COMMITTEES

2006 EXECUTIVE COMMITTEE

President - Jennifer Lindline .............................. New Mexico Highlands University
Vice President - Lewis Land .............................. New Mexico Bureau of Geology & Mineral Resources
Treasurer - Shari Kelley ........................................ New Mexico Bureau of Geology & Mineral Resources
Secretary - Kate E. Zeigler .............................. University of New Mexico
Past President - Jeffrey M. Amato ................................ New Mexico State University

FIELD CONFERENCE
Lewis Land, Chair .................................................. New Mexico Bureau of Geology and Mineral Resources
Penny Boston ............................................................. New Mexico Institute of Mining and Technology
Bill Raatz ........................................................................................................... Oxy Permain, Houston, TX
Dave Love ................................................................. New Mexico Bureau of Geology and Mineral Resources

GUIDEBOOK
Lewis Land, Chair .................................................. New Mexico Bureau of Geology and Mineral Resources
Penny Boston ............................................................. New Mexico Institute of Mining and Technology
Bill Raatz ........................................................................................................... Oxy Permain, Houston, TX
Dave Love ................................................................. New Mexico Bureau of Geology and Mineral Resources
Virgil W. Lueth, Managing Editor .......................... New Mexico Bureau of Geology and Mineral Resources

ROAD LOGS
Lewis Land, Chair .................................................. New Mexico Bureau of Geology and Mineral Resources
Dave Love ................................................................. New Mexico Bureau of Geology and Mineral Resources
Victor Polyak ......................................................................................... University of New Mexico
Peter Scholle ............................................................. New Mexico Bureau of Geology and Mineral Resources
Dana Ulmer-Scholle .................................................... New Mexico Institute of Mining and Technology

REGISTRATION
Maureen Wilks ............................................................. New Mexico Bureau of Geology and Mineral Resources
Lynne Hemenway ............................................................. New Mexico Bureau of Geology and Mineral Resources

LOCAL ARRANGEMENTS
Kate E. Zeigler ............................................................. University of New Mexico

PUBLICATIONS COMMITTEE
Maureen Wilks, Chair .................................................. New Mexico Bureau of Geology and Mineral Resources
Barry Kues ......................................................................................... University of New Mexico
Spencer Lucas ........................................................................ New Mexico Museum of Natural History and Science
Virgil W. Lueth, Managing Editor ........................................ New Mexico Bureau of Geology and Mineral Resources
L. Greer Price ................................................................. New Mexico Bureau of Geology and Mineral Resources

PUBLICATIONS SALES
Maureen Wilks ............................................................. New Mexico Bureau of Geology and Mineral Resources
Ina Crawford ............................................................. New Mexico Bureau of Geology and Mineral Resources
Lynne Hemenway ............................................................. New Mexico Bureau of Geology and Mineral Resources

SCHOLARSHIP
Robert Myers, Chair .................................................. White Sands Missile Range
CONTENTS

Dedication ................................................................................................................................................................................................ vi
President's Message .............................................................................................................................................................................. vii
Conference Organizers' Message .........................................................................................................................................................viii
Field Conference Schedule .................................................................................................................................................................... ix

ROAD LOGS

CAPITAN REEF, BACKREEF, AND MCKITTRICK HILL CAVES - First-day road log, Trip 1, Washington Ranch to Dark Canyon, Mosley Canyon, and Queen Highway, through Indian Basin and Rocky Arroyo, to Azotea Mesa and the McKittick Hill Caves, and return to Washington Ranch by way of Happy Valley ........................................ Lewis Land, David Love, and Victor Polyak 1

MINIPAPERS
Geologic walking tour of Washington Ranch ......................................................... Lewis Land and David Love 15

SLAUGHTER CANYON CAVE AND BLACK RIVER VALLEY - First-day road log, Trip 2, Washington Ranch to Lower Slaughter Canyon, Slaughter Canyon Cave, and Black River Valley ...................... Lewis Land, Dave Love and Victor Polyak 17

MINIPAPERS
The Mouth of Slaughter Canyon .............................................................. Alton Brown 22
Old bat guano in Slaughter Canyon Cave .......... Victor J. Polyak, Yemane Asmerom, and Jessica B.T. Rasmussen 23

WALNUT CANYON AND CARLSBAD CAVERN - First-day, Trip 3, Washington Ranch to Whites City, Walnut Canyon, and Carlsbad Cavern Peter A. Scholle and Dana S. Ulmer-Scholle 25

MINIPAPERS
Unresolved problems with sulfate speleogenesis of Carlsbad Cavern ...................... Alton Brown 36
An unknown crust beneath your feet: Cave pool precipitates of Lower Cave, Carlsbad Cavern, New Mexico ............................................ Leslie A. Melina, Andy Brehm, Ginny Rust, Neil Shannon, and Diana E. Northup 38
Partnering with biologists: Better answers through collaboration ...................... Diana E. Northup 41

COTTONWOOD CAVE - First-day road log, Trip 4, Washington Ranch to Dark Canyon, Mosley Canyon, Queen Highway (NM 137) Queen, Klondike Gap, and Cottonwood Cave ........................................ Lewis Land, David Love, and Victor Polyak 43

MINIPAPERS
Three Permian Series .................................................................................. Spencer G. Lucas 60
Ochoa Group, not Series or Stage, Upper Permian of west Texas and southeastern New Mexico Spencer G. Lucas 62
Occurrences of the fusulinid Yabeina texana in the basal parts of the Tansill Formation and Lamar Limestone Member in the Guadalupe Mountains area, west Texas and New Mexico ........................................... Willis W Tyrrell, Jr., Gorden L. Bell, Jr., John A. Diemer, and Merlvd K. Nestell 64
Thickness variations in the Lamar Limestone and Reef Trail Members of the Bell Canyon Formation, Northwestern Delaware Basin, New Mexico and west Texas ............................................ Willis W Tyrrell, Jr, John A. Diemer, Gordon L. Bell, Jr., and Richard J. Bichsel 67
Regional map of highstand phase of Lower Seven Rivers - Hegler high frequency sequence (HFS) in southeast New Mexico ...................... Willis W Tyrrell, Jr, John A. Diemer, Gordon L. Bell, Jr., and Richard Bichsel 70
Delaware (Lamar) Limestone Roadcut Alton Brown 73
The Bentonite-bearing Manzanita Limestone Member, Cherry Canyon Formation, exposed in a Patterson Hills road cut, Culberson County, Texas John A. Diemer, Willis W. Tyrrell, Jr., Gorden L. Bell, 11.; David H. Griffing 75
Halite depositional cycles in the Upper Permian Salado Formation ......................................................... Robert M. Holt, Dennis W Powers, and Tim K. Lowenstein 78
Pangean monsoon and climatic cycles in NM-Texas State-Line outcrop ...................... Roger K Anderson 80
Gypsum karst of the Chosa Draw area ................................................................. Kevin W Stafford 82
GYPSUM KARST PROCESSES IN THE SEVEN RIVERS FORMATION - **Third-day road log**, Living Desert State Park turnoff at US 285, north to Brantley Dam and Lake McMillan, through Artesia, Lake Arthur, Hagerman, Dexter, and ending at Bottomless Lakes State Park ...................................................................................................................... *Lewis Land and David Love* 85

**MINIPAPERS**

- Bottomless Lakes State Park ................................................................................................................... *Virginia T McLemore* 93
- Hydrogeology of Bottomless Lakes State Park ......................................................................................... *Lewis Land* 95

WASHINGTON RANCH THROUGH SOUTH CARLSBAD AND HAPPY VALLEY, ACROSS TRACY DOME, TO INTERSECTION OF US 285 - **Third-day supplemental road log 1** ........................................................................................................................................ *Lewis Land* 97

BOTTOMLESS LAKES STATE PARK, ACROSS THE PECOS SLOPE ADN INTO THE NORTHERN SACRAMENTO MOUNTAINS TO FORT STANTON CAVE - **Third-day supplemental road log 2** ........................................................................... *Lewis Land* 101

**ROAD LOG REFERENCES** ......................................................................................................................................................................................................................... 107

**COLOR PLATES**

Sixteen color plates that supplement the road logs and articles ........................................................................................................................................................................................................................................... 108

**ARTICLES**

**Geologic Overview**

- Geologic Studies of the Guadalupe Mountains area, New Mexico and west Texas, to 1928 ..................... *Barry S. Kues* 127
- Geology of the Guadalupe Mountains: An overview of recent ideas ............................................................... *Carol A. Hill* 145

**Cave Features**

- Trail guide to and discussion of the geology of Carlsbad Cavern: Main Corridor and Big Room ................. *Michael Queen and Louise D. Hose* 151
- Ferromanganese deposits in the caves of the Guadalupe Mountains ......................................................... *Michael N. Spilde, Diana E. Northup, and Penelope J. Boston* 161
- Biothem: Biologically influenced speleothems in caves of the Guadalupe Mountains, New Mexico, USA ......................................................................................................................... *Michael Queen and Leslie A. Melim* 167
- Got moon milk? The characterization of moonmilk in Spider Cave, Carlsbad Caverns National Park, New Mexico .......................................................................................................................... *Morgan Perrone-Vogt and Katherine Giles* 175

**Speleogenesis**

- Observations from active sulfidic karst systems: Is the present the key to understanding Guadalupe Mountain Speleogenesis? .................................................................................................................. *Louise D. Hose and Jennifer L. Macalady* 185
- Support for a sulfuric acid origin for caves in the Guadalupe Mountains, New Mexico .................................. *Arthur N. Palmer* 195
- Alunite and natroalunite tell a story: The age and origin of Carlsbad Cavern, Lechuguilla Cave, and other sulfuric-acid type caves of the Guadalupe Mountains ........................................... *Victor J. Polyak, William C. McIntosh, Paula P Provencio, and Necip Giiven* 203
- Tectonic Influences on speleogenesis in the Guadalupe Mountains, New Mexico and Texas ....................... *Harvey DuChene and Kimberly I. Cunningham* 211
- Recently discovered passages in Fort Stanton Cave, New Mexico, and implications for speleogenesis and regional geomorphic processes in the northern Sacramento Mountains .......................................................................................................................... *Donald G. Davis and Lewis Land* 219

**Geophysics**

- Electrical Resistivity surveys of karst features near Fort Stanton, Lincoln County, New Mexico ................. *John McLean and Barbara Luke* 227
Evaporite Karst

Intrastratal karst at the WIPP Site, southeastern New Mexico ................................................................. Carol A. Hill 233
Assessment of the geological evidence for karst in the Rustler Formation at the WIPP Site ...................... John C. Lorenz 243
Evaporite karst features and processes at Nash Draw, Eddy County, New Mexico ................................................................. Dennis W. Powers, Richard L. Beauheim, Robert M. Holt, and David L. Hughes 253

Stratigraphy and Sedimentology

Advances in depositional models of the Permian Rustler Formation, southeastern New Mexico .................. Dennis W. Powers, Robert M. Holt, Richard L. Beauheim, and Ron G. Richardson 267

Hydrology

Overview of the WIPP groundwater monitoring programs with inferences about karst in the WIPP vicinity ................................................................. Michael B. Hillesheim, Richard L. Beauheim, and Ron G. Richardson 277
Hydrogeology of Hale Spring and evaluation of declining spring discharge, Ruidoso Downs, New Mexico ........................................................................................................................................................................ Jim Riesterer, Paul Drakos, Jay Lazarus, and Mustafa Chudnoff 287

Quaternary Geology

Geomorphology, stratigraphy, and luminescence age of the Mescalero Sands, southeastern New Mexico ........................................................................................................................................................................ Stephen Hall and Ronald J. Goble 297
Surficial geology in the vicinity of Washington Ranch ......................................................................................... David Love and Lewis Land 311

Paleontology

Pleistocene vertebrates from southeastern New Mexico ............................................................................. Gary S. Morgan and Spencer G. Lucas 317

Economic Geology

Mineral deposits in Eddy County, New Mexico, and their relationship to karst processes .......................... Virginia T McLemore 337
DEDICATION

CAROL A. HILL

With great pleasure, we dedicate this volume to geologist Carol Hill in recognition of her substantial and seminal body of work on the Guadalupe Mountains and their caves. During the last 35 years, she has been a major force in catalyzing interest in and study of this area.

Carol began caving in the Guadalupe Mountains after moving to Albuquerque in 1967 with her spouse, physicist Alan Hill and two young children. She began actively studying the mineralogy and geology of this area in 1970 concurrent with her graduate work at the University of New Mexico. An astute observer, Carol is known for her meticulous thoroughness. Her careful investigations have resulted in well over two hundred publications, but her work is far more than simply encyclopedic. Her broad understanding of Delaware Basin geology has made her 1996 PBS-SEPM publication the definitive work on the subject.

In the speleological community, Carol’s 1987 landmark NMBGMR publication on caves of the Guadalupe Mountains’ remains a widely cited classic almost twenty years after its appearance. It is a foundation document that incited much debate and stimulated others to work in the area. She has also played a critical role in the development of the concept of sulfuric acid speleogenesis, of which the Guadalupe Mountain caves are a world class example (e.g. Hill, 1990).3

Carol Hill is well known and highly respected in the international scientific community. Speleologists and mineralogists worldwide owe her a debt for a series of ground-breaking books beginning in 1976 with the publication of "Cave Minerals". Ten years later, in collaboration with Italian cave mineralogist Paolo Forti, Carol produced "Cave Minerals of the World", the first comprehensive volume on this fascinating branch of mineralogy, followed ten years later by a second edition. Probably the vast majority of speleologists in the world have at least one and probably all three of these volumes on their shelves.

A particularly admirable hallmark of Carol’s scientific career has been her outreach into the broader scientific community. She has published in a wide variety of journals and her works are used and cited far beyond the community of cave scientists. She has been a leader in increasing the visibility, quality, and prestige of cave science in the southwestern United States and beyond.

Besides Carol’s work in Carlsbad Caverns National Park, New Mexico and Guadalupe Mountains National Park, Texas, she has conducted research in Kartchner Caverns State Park and Wupatki National Monument, Arizona, Mammoth Cave National Park, Kentucky, Big Bend National Park, Texas, Jewel Cave National Park, South Dakota, the Waste Isolation Pilot Plant (WIPP) site, New Mexico, and Yucca Mountain, Nevada. Since 1998, her primary research has focused on northern Arizona, where she is using cave and karst science to help unravel the complex history of the Grand Canyon.

Over the years, Carol has been a teacher, mentor and gentle critic to many of her colleagues. She is passionate about her work, but always willing to listen to divergent ideas and opinions. She may not agree with your position, but she always encourages you to pursue your ideas. She has the remarkable ability to draw the best out of her colleagues, thereby increasing the scope and value of both her own work and theirs. Carol has accomplished all of this while raising a family of two children and helping Alan run his business in laser research and development! Now grandparents of three, Carol and Alan still reside in Albuquerque, New Mexico. She remains an active adjunct faculty member of the Earth and Planetary Sciences Department at the University of New Mexico.

On behalf of the speleological, mineralogical, and geological communities, we thank Carol for her thirty-five years of sustained and high quality effort to advance the science of this region and its unique international treasures.


Welcome to southeastern New Mexico and the 57th annual Fall Field Conference of the New Mexico Geological Society. This year's conference marks our third venture into the Carlsbad area. Our hosts will share with us a number of wide-ranging geologically and environmentally relevant topics as we explore the subterranean environments of caves; the oil, natural gas, and mineral resources of the area; and the engineering hazards of karst terrain. The hosts for this year's conference are Lewis Land (New Mexico Bureau of Geology and Mineral Resources), Penny Boston (New Mexico Tech), and Bill Raatz (Oxy Permian). Each of these individuals served as editors of the guidebook, along with David Love (New Mexico Bureau of Geology and Mineral Resources) and Kate Ziegler (University of New Mexico). Virgil Lueth once again served as the guidebook's Managing Editor. I recognize all of your countless hours of hard work and thank you for bringing us a professional, high quality publication.

Throughout the conference, attendees will be exposed to the area's regional stratigraphy and features associated with sulfuric acid speleogenesis and cave formation. On the first day, each participant will have a chance to tour at least one of the diverse and magnificent limestone caves of the Guadalupe Mountains – including the world famous Carlsbad Caverns National Park. On the second day, the group will visit Parks Ranch Cave – the second longest gypsum cave in the United States. On the last day, the hosts will share with us hydrology and environmental hazards associated with gypsum karst.

I would like to take this opportunity to thank the many individuals who have contributed to the Society's ongoing success throughout 2006, including Peter Fawcett, Spencer Lucas, Bill McIntosh, Bob Myers, Adam Read, Maureen Wilks, and Tom Williamson. I thank the Spring Meeting Chairs Matthew Heizler and Stacy Timmons for bringing us an informative meeting. I also thank the Board of the Foundation, headed by Paul Catacosinos, for its continued support of scholarships, fellowships, and research grants to both graduate and undergraduate students in New Mexico. The Society acknowledges the continuing support of the New Mexico Bureau of Geology and Mineral Resources. In particular, I thank Peter Scholle, the Bureau's Director, for his support of Society functions and Lynn Hemenway for her support of daily operations.

Like my predecessors, I remain impressed by the participation and commitment of New Mexico geologists to maintaining the quality of our field trips and the distinction of the New Mexico Geological Society. The Society's favorable financial condition and solid reputation are the result of more than 50 years of member participation and contributions. I encourage each and every one of you to volunteer your time and talent to the Society and continue our legacy of being one of the premier geological societies in the nation.

I thank our hosts for their preparation, organization, and coordination of this year's Fall Field Conference. I sincerely hope that you enjoy the fascinating geology, economic wealth, and scenic treasures of southeastern New Mexico's Caves and Karst region.

Jennifer Lindline
CONFERENCE ORGANIZERS’ MESSAGE

Welcome to southeastern New Mexico, the Guadalupe Mountains, and the lower Pecos Valley. The spectacular and remote geology of the Guadalupe Mountains region has been visited only twice by the New Mexico Geological Society, first in 1954, and more recently in 1993. This area of the state is of immense economic and scientific importance due to its prolific oil and gas production and its designation by the International Union of Geological Sciences as a Global Stratotype Section for rocks of middle Permian age. Outcrops in the Guadalupe Mountains provide one of the world’s finest exposed examples of a rimmed carbonate platform margin, as represented by the Capitan Reef and its associated forereef talus, deep basin, and backreef facies. Some fundamental concepts of the Permian stratigraphy of North America were originally developed in this area by workers such as George Shumard, G. H. Girty, and G. B. Richardson, as documented by Barry Kues in his Guidebook paper on early geological investigations in the Guadalupes. Building on this foundation, detailed paleontologic, stratigraphic, sedimentologic, and mapping studies were conducted throughout the mid-twentieth century by such preeminent geoscientists as Phillip B. King, Norman Newell, Phil Hayes, Ward Motts, George Bachman, Vincent Kelley, and Lloyd Pray. These studies helped lay the foundation for the new discipline of carbonate sedimentology.

The Guadalupe Mountains region is also famous for its world-class limestone caves. Two of the largest and deepest known cave systems in North America – Carlsbad Cavern and Lechuguilla Cave – as well as hundreds of other caves, are developed in Permian strata of the Guadalupes. For this reason, "Caves and karst of southeastern New Mexico" has been chosen as the specific theme for this year’s Conference. Beginning in the 1970s, a new paradigm of speleogenesis for caves in the Guadalupe Mountains began to evolve, based on the premise that the large rooms in these caves were of hypogenic origin and had been excavated by ascending waters charged with sulfuric acid, derived from hydrocarbon deposits in the Delaware Basin. The development of this model through the last three decades of the twentieth century was a collaborative effort that included the work of many well known cavers and cave scientists, including Stephen Egemeier, David Jagnow, Kim Cunningham, Michael Queen, Harvey DuChene, Donald Davis, Art Palmer, and Carol Hill, to whom this year’s guidebook is dedicated. In the last fifteen years, there has been increasing scrutiny of the role of microbial processes in cave development, by geoscientists and microbiologists such as Diana Northup, Penelope Boston, Mike Spilde and others. Several of these workers have contributed papers to this year’s Conference Guidebook.

In addition to the well-known limestone caves of the Guadalupes, the Carlsbad region also provides outstanding exposures of gypsum karst developed in the Castile and Seven Rivers Formations. These features include Parks Ranch Cave, the second-longest gypsum cave in the United States. The role of gypsum karst in the hydrology of the lower Pecos Valley will be a second recurring theme of this year’s Conference.

On the first day of the Conference, we will divide into four smaller groups. All four trips on Day One will provide opportunities to examine the results of sulfuric acid speleogenesis, as manifest in some of the finest examples of limestone caves in the southwest. These trips are organized according to degree of difficulty, ranging from the Carlsbad Cavern tour, which will be conducted entirely on paved trails with artificial lighting and an elevator ride back to the surface; to the McKittrick Hill caves, which are undeveloped and will require more physical agility to visit. The second day of the conference will focus on regional geology of the Delaware Basin, and more specifically on gypsum karst of the Castile Formation, culminating in a visit to Chosa Draw and Parks Ranch Cave. The Chosa Draw area contains some of the best exposed examples of epigenetic gypsum karst development on the Gypsum Plain, including epikarst, sinkholes, resurgent springs, skylights, and cavernous porosity. Day Three will emphasize karst hydrology and engineering problems associated with the Seven Rivers gypsum, and will culminate in a visit to the spectacular gypsum cenotes at Bottomless Lakes State Park, east of Roswell.

This year’s Guidebook also includes the first detailed report, by Donald Davis, on the 2001 discovery of the Snowy River pool deposit in Fort Stanton Cave, in the Sacramento Mountains. It has been suggested that the Snowy River deposit, at almost three surveyed km and still going, may be one of the world’s longest cave formations. Because of the distance involved, a trip to Fort Stanton Cave is not practical, but a supplemental road log across the Pecos Slope and northern Sacramentos to Fort Stanton Cave has been provided.

The organizing committee would like to extend their thanks to all those who provided assistance with the Conference this year, including Maureen Wilks, Lynne Hemenway, Dana Ulmer-Scholle, Adam Read, Mark Mansell, Lewis Gillard, Dave McCraw, Leo Gabaldon and many others. We wish particularly to acknowledge the road logging assistance provided by Dave Love and logistical support of Kate Zeigler. This year’s Conference would not have been possible without the support of the New Mexico Bureau of Geology and Mineral Resources and the Bureau’s Director, Peter Scholle. Finally, we would like to acknowledge the outstanding work of our (always smiling) managing editor, Virgil Lueth.

Lewis Land
Penelope Boston
Bill Raatz
FIELD CONFERENCE SCHEDULE

**Wednesday, September 27, 2006 – Pre-conference field trips and registration**
(Field trippers should bring their own lunches)

- 6:15am  Tour of the Waste Isolation Pilot Plant (WIPP)
- 7:00am  Tour of Intrepid potash mine
- 8:00am  Tour of Mosaic potash mine
- 7:00am  McKittrick Canyon Permian Reef geology trail
- 1:00pm  Tour of Nash Draw
- 6:00-9:00pm  Registration and ice-breaker party at Washington Ranch.

**Thursday, September 28, 2006 – First Day: Limestone caves of the Guadalupe Mountains: Carlsbad Cavern, Slaughter Canyon Cave, Cottonwood Cave, and McKittrick Hill Caves**

- 6:00-7:15am  Breakfast (provided)
- 6:00-7:15am  Registration, Washington Ranch.
- 7:15am  Caravans begin leaving Washington Ranch for field trips (lunch provided)
- 6:30pm  Barbecue (provided) at Washington Ranch.

**Friday, September 29, 2006 – Second Day: Regional geology and evaporite karst of the Castile Formation; Parks Ranch Cave**

- 6:00-7:15am  Breakfast (provided)
- 7:30am  Caravan departs Washington Ranch (lunch provided at Chosa Draw)
- 6:00pm  Caravan returns to Washington Ranch.
- 7:00-9:00pm  Annual banquet (provided). Dr. Art Palmer, keynote speaker.

**Saturday, September 30, 2006 – Third Day: Hydrology and engineering hazards of gypsum karst, Seven Rivers Formation**

- 6:00-7:30am  Breakfast (provided)
- 8:15am  Caravan departs Washington Ranch (lunch provided at Bottomless Lakes)
- 2:00pm  Conference ends at Bottomless Lakes State Park, east of Roswell.

**Sunday & Monday, September 31 – October 1, 2006 – Post-conference field trip to challenging caves of the Guadalupe Mountains**