, including the Texas Water Development Board and the Texas Commission on Environmental Quality, are currently under review by the Sunset Advisory Commission. The Sunset Advisory Commission, made up of senators, representatives, and members of the public, is charged with reviewing state agencies approximately every 10 years and making recommendations to the Legislature on (1) whether or not an agency deserve to live and (2), if the answer to (1) is "yes", what needs to change in the agency's enabling legislation. If the answer to (1) is "no", the agency rides off into the sunset, never to be seen again (cue mournful country music and the distant yelp of a lone coyote).

At present, the Sunset staff report on the Texas Water Development Board is on the streets. Sunset staff recommendations include (1) continuing to increase the Board's bonding authority, (2) requiring representation of regional water planning groups in decisions on desired future conditions, (3) transferring the petition process on the reasonableness of desired future conditions to the Texas Commission on Environmental Quality, and (4) requiring that the Board monitor the implementation of the state water plan. Because the Board was created through a constitutional amendment, it's not subject to riding off into the sunset, at least not at the hands of the Sunset Commission. The staff report on the Board goes before the Commission in November with a final decision coming in December. Then the recommendations go to the Legislature for consideration. A report on the Texas Commission on Environmental Quality is forthcoming. On the groundwater side, there's a lot of chatter about desired future conditions and potential changes to the process. Besides the aforementioned Sunset staff recommendations, the Texas Water Development Board is considering a policy recommendation related to desired future conditions.

Furthermore, the Texas Water Conservation Association is working on a potential consensus document concerning the desired future conditions process. Other water issues likely to come up during session include water conservation, rainwater harvesting, and environmental flows. All in all there is plenty for the Legislature to focus on outside of water issues, but undoubtedly water will receive some furtive glances. Special sessions, anyone?

presentation

December 6, 2010, bureau of economic geology

"Rumblings from the laboratory: Past, Present, and Future"

Carl H. Sondergeld, PhD.
AAPG/SEG Distinguished Speaker

University of Oklahoma, Norman, OK

The complexity of rocks in nature, and its resultant imprint on rock properties, makes empirical laboratory studies necessary and relevant. Numerous efforts are currently trying to use theoretical models to predict petrophysical and seismic rock properties from microscale images of rocks. However, modeling can only honor the physics of the chosen model; measurements are still needed to define and calibrate this physics. Historically, laboratory measurements have been used to develop an understanding of the physical response of rock and fluid systems under various conditions (frequency, temperature, stress, sample size, etc.). Early work was conducted to develop a better understanding of the correlations between compressional velocities, composition, density, porosity, and pore fluid type; this proved crucial to understanding sonic logs and seismic bright spots. The ability to measure shear and polarized shear velocities significantly expanded the applicability of rock physics to geophysical and engineering problems. Combining P and S-wave data, along with concepts of elasticity, provided the basis for lithology and fluid discrimination. Experimental confirmation of the Biot-Gassmann theory provided rock physics with one of the most important tools for the analysis of prestack seismic data. New directions in rock physics research will extend the application by incorporating petrophysical characterization into our measurement. Concepts of capillarity and wettability are rarely incorporated into seismic modeling; however, both control fluid saturation and distribution. Promising future rock physics research include examination of the effects of pore microstructure on elasticity, examination of velocity behavior at temperatures and pressures equivalent to those found in deep basins, and the effects of CO_2 and time on seismic wave propagation through reservoir rocks. Simultaneous measurements of multiple properties will provide stronger modeling constraints. Application of new measurement and imaging technologies will allow us to extract more information from smaller and smaller samples, including samples from drill cuttings. Our history is rich with examples of how laboratory measurements have lead to innovations in field-scale technologies. This talk will highlight past accomplishments in rock physics, and more importantly, will focus on future directions in rock physics and the promising and critical role of laboratory measurements in the development of new and innovative technologies.

presentation

February 7, 2011, bureau of economic geology

“Anchialine fauna of the Edwards Balcones Fault Zone Edwards Aquifer & Associated Areas, Texas / USA & Mexico”

Glenn Longley, Ph.D

Edwards Aquifer Research and Data Center

Texas State University, San Marcos, Texas

The geologic setting and characteristics of the Edwards Aquifer and associated systems will be discussed so that a better understanding of how such an assemblage of marine relicts can now occur in the aquifer and associated aquifers. In the Cretaceous, the area where many marine relicts occur would have been an extensive, partially/completely submerged karst, similar to that presently found in the Bahamas, Yucatan Peninsula, and on or around many islands in the Caribbean and in other regions where a karst terrain is exposed to marine inundations and/or transgressions. This kind of setting is conducive for the development of anchialine habitats. Explanations for the high taxonomic diversity will be given for the arthropods in the system. Stranding, the phenomenon of marine/brackish water animals being literally “left behind” in caves when marine water recedes and is slowly replaced by freshwater. The organisms slowly adapt to living in limnic habitats. Texas has two distinctly different subterranean amphipod faunas: (a) the deep groundwater fauna consisting primarily of marine relicts and a shallower aquifer fauna of non-marine derived crustaceans and salamanders. Evidence for a Tethyian marine origin of Texas-Mexican crustacean fauna will be provided. A short discussion of the morphological differences present in the amphipods will be discussed in connection with the niche considerations where so many different species are found in the same well location. Species proposed for listing as Endangered will be discussed.

presentation

April, 2011, bureau of economic geology

"Mapping and characterizing Texas' brackish aquifers"

John Meyer, P.G.

Texas Water Development Board

Brackish groundwater (water containing Total Dissolved Solids between 1,000 and 10,000 ppm) constitutes an important source of water supply for desalination in Texas. However, one of the more challenging issues and a potential roadblock to its more widespread use is the lack of detailed information on aquifer sections that contain brackish water. While a 2003 Texas Water Development Board (TWDB) funded study helped lay the foundation for estimating brackish groundwater volumes in the state (almost 2.7 billion acre-feet), the study was by design regional in scope, limited in areal extent, and narrow in its assessment of groundwater quality. To improve on the 2003 study, TWDB requested and received funding from the 81st Texas Legislature in 2009 to implement a program (the Brackish Resources Aquifer Characterization System program or BRACS) to gather more detailed information on the brackish aquifers. The goals of BRACS are to map and characterize the brackish aquifers of the state in greater detail using existing geophysical well logs and available aquifer data, build replicable numerical groundwater flow models to estimate aquifer productivity and performance, and develop parameter screening tools to help assess the viability of brackish groundwater supplies. Initially, as part of a pilot study we are mapping and characterizing a 1,000 to 1,500-foot-thick clastic aquifer in West Texas - the Pecos Valley Aquifer. One or two additional smaller secondary projects may be added to the pilot study. Eventually, depending on the availability of data, we plan to map all the other aquifers in the state (9 major aquifers and 21 minor aquifers). We will prepare a full project report for the pilot study by the end of August 2011.

presentation

May 2, 2011, bureau of economic geology

"CO2 Goes Underground: A Texas Love Story"

Rebecca Smyth, P.G.
Bureau of Economic Geology

This talk will explore the relationship between carbon sequestration and enhanced oil recovery in Texas.

posters

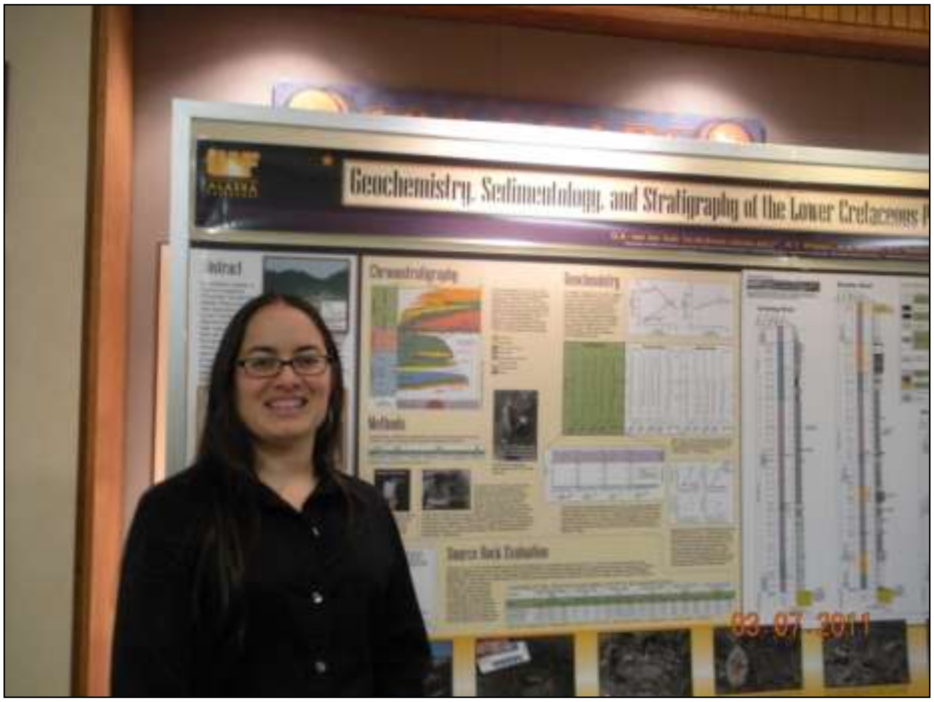
March 7, 2011, bureau of economic geology

The March meeting of the Austin Geological Society was the annual poster session meeting with 13 member posters on display, and an additional 8 student science fair posters. Below are some photos and a list of poster titles and authors.

Connie Wong, Jay Banner, Marylynn Musgrove, and Barbara Mahler	Investigating surface and groundwater mixing dynamics under varying antecedent moisture conditions in a karst aquifer, Central Texas
Eddie Collins, Robert Baumgardner	Draft geologic map of the east part of the Cleburne 30X60 minute quadrangle and related material
Wayne C. Orlowski	Hands-On Experience for Earth Science Teachers at the Outcrop
Earle McBride, M. Dane Picard	Remnants of D-Day, 6 June 1944, Recorded in Omaha Beach Sand, Normandy
Anthony B. Rodriguez	Comparison of the age, structure, and mechanism of the deepwater Mexican Ridges province to other passive margin foldbelts around the Gulf of Mexico
Rebecca Smyth	
Mustafa Saribudak, Nico M. Hauwert, and Alf Hawkins	Geophysical Signature of Main Barton Springs and its Implications on Groundwater Flow Path of the Edwards Aquifer, Austin, TX
Nathan Sheffer	Evaluation of in-situ arsenic remediation with iron using push-pull aquifer tests in the Ogallala aquifer
J. Richard Kyle	Exploration Potential for Pb-dominant Mississippi Valley Type Deposits in Central Texas
Bridget R. Scanlon	Comparison of Irrigated Agriculture in the US High Plains and North China Plain
Linda Ruiz McCall, Katherine K. Ellins, and Bridget Cameron	Water Conservation: A Tool to Build Understanding, Service and Awareness about Natural Resources
D. A. Van der Kolk, M. T. Whalen, M. A. Wartes, and R. J. Newberry	Geochemistry, Sedimentology and Stratigraphy of the Lower Cretaceous….
Brian Smith and Brian Hunt	Hydraulic Interaction between and within the Edwards and Trinity Aquifers: Results from two multiport monitor wells.

Earle McBride discusses his poster: "Remnants of D-Day, 6 June 1944, Recorded in Omaha Beach Sand, Normandy"

Bridget R. Scanlon discusses her poster "Comparison of Irrigated Agriculture in the US High Plains and North China Plain" with Kirk Holland.



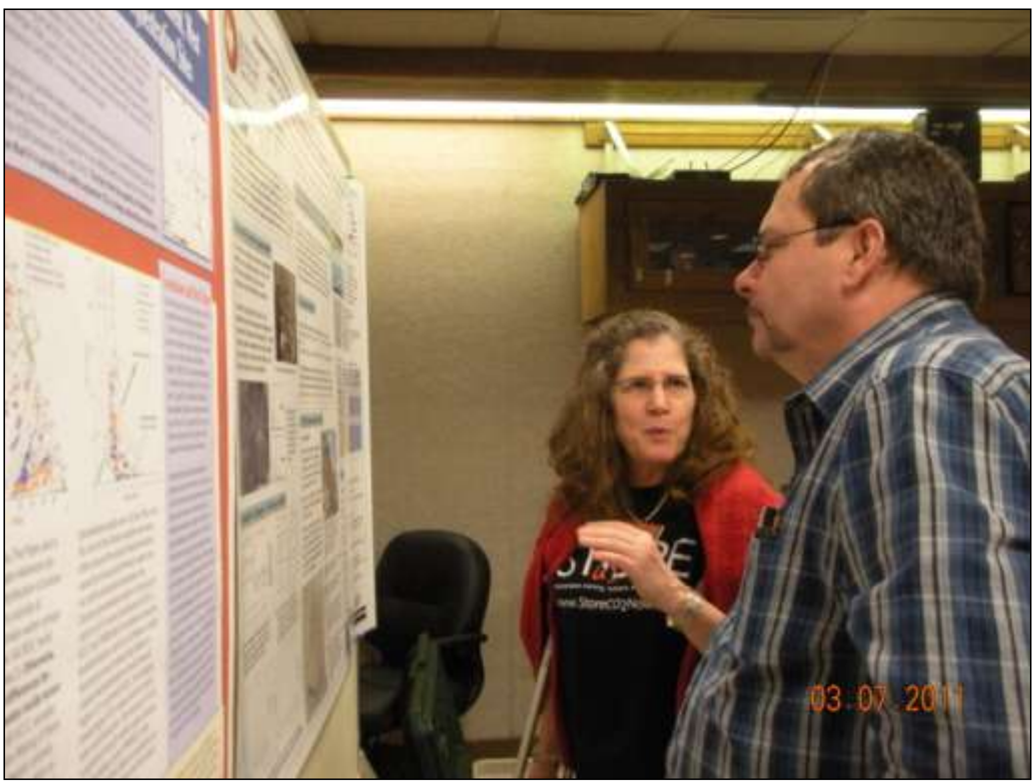
Dolores Van der Kolk presents her poster.

Brian Smith discusses his poster "Hydraulic Interaction between and within the Edwards and Trinity Aquifers: Results from two multiport monitor wells."

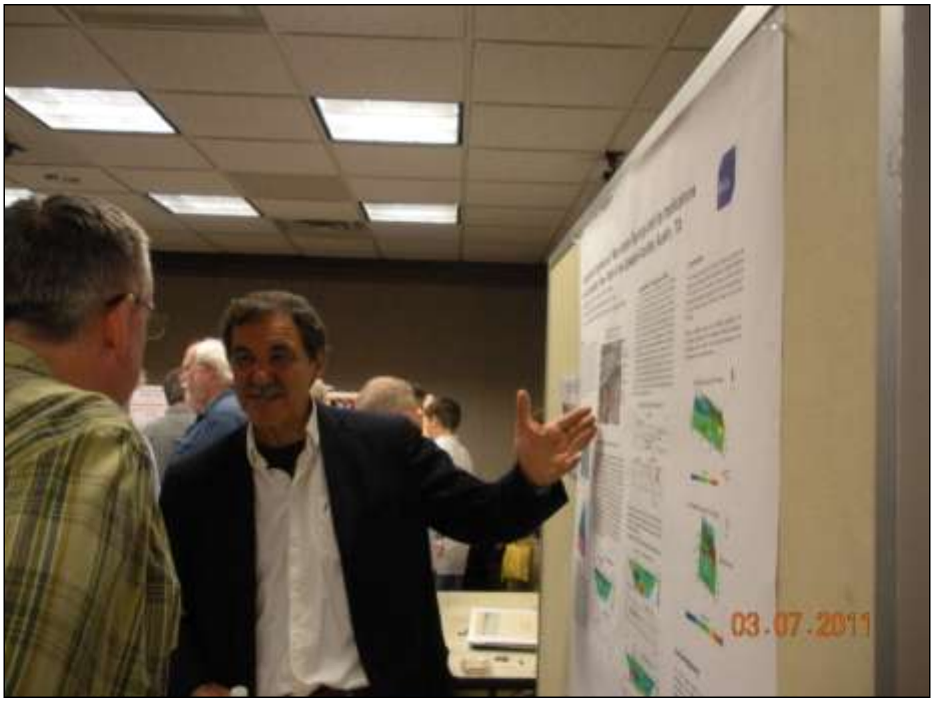
Eddie Collins discusses his poster titled: "Draft geologic map of the east part of the Cleburne 30X60 minute quadrangle and related material" with Robert Reed.

AGS members discuss their posters.

Anthony B. Rodriguez discusses his poster.



Rebecca Smyth discusses her poster.



Mustafa Saribudak discusses his poster.

Student science festival posters

AGS volunteers judged at the annual Regional Science Festival on February 24, 2011. The following students were selected for recognition by AGS for their projects in the Earth & Planetary Science or Environmental Categories:

- Chris Painter, Murchison Middle School, AISD
- Kellen Foyt, Webb Middle School, AISD
- Ryan McBroom, Walsh Middle School, RRISD
- Shane Bentke, Brenham Jr. High, Brenham ISD
- Mychaella Bowen, Austin Jewish Academy MS
- Zach Nunnery, Bowie High, AISD
- Shankar Srinivasan, Harmony SA BCS High School
- Mark Sands & Calvin Ling, LASA, AISD

These students were invited to exhibit their projects at the Annual AGS Poster Session meeting on March 7 and submit their project abstracts for publication in the AGS Bulletin. They were also given a tour of BEG research activities that evening. Submitted abstracts are on the following pages.

Thanks to the following AGS members, and non-AGSers, for volunteering to be the judges: Al Cherepon, Joe Beery, Nathanael Banda, Pat Bobeck, Clover Clemons, Robin Gary, Diane Poteet, Sylvia Pope, Brian Smith, Scott Tiller, & John Mikels.

Robert Traylor discusses a poster of one of the science fair students.

Shane Valentine and Pat Bobeck discuss a poster with one of the science fair students.

How Renewable is College Station's Groundwater?

Shankar Srinivasan
Harmony SA High School, Bryan-College Station

The Earth's surface is about 70.8% water, of which 2% is potable. The potable water is mainly from aquifers. One big problem today is that even though we know that a majority of water is in aquifers, we frequently do not know the actual quality of the water and the way the water flows in and leaves aquifers (naturally or by pumping from wells). This study helps us better understand these uncertainties and even the causes for them. In *How Renewable is College Station's Groundwater,* samples from wells were taken in order to see the purity, amount and isotopic values in the water. In this study, a bailer was used to purge water from a well. Once the well was purged, samples were taken for analyses. Then an YSI 85 probe was used to measure the conductivity, dissolved oxygen, and temperature of the water. Then an electronic water level probe was used to measure the depth to water in the well. The samples were also analyzed with an isotope ratio mass spectrometer. In conclusion the data showed that the water in all the sampled wells had about the same conductivity and dissolved oxygen concentrations; although, the conductivities indicated that the Total Dissolved Solids (TDS) concentrations were too high for public drinking water. On 10/12/10, water levels in well nest “C” were higher than levels in well nests “A” and “B”. However, on 11/13/10 water levels in all of the wells were about the same, indicating the variability in groundwater levels, over space and time. This variability is due to combinations of recharge to and discharge from (including pumping) the aquifers.

Detecting Oil Spills Using Synthetic Aperture Radar

Mark Sands & Calvin Ling
Liberal Arts & Science Academy, Austin ISD

The BP oil spill has attracted much attention from the scientific community, on the development and application of suitable detection and mitigation measures. Following an oil spill, timely and accurate measurement and monitoring of the spill is necessary for effective cleanup strategies. This study investigated the feasibility of detecting the depth and extent of an oil layer on a water surface, using downward-looking synthetic aperture radar (SAR). Laboratory measurements were taken using SAR on a layer of motor oil (which is electrically similar to crude oil) on top of a pool of water. The resulting SAR images show that the air-oil and oil-water interfaces form distinct features in the image. The positions of the features agree with a theoretical simulation of the interfaces. Oil patches of different volumes were then examined, and the thickness of the patches is clearly visible in the resulting SAR images. Next, mixtures of oil and water ranging from 0% oil to 100% oil, in 10% increments, were prepared. These realistically represent the conditions of an actual oil spill, as spilled oil becomes mixed with the underlying water. Measurements of these mixtures show that oil layer thickness can be determined when the mixture contains at least 60% oil.

austin geological society bulletin

field trip

Spring 2011 Field Trip

Geology and Geomorphology of the Enchanted Rock State Natural Area Central Texas.

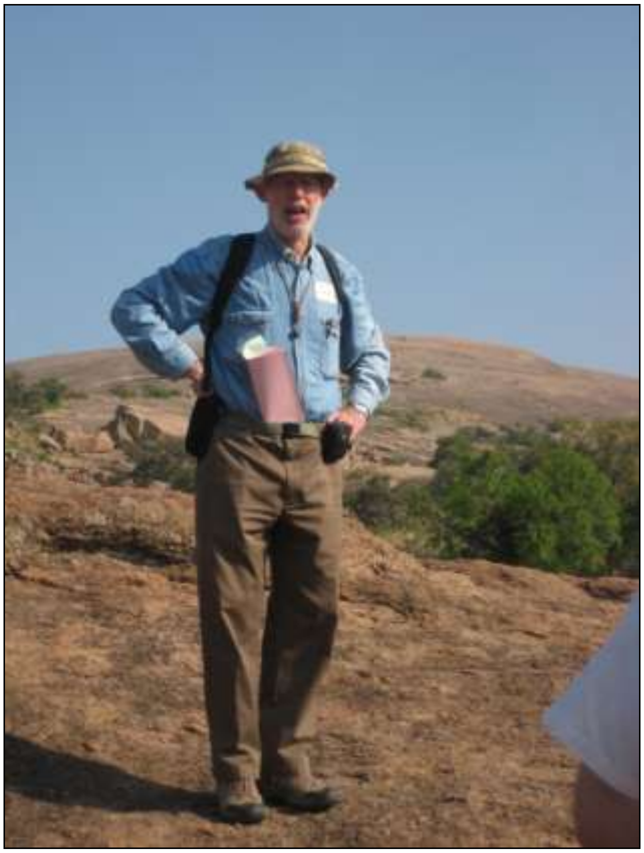
trip coordinators:

Robert Reed and Jim Petersen

The Spring, 2011, AGS field trip was conducted on 26 March, with an excursion to Enchanted Rock State Natural Area (ERSNA). The tour of Enchanted Rock was led by Dr. Rob Reed of the Bureau of Economic Geology and Dr. Jim Petersen of the Geography Department at Texas State University. Rob focused on the emplacement and structural setting of the mass of granite that includes Enchanted Rock, with special attention on the context of ERSNA within the much more extensive Enchanted Rock batholith, with detailed insights on various petrographic features visible in the granite. Jim provided valuable lessons on the landforms and weathering aspects of the rock mass. During the drive to and from Enchanted Rock we discussed the context of this remarkable landform in context of Paleozoic stratigraphy and structure (grabens that result in high-standing “mountains”) and the presence of the high-standing edges of the Edwards Plateau, clearly visible from the summit of Enchanted Rock. Attendees were especially grateful that the bus made it past Dripping Springs, unlike our previous attempt to reach ERSNA back in October 2010. It was a day well spent. AGS Guidebook 32 is available at the Bureau of Economic Geology.

Robert Reed looking at map of the pluton.

Robert Reed and group looking at schlieren.



Chock Woodruff

Pat Dickerson, Rob Reed, and Ann Molineux.

Kenneth and Annette Cride.

Geology of Texas Industrial Minerals

J. Richard Kyle
Department of Geological Sciences and Bureau of Economic Geology,
Jackson School of Geosciences, University of Texas at Austin

Abstract

Texas is an important producer of industrial mineral resources that are used widely by the state's growing population, typically ranking in the top five states in terms of annual production value. These varied resources are used extensively in construction and chemical industries, and their production and consumption rates typically are a direct reflection of the state's economic vitality. The total value of Texas' industrial mineral production reached a peak of $3.4 billion in 2008. More than 90% of current Texas industrial mineral value is from the production of cement, crushed stone, and construction sand and gravel.

Texas produces more crushed stone than any other state with more than 200 quarries; an equal number of operations produce sand and gravel from unconsolidated surface deposits. Cement is the most valuable Texas industrial mineral with current annual production valued at more than $1 billion. Production of industrial chemicals constitutes a smaller component of Texas' industrial mineral production. The salt and lime industries are the most significant, with annual production of each reaching more than $130 million. Zeolites, specialty clays, sodium sulfate, helium, and talc are additional chemical materials produced in the state. Texas has long been the leading sulfur-producing state, but now sulfur is recovered from "sour" crude oil and natural gas refineries.

Industrial mineral production areas typically are those where favorable geologic units occur at or near the surface relatively near population centers and/or favorable transportation networks. These essential mineral resources are products of past geologic events that have affected this portion of the Earth's crust. Mesoproterozoic plate tectonic processes constructed a mountain belt about 1.1 to 1.2 billion years ago. Subsequent uplift resulted in the exposure of these metamorphic rocks and granites in central and west Texas to form sources of dimension stone and talc. Shallow marine environments during the Cambrian-Ordovician, Permian, and Cretaceous periods produced extensive carbonate strata that form the Edwards Plateau and other surface belts of limestone that are essential to crushed stone, cement, and lime production. Extensive Jurassic evaporites, present under the Texas Coastal Plain, have been deformed into salt domes that are sites for salt production.

Surface deposits of Cenozoic age blanket older deposits in much of Texas and provide many valuable industrial mineral resources. Cenozoic strata were deposited by river and coastal processes that distributed gravels, sands, and muds eroded from the Rocky Mountains and the continental interior. Deposition of these thick sedimentary successions extended the Texas shoreline and built the Coastal Plain. These Coastal Plain sediments are sources of common clay for brick and ceramic manufacture. Volcanic ash provided unusual Coastal Plain sediments that were altered to valuable zeolites, bentonites, and other clay deposits. Unconsolidated alluvial deposits of Texas' major river systems are important sources of industrial sand and construction sand and gravel.

Introduction

The varied Earth materials that form the diverse surface formations of Texas provide many valuable industrial rocks and minerals used by modern society. Use of Earth materials by Texas residents started in prehistory, with the use of clay for pottery, flint for projectile points and tools, grinding stones for food production, and many other uses of local rocks and minerals (e.g. www.texasbeyondhistory.net/). European settlers likewise made use of native materials in the construction of dwellings and fortifications, as well as other daily uses.

Today Texas is an important producer of industrial mineral resources, typically ranking in the top five states in terms of annual production value of nonfuel minerals (minerals. usgs.gov/minerals/). These varied resources are used extensively by the state's ever-growing population for the construction and chemical industries, and their production typically reflects the state's economic vitality. Soils and water that are essential to agricultural and forest industries also can be considered in the context of the state's industrial mineral endowment. Industrial mineral consumption typically tracks regional population trends, and thus is affected by the more than doubling of Texas' population in the last 40 years to its current 26 million residents (Fig. 1). Production of industrial minerals slows in response to regional or global economic downturns and escalates in response to economic recovery (Fig. 1).

Industrial mineral consumption is focused on the five major metropolitan areas of the state—Houston, Dallas-Fort Worth, San Antonio, Austin, and El Paso—that comprise more than 17 million residents (txsdc.utsa.edu/). The four most populous cities, as well as a number of smaller metropolitan regions, occur in the eastern third of the state. The interplay between this focused demand and the presence of favorable surface geology capable of supplying these needed materials dominates the pattern of industrial mineral production in Texas (Fig. 2).

Industrial rocks and minerals are produced in essentially all 254 counties in Texas, principally related to local construction and industrial activities. Industrial mineral production provides local employment, and unusual mineral concentrations provide specialty products for regional, national, and international distribution. For low unit value industrial raw materials, near-coastal consumption sites may facilitate bulk oceanic transport of international raw materials, in competition with regional land sources that require truck or train transport that is more expensive per unit. As the principal example, Langer (2002) estimated that 12% of the aggregate supply for the Houston market was imported.

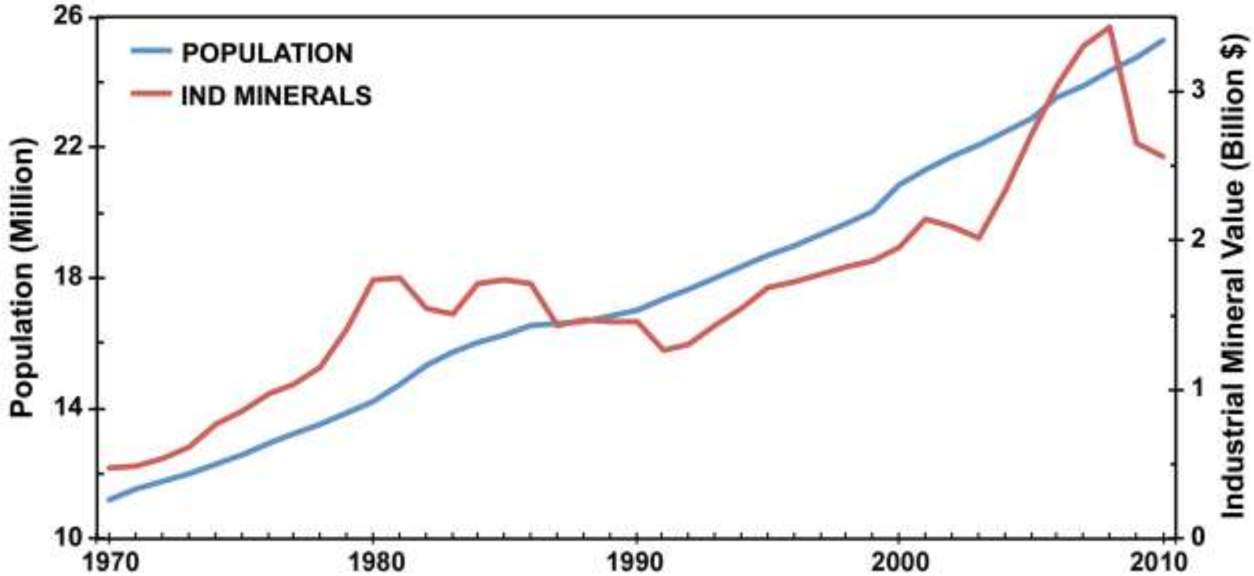


Figure 1. **Growth of Texas population and industrial minerals production from 1970 to 2010. Data compiled from the Texas State Data Center txsdc.utsa.edu/and the U.S. Geological Survey minerals.usgs.gov/minerals/pubs/state/tx.html. Updated from Kyle (2008).**

Texas Construction and Industrial Materials

Crushed stone, sand, and gravel, that are consumed in large quantities by the construction industry, dominate annual state production in terms of tonnage and total value (Fig. 3). Texas produces more crushed stone than any other state with more than 200 quarries typically with a total annual production value approaching $1 billion. An equal number of operations produce sand and gravel from unconsolidated surface deposits (minerals.usgs.gov/minerals/pubs/state/tx.html). Although limestone is the most common crushed stone in Texas (Fig. 4A), unusual aggregates are produced from a Cenozoic granitic laccolith at Sierra Blanca in west Texas and from Cretaceous “trap rock” intrusions in the Uvalde area (Fig. 4B) for railroad bases, pavement coatings, and glass products.

Cement, another vital construction material with limestone and clay serving as the key raw materials, is by far the most valuable industrial mineral product in Texas. Current annual production is valued at more than $1 billion (Fig. 3). Because of its immediate and regional use in the construction industry, cement production is a revealing commodity that tracks the strength of local and regional economies. Texas’ 12 cement plants are mostly associated with the extensive Cretaceous limestones of the Edwards Plateau in central Texas (Fig. 2) that are near major consumption centers and transportation networks. Currently, cement imported from contiguous Mexico supplies the greater El Paso market.

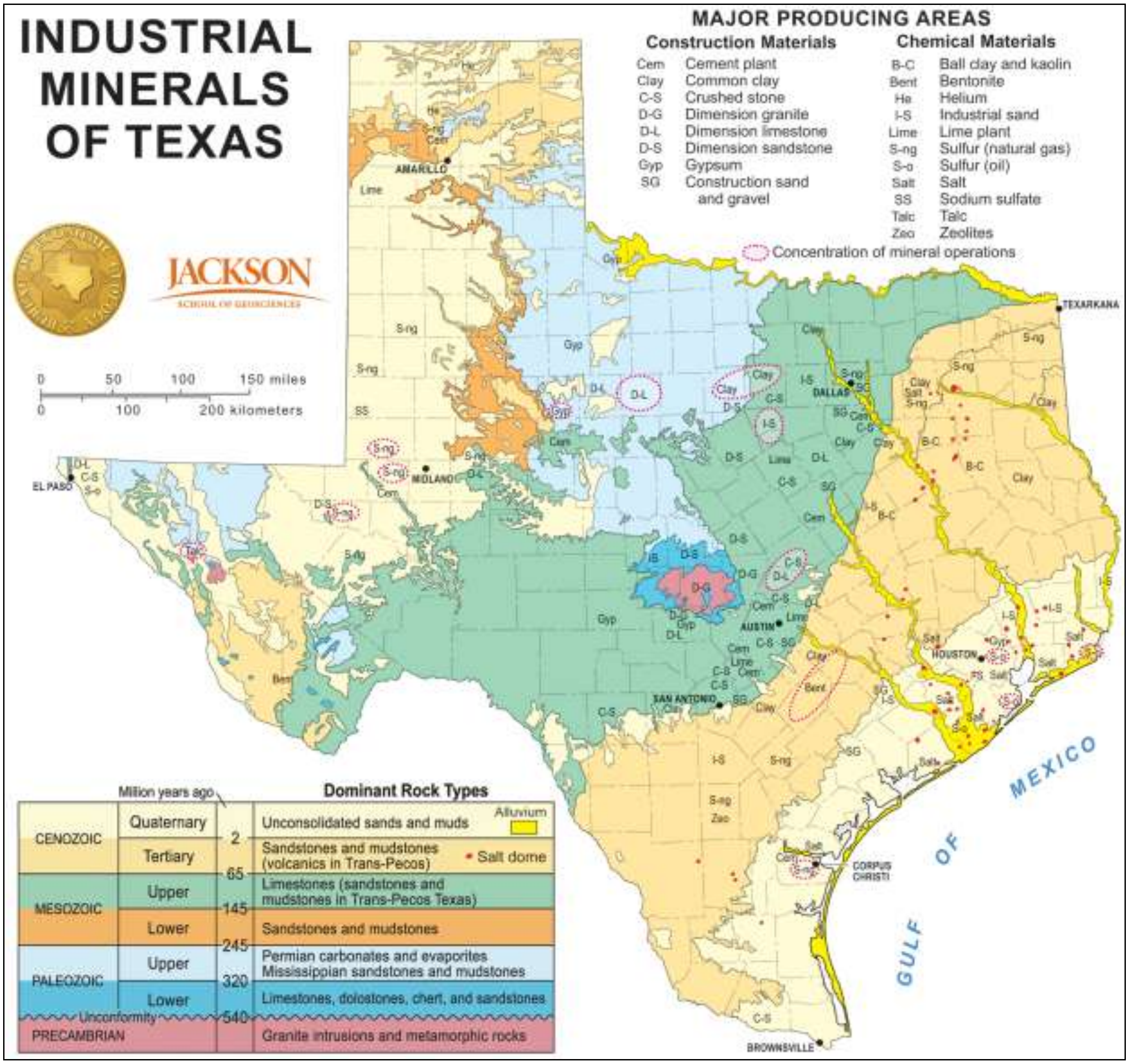


Figure 2. **Generalized geologic map of Texas showing location of major industrial minerals producers. Modified from Kyle (2008).**

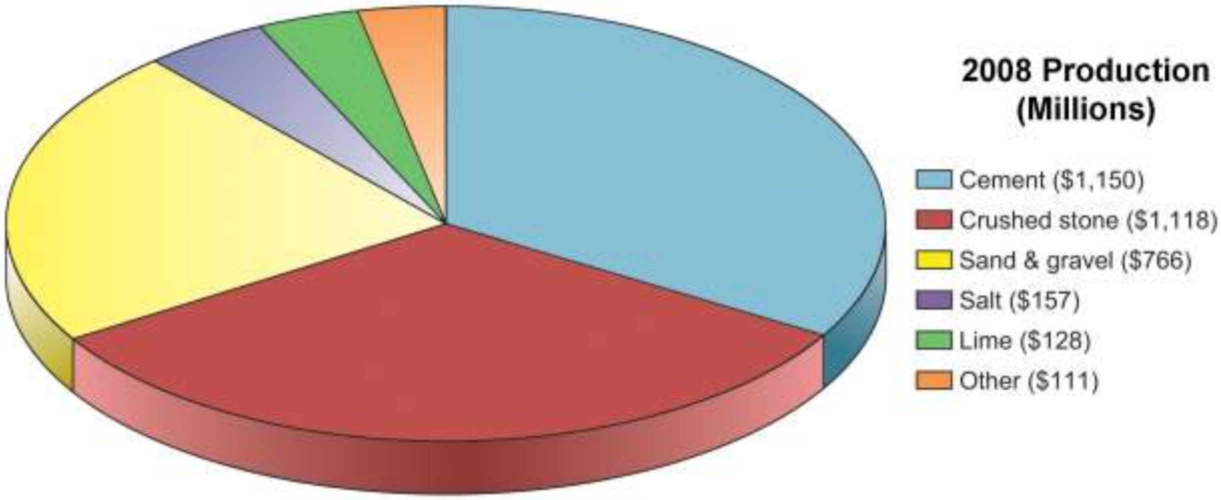


Figure 3. **Value (million $) of Texas industrial minerals production for 2008 totaling $3.4 billion. "Other" includes brucite, clays (ball, bentonite, common, Fuller's earth, kaolinite), dimension stone, natural gemstones, gypsum, helium, talc, and zeolites. Data from the U.S. Geological Survey, minerals.usgs.gov/minerals/pubs/state/tx.html.**

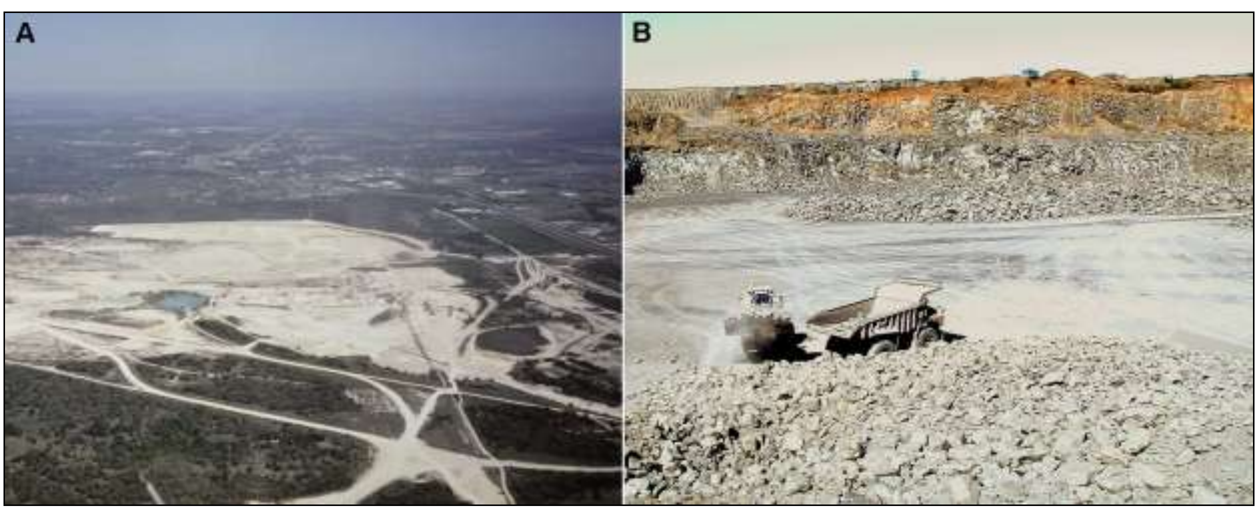


Figure 4. **Texas aggregate quarries. A. Aerial view of the Texas Crushed Stone quarry in Cretaceous limestone at Georgetown, Texas; B. Knippa trap rock quarry in Cretaceous columnar basalt near Uvalde, Texas.**

Gypsum is used mainly in plaster and wallboard in building interiors, as well as in cement manufacture. Most commercial Texas production is from Permian evaporitic strata of north-central Texas (Fig. 2); extensive Permian gypsum deposits of the Delaware Basin in west Texas are not produced at present. Cretaceous gypsum deposits on the Edwards Plateau are used primarily in the local cement industry. Synthetic gypsum is produced from flue gas desulfurization for air quality reasons and represents an increasing competitor for natural gypsum in a variety of uses. Clays of various types largely in the Coastal Plain (Fig. 2) are used in many products, with common clay consumed in large quantities in the manufacture of bricks and tile.

Several geologic types of dimension stone, mostly for monuments and building exteriors but with growing high-end residential use, are produced in Texas (Fig. 2; Garner, 1992). The largest volume production is the Precambrian granites of the Llano Uplift of central Texas; these attractive stones were used to build the Texas state capitol (Fig. 5A) and numerous other state and county government buildings. Cretaceous grainstone and fossil-moldic limestones are also popular local architectural stones (Fig. 5B), with lesser use of grainstones and red sandstones of other geologic ages (Fig. 2).

Developments in one industry may have interrelated effects in others. A timely example is the recent growth in production of petroleum from “unconventional” reservoirs, particularly the striking expansion of directional drilling and hydraulic fracturing techniques to allow production of natural gas from shale formations. Texas has multiple unconventional petroleum plays, and the production of industrial sands for proppants to keep hydraulic fracture networks open has doubled in the past decade (Fig. 6). One of Texas’ major frac sand-producing areas is near Voca, Texas, where sands are produced from the Cambrian Hickory Sandstone on the northwestern flank of the Llano Uplift. Despite its great age, the Hickory remains friable along the flanks of the Llano Uplift where it was never buried deeply. Because of its poorly cemented nature and the occurrence of well-rounded quartz grains in a variety of sizes appropriate for various proppant applications (Kyle and McBride, 2013), the Hickory in the Voca area has been a source of industrial sand for several decades (Barnes and Schofield, 1964), and production has steadily increased. Production generally is from a near-surface 50- to 65-ft interval in the lower Hickory.

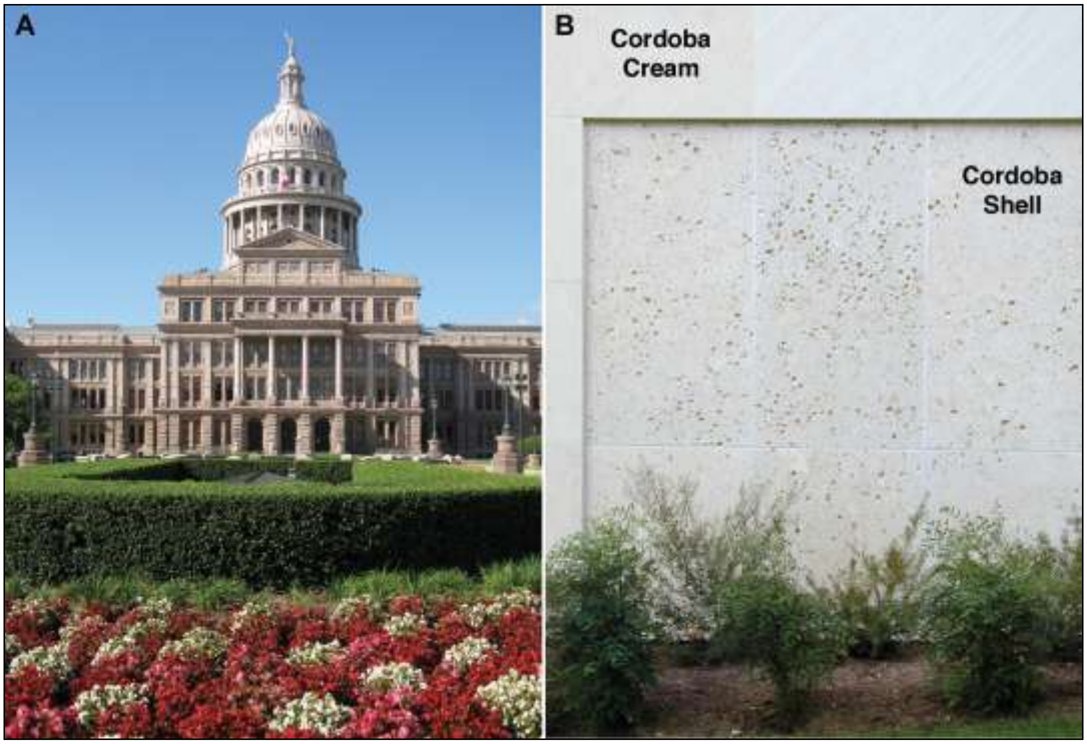


Figure 5. **Texas dimension stone uses. A. Texas capitol building (North face) in Austin constructed of Central Texas granite; B. Exterior of the Jackson Geology Building at The University of Texas at Austin faced with Cretaceous limestone (Cordoba Shell and Cordoba Cream).**

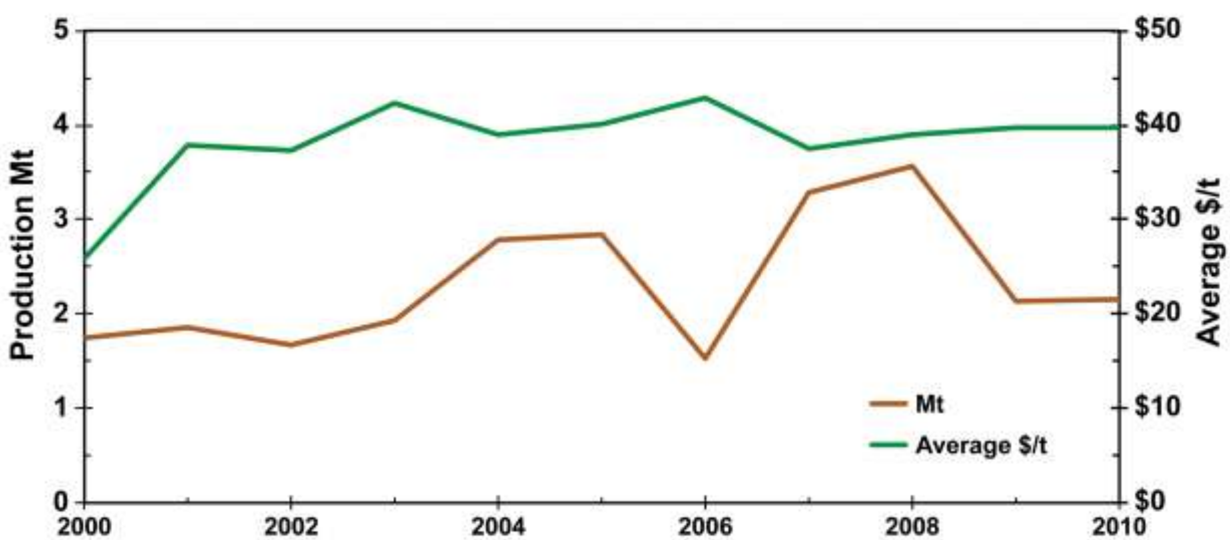


Figure 6. **Texas industrial sand production from 2000 to 2010. These data include all types of industrial sands, and current prices of hydraulic fracturing sands are considerably higher than the average value shown. Data from the U.S. Geological Survey, minerals. usgs.gov/minerals/pubs/state/tx.html - myb**

Texas Chemical Minerals

Many industrial minerals are used in chemical industries, with uses ranging from specific industrial applications to serving as the source of valuable elements. Production of industrial minerals for these industries constitutes a smaller, but significant, component of Texas' mineral resource production (Fig. 3). Salt—sodium chloride—is used for diverse purposes, but most of it is produced as rock salt or brines from Texas salt domes as a source of chlorine for the manufacture of hydrochloric acid, a widely used industrial chemical. The Hockley dome in the Houston area and the Grand Saline dome in the East Texas Basin currently are the only Texas producers of salt from underground mines (Fig. 2). Salt is Texas' largest tonnage chemical material industry with its current annual value reaching more than $150 million (Fig. 3).

Specialty clays, zeolites, sodium sulfate, helium, and talc are additional chemical materials produced in Texas (Fig. 2). Although most of Texas clay production is common clay for manufacture of bricks and other building materials, specialty clays are produced locally. Bentonitic clays are produced in the central Gulf Coast (Fig. 2) for diverse uses in industrial processes including drilling fluids and refining of vegetable oils. Ball and kaolin clays are used as fillers and coating agents in the rubber and paper industry and in ceramic products. A single producer in the south-central Gulf Coast markets zeolites for their ion-exchange capacity, as used in water treatment and other purification processes (Fig. 2).

In addition to its importance in the construction industry, limestone also has many chemical uses, including flue-gas desulfurization of sulfur dioxide from coal-fired power plants. This process produces synthetic gypsum that is becoming an alternative to natural gypsum for wallboard and cement manufacture. Lime—calcium oxide produced by calcining limestone—has many uses, including water purification, paper manufacture, and sugar refining. Lime is the second most valuable Texas' industrial chemical product with a current value of more than $120 million (Fig. 3). Lime production facilities tend to be located in the same areas as cement plants, reflecting the availability of high-purity limestone (Fig. 2).

Sulfur is another important industrial chemical that is used principally for the manufacture of sulfuric acid. Sulfur was once produced in large quantities from native sulfur deposits that resulted from microbial alteration of calcium sulfate in Coastal Plain salt-dome cap rocks and in the Permian evaporite strata in west Texas (Kyle, 1999, 2002). These deposits were extracted via the Frasch process, which involves injecting superheated water into the sulfur-bearing formation to liquefy the sulfur so that it could be pumped to the surface. These types of deposits ceased to be economically viable with the expansion of nondiscretionary sulfur production related to the Clean Air Act (Fig. 7; Kyle, 2002), with the last Texas production from the Culberson deposit in west Texas in 1999. Now sulfur is produced in more than 60 refineries of "sour" crude oil and natural gas from Texas and imported sources (Fig. 2). Although no longer tallied under state industrial mineral production, Texas remains the leading U.S. sulfur-producing state, with 3.1 million tonnes in 2010 accounting for more than one-third of U.S. production (Fig. 8).

A variety of other industrial minerals have been produced from Texas deposits for the chemical industries (Fig. 2). Talc deposits in the Allamoore district of west Texas are mined for fillers in ceramic, paper, plastic, and rubber products (Fig. 9). The principal domestic source of helium is supplied from natural gas in the Texas Panhandle fields. Sodium sulfate is produced from brines underlying alkaline lakes in west Texas (Fig. 2).

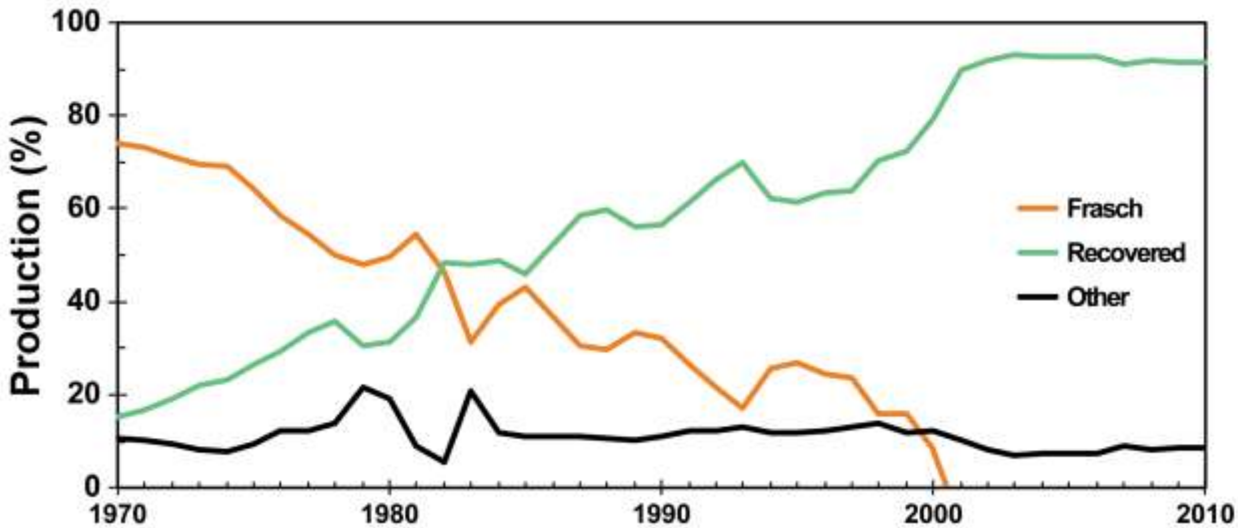


Figure 7. **U.S. sulfur production from 1970 through 2010 showing end of discretionary Frasch production and current dominance of nondiscretionary recovered sulfur. Data from the U.S. Geological Survey minerals.usgs.gov/minerals/pubs/commodity/sulfur/, updated from Kyle (2002).**

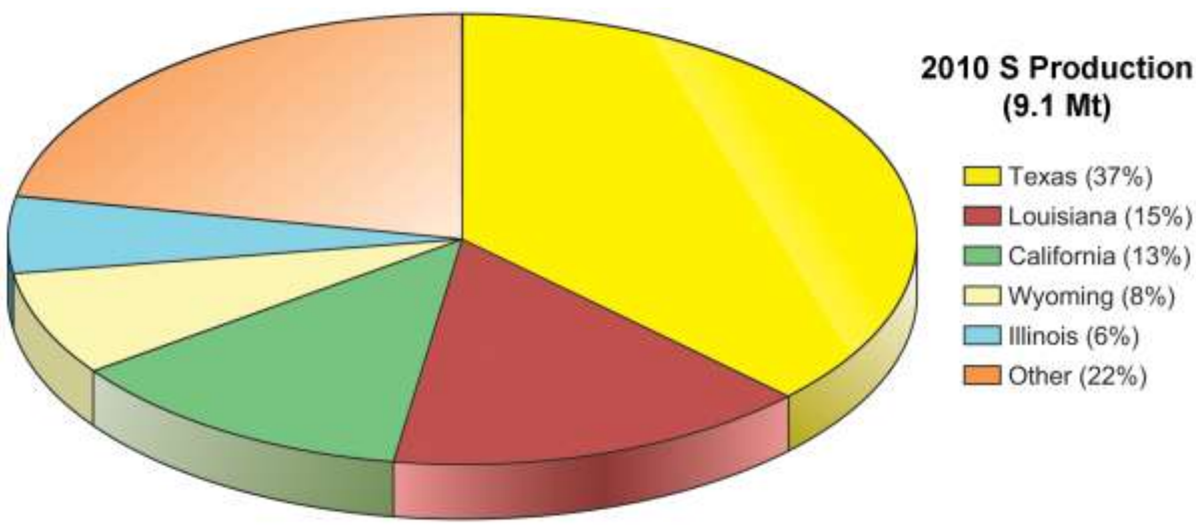


Figure 8. **U.S. sulfur production by state for 2010. Data from the U.S. Geological Survey minerals.usgs.gov/minerals/pubs/commodity/sulfur/.**

Not represented in any of the current production are many other occurrences of metallic and industrial minerals, notably in west Texas and in the Llano Uplift of central Texas (e.g. Price et al., 1983; Kyle, 2000; Becker and Kyle, 2011). Some of these deposits have had minor production, but most known deposits are currently inactive. However, silver production from the Shafter deposit in Presidio County resumed production in mid-2012 (www.aurcana.com/s/Shafter.asp). The current mining is from the downdip extension of the ore zone of the Presidio mine that was in production from 1883 until the early 1940s. The Red Hills deposit in the western part of the Shafter district was the site of an extensive drilling program in 2011 to evaluate the copper and molybdenum resources (Tietz, 2012). The Red Hills deposit is the easternmost Laramide porphyry deposit of the type that is mined extensively elsewhere in southwestern North America (Gilmer et al., 2003).

The Round Top beryllium-uranium-rare earth element deposit near Sierra Blanca in Hudspeth County currently is being reevaluated (trer.com/), building on an extensive exploration program for beryllium in the 1980s (Fig. 10). Round Top exploration has been boosted by the current emphasis on developing domestic REE sources to counter restricted supply from foreign sources.

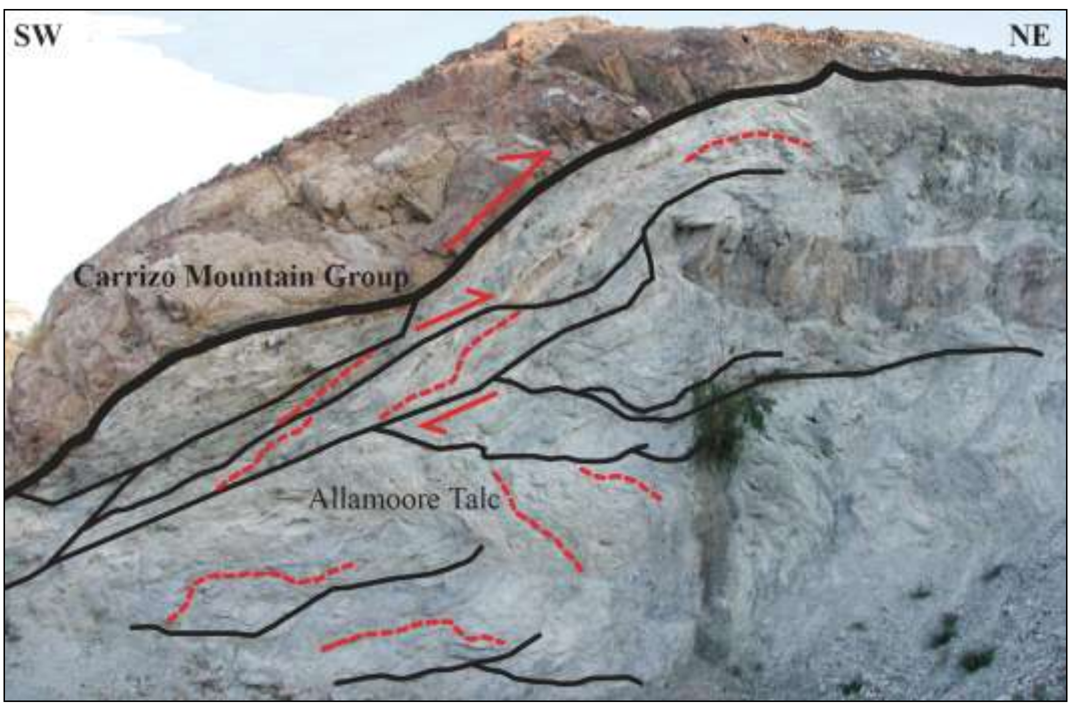


Figure 9. **Exposure of talc along the Streeruwitz Thrust, Texola mine, Allamoore talc district, Hudspeth County, Texas. From Davis (2007).**

Geology of Major Producing Regions

Most industrial minerals are relatively common Earth materials that can only be produced commercially by relatively low-cost surface extraction and processing techniques. Thus, industrial mineral production areas typically represent where favorable geologic units occur at the surface near the population centers that will consume the products, or where there is a transportation advantage to get these products to regional, national, or global markets.

All of these essential mineral resources are products of past geologic events that have affected this portion of the Earth's crust. Ancient plate tectonic processes created a vast mountain range, the deeply eroded roots of which are represented by the Precambrian metamorphic rocks and granites exposed in the Llano region of central Texas and smaller exposures in west Texas. These igneous and metamorphic rock units are sources of diverse construction and chemical materials, ranging from dimension stone (Fig. 5) to talc (Fig. 9).

Texas was covered by shallow seas during the early Paleozoic (Cambrian-Ordovician), the late Paleozoic (Permian), and the late Mesozoic (Cretaceous). These environments produced the extensive carbonate strata that form the Edwards Plateau and other surface belts of limestone that are essential to Texas' crushed stone, cement, and lime production (Figs. 2, 4A).

Evaporation of these shallow seas in the Permian and Cretaceous also produced local gypsum deposits. Even more extensive lower Mesozoic evaporites, present under the Texas Coastal Plain, have been deformed into local salt domes that supply salt via underground mines and brine operations (Kyle, 1999; Fig. 2). Sulfur was once produced in large quantities from alteration zones related to microbial sulfate-reduction in Coastal Plain salt-dome cap rocks and in the Permian evaporites in west Texas (Kyle, 2002).

Surface deposits of Cenozoic age blanket older deposits in much of Texas and provide many valuable industrial mineral resources. Cenozoic strata were deposited by river and coastal processes that distributed gravels, sands, and muds eroded from the ancestral Rocky Mountains and the continental interior. Deposition of these thick sedimentary sequences built the Coastal Plain and extended the Texas shoreline to its current position (and beyond during the glacial period that resulted in lower sea level 18,000 years ago). Coastal Plain sediments are also the source of much of the clay used in brick and ceramics. Most construction sand and gravel and industrial sand are produced from the unconsolidated alluvial deposits of Texas' major river systems (Fig. 2).

Trans-Pecos Texas, arguably the most diverse geologic region of Texas, including exposures of the oldest rocks in the state, has been affected by several younger tectonic events. This area includes the eastern margin of the Laramide (Rocky Mountain) orogeny and the extensional tectonic regime that remains active. The talc deposits in the Allamoore district are associated with complex tectonic and fluid events along the 1.0 billion-year-old Streeruwitz thrust (Fig. 9; Davis, 2007). In the early to mid-Cenozoic, the region was the site of extensive magmatism, including explosive volcanic centers. Hydrothermal systems associated with this magmatic activity produced a variety of hydrothermal mineral deposits, including concentrations of zinc, lead, silver, and mercury, as well as industrial minerals such as fluorspar (Fig. 11) with local enrichment of beryllium, uranium, and rare earth elements (Price et al., 1983; Kyle, 1990). Many of these deposits occur as replacements of Cretaceous limestones (Fig. 11), but the silver and associated mineralization at Shafter occurs as a stratabound zone in karsted Permian carbonates just below the pre-Cretaceous unconformity.

Volcanic ash from mid-Cenozoic eruptions in Trans-Pecos Texas and elsewhere in southwestern North America supplied unusual Coastal Plain sediments that were altered to valuable industrial zeolites, bentonites, and other clay deposits. Tertiary volcanic ash also was the source of uranium that was concentrated by groundwater to form Texas uranium deposits in the south Texas Coastal Plain (Galloway, 1977).

Figure 10. **Panorama of the northeast flank of the Round Top laccolith in Hudspeth County showing drill roads related to the 1980s exploration program for beryllium.**

Figure 11. **Replacement fluorspar concentrations in Cretaceous limestone, Christmas Mountains fluorspar district, Brewster County, Texas. Mining took place in the 1980s.**

Conclusions

Texas' industrial mineral production typically contributes more than three billion dollars to the state economy annually. About 90% of current state industrial mineral value is from the production of cement, crushed stone, and construction sand and gravel. Industrial mineral production provides local employment, and unusual mineral concentrations provide specialty products for broader distribution.

Increased production and consumption of industrial mineral resources is tied to regional population increases, a trend that seems likely to continue because the state's population is predicted to double in the next 50 years (txsdc.utsa.edu/). Near-coastal major consumption sites may experience increased supply of bulk industrial raw materials via oceanic transport from international sources, in competition with regional land sources and transport. Developments in other resource industries, as well as governmental regulation, can have major impacts on industrial minerals production and consumption issues.

Texas' abundant and varied industrial mineral resources are products of a geologic history affecting this part of the Earth's crust for more than a billion years. Understanding the geologic and economic framework about Earth resources allows for more informed decisions about the societal issues that Texas will face in the future.

Acknowledgments

I am grateful to various mining companies that have allowed access to their properties for educational and research purposes for the past several decades. Thanks also to many students and other colleagues who contributed to studies of specific Texas mineral resources. Brent Elliott generously reviewed an earlier draft of this manuscript.

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