BULLETIN

Corpus Christi Geological Society

and

Coastal Bend Geophysical Society

May
2019
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P.O. BOX 1068* C.C.TX. 78403
2018-2019
www.ccgeo.org

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GEOLOGICAL SOCIETY COMMITTEES & CHAIRPERSONS

MEMBERS PLEASE NOTE COMMITTEES CONTINUE TO FUNCTION WITHOUT A NAMED CHAIR, ALL ARE WELCOME TO ANY COMMITTEE THAT SUITES YOUR INTERST

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Type Logs	**OPEN**		

COASTAL BEND GEOPHYSICAL SOCIETY
P.O. BOX 2741*C.C. TX. 78403
2017-2018

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Visit the geological web site at www.ccgeo.org

CCGS/CBGS JOINT MEETING SCHEDULE 2018-2019

September 2018						
S	M	T	W	Th	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30						

Wednesday Sept. 19th at 5:30 BBQ Kickoff at Hoegemeyers Barbeque Barn. Meet/greet our special guest, Dr. Satinder Chopra*
*One of the most widely published geoscientists of our day.

October 2018						
S	M	T	W	Th	F	S
	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			

November 2018						
S	M	T	W	Th	F	S
				1	2	3
4	5	6	7	8	9	10
11	12	13	14	15	16	17
18	19	20	21	22	23	24
25	26	27	28	29	30	

11:30am-1:00pm
Speaker Dr. Jeremy Meyer, Senior Vice President GeoMechanics. "The application of Geomechanics to Unconventional Development"

December 2018						
S	M	T	W	Th	F	S
						1
2	3	4	5	6	7	8
9	10	11	12	13	14	15
16	17	18	19	20	21	22
23	24	25	26	27	28	29
30	31					

No meeting

January 2019						
S	M	T	W	Th	F	S
		1	2	3	4	5
6	7	8	9	10	11	12
13	14	15	16	17	18	19
20	21	22	23	24	25	26
27	28	29	30	31		

11:30am – 1:00pm
Speaker: Hongliu Zeng research scientist Bureau of Eco. Geology, Jackson School of Geosciesnces, The Univ. of Tx. Austin. "Seismic Sedimentology Talk"

February 2019						
S	M	T	W	Th	F	S
					1	2
3	4	5	6	7	8	9
10	11	12	13	14	15	16
17	18	19	20	21	22	23
24	25	26	27	28		

Collegiate Month

CCGS/CBGS Joint Meeting Schedule 2018-2019

March 2019							April 2019							May 2019						
S	M	T	W	Th	F	S	S	M	T	W	Th	F	S	S	M	T	W	Th	F	S
					1	2		1	2	3	4	5	6				1	2	3	4
3	4	5	6	7	8	9	7	8	9	10	11	12	13	5	6	7	8	9	10	11
10	11	12	13	14	15	16	14	15	16	17	18	19	20	12	13	14	15	16	17	18
17	18	19	20	21	22	23	21	22	23	24	25	26	27	19	20	21	22	23	24	25
24 31	25	26	27	28	29	30	28	29	30					26	27	28	29	30	31	

No meeting	11:30-1:00pm Speaker: Steve Tobias |Near FXLLC "Applying New Technologies to Old Areas; Relative Geologic Time, Wheeler Diagrams & Near Field Exploration in Faulted Plays"	11:30-1:00pm Speaker: Dr. James Gibeaut Endowed Chair for Coastal & Marine Geospatial Sciences at the Harte Research Institute for Gulf of Mexico Studies at Teas A&M University—Corpus Christi

Calendar of Meetings and Events

Calendar of Area Monthly Meetings

Corpus Christi Geological/Geophysical Society..... Third Wed.—11:30a.m.
SIPES Corpus Christi Luncheons..... Last Tues.—11:30a.m.
South Texas Geological Society Luncheons..... Second Wed—noon San Antonio
San Antonio Geophysical Society Meetings..... Fourth Tuesday
Austin Geological Society..... First Monday
Houston Geological Society Luncheons..... Last Wednesday
Central Texas Section of Society of Mining, Metalllurgy & Exp..... 2nd Tues every other month in San Antonio

SPONSORS

PRESIDENTS LETTER

It’s been great visiting Earth and all you actual Humans. But I’m returning this useful body to its proper owner and as the song by TOM PETTY/JEFF LYNNE says:

“I'm gonna free fall, out into nothin'
Gonna leave this world for a while”

The mothership informs me that my talents at being a geologist may no longer be needed, as we have found copious amounts of materials that form CO2 when combusted. They are suggesting that I repurpose the few functioning brain cells I have, into higher goals. However, I found I am fond of geologists. I believe that this is due to our innate ability to be both left and right brained. I enjoy your company because of the conversations, hobbies, rocks, art, photography, genealogy, dancing, etc. You are all multitalented earth scientists. So, I won’t bid you farewell, just commingle with you for a while and move into a new more friendly form until the restraining orders expire.

I want to thank the entire board for doing all the work and allowing me to just breeze through. I want everyone to appreciate the blessings of where we are on Earth and what time we are living on it. You of all people, share the greatest abundance of resources, food, entertainment, and FREEDOM of the entire Human race through all time. You should be thankful every day that you don’t have to walk 5 miles and carry water containers on your head; and for AC. You have privilege and opportunity above all people or you would not be reading this. I am glad that you choose a path that puts you here, rather than in a gutter, abandoned, drug addicted or homeless. We have the choices we make (and parental guidance we can take, if necessary) that lay a path for our future or present; some have greater opportunity than others. I for one was one lucky human body, born in Japan in 1951 with a Japanese mother under American occupation on a US army base. So I was American at birth, and my mother insisted I learn English first, and pressed me to excel in everything I tried to do. Good parents, good location for birth, good genes, good schools, great universities and a great Country to be proud of. I got it all, and so do you. Use your skills to guide someone else - your children, relatives, young geologists. Share this Earth with others, without prejudice and as a great American President once said “with malice toward none.”

Frank G Cornish
Benevolent Overlord,

Summer and Fall Scholarship Awards

The Corpus Christi Geological Society awarded $4,250 in scholarships to 6 local students in April 2019 from Del Mar, TAMU-CC, and TAMU-K. These scholarships are to be used for the Summer and Fall 2019 semesters.

Allison Mrotek, TAMUK; Andrew Edlin, TAMUK; Rikki Ponce, TAMUK; Skylar Meehan, Del Mar; Drianna Watkins, TAMUCC; Charles Anderson, TAMUCC

The CCGS Scholarship fund received donations from member contributions, the CCGS Golf Tournament, The CCGS Pub Crawl, the CCGS Fishing Tournament, and the Corpus Christi Oilman's Tennis Tournament. These donations are vital to allow the committee to fund the scholarships for our striving students. Every donation is very much appreciated.

We hosted the second annual CCGS Golf Tournament on Friday, April 5th and then the Pub Crawl on Saturday, April 6th. It was a fun weekend. Many thanks to Fermin Munoz for organizing the golf tournament and to BJ Thompson for an excellent job on the pub crawl! A big thank you to TAMU-CC members of the Geology Club that helped with the Golf Tournament: Robby Carte, James Crisp, Sam Ortegon, Brianna Watkins and Breana Wells. They helped with registration, pickup, and manned the longest drive hole. They added an extra fund-raising event to determine which club could be used for that drive, each player spun a wheel. Whatever club the wheel landed on, that was the club that had to be used. However, if you didn't like the spin, for $5 you could spin again, or for $20 use the club of your choice. It was a lot of fun, especially for the golfers that didn't have strong tee shots.

The Scholarship Committee members are:
Brent Hopkins, Treasurer, Frank Cornish, CCGS President
BJ Thompson, Sebastian Wiedmann, and Casey Mibb, Members

Dawn S. Bissell
Scholarship Committee

CBGS President's Letter

CBGS Board 2019-2020

Dr. Subbarao Yelisetti- President
Samara Omar- Vice President
Erik Scott- Secretary/ Treasurer
Lonnie Blake - Golf Chair
Matt Hammer - Scholarship Chair

CBGS Scholarships

The board awarded three scholarships of $2,000 each to undergraduate geophysics majors from Texas A&M University-College Station, University of Houston and Texas A&M University-Kingsville in 2017-2018. We will be awarding the scholarships again this year.
The following criteria is followed in awarding the scholarships.
1. Must be a citizen of the USA
2. Must have declared Major Geophysics at the main campus of the receiving university
3. Must have GPA 3.0
4. Must be in good standing with the school
5. Must make effort to attend a Coastal Bend Geophysical Society Meeting in Corpus Christi Texas after being awarded a scholarship to be recognized by the society.

News

- According to the U.S. Energy Information Administration (EIA), U.S. natural gas output was projected to increase to a record 79.8 billion cubic feet per day (bcfd) in May, up by 0.9 bcfd over the April forecast. This marks the 16th consecutive monthly increase.
- According to EIA, U.S. shale output forecast to hit record 8.46 million barrels per day in May.
- The U.S. rig count remains higher than a year ago. Producers drilled 1,388 wells and completed 1,392, the most since January 2015, in the biggest shale basins in March as reported by Devika Krishna Kumar and Scott DiSavino.

CBGS Business

CBGS currently has 60 active members, 4 honorary members, and 60 student members.

CBGS workshops/talks

- As part of the annual Kickoff Bar-B-Q, CBGS hosted Dr. Satinder Chopra on Sep 19, 2018 at the EOG conference center. His talk was entitled "Seismic reservoir characterization of Utica-Point Pleasant shale with efforts at quantitative interpretation – a case study".
- CBGS offered a land seismic acquisition workshop on Dec 5th in EOG conference center with the following talks.

Talks:

1. A Brief Introduction to Seismic Acquisition (Students & New Professionals Encouraged) by Lonnie Blake, EOG
2. A Comparison of Long, Short, and Slip Sweep 3D Data Image Volumes Acquired And Constrained By Equivalent Source Time (KWP Phase I) by J. W. (Tom) Thomas, Kevin Werth, Tom Phillips, Chris Lindsey Dawson Geophysical Co.
3. A Comparison of 3D Multi-Component (9C) Data Image Volumes Acquired With Conventional and Simultaneous Source Techniques Also With Adequate Spatial Resolution For Compressive Sensing Investigation (KWP Phase 2) by J. W. (Tom) Thomas, Kevin Werth, Tom Phillips, Chris Lindsey Dawson Geophysical Co.
4. SAExporation - More, Recent Advances in Onshore Seismic Data Acquisition Methods by Howard Watt, SAExporation, Houston

CBGS is looking forward to offer many such workshops in the future. Topic/speaker suggestions are welcome. Email your suggestions to Lonnie_Blake@eogresources.com or Subbarao.Yelisetti@tamuk.edu

Golf Tournament

CBGS organized its annual **Golf Tournament** to fund its scholarship program in the first week of October, 2018 at Northshore Country Club. Raised ~$4,000 for the scholarship fund.

If you are interested in our next Golf Tournament, please contact Lonnie Blake at 361-887-2665 or Lonnie_Blake@eogresources.com

New Degree Tracks at TAMUK

- Texas A&M University-Kingsville (TAMUK) started its first cohort of MS Petrophysics program in Fall 2018. If you are interested in joining this program in Fall 2019, please contact the graduate coordinator for MS in Petrophysics, Dr. Subbarao Yelisetti at Subbarao.Yelisetti@tamuk.edu.
- **BS degree in Geophysics, Minor in Geophysics and Certification in Geophysics** offered at Texas A&M University-Kingsville since Fall 2017. Interested students can contact Dr. Subbarao Yelisetti (Subbarao.Yelisetti@tamuk.edu) for additional information.

Exploration Geophysics and Borehole Geophysics classes **PHYS 5382 Exploration Geophysics** and **PHYS 5388 Borehole Geophysics** classes are offered in Fall 2019 at Texas

A&M University-Kingsville. This is available for the professional community as well as our students. You can sign up as a "transient" student in order to take classes without actually enrolling in the school. If anyone in the professional community wishes to sign up for this, please contact, Dr. Subbarao Yelisetti Subbarao.Yelisetti@tamuk.edu.

SEG Distinguished Lecture

CBGS and TAMUK SEG student chapter organized 2018 SEG Distinguished Lecture in January, 2018. We wish to organize many more lectures in the future.

Education/Events

-SEG

SEG 2019 annual meeting will be held in San Antonio, TX from Sep 15-20th. Abstract deadline is April 1, 2019. See https://seg.org/Annual-Meeting-2019 for additional details.

See https://seg.org/Education/Lectures/Distinguished-Lectures for information about upcoming SEG distinguished lecture in Houston and other locations.

See https://seg.org/Education/Lectures/Honorary-Lectures for SEG honorary lecture locations in Texas.

-AAPG

2019 AAPG annual convention and exhibition will be held in San Antonio, TX from May 19-22, 2019.
https://ace.aapg.org/2019

-AGU

2019 Fall AGU annual meeting will be held in San Francisco, CA from December 9-13th, 2019.
https://fallmeeting.agu.org/2018/future-meetings/

-GSA

The Geological Society of America's 131st annual meeting will be held in Phoenix, AZ from 22-25th September 2019.
http://www.geosociety.org/GSA/Events/Annual_Meeting/GSA/Events/gsa2019.aspx

Monthly Saying

"The healthful balm, from Nature's secret spring,
The bloom of health, and life, to man will bring;
As from her depths the magic liquid flows,
To calm our sufferings, and assuage our woes"
- Seneca Oil Advertisement c 1850 (before oil was recognized as an energy source and oil from seeps was used primarily for medicinal purposes).

Monthly Summary

Texas Oil and Gas Info	Current Month	Last Month	Difference	
Texas Production	**MMBO/BCF**	**MMBO/BCF**	**MMBO/BCF**	
Oil	123.6	122.8	0.8	December
Condensate	15.4	15.3	0.1	December
Gas	730.3	720.4	9.9	December
	Current Month	**Yr to date - 2019**	**Yr to date - 2018**	
Texas Drilling Permits	1137	3294	3483	March
Oil wells	315	864	885	March
Gas wells	69	176	242	March
Oil and Gas wells	688	2017	2121	March
Other	8	29	26	March
Total Completions	665	2469	2712	March
Oil Completions	493	1819	2067	March
Gas Completions	127	547	501	March
New Field Discoveries	0	2	6	March
Other	2	10	9	March

Subbarao Yelisetti
President, CBGS

CORPUS CHRISTI GEOLOGICAL SOCIETY
COASTAL BEND GEOPHYSICAL SOCIETY

LUNCHEON MEETING ANNOUNCEMENT

May 15, 2019

Location:	**Water Street Events (Previously the Seafood Company Restaurant) 300 Block N. Water Street, CC, TX 78401**
Student Sponsor:	**Imagine Resources, Nye Exploration, Viper Exploration, Ltd.**
Bar Sponsor:	**Sponsorship Opportunities Available!!!!!!**
Time:	**11:30 am Bar, Lunch follows at 11:45 am, Speaker at 12:00 pm**
Cost:	**$25.00 (additional $10.00 surcharge without reservation; NO SHOW may be billed and non-RSVP attendees cannot be Guaranteed a lunch); FREE for students with reservation (discounted by our generous sponsors)!**
Reservations:	**Please RSVP by 4PM on the FRIDAY before the meeting! E-Mail: arrangements@ccgeo.org**

Please note that luncheons RSVPs are a commitment to the Water Street Events and must be paid even if you can't attend the luncheon.

SPONSORSHIPS OPPORTUNITIES ARE AVAILABLE!
IF YOU WOULD LIKETO SPONSOR, PLEASE CONTACT US AT:
arrangements@ccgeo.org

NYE
Exploration & Production, LLC
802 N. Carancahua, Suite 1840
Frost Bank Plaza
Corpus Christi, TX 78401
www.nyexp.us

Imagine
Resources, LLC

VIPER
EXPLORATION,

LTD

Sea Level Rise, Shifting Environments, and Future Hurricanes on the Texas Coast

The Texas coast is susceptible to impacts of sea level rise as shown by historical changes in environments, erosion, flooding, and storm surge. Modeling of the impacts of future storms and higher water levels as sea level continues to rise during this century demonstrates the importance of planning human activities and conserving natural environments on a shifting baseline.

James C. Gibeaut
Chair for Geospatial Sciences
Harte Research Institute
Texas A&M University – Corpus Christi

Biography

Dr. James Gibeaut is the Endowed Chair for Coastal and Marine Geospatial Sciences at the Harte Research Institute for Gulf of Mexico Studies (HRI) at Texas A&M University – Corpus Christi. He earned a B.S. in geology from Ohio State University, a M.S. in coastal geology from the University of Rhode Island, and a Ph.D. in Marine Science from the University of South Florida. He is a coastal geologist who uses remote sensing, GIS, and field surveys to measure and understand coastal change. Currently, his main research focus is modeling the effects of relative sea-level rise and storms on coastal systems and projecting future impacts on natural and built environments. Dr. Gibeaut places the results of his research in the context of improving coastal resiliency and often advises agencies and decision makers regarding coastal policy.

$10,000 CASH & PRIZES GUARANTEED

Thursday July 25th

Treasure Island Bar @ 5:00PM

315 N. Alister St. Port Aransas, TX 78373

Registration: 5:00 - 7:00PM

Captains Meeting: 7:15PM

Dinner, Drinks, Door Prizes!!

Friday July 26th

Roberts Point Pavilion

Bay Weigh-in: 2:00-5:00PM

Offshore Weigh-in: 4:00-7:00PM

Cash Prizes, Trophy Presentation!!

Come and Join Us!!

PORT ARANSAS, TX

ldevine@suemaur.com @cc_geo @ccgeologicalsociety

CORPUS CHRISTI GEOLOGICAL SOCIETY
10TH ANNUAL SALTWATER FISHING TOURNAMENT

The CCGS Saltwater Fishing Tournament will be held Friday, July 26, 2019 for you and your guests at the **Roberts Point Pavilion** located in Port Aransas, Texas. We invite you to join us in support of the **CCGS Scholarship Trust Fund**.

Fishing Hours will be from:
Offshore Division 12:01 AM to 7:00 PM Friday, July 26, 2019
Bay Division 6:00 AM to 5:00 PM Friday, July 26, 2019

Dock/Ramp departure time:
Offshore Division Boats may leave after Captain's Meeting Thursday, July 25, 2019
Bay Division 5:00 AM Friday, July 26, 2019

Weigh-In Time & Location will be:
Offshore Division 4:00 PM to 7:00 PM Friday, July 26, 2019 at the Roberts Point Pavilion
Bay Division 2:00 PM to 5:00 PM Friday, July 26, 2019 at the Roberts Point Pavilion

REGISTRATION: Early Registration will be by mail/e-mail with on-site registration available at **Treasure Island Bar** from 5:00 PM to 7:00 PM Thursday, July 25, 2019. Don't forget your money for the fish pots!!!!!

CAPTAIN'S MEETING: **At least one team member must check-in and attend the Captain's meeting Thursday, July 25, 2019 at the Treasure Island Bar. Meeting will be held at 7:30PM. All anglers are encouraged to participate.**

PRE-PARTY & DOOR PRIZES: **New Venue: Treasure Island Bar (315 N. Alister St. Port Aransas, TX 78373). Dinner, drinks, and entertainment will be provided Thursday evening from 5:00 to 9:00 PM. NOTE: Door prize give away will be Thursday immediately following the Captain's Meeting. You must be present to win. Food and drinks will be provided the day of the tournament from 2:00 PM to 8:00 PM.**

COST:
Early tournament registration fee per Team/boat on or before July 12, 2019:
Offshore Division: $400.00
Bay Division: $300.00
Tournament registration fee per Team/Boat after July 12, 2019:
Offshore Division: $500.00
Bay Division: $400.00

TEAM AWARDS: The awards presentation for the Bay Division will start at/about 5:30 PM. Awards for the Offshore Division will start at/about 7:30 PM. **Cash Prizes will be awarded for Heaviest Stringer (Bay Division) and Offshore Grand Champion (Offshore Division). Amount TBD.** The following categories will be presented to 1st & 2nd place teams:

Bay Division:	Offshore Division:
Heaviest Stringer (1 Red Drum, 1 Speckled Trout, 1 Flounder)	Offshore Grand Champion
Heaviest Speckled Trout	Catch and Release Champion
Heaviest Red Drum (Redfish)	Heaviest Wahoo
Heaviest Flounder	Heaviest Dolphin (Dorado/Mahi)
Heaviest Black Drum	Heaviest BlackfinTuna
	Heaviest Yellowfin Tuna

FISH POTS: Offshore and Bay Division fish pots are available, and payments can be submitted via your registration forms, or at the on-site registration. **15% OF ALL FISH POTS WILL GO TO THE CCGS Scholarship Trust Fund.**

CONTACT: **Leighton Devine** 361-510-8872

CCGS Saltwater Fishing Tournament Rules

This year's tournament will be open to any and all Oilfield affiliated members and their guests. This is a **TEAM TOURNAMENT** with both bay and offshore fishing divisions.

OFFSHORE AND BAY DIVISIONS:

- All fish must be caught on Friday, July 26, 2019 during the specified tournament fishing hours.
- No contestant will be eligible for awards unless registered in advance. Angler substitutions must be made by 7:00 PM July 25, 2019.
- Changing of fishing divisions must be done by 7:00 PM July 25, 2019.
- **Live, Dead and Artificial baits are legal.** All fish must be caught by rod and reel only. The use of trotlines, seines, dynamite, spear fishing, or any other illegal means of fishing are strictly prohibited. All Federal, and State recreational fishing and Boating Laws apply.
- **Weigh-In Station:** All fish weighed must be legal according to Federal and State game laws. Any team/boat attempting to weigh a fish that is not legal will be disqualified. Fish that are frozen, gutted, or otherwise mutilated will not be eligible and the team attempting to weigh such a fish will be disqualified. All fish are subject to further inspection if deemed necessary by the Weighmaster. Please be aware of your fishing division's weigh-in time as no fish will be weighed in before or after each division's allotted weigh-in time**. No sorting or substituting fish** while in the weigh-in line.
- All contestants are personally/solely responsible for any fines/actions resulting from any violations of Federal or State game laws, boating laws, or any other law relevant to boating and/or fishing. You are strongly encouraged to practice safe boating and use common sense.
- **ONE TEAM MEMBER MUST CHECK-IN AND ATTEND THE CAPTAIN'S MEETING THE DAY BEFORE THE TOURNAMENT AT THE TREASURE ISLAND BAR. THE OFFSHORE DIVISION'S OBJECT OF THE DAY WILL BE AVAILABLE AT THIS TIME.**
- Only one boat per team is allowed, any team found fishing from multiple boats will be disqualified.
- Transfer of fish from one boat to another is not allowed.
- Teams are subject to disqualification from the tournament, and may be administered a polygraph test, in the event of any violation of tournament rules or suspected of foul play, including the weighing-in of fish which appear to have been caught prior to the day of the tournament. Contestants will be responsible for the cost of polygraph testing if they fail.
- The Tournament Chairman or Weighmaster will act as judge, and will handle all disputes or interpretations of the rules. **THE DECISIONS OF THE JUDGES ARE FINAL!**
- **In case of bad weather and tournament cancelation, registration fees and 15% of fish pots will be donated to the CCGS Continuing Education Programs. Tournament will not be rescheduled. The CCGS Fishing Tournament Board will make any/all decisions regarding tournament cancelation during the Captain's Meeting Thursday, July 25, 2019.**

OFFSHORE DIVISION:

- Boats entered in the Offshore Division may leave the dock/boat ramp after the Captain's Meeting, with lines in the water no earlier than 12:01 AM. **YOU MUST BE IN THE WEIGH-IN LINE** (visible to the tournament Weighmaster) no later than 7:00 PM. **NO EXCEPTIONS!**

  Offshore division dock/ramp departure time: After Captain's Meeting
  Offshore division fishing hours: 12:01 AM to 7:00 PM
  Offshore division Weigh-In time: 4:00 PM to 7:00 PM

- **BOAT CHARTERS ARE ALLOWED. IGFA RULES APPLY, WITH ONE RULE MODIFICATION REGARDING ANGLING REGULATIONS. DECKHANDS ARE ALLOWED TO REMOVE ROD, STRIKE AND HOOK FISH THEN PASS THE ROD TO THE ANGLER.**

CCGS Saltwater Fishing Tournament Rules

OFFSHORE DIVISION: *(cont.)*

- **All Billfish will be released.** To qualify for catch and release points, a digital image, or a video from a camera clearly showing both the dorsal fin of the fish, and the object of the day must be present, and visible. The digital image/video must be submitted to the weigh station at the time of weigh-in. All Billfish must remain in the water. Images/videos showing the fish in the boat WILL NOT be eligible for points, and will disqualify the team/boat. In order to receive points for a blue marlin, the picture must clearly show it is a blue marlin; otherwise the fish will be scored as a white marlin. **LAPTOP WITH A USB CONNECTION WILL BE AVAILABLE; IT IS THE BOAT/TEAM'S RESPONSIBILITY TO PROVIDE ANY NESSECARY CABLES OR CORDS TO UPLOAD DIGITAL IMAGES.**

- **Offshore Catch & Release points are as follows:**

  Blue Marlin …… 500 Points
  White Marlin …… 300 Points
  Sailfish …… 200 Points

- **All boats registered in the tournament will act as committee boats.** All catch and release fish must be reported on VHF channel 68, stating the Boat name, species of billfish released, and time of the release. When the catch and release report is received by another boat in the tournament, the receipt of time will be recorded. If you are unable to reach another boat in the tournament to record release, you may proceed to the weigh-in and report the catch and release.

- All other eligible offshore fish may be weighed in and scored (1) point per pound. Eligible offshore fish species include: **Wahoo**, **Dolphin** (Dorado/Mahi), **Yellowfin Tuna, & Blackfin Tuna.** Only these fish species will be weighed in. **EACH BOAT/TEAM MAY ONLY WEIGH-IN ONE FISH PER ELIGIBLE SPECIES.** Remember Weigh-In time for the Offshore Division is from 4:00 PM to 7:00 PM.

- In the event of a tie, the first team to accumulate points by earliest time will be declared the winner.

BAY DIVISION:

- Boats entered in the Bay Division may not leave the dock/boat ramp earlier than 5:00 AM with lines in the water no earlier than 6:00 AM. **YOU MUST BE IN THE WEIGH-IN LINE** (visible to the tournament Weigh Master) no later than 5:00 PM. **NO EXCEPTIONS!**

  Bay division dock/ramp departure time: 5:00 AM
  Bay division fishing hours: 6:00 AM to 5:00 PM
  Bay division Weigh-In time: 2:00 PM to 5:00 PM

- Bay Division Teams may launch and fish anywhere on the bays, as long as the weigh-in deadlines are made at the Roberts Point Pavilion. No Bay Division Team is allowed to fish past the end of the jetties, or anywhere offshore. Wade fishing is allowed.

- Each Team member is allowed to have only one line in the water at any time during tournament fishing hours.

- All fish must be caught by rod and reel in adherence to Texas State Law.

- **FISHING GUIDES ARE ALLOWED**. However, all fish weighed in must be caught by registered anglers.

- Eligible Bay Division fish species include: **Speckled Trout**, **Red Drum** (Redfish), **Flounder**, & **Black Drum**. Only these fish species will be weighed in. No oversized, tagged Redfish will be weighed in. The Weigh-in of any undersized fish will disqualify the team. Remember Weigh-In time for the Bay Division is from 2:00 PM to 5:00 PM.

- **EACH TEAM/BOAT MAY ONLY WEIGH-IN ONE FISH PER ELIGIBLE SPECIES.**

- In the event of a tie by fish weight, length and girth will determine the winner.

CORPUS CHRISTI GEOLOGICAL SOCIETY
10TH ANNUAL SALTWATER FISHING TOURNAMENT

TEAM REGISTRATION FORM

Tournament registration fee on or before July 12, 2019: Offshore Division: $400.00, Bay Division: $300.00. Tournament registration fee during on-site registration: Offshore Division: $500.00, Bay Division: $400.00. **Registration fee includes Team entry into the tournament, Dinner, awards, tournament t-shirt, & a chance to win door prizes.** Additional dinner tickets: $20.00 per person. **Official Tournament Fishing Shirts: $50.00 (pre-order only).** By participating in the fishing tournament you are helping to support the CCGS Scholarship Trust Fund. We look forward to seeing you there.

TEAM REGISTRATION:

Boat/Team Name: _____ **Division: Offshore** _____ **Bay** _____ ***(Check one)***

TX No.: _____ **Make:** _____ **Length:** _____

Angler #1: _____ **Company:** _____
(Team Captain)

Address: _____

Phone: _____ **Email:** _____

Angler #2: _____ **Angler #3:** _____

Angler #4: _____ **Angler #5:** _____
(Applies for Offshore Division only)

**Please note Bay Division teams may have up to 4 anglers, and Offshore Division teams may have up to 6 anglers.*

By entering the "CORPUS CHRISTI GEOLOGICAL SOCIETY SALTWATER FISHING TOURNAMENT" We hereby waive all liability claims against tournament sponsors, hosts, officials and all persons associated with said tournament. We acknowledge that we have received a copy of, understand and agree to abide by all tournament rules, and understand my team will be disqualified for violation of any rules. We agree to abide by tournament official's rulings. We understand our entry fee is non-refundable.

Team Captain: _____ _____
Sign *Date*

FISH POTS : *(optional)*
To participate in the fish pots please indicate which categories the team wants to enter. Teams will be able to enter into the fish pots until the end of on- site registration at 7:00 PM July 25, 2019. ***15% of the fish pots will be donated to the CCGS Scholarship Trust Fund.***

Bay Division

Heaviest Team Fish				
Red Drum	Speckled Trout	Flounder	Black Drum	Spot Pot
$100.00	$100.00	$100.00	$100.00	$100.00

Offshore Division

Total Catch and Release points			Heaviest Team Fish			
Blue	White	Sail	Wahoo	Dolphin	Blackfin Tuna	Yellowfin Tuna
$300.00	$300.00	$300.00	$100.00	$100.00	$100.00	$100.00

Payment Information: **Registration fee:** _____
Email with Credit Card Authorization Form to ldevine@suemaur.com or,
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Corpus Christi, Texas 78401

Fish Pot total: _____
Additional Dinner Tickets: _____
Tournament Fishing Shirt: _____
Sizes: XXL_____ **XL** _____**L** ____**M** _____

Total Amount: _____

CORPUS CHRISTI GEOLOGICAL SOCIETY
10TH ANNUAL SALTWATER FISHING TOURNAMENT

SPONSORSHIP FORM

The Corpus Christi Geological Society (CCGS) is pleased to announce the 10th annual saltwater fishing tournament. The fishing tournament is being held Friday July 26, 2019 in Port Aransas, at the Roberts Point Pavilion, and will consist of two fishing divisions (offshore/bay). The goal is to conduct a quality industry event that will support the CCGS Scholarship Trust Fund. Sponsorships are needed to maintain this program, and provide support for our future industry leaders.

Registration can be made until July 25th during the Captain's Meeting, with the tournament on July 26, 2019. We look forward to seeing you there.

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Team Entry Fee (Early/Late): **Bay Division: $300/$400** **Offshore Divison: $400/$500**

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Name on Credit Card: _____

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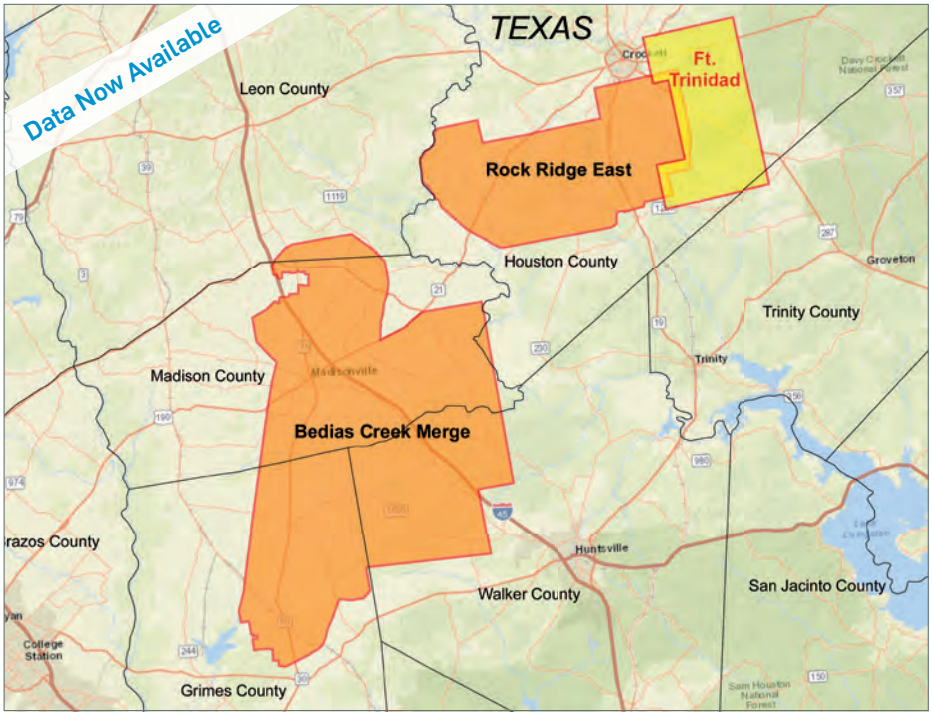

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A seismically induced onshore surge deposit at the KPg boundary, North Dakota

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The most immediate effects of the terminal-Cretaceous Chicxulub impact, essential to understanding the global-scale environmental and biotic collapses that mark the Cretaceous–Paleogene extinction, are poorly resolved despite extensive previous work. Here, we help to resolve this by describing a rapidly emplaced, high-energy onshore surge deposit from the terrestrial Hell Creek Formation in Montana. Associated ejecta and a cap of iridium-rich impactite reveal that its emplacement coincided with the Chicxulub event. Acipenseriform fish, densely packed in the deposit, contain ejecta spherules in their gills and were buried by an inland-directed surge that inundated a deeply incised river channel before accretion of the fine-grained impactite. Although this deposit displays all of the physical characteristics of a tsunami runup, the timing (<1 hour postimpact) is instead consistent with the arrival of strong seismic waves from the magnitude M_w ~10 to 11 earthquake generated by the Chicxulub impact, identifying a seismically coupled seiche inundation as the likely cause. Our findings present high-resolution chronology of the immediate aftereffects of the Chicxulub impact event in the Western Interior, and report an impact-triggered onshore mix of marine and terrestrial sedimentation—potentially a significant advancement for eventually resolving both the complex dynamics of debris ejection and the full nature and extent of biotic disruptions that took place in the first moments postimpact.

KPg extinction | Chicxulub | Hell Creek Formation | tsunami | impact

The Chicxulub meteoric impact marks the end of the Cretaceous and the onset of profound planet-scale climatic changes that initiated a mass extinction in the earliest Cenozoic (1, 2). Intimately associated with the third-greatest global extinction, a variety of immediate and protracted results have been proposed for the Chicxulub impact, including atmospheric perturbations and long-term global climatic shifts (3), possible impact-induced volcanism (4), and eventual worldwide ecological collapse (1). More-instantaneous effects, much more poorly resolved, include seismic disturbances (5–7) and the triggering of seiches (harmonic waves that can develop in large bodies of water) and megatsunami (8–10). Some of the most visually apparent disturbances are the tsunami/seiches recorded in high-energy sediment packages up to 9 m thick in marine deposits throughout the Gulf Coastal Plain and Caribbean (8–10). It is problematic, however, to trace their geographic extent in the Western Interior Seaway (WIS) because the terminal-Cretaceous geologic record for that depositional system is not preserved. In addition, evidence of onshore inundation by Chicxulub tsunami is thus-far unknown.

Regrettably, in the geologic record, there is a lack of coeval records with high temporal resolution on the scale of minutes to hours. Consequently, and despite voluminous previous work on the Chicxulub impact, a full understanding of the effects and ecological impact during the first hours or days postimpact has not been resolved. Here, we report the Tanis site, which documents a turbulently deposited, rapidly emplaced sediment package directly overlain by the Cretaceous–Paleogene (KPg) boundary tonstein. The site, situated in the continental Hell Creek Formation in southwestern North Dakota (Fig. 1), displays inland-directed flow indicators and holds a mixture of Late Cretaceous marine and continental biota, implying that its emplacement is related to sudden onshore inundation surges. A suite of ejecta types, including ejecta spherules preserved within the deposit sediments (captured by the gills of fish entombed within the deposit and preserved as unaltered glassy spherules embedded in amber), indicate that deposition occurred shortly after a major bolide impact. Unaltered impact-melt glass exhibits a clear geochemical and geochronological link with the Chicxulub impact. A well-defined cap of iridium-bearing, fine-grained impactite tonstein directly overlying the deposit provides a well-constrained chronology—that is, after impact but before the finest ejecta settled—that can provide a detailed record of conditions shortly after the impact. The time frame indicated by the embedded ejecta and capping tonstein at Tanis overlaps with arrival times calculated for seismic waves generated by the Chicxulub impact, a

Significance

The Chicxulub impact played a crucial role in the Cretaceous–Paleogene extinction. However the earliest postimpact effects, critical to fully decode the profound influence on Earth's biota, are poorly understood due to a lack of high-temporal-resolution contemporaneous deposits. The Tanis site, which preserves a rapidly deposited, ejecta-bearing bed in the Hell Creek Formation, helps to resolve that long-standing deficit. Emplaced immediately (minutes to hours) after impact, Tanis provides a postimpact "snapshot," including ejecta accretion and faunal mass death, advancing our understanding of the immediate effects of the Chicxulub impact. Moreover, we demonstrate that the depositional event, calculated to have coincided with the arrival of seismic waves from Chicxulub, likely resulted from a seismically coupled local seiche.

Author contributions: R.A.D., D.A.B., P.L.M., F.J.M., and M.A.R. designed research; R.A.D., J.S., D.A.B., K.K., P.L.M., A.O., P.L., M.A.R., L.G., and W.A. performed research; R.A.D. performed field excavations; D.A.B., P.L., L.G., and W.A. performed field work; R.A.D., J.S., D.A.B., K.K., P.L.M., P.L., F.J.M., J.V., M.A.R., L.G., and W.A. analyzed data; and R.A.D., J.S., D.A.B., P.L.M., A.O., and W.A. wrote the paper.

The authors declare no conflict of interest.

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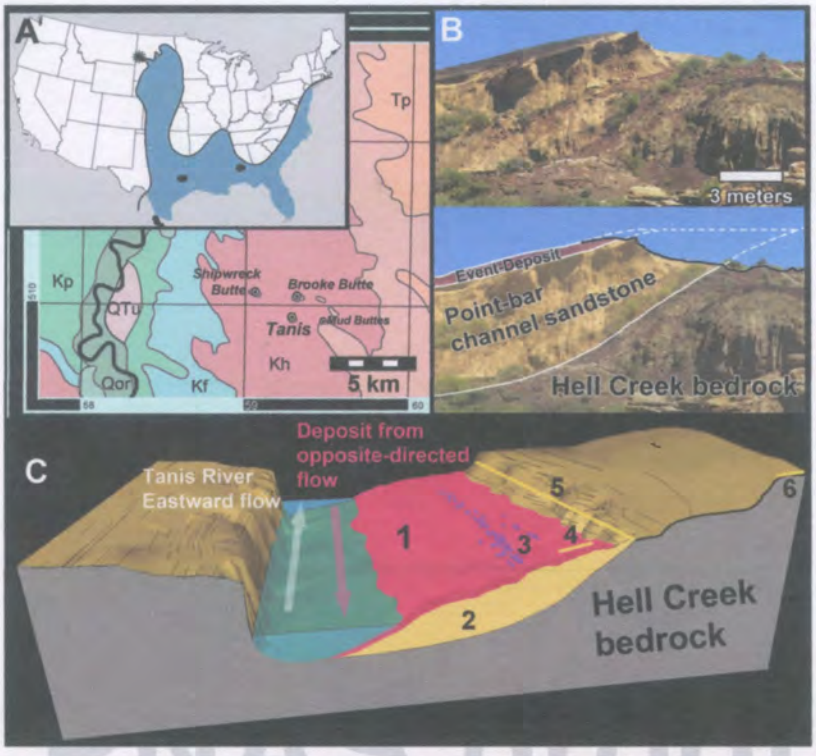

Fig. 1. Map of the Tanis study locality. (*A*) Tanis within a regional context (large map) and on a national map (*Inset*). Reprinted with permission from ref. 14; black dots in *Inset* are previously documented KPg tsunami localities; star denotes Tanis. Kf, Fox Hills Formation; Kh, Hell Creek Formation; Kp, Pierre Shale; Qor, Holocene; QTu, Quaternary and Upper Tertiary; Tp, Slope Formation. (*B*) Photo and interpretive overlay of an oblique cross-section through Tanis, showing the contact between the angled point-bar sandstone and the gray Hell Creek bedrock. (*C*) Simplified schematic depicting the general contemporaneous depositional setting for the Event Deposit (not to scale). The Event Deposit (1) covers the slope of a prograding point bar of a meander (2), which incised into the Hell Creek bedrock during the late Cretaceous. Location of the densest carcass accumulations (3) along the slope; location of KPg boundary tonstein directly overlying the Event Deposit (4); location of KPg tonstein overlying the adjacent overbank (5); location of Brooke Butte (6), the closest KPg outcrop to Tanis.

peculiar coincidence that suggests the impact played a causative role in triggering the Tanis depositional event. Tanis is noteworthy in recording a brief period of time that directly followed (within tens of minutes to hours) the Chicxulub impact. Furthermore, the possibly impact-triggered depositional event is a phenomenon thus-far undocumented in continental facies. The Tanis site therefore provides another dimension to our understanding of how the Chicxulub impact could have affected life on Earth.

Geologic Setting

The continental Hell Creek Formation is a Late Maastrichtian wedge of clastic fluvial sediments that prograded eastward into the epicontinental WIS during the last ~1.3 My of the Cretaceous (11). The sediments comprise alternating bedded floodplain mudstones, paleosols, and crevasse splays, punctuated by point-bar sandstones from numerous incised meandering rivers flowing east into the WIS (12). While the geologic record of the WIS is missing beyond the Upper Campanian/mid-Upper Maastrichtian (13–15), most reconstructions support a long, narrow seaway still connected to the paleo-Gulf of Mexico at the close of the Cretaceous (e.g., refs. 13–17; Fig. 1). Cephalopod assemblages in the Pierre Shale strongly support a persistent interchange with southern taxa, indicating a sizable Late Maastrichtian corridor to the Gulf of Mexico (13) that lasted until the end of the Cretaceous. Persistent marine influence throughout the upper Hell Creek Formation, supported by marine and brackish fossils found as far west as the Little Missouri River at the Montana–North Dakota border (west of Tanis) and as far east as Bismarck, North Dakota (over 250 km to the east), as well as two marine incursions—the Breien and Cantapeta transgressions—indicate that the fluctuating, reticulated terminal-Cretaceous shoreline was not far away from the Tanis region in southwestern North Dakota (15, 18–22).

The KPg boundary is a synchronous benchmark in the geologic record, where it is delineated by a global ejecta layer composed of fine impact-derived material that began settling out from the atmosphere shortly after impact (1, 2). This ejecta layer, known locally in the Western Interior of the United States as the KPg tonstein, is the clearest and most precise marker that divides the Cretaceous and the Paleogene. It is distinguished by impact-related debris, including a distinctive iridium anomaly, shocked minerals, ejecta spherules, microkrystites, nanodiamonds, and occasionally unaltered impact-melt glass (2, 23). In the Western Interior, the KPg tonstein is easily recognized due to its conspicuous contrast in color and texture from the bounding fluvial and overbank sediments and its stratigraphic placement between uppermost Cretaceous paleosol and a thin, basal Paleogene lignite/carbonaceous shale. The KPg tonstein thus enables correlation of the KPg boundary over long distances. In southwestern North Dakota, as with the rest of the Western Interior, the KPg boundary always occurs either precisely at the Fort Union–Hell Creek formational contact, or slightly above (11). When ideally preserved, the KPg boundary clay in the Western Interior manifests as a 1- to 2-cm compact peach-colored, dual-layered tonstein clay bed (2, 23). The lower layer, which can vary from 0.7 to 1.7 cm in the local study region of southwestern North Dakota,

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consists of the coarsest material, such as ejecta spherules, whereas the fine-grained upper layer, which can vary from 4 mm to ~1 cm in the local study region, contains an enrichment of platinum group elements (PGEs) such as iridium as well as the bulk of shocked minerals. However, at most localities in the study region, impact-generated debris is rare and often completely absent, rendering the KPg boundary identifiable only via biostratigraphy (11).

Tanis Event Deposit

At Tanis, the Cretaceous and Paleogene strata are separated by the Event Deposit, a high-energy clastic sediment package immediately underlying the in situ KPg tonstein. The Event Deposit is a ~1.3-m-thick bed that shows an overall grading upward from coarse sand to fine silt/clay and is associated with a deeply incised, large meandering river that flowed eastward during the latest Cretaceous. The deposit sharply overlies the aggrading surface of a point bar in a drapelike fashion (Fig. 1 and *SI Appendix*, Fig. S1) and is further characterized by bidirectional flow and a transition from upper- to lower-flow–regime sedimentary structures. The underlying point bar is characterized by epsilon cross-stratification, moderately to well-defined lateral accretion tabulae, and thickness exceeding typical crevasse splay deposits, features that define the point-bar deposits common throughout the Hell Creek Formation (12). The channel of the Tanis River incised deeply into the underlying strata, similar to other Hell Creek-incised channels and comparable to modern subtropical rivers (*SI Appendix*, Fig. S2). In the extant state of preservation, the point bar exhibits ~10.5 m of isochronous elevation change along its inclined surface and its width extends <50 m perpendicular to paleoflow direction. These dimensions are in the upper size range for point bars in the Hell Creek Formation (12) and compare favorably with analogous modern rivers with large channels that are tens to hundreds of meters wide (e.g., Suwannee, Alapaha). The Tanis point bar also shows pedogenic and bioturbational signs of prolonged subaerial exposure until immediately before being covered by the Event-Deposit sediments (see below and *SI Appendix*).

The Event Deposit (Fig. 2) is subdivided into two graded subunits based on a minor, abrupt increase in grain size, showing evidence for at least two successive surges. The ~50-cm-thick basal unit 1 sharply overlies the point-bar surface and includes biological (flow-aligned carcasses and tree trunks) and sedimentary (cross-bed foresets, asymmetry/orientation of current ripples, truncated flame structures, etc.) flow structures indicative of a westward or inland flow direction that is opposite of the natural paleocurrent of the contemporaneous Tanis River. The base of unit 1 comprises a matrix-supported, massive coarse-sand conglomerate, with angular pebble- to small boulder-sized rip-up clasts derived from the underlying Hell Creek strata. As shown in Fig. 2, the massive sand (1a) at the base of unit 1 has a sharp nongradational basal contact with the underlying point-bar surface and vertically grades into a thin (~3-cm) zone of plane-parallel bedding of interlaminated sand–silt (lower 1b); climbing ripples (mid 1b); sinuous, wavy lamination (upper 1b); low-angle cross-lamination (lower~1c); fine, discontinuous subparallel lamination (upper 1c); and nearly structureless fine silt/mud near the top (1d). Flow-direction reverses 180° toward the east—seaward—near the top of unit 1. The succeeding unit 2 resembles upper unit 1 in structure and grain size, starting with climbing ripples in an alternating sand–silt laminated interval (2a), and grading to structureless fine silt/mud at the upper terminus (2b and 2c). Flow in lower unit 2 is directed westward—inland—but reverses 180° in the upper portion, indicating eastward flow. The end of the inundation event is marked by organic-rich, fissile clay containing mats of fragmented plant matter (2c). The upper terminus is directly capped by a thin, in situ 1- to 2-cm-thick band of impactite tonstein (Figs. 2 and 3). The slightly thicker tonstein on the adjacent paleosurface of the river terrace just outside the main channel is indistinguishable from the dual-layered KPg ejecta layer elsewhere in the Western Interior; the lower layer is dominated by impact spherules and the upper layer is iridium rich (3.8 ppb) and contains the bulk of the shocked minerals (23). The tonstein on top of the Event Deposit represents mainly the upper part of the dual layer, with most of the spherule abundance

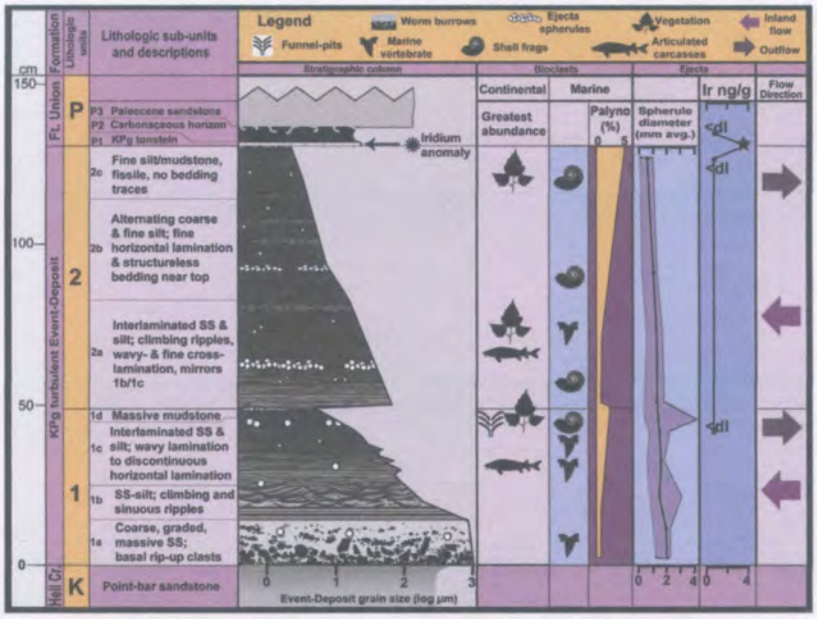

Fig. 2. Tanis site stratigraphy and fossil distribution. Stratigraphic section of Tanis, outlining the lithological subdivisions and grain-size profile for the Event Deposit, abundance and primary stratigraphic distribution for a selection of continental and marine fossils, abundance of marine palynomorphs (palyno %), select impact-derived materials, and flow direction.

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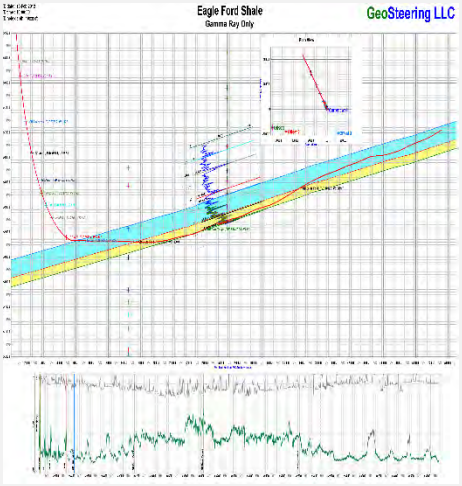

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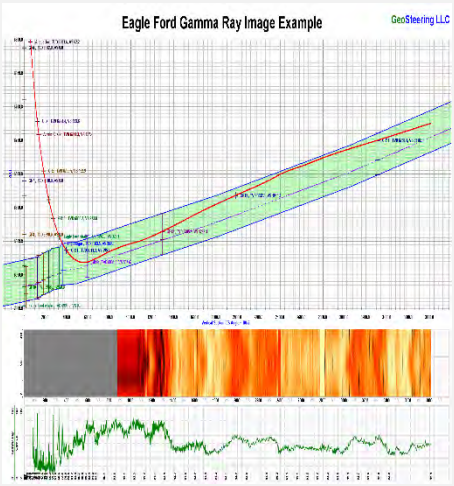

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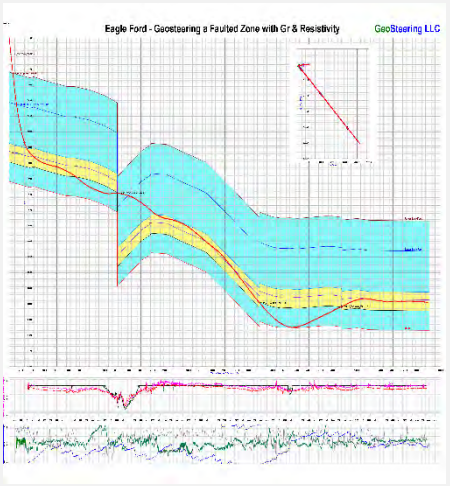

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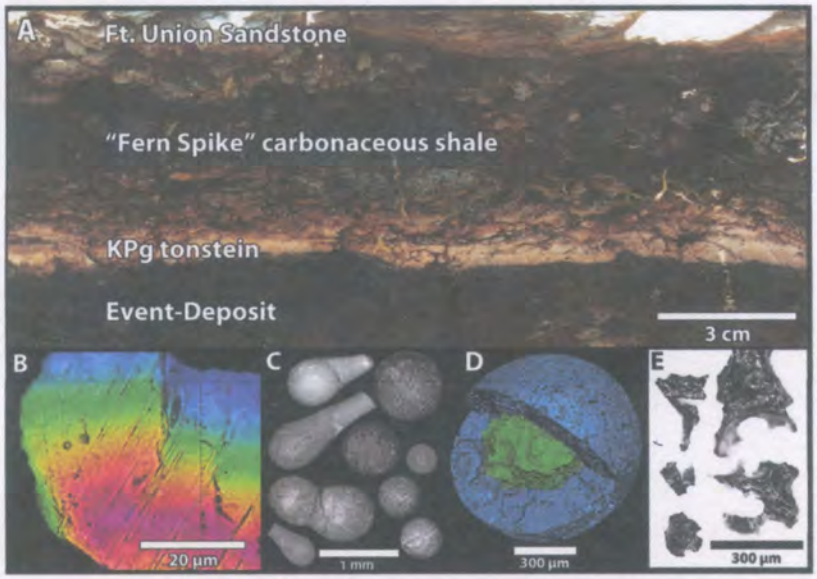

Fig. 3. Chicxulub tonstein capping the Event Deposit at Tanis and representative impact-derived materials. (*A*) Iridium-enriched tonstein in situ atop the Event Deposit. (*B*) Shocked mineral with multiple intersecting planar deformation features (FAU.DGS.ND.161.977.T). (*C*) Clay-altered ejecta spherules (FAU.DGS.ND.161.33.T), some with prominent schlieren. (*D*) Micro-CT of a clay-altered ejecta spherule with unaltered glass core (FAU.DGS.ND.161.11.T). (*E*) Shards of unaltered impact glass (FAU.DGS.ND.161.45.T).

distributed throughout the Event Deposit beneath. The tonstein is overlain by a thin (~6-cm-thick) lignitic horizon of plant remains. The Event Deposit and underlying strata represent the typical Hell Creek *Wodehouseia spinata* palynofacies (24), and a "fern spike" within a depauperate palynofacies (25) characterizes the lignitic horizon.

Composition and structure of the Event Deposit and subjacent point bar imply an abrupt inundation of a paleosurface that was subaerially exposed for considerable time before deposition. Prolonged subaerial exposure is corroborated by colonization of the point bar by terrestrial organisms, open burrows that are filled with sediment from the overlying basal Event Deposit, pedogenic structures, and invertebrate fossils found entombed in some of the burrows. The sharp, nongradational basal contact with the underlying point-bar surface is further evidence for an abrupt event. Climbing ripples, pronounced grading of the deposit, water-escape structures, truncated flame structures, and steady vertical transition from upper- to lower-flow-regime flow structures provide additional proof that accumulation of the sediment package was brief and episodic, rapidly emplaced out of a dense suspension load (26). Coarse grain size, abundant subangular rip-up clasts, and imbricated debris in the basal portion indicate that the initial stages of deposition were rapid, turbulent, and high energy.

The minimum estimated runup height of the inundation was great, at least ~10 m based on the observed paleorelief of the point bar underlying the Event Deposit (*SI Appendix*, Fig. S1). The sizable runup height, large-scale bidirectional flow, and thick draped sediment package at Tanis are unusual for the Hell Creek Formation. In addition, Tanis exhibits a depositional scenario that was unusual in being highly conducive to exceptional (largely three-dimensional) preservation of many articulated carcasses (Konservat-Lagerstätte). Such Konservat-Lagerstätten are rare occurrences in the fossil record because they require special depositional circumstances. Since Tanis is the only known site in the Hell Creek Formation where such conditions were met, the deposit attests to the exceptional nature of the depositional episode.

The lithology, entombed marine invertebrates, fossil preservation, and chronology of Tanis each preclude correlation with either the Cantapeta or Breien marine incursions (18, 19). These marine tongues transgressed over broad swaths of the Hell Creek, while the Tanis Event Deposit is restricted to a paleoriver valley and is conspicuously absent from the adjacent floodplains. The glauconitic lithology and graded basal contact of the marine tongues, indistinguishable from the Fox Hills Formation (19), also differ from the laminated sand–silt lithology and sharp basal contact of the Event Deposit. Tanis lacks *Ophiomorpha*, a trace fossil ubiquitous in the Hell Creek marine tongues (18, 19), and the Tanis marine mollusks consist almost exclusively of the ammonite *Sphenodiscus lobatus*, in sharp contrast with the *Crassostrea*- and *Corbicula*-dominated Breien and Cantapeta, where *S. lobatus* is absent (18, 19). Nacreous mollusk shell preservation at Tanis also contrasts with the poorly preserved, primarily limonitic steinkerns (internal casts of mollusks) from the marine tongues (19). The KPg tonstein overlying the ejecta-bearing deposit constrains Tanis to shortly after impact, technically the basal-most minutes/hours of the Paleogene. Biostratigraphy (megafloral and palynological) retains a terminal-Cretaceous signature, therefore in agreement with a depositional event that occurred precisely at the Cretaceous–Paleogene transition. This chronology is considerably younger than the Cantapeta and Breien marine sequences, which invaded the upper (but not uppermost) and the lower to middle parts of the Hell Creek Formation, respectively (11, 18, 19). Consequently, the Tanis Event Deposit cannot be correlated with the known Hell Creek marine transgressions.

Ejecta, Connection with Chicxulub, and Chronology of the Deposit

Our assumption that deposition at Tanis occurred immediately after a large meteoric impact is substantiated by the following (Figs. 3–5): (*i*) ejecta spherules, (*ii*) microkrystites, (*iii*) shocked minerals with multiple intersecting sets of planar deformation features, (*iv*) unaltered impact-melt glass, and (*v*) an iridium anomaly (3.8 ppb) within the fine-grained tonstein capping the Event Deposit. Each of these features is independently a clear signature of impact and reaffirms an impact event shortly before

the Tanis depositional event. These impact-derived materials are absent from the bounding strata below the Event Deposit and above the tonstein.

Splash-form and round ejecta spherules (*SI Appendix*, Fig. S10), the majority ranging from 0.3 to 1.4 mm in diameter, occur throughout the Tanis deposit, with a few at the contact between the capping KPg tonstein and the underlying Event Deposit. By comparison, spherules from ~3,000 km away from the crater, in Gorgonilla Island, Colombia, average about 1 mm in diameter (27); those from ~1,700 km away at Blake Nose, western North Atlantic, average 1 to 3 mm (28); those from ~1,000 km away in Beloc, Haiti, average 3 to 4 mm, up to 8 mm or more (8); and those from ~1,044 km away in El Mimbral, Mexico, average 3 to 5 mm, with blebs up to 15 mm (9). Although there is not a perfectly linear relationship between spherule size and distance from the crater (e.g., spherules at El Mimbral can be larger than some examples from closer to the crater, in Beloc), spherules show a general decrease in size with distance. The most common spherule size range at Tanis (0.3 to 1.4 mm) is reminiscent of the average size expected in the Western Interior relative to distance from the crater and is comparable to ejecta from nearby outcrops. The infrequent, large-sized outliers at Tanis are similar in size to the lowest size ranges from proximal localities such as El Mimbral and Beloc. However, they are much smaller than the average or largest examples from those localities.

Although repeated reworking might explain the isolated spherule occurrences in the deposit, other observations suggest that primary air-fall deposition has been recorded in several horizons. Spherules occasionally occur in thin, close-packed, size-graded lenses (Fig. 4 *A*–*D*) in upper unit 1 and unit 2. Spherules in the graded lenses far exceed the surrounding fine grain size and therefore exceeded transport capacity. This is supported by the fact that they are not accompanied by a coarser-grained influx, which would have signified a pulse in flow velocity that could have carried them in. Flow velocity sufficient to carry the spherules would have eroded the fine-grained contextual sediment and hampered its deposition; therefore, it is unlikely that the spherules in the lenses were transported or reworked subsequent to deposition. Rather, these observations indicate that they were deposited directly after settling through the air and/or water column, and thus their deposition should align closely with ejecta arrival times based on their ballistic trajectories.

As a second potential example of primary deposition of ejecta, the contact zone between units 1 and 2 contains scattered, uncommon, 3- to 8-cm-deep funnel-like cones of down-warped laminations, which typically contain a single, unusually large (~3-mm) spherule at their base (Fig. 4*E* and *SI Appendix*, Fig. S12). These warped structures are rare, as fewer than 15 were recovered in >400 m^3 volume of excavated sediment, and are overlain by undisturbed Event-Deposit sediment, indicating that they were produced syndepositionally. Spherules settling out of suspension are unlikely to have created such warped depressions, but rather, the 3- to 8-cm penetration and down-warping suggest that a descending spherule fell at terminal velocity on an exposed, soft surface between the two main surge pulses or, at most, was covered by a few centimeters of water.

Additional spherules were recovered from amber blebs attached to tree trunks or large branches (Fig. 5 and *SI Appendix*, Fig. S14). Those spherules are completely unaltered impact glass, shielded from chemical weathering by their enclosure in amber. Even more remarkable are spherules concentrated in the gill rakers of more than 50% of acipenseriform (sturgeon and paddlefish) fish carcasses within the deposit (Fig. 6 and *SI Appendix*, Fig. S15). Passive suspension feeding is a common specialization among some acipenseriforms (i.e., certain paddlefish taxa), which sieve food with their gills while swimming open-mouthed (29). It is most likely that the Tanis paddlefish inadvertently aspirated the spherules by this mechanism when the ejecta settled through the water column. Spherules within the fish carcasses at Tanis suggest that the impact event and associated macrofossils were temporally correlated.

The geochemistry and radiometric age of unaltered impact glass from Tanis directly correlate with the Chicxulub impact. Although most Tanis spherules are diagenetically altered to smectitic clay, some very rare spherules still contain a core of unaltered glass (Fig. 3*F*). Tanis is only the fourth (1, 8, 27, 30) outcrop to contain unaltered Chicxulub impact glass. The glass is dark and vesicular, with pockmarked surfaces, includes some internal crystals of melilite and encapsulated debris, and has extremely low water content (0.02 to 0.03%), consistent with impact origin. The unaltered impact glass is geochemically nearly indistinguishable

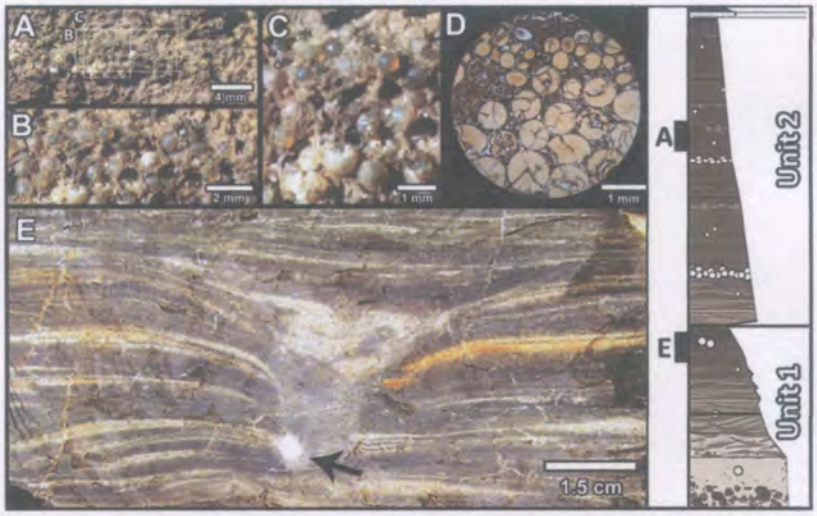

Fig. 4. In situ ejecta at Tanis. (*A*–*C*) Field photos of an ejecta lens in situ. (*D*) Petrographic thin section of a spherule lens (FAU.DGS.ND.161.88.T). (*E*) Cross-section of down-warped "microcrater" caused by incoming ejecta, with arrow pointing to spherule (FAU.DGS.ND.161.65.T). (*Right*) Region of origin for the items pictured.

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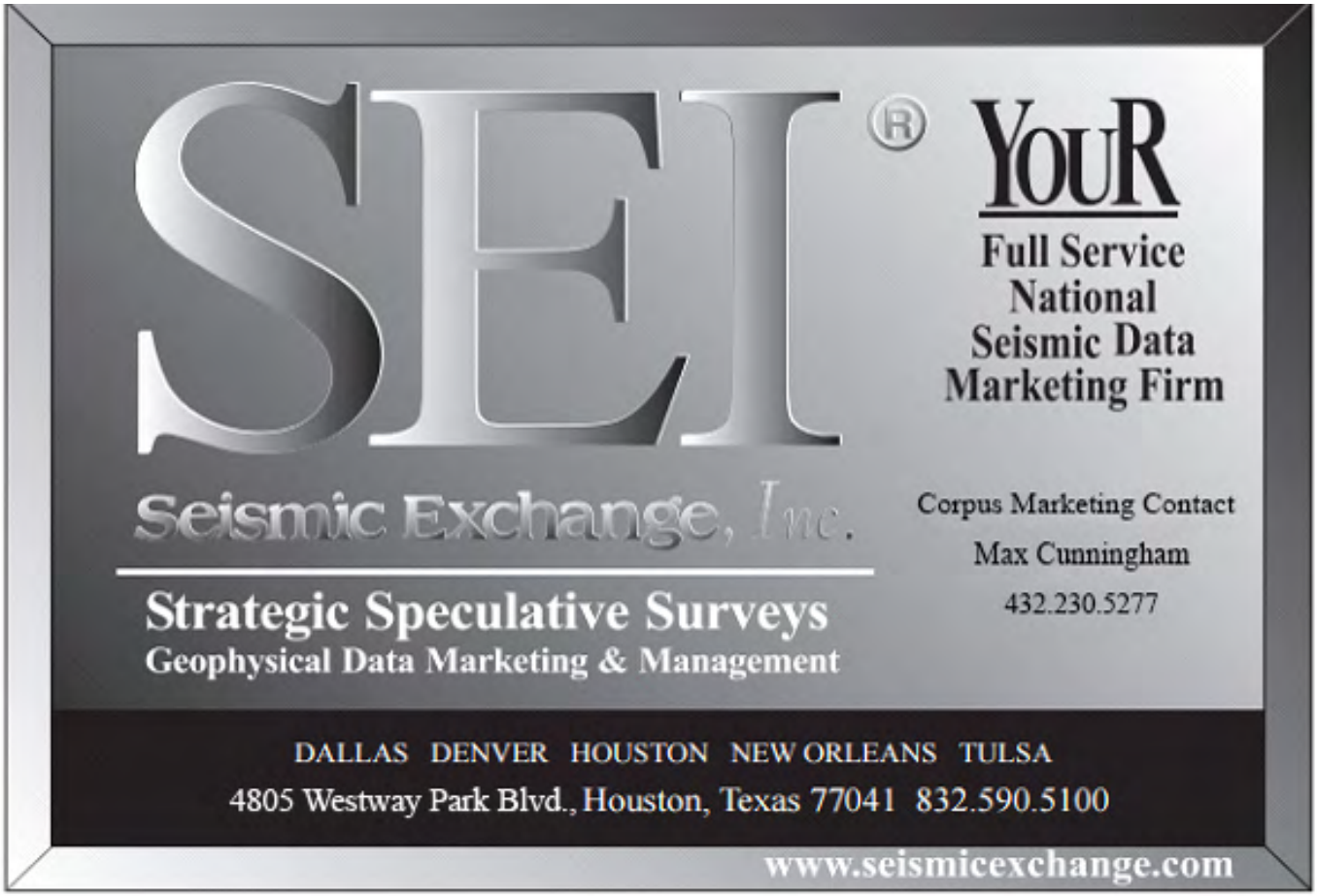
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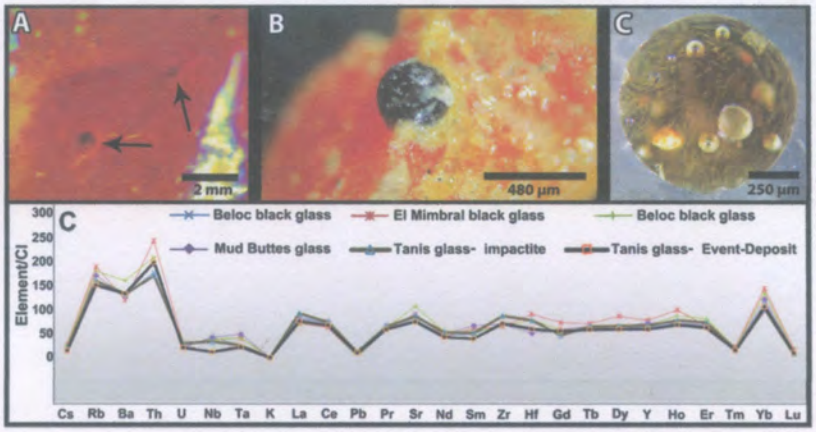

Fig. 5. Chicxulub impact glass from Tanis, and geochemical comparison. (*A*) Magnified view of spherules within amber (FAU.DGS.ND.161.77.T). (*B*) Exposed unaltered spherule, in situ within amber (FAU.DGS.ND.161.735.T). (*C*) Thin section of unaltered glassy spherule recovered from amber (FAU.DGS.ND.161.997.T). (*D*) CI-normalized geochemistry highlighting the strong match between the ranges for Chicxulub black glass and the Tanis specimens.

from the major element (*SI Appendix*, Fig. S16 and Table S3) and trace element (Fig. 5*D* and *SI Appendix*, Table S3) ranges exhibited by Chicxulub black glass (30). $^{40}Ar/^{39}Ar$ analysis of the Tanis glass yielded a weighted radiometric date of 65.76 Ma ± 0.15 My, following the calibration of Kuiper (31), identical in age with Chicxulub impact dates from elsewhere (32).

Because the Tanis deposit contains ejecta throughout and is also capped by the KPg tonstein, the depositional event took place during a narrow window of time: after impact but before deposition of the fine-grained KPg tonstein. Given this constraint, we can deduce that the Event Deposit was emplaced within a matter of hours after the Chicxulub impact event. This chronology can possibly be further constrained by the timing of incoming ejecta embedded within the deposit. The time span between ejection and deposition of primary air-fall debris is governed by the ballistic trajectory of the spherules, also taking atmospheric drag into account (5). We assume a scenario in which ejecta-curtain material, launched at about a 45° elevation angle and seen as the glassy or altered-glass spherules at Tanis, arrived before the shocked quartz that was launched at steep angles in a "warm fireball" produced by release of CO_2 from shocked limestone after departure of the ejecta curtain (33). The travel times to Clear Creek, Colorado, and Brownie Butte, Montana (33), have been recalculated (34) for Tanis, revealing that ejecta-curtain spherules launched at assumed elevation angles of 30° to 60° reach the top of the atmosphere above Tanis from 13 to 25 min after impact. Shocked quartz from the warm fireball, launched at angles from an assumed 70° to the limit of the forbidden zone at 79°, begins to reach the atmosphere above Tanis about 38 min after impact and ceases reaching Tanis about

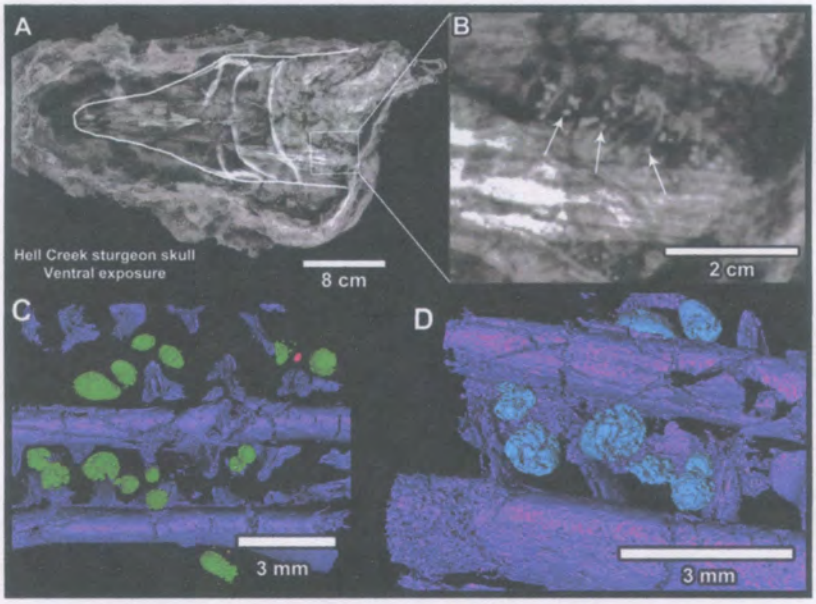

Fig. 6. Acipenseriform fish with ejecta clustered in the gill region. (*A*) X-ray of a fossil sturgeon head (outlined, pointing left; FAU.DGS.ND.161.115.T). (*B*) Magnified image of the X-ray in *A* showing numerous ejecta spherules clustered within the gill region (arrows). (*C* and *D*) Micro-CT images of another fish specimen (paddlefish; FAU.DGS.ND.161.29.T), with microtektites embedded between the gill rakers in the same fashion.

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2 h after impact. Based on this constraint, if the ejecta embedded in the Event Deposit represents primary air-fall as suggested by its mode of deposition, then the surges arrived sometime between ~13 min and 2 h after impact. The fine-grained KPg tonstein subsequently settled on top, beginning in the ensuing hours. This is consistent with ejecta arrival times calculated by previous studies (35).

Biota in the Event Deposit

Biological debris supports a rapid depositional event, and its imbrication indicates deposition via bidirectional currents. Fossil fish and logs are in some instances oriented obliquely through the Event Deposit, spanning the entire thickness. Such vertical orientation indicates that the entire deposit was emplaced quickly. A prolonged duration of time, or emplacement by multiple episodes separated by considerable time (i.e., repetitive phenomena such as tidalites), would have degraded the carcasses, contradicting what we see at Tanis. Taphonomy of the carcasses, including three-dimensional and near-identical states of preservation, demonstrate that the carcass assemblage represents a sudden mass-death accumulation, likely caused by extremely rapid burial in the fine-grained sediment. Interwoven articulated vertebrate carcasses with heads pointed toward the incoming flow direction, and elongate trunks/branches from trees that are strongly parallel-oriented by flow, support a bidirectional paleocurrent direction at the time of deposition (Fig. 7 and *SI Appendix*, Fig. S26).

The absence of scavenging despite the shallow burial of plentiful, large carcasses and the lack of root traces along the upper surface of the Event Deposit may suggest a depleted local biodiversity after deposition. Megaflora (*SI Appendix*, Fig. S20) diagnostic for the terminal Cretaceous (36), and terrestrial palynomorphs (*SI Appendix*, Fig. S21) indicating subzone E (24) of the *Wodehouseia spinata* assemblage (= uppermost Cretaceous, including the KPg boundary), are consistent with a terminal-Cretaceous event, before appearance of the first Paleogene taxa. The dense accumulation of vertebrate carcasses has not been reported in any other Hell Creek flooding event, despite the Hell Creek being a fluvially dominated depositional setting, and is reminiscent of rafted organic material associated with major inundation surges (37).

Very well-preserved isolated fragments and partial shells of (marine) ammonites (aragonitic and nacreous, no signs of dissolution), predominantly *S. lobatus*, are diffused throughout the deposit. Marine dinocysts include markers for the latest Maastrichtian (38, 39), but no Danian markers. These marine fossils contrast starkly with the many continental (= freshwater) paddlefish and sturgeon carcasses in the same strata. The mixed fossil assemblage of well-preserved continental and marine fossils supports injection of biological remains from a contemporaneous marine environment, likely the WIS, possibly combined with slightly older unconsolidated or unlithified seafloor oozes scoured during inundation. As mentioned in the *Geologic Setting* section, brackish/marine indicators existed within several to tens of kilometers from the Tanis region throughout the uppermost Hell Creek Formation, indicating that the WIS shoreline was not appreciably distant. $\delta^{18}O$ values from −0.5 to −4‰ Vienna Pee Dee Belemnite (VPDB) support a brackish to fully marine origin for ammonites and vertebrate marine fossils, ruling out freshwater tolerance that occurs with certain marine taxa in the Hell Creek (e.g., *Myledaphus* ray, some orectolobiform sharks). The mix of fully marine and freshwater taxa superficially resembles the Cantapeta and Breien tongues, but as discussed in *Tanis Event Deposit*, the lithology, faunal composition, preservation, and chronology are incompatible.

Depositional Mode

In modern fluvial depositional environments, as with the Hell Creek Formation, major high-energy depositional events or hydrological surges are related either to massive storms or to river flooding. The sedimentological features at Tanis, particularly the large-scale bidirectional flow, high runup, thick deposit, and

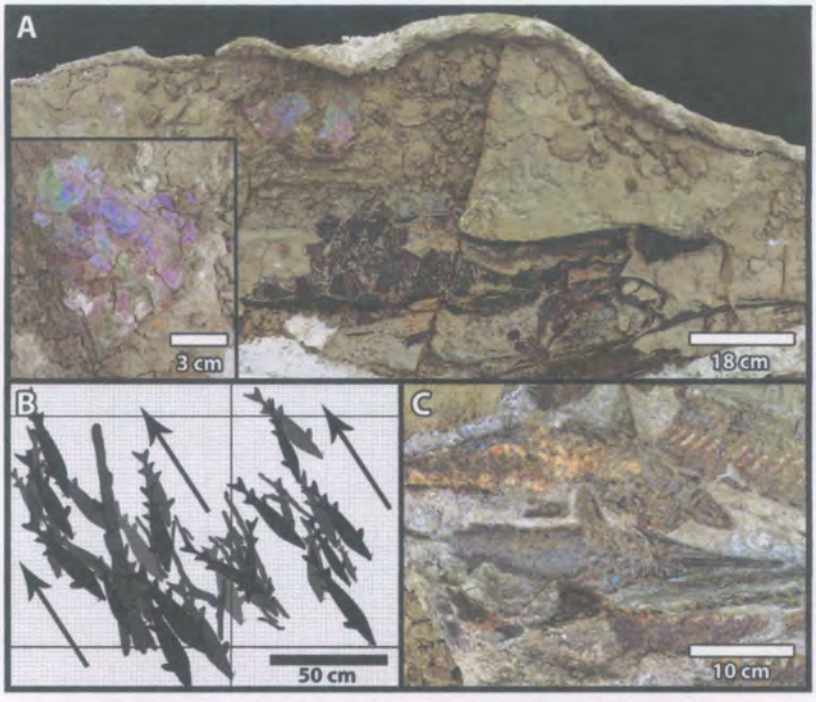

Fig. 7. The Tanis Konservat-Lagerstätte. (*A*) Plaster field jacket with partially prepared (freshwater) acipenseriform fish (FAU.DGS.ND.161.116.T) next to a nacreous ammonite shell (*Inset*). (*B*) Partial site map showing carcasses oriented by flow. (*C*) Field photo showing mass grave of fish carcasses, aligned by flow.

draped sediment package of relatively even thickness, are incompatible with storms and river flooding (37, 40) and do not ally with other common terrestrial or marginal-marine depositional mechanisms such as tidalites. The depositional mode and sedimentology at Tanis compare most favorably with an inundation surge (37, 40), with the physical characteristics of a tsunami (refs. 40–42 and *SI Appendix*, Figs. S8 and S9) that could have emanated from the impact site up the WIS or, alternatively, due to a more localized seiche.

The large inland-directed surge complex at Tanis, incompatible with either river flooding or storm deposits, was a rare and unusual occurrence in the Hell Creek Formation. Because this depositional event occurred immediately after the Chicxulub impact, which itself was a rare occurrence, the two events could likely have borne a causative, rather than just a coincidental, relationship. A large-scale inundation such as the one that affected Tanis could have resulted from a variety of impact-related triggering mechanisms. Onshore inundation by a massive tsunami caused by the Chicxulub impact (i.e., propagating directly from the impact site), which has already been documented in marine facies at more proximal localities (9, 10), might have been capable of producing the sedimentary surge deposit preserved at Tanis. However, such a tsunami would have been greatly attenuated in the shallow WIS, even assuming the WIS was an uninterrupted, open corridor at that time, which is not presently known. Similarly, a locally triggered seiche could have been equally capable of onshore inundation, resulting in a sedimentological end product nearly indistinguishable from tsunamite. Seismic waves generated by the Chicxulub impact have been suggested to be powerful enough to cause (*i*) a pulse in marine volcanism at diverging plate margins (4), (*ii*) terrestrial seismic ground movements in the Western Interior (5), and (*iii*) acceleration of Deccan volcanism (7). Such seismic waves were probably also sufficient to trigger seiches at large distances. The capability for seismic shaking to trigger seiche activity is reaffirmed by historical observations, in which S waves from the lesser moment magnitude M_w ~9.2 Tohoku earthquake (Japan, 2011) caused seismic seiches with an amplitude >1.5 m in Norwegian fjords nearly 8,000 km from the epicenter (43), a greater distance than between the Chicxulub crater and Tanis (~3,000 km).

Emplacement Mechanism

The timing and correlation of the depositional event to the impact-induced effects (seismic waves and arrival of ejecta) provide constraints for deciding which triggering scenario was most plausible. Most importantly, it appears implausible that a tsunami from the Gulf could have caused the Tanis depositional event for three principal reasons: (*i*) while the WIS is thought to have remained connected to the Gulf in the latest Cretaceous, it is unconfirmed whether a connection was, in fact, present at that time; (*ii*) the variably shallow epicontinental WIS would have greatly attenuated the tsunami waves; and (*iii*) the travel time for a tsunami from Chicxulub to Tanis would have been a minimum of 18 h based on tsunami travel calculations (*SI Appendix*).

At a paleoepicentral distance of ~3,050 km from the center of Chicxulub, Tanis would have received P, S, and Rayleigh waves 6, 10, and 13 min after impact, respectively. A seismically induced seiche wave could have been generated soon thereafter, with constituent surge pulses each lasting tens of minutes, depending on the period of the seiche wave. (The latter cannot be determined with any precision because the average depth of the water body is not known.) The seismic wave arrivals would have been followed closely by the arrival of impact-melt spherules from the ejecta curtain. Based on ballistic trajectory calculations (5, 33, 34) and assuming that most of the spherules were ejected from Chicxulub at an angle of ~45° to 50° from the horizontal, spherules would have begun arriving at Tanis ~15 min postimpact. The vast majority would have fallen at Tanis within 1 to 2 h of impact. This time frame is entirely consistent with the calculated timing of a seismic seiche generated in a local arm of the WIS in the Tanis region. Thus, seismic waves from Chicxulub arrived at the Tanis region just minutes before the window of deposition and long before a tsunami from the Gulf could have reached it. The correlation in timing between the arrival of seismic waves from Chicxulub and the Tanis depositional episode supports the plausibility that seismic wave energy triggered the depositional episode.

The Chicxulub impact generated a very large earthquake, with reconstructed estimates supporting a moment magnitude in the range of M_w ~10 to 11.5 (44, 45). Globally induced seiche magnitudes from historical earthquakes can be used to scale the potential maximum amplitude of a seiche at Tanis triggered by Chicxulub. For example, the great 2011 Tohoku earthquake in Japan (M_w ~9.2) generated a well-documented ~1.5 m amplitude seiche in a Norwegian fjord nearly 8,000 km from the epicenter (43). Given that seismic ground motion increases by a factor of ~30 with every factor of 2 increase in moment magnitude, we straightforwardly infer that the Chicxulub earthquake could have easily generated seiches worldwide with amplitudes of the order 10 to 100 m. The runup height of the Tanis Event Deposit is at least 10 m, compatible with this estimated seiche magnitude and, as explained in *Ejecta, Connection with Chicxulub, and Chronology of the Deposit*, possessed the right timing based on ballistic trajectory calculations for the arrival of impact spherules at Tanis. Moreover, these calculations show that large-amplitude seiches were likely induced in enclosed or semienclosed bodies of water worldwide, and that some of the resulting deposits (e.g., ref. 46) might be mistakenly attributed to tsunami.

Additional (remote) scenarios could potentially have coincided with ejecta arrival, with unknown affects or influence on the propagation of a seiche. For example, previous studies have suggested that the temperature differential caused by interaction of ejecta with the atmosphere, which could have had a marked effect on a ~4,000-km-diameter area around the Chicxulub crater, was capable of rapidly inducing violent meteorological events (47). The projected gale-force winds would have largely cooccurred with ejecta arrival (47) and, if so, could have affected the WIS during the same time interval as the Tanis depositional event. Similarly, strong seismic ground motion could have caused landsliding in the WIS near Tanis, resulting in a local surge deposit. Although such mechanisms have not been quantified sufficiently in terms of either amplitude or timing, they might be considered as potentially testable hypotheses in future studies. At this point, we consider a seiche to be the most obvious and best-supported mechanism to explain the Tanis Event Deposit.

Observations at Tanis expand our knowledge of the Chicxulub impact's damaging effects and their far-reaching scope. The highly probable link between impact-induced seismic shaking and the onshore inundation surge at Tanis reveals an important additional mechanism by which the Chicxulub impact could have caused catastrophic conditions in the Western Interior, and possibly worldwide, far from the impact site. Thus, we identify a potential additional mechanism for abrupt, extensive damage to widely spaced regions and ecologies. The global extinction event, therefore, could have had a rapidly delivered precursor, both at the local and global scales, minutes after impact.

Materials and Methods

Analyses of Major and Trace Elements. Geochemical analysis of ejecta was carried out at the Florida Center for Analytical Electron Microscopy and Activation Laboratories Ltd. via laser-ablation, inductively coupled plasma mass spectroscopy (LA-ICP-MS), ICP-MS, and energy-dispersive spectroscopy (EDS). LA-ICP-MS utilized a Perkin-Elmer Sciex ELAN DRC II under standard operating parameters (*SI Appendix*, Table S1), coupled to a laser-ablation unit (New Wave, 213 nm, UP-213). The data were reduced using GLITTER data reduction software (GEMOC). ICP-MS utilized a ThermoFisher Element

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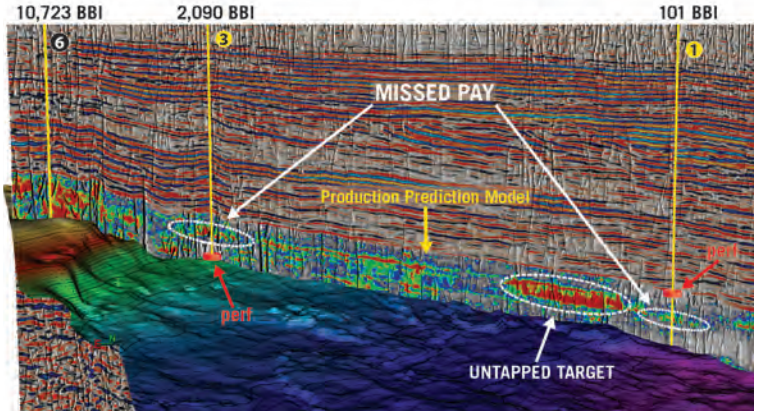

An arbitrary line through 3 vertical wells in the West Texas Permian Basin shows the lateral variations of the Production Prediction Model and reveals refrac potential for Wells 1 and 3 where the red disks indicate the actual completion intervals and the white circles highlight the missed pay. Note the untapped target near Well 1.

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2, and PGE concentrations were measured following the methods of Becker et al. (48). EDS was carried out on a JEOL 8900r equipped with five wavelength-dispersive spectrometers. The measurements were counted for 10-s periods at 20 nA, 15 kV.

Scanning Electron Microscopy. Scanning electron microanalysis was carried out at on a JEOL 8900r operated at 15 kV, and specimens were examined via electron backscatter, secondary electron imaging, and EDS.

Micro-CT. Micro-computed tomography (micro-CT) analysis was performed using a 5-μm-resolution scanner via a transmission-type X-ray source operated at 70 kV and 100 μA. Resolution for each specimen was a voxel size of ~5 to 10 μm, and 3D reconstructions and meshes were assembled in Avizo 8.1 and in the reconstruction software Octopus.

Grain Size. For grain-size fractions above 370 μm, traditional sieving techniques were employed; sediment finer than 370 μm was quantified using a hydrometer following standard procedures. Three identical samples from each stratigraphic sampling level were analyzed and then averaged to produce the final values. Graphs of grain-size distribution were generated for each sampled interval, and average grain sizes for each interval were graphed for the total stratigraphic thickness of the deposit.

$^{40}Ar/^{39}Ar$ Dating. Unaltered impact glass was dated using $^{40}Ar/^{39}Ar$ geochronology. Single grains of impact-melt glass were irradiated together with Beloc tektite and IrZ sanidine for 18 h at the Oregon State University TRIGA reactor in the cadmium-shielded cadmium-lined in-core irradiation tube facility. Sanidine from the IrZ bentonite, located a few centimeters above KPg (49) and ~300 km northwest of Tanis, is used as standard. If the impact-melt glass from Tanis originated from the Chixculub impact, all samples (Tanis, Beloc, and IrZ) should yield the same $^{40}Ar^*/^{39}Ar_K$ ratio corrected for small neutron flux gradients and their corresponding R value, or $(^{40}Ar^*/^{39}Ar_K)_{tektite}/(^{40}Ar^*/^{39}Ar_K)_{IrZ} = 1$. The age calibration model (e.g., refs. 32, 50, and 51) is not relevant for this purpose, but the calibration model of ref. 32 is used to calculate ages. $^{40}Ar/^{39}Ar$ analyses were performed at the geochronology laboratory of the Vrije University Amsterdam. Single glass shards or sanidine was fused with a Synrad CO_2 laser beam, and released gas was exposed to NP10 and St172 getters and analyzed on a Helix MC noble-gas mass spectrometer. The five argon isotopes were measured simultaneously with ^{40}Ar on the H2-Faraday position with a 10^{13} Ω resistor amplifier, ^{39}Ar on the H1-Faraday with a 10^{13} Ω resistor amplifier, ^{38}Ar on the AX-compact discrete dynode (CDD), ^{37}Ar on the L1-CDD, and ^{36}Ar on the L2-CDD. Gain calibration is done by peak jumping a CO_2 reference beam on all detectors in dynamic mode. All intensities are corrected relative to the L2 detector. Air pipettes are run every 10 h and are used for mass discrimination corrections. The atmospheric air value of 298.56 from Lee et al. (52) is used. Detailed analytical procedures for the Helix MC are described in Monster (53). The correction factors for neutron interference reactions are $(2.64 \pm 0.02) \times 10^{-4}$ for $(^{36}Ar/^{37}Ar)_{Ca}$, $(6.73 \pm 0.04) \times 10^{-4}$ for $(^{39}Ar/^{37}Ar)_{Ca}$, $(1.21 \pm 0.003) \times 10^{-2}$ for $(^{38}Ar/^{39}Ar)_K$, and $(8.6 \pm 0.7) \times 10^{-4}$ for $(^{40}Ar/^{39}Ar)_K$. All errors are quoted at the 2σ level and include all analytical errors. All relevant analytical data for age calculations are found in *SI Appendix*, Table S2.

Light Microscopy, Thin Sections. Thin sections for optical microscopy and electron microprobe analysis were prepared by National Petrographic Services, Houston, Texas, using standard procedures. Initial observations were made with an Optima ZM-160AT dissecting scope and an Ernst Leitz Wetzlar light microscope; traditional petrographic observations were made with an Olympus BH2 and Leica DM750P in normal, polarized, and cross-polarized light.

Palynology. Palynological slides were prepared by Global Geolabs Ltd., Medicine Hat, Canada, using standard palynological processing procedures. A 10% solution of HCl was added to each polypropylene beaker of sediment. After dissolution of carbonate fractions, HCl was decanted and replaced with distilled water, which was decanted and replaced several times to remove any remaining calcium ions. A 70% solution of HF was added before centrifuging at 4,450 × *g* for 5 min. After removal of HF and neutralization of the residue, 25 mL of $ZnBr_2$ was added, and the tube was ultrasonicated for approximately 10 s. Specimens were allowed to sit for 10 min and then centrifuged at 4,450 × *g* for 15 min. Buoyant "float" was removed and centrifuged for an additional 2 min. In a 20-mL glass tube, 3 mL of Schultz solution was added, vortex-mixed, and placed in hot bath. Schultz solution was removed and neutralized via multiple steps of centrifuging and washing, and a 10% solution of NN_4OH was added for 2 min. This was then neutralized via multiple steps of centrifuging and washing. Note: the marine dinocysts are incredibly fragile and thin walled; they can degrade rapidly with excessive use of this last oxidation step, leading to underrepresentation in the finished slides. The sieved fractions were pipetted onto a slide and mixed with polyvinyl alcohol. After drying of the polyvinyl alcohol, one drop of clear casting resin was added, followed by a coverslip.

Isotope Geochemistry. Powdered samples were analyzed with a Gas Bench II linked to a Thermo Finnigan dual-inlet MAT 253 Stable Isotope Ratio Mass Spectrometer. Isotopic data were reported according to the VPDB international standard, with analytical precision to ±0.4‰.

Isolation of Ejecta Particles. Ejecta spherules and shocked quartz were primarily retrieved via bulk sediment processing using standard sieving procedures, but this led to underrepresentation of spherules due to tendency of the delicate smectite to fracture and disintegrate when subjected to the rigors of disaggregating, washing, and sieving. When practical, spherules and spherule lenses were also handpicked from the outcrop or gills of fish carcasses during the extensive excavations. Relict impact glass and shocked quartz were recovered through sieving, and glass was also directly removed from the cores of some partially altered clay spherules. Sieved sediment ≤500 μm was subjected to magnetic separation to recover microkrystites. Several ejecta spherules were isolated from amber specimens via gentle crushing of the amber with a wooden laboratory spatula, and the remaining amber fragments were saved in a clean vial for later analysis.

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1. Alvarez LW, Alvarez W, Asaro F, Michel HV (1980) Extraterrestrial cause for the Cretaceous-Tertiary extinction. *Science* 208:1095–1108.
2. Smit J (1999) The global stratigraphy of the Cretaceous-Tertiary boundary impact ejecta. *Annu Rev Earth Planet Sci* 27:75–113.
3. Pierazzo E, Kring DA, Melosh HJ (1998) Hydrocode simulation of the Chicxulub impact event and the production of climatically active gases. *J Geophys Res* 103:28607–28625.
4. Byrnes J, Karlstrom L (2018) Anomalous K-Pg-aged seafloor attributed to impact-induced mid-ocean ridge magmatism. *Sci Adv* 4:eaao2994.
5. Sleep N, Olds E (2018) Remote faulting triggered by strong seismic waves from the Cretaceous-Paleogene asteroid impact. *Seismol Res Lett* 89:570–576.
6. Denne R, et al. (2013) Massive Cretaceous-Paleogene boundary deposit, deep-water Gulf of Mexico: New evidence for widespread Chicxulub-induced slope failure. *Geology* 41:983–986.
7. Richards MA, et al. (2015) Triggering the largest Deccan eruptions by the Chicxulub impact. *Geol Soc Am Bull* 127:1507–1520.
8. Maurrasse FJ, Sen G (1991) Impacts, tsunamis, and the Haitian Cretaceous-Tertiary boundary layer. *Science* 252:1690–1693.
9. Smit J, et al. (1992) Tektite-bearing, deep-water clastic unit at the Cretaceous-Tertiary boundary in northeastern Mexico. *Geology* 20:99–103.
10. Witts J, et al. (2018) A fossiliferous spherule-rich bed at the Cretaceous-Paleogene (K-Pg) Boundary in Mississippi, USA: Implications for the K-Pg mass extinction event in the Mississippi embayment and eastern Gulf Coastal Plain. *Cretac Res* 91:147–167.
11. Johnson KR, Nichols DJ, Hartman JH (2002) Hell Creek Formation: A 2001 synthesis. *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*, eds Hartman JH, Johnson KR, Nichols DJ (Geolog Soc Am, Boulder, CO), Vol 361, pp 503–510.

12. Fastovsky D (1987) Paleoenvironments of vertebrate-bearing strata during the Cretaceous-Paleogene transition, eastern Montana and western North Dakota. *Palaios* 2:282–295.
13. Kennedy W, Landman N, Christensen W, Cobban W, Hancock J (1998) Marine connections in North America during the late Maastrichtian: Palaeogeographic and palaeobiogeographic significance of *Jeletzkytes nebrascensis* zone cephalopod fauna from the Elk Butte member of the Pierre Shale, SE South Dakota and NE Nebraska. *Cretac Res* 19:745–775.
14. Cochran K, Landman N, Turekian K, Michard A, Schrag D (2003) Paleoceanography of the Late Cretaceous (Maastrichtian) Western Interior Seaway of North America: Evidence from Sr and O isotopes. *Palaeogeogr Palaeoclimatol Palaeoecol* 191:45–64.
15. Landman N, Johnson R, Edwards L (2004) Cephalopods from the Cretaceous/Tertiary boundary interval on the Atlantic Coastal Plain, with a description of the highest ammonite zones in North America. Part 2. Northeastern Monmouth County, New Jersey. *Bull Am Mus Nat Hist* 287:1–107.
16. Bartlett JA (2004) Taphonomy, geology, and paleoecology of the Sandy Site, an exceptional assemblage in the Maastrichtian Hell Creek Formation of South Dakota. Master's thesis (North Carolina State University, Raleigh, NC).
17. Schulte P, Speijer R, Mai H, Kontny A (2006) The Cretaceous-Paleogene (K-P) boundary at Brazos, Texas: Sequence stratigraphy, depositional events and the Chicxulub impact. *Sediment Geol* 184:77–109.
18. Hartman JH, Kirkland JI (2002) Brackish and marine mollusks of the Hell Creek Formation of North Dakota: Evidence for a persisting Cretaceous seaway. *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*, eds Hartman JH, Johnson KR, Nichols DJ (Geolog Soc Am, Boulder, CO), Vol 361, pp 271–296.
19. Hoganson JW, Murphy EC (2002) Marine Breien member (Maastrichtian) of the Hell Creek Formation in North Dakota: Stratigraphy, vertebrate fossil record, and age. *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*, eds Hartman JH, Johnson KR, Nichols DJ (Geolog Soc Am, Boulder, CO), Vol 361, pp 247–269.
20. Jeletzky JA (1965) Taxonomy and phylogeny of fossil Coleoida (=Dibranchiata) (Geological Survey of Canada, Ottawa), Paper 65-2, Vol 42, pp 72–76.
21. Wroblewski A (2004) New Selachian paleofaunas from "fluvial" deposits of the Ferris and lower Hanna formations (Maastrichtian-Selandian: 66-58 Ma), southern Wyoming. *Palaios* 19:249–258.
22. Landman N, Remin Z, Garb M, Chamberlain J, Jr (2013) Cephalopods from the Badlands National Park area, South Dakota: Reassessment of the position of the Cretaceous/Paleogene boundary. *Cretac Res* 42:1–27.
23. Bohor BF, Foord EE, Modreski PJ, Triplehorn DM (1984) Mineralogic evidence for an impact event at the cretaceous-tertiary boundary. *Science* 224:867–869.
24. Nichols DJ (2002) Palynology and palynostatigraphy of the Hell Creek Formation in North Dakota: A microfossil record of plants at the end of Cretaceous time. *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: an Integrated Continental Record of the End of the Cretaceous*, eds Hartman JH, Johnson KR, Nichols DJ (Geolog Soc Am, Boulder, CO), Vol 361, pp 393–456.
25. Bercovici A, Vajda V, Sweet A (2012) Pollen and spore stratigraphy of the Cretaceous-Paleogene mass-extinction interval in the Northern Hemisphere. *J Stratigr* 36: 166–178.
26. Jobe Z, Lowe D, Morris W (2012) Climbing-ripple successions in turbidite systems: Depositional environments, sedimentation rates and accumulation times. *Sedimentology* 59:867–898.
27. Bermudez H, et al. (2015) The Cretaceous-Paleogene boundary at Gorgonilla Island, Colombia, South America. *Terra Nova* 28:83–90.
28. Klaus A, et al. (2000) Impact-induced mass wasting at the K-T boundary: Blake Nose, western North Atlantic. *Geology* 28:319–322.
29. Grande L, Bemis W (1991) Osteology and phylogenetic relationships of fossil and recent paddlefishes (Polyodontidae) with comments on the interrelationships of Acipenseriformes. *J Vertebr Paleontol* 11:1–121.
30. Belza J, et al. (2015) High spatial resolution geochemistry and textural characteristics of 'microtektite' glass spherules in proximal Cretaceous–Paleogene sections: Insights into glass alteration patterns and precursor melt lithologies. *Geochim Cosmochim Acta* 152:1–38.
31. Kuiper KF, et al. (2008) Synchronizing rock clocks of Earth history. *Science* 320: 500–504.
32. Sprain C, Renne P, Wilson G, Clemens W (2014) High-resolution chronostratigraphy of the terrestrial Cretaceous-Paleogene transition and recovery interval in the Hell Creek region, Montana. *Geol Soc Am Bull* 127:393–409.
33. Alvarez W, Claeys P, Kieffer SW (1995) Emplacement of Cretaceous-Tertiary boundary shocked quartz from chicxulub crater. *Science* 269:930–935.
34. Alvarez W (1996) Trajectories of ballistic ejecta from the Chicxulub crater. *Spec Pap Geol Soc Am* 307:141–150.
35. Kring D, Durda D (2002) Trajectories and distribution of material ejected from the Chicxulub impact crater: Implications for postimpact wildfires. *J Geophys Res* 107: 6-1–6-22.
36. Johnson KR (2002) Megaflora of the Hell Creek and lower Fort Union Formations in the western Dakotas: Vegetational response to climate change, the Cretaceous-Tertiary boundary event, and rapid marine transgression. *The Hell Creek Formation and the Cretaceous-Tertiary Boundary in the Northern Great Plains: An Integrated Continental Record of the End of the Cretaceous*, eds Hartman JH, Johnson KR, Nichols DJ (Geolog Soc Am, Boulder, CO), Vol 361, pp 329–392.
37. Morton R, Gelfenbaum G, Jaffe B (2007) Physical criteria for distinguishing sandy tsunami and storm deposits using modern examples. *Sediment Geol* 200:184–207.
38. Slimani H, Louwye S, Dusar M, Lagrou D (2011) Connecting the Chalk Group of the Campine Basin to the dinoflagellate cyst biostratigraphy of the Campanian to Danian in borehole Meer (northern Belgium). *Neth J Geosci* 90:129–164.
39. Schiøler P, Wilson G (1993) Maastrichtian dinoflagellate zonation in the Dan Field, Danish North Sea. *Rev Palaeobot Palynol* 78:321–351.
40. Peters R, Jaffe B (2010) Identification of tsunami deposits in the geologic record: Developing criteria using recent tsunami deposits (U.S. Geological Survey, Reston VA), Open-File Report 2010–1239.
41. Matsumoto D, et al. (2008) Truncated flame structures within a deposit of the Indian Ocean tsunami: Evidence of syn-sedimentary deformation. *Sedimentology* 55: 1559–1570.
42. Srinivasalu S, et al. (2009) Characteristics of 2004 tsunami deposits of the northern Tamil Nadu coast, southeastern India. *Bol Soc Geol Mex* 61:111–118.
43. Bondevik S, Gjevik B, Sorensen M (2013) Norwegian seiches from the giant 2011 Tohoku earthquake. *Geophys Res Lett* 40:3374–3378.
44. Meschede M, Myhrvold C (2011) Antipodal focusing of seismic waves due to large meteorite impacts on Earth. *Geophys J Int* 187:529–537.
45. Day S, Maslin MA (2005) Linking large impacts, gas hydrates, and carbon isotope excursions through wide-spread sediment liquefaction and continental slope failure: The example of the K-T boundary event. *Large Meteorite Impacts III*, eds Kenkmann T, Hörz F, Deutsch A (Geolog Soc Am, Boulder, CO), Vol 384, pp 239–258.
46. Korbar T, et al. (2017) Potential Cretaceous-Paleogene boundary tsunami deposit in the intra-Tethyan Adriatic carbonate platform section of Hvar (Croatia). *Geol Soc Am Bull* 127:1666–1680.
47. Kring DA, Showman AP, Durda DD (2005) Global winds and aerosol updrafts created by the Chicxulub impact event. 36th Lunar and Planetary Science Conference (Lunar and Planetary Institute, Houston), Abstract 1544. Available at https://www.lpi.usra.edu/meetings/lpsc2005/pdf/1544.pdf. Accessed February 2, 2019.
48. Becker H, et al. (2006) Highly siderophile composition of the Earth's primitive upper mantle: Constraints from new data on peridotite massifs and xenoliths. *Geochim Cosmochim Acta* 70:4528–4550.
49. Renne PR, et al. (2013) Time scales of critical events around the Cretaceous-Paleogene boundary. *Science* 339:684–687.
50. Renne P, Balco G, Ludwig K, Mundil R, Min K (2011) Response to the comment by W.H. Schwarz et al. on "Joint determination of ^{40}K decay constants and $^{40}Ar^*/^{40}K$ for the Fish Canyon sanidine standard, and improved accuracy for $^{40}Ar/^{39}Ar$ geochronology" by Renne et al. (2010). *Geochim Cosmochim Acta* 75:5097–5100.
51. Renne P, Mundil R, Balco G, Min K, Ludwig K (2010) Joint determination of ^{40}K decay constants and $^{40}Ar^*/^{40}K$ for the Fish canyon sanidine standard, and improved accuracy for $^{40}Ar/^{39}Ar$ geochronology. *Geochim Cosmochim Acta* 74:5349–5367.
52. Lee J-Y, et al. (2006) A redetermination of the isotopic abundances of atmospheric Ar. *Geochim Cosmochim Acta* 70:4507–4512.
53. Monster MWL (2016) Multi-method palaeointensity data of the geomagnetic field during the past 500 kyrs from European volcanoes. PhD thesis (Utrecht University, Utrecht, The Netherlands).

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Estes Cove
Fulton Beach
Goose Island
Half Moon Reef
Nine Mile Point
Rockport, West
St. Charles
Tally Island
Tract 831-G.O.M. (offshore)
Virginia

BEE COUNTY
Caesar
Mosca
Nomanna
Orangedale(2)
Ray-Wilcox
San Domingo
Tulsita Wilcox
Strauch_Wilcox

BROOKS COUNTY
Ann Mag
Boedecker
Cage Ranch
Encintas
ERF
Gyp Hill
Gyp Hill West
Loma Blanca
Mariposa
Mills Bennett
Pita
Tio Ayola
Tres Encinos

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Coloma Creek, North
Heyser
Lavaca Bay
Long Mott
Magnolia Beach
Mosquito Point
Olivia
Panther Reef
Powderhorn
Seadrift, N.W.
Steamboat Pass
Webb Point
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Luttes
San Martin (2)
Three Islands, East
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Cook
Nordheim
Smith Creek
Warmsley
Yorktown, South

DUVAL COUNTY
DCR-49
Four Seasons
Good Friday
Hagist Ranch
Herbst
Loma Novia
Petrox
Seven Sisters
Seventy Six, South
Starr Bright, West

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Berclair
North Blanconia
Bombs
Boyce
Cabeza Creek, South
Goliad, West
St Armo
Terrell Point

HIDALGO COUNTY
Alamo/Donna
Donna
Edinburg, West
Flores-Jeffress
Foy
Hidalgo
LA Blanca
McAllen& Pharr
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Mercedes
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Penitas
San Fordyce
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San Salvador
S. Santallana
Shary
Tabasco
Weslaco, North
Weslaco, South

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LaWard, North
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Maurbro
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Hoelsher
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Coy City
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Runge

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Candelaria
Julian
Julian, North
Laguna Madre
Rita
Stillman

KLEBERG COUNTY
Alazan
Alazan, North
Big Caesar
Borregos
Chevron (offshore)
Laguna Larga
Seeligson
Sprint (offshore)

LA SALLE COUNTY
Pearsall
HAWKVILLE:EAGLEFORD

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Hope
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Houdman
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Lucille
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White Creek
White Creek, East

MATAGORDA COUNTY
Collegeport

MCMULLEN COUNTY
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Brazil
Devil's Waterhole
Hostetter
Hostetter, North

NUECES COUNTY
Agua Dulce (3)
Arnold-David
Arnold-David, North
Baldwin Deep
Calallen
Chapman Ranch
Corpus Christi, N.W.
Corpus Christi West C.C.
Encinal Channel
Flour Bluff/Flour Bluff, East
GOM St 9045(offshore)
Indian Point
Mustang Island
Mustang Island, West
Mustang Island St. 889S(offshore)
Nueces Bay/Nueces Bay West
Perro Rojo
Pita Island
Ramada
Redfish Bay
Riverside
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Saxet
Shield
Stedman Island
Turkey Creek

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Odem
Plymouth
Portilla (2)
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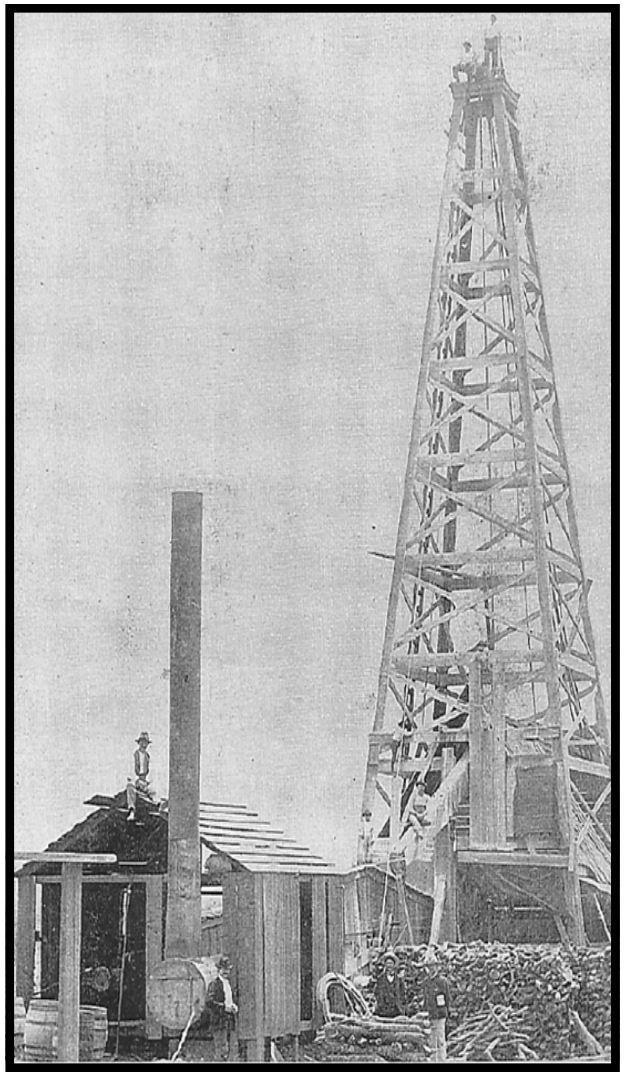

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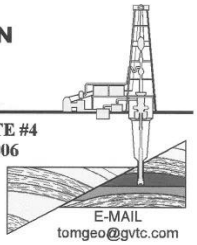

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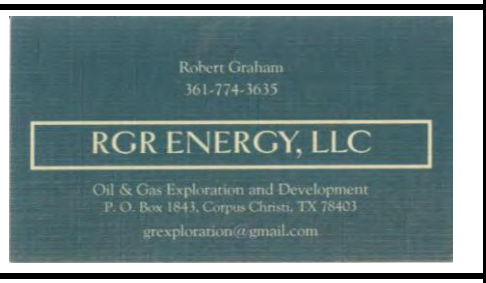

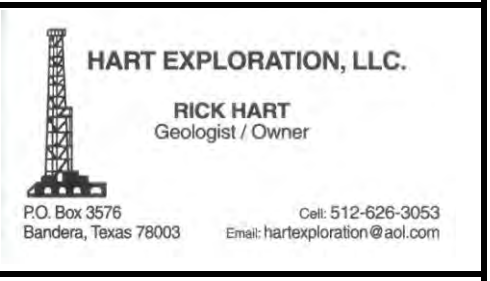

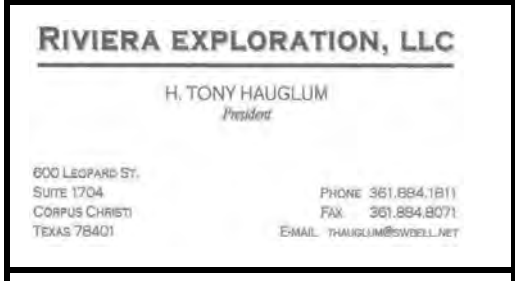

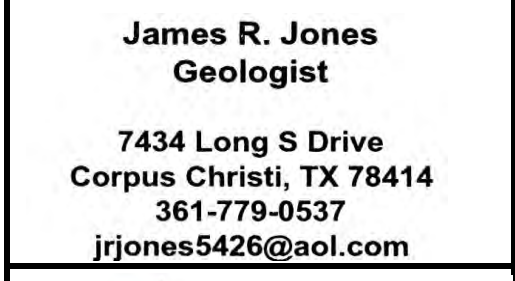

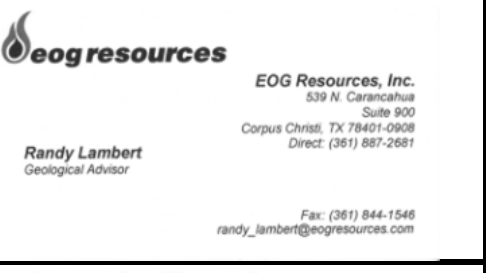

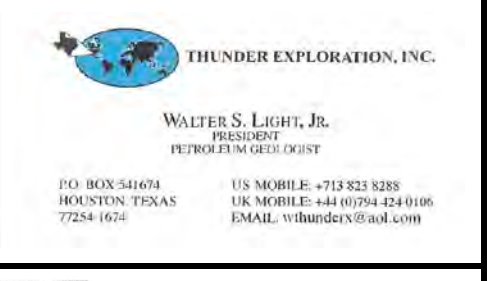

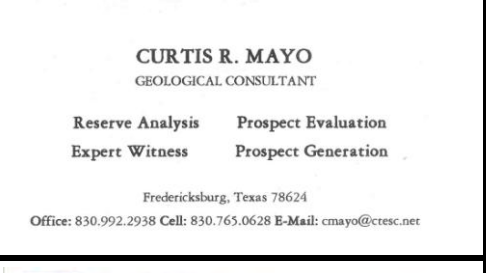

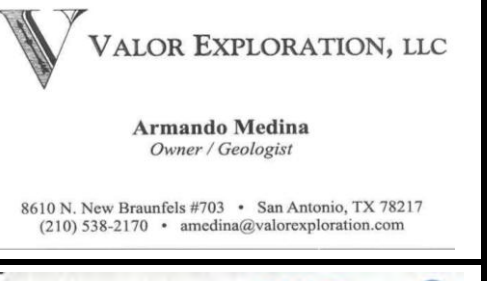

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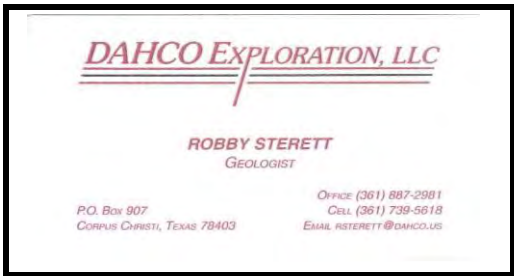
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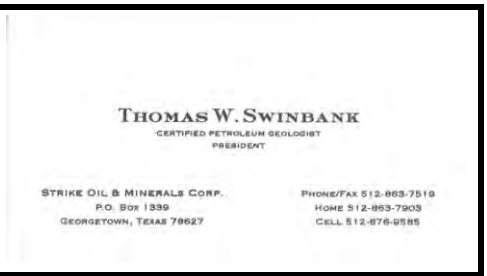
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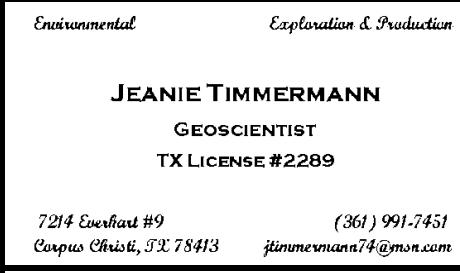
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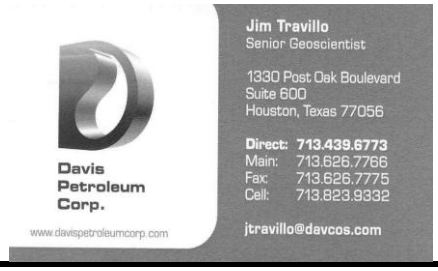
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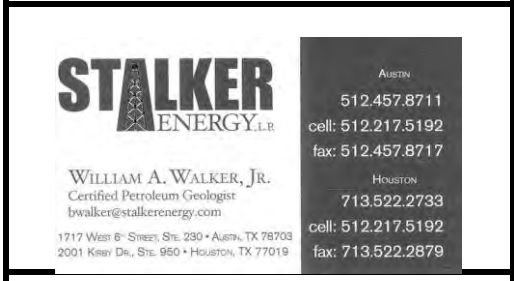
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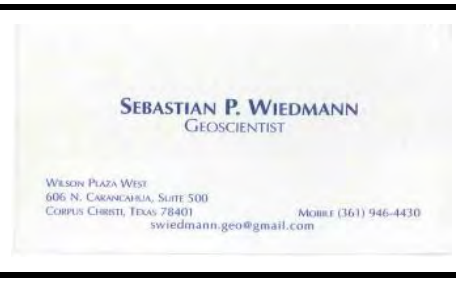
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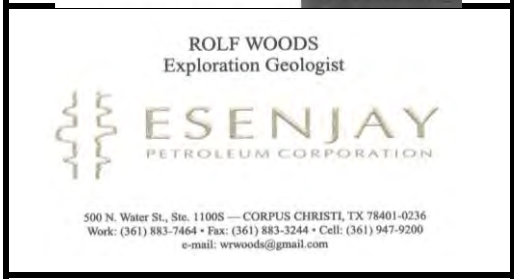
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