

New Mexico Geological Society

Downloaded from: <https://nmgs.nmt.edu/publications/guidebooks/53>



Front Matter

(Usually includes Dedication, President's Message, & Conference Organizer's Message.)

in:
Geology of White Sands, Lueth, Virgil; Giles, Katherine A.; Lucas, Spencer G.; Kues, Barry S.; Myers, Robert G.; Ulmer-Scholle, Dana; [eds.], New Mexico Geological Society 53rd Annual Fall Field Conference Guidebook, 362 p.
<https://doi.org/10.56577/FFC-53>

This is a section from the 2002 NMGS Fall Field Conference Guidebook.

Annual NMGS Fall Field Conference Guidebooks

Every fall since 1950, the New Mexico Geological Society (NMGS) has held an annual [Fall Field Conference](#) that explores some region of New Mexico (or surrounding states). Always well attended, these conferences provide a guidebook to participants. Besides detailed road logs, the guidebooks contain many well written, edited, and peer-reviewed geoscience papers. These books have set the national standard for geologic guidebooks and are an essential geologic reference for anyone working in or around New Mexico.

Free Downloads

NMGS has decided to make peer-reviewed papers from our Fall Field Conference guidebooks available for free download. This is in keeping with our mission of promoting interest, research, and cooperation regarding geology in New Mexico. However, guidebook sales represent a significant proportion of our operating budget. Therefore, only *research papers* are available for download. *Road logs*, *mini-papers*, and other selected content are available only in print for recent guidebooks.

Copyright Information

Publications of the New Mexico Geological Society, printed and electronic, are protected by the copyright laws of the United States. No material from the NMGS website, or printed and electronic publications, may be reprinted or redistributed without NMGS permission. Contact us for permission to reprint portions of any of our publications.

One printed copy of any materials from the NMGS website or our print and electronic publications may be made for individual use without our permission. Teachers and students may make unlimited copies for educational use. Any other use of these materials requires explicit permission.

This page is intentionally left blank to maintain order of facing pages.

GEOLOGY OF WHITE SANDS

Editors:

Virgil W. Lueth

Katherine A. Giles

Spencer G. Lucas

Barry S. Kues

Robert Myers Dana

S. Ulmer-Scholle



**New Mexico Geological Society
Fifty-third Annual Field Conference
October 3-5, 2002**

CONTENTS

Dedication.....	vi
President's Message.....	vii
Editor's Message	viii
Memorial.....	viii
Committees	ix
Field Conference Schedule and Credits.....	x

ROAD LOGS

First-day road log, from Alamogordo to Tularosa, Mockingbird Gap, Trinity Site, Oscuro, and Three Rivers	1
..... <i>S.G. Lucas, L.W. Lueth, B.S. Kues, R.G. Myers and K.A. Giles</i>	
Minipapers:	
History of the geochronology of the Carrizozo Lava Flows	6
Copper Glance – Estey City's Brief Moment In The Sun	9
M. L. Thompson's Pennsylvanian stratigraphy in the Oscura Mountains, New Mexico.....	15
Lake Trinity	17
The Sierra Blanca Basin	21
Sierra Blanca Coal field, Lincoln and Otero Counties, New Mexico	21
The Three Rivers Petroglyph Site, Otero County, New Mexico.....	26
Second-day road log, from Alamogordo to Tularosa, Rhodes Canyon, Lake Lucero, and return to Alamogordo.....	29
..... <i>K.A. Giles, S.G. Lucas, L.W. Lueth, and R.G. Myers</i>	
Minipapers:	
Forgotten by most – Remembered by a few, the Good Fortune Camp, San Andres Mountains, Sierra County, New Mexico	30
Enigmatic oolitic ironstone in the Cambro-Ordovician Bliss Sandstone	35
Early Ordovician El Paso Formation and late Ordovician Montoya Formation, Rhodes Canyon	35
Upper Pennsylvanian section in Rhodes Canyon	39
Playa lake shorelines and the Holocene history of the White Sands dune field.....	45
Fossil molluscan fauna from Pleistocene Lake Otero, Tularosa basin, southern New Mexico.....	47
..... <i>M.E. Gordon, G.S. Morgan, and S.G. Lucas</i>	
Quaternary flooding of the tularosa basin? - Implications of a soil-water-chloride profile from wsmr	49
Third-day road log, from Alamogordo to White Sands, San Agustin Pass, Organ Quarry, and Tortugas Mountain.....	53
..... <i>V.W. Lueth, S.C. Lucas, K.A. Giles, B.S. Kues</i>	
Minipapers:	
Geoarcheology of the Jarilla Mountain fans and adjacent Tularosa Basin floor	60
Road Log References	74

ARTICLES

Geophysics

Shallow geophysical study of the Grapevine Canyon area, eastern Tularosa Basin: Implications for groundwater resources..	79
..... <i>W.L. Belzer; K.C. Miller, S. Harder</i>	

Structure and Tectonics

Lower Paleozoic isopach maps of southern New Mexico and their implications for Laramide and Ancestral Rocky Mountain tectonism.....	85
..... <i>S. M. Lather and R. W. Harrison</i>	
Evidence for Pennsylvanian transpression from preliminary kinematic fault analysis in the Sacramento Mountains, New Mexico	103
..... <i>A.W. Howell, E.A. Erslev and S. M. Lather</i>	
Paleoseismicity of the Alamogordo Fault along the Sacramento Mountains, Southern Rio Grande Rift, New Mexico	107
..... <i>D.J. Koning and E.J. Pazzaglia</i>	

Volcanology and Igneous Petrology

New Precision topographic measurements from the Carrizozo and McCartys basalt flows, New Mexico	<i>J.R. Zimbelman and A.K. Johnston</i>	121
Geology and geochemistry of the mid-Tertiary alkaline to calc-alkaline intrusions in the northern Hueco Mountains and adjacent areas, McGregor Range, southern Otero County, New Mexico	<i>V.T. McLemore</i>	129

Stratigraphy, Paleontology and Sedimentology

A stratigraphic history of the Tularosa Basin area, south-central New Mexico	<i>W.D. Raatz</i>	141
Cherty facies of the late Ordovician Montoya Group, southern New Mexico and western Texas: Implications for Laurentia oceanography and duration of Gondwana glaciation	<i>M.C. Pope</i>	159
Fluctuations in Late Pennsylvanian (Virgilian) seawater chemistry inferred from submarine cements of phylloid algal mounds, western Orogrande basin (New Mexico).....	<i>S.C. Seals, G.S. Soreghan and R.D. Elmore</i>	167
Type section of the upper Carboniferous Bursum Formation, south-central New Mexico, and the Bursumian Stage	<i>S.G. Lucas, K. Krainer and B.S. Kues</i>	179
Invertebrate paleontology of the Bursum Formation type section (Latest Pennsylvanian), Socorro County, New Mexico...	<i>B.S. Kues</i>	193
Permian stratigraphy in the Jarilla Mountains, Otero County, New Mexico.....	<i>S.G. Lucas and K. Kramer</i>	211
Stratigraphy and correlation of the lower Permian Hueco group in the southern San Andres Mountains, Dona Ana County, New Mexico	<i>S.G. Lucas, K. Krainer and B.S. Kues</i>	223
A marine invertebrate fauna from the upper part of the Panther Seep Formation (Earliest Wolfcampian) near Hembrillo Pass, San Andres Mountains, south-central New Mexico.....	<i>B.S. Kues</i>	241
Lower Wolfcampian conglomerate in the southern Caballo Mountains, Sierra County, New Mexico: Stratigraphy, correlation, and implications for Late Pennsylvanian-Early Permian Tectonics	<i>T.F. Lawton, K.A. Giles, G.H. Mack, D.S. Singleton, and A.D. Thompson</i>	257
Pleistocene vertebrates from the White Sands Missile Range, southern New Mexico	<i>G.S. Morgan and S.G. Lucas</i>	267
The Otero Formation, Pleistocene lacustrine strata in the Tularosa Basin, southern New Mexico	<i>S.G. Lucas and J. W. Hawley</i>	277
Mammal footprints from the upper Pleistocene of the Tularosa Basin, Dona Ana County, New Mexico	<i>S.G. Lucas, G.S. Morgan, J. W. Hawley, D. W. Love and R.G. Myers</i>	285
Alluvial fan stratigraphy along the southern Sacramento Mountains, N.M., and inferences regarding late Quaternary paleoclimate, soils, and sedimentation	<i>D.J. Koning, Pazzaglia, and R. Smartt</i>	289

Hydrogeology

Apparent age of ground water near the southeastern margin of the Tularosa Basin, Otero County, New Mexico....	<i>G.E. Huff</i>	303
Conceptual model of the bolson-fill aquifer, Soledad Canyon area, Dona Ana County, New Mexico	<i>C.A. Naus</i>	309
Investigation of hydrothermal resources in the Rio Grande rift regio.....	<i>B. Rzonca and D. Schulze-Makuch</i>	319
Evidence for the discharge of hydrothermal water into Lake Lucero, White Sands National Monument, southern New Mexico	<i>D. Schulze-Makuch</i>	325

Economic Geology

Petroleum geology of the McGregor Range, Otero County, New Mexico	<i>R.F. Broadhead</i>	331
Mineral resources of the northern and central San Andres Mountains, White Sands Missile Range, New Mexico.....	<i>V.T. McLemore</i>	339
White Sands, N.M., as a part of an image processing laboratory	<i>P.C. Goodell and H. Ghrelat</i>	353
The Chess Draw Depression, Otero Co., New Mexico: An altered sublaccolic, alkalic system	<i>P.C. Goodell, V.W. Lueth and T.C. Willsie</i>	357

DEDICATION

In 1946, with the prospect of \$3 per day in field expenses from the New Mexico Bureau of Mines and Mineral Resources, two young Ph.D. students from the California Institute of Technology flew over the Sacramento Mountains with a plan to jointly map the western escarpment for their dissertations. When one student decided against the project, the other, Lloyd C. Pray, was pleased: now he would have the whole place to himself.

Over the next four years Lloyd spent 13 months in the field, largely on foot, creating a geologic map and report that were destined to become classic. This work includes naming the Orogrande basin as well as the Valmont, Gobbler, Beeman, and Holder formations. Working with New Mexico colleagues such as Frank Kottlowski, Rousseau Flower, Art Bowsher, E. C. Anderson, Eugene Callaghan, and M. L. Thompson, the dissertation was completed in 1952 and published in 1961 as NMBM&MR Bulletin 35. Since its completion, Lloyd's work has been the foundation for uncounted theses, dissertations, and field trips, a legacy that has raised the Sacramento Mountains area to one of the classic field sites in the world.

Raised in northern Wisconsin along the Lake Superior shoreline, Lloyd attended Carleton College in Minnesota as a chemistry major until getting "hooked" into geology by enthusiastically delivered lectures. He graduated in 1941 magna cum laude and Phi Beta Kappa, and moved on to the California Institute of Technology, receiving his Master's degree in 1943 on the petrography of granodiorites. After one year with the USGS studying pegmatites in the Black Hills and southern

Lloyd returned to Cal Tech with a National Research Council Fellowship to begin his Sacramento Mountains Ph.D. From 1948-1956 Lloyd was on the Cal Tech faculty, teaching field geology and sedimentology while achieving tenure and the rank of Associate Professor. An opportunity to leave L.A.'s asphalt jungle and join Marathon Oil's Denver Research Center proved appealing, and Lloyd began his industry career. The Marathon years, 1956-1968, covered the golden age in the development of carbonate sedimentology as a discrete science. Industry research groups, including Marathon, led the way in unraveling many mysteries of carbonate deposition and diagenesis. Lloyd's work in the Guadalupe and Sacramento mountains, Paradox basin, and other regions were often controversial and thought provoking as he proposed new theories on the nature of bioherm growth patterns, the role of calcareous algae in bioherms, the classification of carbonate pore systems, syntectonic deposition, compaction, and the timing of cementation and lithification. In addition to research, his group trained production and exploration geologists on the nuances of working in new but often giant carbonate hydrocarbon fields.

In 1968 a desire to teach more and oversee graduate field studies led Lloyd to accept a professorship at the University of Wisconsin-Madison. Over the next 21 years he would supervise 34 graduate theses, most performed in the Guadalupe/Sacramento mountains area. Students in the "Wisconsin mafia" would commonly explore one unit or environment of a complex system in detail, with Lloyd masterfully weaving those individual studies into a comprehensive regional interpretation. With this method Lloyd and his students contributed vastly to our knowledge of carbonate systems in general, and the Guadalupe Mountains Permian Reef complex in specific, with results disseminated widely in a number of guidebooks and symposium volumes.

Lloyd never forgot his early inspiration as an undergraduate at Carleton, and enthusiastically taught large classes of geology for nonmajors throughout his UW career. His 1988 award as a University of Wisconsin Distinguished Teacher and his 1998 AAPG Distinguished Educator medal are testament to his effectiveness as both a graduate and undergraduate educator, as are the success, intense affection and loyalty of his former students.

In addition to his teaching awards, Lloyd is an honorary member of SEPM and Permian Basin Section-SEPM, recipient of the SEPM Twenhofel Medal for Excellence in Sedimentary Geology, past treasurer, vice president, and president of SEPM, past AAPG distinguished lecturer, winner of numerous best paper awards, and a 1991 honoree for "Achievements in Geology" at his Carleton College 50th reunion. Last but not least, Lloyd and wife Carrel (of 57 years!) raised four sons and can boast of 12 grandchildren.

For those who know and have shared time in the field with him, Lloyd's greatest talents are his infectious curiosity and enthusiasm coupled with his clarity of thought and the ability to communicate the logic of those thoughts to his less perceptive listeners.

It is an honor for the New Mexico Geological Society to dedicate our 53rd Field Conference, "Geology of the White Sands", to a man who has contributed so much to our understanding of southern New Mexico and West Texas and who has taught so many the skills to contribute further, Lloyd C. Pray.

Bill Raatz and Kate Giles



From right to left, Lloyd C. Pray, Frank E. Kottlowski, James L. Wilson, and Dave V. Lemone on the 1994 field trip to the San Andres Mountains.

Appalachians, and two years in the US Navy as a Hydrographic Officer,

PRESIDENT'S MESSAGE

Welcome to the 53rd annual field conference of the New Mexico Geological Society. Fifty years after White Sands Missile Range was established by the U.S. Army the Society is visiting Rhodes Canyon for the first time since 1955. We will visit some areas for the first time ever. The tour of the Oscura and San Andres Mountains will allow for an overview of the complete geologic record from the Proterozoic to the Neogene of south-central New Mexico. Even after the September 11th attacks on New York and Washington, our industrious co-chairs, Kate Giles, Virgil Lueth, Spencer Lucas, Barry Kues and Bob Myers were determined that this conference would prevail. We appreciate their efforts and those of all the authors for submitting articles. Once again we are fortunate to have on board Dana Ulmer-Scholle as our hardworking guidebook editor. Without her time and effort the guidebook would never see the light of day.

As always, the executive committee acknowledges the solid support of the New Mexico Bureau of Geology and Mineral Resources. In particular we owe special thanks to Peter Scholle, Director of the Bureau and State Geologist, for his advice and support of Society functions. Also, Theresa Lopez, Susie Kyle and Linda Ulbricht at the Bureau cheerfully and expertly keep the Society operating smoothly on a daily basis.

The 2002 NMGS Spring meeting in Socorro drew a record audience of 169 participants, 121 professionals and 48 students. Special thanks to Brian Brister (General Chair), Kate Giles and Nancy McMillan (Program Chairs) and Bill Raatz and Theresa Lopez (Registration Chairs) for organizing a truly outstanding meeting this year.

The Society continues to be financially healthy, in spite of all the financial market gyrations. Sales of publications provide a steady income of about \$30-34,000 per annum. Towards the end of this year we look forward to both the publication of the revised New Mexico Geologic Highway Map compiled by the late Frank Kottowski and myself, and Volume I of the Geology of New Mexico, edited by Greg Mack and Kate Giles. Our investment portfolio has recovered to pre-Sept. 11 levels and our investment income is rising.

This year we will award approximately \$28,000 in scholarships, fellowships, and research grants to outstanding graduate and undergraduate students in New Mexico. The continued growth in our scholarship funds, especially the Lucille Pipkin Fund has enabled us to provide free membership to students and offer them a 50% discount on all our publications. This year we will also award a full 1-year tuition scholarship to a 4th year student at NMSU, UNM, ENMU, and NMT for a total of 4 scholarships. The Society continues to provide awards in the Earth Science category to both Junior and Senior at the all the regional and State Science Fair.

The 2003 Fall Field Conference is being organized by Bill Berglof, Spencer Lucas, Steve Semken and Andrew Heckert, and will focus on the geology around Grants and Gallup in west-central New Mexico. In 2004 we will visit the Taos region under the skillful guidance of Paul Bauer. Please contact these chairpersons if you can make a contribution to their field conference or guidebook.

It's been thirteen years since I first attended a NMGS Fall field conference as a flagperson, and I am as impressed now as I was then with the enormous amount of participation and coordination necessary to maintain the quality of our field trips, and our Society. That the field trips happen consistently year after year is due to the many talented individuals working for the benefit of the geologic community. I encourage you all to become involved with the society, and thank all the volunteers who have made this year's conference a success. As always on a Fall Field Conference, enjoy the company, the scenery and of course the geology.

Maureen Wilks

EDITOR'S MESSAGE

In 1942 the ranchers and miners living on the roughly 3200 square mile area that was destined to become White Sands Missile Range, leased their land to the United States Government in order to establish the Alamogordo Bombing Range. On July 9, 1945 Whites Sands Missile Range (WSMR)) was formally established and on July 16 the first atomic bomb was tested at the Trinity Site on the north end of the range. The events of that day would change the course of history for this area in New Mexico and for the entire World. We are pleased and honored to be the editors for the 53rd NMGS Fall Field Conference, and coordinators of the second visit for the Society to the geologically diverse and historically fascinating WSMR. In 1955 the 6th NMGS Fall Field Conference ventured briefly onto WSMR into Rhodes Canyon and was led by Frank Kottlowski. To this day, Frank's pioneering work on the Paleozoic stratigraphy of the region has not been superseded and is briefly summarized in his Memorium in this volume.

Geoscientists with the "right stuff" (those with great patience and perseverance) have been granted limited access to WSMR over the past few decades. These geoscientists, standing on the shoulders of giants such as Frank Kottlowski and Lloyd Pray, have provided us with the geologic framework of the area. The field trip and guidebook cover an extremely wide range of geologic topics. These topics include a visit to the Proterozoic basement, an overview of nearly the entire Paleozoic, Mesozoic, and Cenozoic stratigraphy, Ancestral Rocky Mountains, Laramide and Rio Grande rift tectonics, coal and mineral deposits, eolian and soil processes of White Sands, and volcanic processes of the anomalously long Carrizozo lava flow.

WSMR not only has an incredibly rich geologic history, but the human history of the area has served as the inspiration for many novels, fodder for folklore, and instigation for treasure hunts. In the course of our geologically oriented traverse of the area, we will be fortunate to visit historic sites ranging from the Native Americans who left the petroglyphs that we'll view at Three Rivers, to the testing of the first atomic bomb at the Trinity Site that brought us into the Atomic Age. Our journey across the Tularosa Basin and through Rhodes Canyon and Mockingbird Gap will take us past many structures abandoned by the ranching and milling communities of the past and will trace the rare passages through the San Andres Mountains that were used by the Spanish and early settlers in the region.

We gratefully acknowledge the contributions of the authors, the reviewers of articles, minipapers and road logs, and the hard work of the committees. Support of the field conference was provided by the New Mexico Bureau of Geology and Mineral Resources. Special thanks to Dana Ulmer-Scholle for her time and skills as managing editor and to Greg Wahlman and Tim Lawton for photographic contributions.

Virgil Lueth
Kate Giles
Spencer Lucas
Barry Kues,
Bob Myers

MEMORIAL

No trip to the San Andres Mountains would be complete without remembering one of the pioneers of modern New Mexico geology, Frank E. Kottlowski. He left an indelible mark on the geology and geologists of this state. On this field conference, we will review the Paleozoic stratigraphy that Frank helped establish. Some of his earliest of over 170 publications were based on the geology in the San Andres. Frank helped lead the first and only foray by the New Mexico Geological Society into the White Sands Missile Range on the 6th Field Conference in 1955. On the trip he lead the Day 1 field excursion to Rhodes Canyon and also published a number of papers in the guidebook, including one titled, "The Geology of the San Andres Mountains." His publications about the area continue to be cited to this day (see Road-log References, this guidebook). As we enjoy this field conference on the White Sands Missile Range please take time to remember Frank as we walk on "his rocks." But, we probably will not need much prompting to recall such a fine man. His legacy lives on through all of the people who consider themselves lucky to have known him and those who did not have the privilege, but have the opportunity to build on his work.

Virgil W. Lueth
Katherine Giles
Field Conference Co-chairs

COMMITTEES

2002 EXECUTIVE COMMITTEE

Maureen Wilks, President	New Mexico Bureau of Geology & Mineral Resources
Gary Stephens, Vice-President	U.S. Bureau of Land Management
Jeffry Amato, Treasurer	New Mexico State University
Brian Brister, Secretary	New Mexico Bureau of Geology & Mineral Resources New
Virgil Lueth, Past President	Mexico Bureau of Geology & Mineral Resources

FIELD CONFERENCE

Virgil Lueth, Co-chair	New Mexico Bureau of Geology & Mineral Resources
Katherine Giles, Co-chair	New Mexico State University

GUIDEBOOK

Virgil W. Lueth	New Mexico Bureau of Geology & Mineral Resources
Katherine A. Giles	New Mexico State University
Spencer G. Lucas	New Mexico Museum of Natural History & Science
Barry S. Kues	University of New Mexico
Robert Myers	CSTE-DTC-WS-ES-E, White Sands Missile Range
Dana Ulmer-Scholle, Managing Editor	New Mexico Institute of Mining & Technology

ROAD LOGS

Virgil W. Lueth, Chair	New Mexico Bureau of Geology & Mineral Resources
Spencer G. Lucas	New Mexico Museum of Natural History & Science
Katherine A. Giles	New Mexico State University
Barry S. Kues	University of New Mexico
Robert Myers	CSTE-DTC-WS-ES-E, White Sands Missile Range

REGISTRATION

Maureen Wilks	New Mexico Bureau of Geology & Mineral Resources
Teresa Lopez	New Mexico Bureau of Geology & Mineral Resources

LOCAL ARRANGEMENTS

Katherine A. Giles	New Mexico State University
Virgil W. Lueth	New Mexico Bureau of Geology & Mineral Resources

PUBLICATIONS COMMITTEE

James M. Barker, Chair	New Mexico Bureau of Geology & Mineral Resources
Richard M. Chamberlin	New Mexico Bureau of Geology & Mineral Resources

PUBLICATION SALES

Linda Ulbricht	New Mexico Bureau of Geology & Mineral Resources
Theresa Lopez	New Mexico Bureau of Geology & Mineral Resources
Susie Kyle	New Mexico Bureau of Geology & Mineral Resources

FIELD CONFERENCE SCHEDULE AND CREDITS

Wednesday, October 2, 2002 – Registration Day

6:00 – 9:00 PM Registration and ice-breaker party, Holiday Inn Express

Thursday, October 3, 2002 – First Day, round trip from Alamogordo to Trinity Site and return.

6:00 – 7:15 AM Breakfast (not provided)
7:00 – 7:30 AM Registration, Holiday Inn Express
7:30 AM Vans leave Holiday Inn Express
5:30 PM Last stop and Barbeque, Three Rivers Petroglyph National Recreation Area
7:30 PM Return to Alamogordo

Friday, October 4, 2002 – Second Day, round trip from Alamogordo to Rhodes Canyon and return via Lake Lucero.

6:00 – 7:15 AM Breakfast (not provided)
7:00 – 7:30 AM Registration, Holiday Inn Express
7:30 AM Vans leave Holiday Inn Express
5:30 PM Vans return to Alamogordo
6:00 – 7:00 PM Social hour at the Elks Lodge, 2290 Hamilton Road, Alamogordo
7:00 – 8:00 PM Annual Banquet (provided), Elks Lodge, 2290 Hamilton Road, Alamogordo

Saturday, October 5, 2002 – Second Day, Alamogordo to Las Cruces

6:00 – 7:15 AM Breakfast (not provided)
7:30 AM Caravan leaves Holiday Inn Express
1:00 PM Field Conference ends at New Mexico Farm & Ranch Museum

CREDITS

Front Cover: Photograph by Timothy F. Lawton

Inside Front Cover: Mark Mansell and Dana Ulmer-Scholle

Trip Map: Virgil Lueth

Frontispiece: Photograph by Virgil W. Lueth and Dana Ulmer-Scholle.

Inside Back Cover: William D. Raatz and Spencer G. Lucas

Logistical Assistance: Jim Barker and Gretchen Hoffman (NMBGMR), New Mexico Bureau of Geology and Mineral Resources, New Mexico Museum of Natural History and Science, New Mexico State University, and Debbie Bingham, United States Army (White Sands Missile Range)

Photography and Figures: Virgil Lueth, Katherine Giles, Spencer Lucas, Robert Eveleth, New Mexico Bureau of Geology and Mineral Resources

Formatting and Production: Dana Ulmer-Scholle

Printer: Starline Printing, Albuquerque, NM