Rockhounding and Earth-Science Activities in Oklahoma

1995 Workshop

Kenneth S. Johnson and Neil H. Suneson, *Editors*

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Proceedings of a two-day workshop held October 28–29, 1995, at Omniplex Science Museum, Oklahoma City, Oklahoma.

Workshop co-sponsors:

Oklahoma Geological Survey,
the Gem and Mineral Clubs of Oklahoma,
and Omniplex Science Museum

The University of Oklahoma
Norman, Oklahoma

1996

SPECIAL PUBLICATION SERIES

The Oklahoma Geological Survey's Special Publication series is designed to bring timely geologic information to the public quickly and economically. Review and editing of this material has been minimized in order to expedite publication.

Rose Rock—Oklahoma's Official State Rock

Cover Photograph

The distinctive sandy-barite crystal clusters found in central Oklahoma are known popularly as "rose rocks" because of their reddish-brown color and their resemblance to a rose in full bloom. The mineral barite (barium sulfate, $BaSO_4$) grows as a cluster of divergent blades and gives these rosettes their "petals." The central Oklahoma rosettes are unique because they grew within an ancient red sandstone, incorporating quartz sand grains and acquiring the red color of the host rock. Sand and barite occur in these concretions in nearly equal proportions; thus, they are best known to geologists as "sand-barite rosettes." They also are called "barite roses" or "petrified roses."

Well-formed specimens, such as the two-inch rose on the cover, are highly prized by collectors. Rose rocks are in greatest concentration in the Permian Garber Sandstone in a narrow belt that extends 80 miles through the central part of Oklahoma between Pauls Valley and Guthrie. The most abundant and well-formed specimens are found in an area just east of Norman and Noble.

The rose rock became the official state rock on April 8, 1968, when Governor Dewey F. Bartlett signed House Bill 1277. The rose rock then joined the other symbols of Oklahoma: scissor-tailed flycatcher (state bird), "Oklahoma," (the state song), Indian blanket (state wildflower), redbud (state tree), collared lizard or mountain boomer (state reptile), American buffalo (state animal), white bass (state fish), Indiangrass (state grass), and mistletoe (state flower).

Photograph by Kenneth S. Johnson

Two members of the Oklahoma Academy of Science look at fossils in the Devils Kitchen Conglomerate Member of the Deese Group at the spillway of Lake Murray. This outcrop contains a number of rock types, including fossiliferous limestone and shale, sandstone, and conglomerate. The rocks that contain fossils were deposited in a marine environment, but those that don't may have been deposited in a continental setting—raising the question of whether the sea level rose and fell drastically in relation to the land surface.

Photograph by Neil H. Suneson

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PREFACE

Oklahoma is a treasurehouse for rockhounds. The State contains a great variety of rocks, minerals, and fossils. At present there are 12 active gem and mineral clubs in various parts of the State (see list on page vi), and they have a total membership of about 930 men, women, and children.

This volume contains the proceedings of a two-day workshop that focused on the rocks, minerals, and fossils of Oklahoma, and on earth-science activities in Oklahoma schools. The workshop, held at Omniplex Science Museum in Oklahoma City, October 28–29, 1995, was co-sponsored by the Oklahoma Geological Survey (OGS), the gem and mineral clubs of Oklahoma, and Omniplex Science Museum. About 180 people registered for the workshop.

The workshop came about when OGS contacted all 12 clubs in Oklahoma and proposed that representatives from each club attend a preliminary meeting in March 1995, to identify topics and issues that would be of interest to rockhounds of Oklahoma. As a result of that organizational meeting, attended by 19 people (see list below), we designed a program of topics and issues, and then identified the person or persons best qualified to address each topic. Omniplex, through the cooperation of Beth Bussey, Museum Education Director, offered to host the workshop in the museum's theater. The results of this cooperative undertaking have been most rewarding: an excellent program and speakers, fine cooperation by all the Oklahoma clubs, and a very good meeting site at Omniplex. This proceedings volume for the workshop provides a permanent record of the efforts that were undertaken.

Special thanks are expressed to the speakers (authors) who contributed to this workshop. Each was successful in presenting an excellent talk and in preparing an article for this volume.

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and Neil H. Suneson
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Contents

Oklahoma Gem and Mineral Clubs

Ada Hardrock & Fossil Club
923 E. 34th Street
Ada, Oklahoma 74820
Meets 2nd Thursday, 7:30 p.m.
Place varies

Enid Gem & Mineral Society
2614 W. Oklahoma
Enid, Oklahoma 73703
Meets 1st Thursday, 7:30 p.m.
Hoover Building
Garfield County Fairgrounds

McCurtain County Gem & Mineral Club
406 S.E. Avenue "E"
Idabel, Oklahoma 74745
Meets 3rd Tuesday, 7:30 p.m.
Idabel Public Library

Mount Scott Gem & Mineral Society
44 N.W. 29th Street
Lawton, Oklahoma 73505
Meets 4th Friday, 7:00 p.m.
Lawton Town Hall
5th Street and "B" Avenue

N.W. Arkansas Gem & Mineral Society
Route 1, Box 288A
Colcord, Oklahoma 74338

Oklahoma Mineral & Gem Society
P.O. Box 25632
Oklahoma City, Oklahoma 73125
Meets 3rd Thursday, 7:30 p.m.
Will Rogers Garden Center
3400 N.W. 36th

Osage Hills Gem & Mineral Society
P.O. Box 561
Bartlesville, Oklahoma 74005
Meets 3rd Thursday, 7:00 p.m.
First Presbyterian Church
5th and Dewey

Rough and Tumbled Rock & Gem Club
129 Viola Avenue
Ponca City, Oklahoma 74601
Meets 4th Tuesday, 7:00 p.m.
102 North First Street

Shawnee Gem & Mineral Club
10 Donna Lane
Shawnee, Oklahoma 74801-5614
Meets 1st Tuesday, 7:30 p.m.
Northridge Church of Christ

Stillwater Mineral & Gem Society
1116 South Gray
Stillwater, Oklahoma 74074
Meets 4th Tuesday
First United Methodist Church

Tahlequah Rock & Mineral Society
P.O. Box 932
Tahlequah, Oklahoma 74465

Tulsa Rock & Mineral Society
P.O. Box 2292
Tulsa, Oklahoma 74101
Meets 2nd Monday, 7:00 p.m.
Tulsa Downtown Library

Dr. Mike Soreghan of the School of Geology and Geophysics, University of Oklahoma, examines sedimentary features in the Rocky Point Conglomerate Member of the Deese Group near the lodge at Lake Murray State Park. The Rocky Point Conglomerate is about 310 million years old and contains rock fragments eroded from the Ouachita Mountains. Formations such as the Rocky Point provide evidence for the age of the initial uplift of the Ouachitas.
Photograph by Neil H. Suneson

Geology of Oklahoma

Kenneth S. Johnson
Oklahoma Geological Survey
Norman, Oklahoma

INTRODUCTION

Oklahoma contains an abundance of rocks, minerals, and fossils that are highly prized by collectors, and the present-day distribution of these specimens is a direct result of the geologic history of the State. The following discussion is modified from an earlier report by Johnson (1971).

At many times in the past, forces within the Earth resulted in portions of Oklahoma and surrounding states alternately sinking below and rising above sea level. Large areas were at times covered by shallow seas, and thick layers of marine shale, limestone, and sandstone were deposited. In adjacent areas, at the same time, sandstones and shales were laid down as alluvial and deltaic deposits near the ancient seas. When these areas later were elevated above the seas, the earlier-deposited rocks and sediments were exposed and eroded, just as they are being eroded in today's land areas. Uplift was accomplished either by gentle arching of broad areas or by the formation of mountains where rocks had been intensely folded, faulted, and thrust upward.

Three principal mountain belts, the Ouachita, Arbuckle, and Wichita Mountains, are in the southern third of the State (Fig. 1). These were the sites of folding, faulting, and uplifting during the Pennsylvanian Period of geologic time. In addition to exposing a great variety of structures, these fold belts brought to the surface igneous rocks and thick sequences of Paleozoic sedimentary rocks seen at few other places in the Midcontinent area. These uplifts also are the sites where one can observe and collect a great number of fossils, rocks, and minerals that are inaccessible in any other part of Oklahoma.

The principal sites of sedimentation were in great elongate basins that subsided more rapidly than adjacent areas and received deposits 10,000–40,000 ft thick. The major sedimentary basins were confined to the southern half of the State and include the Anadarko, Arkoma, Ardmore, Marietta, Hollis, and Ouachita basins; the Ouachita basin was at the site of the present Ouachita Mountains (Fig. 1).

Rocks of every geologic period (Fig. 2) crop out in Oklahoma, and thus a great variety of fossils can be found in the State. Nearly 99% of Oklahoma's outcropping rocks are of sedimentary origin, and the remainder are mainly igneous rocks in the Wichita and Arbuckle Mountains and a smaller area of mildly metamorphosed rocks in the Ouachita Mountains. Rocks of Permian age are exposed at the land surface in about 46% of the State (Fig. 3). For the rest of the State, Pennsylvanian rocks make up about 25% of the surface, Tertiary rocks about 11%, Cretaceous rocks about 7%, Mississippian rocks about 6%, Ordovician rocks about 1%, and Cambrian rocks about 1%; Precambrian, Silurian, Devonian, Triassic, and Jurassic rocks each crop out in less than 1% of the State. Not included in these estimates are the younger Quaternary river, terrace, and lake deposits that overlie pre-Quaternary rocks in about 25% of the State.

PRECAMBRIAN AND CAMBRIAN IGNEOUS ACTIVITY

The oldest rocks known in Oklahoma are Precambrian granites and rhyolites formed 1.05–1.35 billion years ago (Fig. 4). Preexisting rocks into which these granites were injected have been destroyed by erosion, metamorphism, or complete melting in magma, although remnants may exist deep underground in some unexplored areas. In a later episode of igneous activity, during the early and middle parts of the Cambrian Period, a different group of thick granites, rhyolites, gabbros, and basalts formed in southwestern and south-central Oklahoma. Heat and fluids given off by the Cambrian magmas changed an older group of sedimentary rocks into metamorphic rocks.

Precambrian and/or Cambrian igneous and metamorphic rocks underlie all of the State and are the floor or basement upon which younger rocks rest (Figs. 3,4). The top surface of the basement rocks typically is about 1,000 ft below the Earth's land surface in the Ozark uplift of northeastern Oklahoma. To the south and southwest, the basement surface plunges to greater depths toward the great basins of southern Oklahoma, where it is locally 30,000–40,000 ft underground (Figs. 3,5). Adjacent to the basins, basement rocks have been uplifted above sea level in two major fault blocks and are now exposed in the Wichita and Arbuckle Mountains. Igneous rocks, including veins and hydrothermal minerals, crop out locally in these mountain areas.

LATE CAMBRIAN AND ORDOVICIAN PERIODS

Following a brief period when the newly formed Cambrian igneous rocks and the ancient Precambrian rocks were partly eroded, Oklahoma sank below sea level, and shallow seas covered all of the State during various parts of the Paleozoic Era. This was the beginning of a long period of geologic time (about 525 million years) when parts of

Johnson, K. S., 1996, Geology of Oklahoma, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 1–9.

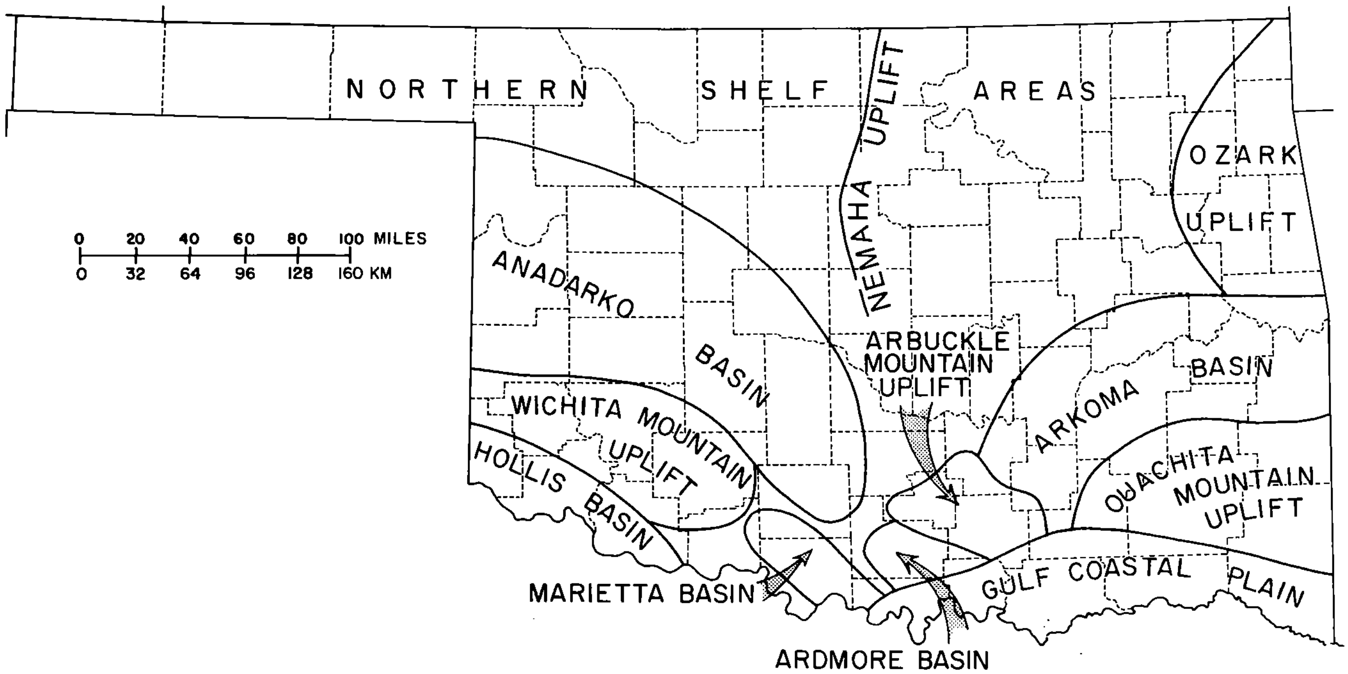

Figure 1. Major geologic provinces of Oklahoma.

Era	Period	Major biologic events		Millions of years ago
				0
CENOZOIC	Quaternary	First humans		2
	Tertiary	Mammals become abundant		65
MESOZOIC	Cretaceous	First flowering plants	"Age of Dinosaurs"	140
	Jurassic	First birds		200
	Triassic	First dinosaurs/ first mammals		250
PALEOZOIC	Permian	Mass extinction of most marine invertebrates		290
	Pennsylvanian	Major coal-forming swamps		330
	Mississippian	First reptiles		365
	Devonian	First amphibians		405
	Silurian	Early land plants		425
	Ordovician	Early fish		500
	Cambrian	Trilobites/shelled animals		570
PRECAMBRIAN		Early life-forms without shells		

Figure 2. Geologic time scale and major worldwide biologic events.

Oklahoma were alternately inundated by shallow seas and then raised out of the seas to become the sites of erosion or of river, lake, and/or deltaic deposition. Rocks formed in almost all these sedimentary environments are the hosts for abundant fossils and mineral deposits.

The first sea invasion, in Late Cambrian time, moved across the State from the east or southeast. The basal Reagan Sandstone (Fig. 4), consisting of sands eroded from the weathered basement-rock surface, was deposited only in the southeastern half of Oklahoma, whereas the thick overlying formations of Late Cambrian and Ordovician age once covered the entire State (Fig. 6). The thickness of these sediments increases southward from about 2,000 ft in northern shelf areas to 10,000 ft in the Anadarko basin, Ardmore basin, and Arbuckle Mountains region. In all but the southeast, limestone and dolomite (e.g., Arbuckle Group and Viola Limestone) are the major rock types, with sandstone (e.g., Simpson Group) and shale (e.g., Sylvan Shale) less abundant. Sedimentary rocks of the Ouachita basin, however, include thick units of black shale and sandstone, along with lesser amounts of limestone and chert.

Limestones of Late Cambrian and Ordovician age exposed in the Arbuckle and Wichita Mountains contain an abundance of the fossil shells, molds, and casts of the earliest marine invertebrates (such as trilobites, brachiopods, and bryozoans) that inhabited Oklahoma.

SILURIAN AND DEVONIAN PERIODS

Except for deposits in the Ouachita basin, Silurian and Devonian sedimentary rocks consist of limestone and do-

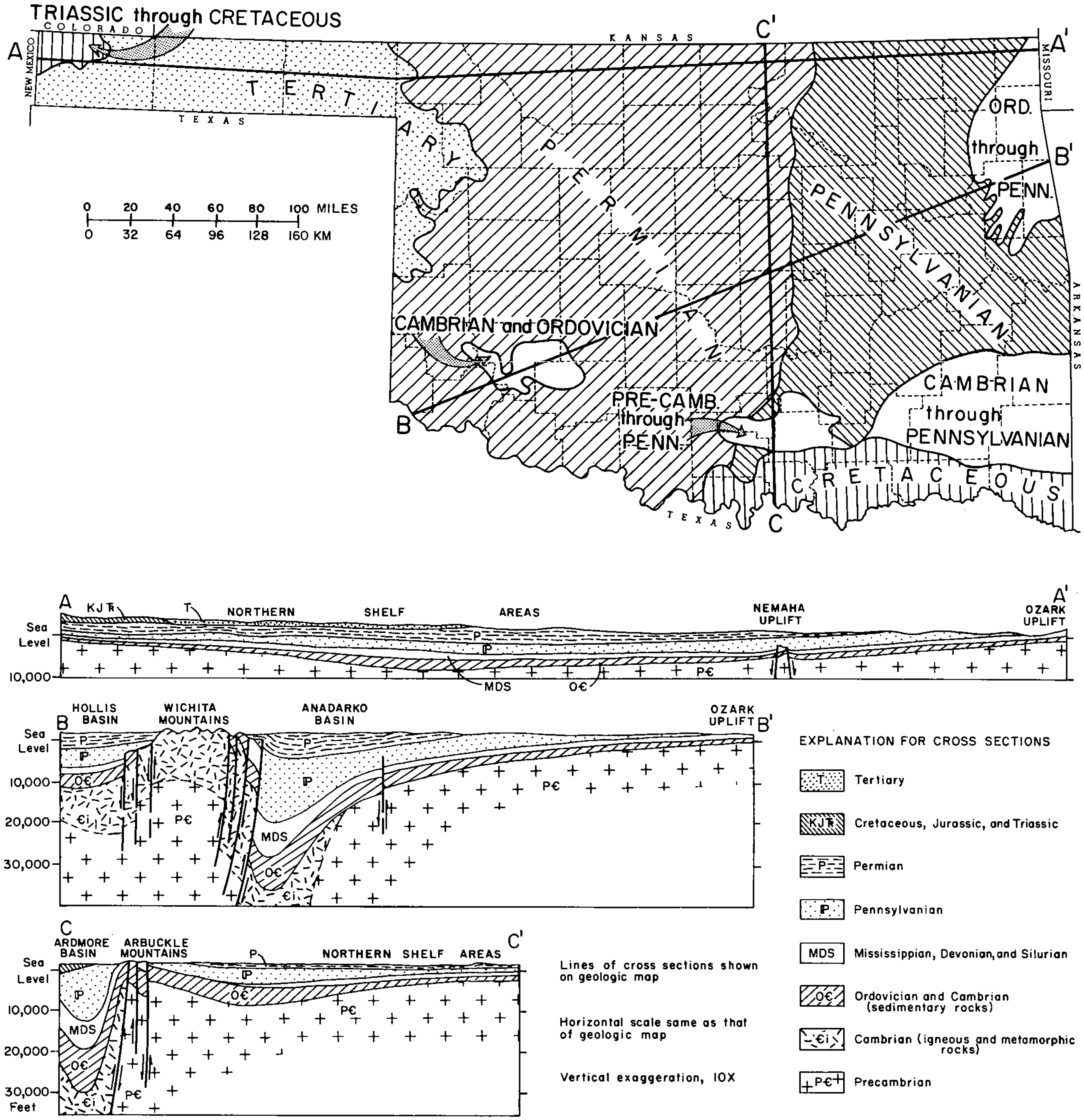

Figure 3. Generalized geologic map and geologic cross sections of Oklahoma. Cross sections follow lines A–A′, B–B′, and C–C′ on map.

lomite of the Hunton Group overlain by the black Woodford or Chattanooga Shale (Fig. 7). The Hunton Group (Silurian–Early Devonian) is commonly 100–500 ft thick (maximum, 800 ft) and has been eroded from the northern shelf areas. Silurian and Devonian invertebrate fossils, such as brachiopods, trilobites, and crinoids, are abundant in the Hunton Group and equivalent strata exposed in the Arbuckle Mountains and parts of the Ozark uplift.

Following widespread uplift and erosion, the Upper Devonian to Lower Mississippian Woodford Shale was deposited in essentially the same areas as the Hunton and also northward into Kansas. The pre-Woodford erosional unconformity is one of the most conspicuous unconform-

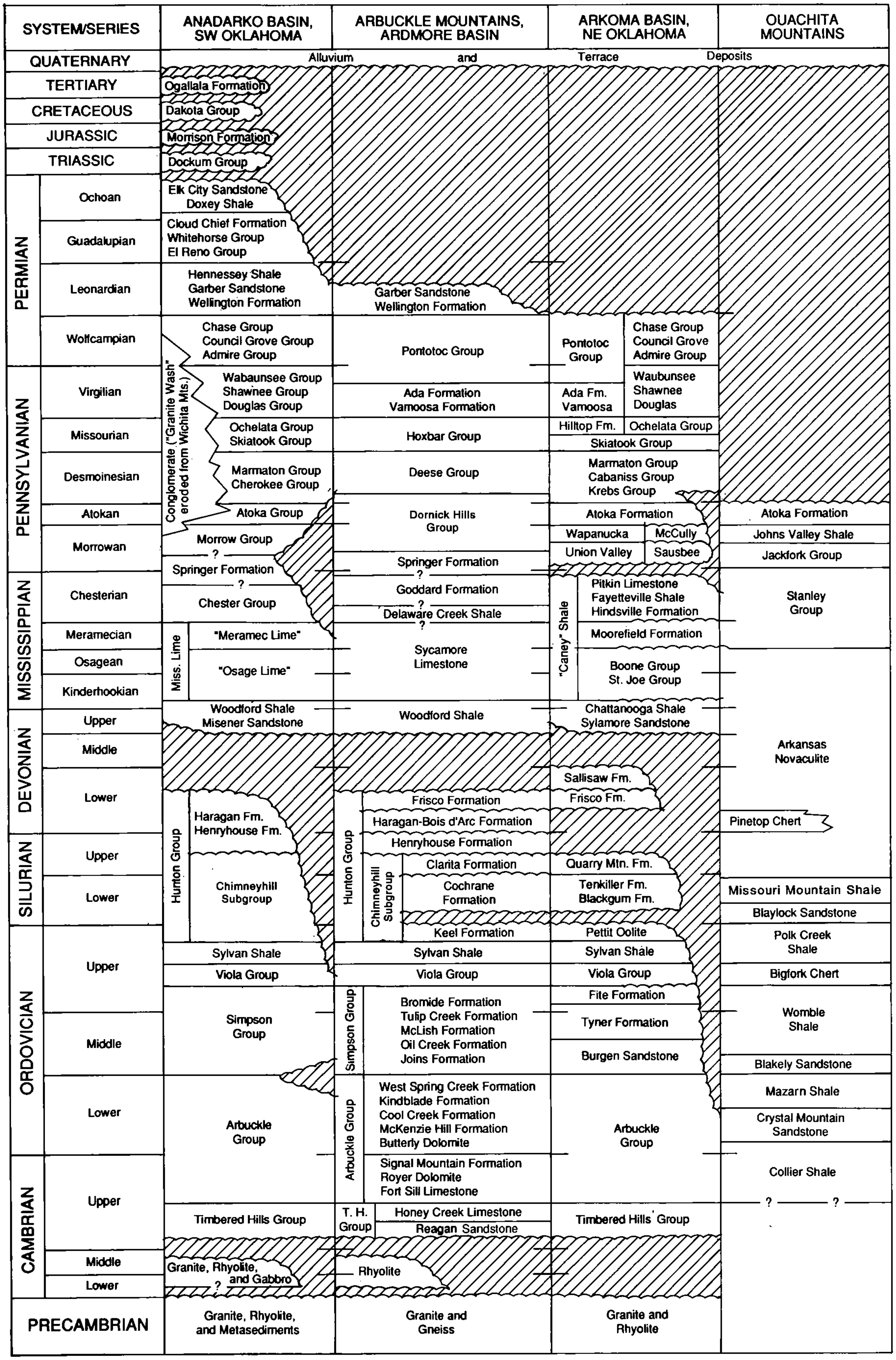
SYSTEM/SERIES
ANADARKO BASIN, SW OKLAHOMA
ARBUCKLE MOUNTAINS, ARDMORE BASIN
ARKOMA BASIN, NE OKLAHOMA
OUACHITA MOUNTAINS
QUATERNARY
Alluvium and Terrace Deposits
TERTIARY
Ogallala Formation
CRETACEOUS
Dakota Group
JURASSIC
Morrison Formation
TRIASSIC
Dockum Group
PERMIAN
Ochoan
Elk City Sandstone
Doxey Shale
Guadalupian
Cloud Chief Formation
Whitehorse Group
El Reno Group
Leonardian
Hennessey Shale
Garber Sandstone
Wellington Formation
Garber Sandstone
Wellington Formation
Wolfcampian
Chase Group
Council Grove Group
Admire Group
Pontotoc Group
Pontotoc Group
Chase Group
Council Grove
Admire Group
PENNSYLVANIAN
Virgilian
Conglomerate ("Granite Wash" eroded from Wichita Mts.)
Wabaunsee Group
Shawnee Group
Douglas Group
Ada Formation
Vamoosa Formation
Ada Fm.
Vamoosa
Waubunsee
Shawnee
Douglas
Missourian
Ochelata Group
Skiatook Group
Hoxbar Group
Hilltop Fm.
Ochelata Group
Skiatook Group
Desmoinesian
Marmaton Group
Cherokee Group
Deese Group
Marmaton Group
Cabaniss Group
Krebs Group
Atokan
Atoka Group
Dornick Hills Group
Atoka Formation
Atoka Formation
Morrowan
Morrow Group
Wapanucka
McCully
Johns Valley Shale
Union Valley
Sausbee
Jackfork Group
Springer Formation
Springer Formation
MISSISSIPPIAN
Chesterian
Chester Group
Goddard Formation
Delaware Creek Shale
Pitkin Limestone
Fayetteville Shale
Hindsville Formation
Stanley Group
Meramecian
Miss. Lime
"Meramec Lime"
Sycamore Limestone
"Caney" Shale
Moorefield Formation
Osagean
"Osage Lime"
Boone Group
St. Joe Group
Kinderhookian
DEVONIAN
Upper
Woodford Shale
Misener Sandstone
Woodford Shale
Chattanooga Shale
Sylamore Sandstone
Arkansas Novaculite
Middle
Lower
Sallisaw Fm.
Frisco Formation
Frisco Fm.
Hunton Group
Haragan Fm.
Henryhouse Fm.
Haragan-Bois d'Arc Formation
Pinetop Chert
SILURIAN
Upper
Henryhouse Formation
Clarita Formation
Quarry Mtn. Fm.
Lower
Chimneyhill Subgroup
Cochrane Formation
Tenkiller Fm.
Blackgum Fm.
Missouri Mountain Shale
Blaylock Sandstone
Keel Formation
Pettit Oolite
ORDOVICIAN
Upper
Polk Creek Shale
Sylvan Shale
Sylvan Shale
Sylvan Shale
Viola Group
Viola Group
Viola Group
Bigfork Chert
Middle
Simpson Group
Bromide Formation
Tulip Creek Formation
McLish Formation
Oil Creek Formation
Joins Formation
Fite Formation
Tyner Formation
Burgen Sandstone
Womble Shale
Blakely Sandstone
Lower
Arbuckle Group
West Spring Creek Formation
Kindblade Formation
Cool Creek Formation
McKenzie Hill Formation
Butterly Dolomite
Arbuckle Group
Mazarn Shale
Crystal Mountain Sandstone
CAMBRIAN
Upper
Signal Mountain Formation
Royer Dolomite
Fort Sill Limestone
Collier Shale
Timbered Hills Group
T. H. Group
Honey Creek Limestone
Reagan Sandstone
Timbered Hills Group
Middle
Lower
Granite, Rhyolite, and Gabbro
Rhyolite
PRECAMBRIAN
Granite, Rhyolite, and Metasediments
Granite and Gneiss
Granite and Rhyolite

Figure 4 (facing page). Generalized correlation of rock units in Oklahoma (from Johnson and Cardott, 1992). Height of boxes is not related to thickness of rock units.

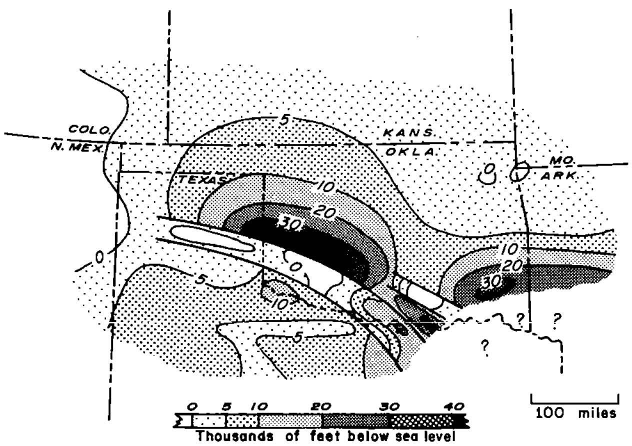

Figure 5. Generalized contours showing elevation (below sea level) of eroded top surface of Precambrian and Cambrian basement rocks in Oklahoma and parts of surrounding states.

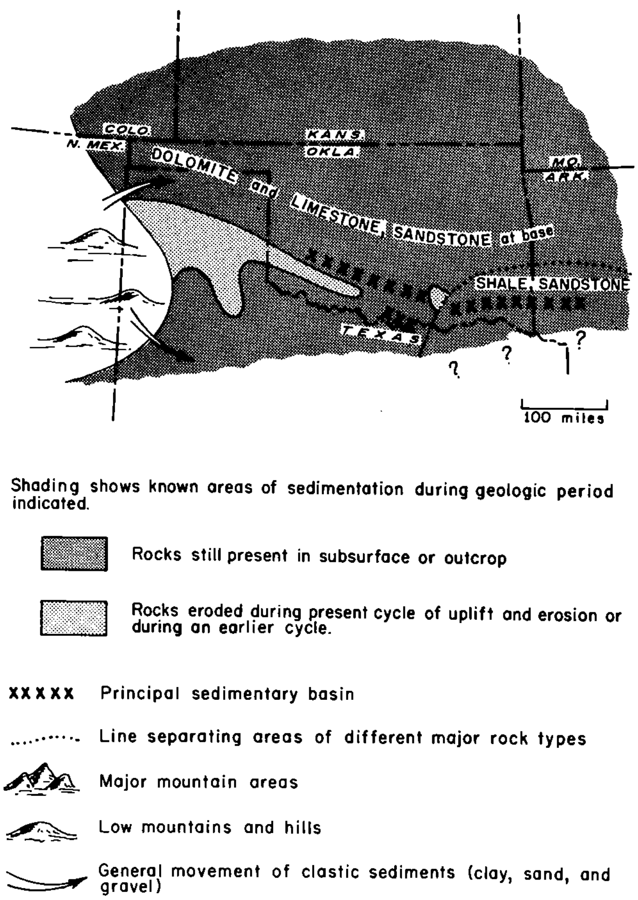

Figure 6. Late Cambrian–Ordovician paleogeography ("ancient geography") of Oklahoma with explanation of map symbols for Figures 6–17.

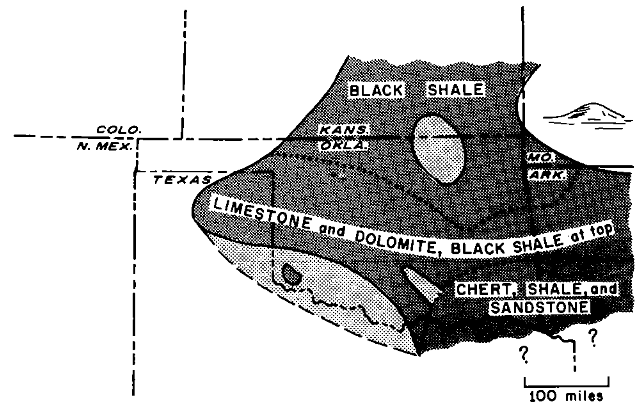

Figure 7. Silurian-Devonian paleogeography of Oklahoma.

ities in the State: 500–1,000 ft of strata were removed by erosion over broad areas, and the Woodford or younger Mississippian units rest on rocks principally of Ordovician and Silurian age. The Woodford Shale commonly is 50–200 ft thick, but reaches 600 ft in the Arbuckle Mountains. In the Ouachita basin, sandstone and shale of the Blaylock and Missouri Mountain Formations were deposited during the Silurian Period, and the Arkansas Novaculite (chert) was laid down during Devonian and Early Mississippian time. Total thickness of these three formations in the Ouachitas is 500–1,000 ft.

MISSISSIPPIAN PERIOD

During the first half of the Mississippian Period, shallow seas covered all of Oklahoma (Fig. 8). Limestone and interbedded chert were the dominant sedimentary products in most areas, and deposition of the Arkansas Novaculite continued in the Ouachita basin. Important units are the Boone Formation in the Ozarks, the Sycamore Limestone in southern Oklahoma, and the "Mississippian lime" (a general term applied to thick Mississippian limestones) in the subsurface across northern Oklahoma. Early Mississippian limestones are the youngest of the thick carbonate sequences that attest to early and middle Paleozoic crustal stability in Oklahoma.

In the last half of the Mississippian Period, shale and sandstone were the dominant sedimentary units, with major sites of deposition being the rapidly subsiding basins in southern Oklahoma. Principal Mississippian formations of southern Oklahoma (excluding the Ouachita area) are the Delaware Creek Shale, Goddard Shale, and the Springer Formation (part of which is Early Pennsylvanian); these strata and the underlying Sycamore have a total thickness of 1,500–6,000 ft in the Ardmore and eastern Anadarko basins and nearby areas. However, the greatest thickness of Mississippian strata is the 10,000 ft of interbedded sandstone and shale making up the Stanley Group of the Ouachita basin. Mississippian strata in central and north-central Oklahoma were largely removed by Early Pennsylvanian uplift and erosion. The Mississippian rocks remaining there are generally 200–600 ft of cherty limestones that thicken to the west and are 5,000 ft thick in the western Anadarko basin.

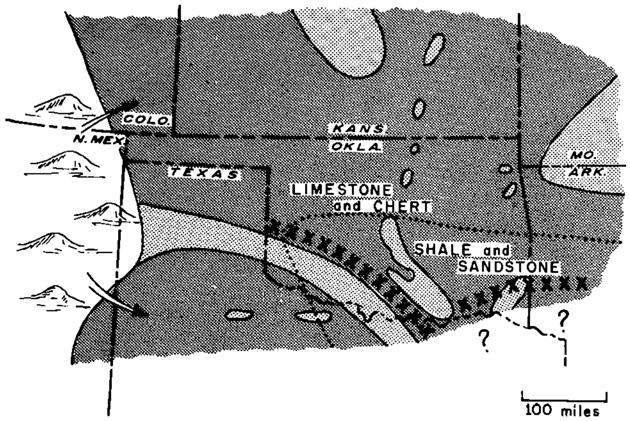

Figure 8. Mississippian paleogeography of Oklahoma.

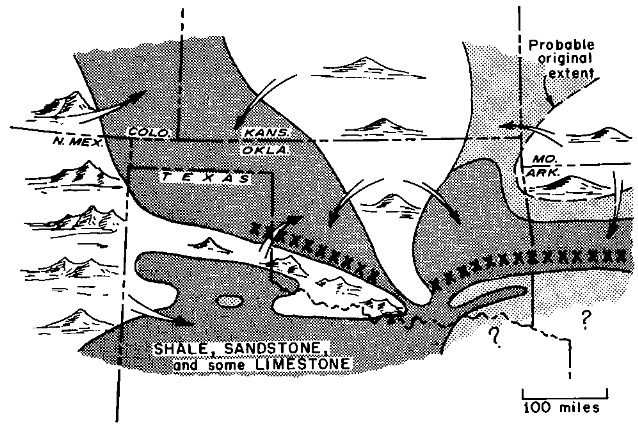

Figure 9. Early Pennsylvanian (Morrowan–Atokan) paleogeography of Oklahoma.

Mississippian rocks are the host to a variety of fossils and minerals. Outcropping marine limestones and shales contain abundant invertebrate fossils (such as crinoids, bryozoans, blastoids, and brachiopods) in the Arbuckle Mountains and in the Ozark uplift. The world-famous Tri-State mining district (Miami-Picher area) contains beautiful crystals of galena, sphalerite, and calcite (along with other minerals) in the northern part of the Ozarks.

PENNSYLVANIAN PERIOD

The Pennsylvanian Period was a time of important crustal unrest in Oklahoma: a time of both orogeny (the process of forming mountain ranges by folding, faulting, and thrusting) and basinal subsidence in the south, and of gentle raising and lowering of broad areas in the north. Sharp uplifts to the west, in Colorado and New Mexico, gave rise to chains of mountains commonly referred to as the "Ancestral Rockies." Rocks deposited earlier in the Wichita, Arbuckle, and Ouachita Mountains areas were deformed and thrust up into major mountains, while nearby basins subsided more rapidly and received the greatly increased sediment load eroded from the highlands. Pennsylvanian rocks are dominantly marine shale, but beds of sandstone, limestone, conglomerate, and coal also are present. They commonly are 2,000–5,000 ft thick, but are as much as 16,000 ft thick in the Anadarko basin, 15,000 ft in the Ardmore basin, 13,000 ft in the Marietta basin, and 18,000 ft in the Arkoma basin.

The Pennsylvanian Period is important to collectors in Oklahoma for two principal reasons. First, Pennsylvanian marine and nonmarine sedimentary rocks contain abundant invertebrate and plant fossils in outcrops of eastern and south-central Oklahoma. The invertebrates include a wide variety of brachiopods, crinoids, bryozoans, gastropods, and pelecypods; the plant remains include petrified wood, fossil leaves, and extensive layers of coal. Vertebrate fossils are primarily represented by shark teeth. And second, Pennsylvanian mountain-building processes caused uplift of the previously deeply buried Precambrian through Mississippian rocks; now, these older fossiliferous and mineral-bearing rocks are exposed, after removal of younger (overlying) strata, in the Wichita, Arbuckle, Ouachita, and Ozark uplift areas.

The Pennsylvanian Period is subdivided into five epochs of time: Morrowan (oldest), Atokan, Desmoinesian, Missourian, and Virgilian (youngest). Orogenies occurred in all five epochs, but different areas were affected to different degrees by each pulse of mountain building.

The major Pennsylvanian orogeny, commonly called the Wichita orogeny (in Morrowan and early Atokan time), was characterized by strong folding and uplift of pre-Atokan rocks and resulted in 10,000–15,000 ft of uplift in the Wichita Mountains and in the Criner Hills south of Ardmore (Fig. 9). Conglomerate and eroded granitic fragments (locally referred to as "granite wash") were commonly deposited near major uplifts, and these coarse sediments grade into sandstone and shale toward the middle of the basins. A broad, north-trending arch across central Oklahoma was raised above sea level during this time; along its axis was a narrow belt of fault-block mountains (the Nemaha uplift) extending northward from the Oklahoma City area into Kansas. Morrowan and Atokan uplift was accompanied by erosion that removed part or all of the pre-Pennsylvanian sedimentary rocks from the raised mountain areas and the central Oklahoma arch. In fact, the unconformity at the base of Pennsylvanian rocks is the most profound Paleozoic unconformity in Oklahoma and can be recognized everywhere but in the deeper parts of major basins.

Principal pulses of folding and thrusting (perhaps as much as 50 mi of thrusting to the north) in the Ouachita Mountains began in Atokan time and were strongest during the Desmoinesian Epoch (Fig. 10); these pulses are referred to as the Ouachita orogeny. In a series of movements lasting through the remainder of the Pennsylvanian Period, the thick sedimentary sequence in the Ouachita basin was uplifted to form a major mountain range. In deforming the Ouachita trough, basinal downwarping shifted northward into the Arkoma basin during Atokan and Desmoinesian time and then ceased with folding and

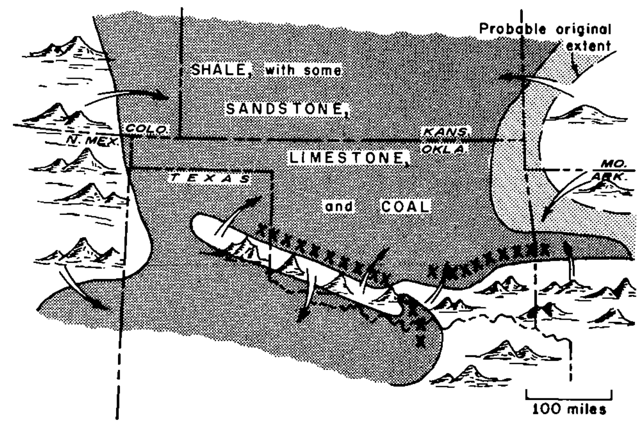

Figure 10. Middle Pennsylvanian (Desmoinesian) paleogeography of Oklahoma.

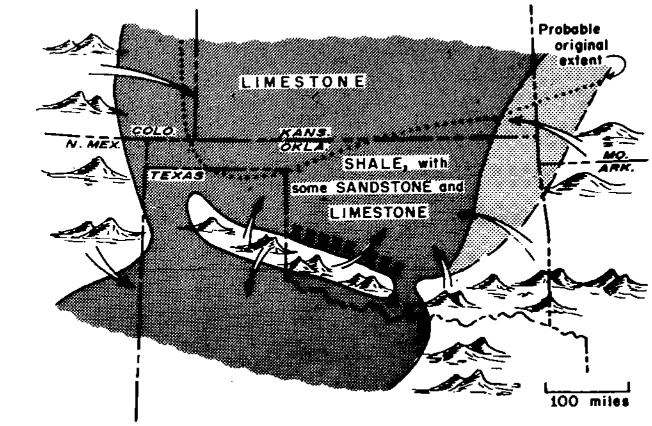

Figure 11. Late Pennsylvanian (Missourian–Virgilian) paleogeography of Oklahoma.

faulting of the Arkoma basin. Of special importance in the Arkoma basin and northeastern Oklahoma are the coal beds formed during Desmoinesian time from decaying trees and other plant matter that accumulated in swamps. Desmoinesian strata also are well known for containing fossil trees, wood, and leaves at scattered locations in eastern Oklahoma.

The last major Pennsylvanian orogeny, called the Arbuckle orogeny, was one of strong compression and uplift during Virgilian time. It affected all mountain areas of the south and is represented by most of the prominent folding in the Ardmore, Marietta, and Anadarko basins (Fig. 11). Much of the folding, faulting, and uplift in the Arbuckle Mountains is believed to have occurred in Virgilian time. Thus, by the end of the Pennsylvanian Period, the mountain systems of Oklahoma were substantially as we know them today, although subsequent gentle uplift and accompanying erosion have cut more deeply into underlying rocks and have greatly reduced the height of the mountains.

PERMIAN PERIOD

Following the period of mountain building, an Early Permian shallow inland sea covered most of western Oklahoma (Fig. 12), extending northward from western Texas to Nebraska and the Dakotas. The climate was warm and dry, and thick layers of gypsum (or anhydrite) and salt, such as the Wellington and Cimarron evaporites, were deposited from evaporating sea water. The Ouachitas, Arbuckles, and Ozarks were still fairly high, and along with the Wichitas they supplied sand and mud to the depositional areas of central and western Oklahoma. Alluvial, deltaic, and nearshore-marine deposits of red sandstone and shale interfinger with the marine red shale, anhydrite, limestone, dolomite, and salt—typical deposits of the middle of the broad Permian sea. Most Lower Permian outcrops are red shales, although thin limestones and dolomites are present in north-central Oklahoma, and cross-bedded sandstones such as the Garber are common in central and south-central areas. The red color so common in

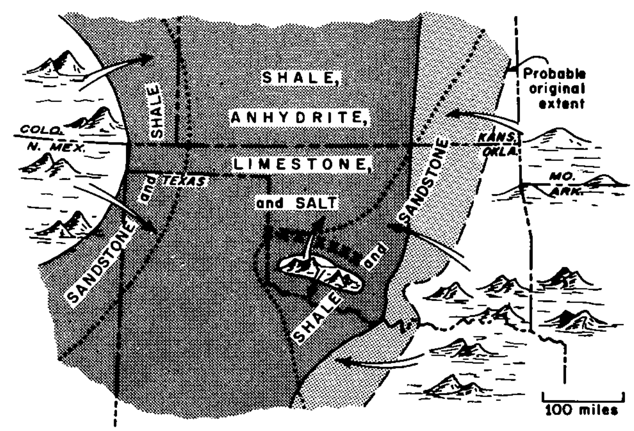

Figure 12. Early Permian paleogeography of Oklahoma.

Permian rocks results from a stain of red iron oxides (chiefly the mineral hematite) deposited with the sand and mud.

By Late Permian time the Wichitas were mostly covered with sediment and the mountains of the east were largely worn down (Fig. 13). Red shale and sandstone typify the sediment of the time, although white gypsum beds of the Blaine and Cloud Chief Formations are conspicuous. Thick salt units are associated with the Blaine in the subsurface. The Rush Springs Sandstone forms canyon lands in much of western Oklahoma and is important as a fresh groundwater aquifer. Thickness of the entire Permian sequence is generally 1,000–5,000 ft, but reaches 6,000–6,500 ft in deeper parts of the Anadarko basin.

Permian sedimentary rocks that crop out in central and western Oklahoma contain a wide variety of fossils and minerals. The fossils include vertebrates (such as fish, amphibians, and reptiles), insects, and a few marine invertebrates; the minerals include gypsum (selenite and satin spar), halite, and the rose rock (barite rose—the official state rock of Oklahoma).

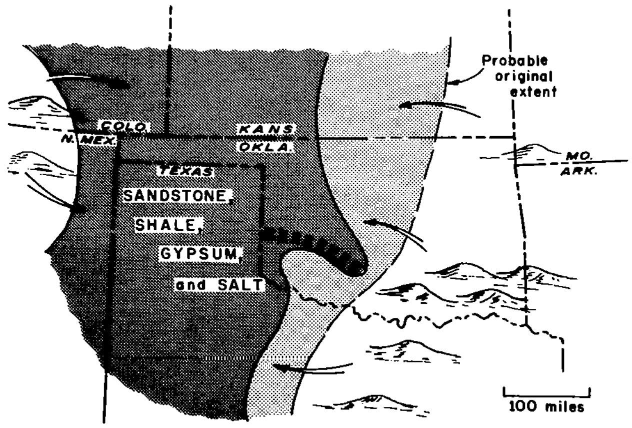

Figure 13. Late Permian paleogeography of Oklahoma.

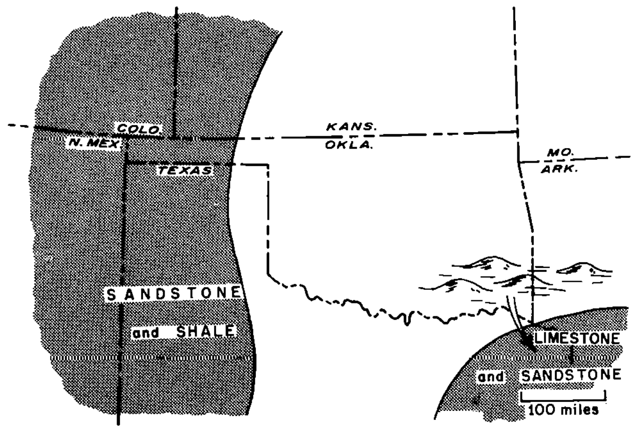

Figure 14. Triassic–Jurassic paleogeography of Oklahoma.

TRIASSIC AND JURASSIC PERIODS

Most of Oklahoma apparently was above sea level during the Triassic and Jurassic Periods (Fig. 14), and deposits of those ages that are still preserved are restricted to the Panhandle. Sandstones and shales in the Panhandle and adjacent areas were deposited mainly in rivers and lakes draining the hills of central Colorado, although some of the sand and mud must have come from lowlands of central and western Oklahoma where the previously deposited Permian sedimentary layers cropped out. Triassic and Jurassic strata of the Panhandle are chiefly red and gray, and their thickness is typically 200–600 ft.

The Ouachitas in the southeast were probably an area of low mountains and hills. Sands eroded from the Ouachitas were carried southward to the early Gulf of Mexico, which nearly reached into Oklahoma during the Jurassic. Triassic and Jurassic strata just southeast of Oklahoma are limestone, sandstone, shale, and evaporites that now are covered by later Cretaceous sedimentary units of the Gulf Coastal Plain.

Triassic and Jurassic fossils of Oklahoma include vertebrates, such as dinosaurs, crocodiles, turtles, and fish, along with some invertebrates. The Jurassic Morrison Formation is especially noteworthy because of its abundant dinosaur remains.

CRETACEOUS PERIOD

Cretaceous seas covered all but northeastern and eastern Oklahoma (Fig. 15). The ancestor of the Gulf of Mexico extended up to and across the southeastern part of the State in Early Cretaceous time, and shallow seas then spread northward in the last great inundation of Oklahoma and the Western Interior of the United States during the Late Cretaceous. Shale, sandstone, and limestone are generally 450 ft thick in the Panhandle and as much as 2,000–3,000 ft thick in the Gulf Coastal Plain of the southeast. A major unconformity is well exposed throughout the southeast where Cretaceous strata rest on rocks ranging in age from Precambrian through Permian. Formation of the Rocky Mountains to the west in Late Cretaceous and early

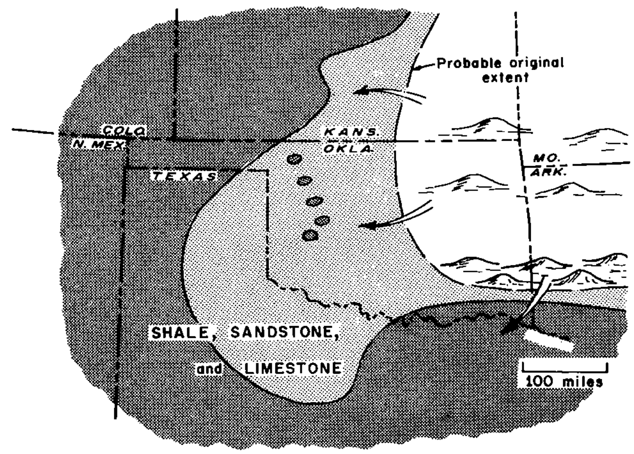

Figure 15. Cretaceous paleogeography of Oklahoma.

Tertiary time was accompanied by broad uplift of all of Oklahoma: this imparted an eastward tilt to the entire State and caused final withdrawal of the sea.

Cretaceous strata contain beds of fossilized marine invertebrates (mainly oysters) and petrified wood in most outcrops in Oklahoma; they also contain echinoids, shark teeth, and giant ammonites near Lake Texoma in the south and dinosaur remains at various locations in the south and southeast.

TERTIARY PERIOD

The State's general pattern of east-flowing drainage had its beginning in the Tertiary Period. The precursor of the Gulf of Mexico extended almost to the southeast corner of Oklahoma in early Tertiary time (Fig. 16), and the shoreline gradually retreated southward through the remainder of the period. Sedimentary materials deposited just southeast of Oklahoma include marine and nonmarine sand, gravel, and clay. In late Tertiary time, a thick blanket of sand, silt, clay, and gravel eroded from the Rocky Mountains was laid down across the High Plains of western

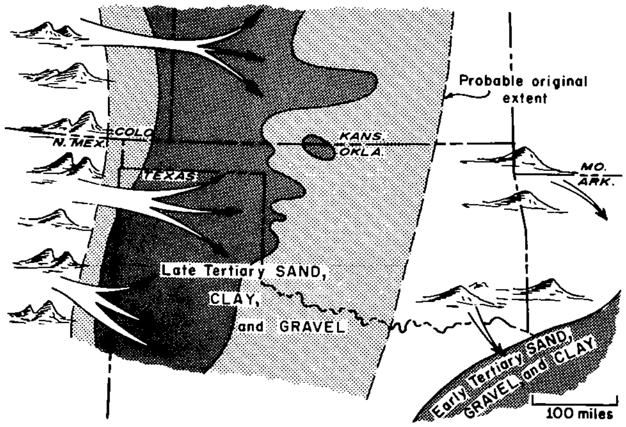

Figure 16. Tertiary paleogeography of Oklahoma.

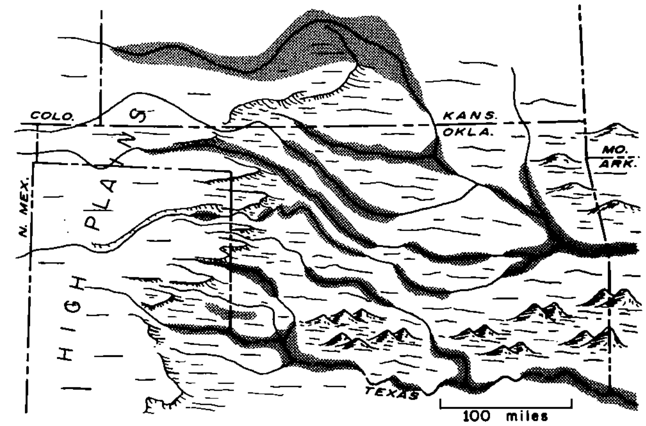

Figure 17. Major rivers of Oklahoma and principal deposits of Quaternary age.

Oklahoma and farther east by a system of coalescing major rivers and lakes; many of these deposits were intermittently reworked by winds, thus resulting in extensive layers of windblown or eolian sediment. All these deposits, principally the Ogallala and Laverne Formations, are generally 200–600 ft thick in western Oklahoma and originally may have extended across central Oklahoma. Tertiary sediments contain fossil wood, snails, and clams, and scattered remains of vertebrates, such as horses, camels, rhinoceros, and mastodons.

QUATERNARY PERIOD

The Quaternary Period, the past 2 million years of Earth history, is divided into the older Pleistocene Epoch (the "Great Ice Age") and the Holocene or Recent Epoch that we live in today. The boundary between these epochs is set at about 10,000 years ago, at the end of the last of four great episodes of continental glaciation. While continental glaciers extended from Canada southward only as far as northeastern Kansas, Oklahoma's surface was being sculptured by major rivers fed by meltwater from Rocky Mountain glaciers and by the increased precipitation associated with glaciation (Fig. 17). Major individual drainage systems of today were initiated during the Pleistocene. The shifting early positions of these rivers are marked by old alluvial deposits that have been left as terraces that now are tens to hundreds of feet above the present flood plains.

The Quaternary Period is characterized as a time of erosion. Rocks and loose sediment at the surface are being weathered to soil, and the soil particles then are carried away to streams and rivers. In this way, hills and mountain areas are being worn down, and sediment is transported to the sea or is temporarily deposited on the banks and in the bottoms of rivers and lakes. Sand, silt, clay, and gravel deposits of Pleistocene and Holocene rivers and lakes are unconsolidated and typically are 25–100 ft thick. Finding Pleistocene terraces 100 ft to more than 300 ft above modern flood plains attests to the great amount of erosion and downcutting performed by major rivers in the past 2 million years. The modern flood plains of rivers and streams consist mainly of alluvial deposits laid down during the Holocene Epoch.

Quaternary sediments locally contain fossil wood, snail shells, and the bones and teeth of land vertebrates such as horses, camels, bison, and mammoths.

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Minerals of Oklahoma

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To discuss the minerals of Oklahoma is a real challenge, and it is difficult to summarize 50 years of collecting and observation into a brief report. Most of my observations were reported upon earlier in the book that I published under the title *A Rockhound's Guide to the Gems and Minerals of Oklahoma* (Gilmore, 1963).

In this report I want to describe briefly some of the more important and interesting mineral occurrences in Oklahoma, and I refer the reader to my earlier book and the general literature for more comprehensive data. The occurrences I will describe are herein listed under their general location in Oklahoma.

1. TRI-STATE MINING DISTRICT

The Tri-State area of Ottawa County is the most mineral-productive area of Oklahoma. It has been mined since the beginning of this present century. The primary economic minerals are the lead and zinc ores (galena and sphalerite), found primarily in the fault zones and preexisting cavities and the water courses of the Mississippian formations. These are believed to be secondary-enrichment deposits resulting from the downward migration of chemicals originally in the overlying Pennsylvanian formations, and some are magmatic deposits from the underlying granite.

Many other finely crystallized minerals are found in the area: chalcopyrite, dolomite, calcite, pyrite, marcasite, and some minerals from the oxide zone, such as smithsonite, hydrozincite, hemimorphite, barite, and pyromorphite. There are also breakdown minerals such as melanterite, chalcanthite, gypsum, etc.

2. PEORIA AND LINCOLNVILLE AREAS

Peoria and Lincolnville are two mining camps that were mined early in this century (about 1891 to 1923) mostly for shallow deposits (as much as about 100 ft deep). The ores were basically in the oxide zones of the Tri-State District. Samples of many of the early-mined minerals from here are still found on the boulder piles and spoil heaps of the area.

Hemimorphite is a common find, along with sphalerite, smithsonite, hydrozincite, galena, cerussite, anglesite, pyromorphite, etc., as well as dolomite, calcite, white chert, and cherokite as breccia filling.

3. SPAVINAW AREA

In Spavinaw, there is an outcrop of the top of a mostly covered Precambrian granite mountain. This is surrounded by the Cotter Dolomite of Ordovician age. After some movement during the raising of the Ozark uplift there was mineralization in the contact zone and the surrounding area. Several shafts have been sunk in an attempt to find economic ore. For the most part, these have been failures. The dumps from these explorations do provide a fair source for collecting.

Behind the lumber yard and in the field to the right are some mine dumps. These provide limonite, hematite, and pyrite, along with pseudomorphs after pyrite in very fine crystal form and a few specimens of native copper in arborescent form.

At the road, where it crosses Spavinaw Creek below the dam, the granite crops out, and on its upside (toward the dam) is a dump with dolomite crystals up to 0.75 in. across; also glauconite, pyrite, and a black hydrocarbon (probably maltha). Small quartz crystals (up to 0.25 in. long) are found in the valleys along the creek in the Cotter Dolomite; these crystals fluoresce a brilliant green color, owing to the hydrocarbons included in the crystals.

Down the creek, about 100 yd below the bridge, was a shaft about 80 ft deep; it yielded galena and cerussite, and some of these minerals may still be found by digging at the dump. At the fish ponds near the dam, and on the banks of the ponds, galena and cerussite can be found as well as small pieces of stibnite, valentinite, and cervantite.

Near the mouth of the creek, where it enters the Illinois River, there is a tunnel for the Spavinaw-Tulsa water supply. This site has yielded barite crystals up to several inches across.

On the road just below the dam is a cattle guard. Around this, and down toward the creek, can be found some fine oolite that has been agatized (a banded agate); some of this material can be cut and polished into beautiful cabochons.

4. MARBLE CITY AREA

The area is mined for high-purity limestone in the Quarry Mountain Formation. The minerals found are step calcite, galena, pyrite, and goethite.

*Deceased, December 18, 1995.

Gilmore, E. L., 1996, Minerals of Oklahoma, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 11–12.

5. McCURTAIN COUNTY AREA

On the crest of Pine Mountain there are several prospect pits for psilomelane; these pits also contain pyrolusite and manganite. Near the town of Watson, good clusters of quartz are present; also, some very fine crystals of calcite that fluoresce a brilliant red are found.

On Glover Creek, quartz crystals are present, some with chlorite phantoms.

6. RAVIA AREA

In Johnston County, near Ravia, sphalerite and smithsonite are present in a zone 500–3,000 ft wide and 15 mi long.

7. MARLOW AREA

In Stephens County, fine crystals and clusters of selenite are found on Little Beaver Creek in Section 13.

8. COMANCHE COUNTY

Near Cache, in Comanche County, barite nodules and radial crystal balls of barite are present in the road cuts.

On the Fort Sill Military Reservation, crystals of zircon, up to 1 in. across, are found. Also, the reservation contains good crystals of aegirite and rutilated smoky quartz.

9. GREER COUNTY

Near Granite, in Greer County, large quartz crystals and feldspar crystals are present in vugs of the Reformatory Granite.

10. CUSTER COUNTY

In the Cloud Chief Gypsum, probertite is found as nodules along bedding planes in the lower anhydrite.

Near Foss Lake, tyuyamunite and carnotite, as well as uraninite, are present in several locations; some of these uranium minerals have been mined in this area.

11. PANHANDLE AREA

In the extreme western counties of the Panhandle, good deposits of agate, petrified wood, and agatized fossil algae are present in the Ogallala Formation, terrace deposits, and alluvium.

12. HARPER COUNTY

In Harper County, just north of Rosston at Twin Buttes, crystals of aragonite are found; these pseudohexagonal twin crystals are locally known as "Indian money." From 4 to 9 mi south of Buffalo, on Highway 270, large layers of agate crop out.

13. GREAT SALT PLAINS

At Jet, in Alfalfa County, the Great Salt Plains contains numerous hourglass selenite (gypsum) crystals that are now growing and enlarging just below the surface of the salt flats.

14. OSAGE COUNTY

At Phillips Lake, in Osage County, chert containing fusulinids is present near the dam; the chert can be cut into gem stones.

15. PAWNEE COUNTY

A couple miles north of Lela, several prospects for copper contain both azurite and malachite. Most of these samples have formed as a replacement after organic material. Some of the fossil leaves look quite fresh and are replaced with copper salts.

16. PAYNE COUNTY

West of Stillwater, wood in a coal seam is replaced by chalcocite, malachite, and azurite.

17. LOGAN COUNTY

At Guthrie, wood casts are filled with barite.

18. CLEVELAND COUNTY

Around Norman and Noble, in the Garber Formation, are found samples of barite roses, the Oklahoma State Rock.

19. GARVIN COUNTY

At Paoli, nodules of chalcocite and malachite are found over an area of 1 sq mi; the area also contains massive barite and barite nodules.

20. PRAGUE AREA

South of Prague, copper has been mined. This locality yields malachite in sandstone.

21. SEMINOLE AND OKFUSKEE COUNTIES

Within the triangle from Boley to Sasakwa to Konawa, the Vamosa Formation contains a large amount of agate, jasper, and other silica minerals; these materials are locally known as "Boley agate."

22. ADA AREA

In a quarry near Ada, fine marcasite crystals, up to 1.5 in. long, are present, along with sphalerite, pyrite, and galena.

SUMMARY

This paper is but a brief overview and introduction to the great variety of minerals in Oklahoma. I hope that it has helped excite the readers' interest to join with other rockhounds, to search the literature, and to go into the field and collect minerals.

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Macroinvertebrate Fossils of Oklahoma

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INTRODUCTION

Oklahoma is known as one of the most fossil-rich states in the union. Oklahoma is blessed with rock outcrops of every geologic period from Cambrian to Quaternary. Geologists find fossils from every period and most sedimentary rock units in the State. The wide variety of environments represented in the geologic column results in an equally large variety of life forms preserved as fossils. This paper is an abbreviated review of many of the invertebrate fossil groups that have been found in Oklahoma.

GRAPTOLITES

Graptolite means "writing on rocks," and graptolite fossils are common in the Ordovician of Oklahoma. These organisms were pelagic or floating animals that were buried in carbonate or clastic muds on the ocean bottom. By studying well-preserved specimens from Oklahoma, geologists have determined that graptolites were colonial and bisexual (Ruedemann and Decker, 1934; Decker and Hassinger, 1958). Graptolites from the Viola Group have revealed reproductive elements and immature forms (Decker and Gold, 1957; Bates and Kirk, 1991). There are many single- and double-stalk types (Pl. I, Fig. 1), as well as unusual sacklike varieties (Whittington, 1954). Most are preserved as carbon film, but three-dimensional specimens preserved in pyrite are known from the Viola Group of Coal County in southern Oklahoma.

There are also several Silurian and Devonian forms from the Hunton Group of the Arbuckle Mountains (Decker, 1935,1941). There are no known post-Devonian graptolites in Oklahoma.

BRYOZOANS

Branching, fenestrate or fan (Pl. I, Fig. 2), and encrusting bryozoans were present throughout much of Oklahoma's geologic history. Although present as early as the deposition of the Cambrian–Ordovician Arbuckle Group, bryozoans first became a large portion of the invertebrate fauna of Oklahoma in the Middle Ordovician (Loeblich, 1942; Farmer, 1974; Key, 1990). These colonies have been described as the best-preserved Ordovician bryozoan fauna in the world (Farmer, 1974). Bryozoans dominated the lithology at many outcrops of the Ordovician Mountain Lake Formation. The sea bed was covered with both small bryozoan sea fans and branching bryozoans (with 15 arms) that reached grapefruit size. Encrusting bryozoans partially or totally encased trilobite skeletal fragments, brachiopods, crinoids, and cystoids.

Through much of the early and middle Paleozoic, bryozoans survived in small numbers as encrusting and occasionally branching forms. A delicate, conical fenestrate bryozoan is known from the Lower Devonian Haragan Formation of Coal County (Cuffey and others, 1995).

In the Mississippian Period, bryozoans again formed a large proportion of the fauna in northeastern Oklahoma (Snider, 1915). Fenestrate bryozoans reached their pinnacle in *Archimedes* sp., a huge bryozoan with a corkscrew stalk (Condra and Elias, 1944). Long, delicate fans extended from the screwlike edges. At some sites the rocks are, to a great extent, composed of this genus.

The bryozoan explosion continued through the Pennsylvanian Period. Almost every Pennsylvanian unit contains bryozoans, often in large numbers. Large bioherms of branching bryozoans can be found in the Wann Formation near Copan, Washington County, and in the Neva Limestone and Roco Shale, Pawnee County (Naff, 1981).

Bryozoans whose branches are triangular in cross section have been retrieved from various Pennsylvanian sites. Limestones associated with the coals near Chelsea, Oklahoma, have produced partially crushed specimens of these bryozoans. The author has collected material from a bioherm in the Hogshooter Formation of Washington County (Strimple and Cocke, 1973). The most elaborate specimens that I have found are from the Pumpkin Creek Formation at Lake Murray.

Many believe that Oklahoma bryozoans exist only in the fossil record, but that is incorrect. Clear, silt-free streams in Oklahoma have encrusting freshwater bryozoans attached to rocks and logs. *Pectinella* sp. occurs as large gelatinous blobs in shaded waters (Pennak, 1989).

SPONGES

Articulate sponges are uncommon, as most are preserved only as separate spicules (Rigby and Toomey, 1978). The earliest Oklahoma articulate sponges are from the Middle Ordovician Pooleville Member of the Bromide Formation in the Criner Hills of Carter County (Rigby and Gutschick, 1976). They are spherical in shape and have long spicule spines that reach 7 cm in length (Pl. I, Fig. 3).

Hexactinellids are one of the longest-living sponge fami-

Simpson, L. C., 1996, Macroinvertebrate fossils of Oklahoma, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 13–26.

lies, having survived from the Early Cambrian (Rigby and Xian-Guang, 1995) to Recent time (Schulze, 1887). A hexactinellid protosponge has been discovered at one Pooleville Member site in the Criner Hills. These lobate sponges resemble *Cyathophycus* sp. (Rigby, 1995).

Sponges are rare in Silurian and Devonian rocks. Mississippian rocks have yielded spicules and fragmentary specimens (Elias, 1957, p. 379–383; Rigby and others, 1970). In the Pennsylvanian, finger sponges, *Wewokella* sp. (Girty, 1915, pl. 1); cup sponges, *Arakespongia* sp. (Rigby and others, 1970, fig. 1); and string of pearl sponges, *Amblysiphonella* sp., and *Girtyocoelia* sp. (Naff, 1972, fig. 1) all became more common.

Small sponge bioherms, 0.5 m in diameter, and numerous solitary specimens have been found in the upper Francis Formation at Ada and the Wann Formation at Bartlesville. I have discovered finger sponges 3 cm in diameter and 60 cm long. Similar sponges live in the Caribbean today.

Post-Pennsylvanian sponges of Oklahoma are all freshwater animals. Pliocene and Pleistocene sponge spicules have been discovered in the ash beds of northwestern Oklahoma (Branson, 1967). Recent encrusting sponges are known in the eastern half of Oklahoma. These small, irregularly shaped sponges of the genus *Spongilla* sp. attach to the substrate, logs, and structures in lakes and clear, permanent streams (Pennak, 1989). They represent a continuing link to Oklahoma's ancient past.

CORALS

Coral virtually started in the Middle Ordovician in Oklahoma. At the base of the Pooleville Member of the Bromide Formation in the Criner Hills (Frederickson, 1957), huge *Tetridium* sp. corals grew. These spherical forms reach 30 cm in diameter. After the Middle Ordovician, coral degenerated to much smaller solitary and colonial forms during the middle Paleozoic (Amsden, 1956; Sutherland, 1965).

Upper Mississippian rocks reveal a renewed increase in coral development in northeastern Oklahoma (Webb, 1987). The Pennsylvanian seas produced the last major expansion of coral in this State. Solitary rugose coral (Pl. I, Fig. 4) is present in most marine units in eastern Oklahoma. Rugose corals reach their maximum size (over 35 cm) and numbers in the Dewey Limestone at Bartlesville (Sutherland and Cocke, 1960; Cocke, 1966). Coral bioherms developed in many Pennsylvanian units including the Dewey, Wann, and Hogshooter of northeastern Oklahoma (Cocke, 1966; Strimple and Cocke, 1973) and the Wapanuka of southern Oklahoma (Rowett and Sutherland, 1964; Rowett, 1966).

Coral is virtually unknown in Permian through Tertiary rocks of Oklahoma. However, Recent solitary and colonial freshwater forms are present in lakes and permanent streams, especially in central and eastern Oklahoma (Pennak, 1989).

BRACHIOPODS

Brachiopods are the most common Paleozoic fossils in Oklahoma. There are over 700 species of articulate (strong hinge mechanism connecting the two shells or valves) brachiopods in rocks ranging in age from Cambrian to Pennsylvanian (Pl. I, Fig. 5A). The largest brachiopod faunas are in the Ordovician, Devonian, and Pennsylvanian rocks. Individual specimens from the Lower Devonian and Pennsylvanian reach 8 cm across!

Spiny articulate brachiopods occur in the Pennsylvanian of southern Oklahoma. In the Ardmore basin, members of the genus *Teguliferina* occur in small silicified "patch reefs." The brachiopod reefs are composed of dense clusters of specimens attached by long spines (Sutherland, 1989). Very spiny brachiopods are in the underclays associated with the coal beds of southeastern Oklahoma.

The inarticulate (weak hinge mechanism between valves) brachiopods are not as common, but are longer lived than the articulates. The two most common inarticulate brachiopod genera are *Lingula* and *Orbiculoides* (Pl. I, Fig. 5B,C).

Lingula sp. is a simple, long-lived brachiopod that has existed for over half a billion years. It has a long and narrow shell connected to a long fleshy stalk. *Lingula* sp. burrows in the mud and extends itself to eat. The genus still flourishes in the South Pacific (Feldman, 1992). The preference of *Lingula* for muddy sea-floor settings explains its longevity in Oklahoma geologic history.

Lingula sp. represents the longest-living brachiopod genus in Oklahoma. It was one of the first brachiopods, when it appeared in the Early Ordovician, and was the last Oklahoma brachiopod, surviving in the State into the Early Permian (Hall, 1966).

CEPHALOPODS

Cephalopods were a very long lived and successful group in Oklahoma. They can be divided into straight forms, the nautiloids, and coiled forms, the ammonoids (Pl. I, Fig. 6). The first fossil described in Oklahoma was a Mississippian ammonoid *Goniatites choctawensis* Shumard, described in 1863 (Branson, 1958).

Nautiloids are common in Ordovician through Pennsylvanian sedimentary rocks. The largest specimens are found in the Middle Ordovician Bromide Formation of the Criner Hills and the Pennsylvanian Wann and Fort Scott Formations of northeastern Oklahoma. Ordovician nautiloids are commonly 1 m in length; some have reached almost 2 m long and 14 cm in diameter. Although most Pennsylvanian nautiloids are less than 5 cm in length, the largest forms are 1–1.25 m in length (Unklesbay, 1962, pl. 1). Large, straight nautiloids have been recovered from stream beds south of Bromide, Oklahoma. These large specimens are unusual in that they are preserved in clear calcite.

Many nautiloids are distributed as solitary specimens. Occasionally, several nautiloids are found scattered over one bedding plane. However, vast death assemblages are known from the Silurian (lower Hunton Group) of southern Oklahoma. Three limestone units, each 2–3 cm thick, in the Silurian Clarita Formation of Coal County are almost entirely composed of nautiloids that are 3–15 cm long. They are stacked on top of each other in such huge numbers that a rock 30 cm^2 in area can contain 100 individuals. Positive identification of these poorly preserved specimens has not been accomplished. There is no current direction noted in the nautiloid coquina. The upper part of the overlying Silurian Henryhouse Formation contains similar fossil assemblages. At one site in Pontotoc County, a 1-in.-thick unit produced thousands of partially inflated nautiloids. Like the assemblages from the Clarita, these specimens are difficult to identify and show no current direction. These nautiloid assemblages are similar to death assemblages of Recent Pacific squids. Squids litter the sea floor following mass mating events. Nautiloids and squids have similar physiology. This likeness supports the interpretation that these concentrations of Silurian straight nautiloids may be the result of mass mating events.

There are only a few coiled cephalopod specimens from the Ordovician Viola Group and the Silurian Henryhouse Formations (Miller and Collinson, 1952) of southern Oklahoma. Ammonoids are found in larger numbers and great variety beginning in the Mississippian (Girty, 1909; Elias, 1958; Gordon, 1960). Following rains, *Goniatites* and other genera can be recovered from stream cuts in Mississippian rocks of Pontotoc and Coal Counties.

Paleontologists have found over 50 genera of Pennsylvanian ammonoids in Oklahoma (Miller and Cline, 1934; Miller and Owen, 1937,1944; Miller and Moore, 1938; Unklesbay, 1954,1962; Miller and Furnish, 1958). The largest ammonoid faunas are from the Middle Pennsylvanian Marmaton Group (Unklesbay, 1962, p. 13–18). Most specimens are small and round, but two localities produce triangular ammonites (Unklesbay, 1962, pl. 13). The Morrowan Gene Autry Shale in the northern Ardmore basin is rich in ammonoids (Manger and others, 1992). I viewed a 30-m^2 outcrop of Gene Autry shale containing 2,000 ammonoids. Most were specimens of *Axinolobus* sp., 2 cm in diameter.

Cephalopod shell material is best preserved in the Pennsylvanian Buckhorn Limestone, south of Sulphur. These limestone deposits were soaked in petroleum soon after deposition. The shell material was preserved in its original state by the oil (Squires, 1973). The beds contain nautiloids, ammonoids, gastropods, and brachiopods. This assemblage represents some of the oldest original shell material in the world (Roland and others, 1973; Squires, 1976).

The pinnacle of coiled cephalopod development occurred during the Cretaceous Period, with the explosive development of the ammonites. Cretaceous limestones and shales of south-central and southeastern Oklahoma have yielded over 40 genera of ammonites. There are not only a large variety of ammonites, but millions of specimens. Ammonites represent a large percentage of the fossil volume of these beds. The Duck Creek Shale and Fort Worth Limestone are so fossil rich that groups of 100 amateurs have collected 800 medium to large specimens in an afternoon.

The smallest ammonites are less than 1 cm in diameter and are preserved in dark hematite and limonite. They are most common in the middle of the Duck Creek Formation. Specimens 3–7 cm in diameter are present in most outcrops in the Lake Texoma area. These small ammonites are often overlooked. The larger ammonites are generally preserved as limestone casts although some are recovered with shell material attached. An average size for the larger ammonites in the Cretaceous of southern Oklahoma is 15 cm. The maximum size that I have discovered in the Fort Worth Limestone is 110 cm in diameter; that specimen's weight was estimated at 750 pounds.

GASTROPODS

Gastropods are widely distributed throughout almost the entire geologic history of Oklahoma, appearing in Ordovician through Recent deposits. The Middle Ordovician McLish and Oil Creek Formations along Interstate 35, in the southern Arbuckle Mountains, contain one of the State's largest fossil snails, *Maclurites* sp. (Decker and Merritt, 1931, pl. 8).* Lower Devonian, Pennsylvanian, and Cretaceous sedimentary rocks also contain large gastropod faunas. The largest specimens of these periods reach 5–10 cm in diameter (Pl. II, Fig. 1).

There are two species of Pennsylvanian gastropods that have retained their original shell coloring. Shell-color patterns of the genus *Naticopsis* were preserved by early oil encroachment into the Buckhorn Limestone of Murray County, south of Sulphur, Oklahoma (Squires, 1976). Most of the gastropods in the Fort Riley Limestone of Kay County are dull with a uniform color; however, one currently unidentified species is glossy and has a uniform tan and brown color pattern, similar to recent gastropods. Shell geometry and color pattern are aids for identification to the level of species.

There are numerous fossil snails in Oklahoma's Pliocene and Pleistocene rocks. Some sites in western Oklahoma have yielded thousands of specimens (Leonard and Franzen, 1944; Taylor and Hibbard, 1955). A water well drilled in alluvium of the Canadian River at Union City encountered, at depths of 12–18 m below the surface, layers containing hundreds of snail specimens 1–3 cm in diameter.

Snails continue to be a major fauna in modern invertebrate zoology (Pennak, 1989). There are many common terrestrial and freshwater forms in every county of Oklahoma .

ECHINODERMS

Starfish

Starfish are first recorded in the Middle Ordovician Bromide Formation. There are three genera, but the largest and most common genus is *Urasterella* sp. (Pl. II, Fig. 2) (Sprinkle, 1982); at least one specimen reached 7 cm in diameter. Starfish were quite rare until the Pennsylvanian, when some starfish and brittlestars as much as 3 cm across formed well-preserved specimens (Hattin, 1959), though most examples of that period generally occur as casts (Chenoweth, 1960). Occasionally, large groups of starfish and brittlestars have been found around Lake Texoma. Many specimens are very high quality and some are pyritized. One group of starfish, each as much as 6 cm in diameter, was found in the Duck Creek Formation along the northwestern shore of the lake. The southeastern shore of Lake Texoma has provided large groups of small pyritized starfish.

**Caution:* When collecting on divided highways, always park well off the road on the right-hand side.

Blastoids

Except for a few Silurian specimens (Reimann and Fay, 1961), blastoids are generally restricted to the Mississippian and Pennsylvanian of the eastern half of northeastern Oklahoma (Pl. II, Fig. 3) (Moore and Strimple, 1942; Galloway and Kaska, 1957). They are common in certain Mississippian black shales and limestones. Nearshore marine environments were ideal for blastoids. Huge beds of blastoids grew in the tidal channels between barrier islands in the Morrow Group (Katz, 1978). At one residential site, over 10,000 were found in an outcrop of just a few acres.

Crinoids and Cystoids

Arbuckle Group limestone north of the Wichita Mountains, and in the southern Arbuckle Mountains, has produced a few crinoids recently. An unusual eocrinoid, *Mandalacystis* (Pl. II, Fig. 4), occurs in the I-35 outcrop of the Middle Ordovician Oil Creek Formation in the Arbuckle Mountains (Lewis and others, 1987). The first large, diverse crinoid faunas occurred in the Middle Ordovician Bromide Formation. These beds produced over 15,500 specimens from 44 sites. These numerous sites in six counties have yielded 60 genera of crinoids, cystoids, carpoids, echinoids, and starfish (Sprinkle, 1982).

The Bromide echinoderm faunas reveal important aspects of the evolution of this animal group. Bromide *Platycystes* sp. represented the last in their line (Frest and others, 1979). Calceocrinoids evolved in the Ordovician and are well represented in the Bromide (Brower, 1977,1987; Sprinkle, 1982). Evolution of the calceocrinoids can be traced into the Silurian units in southern Oklahoma. Large specimens have recently been found in the lower Henryhouse Formation of Pontotoc County. A bizarre form of paracrinoid, *Oklahomacystes* sp., is found in large numbers associated with bryozoan bioherms of the Mountain Lake Formation. Although they are found in six states and eastern Canada, 99.9% of all known specimens are from the Arbuckle Mountains of Oklahoma.

In the Silurian-Devonian Hunton Group, crinoids are most commonly represented by their attachments (roots and bulbs). In certain zones, especially in the Haragan and Bois D'Arc Formations, thousands of crinoids covered the sea floor. Silurian crinoid roots are exposed in some outcrops south of Ada. Lower Devonian crinoid bulbs, *Scyphocrinites* sp., are very common south of Fittstown and along State Highway 7d in the northern Arbuckle Mountains (Strimple, 1963; Fay, 1989). Unfortunately, the crinoid stems and heads were eaten or swept away, and only the roots that anchored them in the soft sediments were preserved.

The Mississippian Period, the "Age of Crinoids," heralded an increase in crinoid diversity in northeastern Oklahoma (Strimple, 1949a,1951; Strimple and Koenig, 1956). This trend was amplified during the Pennsylvanian with crinoids diversifying and filling many niches. Pennsylvanian rocks in eastern Oklahoma yield many crinoid genera (Strimple, 1949b,1961,1962; Strimple and Moore, 1971; Moore and Strimple, 1973). One of the most elaborately ornamented is *Aglaocrinus* sp. from the Sausbee Formation of Cherokee County (Strimple, 1982) (Pl. II, Fig. 5).

Carpoids

Carpoids are a rare and very unusual type of echinoderm. Some of the oldest carpoids are from the Middle Ordovician Bromide Formation (Strimple, 1953,1961) in the Criner Hills. The youngest carpoids also come from the Pennsylvanian of Oklahoma at Lake Murray (Kolata and others, 1991). These specimens, which represent the entire geologic history of this group, were collected from sites that are only a few miles apart.

Echinoids

The first minute echinoids were discovered in the Middle Ordovician Bromide Formation (Strimple, 1982). In 1990, an amateur collector recovered a few complete specimens in the Upper Mississippian Pitkin Limestone at Braggs Mountain, near Muskogee. Pennsylvanian echinoids are predominantly represented by loose plates and spines of the genus *Archaeocidaris* (Chenoweth, 1966). Echinoid material is found in the Pennsylvanian Francis Formation at Ada, the Wann and Dewey Formations of Washington County, the Lecompton Limestone near Drumright, and the Oologah Limestone of Tulsa County (Pl. II, Fig. 6A,B).

Like the ammonites, echinoids also reached their zenith in Oklahoma during the Cretaceous Period. Similar to the crinoid bulbs of the Lower Devonian, some Lower Cretaceous echinoids are deposited in huge compact beds where they are stacked two to three layers deep. These echinoid "coquinas" are 5-10 cm thick and cover areas a few square meters to many acres in size. Some deposits undoubtedly hold millions of specimens. Unfortunately, most of the echinoids in these "coquina" deposits are crushed. Solitary specimens are also common in most Cretaceous rock units (Pl. II, Fig. 6C).

ARTHROPODS

Crustaceans and Insects

The earliest known large crustaceans are from the Upper Silurian Henryhouse Formation of the Arbuckle Mountains (Ruedemann, 1935). The oldest fauna of branchiopods, large valved crustaceans, are known from the middle part of the Upper Devonian Woodford Shale (Cooper, 1932).

The Permian crustaceans are restricted to Noble County, Oklahoma. In northern Noble County, branchiopods are present in the Wellington Formation (Tasch, 1964). These generally sterile marine deposits also produced two eurypterid heads (Decker, 1938). They represent some of the youngest eurypterids in the world, and the only specimens from the Midcontinent. In southern Noble County, the Lower Permian is represented by terrestrial sedimentary rocks. Conchostracans (clam shrimp) are common around Perry in thin limestones in the Wellington Formation; the limestones were deposited in restricted ponds located on a flat coastal plain (Raymond, 1946; Tasch, 1962). These lacustrine limestones have also yielded all the insect fossils known from Oklahoma; 30 species of insects, preserved as wings, are known from the Perry area (Carpenter, 1947; Raasch, 1946; Tasch and Zimmerman, 1959; Tasch, 1962).

Fragmentary crab material is known from the Cretaceous deposits of southern Oklahoma. Cretaceous marine crustaceans are more common to the south in Texas.

Freshwater crustaceans are well represented today in Oklahoma. I have collected a variety of freshwater shrimp, *Paleomonetes* sp., in lakes and streams of central Oklahoma. Shrimp, as long as 1 in., have been commercially harvested in Walnut Creek in McClain County since the 1890s (Mr. Jimmy Pigg, personal communication, 1992)! Conchostracans are as common in Oklahoma today as they were in the Permian ponds of Noble County (Pennek, 1989). Crayfish are also quite common in the lakes and streams of Oklahoma. The largest concentrations may be the black crayfish in the stream headwaters above Lake Ellesworth near Meers in the Wichita Mountains. Oklahoma has terrestrial crustaceans represented by the common sow bugs and pill bugs (Pennak, 1989).

Trilobites

Although there are a few Cambrian trilobites (Stitt, 1971,1977), by the Ordovician, trilobites had become a dominant member of the Oklahoma fauna (Shaw, 1974). The Middle Ordovician Pooleville Member of the Bromide Formation is characterized by the 1.5-cm-long, spiny-nosed *Lonchodomus* sp. as well as by the greatest concentration of trilobites in the State. In the Criner Hills there are three thin limestones in the upper and lower Pooleville that contain an apparent death assemblage of *Homotelus* sp. trilobites (Raines, 1982). At some sites there are as many as 175 beautifully preserved, articulated, 3–7-cm-long trilobites per square meter (Pl. III, Fig. 1). At other sites, however, later tectonic activity shattered the delicate shells of the trilobites.

The overlying Viola Limestone contains *Isotelus* sp. trilobites that reach 28 cm in length. *Isotelus* sp. are the largest trilobites in America, and the Oklahoma specimens are the largest trilobites west of the Mississippi River (Amsden and Ham, 1959) (Pl. III, Fig. 2). The genus *Cryptolithoides* is the index fossil for the Viola Group (Shaw, 1991) (Pl. III, Fig. 3). At some places, 35 heads and tails, or five complete specimens, can be preserved in 30 cm^2 of Viola Limestone. *Cryptolithoides* sp. are preserved in white, gray, black, pink, and red minerals.

The Silurian-Devonian represents a major time of trilobite diversification and evolution. Phacopid and dalmanitid trilobites developed into a large part of the fossil community. The Silurian phacopid *Ananaspis* evolved into the most common trilobite of the Lower Devonian, *Paciphacops* sp. (Pl. III, Fig. 4). *Dalmanites* sp. developed into *Huntonia* sp., the largest trilobite of the Devonian.

Specimens of *Huntonia* sp. that are 13 cm long have been recovered in the Lower Devonian Haragan Formation (Pl. III, Fig. 5). All invertebrates increased dramatically in size in the overlying Bois D'Arc Formation. Phacopids doubled to 10 cm in length in large specimens of *Viaphacops* sp. (Campbell, 1967,1977). Incomplete *Huntonia* sp. material represented specimens that were 20–30 cm long.

Spiny trilobites, the odontopleurids, also reached their pinnacle of development during the Devonian (Campbell, 1977). The most common of these exotic trilobites is the genus *Leonaspis*. It has fine spines and eyes on stalks. Its facial comb facilitated extraction of organic material from the muddy sea floor (Pl. III, Fig. 6).

Dicranurus is the largest of the Oklahoma odontopleurids, reaching 12 cm in length. This trilobite was well protected with long spines protruding from the head, thorax, and tail. The curved tusklike head spines protected the upper thorax. Some specimens are found outstretched. However, even with their long spines, *Dicranurus* could enroll into a fairly tight ball.

The Early Devonian represented the last great trilobite hurrah. Trilobites are unknown in Upper Devonian rocks and are quite rare in the Mississippian of Oklahoma.

Trilobites became more common again in the Pennsylvanian; however, they are small and not very diversified. A large percentage of the Pennsylvanian trilobites belongs to the genus *Ditomopyge* (Pabian and Strimple, 1976; Pabian and others, 1993). These 1–2-cm-long trilobites are not only small but often enrolled. Trilobite material is known from the Lower Permian Chase Group of Oklahoma. Soon after these specimens were buried, trilobites became extinct worldwide.

Plate I

Figure 1. Graptolites from the Ordovician Viola Group, Carter County (after Ruedemann and Decker, 1934, pls. 41,42). *A—Diplograptus recurrens*, ×2.5, from Arbuckle Mountains. *B—Dicranograptus nickolsoni* var. *geniculatus*, ×2.5, from Criner Hills.

Figure 2. Pennsylvanian bryozoans (after Naff, 1972, fig. 1). *A—Thamniscus* sp., ×1, branching bryozoan. *B—Fennestrellina* sp., ×5, fan bryozoan. Both resemble specimens from Ordovician through Pennsylvanian.

Figure 3. *Dierespongia palla*, ×1 (USNM [U.S. National Museum] 188528), sponge from Ordovician Pooleville Member, upper Bromide Formation, Criner Hills, Carter County (after Rigby and Gutschick, 1976, pl. 1, fig. 3).

Figure 4. Two species of *Lophophyllidium* sp., ×3, Pennsylvanian solitary rugose coral (after Naff, 1972, fig. 1).

Figure 5. Brachiopods. *A—Lepidocylus cooperi*, ×1 (OU [Oklahoma Museum of Natural History] 5804); three views of Ordovician articulate brachiopod from the Viola Group of the Arbuckle Mountains (after Alberstadt, 1973, pl. 6, fig. 4). *B—Lingula* sp., ×1. *C—Orbiculoidea* sp., ×2, view of both valves. These inarticulate brachiopods remained unchanged from the Ordovician through the Permian in Oklahoma (after Naff, 1972, fig. 1).

Figure 6. Pennsylvanian cephalopods. *A*—Ammonoid, *Paralegoceras texanum*, ×1 (SUI [State University of Iowa] 13998), Atoka Group, Coal County. *B*—Nautiloid, *Mooreoceras tuba*, ×1 (OU 3923), Stuart Formation, Coal County. Both specimens after Unklesbay (1962, pl. 1, fig. 12, and pl. 14, fig. 1).

Fig. 1

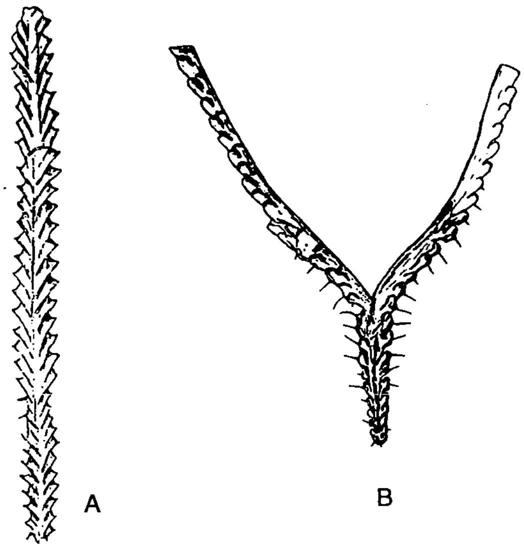
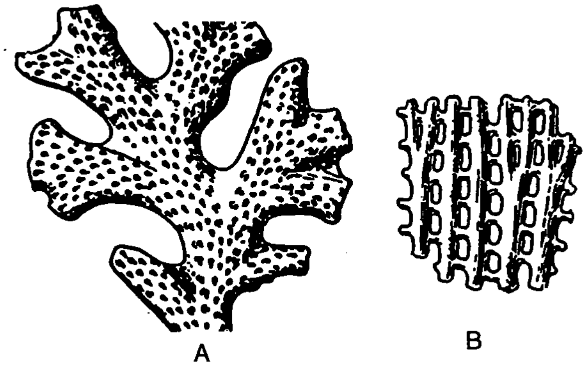


Fig. 2



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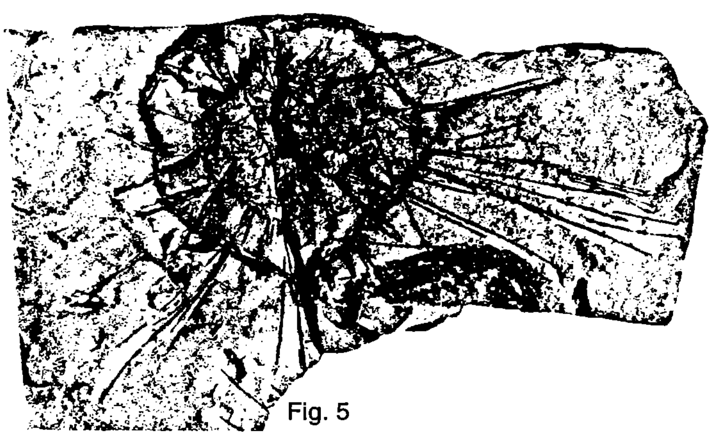
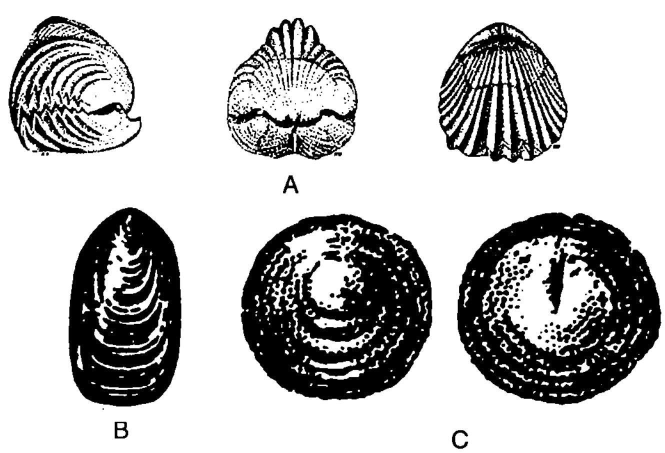


Fig. 4

Fig. 5



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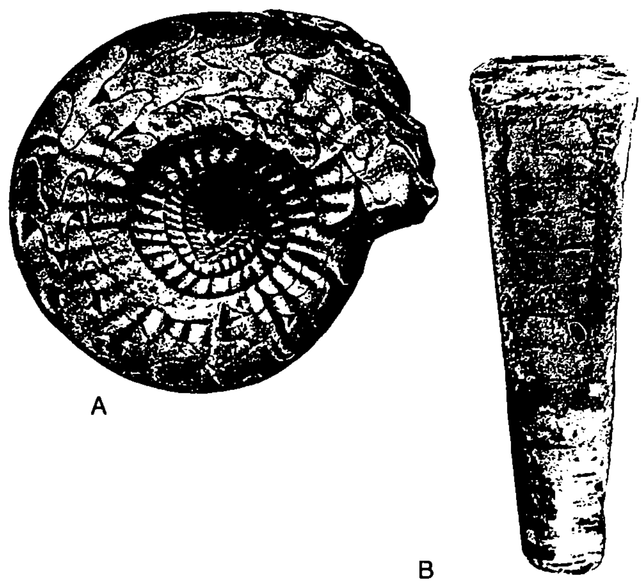


Plate II

Figure 1. Large gastropods. *A—Macluites magna*, ×1, Middle Ordovician Oil Creek Formation outcrops along Interstate 35 in the southern Arbuckle Mountains. *B—Tylostoma tumidum*, ×0.5, Lower Cretaceous rocks, Bryant County (after Finsley, 1989, pl. 48, photograph 127).

Figure 2. *Urasterella* sp., Ordovician starfish from the Mountain Lake Formation, lower Bromide Formation, Arbuckle Mountains (after Sprinkle, 1982, pl. 42, fig. 9).

Figure 3. *Pentremites rusticus,* ×2, Pennsylvanian blastoid from the Wapanucka Formation, Pontotoc County (after Katz and Strimple, 1978).

Figure 4. *Mandalacystis dockeryi*, reconstruction of Ordovician eocrinoid from the Oil Creek Formation road cut on Interstate 35 in the southern Arbuckle Mountains (after Lewis and others, 1987, fig. 1).

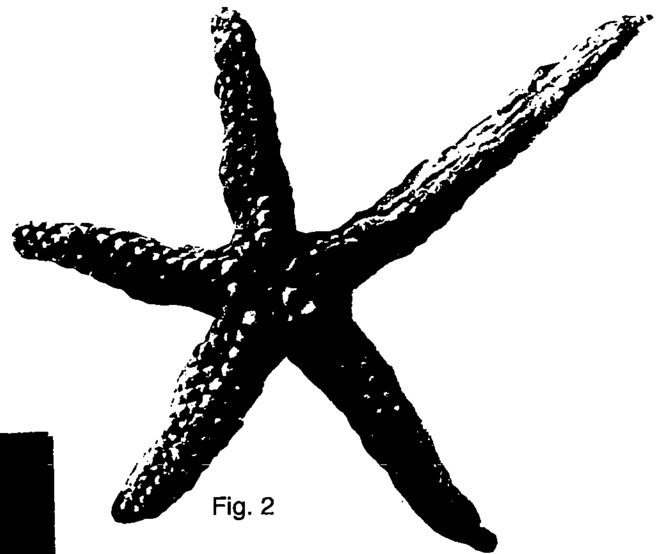
Figure 5. *Aglaocrinus oklahomensis*, ×0.75, OU 7337A; three views of the holotype crown from the Pennsylvanian Sausbee Formation, Cherokee County.

Figure 6. Echinoids. *A,B—Archaeocidaris megastylus*, Pennsylvanian echinoid from the Oologah Formation of Tulsa County (after Chenoweth, 1966, figs. 1,2,3). *A*—lower half of protective spine, ×0.75; the base of the spine contains an indention for plate attachment. *B*—Interambulacral plate; these plates cover the echinoid and the indention in the base of the spine attaches to the central or primary tubercal by muscles in life, ×2. *C—Hemiaster elegans washitae*, ×1, USNM 304188, Lower Cretaceous Duck Creek Formation; one of the most common echinoid genera in southern Oklahoma (after Kier, 1981, text-fig. 1-C).

Fig. 1

A

B



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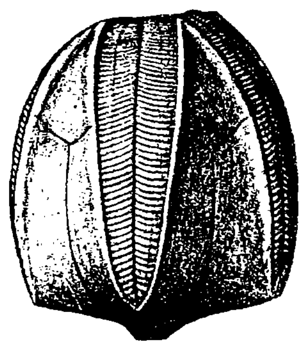


Fig. 3

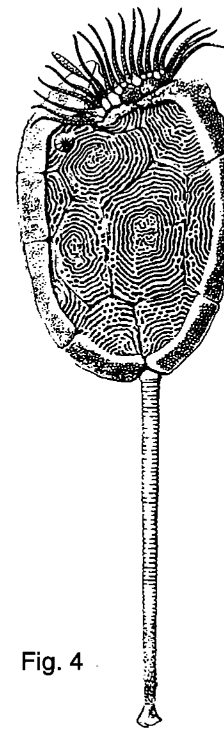


Fig. 4

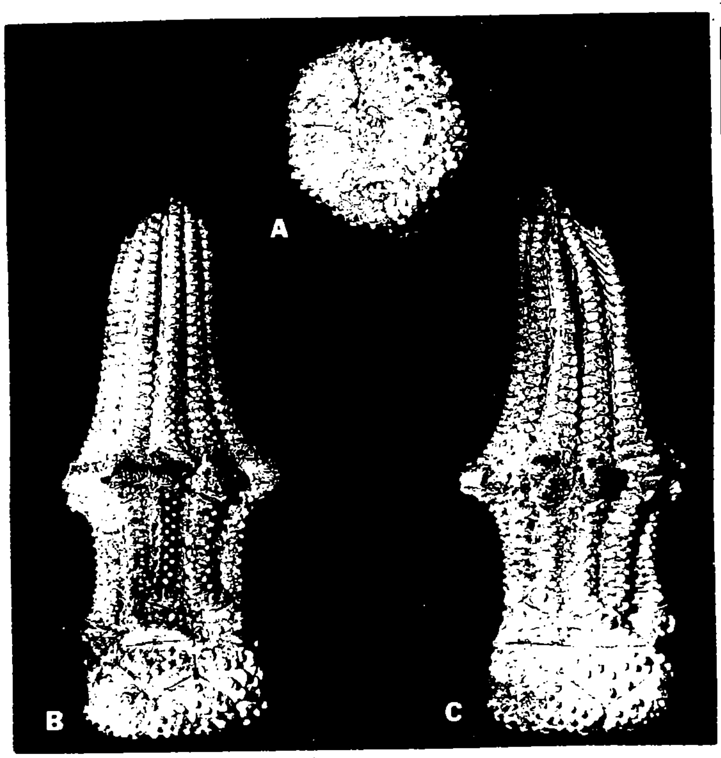
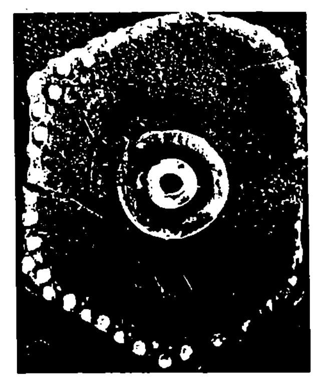
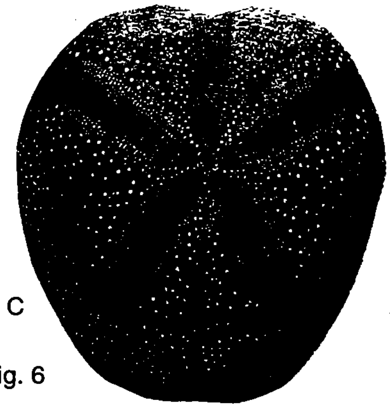


Fig. 5

A



B



C

Fig. 6

Plate III—Trilobites

Figure 1. *Homotelus bromidensis*, ×1, concentration of trilobites from the lower Pooleville Member of the Bromide Formation, Criner Hills (after Levi-Setti, 1993, pl. 134).

Figure 2. *Isotelus* sp., ×0.5, OU 3119; 20-cm trilobite from the Middle Ordovician Trenton Formation of the lower Viola Group, Coal County (after Amsden and Ham, 1959). This specimen and a 28-cm *Isotelus* sp. from the same site represent the largest complete trilobites found in the United States west of the Mississippi River.

Figure 3. *Cryptolithoides ulrichi*, ×1.5, characteristic cephalons (heads) of this trilobite that is an index fossil for the Ordovician Viola Group in southern Oklahoma (after Shaw, 1991, fig. 7, parts 6,9).

Figure 4. *Paciphacops raymondi*, most common Lower Devonian trilobite, Coal County. *A*—Enrolled specimen, ×3.5, OU 6810. *B*—Outstretched specimen, ×1.75, OU 3426 (after Campbell, 1977, pl. 7, 8).

Figure 5. *Huntonia lingulifer*, ×1.25, Lower Devonian Haragan Formation, Coal County. Fragments of this trilobite are common, but complete specimens are rare. Maximum size, 13 cm, although fragments indicate that some individuals reached 30 cm (after Levi-Setti, 1993, pl. 216).

Figure 6. *Leonaspis williamsi*, ×3, small spiny odontopleuridae trilobite from same age and location as Figure 5 (after Levi-Setti, 1993, pl. 206).


Fig. 1

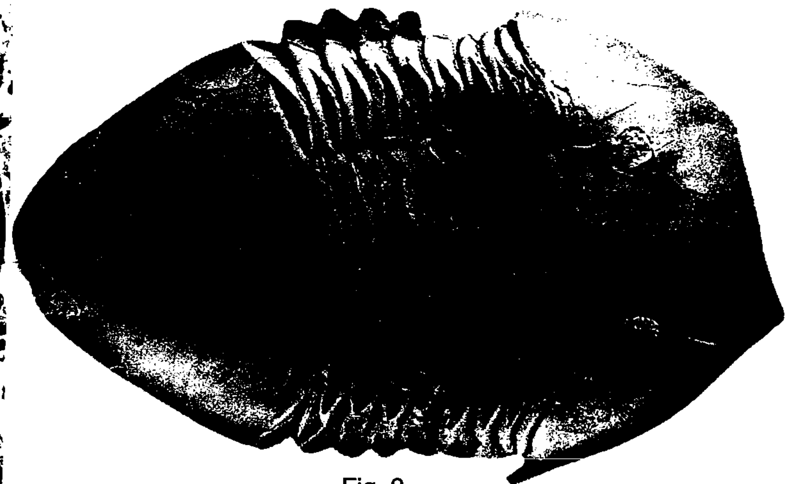


Fig. 2

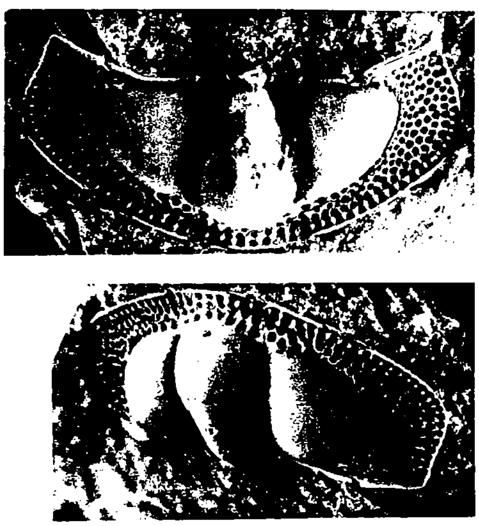


Fig. 3

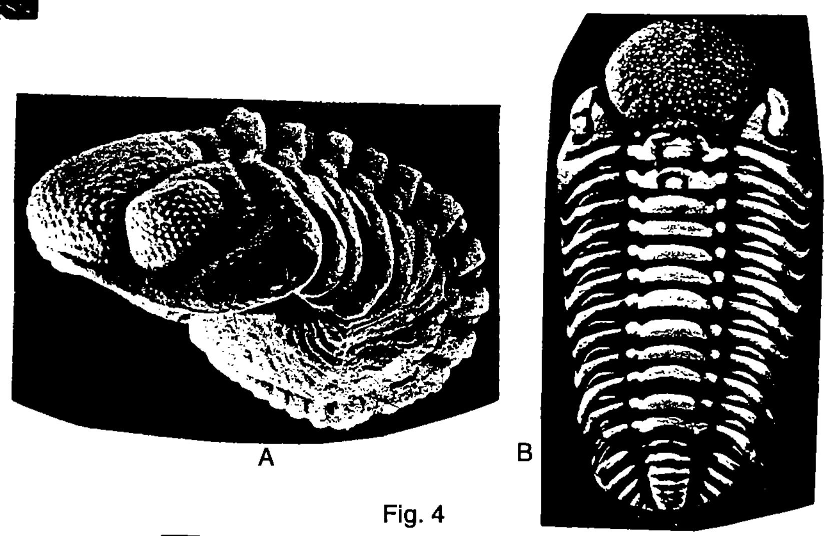

A B

Fig. 4

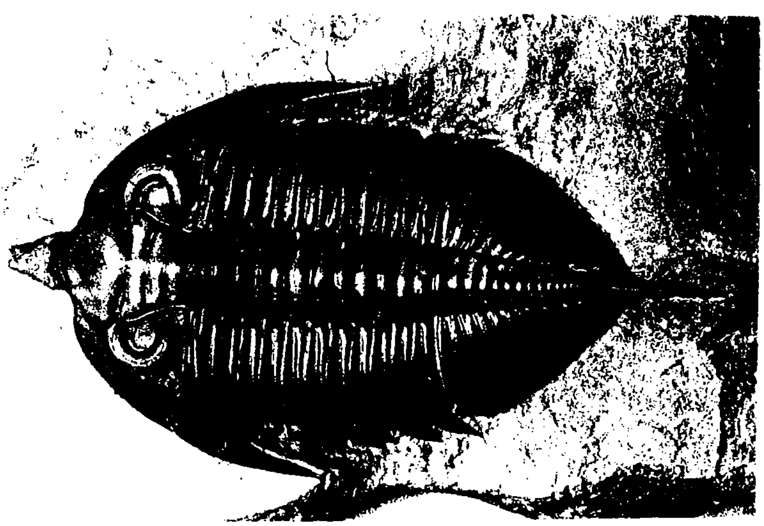


Fig. 5

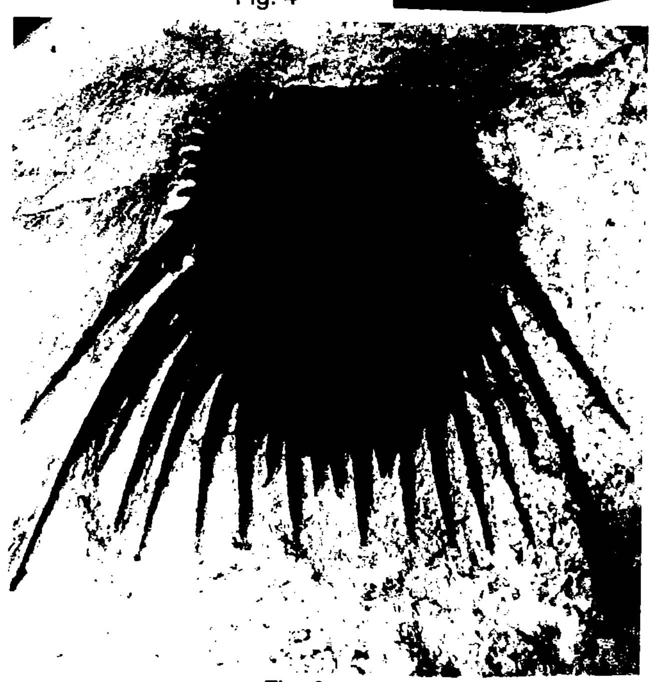


Fig. 6

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Collecting, Preparing, and Displaying Mineral Specimens

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Field guides for amateur collectors contain much of the information presented below, though to differing degrees of detail. One excellent source of information is *Field Collecting Gemstones and Minerals* (Sinkankas, 1961). A large part of success in collecting, preparing, and displaying mineral specimens relies on common sense and aesthetic judgment, both of which vary among individuals and are difficult to elucidate in writing.

COLLECTING

Advice here does not include the ethical or legal aspects of collecting mineral specimens, only the mechanical details. If you care enough to spend a few hours or days on a collecting venture, then you should be prepared for any result—big or small, grand or disappointing. The biggest mistakes that are commonly repeated by novices and experienced collectors alike include (1) not having the proper tools to do the job, (2) not having the proper means of conveying collected specimens without causing damage, and (3) not allowing enough time for difficult collecting tasks. In all three cases, the result is that fine mineral specimens get ruined, which is a disappointment to the collector and a crime against nature.

Equipment

The choices of tools obviously depend on the nature of the job, but when I go collecting, the list of equipment I have on hand is shown in Table 1. This list is of course excessive if one is hiking miles into a wilderness area, but it gives an idea of what makes me feel prepared to collect. I've used all of this equipment, and regularly, except the snake-bite kit. I carry a snake-bite kit for good luck only; the current medical wisdom is that the use of snake-bite kits poses greater threats to life than the bite itself if medical help is available within a few hours. From years of field work in central Arizona, I learned two ways to avoid contact with snakes: work when they are not out (very cold or very hot days), and make plenty of noise (most snakes make for cover when they feel you coming toward them). If you want to encounter snakes, then do your collecting at sunrise or sunset, when snakes come out of dens and humans tend to be quiet by nature.

TABLE 1.—COLLECTING EQUIPMENT

4	cold chisels—two large, two small: two with a sharp (breaker) point, two with a wedge (chisel) point
1	standard rock hammer (~10 oz. head with breaker point)
1	cement-cracking hammer (small, short-handled sledge with ~2 lb head)
1	large sledge (~15 lb head)
2	steel pry bars, ranging from 2 ft (~1 lb) to 6 ft (~30 lb) in length (weight)
1	hand claw trowel
1	folding (military issue) shovel with pick
1	10× magnifying loupe
2	pairs of work gloves
1	pair of safety glasses

Note: Other miscellany may include insect repellent, first-aid kit, snake-bite kit, compass, tape measure, sample bags, marker pens, labeling tape, hat, rain jacket, canteen, and large jug of water.

Here are a few other useful points. Use hammers or chisels that are intended for use on rocks and for being struck by metal. Standard carpenter's hammers are brittle and can fragment. Always wear eye protection when hammering. Always wear heavy work gloves when digging or collecting for coarse-grained crystals of minerals such as quartz; broken quartz edges are sharp as glass. Turn rocks with a pick or pry point to look for scorpions and spiders. Never accept a rock specimen into the palm of your hand; grab the specimen on top or the sides and look underneath first.

Packing Materials

I have been on trips when I was surprised by my lack of preparedness for transporting collected specimens. Better to think grandly and carry sturdy boxes with lids, a variety of packing materials, and sealing tape than to ruin specimens by allowing them to roll and break. Note that some papers contain hard mineral fillers that can scratch soft minerals such as gypsum and newsprint ink can soil specimens. Wrap specimens in clean paper, cloth, or plastic before wrapping with newspaper.

Time

Most collectors have great anecdotes about locating the prize specimen just at the end of their collecting trip. The

London, D., 1996, Collecting, preparing, and displaying mineral specimens, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 27–31.

only responsible action to take then is to leave the specimen in the ground if you do not have or are not willing to allow sufficient time to extract it carefully. Years ago, I went to see the largest documented crystal of kyanite, approximately 75 cm in length, exposed in an outcrop near Roxbury, Connecticut. Collectors had evidently tried to chisel the crystal out of its surrounding metamorphic rock and, in the frustration of their failure, had pounded parts of the crystal to powder. That story should make any thoughtful collector grimace.

PREPARING SPECIMENS

Understand that most sample preparations are irreversible and progressively change specimens from their natural state into something increasingly man-made. Many sample preparations are so widely utilized (e.g., washing in water) that no one gives a second thought, and the preparation leaves the specimen in a "natural" state. Other preparations may border on fabrication or falsification and may decrease the value of a specimen. Some treatments are widely accepted; some are not. As a generality, the more natural a specimen *looks*, the more it is valued. Pearl (1973) compiled a guide to the cleaning and preserving of mineral specimens.

Trimming

Hand trimming with a hammer or use of a hydraulic splitter leaves specimens with natural-looking cleavage surfaces that are more desirable than sawed surfaces. The problem with breaking methods is that breaks may be unpredictable or uncontrollable and can ruin the specimen. When in doubt, use a rock trim saw. If scrap material is available, practice hand trimming or splitting to learn the material's properties before proceeding to valued specimens.

Water Cleaning

Washing in water is the least severe of all preparations. Use nylon brushes for soft specimens (e.g., gypsum, calcite), wire brushes for minerals of hardness >4. High-pressure water sprays give more effective cleaning without abrasion. Pressurized water cleaners are available commercially or can be made cheaply. For large (robust) specimens or large numbers of specimens, consider using a manual car wash; specimens must first be secured into plastic or vinyl trays (e.g., used commercial dishwasher racks) to keep them from tumbling under the water jet.

Chemical Cleaning

Detergents can help remove organic stains from weathered specimens but have little effect on other coatings. Organic stains and some lichens can also be removed by soaking specimens in commercial chlorine bleach (approximately 1 part liquid bleach to 5 parts warm water). Bleaches are oxidizers, and reduced compounds may react adversely with the bleach and cause surface tarnishing (especially sulfide minerals, which should not be soaked in bleach). Most sulfide minerals can be noticeably cleaned by gently brushing them with any fluoride-bearing toothpaste; sodium fluoride has replaced the more effective stannous fluoride in toothpastes, but both are beneficial.

Acid cleaning should be considered as a last-ditch effort to improve the look of a specimen. Most native elements, sulfides, carbonates, phosphates, vanadates, some sulfates, and even some silicates are reactive with weak to strong acids. Mineral textbooks, especially older ones, tend to note the reactivity of a mineral species with acids, bases, oxidizers, etc.; consult these sources or test cull material before proceeding with good specimens. Technical HCl (muriatic) acid will remove carbonates, phosphates, and certain other minerals. Oxalic acid solutions are effective at removing ferruginous stains. Hydrofluoric acid (HF) dissolves most minerals except fluorite, topaz, tourmaline, and some micas.

Acids are hazardous to health and environment. They should be used sparingly, following safe procedures, and should be fully neutralized before disposal. A few guidelines for using acids are listed in Table 2. Sinkankas (1961) has provided additional details for using acids in sample preparation.

TABLE 2.—GUIDELINES FOR USING ACIDS

Use only in well-ventilated areas, preferably in commercial chemical hoods but at least outdoors, never in closed rooms.
Never stand directly over acid baths.
Always wear protective clothing, eye guards, and acid-resistant rubber gloves.
Always dilute acid by adding acid to cold water; never add water to concentrated acid.
Do not boil acid; use hot-water baths.
Have abundant baking soda available to neutralize spills.

Mechanical Cleaning

Mechanical cleaning can consist of using small pry tools and picks, brushes, air-abrasion guns, and tumblers. Dental tools make effective mechanical picks, but such tools tend to have high hardness ($H = 6$) and will scratch softer specimens. Nylon or wire brushes are very effective for cleaning intricate specimens. Air-abrasion guns act as sandblasters to remove soft or loosely attached surface materials. Some commonly used abrasives include ground walnut shells, powdered gypsum, or dolomite. Quartz sand or glass beads are very aggressive in high-pressure air jets and can be used to shape specimens; they will, however, pit and dull the surfaces of all but the very hardest minerals ($H = 9$–10). Rotating and vibratory tumblers exert the same mechanical action on specimens but tend to round corners and edges to a greater degree.

Repairs and Sealants

Broken or fractured specimens may be repaired or stabilized with glues or epoxies if the repair adds aesthetic and monetary value to the specimen. This is usually but not always the case. A repaired specimen is always less valuable, sometimes by orders of magnitude, than the specimen would have been had it not needed repair. With this valuation in mind, the consensus among mineral collectors is that *it is absolutely unethical* to offer (sell, trade) a repaired specimen without clearly indicating (usually written on the label) that it is repaired. Failure to do so is construed as false representation of the specimen, which is fraud.

When repairing a specimen, one needs to decide if the repair should be permanent or not. White glue and acetate or cyanoacrylate cement are easily dissolved away, so that repairs using these materials can be undone if so desired. Epoxy and rubber cement are essentially permanent fixes. My personal preference for repairs is thick (viscous, not runny) cyanoacrylate supercement, which holds well with thin films, does not yellow, is not water-soluble (specimens can be washed in water), and is removable with any polar organic solvent (acetone, nail polish remover, etc.). For nonporous materials such as single crystals, however, the strongest bonds are obtained with epoxies, some of which are specially designed for use with rock materials. These epoxies are available through lapidary supply and hardware stores. When selecting epoxies, choose one that possesses low viscosity, sets at room temperature, dries clear, and does not yellow.

Sealants are needed if a specimen is reactive with air. Most minerals are not appreciably reactive, but a few sulfides (marcasite, pyrrhotite) are, and some hydrous salts (e.g., borax) deliquesce. Very light weight spray lubricants can create nonpermanent air seals for sulfides. Clear spray lacquers are used more commonly; these offer better sealing but are difficult to remove. As with adhesive repairs, it is deemed unethical to offer a sealed specimen as entirely natural.

DISPLAYING SPECIMENS

Whether for personal pleasure or for competition, the display can make or break a collection. Good display does not necessarily require expensive props and lighting; a good sense of spatial design, clear presentation of specimens and text, and the use of lighting (fluorescent or incandescent) are the keys. The following gives a few guidelines that may assist in display design.

Lighting

Select lighting to match the color of your specimens. Incandescent (tungsten-filament) lighting is very warm in color, rich in red, orange, and yellow, and hence brings out the best in specimens with such warm hues. There is almost no blue in standard tungsten-filament lighting, so that specimens with cool green, blue, or purple color (e.g., fluorite) go dull gray in such lighting. To bring out the cooler hues of greens, blues, and purples, use "cool white" fluorescent lighting. To my eye, the fluorescence bulbs sold as "daylight" are not compensated well for mineral display. Very hot (1400 K) incandescent ("halogen") bulbs come close to optimal lighting for both warm and cool hues of minerals, but still fall short on the blues. Halogen lamps also are expensive, and the bulbs have relatively short life times.

If possible, always include "cool-white" fluorescent lighting in a display; the fixtures are inexpensive, bulbs are long-lived, and they give off minimal heat. Add standard incandescent lighting (100 W per bulb is adequate) to the fluorescents to bring out warm colors.

Shelving, Pedestals, Mounting, and Arrangement

For competition and exhibit, solid pedestal bases focus attention on specimens better than horizontal shelving. Using pedestals of different dimensions creates elevation and a flow of layout that can make a display more engaging and easier to follow. The drawbacks of pedestal display is that the bases are comparatively expensive, and fewer specimens can be accommodated in the display. Whether using shelving or pedestals, uncrowded displays always have more impact than crowded cases.

In shelving cases, use tempered safety glass with adequate bracket support. Glass permits more overhead lighting through to lower shelves. Arrange displays vertically so that the smallest, most transparent specimens lie on upper shelves, allowing more light to pass below. Locate specimens on lower shelves to minimize shadowing from specimens above.

Mineral specimens are harder than glass shelving or most pedestal materials, and hence can scratch these surfaces. Always place specimens directly up or down on surfaces; don't drag them. Self-adhesive pads (e.g., Moleskins) can be strategically and invisibly placed on the bottom of specimens to prevent scratching.

Mineral vendors sometimes describe specimens as "displays well." This phrase means that the best attributes of the specimen are put forward in display without the use of stands, props, or adhesives to orient and balance the specimen. If supports must be used, be sure that they are softer than the minerals being supported so that specimens aren't scratched. Oil-free mounting putty is available from lapidary and mineral supply vendors for standing or orienting loose crystals or small specimens.

Display Case

The purpose of the display case is to provide a secure environment that presents specimens at their best. The case should not, therefore, detract from or compete with the display. The interiors of solid (opaque) cases should be a neutral color (grays, tans) to set off minerals at their best. For specific displays, black or white backgrounds add dramatic effect but are not suitable for minerals of the same color. The grain of clear-finished wood adds color (may be desirable, or not) but, more important, adds texture that distracts viewers from the specimens themselves. I recommend against clear-finish wood backdrops.

Mirrored glass–backed displays are popular for the appearance of depth that they create. They also allow display of the back sides of specimens, which may or may not be desirable. They do, of course, reflect the viewer and his/her background as well, which again provides another source of distraction from the specimens. (Most humans cannot help but look at themselves when faced with a mirror.)

If displays are free-standing, then an all-glass case affords the best viewing and lets the most light in or out. Because of the transparency of all-glass displays, the ambient light from outside the case can affect the color of specimens.

Serious about Display?

If you cannot find what you're looking for in any of the usual furniture or science supply houses, here is a directory of vendors that serve the trade show and museum exhibit and design building industry: the annual Source Book Directory, published by Exhibit Builder, Inc.; P.O. Box 4144; Woodland Hills, CA 91365 ($25 in 1994). The annual source book lists hundreds of vendors of all elements of display, individual components (lighting, graphics, pedestals) to finished displays.

SOME TIPS ON COMMON OKLAHOMA MINERALS

Here are a few recommendations for the preparation of minerals that are commonly sought or collected from Oklahoma.

Barite Roses

Contrary to popular belief, barite roses from near Norman are shiny and mostly light pink to sandy colored. The red coloration that coats and dulls their surfaces is a mixture of very fine grained iron oxide and clay. This can be removed to various degrees, depending on the desired product. Start by washing specimens in water; use a nylon brush to clean surfaces. To remove more red (but retain it in crevasses), scrub specimens with a fine wire brush. To get rid of the coating completely, use a high-pressure water jet, as at a manual car wash. Specimens exposed at the surface have a black organic coating and sometimes chemical weathering or their surfaces. Much of this can be removed by a quick dip in chlorine bleach as noted above. If this proves inadequate, sandblasting is the final solution. Before using a sandblaster or similar air-particle abrasion tool, test its cutting power on cull material. Barite is relatively soft ($H = 3$), and the quartz sand in the roses is hard ($H = 7$). Once cleaned, therefore, the quartz from one rose will scratch the barite of another if the roses are allowed to rub. After cleaning, rose specimens must be separated or wrapped individually to be transported.

Tri-State District

Specimens of calcite, galena, sphalerite, etc. from the abandoned lead-zinc mines near Picher and Commerce are rarely found today, but plenty of these specimens are still available from dealers and private collectors. A general rule is that if a specimen is weathered, there is little that can be done to improve its appearance. Fluoride-bearing toothpaste will clean sulfides somewhat, but not etched or pitted specimens. Do not clean sulfide (or sulfide-bearing) specimens with acids, oxidizers (bleach), or alkalis. Marcasite from the Tri-State district tends to be unstable in air; specimens that develop white-yellow powdery surfaces must be cleaned, dried, and then coated with lacquer or oil to prevent oxidation.

Dipping dull, weathered calcite into muriatic acid quickly produces a very smooth, shiny dissolution surface. The appearance of acid-cleaned calcite, however, is distinctly unnatural, and in my opinion a regrettably large number of calcite specimens from Oklahoma's Tri-State district have been ruined by acid dips. If one must brighten the surface luster of calcite with acid, then I recommend two steps in the procedure. First, dilute concentrated muriatic acid with water to about 20% acid by volume. Second, apply the acid with an atomizing pump sprayer (be sure not to do this in a breeze that might carry the acid mist). Acid mist can be applied in very light doses to calcite surfaces; reaction ends in about 1 second, and portions of specimens that one does not want to dissolve can be easily protected. By repeated applications of acid mist, selected portions of specimens can be brightened slightly to give a higher luster, but other portions of the specimen can remain natural; the combination of lusters gives a more natural appearance to the specimens. Truth-in-disclosure ethics apply here: it is unethical to represent an acid-modified crystal as natural.

Quartz

McCurtain County in southeast Oklahoma produces some of the finest and most diverse quartz specimens found in the world. Like the better-known quartz veins in Arkansas, those in southeast Oklahoma occur within clay-filled fractures in sandstone and shale. The red ferruginous clay can be partially removed with a flocculating agent (e.g., Calgon) and with a high-pressure water spray. Iron oxide coatings are removable by soaking specimens in oxalic acid.

Oxalic acid is considered a weak to moderate acid that is much more effective when hot. Heating quartz specimens, however, can rupture trapped fluid inclusions and hence cause internal cracks and breakage. Smoky quartz possesses enough internal strain that heating can cause crystals (even inclusion-free ones) to shatter. When in doubt, take time to soak specimens in covered plastic containers at ambient temperature (weeks or months in cold acid instead of hours in hot acid).

The hopper (also called bubble or window) quartz crystals from McCurtain County contain red-ochre ferruginous clay, and the red color is deemed as desirable. If oxalic acid gains access to interior clay layers, it will bleach them to yellow-white. Most collectors who recognize the aesthetic and market value of the reddish clays now clean their specimens in plain water and then take very light abrasives to the crystal surfaces to dislodge clays. These specimens should not be boiled or soaked in acid.

Gypsum

Clear and sand-filled crystals of gypsum can be collected throughout Oklahoma, but the sand-filled crystals dug from the Salt Plains Wildlife Refuge near Jet are the best known and most accessible. Several collectors have told me that the crystals are more fragile when they first come out of the ground than after they've dried. There is no obvious reason why this should be so, unless the gypsum loses excess water upon exposure to air or included clays dry out and bind the samples together better. Gypsum is very soft and scratches so easily that even some packing paper (newsprint) can scratch specimens. As with barite, the sand contained by the crystals is much harder than the gypsum, and specimens that touch will leave scratch marks. Wrap gypsum crystals in plastic bags or clean cloths for transportation.

SUGGESTIONS?

There is a wealth of useful information on collecting, sample preparation, and display among collectors. If you have some useful tips, please pass them along to me for inclusion in the next (?) edition of this article. I'll be happy to give further details on what I know, especially in sample preparation and display. I've not attempted to treat lapidary techniques because I have no expertise there. Any volunteers for that topic?

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Fossil Collecting, Preparation, and Display

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COLLECTING FOSSILS

Fossil collecting is a fascinating, rewarding hobby enjoyed by many. Fossils arouse a curiosity within us and provide us with a history of life on Earth. Those of you who have children or grandchildren should include them on your hunts. Since fossils have a recognizable, symmetrical shape, even young children can come to easily recognize them; most fossil collectors today probably found and picked up their first fossils as children.

Oklahoma is a wonderful place for collecting fossils. All the geologic periods are represented by rocks in Oklahoma, and we have an abundance of sedimentary rocks in which fossils are found. Sedimentary rocks in Oklahoma also represent a wide variety of depositional environments, thus yielding a variety of fossils: protozoa, algae, plants, invertebrates, and vertebrates.

There are many publications that are helpful to collectors, including those of the Oklahoma Geological Survey. OGS has published guidebooks, some general in nature and others on specific areas, formations, or types of fossils. Examples include *Guidebook for Geologic Field Trips in North-Central Oklahoma* (Educational Publication 4); *Late Cambrian and Earliest Ordovician Trilobites, Wichita Mountains Area, Oklahoma* (Bulletin 110); and *Crinoids of the Oologah Formation* (Circular 60). Many of these publications include geologic maps of the area discussed; other geologic maps are published separately. The Tulsa Geological Society has published *Tulsa's Physical Environment*, which includes sections on fossil-collecting localities in that area. The State Highway Department has published detailed road maps of each county, and these may be purchased individually or in an atlas form. Topographic maps can be ordered from the Oklahoma Geological Survey or purchased at various other locations in the State. Additional information can be obtained at various museums and in state parks.

Proper equipment is needed when looking for fossils. Usually, a rock hammer is all you will need; the square head on one end can be used for breaking or chipping larger rocks, and the chisel or pick end can be used for prying up rocks or splitting layered rocks. Sledge hammers, heavy chisels, or crowbars are usually not needed. If fossils are embedded deeply in large, hard rocks, you will probably end up breaking the specimens into pieces rather than getting out a good fossil. You will need some kind of collecting bag, bucket, or box, and individual cloth or plastic bags for your specimens. Material such as newspapers or paper towels can be used to wrap individual fragile specimens. A magnifying glass or hand lens can be helpful, but is not necessary unless you are looking for very small fossils. It is also a good idea to use sunscreen and insect repellent, depending on the time of the year, and to have along a supply of water.

Fossils can be hunted at any time of the year: we prefer the winter, because more rocks are exposed when the grasses and weeds have died down. Also, you don't have to worry about ticks, chiggers, snakes, etc. When collecting fossils you must always respect property rights; don't hunt on posted land and don't leave trash or unfilled holes. You should try to know the geologic period and name of the formation you are hunting. Knowing where to look for fossils is important—you should be able to recognize the common sedimentary rock types on sight. Also, don't take all the fossils; leave some for the next person.

Many exposures are in areas that have been altered by the activities of man. Quarries and pits are a good place to collect. Limestone quarries often yield marine fossils; sand and gravel pits often yield petrified wood and vertebrate fossils; and shale pits can yield a variety of different kinds of fossils. In older quarries, fossils may have weathered out and can be picked up by hand; otherwise they will still be embedded in slabs of rock. Be careful when working on the sides or at the base of a quarry wall, and be careful not to dislodge rocks that may fall on others working below. Coal strip mines often yield fossil ferns, carbonized wood, and tree-bark impressions. Concretions from coal mines can contain rare fossils. Highway and railroad cuts through sedimentary rocks are also excellent places to hunt. Land being cleared for building or road construction may offer excellent fossil collecting; one doesn't feel guilty about taking all the fossils from such a location, because it will soon no longer exist.

Fossil collecting can also be done in natural exposures. Eroded gullies and hillsides often offer excellent exposures of fossil-bearing rock. These areas tend to be best in drier locations, where there is less vegetative cover, or in winter when less vegetation is present. You can often find loose fossils because of natural weathering processes, or you can find slabs of fossiliferous rocks on the slopes or in place. Rocky stream beds can be an excellent source of fossils;

Jaeger, R.; and Jaeger, L., 1996, Fossil collecting, preparation, and display, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 33–38.

Figure 1. Eroded hillside near Clarita, locally known as "trilobite hill." The site now is open on a commercial basis.

Figure 2. Petrified logs on an eroded hillside in semiarid area near Kenton. The site is used as a field-trip location for schools, and collecting is not permitted.

Figure 3. Dinosaur footprints in a streambed near Kenton. The site is used as a field-trip location for schools, and collecting is not permitted.

Figure 4. Mammal bones and teeth found in the Verdigris River at State Highway 51 crossing. The site now is under 25 ft of water in a reservoir.

the fossils are often weathered, but nice specimens such as petrified wood, vertebrate fossils, and marine fossils may be found, although you may not always know their age or the formation from which they came. For examples of fossil-collecting activities, see Figures 1–7.

Fossil collections can also be augmented by trading with others or by purchasing specimens from museums, rock shops, or dealers at shows. Catalogues can be obtained from dealers advertising in various rockhounding and Earth-science magazines.

Many fossils found in Oklahoma and elsewhere need little or no preparation or cleaning. Fossils are usually harder than the matrix that contains them; therefore they may be weathered free and cleaned by the slightly acidic nature of all precipitation. For most fossils, soaking them in soapy water and then using an old toothbrush to get out loose mud is adequate. Even if fossils are still embedded in a rock, don't always try to get them out. A little matrix is not necessarily bad; it tells you something about the environment of deposition. If you have different kinds of fossils in a slab, you have even more information about the ecology of the depositional environment.

However, sometimes you will want to clean matrix away from a fossil to obtain a quality specimen and to reveal fine detail. A number of different tools can be used to remove matrix from hard fossils. Much of this work can and should be done under a microscope. Electric engraving tools are often recommended for rough preparation. Chisels may be used to initially remove specimens from larger pieces of rock; remember to always point the chisel away from the fossil itself. Dental tools can be used for finer work; we know some rockhounds who use knitting needles instead. Air-brush or sandblasting tools can be used under a microscope for very detailed work.

Broken specimens can be glued together by using some type of household glue. Bones can be protected with clear

Figure 5. Collecting a variety of fossils south of Glenpool in a road cut that no longer exists, owing to new road construction.

Figure 6. Collecting brachiopods and other fossils in a limestone quarry at Burbank.

Figure 7. Collecting crinoid bulbs at a quarry south of Fittstown. Fossils are found in outcrops of steeply dipping layers, and thus collectors are lined up along this narrow outcrop.

shellac. Delicate fossils, such as insects, leaves, graptolites, and fish, can be sealed by a clear matte spray or nonglossy plastic spray. Acids can be used to separate fossils from their matrix. Pieces of limestone can be soaked in acetic acid. If the fossils are silicified or pyritized, hydrochloric acid can be used. Let them soak overnight; then remove them and rinse and clean with a toothbrush. This process may need to be repeated several times.

DISPLAYING FOSSILS

The best part of collecting fossils, other than the excitement of finding them yourself, is being able to show them to someone else and saying, "Just look at this!" Whether you want a display at home, or for shows or for community education, you will want to keep in mind *cleanliness, labeling,* and *neatness.* Paying attention to these three details will help you make an eye-catching display.

Get Organized

After bringing home your finds and cleaning them up, you should immediately use your field notes to label the specimens. You can use white enamel or acrylic paint to make a small white spot on each fossil in an inconspicuous place, let it dry, then number it with black ink. The best numbering system uses a letter to denote the phylum or location of the fossil, followed by a number denoting the order in which the specimen was found. For example, B23 might mean the specimen is the 23rd brachiopod added to your collection. You should also make a label on a card that gives the specimen number, specimen name, formation, location where found, collector's name, date found, and reference for identification. You might also want to keep a "master list" of all of your specimens. Much of this process lends itself very well to the use of a computer, should you be so inclined. Figure 8 is a sample label. Without any labeling or identification, fossils are nice to look at but have no importance, no excitement, no memory, no future.

Photographing your specimens can add one more dimension to your collection. Black and white prints of your fossils can be used to illustrate articles you may write, and color slides will make it easier to present programs to large groups.

Displays at Home

How much space you have available for displaying, and how many fossils you have in your collection, will deter-

No.__________
Name______________________________
Formation___________________________
Location____________________________
Collected by_________________________
Date collected_______________________
I.D. Reference_______________________
____

Figure 8. Example of a fossil identification label.

mine what type of display you make at home. You can display your best fossils on built-in shelves (like wall bookshelves) or in a curio cabinet so that every visitor to your home can look at and admire them. A problem with open shelves is keeping your fossils clean; dust seems to accumulate rapidly, and it is quite time-consuming to frequently dust the shelves and the specimens. Also, if your shelves are wood, you need to be careful that the fossils do not scratch them (we sometimes cut pieces of felt the size of the shelves to put under the fossils). A curio cabinet or glassed-in shelves help keep the fossils dust-free, but these are more expensive.

Even more expensive are storage cabinets made especially to store geologic specimens. These contain many slender drawers that may be pulled out and will hold specimens of nearly any size. The drawback to these cabinets is that your specimens are not readily visible—you have to make a point of pulling out the drawers to show your fossils. Similar to these are dentist's cabinets, typesetter's cabinets, and map-storage cabinets; all can be expensive.

Less expensive, but not particularly attractive, are "Riker mounts." These are cardboard boxes, about an inch deep, which are filled with a sheet of cotton and covered with a glass or clear-plastic lid. They *will* keep your fossils clean.

If you choose to display your best specimens in your home, you will still need some way to store all of your other specimens. Shoe boxes, cigar boxes, coffee cans, cardboard trays from soda cans or plants, and inexpensive divided plastic trays are all useful for this. Just remember to *label* each one correctly and do not mix specimens.

Displays for Shows

An exciting activity for the rockhound is getting ready for a local, regional, or national show. The proud owner of fossils will want to display favorites at the show. There are basically two types of entries: competitive exhibits and noncompetitive exhibits.

If you want to compete with other rockhounds for ribbons and trophies, then the competitive category is for you! To prepare a competitive display, you will need current copies of the AFMS Uniform Rules and the AFMS Fossil List. (AFMS is the American Federation of Mineralogical Societies. Every show we have ever attended has been by a club affiliated with AFMS.) Copies of these booklets are available through the local clubs.

To display fossils competitively, you will need to follow the rules set out in the booklets mentioned above. Your specimens will also need to be clean and correctly labeled. How neatly done and eye-appealing your display is will be considered "showmanship," and is usually about 10% of your score. Many clubs own "club cases" that are available for members to use for displays. You can also build your own case, but be careful about the lighting—it should hit your specimens from the front at a high angle to avoid creating large shadows (Figs. 9,10). If you want to build your own case, it is a good idea to go to some shows and look at the fossil cases being used and talk to someone who is an "old hand" at showing or to one of the judges. It also can be beneficial to read the judges' comments on the scorecards of competitive fossil cases before you enter a case.

You will need to decide whether to use risers in your case or to leave the specimens all on one level. We prefer to use risers, but we have seen prize-winning cases with no risers. Risers may be made out of Styrofoam, cut to the width of the case and covered with posterboard (to make sharp edges and corners and flat surfaces) and then with fabric. The fabric should have a simple weave and be a solid color that contrasts with the color of your fossils (we like reds and blues). Felt and broadcloth are both good fabrics to use. You would not want to use brocade, lace, satin, etc. Another way to make risers is to build them out of wood and paint them. Wooden risers should look *seamless*, and the paint should be smooth.

In addition to risers you may use backboards, covered in the same fabric, next to the back and sides of the case. The backboards may be of stiff cardboard or of thin wood. Using them really pulls the case together and can hide scratches or worn places on the insides of the case itself. Make sure there are no wrinkles in the fabric covering the risers and the backboards (Fig. 11).

The best labels are white and printed on heavy paper or on paper attached to posterboard with spray adhesive. We like to determine the placement of our specimens and labels in the case and then attach the "competitive" labels to the risers with double-sided tape. This method saves time in setting up the case and also prevents shifting of the labels should the case be inadvertently bumped by a spectator.

After you have placed your specimens and labels in the case, take a piece of tape and wrap it around your finger with the sticky side out. Then use your "sticky" finger to pick up any lint, fuzz, bits of dirt, or dust inside the case and on the risers. Before you place the glass over the front of the case, be sure to use a glass cleaner on both sides. Neatness counts!

For a noncompetitive display, you will still want to follow most of the guidelines mentioned above. However, with noncompetitive displays you are free to please only yourself and do not have to worry about pleasing the judges or following rules that dictate which specimens are required to enter a certain class. Entering a display in the noncompetitive category is a good way to "get your feet wet" and practice for competitive display. No matter which category you prefer, the best displays are still clean, neat, and labeled!

Educational Displays for the Community

Many times rockhounds are asked to set up displays at libraries or schools or museums and to give programs and bring a display with them. These displays should also be eye-catching (follow the above suggestions!), neat, and correctly labeled. These types of displays give rockhounds the opportunity to create interest in, and increase the awareness of, the importance of rocks, as well as the opportunity to share the joy of collecting fossils. For community displays, it is wise to include some type of reference or information about where to go for more information. Your

Figure 9. Display case in which the light source is too low, thus creating large shadows and making the display look dark.

Figure 10. Display case in which the light source is high and to the front of the case, thus creating few shadows. However, the specimens are a bit crowded.

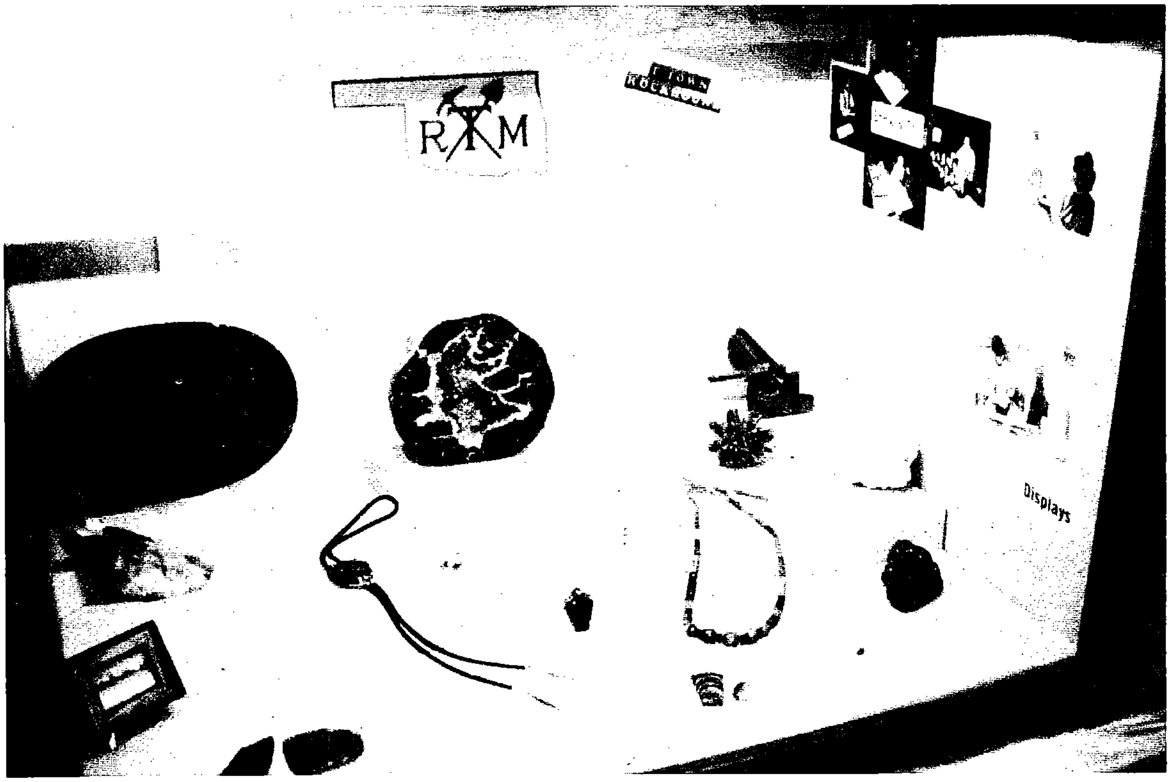

Figure 11. An educational display case that is very well done. References to further information are provided in a typed list on the back wall. Lighting is good, risers and backboards are covered with fabric and have sharp corners, and there are no wrinkles. Also, there is a good color contrast between the specimens and the background fabric.

display can speak volumes, because what we see is worth a thousand words!

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Collecting Minerals and Fossils on Native American Lands

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UNIQUE STATUS OF NATIVE AMERICAN LANDS

Land held in trust or with restricted title for the benefit of individual Indians or tribes is a separate entity from other land owned by the Federal Government, i.e., "public land." The general provisions that regulate activity on public lands do not hold true on reservations, tribal trust lands, and lands held in trust or restricted status for individual Native Americans.

What are these trust and restricted lands? In Oklahoma, most citizens can claim some Native American or Indian heritage, and so the term "Indian land" could be misleading if applied to those landowners. In the context of this discussion, Indian land constitutes that land in which legal title is held either in the name of the United States Government in trust for an Indian tribe or individual Indian or in the name of an individual Indian with Federal restrictions against alienation, known as a restricted fee title. The United States has a legal obligation to protect and manage these lands for the use and benefit of Indian tribes and individual Indians as defined in various treaties, Federal laws, and court cases. Although there are legal differences between trust and restricted fee titles, the Federal Government makes little distinction in how the property is actually managed.

Before Statehood, practically all of Oklahoma (less the Panhandle), approximately 41 million acres, was "Indian Territory" set aside for the Cherokee, Chickasaw, Choctaw, Creek, and Seminole Tribes, known as the Five Civilized Tribes. Through successive treaties, their domains were reduced, and other tribes were relocated into what was called Oklahoma Territory. Briefly and without going into Federal Indian policy and the political attitudes of that period, the tribal governments were dismantled and tribal lands allotted in severalty to tribal members. The allotment process was usually accomplished through the issuance of patents with language specifying that the land would either be held by the United States in trust for a particular tribal member or in the name of the allottee with restrictions against alienation for a specified number of years, usually 25, the expiration of which would result in the issuance of an unrestricted fee patent. After all tribal members received land allotments, and some lands were reserved for government schools and administrative reserves, the "excess" lands were sold or made available for homestead settlement through the various land runs and lotteries of pre-Statehood. Through the years, legislation has been passed extending trust and restricted periods for most tribes.

Unallotted lands that were not sold and lands that the tribes have since purchased or acquired through other means are held by the United States in trust for those tribes. In Oklahoma today, the most common "Indian" title is that in trust. There are approximately 101,835 acres of trust land held for 36 tribes, and about 1,089,829 acres of individually owned trust and restricted lands held by allottees or their heirs located throughout 70 of the 77 Oklahoma counties in a checkerboard fashion. These lands tend to be rural, undeveloped acreage used primarily for agricultural and rural home-site purposes. Figure 1 illustrates the general location of Indian allotted and tribal land in Oklahoma.

STATUS OF FOSSILS ON NATIVE AMERICAN LANDS

Fossil and mineral collecting on Native American lands is not illegal! As most of you are, no doubt, aware, fossils are not protected or regulated by the Antiquities Act of 1906 or the Archeological Resources Protection Act of 1979, unless found in an archeological context. To the best of our knowledge, no tribe in Oklahoma has a permit procedure for fossil or mineral collecting. It behooves the potential collector, however, to consult with a particular tribe on whose land they propose to collect to become aware of any law, resolutions, etc. that tribe may have addressing such collection.

As a point of interest in discussion of the status of fossils, whether or not a fossil has been severed from the land—i.e., actually been removed from the ground—will determine what category of property it is, real or personal. In an Associate Solicitor's opinion issued for the Bureau of Land Management in 1986, it was determined that fossils

Parry, T.; and Trickey, R., 1996, Collecting minerals and fossils on Native American lands, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 39–42.

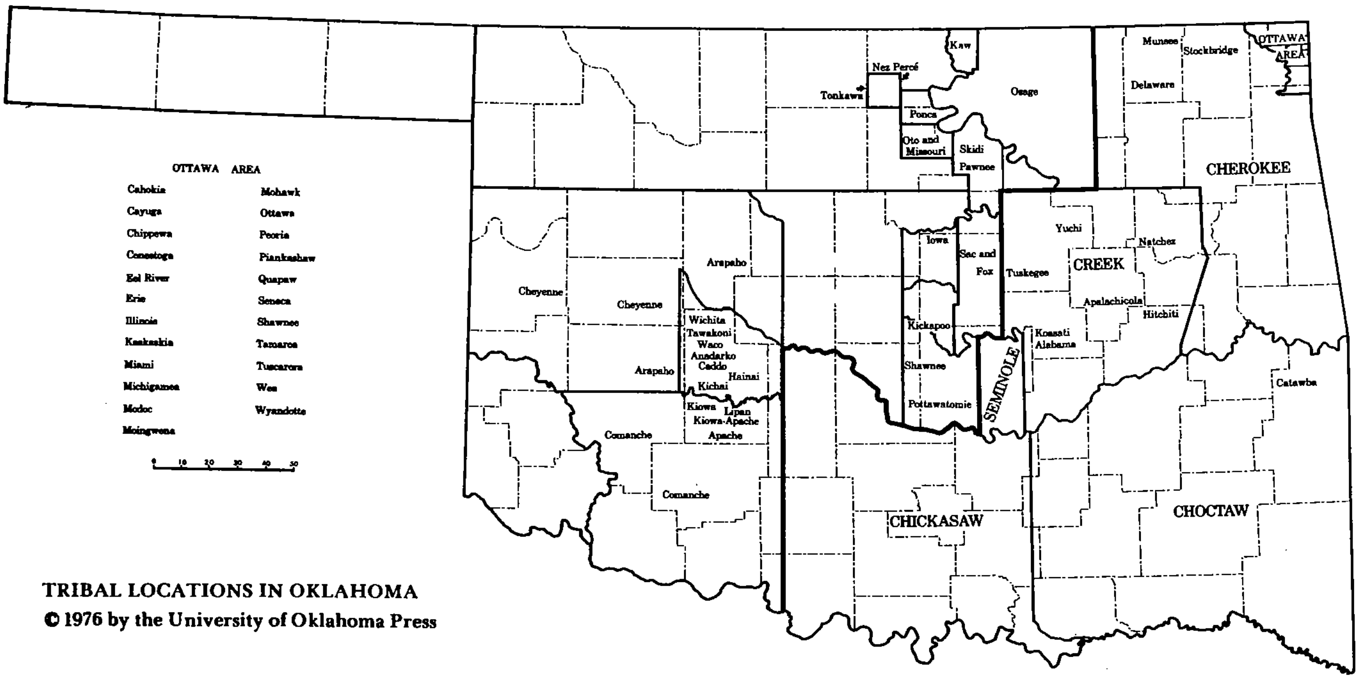

Figure 1. Generalized map of Indian allotted and tribal land in Oklahoma. Modified from Morris and others (1986), *Historical Atlas of Oklahoma*, reprinted by permission of University of Oklahoma Press.

"should generally not be regarded as part of the mineral estate" (Karen L. Dunnigan for the Field Solicitor; memorandum to Billings Area Director, May 25, 1995). We bring this matter up because it has a bearing on when and if the Bureau has a trust responsibility in the management of the resource.

PROCEDURES FOR COLLECTING ON NATIVE AMERICAN LANDS

As in any other activity in which the Federal Government has some jurisdiction, there are certain procedures that must be followed in order to gain access to Native American lands for collecting purposes. Although there are no specific rules or guidelines for permitting fossil or mineral collecting activities on trust or restricted Indian land, minimum Bureau procedures for most land-use activities call for some form of written Bureau-approved authorization. First and foremost, the prospective collector must gain permission from the Indian land owner(s), or tribal government owning the land. Of course, in order to do this, you must know where you are on the landscape, i.e., know the legal description of the land on which you are interested in collecting. Without checking title records or being familiar with the land ownership in a certain area, recognizing Indian land can be difficult. The common "knock and talk" method of inquiry from the nearest house would probably give you the best idea of the ownership of the land in question.

Securing actual written permission could get complicated since most individually owned allotted lands tend to have multiple owners who usually do not actually live on the property. Tribal trust lands are somewhat easier in that once identified, you only need to contact one owner, the tribe. Except in limited circumstances, neither the Bureau nor the tribe can authorize a permit without the individual Indian landowner's consent.

If you have a suspicion that the land may be allotted or tribally owned, your best bet in determining the ownership is to consult with the Realty Officer of the particular Bureau of Indian Affairs Agency within whose jurisdiction the land falls. There are eight agencies representing some 36 tribes and tribal groups. Some tribes have either contracted certain functions, such as realty, or entered into Self-Governance Compacts with the United States to govern their own affairs and provide services previously provided through the Bureau. The different agencies or tribes carrying out the realty function of the Bureau, their locations, and addresses are listed in Appendix 1. In most cases of individual allotted or restricted lands, there will be multiple owners to contact for permission to collect. Names and addresses of owners are available at the respective Bureau Agency Realty Offices or Tribal Realty Offices.

BUREAU AND/OR TRIBAL INVOLVEMENT

The type of fossil or mineral suspected on the land will determine the amount of Bureau involvement in approving the permission to collect. An opinion issued by the Field Solicitor for the Pacific Northwest Region states in part,

> The United States must approve agreements to transfer interests in land, including the removal of fossils from trust lands. The approval must be in the best interest of the beneficial land owner. Agreements concerning fossil removal

> should address the desires of the landowner, including the interest being granted, whether title to the fossils will be transferred upon severance, who is responsible for reclamation, and the value of the interest granted. Each agreement must be approached on a case-by-case basis. (Karen L. Dunnigan for the Field Solicitor; memorandum to Billings Area Director, May 25, 1995)

Granted we suspect that the majority of interest in fossil and mineral collection in Oklahoma is for personal pleasure and extension of scientific knowledge of an area and not toward commercial gain. Still, it is in the collectors' best interests to make every effort to determine who owns or has an interest in the land they want to collect on and to get permission from the owner(s) prior to entering the land. From the perspective of the Bureau of Indian Affairs, not to do so would be considered trespassing, at least, as well as theft of personal, if not government, property. A precautionary note is advised here. Much of the allotted and restricted lands in Oklahoma are not occupied by the owners. In most cases there are agricultural leases, mineral leases, hunting leases, etc. Occasionally, you may come across a lessee who is working the land. The lessee has certain rights in the use of the land. However, unless there has been language included in a lease that gives the lessee rights regarding collection of fossils or minerals (this will most likely not be the case), that lessee is not authorized to grant permission for you to collect on the land.

Many of the different agencies have established procedures for permitting various short-term surface activities. It is recommended that the Agency or Tribal Realty Officer, as the case may be, be consulted on the proper procedures for obtaining landowner consent prior to access. If no commercial or personal gain is anticipated by the collection of fossils or mineral specimens from Indian land, in which the landowner's interest must be protected, then the Bureau or tribe may not need to be involved. In these cases, which will probably be the majority in Oklahoma, negotiation for permission to enter an Indian owner's land and conditions under which fossil specimens could be removed would be between the collector and the owner(s). In those cases where a commercial venture or substantial personal gain is anticipated, involving the Bureau of Indian Affairs not only protects the landowner, it also protects the collector.

Although we are not suggesting that such a vertebrate fossil would be exposed in deposits in Oklahoma, we are sure that all concerned would rather avoid the type of litigation that resulted from the *Tyrannosaurus rex* "Sue" collected on allotted land in South Dakota (*Black Hills Institute of Geological Research v. United States*, 812 F. Supp. 1015, *aff'd in part and rev'd in part, sub nom., Black Hills Institute of Geological Research v. South Dakota School of Mines and Technology*, 12 F.3d 737 [8th Cir. 1993], *cert. denied, Black Hills Institute of Geological Research v. Department of Justice*, ___*U.S.* ___, 115 S. Ct. 61, 103 L. Ed. 2d 18 [1994]). The best way to avoid such a situation is to be aware of the policies and procedures regarding entry onto Indian lands and to know beforehand whether you are about to enter Indian lands and, as stated above, to get permission.

We hope that this discussion has provided some guidance on how best to avoid awkward situations involving Indian lands while you pursue your profession as a geologist or enjoy your avocation as a rockhound.

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APPENDIX 1. BUREAU OF INDIAN AFFAIRS: AREA, AGENCY, AND TRIBAL OFFICES

Bureau of Indian Affairs
Anadarko Area Office
P.O. Box 368
Anadarko, Oklahoma 73005-0368
(405)247-6673
(Bruce Maytubby, Realty Officer)
(Tom Parry, Area Archeologist)

Bureau of Indian Affairs
Anadarko Agency Office
P.O. Box 309
Anadarko, Oklahoma 73005-0309
(405)247-6673
(Eva Rivera, Acting Realty Officer)
(Joe Watkins, Agency Archeologist)

Bureau of Indian Affairs
Concho Agency Office
P.O. Box 68
El Reno, Oklahoma 73036-0068
(405)262-7481
(Scott McCorkle, Realty Officer)

Bureau of Indian Affairs
Pawnee Agency Office
P.O. Box 440
Pawnee, Oklahoma 74058
(918)762-2585
(Ray Springwater, Realty Officer)

Bureau of Indian Affairs
Shawnee Agency Office
624 West Independence, Suite 114
Shawnee, Oklahoma 74801
(405)273-0317
(Robert Jones, Superintendent)

Absentee-Shawnee Tribe of Oklahoma
2025 South Gordon Cooper Drive
Shawnee, Oklahoma 74801
(405)275-4030
(Donnie Smith, Realty Officer)

Sac and Fox Nation of Oklahoma
Route 2, Box 246
Stroud, Oklahoma 74079
(918)968-3526
(Chenenia LaDeaux, Realty Officer)

Bureau of Indian Affairs
Muskogee Area Office
101 North 5th Street
Muskogee, Oklahoma 74401-6206
(918)687-2293
(Randall Trickey, Supervisory Realty Specialist)
(Ben Barnette, Area Archeologist)

Cherokee Nation of Oklahoma
P.O. Box 948
Tahlequah, Oklahoma 74465
(918)456-0671, ext. 434
(Annette Jenkins, Realty Director)

Choctaw Nation of Oklahoma
P.O. Drawer 1210
Durant, Oklahoma 74701
(405)924-8280
(Tom Williams, Realty Director)

Muscogee (Creek) Nation of Oklahoma
P.O. Box 580
Okmulgee, Oklahoma 74447
(918)756-8700, ext. 272
(Rodney Durossette, Realty Director)

Bureau of Indian Affairs
Wewoka Agency
P.O. Box 1060
Wewoka, Oklahoma 74884
(405)257-6257
(Eddie Streater, Realty Officer)

Bureau of Indian Affairs
Chickasaw Agency
P.O. Box 2440
Ada, Oklahoma 74821
(405)436-0784
(Robin Phillips, Realty Officer)

Bureau of Indian Affairs
Osage Agency
P.O. Box 1539
Pawhuska, Oklahoma 74056
(918)287-1032
(Royal Thornton, Realty Officer)

Bureau of Indian Affairs
Miami Agency
P.O. Box 391
Miami, Oklahoma 74355
(918)542-3396
(John Dalgarn, Realty Officer)

Ethics in Collecting Minerals and Fossils

Dan Lingelbach
Stillwater Mineral and Gem Society
Stillwater, Oklahoma

DEFINITIONS

Since this discussion deals with ethics, it is best that we look at the definition of *ethics*. From Webster's (1991) we find "*ethics*—1, the discipline dealing with what is good and bad and with moral duty and obligation; 2 a: a set of moral principles or values; b: a theory or system of moral values; c: the principles of conduct governing an individual or a group." Under the definition of *moral* we find "*Ethical* may suggest the involvement of the more difficult or subtle question of rightness, fairness or equity." In further investigations about ethics, we find it is an area of philosophy. This fact may be the reason why we have some problems with ethical behavior. We don't all follow the same principles in our hobby. We feel we behave ethically, but others may not agree with us. That is why it has become necessary to develop a set of principles for ethical behavior for collecting minerals and fossils and, I would like to add, collecting rocks.

This need was recognized by the Evergreen Rock Club of Seattle, Washington, when in October 1962 they adopted A Rockhound's Code of Ethics (Appendix 1). This code appears to be the basis for the American Federation of Mineralogical Societies (AFMS) Code of Ethics (Appendix 2).

Normally, one would wonder why it is necessary to even consider the definition of the word *rockhound* as used in the title of A Rockhound's Code of Ethics. However, in dealing with Federal agencies, a definition is necessary. A case in point is the Rock and Mineral Specimen Collections Act of 1995, a bill that has been proposed by the American Lands Access Association (ALAA) (Spunaugle, 1995). Here the attempt is to provide enabling legislation so that collecting rock and mineral specimens on certain Federally controlled lands is a bona fide use of public lands. In Section 2 of this act, titled Findings, item (4) states that *rockhounds* "enjoy a reputation as ethical and conscientious land users." Item (4) goes on, "The term 'casual rock and mineral specimen collection' means activities by persons which do not involve the use of power tools, explosives or mechanized excavation equipment, and. . . ." The other additions to this definition involve the following: staying on roads, how much can be removed, and the size of the surface disturbance. Also, there are a number of other items covered by this bill that are of direct interest to rockhounds and that everyone collecting should be aware of. In the definition of *rockhound* from the dictionary (Webster's, 1991) we find two different views, one a specialist and the other an amateur: "*rockhound*—1: a specialist in geology; esp.: one who searches for oil; 2: an amateur rock and mineral collector—*rockhounding*." From Firsoff and Firsoff (1975) we find this definition: "A *rockhound* is a person interested in rocks, stones, and minerals, not for professional, industrial or commercial reasons, but purely as a hobby. . . . It is also nice to think that the rockhound is a nature lover and will avoid wholesale removal of the minerals he collects, keeping a brake on what a Roman poet has described as 'the criminal of love of possession.'" In the Fossil Protection Act of 1995 (Zeleznik, 1995), another bill proposed and supported by the ALAA, we find a definition of *amateur collector*—"an individual who collects fossils for personal enjoyment, recreation, research or educational purposes and without remuneration." Thus, this bill adds "without remuneration." Therefore, *rockhound* in the context of the present discussion will be *an amateur or casual collector of rocks, minerals, and fossils who pursues this activity only as a hobby, is a nature lover, will not willfully damage the environment, will avoid wholesale removal of material, and during collecting receives no remuneration.*

ROCK COLLECTING

Now back to the conduct of rockhounds in collecting. As presented earlier, the AFMS Code of Ethics (Appendix 2) apparently expanded on A Rockhound's Code of Ethics (Appendix 1). In examining the two codes, we find the AFMS additions relate to being informed about all laws, regulations, and rules governing collecting on public lands, boundaries, and ownership. Right now this item is an enormous task because each government agency and sometimes land managers and rangers seem to have their own rules. One effort the clubs and federations are pursuing is developing and getting accepted one set of rules for all Federal and State agencies. The other addition embodied in the AFMS Code deals with reporting of endangered materials and specimens on public lands that should be protected for future generations and also cooperating with field-trip leaders and other authorities. The AFMS Code adds more emphasis on behavior on public lands, since it was omitted in the Rockhound's Code version. This added emphasis is partly due to the nature of ethics, i.e., what was acceptable behavior earlier is not acceptable behavior now. Ethics is a changing set of principles; in our hobby,

Lingelbach, D., 1996, Ethics in collecting minerals and fossils, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 43–47.

this is evident in the proposed ALAA bills. From reference to the proposed wording in the Rock and Mineral Specimens Collections Act of 1995, it would be desirable to expand the AFMS Code of Ethics to include the following: no use of power tools or mechanized excavation equipment, filling excavation holes should not be limited to those dangerous to livestock but all holes, and driving only on established open roads and rights of way. Another way to list the principles of conduct is given by the Golden Rule for Recreational Gold Panners (Appendix 3), which adds where you are restricted to drive.

Even though we feel we are ethical collectors, we need to review the AFMS Code of Ethics regularly. Appendix 2 provided us the opportunity to review the Code of Ethics now. If all of us would take to heart the last item listed in the AFMS Code of Ethics—the Golden Rule—and follow it, we could do away with all of the others listed. To apply the Golden Rule, think of how we would want someone to act if he or she were out in our front lawn digging for rocks. I have a feeling that many of the public-land managers are inclined to look at their areas of responsibility that same way.

MINERAL AND FOSSIL COLLECTING

In addition to the principles in the AFMS Code of Ethics, mineral and fossil collectors need to add some items. This requirement is partly due to the size of most specimens and partly due to the nature of the specimens. Probably the most important is *patience* in carefully removing the specimen from the ground or pocket in order to minimize damage and to recover all repairable fragments that might have been separated from the specimen prior to the discovery or during removal. Another item in mineral and fossil collecting is *proper documentation* of the find. This information may provide geologic information about the structure of the location as well as being useful to a researcher or collector in assessing the potential for additional sites. Also, after the specimen is taken home, patience is required in cleaning, trimming, repairing, and/or restoring the specimen. Responsible mineral or fossil collecting can pay off by providing specimens that one can be proud of, that can be enjoyed by others, and that makes it possible for others to collect their own specimens. Kile (1995a,1995b) has a good condensed discussion of responsible mineral collecting. The same methods should apply to collecting fossils.

COMMERCIAL COLLECTING

Up to this point, the discussion has been primarily centered on the amateur collector (rockhound). Even though the conduct of commercial collectors involves behavior similar to that of amateurs, their conduct is not dictated so much by ethics as it is by regulations. Commercial collectors must have permits to collect on public lands and in many cases to collect on private land. The regulations are extensive and involve considerable research and study in preparing the reports, especially before moving to the location and starting to dig. Since this workshop is intended for the amateur (casual collector), no additional discussion is needed here except to remember that if you use power equipment, etc., you become a commercial collector and permits are required to collect.

SUMMARY

All the principles listed in the AFMS Code of Ethics could be summarized by just one and that is the Golden Rule: treat all others the way you would like to be treated. If all of us could take this rule to heart and follow it, there would be a lot fewer regulations and a lot more satisfied land managers. Follow the Code of Ethics and have happy rockhounding.

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APPENDIX 1. A ROCKHOUND'S CODE OF ETHICS

HOWDY *says:*

A Rockhound's CODE OF ETHICS

I will respect private property and do no rockhunting without the owner's permission.

I will use no firearms or blasting material in rockhunting areas.

I will take all garbage home or deposit it in proper receptacles.

I will leave gates *as found.*

I will cause no willful damage to materials or take more than I can reasonably use.

I will fill excavations which may be dangerous to livestock.

I will discard no burning material—matches, tobacco, etc.

I will build fires in designated or safe places *only*.

I will not contaminate wells, creeks or other water supplies.

I will not damage or tamper with signs, structural facilities or equipment.

I will appreciate and protect our heritage of natural resources and wildlife.

I will always use GOOD OUTDOOR MANNERS.

EVERGREEN ROCK CLUB
Seattle, Washington
Adopted October 7, 1962

APPENDIX 2. AMERICAN FEDERATION OF MINERALOGICAL SOCIETIES CODE OF ETHICS

I WILL respect both private and public property and will do no collecting on privately-owned land without permisson from the land-owner.

I WILL keep informed on all laws, regulations and rules governing collecting on public lands and will observe them.

I WILL to the best of my ability, ascertain the boundary lines of property on which I plan to collect.

I WILL use no firearms or blasting materials in collecting areas.

I WILL cause no willful damage to property of any kind, such as fences, signs, buildings, etc.

I WILL leave all gates as found.

I WILL build fires only in designated or safe places and will be certain they are completely extinguished before leaving the area.

I WILL discard no burning materials--matches, cigarettes, etc.
I WILL fill all excavation holes which may be dangerous to livestock.

I WILL not contaminate wells, creeks, or other water supplies.

I WILL cause no damage to collecting material and will take home only what I can reasonably use.

I WILL support the Rockhound Project H. E. L. P. (Help Eliminate Litter, Please) and will leave all collecting areas devoid of litter, regardless of how found.

I WILL cooperate with field trip leaders and those in designated authority in all collecting areas.

I WILL report to my club or Federation officers, Bureau of Land Management, or other proper authorities any deposit of petrified wood and/or other material on public lands which should be protected for the enjoyment of future generations and for public educational and scientific purposes.

I WILL appreciate and protect our heritage of natural resources.

I WILL observe the "GOLDEN RULE", will use GOOD OUTDOOR MANNERS and will at all times conduct myself in a manner which will add to the stature and public image of Rockhounds everywhere.

APPENDIX 3. GOLDEN RULE FOR RECREATIONAL GOLD PANNERS

Gold nuggets found in the vicinity of Baker City, Oregon. Largest nugget is the famous Armstrong nugget, weighing 80.4 ounces. These nuggets are part of a large collection of gold on display in the lobby of the Baker City Branch, U.S. Bank. Photo courtesy of U.S. Bank.

GOLDEN RULES FOR RECREATIONAL GOLD PANNERS

- If you are unsure about land status, check with the nearest appropriate State, BLM, or USFS authorities.
- If you open a gate, close it.
- If you must cross private land, get permission.
- If you make trash, take it home.
- If you drive, stay on open roads and ways.
- If it is growing, let it grow.
- If it is public land, use, share, and appreciate it.
- If it has obvious historic or scientific value, don't disturb it.
- If you light a fire, control it.

ACKNOWLEDGMENTS

This brochure was prepared by the Oregon Department of Geology and Mineral Industries (DOGAMI), 910 State Office Building, Portland, OR 97201, phone (503) 229-5580. For more information on recreational gold panning or other aspects of geology, contact the above office; DOGAMI's field offices in Baker City, phone (503) 523-3133, and Grants Pass, phone (503) 476-2496; or the nearest USFS or BLM office. DOGAMI also sells a publication entitled *Gold and Silver in Oregon* (Bulletin 61, 1968, paperbound, 337 p., $17.50), which gives detailed information on gold mines in Oregon.

Oregon. Things look different here.

Oregon's Heritage: RECREATIONAL GOLD PANNING

Oregon's Heritage Brochure 2

Rockhounds' Rights Versus Government Regulations on Collecting Minerals and Fossils—A Panel Discussion

Moderated by Kenneth S. Johnson
Oklahoma Geological Survey
Norman, Oklahoma

The following is an edited transcript of the presentations made by four panelists and the discussion between the audience and the panelists.

PANEL MEMBERS
(in order of their presentation)

John Alf	Bartlesville, Oklahoma; Director of American Lands Access Association, member of Tulsa Rock and Mineral Society
John Nichols	Hot Springs, Arkansas; Forest Minerals Geologist, Ouachita National Forest, U.S. Forest Service
Tom Creider	Oklahoma City, Oklahoma; Assistant Director of State Parks, Oklahoma Department of Tourism and Recreation
Laurie Bryant	Casper, Wyoming; Paleontologist, U.S. Bureau of Land Management

Kenneth S. Johnson (Oklahoma Geological Survey): The Workshop Organizing Committee thought that it was important to discuss the various aspects of rockhounds' rights and options for collecting rocks, minerals, and fossils, and government regulations and rules that relate to such collecting. And rather than having just one or two presentations, we felt that a panel discussion would be the best way to explore and understand various positions. So we invited representatives from Federal and State agencies to present information on the rules and regulations for collecting on public lands and representatives from rockhound clubs to present the rockhounds' views and perceptions of access to and collecting on public lands.

Each of the four panelists has been asked to present his/her agency's or group's responsibilities, concerns, and viewpoints on these matters. After these presentations, panelists and the audience will engage in an open discussion. The entire panel discussion will be recorded, transcribed, and edited, and the resulting document will be part of the final publication.

John Alf (Director of American Lands Access Association, Member of Tulsa Rock and Mineral Society): I want to take just a few minutes here in the beginning to mention some things that, at least in my view, are bothering rockhounds these days. It seems that it's getting tougher and tougher for us to continue to do the things we have historically been used to doing. It's getting to be more difficult and, in some cases even illegal, to practice our hobby. I welcome a meeting of this kind because I think this could very well lead to a better understanding between the various types of interest groups represented here. Maybe we can get to understand each other a little better—perhaps generate a little mutual empathy among us.

First, I want to say that I really believe that most rockhounds are ethical. They are ethical people, and they really do want to get along and do what is right. I know that there are bad apples in every barrel, and the rockhound barrel has its share, but I think the professionals and the government folks have their share of bad apples also. However, I also believe that, overall, the bad apples are in a distinct minority. Rockhounds historically have been accustomed to collecting small amounts of rocks, minerals, and fossils from public lands for hobby purposes, and generally this collecting has been done without harm to the land. We want to be able to continue practicing our hobby and to do it in way that's ethically acceptable.

As I see it, there are two major problems that are facing us as rockhounds today: how are we able to get into collecting areas and what are we allowed to do once we get there?

Just getting in seems to be getting tougher and tougher these days, and one of the major reasons for this problem is the proliferation of *wilderness*. In wilderness areas, as you know, no vehicular travel is allowed. Roads we formerly drove are now useless, and rockhounds are effectively excluded from areas that we formerly went into. We are relegated to collecting around the perimeters only, and that's not very satisfactory in most cases.

This concept of wilderness is the result of the Wilderness Act of 1964. The purposes of this act are set forth in the preamble, which contains phrases like "preserve natural conditions," preserve areas that are "untrammeled by man," "primeval character, without permanent improvements or human habitation." From these words, it is pretty clear that the intent of Congress was to preserve existing wilderness, and I emphasize the words *preserve existing wilderness*. The intent wasn't to create new wilderness

Johnson, K. S. (moderator), 1996, Rockhounds' rights versus government regulations on collecting minerals and fossils—a panel discussion, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 49–75.

where there wasn't any before. But now we see that this concept has been expanded to the point where somebody decides that "here's an area that ought to be wilderness" and, whether it conforms to the definitions in the act or not, efforts are made to turn that area into wilderness. The latest major onslaught in this creation-of-wilderness business happened in California, where the California Desert Protection Act was recently signed into law. Thus, at the stroke of a pen, millions of acres of land, encompassing many prime collecting areas for rockhounds, were transformed into wilderness, new national park land, and other types of restricted land.

Another major access problem is being able to get into areas that are still in nonwilderness status. We're frequently finding that the roads we've been using to get to our collecting areas are closed. I guess we might call these administrative closures by the Forest Service and the Bureau of Land Management, and, as rockhounds, we rarely know that such closures are going to happen or why. We just go to an area where we have been before, and there's a "road closed" sign.

The really big thing on the road-closure horizon these days is RS-2477, a law passed in the mid 1800s, permitting creation of, in the words of the act, "highways" across public land to facilitate the development of the West. The word "highways" is significant, because there is a government effort to define "highways" in such manner that the two-track jeep trails that we have been using won't qualify, which then leaves the agencies free to close whatever they want. Consideration of this proposal has been deferred, but it's not dead.

Anyway, there is no doubt that getting into collecting areas is becoming harder because of wilderness proliferation and road closures.

Then we come to the question of what can we do in the areas we can still get into. We believe that the 1872 Mining Law gives us the right to do our collecting. The operative word in the law is *prospecting*, and we believe that our collecting activities fit the definition of prospecting, which is to explore or search for. There has been some consideration given to trying to get regulatory help by having some language incorporated into mining-law reform. There are five bills on that subject before Congress right now, and we certainly don't know what is going to happen on these. We can hope, in any case, that they don't modify the definition of prospecting in our disfavor.

A part of the problem that rockhounds have in doing their collecting is that some land-management people seem to have an agenda of their own, wherein they want to stop all collecting of any kind on public land. We don't think there is any legal basis for this approach, but this attitude is certainly bad for relations between rockhounds and government people. It really doesn't help when rockhounds are called thieves by land-management people because they are stealing government property. I mention this because it has actually happened. I acknowledge that as rockhounds, we hear mostly about the bad things that happen to us, and, to be fair, I suppose that the government people could probably tell their share of horror stories on the flip side of the coin. Actually, however, I think that our problems in this respect show signs of becoming less acute, since recently I've noticed some real improvement in the relationships between rockhounds and at least some of the land-management people. This is encouraging, and I hope it continues.

The last thing I want to talk about is that because of these problems in going about our collecting activities, and because of the lack of any definitive statutory authority, the American Lands Access Association has two major efforts underway to try to establish a legal basis for what rockhounds are doing. The first is the Fossil Preservation Act of 1995. This bill has been more than two years in preparation, and it has been massaged and remassaged and has received input from many different interest groups. We think we finally have the kind of bill that would be satisfactory to both the rockhounds and the rest of the people who are involved. It is nearly ready for introduction into both the House and the Senate, and we hope that will happen soon. A second ALAA effort is to try to get similar enabling legislation covering rocks, minerals, and gemstones. Right now it appears that our best chance might be to try to get the concept inserted into mining-reform legislation when that gets moving.

Anyway, we've got our problems, and I'm sure the land-management folks have theirs. So maybe just getting together and talking about things, as we're going to be doing here today, will clear the air a bit and result in something of benefit to all of us.

You will recall that earlier I talked about road closures and about the creation of new wilderness where none existed before. Well, in closing I'd like to relate a personal experience of mine that shows how these two things go hand in hand and illustrates just how this procedure works. I own property near Copper Lake in Gunnison County, Colorado, and for a number of years accessed the area by jeep. There was a Forest Service campground near the lake, complete with concrete picnic table and trash barrel. Numerous sightseers and picnickers visited the area, and the lake was popular with fishermen. In the late 1970s the Forest Service closed the road—no explanation, just a sign that no vehicular traffic beyond a certain point was allowed. In December 1980 the Colorado Wilderness Act of 1980 was signed into law, encompassing the Copper Lake area, along with many thousands of acres in the surrounding area. Thus, in spite of the fact that an area is heavily used by humans and contains much evidence of human usage and modification, the Wilderness Act's stated purpose can be, and in this case was, subverted in order to create wilderness where none existed before.

John Nichols (Forest Minerals Geologist, Ouachita National Forest, U.S. Forest Service): I very much appreciate the opportunity to be here on behalf of the U.S. Forest Service. There are 135 national forests throughout the United States, and many of them have geologists like me on staff. I was asked to represent the Forest Service here because I've been doing a lot of work with the rockhounding and mineral-collecting communities. Like many of you, I am a member of a club myself, the Hot Springs Geology Club in Hot Springs. For the past several years the Forest Service has assigned me to reach out to the mineral-collecting community by participating in the big mineral show in Tucson, Arizona. It is there I first met and talked with John Alf on this subject.

The Forest Service is very interested in the subject of rockhounding and mineral collecting for a variety of reasons. I passed out information sheets entitled "Rockhounding and Mineral Collecting on National Forests" and "Forest Service Minerals Program Policy" [Handouts 1 and 2]. John Alf pretty well outlined, I think, the bulk of the situation that we're facing. He brought out a lot of good points, and in fact there is very little that I would disagree with him on. One of the things that concerned me when I first saw the title of this panel discussion was that it resembled a "we-versus-them" situation, which would really be against my own personal philosophy. I'd rather see us all working together on these issues.

What I can bring to the table and help you understand is a sense of how an agency the size of the Forest Service works. That, I think, is the critical thing that the rockhounding community needs to understand first. It often surprises me that there are many people who do not know who the U.S. Forest Service is, and yet they may be using national forests a lot. We are not a State agency, nor are we the National Park Service—two of the groups we are often confused with. We are the second-largest *Federal* land-managing agency in the country, responsible for administering over 191 million acres of Federal lands out there.

One of the first questions that I always ask school groups in particular, and even adults when I talk to elderhostel and other groups, is, "Who is the Federal Government?" What I want people to understand is that, in essence, *we* are the Federal Government. So whose lands are these? Well, these are *our* lands. Those 191 millions acres of national forest lands out there belong to each and every one of *us*, and we need to understand that first and foremost. That's precisely why so many of you are interested in gaining access to those lands.

A second point, and one of the key issues that John Alf just brought out, is the issue of *access* to those lands. Well, we can address that concern very quickly. You have full "access" on those Federal lands! You can go where you want on the national forests and nobody will stop you. You may not be able to drive everywhere; you have access only in part by road, but full access by foot on these lands. They are *your*—our—Federal lands.

Places you don't have access to are those areas such as mining operations, where there are hazards, explosives, heavy equipment, etc. For example, miners cannot keep you off of their mining claims, but they can keep you out of their work areas where there are hazards. As Federal land managers, we will work with the miners to make sure that you are aware of those hazards, by requiring that they put up fences, gates, signs, etc., to help you stay out of those areas. Most people understand this. You don't want your kids falling off the side of a 50-ft highwall at a mine while you are rockhounding with your family.

The other issue is, "Once I get there, whether by car, or foot, etc., what can I do?" I think this becomes the key issue for most people, "What can we do?" I'm glad that John Alf talked first, because he framed much of what I've recognized that many of you are concerned with. In looking at the issue of what you can do once you get there, let me first deal with a few specific scenarios. John brought up wilderness areas. As a Federal land-managing agency, the Forest Service does not set the laws. That's the job of Congress. Our job is to *implement* those laws once Congress passes them. So, when you start talking about wilderness areas, you are talking about areas that Congress, not the Forest Service, has decided will be very selectively managed. It's fine to go to the Federal land manager and discuss your opinion about how a wilderness should be administered, but there isn't a lot that the land manager can do.

So if you are looking at access to that land, you've got the access. But if you are looking at collecting minerals off that land, for example, you are talking to the wrong person. The Forest Service District Ranger cannot give you permission to collect minerals in wilderness areas. It is important to keep it as a separate issue. If you want to change the wilderness laws, for example, to allow for mineral collecting, then you've got to deal with Congress to get those laws changed, not with the Federal land manager.

However, most of the national forest lands are administered for a wide variety of resource uses, including mining and rockhounding. The write-up I provided [Handout 2] will explain some things that you may not have been aware of; it lists some national forests that have developed opportunities for mineral collectors and rockhounds. The Ouachita National Forest, the forest I work on, is one of them. We have already developed one quartz crystal–collecting site, and we are working on a second site now, with a third site in planning.

These sites are being developed specifically with the rockhounds in mind. The first site was developed in cooperation with two geology clubs in Arkansas, including the one with which I'm associated. The rockhounding sites on our national forest are reclaimed mines. All mines are required to be reclaimed by the operator when mining has ceased. Generally we require that the operators reclaim them with a "wildlife" emphasis: for example, excavations filled and recontoured and seed mixtures selected to grow plants that benefit the local wildlife. However, in this particular case we saw an opportunity to use some of the completed quartz crystal mines also as sites for rockhounds on the Ouachita forest, because the tailings from these operations usually contain some nice quartz crystals that many rockhounds enjoy looking for. The Ouachita Mountains have some of the best-quality quartz crystals in the world. As a result, there is a lot of quartz crystal–mining activity that takes place, both on private lands and on national forest lands. I have a flyer [Handout 3] about our first developed rockhounding site, called "Crystal Vista [in Arkansas]," which is free to the public. Along with the other sites I mentioned that we were developing, we also are looking at a site having specimen-grade wavellite.

In addition, we have developed a forest policy on the Ouachita National Forest that allows you to pick up surface pieces of quartz crystal for personal use, and not for sale,

Oklahoma Geological Survey
ROCKHOUND WORKSHOP

Omniplex Science Museum, Oklahoma City
October 28-29, 1995

Rockhounding and Mineral Collecting on National Forest Lands

John C. Nichols, Forest Geologist, Ouachita National Forest

The US Forest Service: The US Forest Service is a federal agency under the US Department of Agriculture. The Forest Service is responsible for managing 191,000,000 acres of federal lands contained within 156 National Forests and 19 National Grasslands, located in 40 States from Alaska to Florida, and in Puerto Rico. Each National Forest is divided into units called "Ranger Districts". The Forest lands within each District are the responsibility of the line officer called the "District Ranger". On each Forest, all the Rangers are under the authority of a line officer called the "Forest Supervisor". *For example, the Ouachita National Forest located in Arkansas and Oklahoma -- the oldest and largest in the Southeast -- is 1.6 million acres in size and divided into 12 separate Ranger Districts each with their own office location on the Forest. These District Offices in turn come under the Forest Supervisors Office in Hot Springs, Arkansas.*

National Forest Management: The Forest Service is responsible for managing a wide variety of resources on the National Forests some of which include: recreation, timber, fish, wildlife, threatened and endangered species, mining, cultural resources, soils, water, air quality, wilderness, wild and scenic rivers. While management of one resource will often complement the management of other resources, sometimes just the opposite occurs creating interesting challenges in balanced management. *For example, wilderness management precludes many surface impacting activities, yet there are some mining rights cases that do involve surface impacting activities within wilderness areas.* The publics varied desires for different uses on National Forest lands, as expressed through the myriad of laws governing how those lands are to be managed, are extensive and exhaustive. For every citizen who demands they be managed in one way there are many others with very different and often conflicting desires.

Mineral Collecting on National Forests: Collecting minerals on National Forest lands can be both exciting and challenging. Many developed and undeveloped opportunities already exist to collect rock and mineral specimens. *For example, the Beaverhead National Forest in Montana, the St. Joe in Idaho, and the Ouachita National Forest in Arkansas and Oklahoma, all have developed public mineral collecting locations.* Many National Forests provide information on general specimen locations within the Forest and on Forest policy and rules for the rockhounder and mineral collector. *For example, the Chugach National Forest in Alaska, the Wallowa-Whitman in Oregon, and the Prescott in Arizona are some Forests with histories of placer gold mining. These Forests offer very informative brochures on panning and suction dredging for gold.*

Restricted Access: The old axiom "Gold Is Where You Find It" is true for all minerals. Whether it is quartz crystal in Arkansas, Garnets in Idaho, ruby in North Carolina, or Thundereggs in Oregon, the collector and rockhounder must go to where the minerals are. If an area is unavailable to the collector, the mineral specimens that may be within that area will go undiscovered. This results not only in a loss to the mineral collecting community, but often to the academic and scientific community as well. Areas on National Forests that generally are not available to the mineral collector include wildernesses and designated "wild" portions of rivers that Congress has determined will be very selectively managed. Other areas include lands that Congress has either excluded mineral collecting outright, or have simply not given the Forest Service authority to manage for mineral collecting. It is important for the mineral collector and rockhounder to understand Congress's direction, based on public mandate, for managing the National Forests and how the Forest Service functions in following that direction.

It's "The Law" for the Miner: Some mineral collectors and rockhounders desiring to operate on National Forests may intend to sell the specimens they remove or to conduct what may become significant surface disturbing operations. These collectors and rockhounders should become familiar with the mining laws that provide for and govern mining related activities on National Forests. The mining laws are designed primarily for commercial type exploration and production operations, and require the operator to submit mining plans for reviews and approvals. Under these laws the minerals are removed with the least impact to other resources and the lands are reclaimed by the operator for other uses when mining is completed. These laws offer certain advantages and rights that many mineral clubs and individual collectors often are also willing to take advantage of even though they result in extra effort and expense.

It's "No Law" (yet) for the Collector: Aside from the mining laws, at this time there is no law that provides a specific "right" for mineral collectors and rockhounders to collect specimens from National Forests. However, there are two primary laws concerning the National Forests that do open some doors for collectors:

* The Organic Act of 1897, one of the National Forest creation acts, provided authority to "...make such rules and regulations and establish such service as will...regulate their occupancy and use and to preserve the forests thereon from destruction." -- *Since 1897, mineral collecting has become an important "use" of National Forest lands to many people.*
* The Federal Land Policy and Management Act of 1976 (FLPMA) provided that "...the public lands be managed in a manner that will protect the quality of scientific, scenic, historical, ecological, environmental, air and atmospheric, water resource, and archeological values; that where appropriate will preserve and protect certain public lands in their natural condition; that will provide food and habitat for fish and wildlife and domestic animals; and that will provide for outdoor recreation and human occupancy and use." -- *FLPMA calls for a balance among all uses to "manage", "protect", "preserve" and "provide".*

The "Activity" of Collecting: Generally, the activity of collecting minerals on National Forests does not "significantly" impact (disturb) other Forest resources. Consequently, the collector will often find that simply contacting the District Ranger and explaining what they would like to do is all that is necessary to receive "permission" to conduct their desired activity on the Forest. *For example, typical mineral collecting and rockhounding activities often involves digging and chipping with tools such as small garden trowels, scrapers, and rock hammers. Usually the District Ranger is not concerned with this type of low level impact and will often simply thank the person for contacting the Forest Service and wish them well in their endeavors.* In those cases where the collecting activity could lead to greater resource impacts, the District Ranger may require a written proposal from the parties for formal review and evaluation by the Forest Service. *For example, a mineral collecting club may want to bring a backhoe to a site to remove overburden (dirt) and expose rock to increase the opportunity for its members to collect fresh mineral specimens for a club day outing. The District Ranger will want more information on the collecting locality so that Forest resource specialists can review the area to understand what impacts may occur to other resources. Club officers in turn will want to provide that information well in advance of the planned trip to give the Ranger adequate time to evaluate their proposal.* The greater the amount of surface impact that is being proposed, then generally the more intense the evaluation of that proposed impact will become. A District Ranger "Approval" to operate on the Forest is a written agreement, such as in a letter, contract, permit or other appropriate document, between the Ranger and the operator. The agreement includes whom the responsible party will be and how they will reclaim the impact, and will usually require a reclamation bond to ensure that they complete all necessary reclamation.

For the Benefit of "Science": Many mineral collectors and mineral collecting organizations invest much of their effort in the search and recovery of mineral specimens for educational and scientific purposes. These collectors may publish articles or statements about the significance of their finds in professional and/or lay publications (club magazines and journals). It is important for the collector to help the District Ranger understand that the site the collector wants to access on the Forest is important for these reasons as well. *For example, a scientific or academic endeavor could result in the District Ranger opening a closed road to facilitate temporary access to a collecting locality, or directing resource specialists to evaluate potential impacts from the proposed endeavor ahead of other District work.*

CONCLUSION: The key to mineral collecting and rockhounding on National Forests is communication: making contact and talking with the local District Ranger. Not only will the collector find out what the policies and rules are, but they will discover that the Forest Service can provide many other practical resources such as maps, information on camping, and other recreational activities and sites on the Forest. Some Forests have Geologists or Mining Engineers on staff in the Forest Supervisors office. The Forest Geologist can often provide information on Forest policy and procedure, facilitate communications with the District Ranger, and provide minerals, geology, and reference information that could prove invaluable to the collector or rockhounder.

Definitions (General and Non-binding...)	
Rockhounders: *Those persons interested in the non-commercial search for and removal of rocks and minerals for personal purposes, typically using only small hand tools.*	***Mineral Specimen Collectors:*** *Those persons interested in collecting unique mineral specimens primarily for scientific or academic interests, and often publishing the results.*

Handout 1 (continued)

FOREST SERVICE
MINERALS PROGRAM POLICY

The availability of mineral and energy resources within the National Forests and Grasslands significantly affects the development, economic growth, and defense of the Nation. The mission of the Forest Service in relation to minerals management is to encourage, facilitate, and administer the orderly exploration, development, and production of mineral and energy resources on National Forest System lands to help meet the present and future needs of the Nation.

The Forest Service administers its mineral program to:

1. Encourage and facilitate the orderly exploration, development, and production of mineral and energy resources within the National Forest System in order to maintain a viable, healthy minerals industry and to promote self-sufficiency in those mineral and energy resources necessary for economic growth and the National defense.
2. Ensure the exploration, development, and production of mineral and energy resources are conducted in an environmentally sound manner and that these activities are integrated with the planning and management of other National Forest resources.
3. Ensure that lands disturbed by mineral and energy activities are reclaimed for other productive uses.

The Forest Service policy is to:

1. Process mineral applications, operating plans, leases, licenses, permits and other use authorizations efficiently and timely.
2. Ensure the integration of mineral resource programs and activities with the planning and management of renewable resources through the land and resource management planning process, recognizing the mineral development can occur concurrently or sequentially with other resource uses.
3. Plan and provide for access to an occupancy of National Forest System lands for mineral resource activities, consistent with the overall management objectives and the rights granted through statutes, leases, licenses, and permits. Eliminate or prevent occupancy that is not reasonably incident to and required for the mineral operation.
4. Prior to applying for the administrative withdrawal of National Forest System lands from mineral entry, ensure the consideration of (a) the national interest in strategic and critical minerals, (b) the value of the mineral resource foregone and, (c) the value of the resource or improvement being protected.
5. Ensure that valid existing rights have been established before allowing mineral or energy activities in congressionally designated or other withdrawn areas.
6. Coordinate and cooperate with other Federal and State agencies having authority and expertise in mineral-related activities.
7. Maintain an effective professional, technical, and managerial work force that is knowledgeable in mineral exploration and development.
8. Ensure the uniform application of exploration, development, and reclamation standards.
9. Require a reclamation plan for all mineral exploration and development proposals that would create environmental disturbance, to return the land to other productive uses consistent with land and mineral management goals.
10. Ensure that qualified geologists or mining or petroleum engineers prepare reports and perform site visits of all lands which require the examination of the mineral or geologic character of the lands.

Handout 2

without having to obtain a permit or contract with us first. As long as it is an occasional activity, and is not on land where someone has a contract for quartz, you don't need to make any further contact with us. This is just an example of one national forest and the way it approaches rockhounding, mineral collecting, and such. The Forest Service has recognized for a number of years that this is important to people. The quartz resource on the Ouachita National Forest is there in abundance, and we're not close to depleting it for the rockhound—not yet anyway.

Some other national forests also have quartz crystal-collecting sites [see Handout 2]. An example is the Beaverhead National Forest around Dillon, Montana, developed in cooperation with the Butte Gem and Mineral Society. It provides an exciting and different kind of opportunity for mineral collectors. Other sites are listed in Handout 2 as are some national forest general policies, for example, on gold panning and dredging.

John Alf also mentioned the 1872 Mining Law, which I touched on in Handout 2. An important fact is that some Federal lands are "public-domain" status and others are "acquired" status. For example, the Ouachita National Forest is 1,600,000 acres in size. Of those acres, 700,000 are "public-domain" status, all located in Arkansas, and the remaining 900,000 acres are "acquired"-status Federal lands. The 1872 Mining Law deals with only one class of Federal lands: those that have "public-domain" status. All the Federal lands in Oklahoma are "acquired" status, and so the 1872 Mining Law would not pertain to them. However, there are leasing laws that govern how a person can access the Federal "acquired"-status mineral estate.

Many mineral collectors and rockhounds are willing to come under the mining laws for locatable minerals on public-domain–status lands or for leasable minerals on acquired-status lands. However, that's not going to meet everybody's needs. When you come under those laws, you are coming under a system that's going to probably result in expenditures of funds, time, and effort—perhaps more than what you want to expend as a rockhound. If you are just looking for something to do on a weekend, for example, the effort and expense to keep up a mining claim or lease may not appeal to you. But for a mineral club, it might work very well, and in fact some clubs across the country do that to secure popular collecting sites for their members.

In short, as I pointed out in Handout 2, there are laws for the miners; there are no laws yet for collectors. John Alf touched on this difference as well, and there are efforts being made through his organization and others that are trying to get Federal laws passed for collectors. If successful, this approach would give the Federal land manager, those people that I represent, more freedom and flexibility to work within the scope of those new laws in providing more opportunities for rockhounds.

As things stand at present, the main issues for the mineral-collecting and rockhounding community are (1) access, (2) "What can I do once I get there?" and (3) understanding the organization and structure of the Forest Service well enough so that one knows who should be asked that question. As for this last issue, the Forest Service is broken down into ranger districts. If you have been on national forest lands, you've probably passed right by ranger district offices, because they are located in key places throughout the forest. For example, the Ouachita National Forest is divided into 12 ranger districts, with an office for each one of those districts located in towns and communities across the forest. Each of these offices is accessible to the public and provides all kinds of information on that district and on the forest. It's not a sterile work environment. It is designed for the public.

The public has access to every single Forest Service employee, including the District Ranger—the line officer in charge of that Ranger District. If you are planning a trip into an area, call in advance (if you are going to be traveling any distance) to talk to them and say, "This is where I want to go, and this is what I'd like to do. What can I do?" What you're going to find is that, in an agency the size of the Forest Service, there are geologists like myself or mining engineers working primarily with the mining community who are familiar with the needs of the rockhounding community and who can act, in a sense, as a "liaison" between the mining or rockhounding communities and the Forest Service. If the forest doesn't have a geologist, then there may be a lack of sufficient awareness or understanding about what you want to do as a rockhound.

On the Ouachita National Forest, personnel will often refer public inquiries straight to me on anything dealing with mining laws, rockhounding, minerals, and geology issues. I then can "shepherd" users of the district and help them understand what they can and cannot do based on the appropriate laws and regulations.

The Forest Service has sent me to Tucson, Arizona, for the past couple of years to represent the Forest Service at the Tucson Gem and Mineral Society show, just so that we can make positive contact with the mineral-collecting and rockhounding community and share information with them. I have had people come up to me there and say things like, "You know I've been out there collecting and I was minding my own business and some guy in a Forest Service uniform drove up and ran me off of there." And I then ask, "Did you get his name? Did you talk to him?" Nobody thinks to do that. Forest Service people don't just "drive up and run you off," and if they're doing that, you are probably dealing with somebody who isn't supposed to be doing something that they're doing. You may encounter "zealous" Forest Service employees, just as there are "zealous" rockhounds. I can picture a scenario in which, for example, a Forest Service employee, who is a fisheries biologist, comes upon a gold panner who is panning where the employee had earlier seen a salmon laying her eggs; in a panic, that employee may try to get the gold panner out of there real quick.

There are many resource needs and concerns managed by the Forest Service on national forests. Again I think the main thing is communication. You're concerned with access, and you're asking the right questions if you ask "what can I do when I get there?" But you need to ask it early on, and of the right people, so that you don't get unpleasantly surprised. And maybe we can talk more about that in detail later.

Ouachita National Forest

Arkansas - Oklahoma

Crystal Vista

Crystal Collection Area

Highlights:

Crystal Vista is nestled among the trees high atop Gardner Mountain. The trail starts at the base of the mountain at an elevation of 900 feet and continues about a mile to a final elevation over 1,200 feet. The hike is steep and takes about 25 minutes.

On top of the mountain you will come upon a large 4 acre opening, which was a commercial crystal mine. Quartz crystals can be easily collected off the ground surface. Continue to walk north a short distance to the top of the ridge and enjoy a spectacular view of Lake Ouachita and the surrounding landscape. To the south, the view opens up onto hardwood/pine forests characteristic of north facing slopes of the Ouachita National Forest.

Remember:

- Crystals are for personal use only and not for resale.
- Camping or fires are not allowed.
- Only hand tools such as trowels and rockhammers are permitted.
- Steep slopes are unstable. For your safety please avoid these areas.
- All motorized vehicles must be left at the parking area at the base of the trail.

Crystal Vista is a primitive site without developed facilities such as drinking water or restrooms. There is no garbage pickup so come prepared to pack out whatever you pack in. For an enjoyable experience you will want to carry water, a hat or sun screen, insect repellant and a bag to carry crystals you collect.

Location:

From Mt. Ida, travel south on Highway 27 for 3.8 miles and turn left (east) on county road 2237 (Owley Rd.). Continue on 2237 for 4.1 miles to Crystal Vista trailhead.

Fees: None.

Facilities: None.

Open: Year round.

For More Information:

Womble Ranger District
P.O. Box 255, Highway 270 E.
Mount Ida, AR 71957
(501) 867-2101

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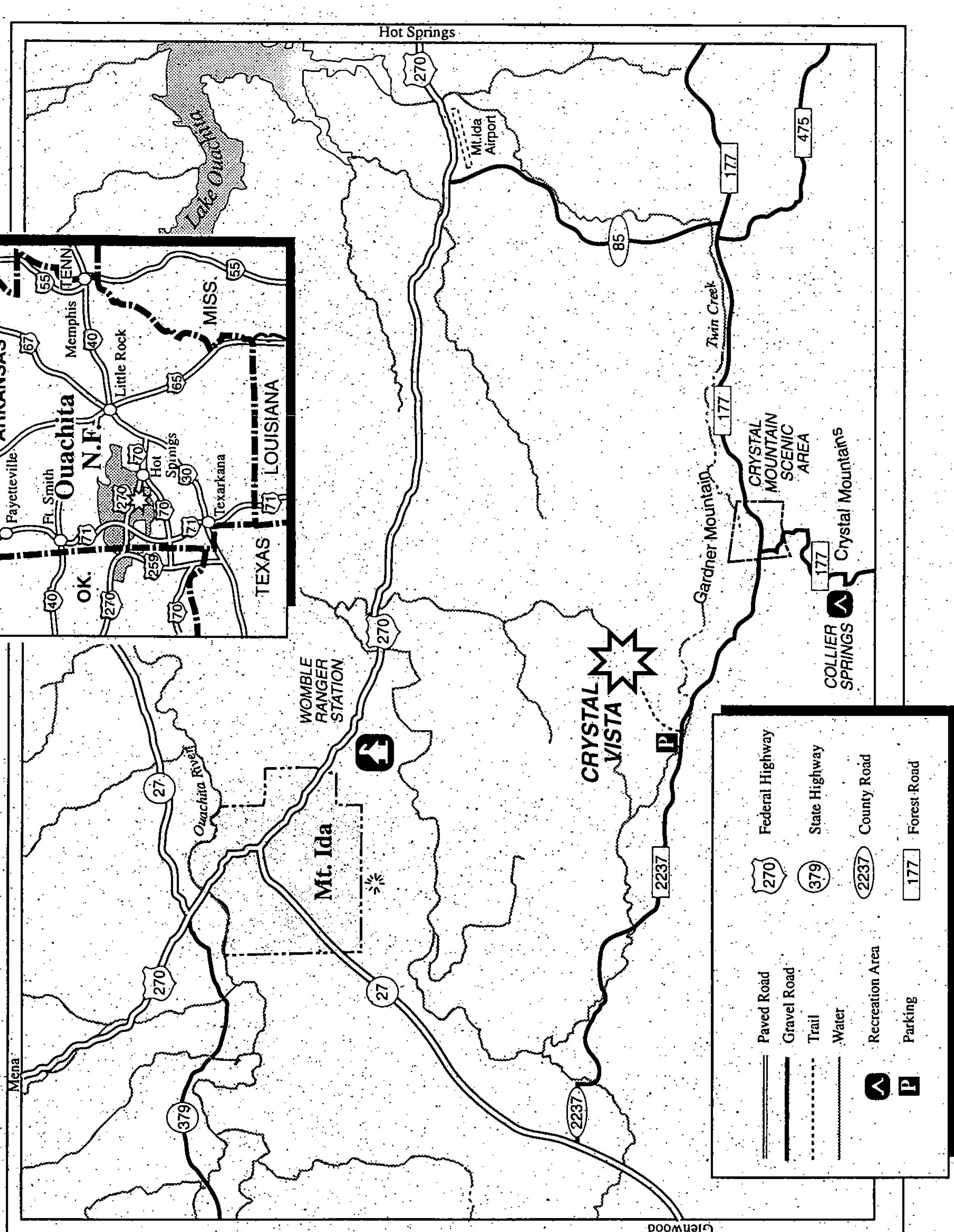
Ouachita National Forest

P.O. Box 1270, Federal Building, Hot Springs, AR 71902 (501) 321 - 5202, TDD (501) 321 - 5307

Handout 3



Crystal Vista
Ouachita National Forest

Handout 3 (continued)

Tom Creider (Assistant Director of State Parks, Oklahoma Department of Tourism and Recreation): By way of background as a State agency, versus the Federal folks that are here, our agency operates under both statute and rules and regulations that are generated at the State level. First, I'd just like to describe our statute, our enabling legislation as it relates to Oklahoma state parks. This statute goes back to the 1930s when Oklahoma state parks were initiated. The statute gives us the mission of providing the public with outdoor-recreation opportunities and preserving and protecting those natural and cultural resources located within Oklahoma state parks. We have some regulations that were enacted; they are not statutory, but are the result of the public open-meeting law or open-meeting process in which you, the public, has an opportunity for input. What I'm going to highlight here, in terms of rules, are not etched in stone. They are changeable; they can be changed. But these are the guidelines under which we operate at the current time.

First of all, in terms of definitions that relate to the rules and regulations under which we operate, *natural resources* means plants, animals, or any natural object or material that has been produced by nature and is located within a park unit. Another park rule that I'm again highlighting (not actually reading) basically says that our agency is responsible for preservation and protection of natural, cultural, and archaeological resources. This rule prohibits possession, destroying, injuring, defacing, removing, digging, killing, disturbing, or removing anything from its natural state.

Another regulation relates to authorized permitting. Some of you may be aware of the rules governing collecting for educational or scientific purposes and may have approached our agency for those purposes. You are probably already aware of this, but we do have authorization, and our managers have authority, to issue permits, again primarily based upon a determination that the action is not in violation of public health or safety, contrary to environmental values, or contrary to the protection of the natural or cultural resources. Primarily, these permits are issued for scientific or educational purposes. Again, these rules are not etched in stone; they are subject to changes as you the public and the agencies, in concert with your efforts, might see fit. There is a review on an annual basis.

We operate 20 of our 55 state park units on Federal land—land that the State leases from Federal agencies. These agencies include the U.S. Army Corps of Engineers and also the Bureau of Reclamation. So some these park units also have Federal regulations that do affect what we, the State, can allow the public to do within those parks.

The philosophy under which we're operating as it relates to these rules is that we view state park resources as public assets—assets that we all own, assets that we are stakeholders in. However, we alone aren't the only stakeholders; future generations are also stakeholders. I think we take a view that, in most cases, state parks in Oklahoma do not cover a very large area and also our knowledge of the geologic resources of the parks is limited. That is no fault of the Oklahoma Geological Survey and others who have tried to help us become more educated in terms of what those assets are. I think that we probably do not have a strong understanding—I'm saying this in terms of myself and our agency in general—of the true abundance of some of these geologic and fossil assets. And so our tendency is to take the view that these assets may be very limited in quantity and that they have a public value; therefore, we have a mission to protect those assets for present and future generations.

I hope that, with the help of individuals such as yourselves, we gain a deeper knowledge about the resources that are available in state parks. Maybe through the efforts of yourselves, as volunteers, some of these assets can be made available to the public through nature centers and other types of displays where we can share this information. Maybe at the same time we can gain additional information from the volunteers, so that if there is abundance of some of these resources, we may be able to modify or change some of the governing regulations. One example, and of course this is on Federal rather than State land, is the Great Salt Plains where authorized crystal hunting is going on. And that's allowed because new crystals are being regenerated by nature. I think there would be more opportunities for allowing collecting if we had greater knowledge and information.

I would just say, in closing, that I am here primarily to learn, and I want to let you know that our agency wants to be responsive to your avocation. We welcome your presence at state parks. But again, collecting, as it exists within our rules and regulations, must be done by permit, and to my knowledge, permits are given basically for scientific or educational purposes. We would hope that the collections would be something that could be shared with other members of the public.

Laurie Bryant (Paleontologist, U.S. Bureau of Land Management): I'll start out in the same way that John Nichols did, by explaining a little bit about what the BLM is. It's the Bureau of Land Management, an agency of the Department of the Interior, and it is the largest land-managing agency in the United States. It administers 270 million acres scattered in 12 western states. Oklahoma is on the eastern edge of the vast areas of BLM-administered lands.

BLM lands are different from Forest Service lands in that much of BLM land is "leftover" land. It's land that was left over after the Homesteading Acts, and often it represents land that was not taken up—land nobody wanted to own because it was dry, it was eroded, it was barren, and nobody wanted it. It ended up in the hands of a couple of different agencies. The BLM is really a mixture of the old General Land Office and the Taylor Grazing Service. Those two agencies were put together in 1946 to administer this huge patchwork of Federally owned lands out here in the West.

One difficult feature is that, unlike the national parks and many national forests, BLM land doesn't have nice, discrete boundaries that you can easily draw. BLM may administer a whole series of scattered 40-acre tracts, separated by acres of private land. That pattern presents difficulties both in managing BLM land and, for you as a hobbyist, in accessing it. I know people have concerns about access to public lands, and some of those concerns are shared by the land managers as well, because if BLM has an isolated 40-acre tract in the center of an ocean of private land, and if the private-land owner is not very inclined to let the land manager across, then we have an access problem too. A lot of BLM land has no legal access to it. It sits out there with lots of private land surrounding it, and we have no right-of-access on any road whereby we can get to that public land. So, that's a problem for the agency, and it's a problem for the public too. BLM is trying very hard to box up some of those isolated tracts, to get rid of them, or perhaps to trade them for other areas that have better access so that the public can use them also.

BLM-administered lands are called public lands because they belong to you. They belong to everybody in America; everyone has equal right of access to them and can use them in a lot of different ways. BLM's enabling legislation, the basic law that runs the BLM, is called the Federal Land Policy and Management Act; it requires that BLM manage all public lands for multiple use and sustained yield. In other words, areas are not ordinarily set aside where only one use can be carried out. These are areas where all kinds of activities can be carried out, including grazing, mining, rockhounding, wildlife habitat, and so on. That's the basic philosophy behind the agency.

I'm a paleontologist for BLM. You might think that, with 270 million acres, BLM would have a whole flock of paleontologists, but in fact we have only three, and it spreads us out just a little bit. All three of us have been hired within the past three years; that rectifies or corrects a situation that's been out there for a long time. The fact is, BLM lands have a lot of really nice fossils on them, but the agency has never had any paleontologists who could explain to the rest of the staff what the rules were for managing their use. Now there are three of us to explain to the other 9,000 staff people how the system works.

In the same way that John Nichols cautioned you, when you go to a BLM office and ask the employees, "What are the rules for fossil collecting?" nine times out of ten they are going to say, "Fossils?" Now the people in Wyoming have learned to call me; they just give me a call, and I send a lot of information out to them to answer most of their questions. If you reach the geologist, the local geologist in that office, you'll get good, solid answers. Those people know what they're talking about. Some archaeologists also have been trained to answer questions about paleontology, and they're a good bunch too. Other staff members? Probably not much help on fossils. Their work is in totally different areas, and they will not have information about fossils. So be careful who you ask. It's like any place else, you've got to reach the person with the information.

I want to read something that I picked up here just recently. This is just a couple of sentences from the House Committee on Public Lands. I want to read it to you because it has a great deal to say about BLM policy—why it is the way it is.

> House Committee on Public Lands: The report of the House Committee is as follows. Persons are now waiting for the Spring to make merchandise of these beautiful specimens, to fence in these rare wonders so as to charge visitors a fee as is now done at Niagara Falls. If this bill fails to become a law this session, the vandals who are now waiting to enter into this wonderland will, in a single season, spoil beyond recovery these remarkable curiosities.

When do you think that was written, and about what? It was written in 1871, about Yellowstone National Park. What this quotation lays out is the heritage of the land-managing philosophy that has come down to BLM today; in some senses it is protective, and in other senses it is commodity oriented. The BLM operates in a somewhat schizophrenic world, where part of the Bureau's work is to lease minerals, sell timber, and so on, and other parts of the Bureau's work involve protecting things like cultural artifacts, wildlife habitat, threatened and endangered species, and scientifically significant fossils. So the heritage of that approach, the protective approach, begins way back in the 19th century, and it is still with us to this day. The American West was really the first area in the world to set aside and to recognize areas of Earth's heritage as being so valuable, so wonderful, and so unique that they needed protection. They needed to be set aside.

Both FLPMA, which is the Federal Land Policy and Management Act, and NEPA, the National Environmental Protection Act, cause the BLM to administer lands in a certain way: in part for multiple and sustained yield and in part to preserve important natural aspects of our national heritage. So what we come down to is this: scientifically significant specimens on public lands are managed to preserve them as irreplaceable parts of the nation's heritage, and other kinds of fossils, other fossil resources, are managed for present and future public benefit and enjoyment.

With that in mind, BLM has tried to develop a balanced treatment of fossil resources on BLM land. Some are reserved as scientifically unique specimens that remain forever in the public ownership. They can be collected only under a permit, and they must be kept in a museum or on display or kept available for study forever. They are no one's property. They never leave the ownership of the Federal government. They may sit in a museum, but they don't belong to the museum; they belong to you. Some areas (very few areas on BLM land) are set aside for special projects, such as interpretation, signs, and developed trails, and some areas are set aside for public education, where classes and school groups can go. And some fossils that are common may be collected by hobbyists.

I put out a number of copies of one of our pamphlets on "Fossil Collecting on Public Lands" [Handout 4]. They are not terribly specific, but there is a lot of general information in there. If you need more specific information, please inquire.

Now there has to be some reason why we are all here today. This is a large group of people. Maybe you have heard stories about new regulations that the BLM is writing to create restrictions on the use of public lands. Maybe *information about:*

Fossil Collecting on Public Lands

U.S. Department of the Interior **Bureau of Land Management**

2515 Warren Avenue
P.O. Box 1828
Cheyenne, Wyoming 82003-1828

Telephone 307-775-6256
TDD 307-775-6130
Fax 307-775-6129

Public lands managed by the Bureau of Land Management are for the use and benefit of all Americans. The fossils found on public lands are part of our national heritage, so there are some special rules for their protection. For more detailed information, contact your local BLM office.

Hobbyists May Collect Some Fossils for Personal Use

Most areas of public lands are open to exploring and hobby collecting, but there are special areas that are managed to protect their scientific and natural resources. Collecting and access may be limited in these areas. Contact your local BLM office to find out about areas where fossil collecting is limited.

Use it Carefully!

Collecting activities that damage the public lands and resources, or that make them dangerous for others, are not permitted. Uprooting large areas of grass, sagebrush, and other plants, or digging large holes may create hazardous conditions, and can contribute to erosion. An archaeological site might even be damaged or destroyed and this is prohibited by the Archaeological Resources Protection Act of 1979. *Many fossil specimens are found right on the surface and digging is often unnecessary.*

Invertebrate Fossils

Invertebrates are animals without backbones. This includes: clams and snails, ammonites, trilobites, and corals. Common invertebrates may be collected in reasonable quantities for personal use, but they can't be traded, bartered, or sold to anyone else.

Commercial collecting of invertebrate fossils from public lands is not allowed. Overcollecting of invertebrates that once were common has made some of them difficult to find. Please remember to leave something for your grandchildren to enjoy!

Vertebrate Fossils

Vertebrates include sharks and other fish, dinosaurs, turtles, mammals – in fact, any animal with a skeleton of cartilage or bone. Because vertebrate fossils are rare and scientifically important, they may be collected only after obtaining a permit from the BLM's Wyoming State Office.

Who May Get A Permit

Permits for collecting vertebrate fossils on public lands are issued to scientists with education and experience in paleontology. These scientists must arrange to put all fossils they collect in a museum or other public institution where they remain the property of all Americans.

Petrified Wood

You may collect as much as 25 pounds of petrified wood, plus one piece per day, for your personal use. You may collect as much as 250 pounds of petrified wood in any calendar year.

You may not "pool" the quotas of several individuals in order to collect pieces larger than 250 pounds.

Petrified wood collected for personal use may not be traded, bartered, or sold to anyone else. If you want to collect larger amounts, or sell the petrified wood you collect, you may apply to the BLM for a mineral material sale permit.

What You Can Do For Your Public Lands

There are only a limited number of fossils, so take only the ones you'll use in your collection. If you find vertebrate fossils, leave them in place because their location and surroundings are as important to scientists as the fossils themselves. Many fossils are extremely delicate and could be destroyed if you try to move them. Take a photo if you can, and report significant finds to the BLM. Natural processes, like rain or snow, are less damaging to the fossil than if **you** try to dig them up.

If you see someone destroying fossils on public lands, or if you are approached by someone asking about vertebrate fossil localities or collecting you can help by contacting your local BLM office. But **DON'T** try to handle these situations yourself!

Private Land

Contact landowners for permission before you collect on private land. Your local BLM office sells maps that show public, private, and other lands and roads that provide legal access to public lands. Always respect private property rights.

Laws and Regulations

Federal Land Policy and Management Act (43 U.S.C. 1732, Sec. 302 (b) of PL 94-579, 1976)

Theft of Government Property (62 Stat. 725; 18 U.S.C. 641)

Destruction of Government Property (62 Stat. 764; 18 U.S.C. 1361)

43 CFR 8365 (hobby collection of common invertebrate fossils; prohibits creating a hazard or nuisance)

43 CFR 3622 (hobby collection of petrified wood; prohibits undue degradation)

43 CFR 3610 (commercial collection of petrified wood)

Archaeological Resources Protection Act (16 U.S.C. 470-aa-470mm; PL 96-96, 1979 and amendments)

WYNF-0024 (6/94)
Page 2 of 2

you've heard that fossil collecting is just plain illegal on the public lands. Maybe you've heard that everyone is going to have to have a permit to collect on the public lands. None of this is true.

I'm here because the BLM is trying to bend over backward to do business in different ways. One of those different ways is to have greatly increased public input. The old way of doing business was for BLM to come up with an idea and ask people if they liked it. In Wyoming we have stopped doing that. What we do now is go to the public and ask, "What's your experience been in the mineral program? Tell us what you think is a problem. Tell us what you think works really well. Tell us what we could do differently. Tell us what you'd like us to do differently." And we have a public meeting on that basis, so that actions we now take are driven by the public. They are not driven by BLM staff. We look for public input to tell us what to do next, and then we work out the details of how that can be done.

I would like to read a bit from a letter from the Director of the BLM. He sends us each a letter every Friday on the computer network; this is very effective because we all get it at once and it's just electronic so you don't have to throw any paper away. Anyway, last Friday, October 20, 1995, he told us about a speech that he made in which he used the word *community*, which I think is a wonderful word. This is a community here. You're part of it, I hope I'm part of it; we're all part of this rockhounding, fossil-collecting community. And he suggested that we in the Bureau should "think in a few simple terms when we're doing our work. One is to work within the limits, understanding that people and landscapes and resources have limits. Another is to remain humble, be flexible, and be willing to change. Look at the big picture." In other words, let's not just look at Oklahoma, let's not just look at the Rocky Mountains, let's look at the big picture. "Think ahead. Don't be thinking just about what we want today; let's be thinking about what we want our grandkids to have when that time comes. Invite everyone to the table, fix what's wrong, work with your neighbors, find common goals, communicate and educate, know the condition of the land, and sustain the productivity and diversity of systems." Now the Director is famous for simple language, and I think those are good statements. I hope that we are as good at putting them into practice as he is at writing them.

Another idea came out in the *Washington Post* of October 26, 1995: "Top priorities sent by the White House Conference on Travel and Tourism." There are ten priorities in here, and priority no. 4 is to preserve our natural, historic, and cultural resources for future generations and to expand urban and rural economic-development opportunities by fostering environmental and cultural travel and tourism. I think these are fine suggestions. I think the idea of all of us sitting down together is the best thing we've probably done in a long time. I thank you for inviting me, and I hope I can provide information and answer questions for you.

DISCUSSION

Ken Johnson: I'd like to provide an opportunity for the four panelists to talk among themselves and then open the meeting up to discussion and questions from the floor.

John Alf: I have a question of John Nichols. I thought I understood you to say, John, that collecting in wilderness areas was not permitted. Is that correct?

John Nichols: Well, you have to look at the wilderness legislation. If you want to collect for scientific or educational purposes, then you can do that. But—unless there is something that I'm not aware of that is specific to a particular wilderness—under the general wilderness legislation, there isn't supposed to be any private collecting inside wilderness areas at all.

John Alf: The reason I bring this up is because I have a paragraph here that apparently is going to be included, or at least is being considered, in the Muggins Mountains Wilderness Management Plan, the Muggins Mountains being in Arizona. And a specific paragraph says, "Restrict the use of dry washers, rocker boxes, and similar devices for recreational mineral extraction within the wilderness portion of the planning area following procedures outlined in 43CFR8560, allow hobby mineral collecting (BLM manual 8560.31.e). The use of shovels and prying tools that disturb the surface in any significant way shall be prohibited." Now the reason for this particular paragraph is that it was originally written very similar to this, but it also said "hand tools, including rock hammers, would be prohibited." And the point was made in a meeting with the folks from Arizona that prospecting *is allowed*, based on the 1872 Mining Act, and how can anybody prospect without being able to use a rock hammer? And they agreed that the thrust of their effort there was really to control dry washing, rocker boxes, and things that hobby gold collectors were using and that was causing damage to the environment. They did not have in mind restricting the use of rock hammers, really, or restricting the collection of minerals and so forth from that particular area. So here's an area that apparently has a policy that allows what we'd like to see.

John Nichols: Yes, John, I think what you're bringing out is kind of what I was alluding to, in the sense that you know Congress can do wondrous things. Back in 1964, when it first passed the wilderness legislation, there were specific wildernesses that came in under that act, which was then applied to subsequent wildernesses. But if you can get additional language in the legislation that satisfies your needs, then that's fine. I mean, Congress can change that legislation to read essentially whatever it wants to read. But in general, when you're talking about collecting activities inside wilderness areas, you've got to be really, really careful. However, I don't think anybody's going to swoop down on you as you're hiking along the trail with your kid, and your kid bends down and picks up a rock and sticks it in a pocket; you know that's ludicrous.

But there are collecting situations in which people target certain areas, and they'll go in with enough "heavy" equipment—and here I'm talking about hand equipment (sledge hammers and such)—and they can do a fair amount of damage in a short period of time. I'm thinking in particular of a couple of cases that I'm somewhat aware of on some other forests, because I was contacted about them. They were quartz-crystal related, and a lot of impact resulted from people going into a wilderness area and removing that stuff. And that is going to attract someone's attention real quick when those kinds of impacts occur.

So in general, when you're asking a land manager, "Can I go in and collect?" you're going to get the legislative answer, "No you can't." However, if special legislation exists that says you can, then you can, under the criteria that are set forth under that legislation.

Now with respect to the 1872 Mining Law, the wilderness legislation closes all wildernesses to the 1872 Mining Law, and so that doesn't fit. As I said before, you can operate under the 1872 Mining Law if you want to, but only on those lands where the 1872 Mining Law applies. The first step is to find public-domain–status lands, and the second step is to find public-domain–status lands that are open to mineral entry. That's a very specific thing. It will work well for some collectors and collecting organizations.

I mentioned the Butte Gem and Mineral Society's cooperative arrangement with the Dillon Ranger District on the Beaverhead National Forest to create "Crystal Park" for rockhounding. They developed it out of their mining claims. They had located, as a club, something like 15 or 20 mining claims in a granitic intrusion that is easy to dig in by hand. Over the years a lot of people have been digging quartz crystal out of that grus. So they located a block of mining claims to secure that area and were already allowing people in there. Then, with the cooperation of the Forest Service, the clubs relinquished those mining claims and turned the location into a crystal-collecting area that they help the Forest Service manage. The Forest Service, in turn, went through a process to withdraw those lands from mineral entry, but specifically allowed them for rockhounding.

So there are different things you can do, but—as Laurie and I both are encouraging—you have to understand the agencies and how they are structured to know how best to work with them. Don't view them as "adversaries." Go to those land managers and talk to them, and make sure you know with whom you're talking. For example, if you're talking to fisheries or wildlife biologists about rockhounding, there's a good chance they're not going to know what you're talking about, and they may end up giving you incorrect or only partly correct information. You need to talk to those people who can walk you through the process. Whether it's the paleontologist, the geologist, or the mining engineer—at the district level, the Forest Supervisor's level, an adjacent national forest, or at the regional office—there is someone in the organization who can walk you through that process.

John Alf: I don't want to monopolize the discussion with questions, but I have another subject to direct to Laurie. You mentioned the protection of resources and particularly the protection of fossils for future generations. Well, one of the things that I think needs to be considered—and I suppose that because you are a paleontologist, you recognize this—is that, at least for surface exposures, an uncollected fossil is a lost fossil. The natural action of weathering and erosion will destroy this thing. And so, in areas where you can't pick up any fossils, particularly in national parks, or in the case of vertebrate fossils, which can't be collected by amateurs anyway, these exposures are just going to result in the destruction of the fossil. You're not really protecting them for future generations. I just wondered if you have any comments on that.

Laurie Bryant: Well, I'd make a couple of comments. First, BLM policy currently recognizes three categories of fossil resources on BLM land: first, petrified wood, which is available for public collection without permit. You are more than welcome on any public lands, unless otherwise posted, to collect up to 25 pounds of petrified wood per day, plus one piece, although no more than 250 pounds may be collected by each person per year. This material is for noncommercial use only. Second, common invertebrate fossils may be collected for noncommercial use, in reasonable quantities, without a permit. Third, vertebrate fossils can be collected only under a permit issued by the BLM. Bureau policy is that, because all vertebrate fossils are scientifically important and are part of the natural legacy of all Americans, these specimens should never become personal property. They remain Federal Government property and must be permanently housed by a museum or university.

In Wyoming during 1995, over 200 people collected fossils and associated data from the public lands under BLM permits. I think it is fair to admit that fossils will always be lost to erosion, no matter how many people are out there collecting them. We're just trying to administer a system that keeps vertebrate fossils and data together in institutions where the greatest number of people have permanent access to them.

John Alf: I'm glad to hear that you recognize that fossils are degraded by natural forces. My wife and I go to South Dakota frequently and do collecting in the Badlands area. We collect only on private land now that we've found that it's illegal to collect on public land. I've seen skulls and turtles and other fossils that often don't take very long to be totally destroyed. The time frame may be a matter of the type of preservation that occurred. Well, anyway I think that we do have a problem with noncollected vertebrate fossils. I think that collection should be encouraged enough to make sure that they do get collected.

Now, one other thing that you mentioned was the permits that you have in Wyoming. I don't suppose that an ordinary amateur would qualify for a permit if he or she found some bones sticking out somewhere that looked like they might be a significant vertebrate discovery. What would it take for an amateur to get the right to collect this? I personally believe that there are plenty of amateurs around who are just as qualified as a person with a Ph.D. to extract fossils and take them out and do a good job of it. But just the fact that the amateur is not connected with an institution of higher learning or something like that may be a disqualification. I'd be interested in your comment on that.

Laurie Bryant: It's true that permits are granted to individuals who have a scientific background and training, and who are connected to institutions—they don't necessarily have to work for a museum or work for a university, they simply have to have an agreement with a museum that can qualify as a Federal repository. In other words, someplace that's safe, that will be there (we think) for a long period of time, and that can hang on to these specimens that are a part of the national heritage. Those are the people who are likely to get the permits, but there is nothing to prevent them from having amateurs on their collecting crews. Talk to Richard Stucky at Denver Museum of Natural History. Richard takes 25 to 30 amateurs, volunteers, school teachers, and/or kids on every trip he takes.

If one of you amateurs found something on public lands and brought in a photograph and said, "Gee, I'd really like to go with you when you take that out," my first preference would be to take you with us when we go to collect it. I think that's an ideal way to get people connected. The real issue for the Federal Government—this is a policy issue, and not something that I can change—is that these fossils have to remain in the public domain.

John Alf: This brings me to my next thought on vertebrate fossils. In the Eocene beds near Kemmerer, Wyoming, there are billions of fossil fish, and in no way are these billions of fish going to wind up in government repositories or repositories of institutions of higher learning. I think amateurs should be able to go ahead and collect fossil fish for their own use, for their own collections. I certainly disagree with the policy or the rules that relegate all fossil fish to this government ownership.

Laurie Bryant: I can understand your frustration when you do see that there is a very large number of fossils out there. However, again, it's a question of policy. That is the way the laws are written; the rules are written that way. I'm not in a position to change them. I'm in a position to do a little refining and clarification of some of the terms of those rules, but I cannot change them. As John Nichols mentioned earlier, the way to deal with that is to go through your congressional representatives. That is your avenue into the legislative process.

John Alf: That is what we are trying to do with the Fossil Preservation Act of 1995; if we can get it passed, then we'll have some of these problems defined anyway. The solution to the problem will be defined, and maybe we'll be better satisfied amateur collectors.

Ken Johnson: I'd like to open it up now to questions from the floor.

Nathan Meleen (Tulsa, Oklahoma; Professor, Oral Roberts University): My question is directed specifically to the government employees. I sense a lot of frustration that's driving the kind of political climate that we're in right now. It strikes me that government seems to be able to work only by regulation. How much can you people, as government employees, influence the system so that frustrating rules, like billions of fossil fish that can't be collected, can be changed? I'm hearing two messages: we can't do anything except what the law says, but we want to be flexible, and we want to hear from you. You know that these messages are conflicting and confusing. Would one of you address that please?

John Nichols: If you think you're hearing something confusing or conflicting in what Laurie and I are saying, then let's make sure that you understand where we're coming from. We're trying to help you understand how best to work with the system as things stand right now. If the laws change, you know that how to work with the system will change. If you get fossil legislation or rockhounding legislation, then you know that there will be changes. Laurie's coming from a specialized background when she's talking about vertebrate fossils—and I'll let her address that arena herself. I'm primarily coming from a rockhounding, mineral-collecting background. So there really isn't a conflict, if that's what you think you're hearing between the two of us.

What I hope that you are hearing from both of us is "understand how the organizations work, because, whether you like them or not, these are your agencies." I'm trying to help you understand the organization of the Forest Service because I have seen that many people, when they're frustrated as they work with the Forest Service, are simply asking questions of the wrong people.

Forest Service employees are human. I'm a geologist, and yet people expect me to know all about trees because I work for the Forest Service. I deflect those questions to the foresters. I'm a specialist dealing primarily with the mining community, and if you go to any of the other people on the Forest Service staff and ask them about mining, they're likely going to refer you back to me.

Again, what we're trying to help you understand is, first and foremost, you've got access to the land even if it may not be what you want. Like Laurie was pointing out, on some of those isolated BLM tracts, the BLM can't even get to them. So, if you get frustrated, for example, because you can't get out to a BLM tract, because there isn't a road to it or the private landowners won't let you across their land to get to that tract, you're wasting your energy if you direct that frustration at the BLM—they may not even be able to get there either. A lot of the things that frustrate you may frustrate us as well.

The second thing we are trying to explain involves "communications" and understanding with whom to talk. I don't know how many organizations are represented here; you said there are 11 collecting groups or clubs [response from Ken Johnson, "11 rock and mineral clubs in Oklahoma"]. How many of those are represented here I'm not sure, but that's a power base for you. If you stand out there by yourself and try to get things done, it's probably going to be a little more frustrating than if you try to do it in the context of your club or organization. And then, in the same context, you may be empowered by a relationship between your club and other clubs and organizations.

Finally, if you can come to the Forest Service from an "educational or scientific" perspective, there is probably going to be a lot more that can be done to accomplish your objectives. I gave an example in Handout 2 that involved the possibility of a District Ranger temporarily opening a closed Forest Service access road in the interests of collecting for scientific or educational purposes.

The Forest Service routinely closes some access roads to reduce environmental impacts and reduce maintenance costs. John Alf had mentioned "How do we know when access roads are closed?" Everything that the Forest Service does is put out in a public format, usually in the local papers as a "public notice." For example, when an environmental analysis on a proposal is conducted, there is a comment time for the public.

Now, if you're interested in what's going on in a forest, say, in Oregon, chances are you're not going to get information on that down here in Oklahoma. But if you're interested enough in that forest in Oregon, you can contact the appropriate office and ask to be put on the mailing list for environmental analyses. If you have a favorite visiting area, for example, on a forest in Oregon, you could let the District Ranger there know you are interested in anything that might have some kind of impact on that area. That's probably the best way to get notified that a road is going to be closed in a given area. But even "closed roads" are still accessible by the public by foot or, in some cases, by other means such as horseback or four-wheelers, if so designated.

Again, do not approach the agencies with these questions as an adversary. Try to find a way to work with the agencies. There is only so much that we can do. The issues are a lot more complex than a lot of people would like for them to be, particularly where rockhounding is concerned; but we're often willing to take a risk and say, "Look, this seems reasonable to us." There are some people in our agency who question if we have authority to allow that. Personally, others and I believe we do, at least to the degree we are seeing now.

The mining laws give clear direction on mining and commercial activities, but, as I pointed out in Handout 2, there is no comparably clear direction yet for the rockhounds, unless they are willing to come under the mining laws. If you want access, then take the responsibility of identifying how best to work with the people at the national forest where you want to have access. You don't go to your next-door neighbor, and say "Hi! I'm here to go dig up your backyard. See ya," and then start digging up his backyard. You knock on the door first, and say, "Hey, look, this is what I'd like to do. This is the shovel I've got; this is how I want to dig the hole." And you work out an agreement.

This brings up another point: a lot of folks have no concept of what you do when you rockhound. They can't even imagine why a person would want a rock in the first place. They're not dumb; these are smart people. It's just that "rockhounding" is out of their realm altogether. So, you need to understand that when you go in there talking to somebody about rockhounding, it may be a case where you're going to be educating them.

For example, I have had people come and ask about suction dredging on the Ouachita National Forest. Now the Ouachita National Forest is not a historical gold-producing area. I came off of a historical gold-producing forest in Idaho and am well familiar with lode- and placer-gold operations, gold panning, and suction dredging. I first try to help these people understand the process they're going to have to go through, which includes taking the time to help educate the District Ranger and that I'll work with them on that. Our personnel on the Ouachita National Forest simply have had no experience with suction dredging, and still have none, because no one has been serious enough to actually do something. If you simply tell a land manager you want to go "dig" someplace, they don't know if you're talking about "digging" with a garden trowel or with a front-end loader. It's a process of "education" that you need to see as an opportunity, not as a hindrance.

Laurie Bryant: I believe that perhaps part of your frustration is similar to ours. There are three branches of government: the judicial, legislative, and executive. John and I work for the executive branch. The legislative branch writes the laws, and those laws are put in place by the executive branch; but we can't change them! Even the Director of the BLM, the Chief of the Forest Service, cannot change them.

New legislation? Mr. Alf has been talking about some new legislation that's coming out. As I understand it, it deals with fossils. I am not, by law, allowed to speak about it because it doesn't yet exist. It hasn't come on the floor of the Congress. When it does come on the floor, BLM may receive a request from the Legislature to give them information, but that hasn't happened yet. We're under a lot of limitations. It may sound funny, but this is the separation of powers: the Legislature proceeds with its business, the executive branch proceeds with its, and the judicial in the same way.

Douglas Kreis (Ada, Oklahoma; Ada Hard Rock and Fossil Club): First, I have a comment. My comment is that I have a degree in conservation, and I just retired from the government after 31 years of being an ecologist. The word *conservation* means wise use, whereas the word *preservation* just runs chills down my back because it means no use, not now, not ever. And I don't think that our lands are meant to be "not used."

Now I have a question for John Nichols. There's a pending land deal, a land trade, on the west slope of the Ouachitas in Oklahoma for forest lands in Arkansas. The intention, I guess, is to swap for Weyerhaeuser lands. Our club spends a lot of time in southeastern Oklahoma on Weyerhaeuser lands. I personally spend 30 to 40 days a year, maybe 50 days a year, down there digging for crystals. We dig with hand tools. We rarely ever dig more than 2 ft deep, and our trenches are maybe 10 ft long. The seams are small, not like the ones in Arkansas. We like to think that the crystals are far superior, and of far greater variety, in Oklahoma because we find that no two seams have the same type of crystal or the same formations or the same colors. They are all unique. We have gone so far as to have our club get written permission from Weyerhaeuser to go in, and all our members have access to the permission slip. And now we hear about this land trade, and the rumor is that roads will be closed, that digging will not be permitted anymore, and that commercial leases will be granted down there. I've been digging down there for 30 years, as have a lot of other people in the Ada area, and incidentally, I was glad to hear that we could get on a mailing list. We don't get the straight story, because we don't get the Broken Bow or the Idabel newspapers.

Would you comment on whether, if the trade goes through, our recreational uses will be curbed, will there be commercial leases, will there be roads closed, and that sort of thing? There is a wonderful network of roads down there now. Some of them are very rough, and we get stuck occasionally, but we take it upon ourselves to get out when we do. We don't bother anybody else with the collecting, but at least we have road access to the area. Carrying in a shovel, a three-pound sledge hammer with a short handle, a few rock hammers, and collecting bags, and then carrying out 25–30 pounds of crystals for 4 or 5 mi is not as easy as it was when I was younger. I might have done it 30 years ago. Would you please comment on this land deal.

John Nichols: I'd be happy to. As far as the roads are concerned, we get a budget from Congress every year. This is something that occurs every year; there are not unlimited funds for Federal agencies. The Forest Service will get a certain amount of money to administer roads. The staff will be making decisions, no doubt—and I'm not speaking authoritatively here, but just based the way these processes typically work—on what to do with all those roads that Weyerhaeuser has put in over the years and on whether it is necessary to allow road access everywhere.

Congress is working on the legislation, and Laurie addressed the fact that there is not much that we can say as Federal employees with regard to anything that Congress is working on or that is proposed as legislation, because we are out of that procedure altogether. We'll just have to wait until Congress makes a decision, and then we'll address our part of it, based on what the legislation says. But, if the legislation goes through, then you have the opportunity to go to the Forest Service and, presuming that those lands include some of your collecting areas, explain to them why it's beneficial to have those roads you're accustomed to using remain open. Your comments are going to be considered right along with everybody else's comments, but I would encourage anyone, and particularly any interested group, to get involved with that process early on.

You mentioned a couple of things, but first, I'd like to ask you a question. Do you sell any of these crystals when you remove them?

Doug Kreis: No, we don't sell them.

John Nichols: Then, you are collecting for personal uses. I can't tell you right now what the Forest Service might do. We already have a forest policy dealing with collecting, and so any additional lands—we have lots of lands that have come in under land exchange, but this is the biggest one that has ever occurred—will probably come in under those same policies. So, it's important for you to let us know that you are interested in maintaining that kind of activity. I'll tell you right up front, if there's a lot of surface disturbance, we may be looking at some kind of a process to try to control that in some way.

We don't have the same authorities in Oklahoma that we have in Arkansas. Back in 1988, Congress passed a law that essentially made all quartz crystal on the Ouachita National Forest in Arkansas a salable mineral, over which we do have full authority. The Oklahoma side does not come under that law. The way in which minerals are disposed in Oklahoma comes under a leasing act, which means you go through a prospecting permit. It's not a complicated process, but does involve the Bureau of Land Management. I'll be happy to talk to those of you who are interested in this in more detail after the program. There are some Tulsa BLM people here who can talk to you, as well, about how that process works. It's not a complicated process; it's not an expensive process, and so don't be afraid because you might have to come under a leasing system.

Neil Suneson (Norman, Oklahoma; Oklahoma Geological Survey): First of all I'd like to make a comment, and then I'd like to ask a question and either open it up to any of the panelists or anyone in the audience. First of all, I've done some looking into the issue of land access, and I think we have to realize that there are all shades of gray in the situation. For example, on the one hand, there are very strict rules and regulations that the Federal agencies have to follow, and on the other, there are policies. By policies, I mean the general attitude of a particular local manager. Some might feel very predisposed toward rockhounds and allow them on the areas they manage; other land managers may really not like rockhounds, period, and he or she is going to discourage mineral collecting. So you have to realize there are all shades of gray between an official law or regulation that is followed all the way through a general policy.

The same shades of gray occur when we talk about amateur collecting vs. commercial collecting. And I think John just alluded to it. We have the amateurs, for example, the Boy Scouts or the Girl Scouts, who collect for their own private collection. Then we step up a little bit, and we have the amateurs who collect their own minerals and trade them. Then we step up a little bit, and we have the amateur collector who sells the minerals, albeit at informal swap meets. Is that a commercial collector? He or she *is* selling the minerals, albeit at an informal rock and mineral swap meet. We can go one step further, and go to Tucson. Here, the amateur might offer some real nice specimens that are commanding premium prices. Then we have the "collector/amateur," who owns a rock shop, who maybe doesn't make a whole lot of money in the rock shop, but still considers it his or her source of livelihood. Then we have the commercial operator who digs crystals or fossils with bulldozers and backhoes. There are all shades of gray here that I think we have to recognize. Where does the definition of *amateur* stop and that of *commercial collector* begin? Perhaps we can legislate that definition, but we must recognize that there are all shades of gray.

Now the question I'd like to ask. First, a personal aside. I was in Washington a year or two ago. I was interested in collecting some petrified wood at Saddle Mountain. I think Saddle Mountain is largely owned or managed by the BLM. I was also aware there was a rockhound club in the area that owned their own collecting site. That's where the locked gate was. I had no access to their collecting site. It was about two miles up Saddle Mountain on a very bad road. On BLM land, however, there was a paved road all the way up to the top of the mountain. I drove along about a mile and found an area where there were lots of holes in the ground and lots of very nice specimens to collect. So I would say that the Federal and State Governments are not the only ones to maintain locked gates.

My favorite conservation organization in this country is the Nature Conservancy. The reason I like them is that if they want a chunk of land, they go and buy it. They don't legislate. They don't have a bunch of lawyers that try to legislate and sue. The Nature Conservancy goes and buys their land. If the rock clubs have a favorite collecting area that is on private land, I would encourage them to buy it. If it's on public land, work with the Forest Service or BLM to trade that area for some other area of land. If it's a road you'd like kept open, say, "Would you mind if we kept it open? Would you mind if we donated or somehow gave you a certain amount of money in order to keep this favorite road of ours open?"

I know there's been a lot of screaming at the Federal Government, "You spend too much of my money. We want our taxes lowered." When the Federal Government closes your favorite road, you might want to look back at yourself. They cannot keep every road in the national forest open for every organization that wants to get in there. So I'd like to ask those of you in the rock and mineral clubs, have you ever considered buying a piece of land to keep it open for fossil collecting? Have you ever locked a gate behind you to keep others out of your favorite collecting area?

Gene Potts (Stillwater, Oklahoma; Oklahoma State Council of Mineralogical Societies and Stillwater Gem and Mineral Society): As for Neil's question and comments about the government not having enough money; the government isn't the only one. We don't have enough money to go buy a collecting site. Now, if we could convince the Nature Conservancy to buy it and give it to us, that would be wonderful! But I don't think we are quite that articulate.

I originally stood up here to make a comment and then to ask a question of John Alf. John referred to the word *preservation* earlier, which brings to mind the government's use of the word *defense*. Well, if you will read about the government and its defense, that's the end of the sentence. But to me the word *defense* needs something else. It needs the word *from*. Defending from what? And the word *preservation* begs the question, *preserving for what?* Who are we preserving these fossils for? If not for our use, then are we waiting for some aliens to come along and to enjoy them?

My question for John is, "Do you people know anything about the policy of the Corps of Engineers and their restricting of collecting on the property that they deem to own?" I would like to hear some comments about that. I've heard from two very close friends, recently, about being apprehended while collecting a pocket full of fossils; they didn't even have a bucket with them, but they were threatened with incarceration if they stooped over one more time. Do you have any comments on it?

John Alf: I can address that question directly because I've just been involved in the last month with the Corps of Engineers, as that organization relates to Kaw Lake. And maybe this is what Gene is referring to. The Corps of Engineers has regulations that specifically prohibit the collection of anything or the removal of anything from any land encompassed within any given project. Apparently they have a special rule that applies to fish. At least I haven't read that fish can't be collected. But I do know that this rule exists in the regulations under which the Corps of Engineers is operating. You can't remove anything; you can't pick up a pebble or a wildflower or anything like that. It's prohibited, without the written permission of the District Engineer. Now the District Engineer, according to the regulations, can give you permission to collect.

We had a situation over near Ponca City where people were picking up fossils just down below the dam at Kaw Lake; one of the individuals was accosted by a ranger, and it was not a very pleasant encounter. So they asked me to get involved, which I did. I talked to the District Engineer's office in Tulsa. The first individual I talked to was the Assistant District Engineer. He said he didn't know anything about this, but that he'd have somebody call who does know. Within 20 minutes I had a call from another individual in the Corps of Engineers, and I outlined the problem. He volunteered the fact that "the District Engineer himself is not going to give you written permission. This authority has been delegated to the Project Manager. And so it's up to the local Project Manager to do this. And, as far as I'm concerned, I don't see any reason why you shouldn't be able to pick up those fossils, as long as you're not going to sell them, or as long as you're not going to go down in there with a pickup truck and take out vast quantities of this stuff; it's okay. And I will call that Project Manager and direct her to let you come in. All that you need to do, as an amateur collector, is to go down there, let her know that you're going down there, that you're an amateur, and that you want to pick up a few of these fossils; and it will be all right." We tested this out two or three weeks ago, and it worked. We had no problem. I think the answer to your question, Gene, is that there is a very specific written regulation against collecting, but there's a very specific manner in which that regulation can be used for the benefit of the fossil collector.

Gene Potts: Would this apply to Lake Texhoma and collecting ammonites?

John Alf: The regulation obviously still says the same thing and applies to Texhoma as well. You couldn't pick up an ammonite and take it off the project land without the written permission of someone, and that authority probably was delegated to the Project Manager. So you would need to contact the Project Manager, if you want to pick up ammonites without getting into trouble.

Doug Kreis: May I speak to that? Four weeks ago, I went down to the dam at Lake Texhoma, to the Corps of Engineers office, to get a permit to collect fossils. I was told that I had to have a permit, that I had to submit the request in writing, that I had to be a member of a club, that I had to provide the fossils to a museum, and that my permit request would have to be reviewed by both the Archaeological Society of Texas and the State Archaeologist in Oklahoma. I said, "Why do you need an archaeological review? These are fossils!" And they said to me, "Because we can't tell an Indian artifact from a fossil." So that's the policy on Lake Texhoma. I haven't written for the permit yet, but I intend to.

John Alf: Doug, let me make this suggestion. Why don't you call the District Engineer in Tulsa and lay out your problem. And I think you'll get some cooperation.

Tom Creider: The Corps' park at Texhoma may be under another district office, rather than Tulsa, so Tulsa may not have the authority. But they can get you the right number, I'm sure.

Richard Killblane (Ponca City, Oklahoma; Kay County Paleontological Society): I'd first like to thank John Alf for getting us permission to dig fossils at Kaw Dam. I think one of our focuses should be on making it the purpose of government policy to encourage research in paleontology, and not to prohibit or restrict the collection and research of fossils. Now having worked for the government I also know, and especially since I've been dealing with the Corps of Engineers, that in obtaining permits, a lot is left to interpretation. I know the BLM representative has already answered this question. I would like to ask the state parks representative about how he interprets "science and educational purposes" for those of us who are trying to get permits.

Tom Creider: In responding to a request for collection of specimens, from the state parks' point of view, there needs to be public benefit. So when we say the collection is for scientific or educational purposes, scientific purposes are met when a university is conducting research. They approach our agency for collection permission, again assuming that we have total authority, that the site is not on Corps of Engineer land, for example. We have a permit process. They articulate the purpose of their study, how many specimens they're going to need, those kinds of parameters. We determine at the front end that the collecting is for a public purpose. For an educational purpose, it would be similar to what the Federal agencies are saying: the collection is going to be displayed in a location where the public can benefit from its display and learn something from it.

Richard Killblane: I'd like to address that issue again. A lot of funding for universities is now being cut, and so there's not going to be much for grants in doing paleontological research. And I know Oklahoma State University has just one professor in this research area. We're really restricted as far as the number of professors who can get out and do the research. There are so many sites available; and there are so few people to actually do the work. I know most of you know that the vast majority of the significant finds have been made by amateurs. Now, the government is basically restricting amateurs from doing the collection by saying "universities."

Tom Creider: Okay. I think you have a valid point. I think, at least to my knowledge, the folks who have approached us for educational collecting have been at least aligned with some institution, whether it's a university or high school. If an amateur comes to us with a permit request and says, "I'm collecting for an association, and we plan to use this for public benefit," I think we'll probably ask some questions, but I don't see us saying that the collector has to have a Ph.D. in order for the results to be of educational benefit. And again, I would say that our regulations are such that we're operating from a perception, maybe an incorrect one at this point, that the specimens in these parks are somewhat rare.

As far as the state parks in Oklahoma are concerned, we're not talking about the vast land resources that some of these Federal agencies are talking about, and so I think from that standpoint we're probably taking a more preservationist role. And again, the preservationist mentality is one based on being stakeholders of the present and future generations. And I don't disagree with a conservation mentality for a lot of other ways of managing public lands. In the case of state parks in this State, as relates to these kinds of resources, that's probably our basic premise at this point.

Ken Johnson: I just want to make a comment here. We have hoped, in setting up this program, to enhance the interaction between the various agencies and the rockhound clubs in the State, and I think this is a perfect example of an opportunity for the rockhound clubs in the vicinity of certain state parks of Oklahoma to explore the possibility of developing educational materials that might possibility of developing educational materials that might be utilized on the park site itself. I suspect that Tom would welcome the opportunity to work with clubs and that the local park ranger would do that as well. So again, it's a question of how would these materials ultimately be used. If the state parks' policy is to require that the collection must go into educational rather than private individual use, there's an opportunity for the clubs to work with a local state park, to lend expertise in minerals, fossils, and geology, and to help develop display materials that can be used on the park grounds. These displays then can be taken out into the schools in the local area to show students the benefits of rockhounding and the collecting materials that are around them.

Carol Holman (Stillwater, Oklahoma; Stillwater Mineral and Gem Society): My question is the same one, or similar. Is it not the same thing that the rockhound is doing when we display at our shows? Are we not doing it for educational purposes? Wouldn't that be considered educational?

Tom Creider: Obviously your show is open to the public. I guess my question would be one of how is the public being exposed to the information. If part of the program is encourages schools to attend, for example, I would say that would be educational. If it's basically a show that's mostly advertised within the ranks of your avocation and other clubs like yours—and I'm not saying that's not educational—but it is less educational because the public that is being serviced is probably a fairly narrow group. I'd just say that what we're trying get to is that more of the general public comes away with a greater understanding of the wealth of geologic resources, in this case in Oklahoma.

Carol Holman: We advertise in the papers that we are having shows and that we are presenting information for teachers. We also demonstrate to the schools. Our Stillwater Club, at least, goes to all of the surrounding area schools to give school talks. So, if we're not able to collect these items, then we are unable to carry out this educational program.

Tom Creider: Well, what I would want to know about the public purpose of a request that came to me for review is, Are the items going to be designated as assets that will be made available to teachers? Will the availability be made known to those teachers doing a unit on some aspect of geology? Will they have some way of knowing who in your club to call and that those resources or specimens would be made available to be part of their lesson plan? That's the sort of thing I would be looking for. And then if you act as the individual who provides a repository for the display, I wouldn't have any problem with that.

Carol Holman: As an example, right now I'm putting together a display of Oklahoma rocks, minerals, and fossils. I've got five boards; I'm getting ready to take them to Tryon Elementary School, where my kids go, and to help them see what Oklahoma has.

Tom Creider: I think that's fine. I mean as far as my agency is concerned, I think that's fine. That's an educational purpose.

Ken Johnson: I think this is a very fruitful area to explore. The clubs can either do it through the State federation or individually contact Tom's office and see what can be done to establish some kind of a good working relationship that can reach out to the individual state parks where collecting can be done, where display can be done, where the schools are, where the clubs are, and things like that. So I think there is an excellent opportunity to expand greatly on this discussion.

Ruby Lingelbach (Stillwater, Oklahoma; Stillwater Mineral and Gem Society): We rockhounds do travel all over, and this 25-pound-per-day limit for your own personal use bothers me a little bit. Every time I go on a trip to a show, and there are a lot of people from different clubs, you can always hear, "Remember the kids and the grab bags." We're not collecting our 25 pounds for our own personal use. We're collecting it for the kids. And we have sold a lot of grab bags—it's one of our money-making schemes. But these grab bags contain material that are the basis for a lot of other collections.

One time I gave a quartz crystal to the grab bags—we were getting short on quartz crystals—and I asked myself, "Well, I have a few in my personal collection—do I really want to give that?" But I went ahead and put it in. Well, I was granted the privilege of seeing the young man who got that crystal. He was holding it in his hand, grinning from ear to ear, showing his teacher what he got. And that crystal is going to be a very precious possession. Now, whether that was part of my 25 pounds, I don't know. But what about the 25 pounds for personal use? Is putting them up for the grab bags, for the rock piles, or whatever, is that against the law?

Laurie Bryant: If we're talking about common invertebrates, and we're talking about reasonable quantities, that is all designated for your personal use. I'm not a lawyer, and I can't speak for the solicitor's office, but it would be my understanding that the occasional gift of specimen to a child, or to a classroom, constitutes your personal use. When we're talking about petrified wood, that's where you hit the 25-pound limit. It only applies to petrified wood. It doesn't apply to crystals—I'm now looking over to the minerals chief here from the local [Tulsa] office to make sure this is true. I haven't said anything about BLM in terms of rock and mineral collecting for one good reason, and that is because I am not a specialist in that area. I don't work in the minerals program. Gary Stuckey is over here sitting in the front row; he does work in that program, and he does know the ins and outs of it. I encourage you to direct questions about rock and mineral collecting to Gary, now or later on.

Another thing that I was going to pick up on just briefly was a comment about some local managers choosing to crack down harder on rockhounds, and other managers telling rockhounds to do whatever they want. It's been my experience that, at least in the BLM, individual calls on variation in the treatment of regulations are strongly discouraged. Individual managers are not free to make up limits on regulations. If the regulations say that it's "25 pounds of petrified wood per person per day," then it's 25 pounds. The manager does not have discretion about that. He doesn't even have discretion about whether rockhounds can go and pick up semiprecious or common varieties of minerals. And I don't know that there is any limit on those. If there is no limit, local managers cannot set a limit on those. The only way those can be limited, as I understand it, is to post an area, to publish notices about it, and request public comment. Local managers just don't have that kind of discretion.

John Nichols: May I follow up on that quickly? I want to make sure that Laurie stressed that the 25-pound limit is for *petrified wood,* and that's under the BLM regulations on BLM lands. When you're talking about the Forest Service, we don't have that restriction. You are talking about different rules and regulations. Our respective agencies and our responsibilities are similar; we both represent "multiple-resource-management agencies," and you'll find a lot of similarities between the two, but we do come under different rules and regulations, and different laws and authorities. In fact, we're even in different departments. As she pointed out initially, she's in the Department of Interior, and the Forest Service is under the Department of Agriculture. We are sister Federal agencies, in that we do a lot of cooperative things because of similar responsibilities; particularly on Forest Service lands where the BLM does have some mineral responsibilities, we work hand-in-hand together.

Also, I want to touch on one of the things that Laurie may have left unsaid. One of the control mechanisms here, if I understand correctly what you were alluding to in regard to collecting gem stones, may not be the quantity "limit," but the "limit" that exists through the surface management of the impact. [To Laurie:] Is that not correct? [Laurie concurred.] The Forest Service certainly sets limits on surface impact. I know that the BLM does as well. So that doesn't mean that you can go on BLM lands with, say, 20 people with shovels and start digging to beat the band and say "anything we find we can keep." It may be true that anything you find you can keep, but you've still got to work with that fellow over there [indicating the BLM employee] or his counterpart on western BLM lands for surface management. And I only bring that out on behalf of the BLM, because it's the same for the Forest Service too.

We still have those responsibilities to evaluate the impact and to make sure that those lands are reclaimed. Generally speaking, the real rockhound doesn't make that much impact. But I have seen a lot of impact from people who would *call* themselves rockhounds that I think most of you would be ashamed of. So, as Neil pointed out early on, there's a wide range of definitions that need to be considered.

George Salwaechter (Enid, Oklahoma; Enid Gem and Mineral Society): My question is about dinosaur bone that is already in collections and the sale and trading of that dinosaur bone. People are concerned about regulations that apply to them at the present time.

Laurie Bryant: I know that people are very concerned. People are concerned that Federal agents are going to show up at their door, take everything in their collection, and find some way to put them in jail. I don't think that's going to happen. There are lot of people who have collections of dinosaur bone. In general, once fossils are out of the ground, it is very difficult to figure out where they actually came from.

If you have a bunch of material that you collected from a mixture of private and public lands over the last however-many years, it may be difficult for you to remember where it came from. I can assure you that if a Federal agent goes looking for a good case where someone is knowingly and willfully—and those are the two requirements, knowingly and willfully—removing government property, which is in this case dinosaur bones, they won't come looking for you. They'll come looking for a situation in which they have some actual evidence—so that they have a good case with which to go to court. They're not looking for rockhounds, for mom-and-pop folks who are out recreating, who are picking up odd bits here and there, who aren't carrying a map, who in fact don't know that there's such a thing as a land-surface-status map. I wouldn't worry about it. It wouldn't cause me any loss of sleep whatsoever.

On the other hand, I would keep in mind that it's not legal to collect vertebrate fossils on public lands, and I would have one of these (a Surface Management Status Map) in my possession so that I knew where I was. I brought some things that BLM prints and publishes for public use along with me. These are called "Land-Status Maps" or "Surface-Management" sheets, and they show, through a series of colors, the ownership or the management agency that has jurisdiction over the land. These are great things. They show you vast areas of public lands where you are free to go out and rockhound to your heart's content. They show you where the private lands are, where you must ask the landowner. Where the State lands are. Where the Forest is. Where the access roads are. Where legal access exists. Roads where you have legal access across private land, and onto public land, are shown on these maps. These are great tools. They are available for every BLM state, and you can get them from any of our offices. You don't even have to go there. You can call, charge them on your credit card, and they'll be sent to you.

All kinds of great stuff are available from the BLM. If you get tired of rockhounding, you can drive the Back Country Byways. You can discover Adobe Town, Wyoming. You can go camping. You can do wild and scenic rivers and streams, wilderness areas, and fishing areas. We have these maps; there are about 15 of them that cover Wyoming in great detail. They show you where you can fish, what you can catch, how you can get there. Mining claims on public lands. All kinds of brochures and information are out there available for you. We are delighted to have you come and get it. In the same way that John Nichols mentioned, every BLM office has a public room, a reception area, and a kiosk where hundreds and hundreds of these pamphlets and booklets are available for you; and they are all free. Only the maps cost money, and they are $4.00 each.

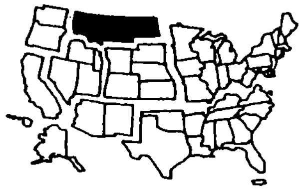
John Nichols: The Forest Service also has similar types of resources and maps. You can get forest maps, on the same scale, one-half inch to a mile. In fact, I've brought along a listing of all the national forests across the country, with their addresses and telephone numbers [Handout 5]. So if you're on Federal lands, between the Forest Service and the BLM—if you total that up, 191 million acres of Forest Service, 270 million acres of BLM—you've got almost a half of billion acres of Federal land out there. And there are maps covering them that are good resources for you.

Dixie Lee Alf (Bartlesville, Oklahoma; Tulsa Rock and Mineral Society): This is to you, Laurie Bryant. You were mentioning the Federal depositories for all vertebrate fossils or scientific specimens. There are only so many museums in the country, and already some of them have a backlog of fossils that have not been studied or even unwrapped. And I just wonder what will be done once all these places get filled up? Will the government build more depositories for them, or what?

Laurie Bryant: In fact, new museums and larger museums are being built all the time. There is a Federal repository being built in Billings, Montana, to handle Federal specimens. The paleontology museum for the University of California at Berkeley recently moved into a new building and refurbished space; they greatly increased their space. They have spent the past ten years going through their unprepared and undocumented materials and getting those all documented. It's probably true that there's not a great deal of money available for museums, but no worse than the limitation on money in government in general, no worse than the limitation on welfare funds. There's just a general lack of available money to do a great many things. But I don't think it harms the science of paleontology any more than it harms any other areas of our lives. Paleontologists are very persistent, and they will persevere in getting specimens documented, displayed, studied, published, whatever it takes. I know a lot of people who work weekends and nights and on their own time and use their own materials because they just want to get it done.

John Alf: Sometime ago John Nichols used the term "power base" in terms of the rockhounds working together to get things done. I'm a director of the organization called "American Lands Access Association." This association is working in your interests. We are a lobbying organization and you don't lobby without money. We need money, we need donations, we need members. So I'd like to encourage everybody here, if you are not already a member, become a member.

Ken Johnson: I want to thank the panelists for extremely interesting information. I think we are a lot closer in our positions than we thought at the beginning. I think time alone will tell how much interaction, cooperation, and development of working relationships will come from this. I'm very optimistic about it. I hope you all are too. I appreciate the four of you for your time, your efforts, and your energy in bringing this to us.



Northern Region
Federal Building
200 East Broadway Street
P.O. Box 7669
Missoula, MT 59807
406-329-3511

Follow the route of the Lewis and Clark Expedition through the Bitterroot Mountains, catch your limit of trout at a pristine alpine lake, or camp under the stars and listen to the howl of the wolf. Whether you're looking for the rigors of a wilderness trek or an easy drive along a scenic byway, you'll find it here in the National Forests of the Northern Region.

IDAHO

Clearwater National Forest
12730 Highway 12
Orofino, ID 83544
208-476-4541

Idaho Panhandle National Forests: Coeur d'Alene, Kaniksu, and St. Joe National Forests
1201 Ironwood Drive
Coeur d'Alene, ID 83814
208-765-7223

Nez Perce National Forest
East U.S. Highway 13
Route 2, P.O. Box 475
Grangeville, ID 83530
208-983-1950

MONTANA

Beaverhead National Forest
420 Barrett Street
Dillon, MT 59725
406-683-3900

Bitterroot National Forest
1801 N. First Street
Hamilton, MT 59840
406-363-3131

Custer National Forest
2602 First Avenue North
P.O. Box 2556
Billings, MT 59840
406-657-6361

Deerlodge National Forest
Federal Building
Corner of Cooper and Main Streets
P.O. Box 400
Butte, MT 59703
406-496-3400

Flathead National Forest
1935 Third Avenue East
Kalispell, MT 59901
406-755-5401

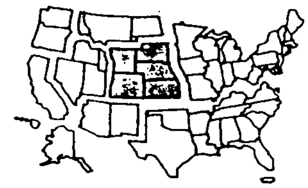
Gallatin National Forest
Federal Building
10 East Babcock Street
P.O. Box 130
Bozeman, MT 59771
406-587-6701

Helena National Forest
Federal Building
301 South Park, Room 334
Drawer 10014
Helena, MT 59626
406-449-5201

Kootenai National Forest
506 U.S. Highway 2 West
Libby, MT 59923
406-293-6211

Lewis & Clark National Forest
1101 15th Street North
P.O. Box 871
Great Falls, MT 59403
406-791-7700

Lolo National Forest
Building 24
Fort Missoula
Missoula, MT 59801
406-329-3750



Rocky Mountain Region
11177 West Eighth Avenue
P.O. Box 25127
Lakewood, CO 80225
303-236-9431

Enjoy the quiet beauty of a mountain meadow, or hike through aspen groves and rugged mountains on well-maintained trails. Challenge yourself on some of the world's finest ski slopes, or relax by a fireplace in a friendly mountain resort. You'll find yourself wanting to return often once you discover the refreshing change of pace awaiting you in the Rocky Mountain Region.

COLORADO

Arapaho and Roosevelt National Forests
240 West Prospect Road
Fort Collins, CO 80526
303-498-1100

Grand Mesa, Uncompahgre, and Gunnison National Forests
2250 U.S. Highway 50
Delta, CO 81416
303-874-7691

Pike and San Isabel National Forests
1920 Valley Drive
Pueblo, CO 81008
719-545-8737

Rio Grande National Forest
1803 West U.S. Highway 160
Monte Vista, CO 81144
719-852-5941

Routt National Forest
29587 West U.S. Highway 40
Suite 20
Steamboat Springs, CO 80487
303-879-1722

San Juan National Forest
701 Camino Del Rio, Room 301
Durango, CO 81301
303-247-4874

White River National Forest
Old Federal Building
Ninth Street and Grand Avenue
P.O. Box 948
Glenwood Springs, CO 81602
303-945-2521

NEBRASKA

Nebraska National Forest
270 Pine Street
Chadron, NE 69337
308-432-0300

SOUTH DAKOTA

Black Hills National Forest
Highway 385 North
Route 2, Box 200
Custer, SD 57730
605-673-2251

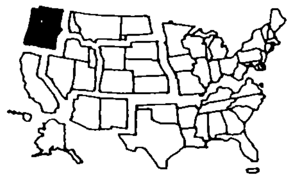
WYOMING

Bighorn National Forest
1969 South Sheridan Avenue
Sheridan, WY 82801
307-672-0751

Medicine Bow National Forest
2468 Jackson Street
Laramie, WY 82070
307-745-8971

Shoshone National Forest
225 West Yellowstone Avenue
P.O. Box 2140
Cody, WY 82414
307-527-6241

Pacific Northwest Region
319 SW Pine Street
P.O. Box 3623
Portland, OR 97208
503-221-2877



Float the Snake River through the deepest gorge in North America, or enjoy a scenic drive around snow-capped Mount Hood. Explore a rain forest of spruce and fir growing beside glacier-fed rivers, or enjoy a forest interpreter's program at Mount St. Helens National Volcanic Monument. From high alpine meadows and craggy peaks to surf-splashed coastlines, the National Forests of the Pacific Northwest Region offer unlimited opportunities for outdoor recreation.

OREGON

Columbia River Gorge National Scenic Area
902 Wasco Avenue
Hood River, OR 97031
503-386-2333

Deschutes National Forest
1645 U.S. Highway 20 East
Bend, OR 97701
503-388-2715

Fremont National Forest
524 North G Street
Lakeview, OR 97630
503-947-2151

Malheur National Forest
139 NE Dayton Street
John Day, OR 97845
503-575-1731

Mount Hood National Forest
2955 NW Division Street
Gresham, OR 97030
503-666-0700

Ochoco National Forest
3000 E. Third
P.O. Box 490
Prineville, OR 97754
503-447-6247

Rogue River National Forest
Federal Building
333 West Eighth Street
P.O. Box 520
Medford, OR 97501
503-776-3600

Siskiyou National Forest
200 NE Greenfield Road
P.O. Box 440
Grants Pass, OR 97526
503-479-5301

Siuslaw National Forest
4077 Research Way
Corvallis, OR 97339
503-750-7000

Umatilla National Forest
2517 SW Hailey Avenue
Pendleton, OR 97801
503-276-3811

Umpqua National Forest
2900 NW Stewart Parkway
P.O. Box 1008
Roseburg, OR 97470
503-672-6601

Wallowa-Whitman National Forest
1550 Dewey Avenue
P.O. Box 907
Baker City, OR 97814
503-523-6391

Willamette National Forest
211 East Seventh Avenue
P.O. Box 10607
Eugene, OR 97440
503-465-6521

Winema National Forest
2819 Dahlia Street
Klamath Falls, OR 97601
503-883-6714

WASHINGTON

Colville National Forest
695 South Main Street
Colville, WA 99114
509-684-3711

Gifford Pinchot National Forest
6926 East Fourth Plain Boulevard
P.O. Box 8944
Vancouver, WA 98668
206-696-7500

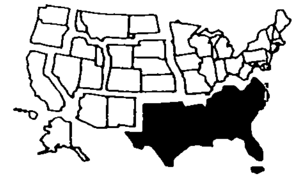
Mt. Baker-Snoqualmie National Forests
21905 64th Avenue W.
Mountlake Terrace, WA 98043
206-775-9702

Okanogan National Forest
1240 South Second Avenue
P.O. Box 950
Okanogan, WA 98840
509-826-3275

Olympic National Forest
1835 Black Lake Blvd. S.W.
Olympia, WA 98502-5423
206-956-2300

Wenatchee National Forest
301 Yakima Street
Wenatchee, WA 98801
509-662-4335

Southern Region
1720 Peachtree Road NW
Atlanta, GA 30367
404-347-4191



Enjoy a refreshing swim in a cool stream, join a tour of the magical Blanchard Springs Caverns, or hike along the famous Appalachian Trail. Explore the exotic beauty of a tropical rain forest, or picnic along the breathtaking Talimena Scenic Drive. The scenery varies as much as the recreation—from cypress swamps and mountain meadows to pine and hardwood forests. Plan an adventure to your National Forests of the Southern Region.

ALABAMA

National Forests in Alabama: William B. Bankhead, Conecuh, Talladega, and Tuskegee National Forests
1765 Highland Avenue
Montgomery, AL 36107
205-832-4470

ARKANSAS

Ouachita National Forest
Federal Building
100 Reserve Street
P.O. Box 1270
Hot Springs, AR 71902
501-321-5202

Ozark-St. Francis National Forest
605 West Main Street
P.O. Box 1008
Russellville, AR 72801
501-968-2354

FLORIDA

National Forests in Florida: Apalachicola, Ocala, and Osceola National Forests
USDA Forest Service
227 North Bronough Street, Suite 4061
Tallahassee, FL 32301
904-681-7265

GEORGIA

Chattahoochee-Oconee National Forests
508 Oak Street NW
Gainesville, GA 30501
404-536-0541

KENTUCKY

Daniel Boone National Forest
100 Vaught Road
Winchester, KY 40391
606-745-3100

LOUISIANA

Kisatchie National Forest
2500 Shreveport Highway
P.O. Box 5500
Pineville, LA 71360
318-473-7160

MISSISSIPPI

National Forests in Mississippi: Bienville, Delta, DeSoto, Holly Springs, Homochitto, and Tombigbee National Forests
100 West Capitol Street, Suite 1141
Jackson, MS 39269
601-965-4391

NORTH CAROLINA

National Forests in North Carolina: Croatan, Nantahala, Pisgah, and Uwharrie National Forests
100 Otis Street
P.O. Box 2750
Asheville, NC 28802
704-257-4200

PUERTO RICO and the VIRGIN ISLANDS

Caribbean National Forest
University of Puerto Rico
Agricultural Experiment Station
Call Box 25000
Rio Piedras, PR 00928-2500
809-766-5335

SOUTH CAROLINA

Francis Marion-Sumter National Forests
1835 Assembly Street, Room 333
Columbia, SC 29201
803-765-5222

TENNESSEE

Cherokee National Forest
2800 North Ocoee Street NW
P.O. Box 2010
Cleveland, TN 37320
615-476-9700

TEXAS

National Forests in Texas: Angelina, Davy Crockett, Sabine, and Sam Houston National Forests
Homer Garrison Federal Building
701 North First Street
Lufkin, TX 75901
409-639-8501

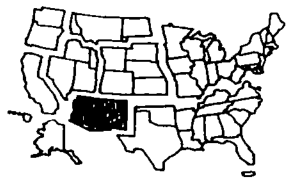
VIRGINIA

George Washington National Forest
101 North Main Street
P.O. Box 233
Harrison Plaza
Harrisonburg, VA 22801
703-433-2491

Jefferson National Forest
210 Franklin Road SW
Caller Service 2900
Roanoke, VA 24001
703-982-6270

Handout 5 (continued)

Southwestern Region
Federal Building
517 Gold Avenue SW
Albuquerque, NM 87102
505-842-3292



If exploring a labyrinth of canyons and mesas, floating in an inner tube down the Salt River past sandstone cliffs, or visiting the fascinating Ghost Ranch Living Museum with its live animal displays sounds like a fun way to relax, then the National Forests of the Southwestern Region are just what you're looking for. Whether you decide to visit the magnificent mountains or colorful desert—or both—you'll find it easy to travel by foot, horseback, or road.

ARIZONA

Apache-Sitgreaves National Forest
Federal Building
309 South Mountain Avenue
P.O. Box 640
Springerville, AZ 85938
602-333-4301

Coconino National Forest
2323 East Greenlaw Lane
Flagstaff, AZ 86004
602-556-7400

Coronado National Forest
300 West Congress Street
Sixth Floor
Tucson, AZ 85701
602-670-6483

Kaibab National Forest
800 South Sixth Street
Williams, AZ 86046
602-635-2681

Prescott National Forest
344 South Cortez
Prescott, AZ 86303
602-445-1762

Tonto National Forest
2324 East McDowell Road
P.O. Box 5348
Phoenix, AZ 85010
602-225-5200

NEW MEXICO

Carson National Forest
Forest Service Building
208 Cruz Alta Road
P.O. Box 558
Taos, NM 87571
505-758-6200

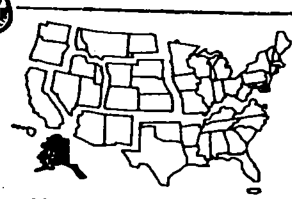
Cibola National Forest
2113 Osuna Road, N.E., Suite A
Albuquerque, NM 87713
505-761-4650

Gila National Forest
2610 North Silver Street
Silver City, NM 88061
505-388-8201

Lincoln National Forest
Federal Building
11th Street and New York Avenue
Alamogordo, NM 88310
505-437-6030

Santa Fe National Forest
Pinon Building
1220 St. Francis Drive
P.O. Box 1689
Santa Fe, NM 87504
505-988-6940

Alaska Region
Federal Office Building
709 West Ninth Street
P.O. Box 21628
Juneau, AK 99802
907-586-8863



North to Alaska! Evergreen forests blanket rugged snow-capped mountains, rushing streams team with salmon, and icebergs the size of office buildings calve from glaciers into the sea. Camp along historic gold rush trails, watch eagles soar above forests from the comfort of a passenger ship, or kayak the shoreline of a quiet fiord. Your National Forests in Alaska are a special reason to visit America's "Last Frontier."

ALASKA

Chugach National Forest
201 East Ninth Avenue, Suite 206
Anchorage, AK 99501
907-271-2500

Tongass National Forest: Chatham Area
204 Siginaka Way
Sitka, AK 99835
907-747-6671

Ketchikan Area
Federal Building
648 Mission
Ketchikan, AK 99833
907-225-3101

Stikine Area
201 12th Street
P.O. Box 309
Petersburg, AK 99833
907-772-3841

Intermountain Region
Federal Building
324 25th Street
Ogden, UT 84401
801-625-5354

Colorful wildflowers carpet alpine meadows during summer, while winter brings powder snow, sought by skiers from around the world. Here you'll find a land of contrasts—from deep red canyons to tall mountains wrapped with pine and fir. Opportunities for sightseeing, camping, and whitewater rafting abound. A visit of a lifetime awaits you in the National Forests of the Intermountain Region.

IDAHO

Boise National Forest
1750 Front Street
Boise, ID 83702
208-364-4100

Caribou National Forest
Federal Building, Suite 294
250 South Fourth Avenue
Pocatello, ID 83201
208-236-7500

Challis National Forest
U.S. Highway 93 North
H/C 63 Box 1671
Challis, ID 83226
208-879-2285

Payette National Forest
106 West Park Street
P.O. Box 1026
McCall, ID 83638
208-634-8151

Salmon National Forest
U.S. Highway 93 North
P.O. Box 729
Salmon, ID 83467
208-756-2215

Sawtooth National Forest
2647 Kimberly Road East
Twin Falls, ID 83301
208-737-3200

Targhee National Forest
420 North Bridge Street
P.O. Box 208
St. Anthony, ID 83445
208-624-3151

NEVADA

Humboldt National Forest
976 Mountain City Highway
Elko, NV 89801
702-738-5171

Toiyabe National Forest
1200 Franklin Way
Sparks, NV 89431
702-355-5301

UTAH

Ashley National Forest
355 North Vernal Avenue
Vernal, UT 84078
801-789-1181

Dixie National Forest
82 North 100 East
P.O. Box 580
Cedar City, UT 84720
801-586-2421

Fishlake National Forest
115 East 900 North
Richfield, UT 84701
801-896-4491

Manti-LaSal National Forest
599 West Price River Drive
Price, UT 84501
801-637-2817

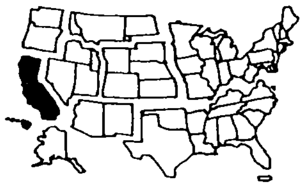
Uinta National Forest
88 West 100 North
Provo, UT 84601
801-377-5780

Wasatch-Cache National Forest
8236 Federal Building
125 South State Street
Salt Lake City, UT 84138
801-524-5030

WYOMING

Bridger-Teton National Forest
Forest Service Building
340 North Cache
P.O. Box 1888
Jackson, WY 83001
307-733-2752

Pacific Southwest Region
630 Sansome Street
San Francisco, CA 94111
415-705-2874



Here is a place where you can use words like "tallest" and "oldest" without exaggerating. For a start, see the coastal redwood (the tallest) or the bristlecone pine (the oldest) trees on earth. Enjoy a picnic by a cool rushing stream, or discover mountain meadows filled with delicate spring wildflowers. Camp among the pine-encircled granite peaks of the Sierra Nevada Mountains, or climb a sleeping volcano—Mount Shasta. You'll find recreation opportunities for everyone in the National Forests of the Pacific Southwest Region.

CALIFORNIA

Angeles National Forest
701 North Santa Anita Avenue
Arcadia, CA 91006
818-574-1613

Cleveland National Forest
10845 Rancho Bernardo Road,
Suite 200
Rancho Bernardo, CA 92127
619-673-6180

Eldorado National Forest
100 Forni Road
Placerville, CA 95667
916-644-6048

Inyo National Forest
873 North Main Street
Bishop, CA 93514
619-873-5841

Klamath National Forest
1312 Fairlane Road
Yreka, CA 96097
916-842-6131

Lake Tahoe Basin Management Unit
870 Emerald Bay Road,
Suite 1
South Lake Tahoe, CA 96150
916-573-2600

Lassen National Forest
55 South Sacramento Street
Susanville, CA 96130
916-257-2151

Los Padres National Forest
6144 Calle Real
Goleta, CA 93117
805-683-6711

Mendocino National Forest
420 East Laurel Street
Willows, CA 95988
916-934-3316

Modoc National Forest
441 North Main Street
Alturas, CA 96101
916-233-5811

Plumas National Forest
159 Lawrence Street
P.O. Box 11500
Quincy, CA 95971
916-283-2050

San Bernardino National Forest
1824 South Commercenter Circle
San Bernardino, CA 92408-3430
714-383-5588

Sequoia National Forest
900 West Grand Avenue
Porterville, CA 93257
209-784-1500

Shasta-Trinity National Forests
2400 Washington Avenue
Redding, CA 96001
916-246-5222

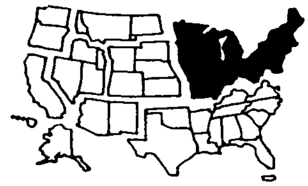
Sierra National Forest
1600 Tollhouse Road
Clovis, CA 93612
209-487-5155

Six Rivers National Forest
500 5th Street
Eureka, CA 95501
707-442-1721

Stanislaus National Forest
19777 Greenley Road
Sonora, CA 95370
209-532-3671

Tahoe National Forest
631 Coyote Street
P.O. Box 6003
Nevada City, CA 95959
916-265-4531

Eastern Region
310 West Wisconsin Avenue,
Room 500
Milwaukee, WI 53203
414-297-3693



Cross-country ski or snow-machine along winter trails. In spring and summer, paddle through the Boundary Waters Canoe Area, and listen for the call of the loon. In the fall, driving among the blazing autumn colors of a hardwood forest should be at the top of your list of things to do. Each season offers special opportunities to enjoy your National Forests of the Eastern Region.

ILLINOIS

Shawnee National Forest
901 South Commercial Street
Harrisburg, IL 62946
618-253-7114

INDIANA and OHIO

Wayne-Hoosier National Forests
811 Constitution Avenue
Bedford, IN 47421
812-275-5987

MICHIGAN

Hiawatha National Forest
2727 North Lincoln Road
Escanaba, MI 49829
906-786-4062

Huron-Manistee National Forests
421 South Mitchell Street
Cadillac, MI 49601
616-775-2421

Ottawa National Forest
2100 East Cloverland Drive
Ironwood, MI 49938
906-932-1330

MINNESOTA

Chippewa National Forest
Route 3, P.O. Box 244
Cass Lake, MN 56633
218-335-2226

Superior National Forest
515 West First Street
P.O. Box 338
Duluth, MN 55801
218-720-5324

MISSOURI

Mark Twain National Forest
401 Fairgrounds Road
Rolla, MO 65401
314-364-4621

NEW HAMPSHIRE and MAINE

White Mountain National Forest
Federal Building
719 North Main Street
P.O. Box 638
Laconia, NH 03247
603-528-8721

PENNSYLVANIA

Allegheny National Forest
Spiridon Building
222 Liberty Street
P.O. Box 847
Warren, PA 16365
814-723-5150

VERMONT

Green Mountain and Finger Lakes National Forests
Federal Building
151 West Street
P.O. Box 519
Rutland, VT 05701
802-773-0300

WEST VIRGINIA

Monongahela National Forest
USDA Building
200 Sycamore Street
Elkins, WV 26241
304-636-1800

WISCONSIN

Chequamegon National Forest
1170 Fourth Avenue South
Park Falls, WI 54552
715-762-2461

Nicolet National Forest
Federal Building
68 South Stevens Street
Rhinelander, WI 54501
715-362-3415

Preparation Techniques in Vertebrate Paleontology

Richard L. Cifelli
Oklahoma Museum of Natural History and Department of Zoology
University of Oklahoma
Norman, Oklahoma

INTRODUCTION

Vertebrate remains are commonly encountered as fossils or subfossils, particularly in Plains states like Oklahoma, which are rich in terrigenous sedimentary rocks and Pleistocene alluvial deposits. Outside of the professional community, however, techniques for the preparation, restoration, and conservation of these fossils are incompletely known and practiced. The purpose of the present account is to briefly outline some of the major techniques for the preparation of fossil vertebrates. Preparation has been the subject of several book-length treatments. One of the most useful aspects of the brief papers in this volume is the bibliographic material they contain, and the reader is accordingly referred also to the following major treatises for detailed descriptions of various aspects of fossil preparation: Kummel and Raup (1965), Rixon (1976), Converse (1984), Feldmann and others (1989), and Leiggi and May (1994). Whether large or small, vertebrate fossils have traditionally been collected and prepared as individual or grouped units. Exceptions to this procedure are certain microvertebrate assemblages, which are recovered through disaggregation of surrounding rock matrix and application of various fossil concentration techniques; these methods are discussed separately below. Fundamental to all aspects of fossil-vertebrate preparation and conservation, however, are adhesives, which thus constitute a logical topic to begin with.

ADHESIVES

Virtually all methods of fossil-vertebrate preparation require the use of one or more types of glue. By varying concentration (amount of solvent), the same compound can often be used as a consolidant resin, repair adhesive, filler, or even as a separator when making molds. In addition to practical qualities (e.g., solubility, hardness, setting time, viscosity), two other properties should be considered when selecting a glue: long-term stability and reversibility. Shellac, celluloid nitrates (e.g., many types of model cement), and five-minute epoxies, for example, are not stable over long periods of time. Their use results in a weak bond and, in some cases, specimen discoloration or damage (see Shelton and Chaney, 1994, for an excellent review of glue properties). Furthermore, although solvents are available for practically any type of glue, some types (e.g., epoxies) are notoriously difficult to remove once set, and their usage should be restricted to situations in which a permanent bond is desired. Three major categories of glues are recommended: (1) butvar and PVA for general specimen repair and consolidation, (2) epoxies for permanent bonds where great strength is needed (especially for large specimens), and (3) cyanoacrylates for consolidation and repair of smaller specimens.

The most widely useful glues for vertebrate fossils are polyvinyl acetate (PVA) and butvar (B-76, a trademark of the Monsanto Corporation). B-76 is highly recommended for most purposes. It is soluble in a variety of solvents; we have had best results dissolving it with 50% acetone and 50% isopropyl alcohol, to which a little water (5% of the total) is later added. Mixed thinly (so that a drop of it rubbed between the thumb and first finger feels slightly tacky as it dries), PVA and butvar work well to consolidate cracked, friable, or powdery bone. Make sure that the surface is free from particles of rock matrix and other extraneous debris before applying consolidant, which can be applied with a brush or (if the fossil is extremely fragile and will disintegrate easily) dripped from a bottle (e.g., container for shampoo or skin conditioner). The consolidant should be thin enough so that it penetrates deep into the specimen; allow it to set completely (so that it has polymerized, which is well past the stage at which the specimen is dry to the touch) before working on the treated area of the specimen. Depending on the stability of the fossil, repeated coats may be needed. In general, it is best to expose, clean, and treat small areas of a specimen, so that work can continue elsewhere while the consolidant is setting. For butvar and PVA, it is useful to have a "stock" solution, the consistency of molasses, on hand. This stock solution can be used without modification for repairing breaks or further dissolved for use as a consolidant. If modification of a repair is called for, both PVA and butvar can be dissolved with acetone, though caution should be used, as the acetone will also dissolve consolidant that has been applied to the bone.

As noted above, use of epoxies should be restricted to situations in which a permanent bond is required. The great virtue of epoxies is their superior strength; they are particularly useful for bonds in large, heavy specimens. However, five-minute epoxies are notoriously weak and degrade with time—do not use them! Epoxies are available in a variety of viscosities and forms. For repairing large

Cifelli, R. L., 1996, Preparation techniques in vertebrate paleontology, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 77–80.

specimens where contact is incomplete (e.g., a mammoth limb element in which the breakage has resulted in the loss of much bone in the original zone of contact), an epoxy paste (e.g., Brutem) can be especially effective. Where large gaps remain, epoxy putty can be used as a filler.

The use of cyanoacrylates ("superglues") has become increasingly widespread, and these adhesives are now to be found in most preparation laboratories across the World. Despite caveats in the conservation literature (e.g., Shelton and Chaney, 1994) that the long-term properties of cyanoacrylates are not well understood, they have been used successfully for at least 20 years without serious problems. Cyanoacrylates with various setting times and viscosities are available, and they can be used in conjunction with accelerators, which make bonding essentially instantaneous. Cyanoacrylates are thus extremely useful in situations in which time is a factor, particularly in the field. Paleobond (a trademark of Uncommon Conglomerates) is formulated especially for use on vertebrate fossils and is highly recommended. The thinnest variety penetrates well and is an exceptional consolidant; thicker varieties can be used for repair or even as a filler. Fragments to be repaired should be first treated with the deep-penetrating consolidant in order to improve bond strength. Accelerator is available in hand-pump or aerosol form; the former is recommended, as it can be more accurately targeted to the relevant area on the specimen. Accelerator can be applied prior to the adhesive or vice versa: where deep penetration is needed or where bone contacts may need to be positioned, apply the accelerator afterward; where an instantaneous bond is needed, apply it first. Depending on mineral content of the bone, an unwanted side effect of most accelerators is that they can discolor the specimen, often a blue-green hue, usually when it is wet. (This somewhat offsets one of the great advantages of cyanoacrylates, the fact that they will bond under damp conditions.) If discoloration is an issue, a small area or scrap of the specimen can be used as a test piece, though mineral content often varies considerably, even within an individual bone.

SPECIMEN COLLECTION

Field techniques for collecting fossil remains of both macrovertebrates (Leiggi and May, 1994) and microvertebrates (Cifelli and others, 1996) have been extensively discussed elsewhere; however, strategies for specimen preparation, and the ultimate success of specimen treatment, are initiated in the field, so that a few comments are warranted here. Perhaps the most neglected aspect of fossil-vertebrate collecting is the recording of adequate field data: without detailed stratigraphic and geographic provenance, the scientific value of any given specimen can be seriously compromised. Detailed notes that include all pertinent information (stratigraphic, lithologic, geographic data, etc.) should be kept; in addition, the site location should be accurately recorded by use of a Global Positioning Satellite, plotting on a 7.5-minute USGS topographic quadrangle or aerial photograph, or a combination of these methods. Where any doubt could later arise, it is also useful to document sites photographically; a good practice is to take both standard 35 mm and Polaroid photographs, so that the latter can be annotated at the site. Where appropriate, specimens should receive field numbers that can be keyed directly to the field notes and map data.

There are at least three main categories of specimen collecting, sometimes used in combination; these are detailed below.

Surface Collecting

Fossil vertebrates are generally found through surface prospecting. An effort should always be made to locate the producing horizon, in order to determine whether additional parts of the same specimen or other materials are present. In many cases, the specimen has either weathered completely out of the rock, or the horizon of origination cannot be located. The ground should be carefully scanned for any important fragments; where a specimen is small and of unusual significance, nearby surface matrix should be collected and dry-screened through mesh of appropriate size (e.g., window screen for very small specimens; ⅛ in. or ¼ in. hardware cloth for larger specimens). Any fragments that are associated or found to fit together should be wrapped and labeled (e.g., with registration marks) accordingly. The assumption that a collector will remember all aspects of any given specimen is almost always unfounded; in general, it is best to record data and mark specimens as though someone else was going to reassemble it, with no verbal commentary from the collector.

Quarrying

When specimens are quarried, the object is usually to recover them intact, or nearly so. After the discovery is made, generally through prospecting, the surface should be carefully worked, as described above, prior to excavating. Depending on the size of the specimen, useful tools include a whisk broom, paintbrushes, and an ear syringe (for brushing or blowing away matrix particles); geologists' hammer, a variety of chisels and other hand tools (an ice pick or sharpened Phillips screwdriver, preferably one that will withstand some hammering, is extremely useful), an entrenching tool (genuine U.S. surplus vastly preferred over cheaply made, imported imitations), glues and consolidants, and larger tools (as needed) are essential.

A common mistake in specimen quarrying is not allowing sufficient room around the specimen: begin a good distance away, in all directions, work down to a level below the fossil horizon, and work gradually inward. Where bone is encountered, work laterally until you can work inward again. For very large specimens, such as articulated skeletons, it will be necessary to expose a certain amount of surface bone so that the specimen can be identified and, as necessary, disassembled into units small enough to collect with the materials and equipment on hand. Where bone is exposed, clean it and treat with consolidant if needed; if fragments cannot be reattached immediately, their associations should be carefully marked prior to wrapping and labeling. Where a number of fragments or individual items are removed, it is useful to make a map, with individual elements bearing numbers or other designations that correspond to those on the wrapped pieces. Small fragments and elements should be well wrapped in tissue or paper toweling; do not simply place them in a pocket or bag, because abrasion and breakage will likely result.

Very small specimens (for which a pocket loupe or hand lens is indispensable) are often recovered within an individual rock clast or counterpart slabs. Where feasible and necessary, these can be trimmed with a hammer and chisel, though it is often better to carry home extra rock than to risk damaging an important specimen. Consolidant should not be applied to microvertebrate specimens unless either the bone or the enclosing rock shows imminent signs of disintegrating. Instability of microvertebrate specimens is often due to cracks in the surrounding rock; where possible, restrict application of consolidant or glue to the rock matrix and do not apply it to the specimen unless necessary.

Larger specimens should almost always be covered with a protective jacket prior to removal from the ground. Surface preparation of the bone should be kept to a minimum: remove enough rock to identify and define the specimen, and leave the rest to protect it. Undercut the fossil as much as possible, so that it appears to lie atop a rock pedestal. Cover both fossil and rock, including the undercut part, with several layers of tissue or paper toweling (which can be made to adhere to the specimen by flicking water at it with a whisk broom), making sure that the paper fits snugly. Small specimens (smaller than a mailbox) can be jacketed with orthopedic surgeons' bandages (the 6 in. rolls are most versatile); larger specimens will require burlap soaked in plaster of Paris. (If the specimen cannot be removed on the same day, this "top jacket" will protect it, provided the jacket is covered with plastic and then reburied.) When the jacket is set, flip the specimen over, remove excess rock matrix, and jacket the bottom side. Each jacket should be labeled with pertinent field data and, where appropriate, the contents should be diagrammatically sketched on the outside.

Collecting Rock Matrix for Microvertebrate Recovery

In many cases, a rock layer is found to contain microvertebrate fossils, but the remains are neither sufficiently abundant nor sufficiently well preserved to justify recovery through quarrying techniques. Because screenwashing (i.e., "underwater screening") is an inherently destructive process, it should be only considered as a course of last resort; however, it is possible to recover diverse, well-represented faunas if sufficient care is taken. Where the presence of a microvertebrate horizon is suspected (for example, as indicated by a lag accumulation of small bone discovered through surface prospecting), the first step is to locate the productive zone, which is generally accomplished by digging a profile that extends through the weathered surface, and examining rock clasts with a hand lens. In general, it is only practical to collect rock that will disaggregate readily in water (e.g., nonindurated, fine-grained sedimentary rock, such as siltstones, mudstones, and claystones), although it is possible to break down indurated rock, depending on mineral content (see Cifelli and others, 1996, for a review). Clear overburden as needed, and collect only the fossiliferous horizon, breaking the rock into chunks the size of walnuts or golf balls. The amount of rock to be collected will depend on a number of factors; in general, it is necessary to collect a minimum of about 225 kg. Samples can be placed in burlap feed sacks, secured with line or parachute cord, and labeled with site data.

SPECIMEN PREPARATION

Mechanical Preparation

Although there exist specialized techniques for chemical preparation (see summary by Rutzsky and others, 1994), mechanical preparation is used on the vast majority of specimens, and this brief survey is accordingly limited to mechanical means of removing rock from fossils. The preparation laboratory should be equipped with a variety of fine chisels, sharpened dental tools (used tools are often available free from a dentist), tool steel (high-speed steel—old drill rod or drill bits work well), tungsten carbide rod in a variety of diameters and sharpened with a variety of points, a cast cutter or mat knife (for removing jackets), a variety of other hand tools (see May and others, 1994), a sandbox (to stand up specimens being repaired), and sand bags in a variety of sizes (to provide support for specimens being worked on). The most useful power tools to have on hand include a bench grinder (for rough sharpening of tools), a flexible-shaft drill (with a variety of bits, used for fine sharpening of tools and for grinding matrix), and, particularly, a pneumatic air scribe (e.g., Chicago Pneumatic, ARO, All-Air), which requires an air compressor. In addition to glues and consolidants, necessary materials include plaster of Paris (for specimen restoration, jacketing, and miscellaneous uses), modeling clay (various uses), and polyethylene glycol (PEG; e.g., Carbowax, a trademark of Union Carbide).

Where a specimen is well embedded in rock matrix (e.g., a jacketed bone), an effort should be made to clear away outside rock first, using strokes directed away from the bone, where possible. The rock will often contain abundant zones of weakness, such as bedding planes and joint cracks. It is generally better to stabilize and break down large clasts mechanically than to attempt removing them whole; the entire block can quickly become unstable, or unseen parts of the specimen can be inadvertently plucked off. Unstable zones of rock or bone can be coated or filled with melted PEG, which is later removed with the rock. The air scribe can greatly speed mechanical preparation, but extreme caution should be exercised, so that vibration does not cause the bone to disintegrate. Commonly, the zone closest to the bone will be more indurated than the parent rock. Obstinate matrix can sometimes be loosened by judicious application (e.g., with an eye dropper) of water or dilute (10 to 15%) acetic acid. Where friable bone is exposed, it should be cleaned of dust and rock particles and treated with consolidant. If possible, specimens should be disassembled along existing fractures, which commonly have separated and are infilled with rock matrix. The contacts should be carefully cleaned, and the fits checked prior to reassembly; if many, complex pieces are involved, it is often appropriate to make a sketch of the specimen and mark the registration of individual fragments.

If a specimen is fragile, complex, and cannot be removed intact from the rock by simply working one side, the prepared side can be jacketed (see above); all overhangs should be filled prior to jacketing. Extremely delicate, vibration-sensitive specimens may require embedding in PEG: first build a clay dam around the specimen (see Madsen, 1996) and fill with liquid PEG; when it has hardened, flip the specimen and prepare the other side. The PEG can be removed with a combination of mechanical preparation and dissolution with water; if a specimen is extremely fragile, it is often best to leave one side—the less informative side—embedded.

Screenwashing

Matrix collected for screenwashing should be thoroughly dried: preexisting water content hampers penetration, which in turn often reduces the extent to which the rock will disaggregate when immersed in water. Rock disaggregation can be tested by placing a small sample in a container of water; if the rock does not disaggregate within a few hours, then it is probably not feasible to attempt washing. (Some lithologies are, however, washable by using specialized methods; see Cifelli and others, 1996). Screen boxes can be fashioned from lumber and aluminum screen, with hardware cloth to support the screen if extended use is anticipated. Window screen is suitable for many applications; for extremely small specimens, a nested set of boxes—one with window screen and one with finer (30 mesh) screen is commonly used (see plans and description in Cifelli and others, 1996). Dried rock is placed in each screen box, which is then immersed in water; depending on how quickly the rock breaks down, it may need to soak for several hours. The boxes are gently agitated until "done" and then placed out to dry. Dried concentrate, which should be handled carefully in order to minimize specimen breakage, should be stored in rigid containers.

Techniques for recovery of microfossils from concentrate will vary, depending on their size and nature; sometimes, no magnification is required (e.g., McKenna, 1962), though more commonly an illuminated magnifier or, better, a binocular microscope using low power (10× to 15×) is employed. In either case, the particles should be thinly and evenly spaced on a nonglossy, white background (painted rectangular cake pans, with a superimposed grid system to assure uniform scanning, are useful for this purpose). Fossils can be manipulated with a moistened, fine paintbrush or watchmaker's forceps. Where a diverse fauna is being recovered, it is advantageous to have a number of small vials (e.g., ½-dram shell vials, with fitting corks) available, so that specimens can be sorted as they are picked; vials can be stored in trays fashioned from lumber with appropriate-sized holes.

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A Geological History of Oklahoma's Vegetation

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EDITORS' NOTE: In 1963, Dr. Leonard R. "Dick" Wilson published the following paper on the paleobotany of Oklahoma. To this day, Dr. Wilson's paper remains a classic reference on plant fossils in the State. With his permission and that of the Oklahoma City Geological Society, we are reprinting his paper, with minor revisions, in hopes of furthering professional and amateur interest in Oklahoma's vegetation. (Original reference: Wilson, L. R., 1963, A geological history of Oklahoma's vegetation: Shale Shaker, v. 13, no. 9, p. 272–286.)

INTRODUCTION

The advent of palynology, the study of spores, pollen, and other microfossils, and its important application to petroleum geology, have made a detailed understanding of the history of vegetation important for a fuller use of that science.

Relatively few geologists have used paleobotany in stratigraphic work, because the larger invertebrate fossils have always been more conspicuous and abundant in the outcrops than in the subsurface. Foraminifera and ostracodes, where present, have served well as stratigraphic markers. Since the discovery that palynological fossils are the most abundant paleontological objects and that they are found in a larger number of sedimentary rocks than are other fossils, they have become important in the exploration for petroleum. A knowledge of the history of vegetation and the relationship of the fossil spores and pollen to their parent plants will give additional stratigraphic information, and the environments of the past will be revealed more completely.

The history of Oklahoma's vegetation has many unexplored facets but with investigation it can become well known because rocks of all geological periods are present in the State. This geologic phenomenon is not possessed by many other areas of comparable size.

Studies of Oklahoma's fossil floras can be divided roughly into those which have dealt with leaf and stem impressions and compressions, those of cellular structures preserved as petrifactions, those of algal masses and parts, those of seeds of Tertiary plants, and those of fossil spores and pollen.

Paleobotanical observations are known to have been made intermittently in Oklahoma since 1853, a period of 110 years. In this time, approximately 100 papers have been published in which fossil plants have been reported or described. More than a third of these have appeared in the last five years.

The earliest recorded observation of plant fossils in Oklahoma appears to be that of Marcou (1856) who, while engaged in a government survey in the Indian Territory, noted the occurrence of fossil plants associated with coal deposits. The first attempts to describe the plant fossils were made by I. C. White in 1882, by C. D. White in 1899, by Hill in 1895, and by Girty in 1899. These studies were largely concerned with the leaf compressions in the Paleozoic coal-bearing rocks. Gould in 1900, 1920, 1921, and 1926 described several small collections of Cretaceous flora. The above publications appeared in what might be termed the period of classical paleobotany, a time when most studies in the United States consisted of leaf collections. Later paleobotanical publications include other phases of plant fossil studies and are noted below in discussions of various geological periods. A bibliography of these was compiled in a publication by Wilson (1960).

THE PALEOBOTANICAL METHOD

The methodology in the historical investigation of fossil vegetation is both direct and indirect. Direct information comes from fossil leaves, petrified wood, and from other structures including spores and pollen. Indirect information comes from one or all of the following:

1. Analysis of the closest geographically placed floras when no plant fossils are known from a region of a particular geologic time.
2. Analysis of rocks of equivalent ages for evidence of physical conditions. Redbeds, evaporites, limestones, and conglomerates are particularly useful as indicators.
3. Recognition of physical events which may have prevented fossil preservation, or of those which removed the fossil record.
4. Possible plant associations with fossil animals when only the latter occur.

Detailed paleobotanical records must be kept in order that evidence may be reexamined as knowledge is accumulated and its understanding undergoes evolution. The records of the plant paleontologist are centered about a carefully curated collection of fossil plants. This collection serves as proof that various plant forms were preserved in certain geological deposits and keeps fossils available for restudy when additional information is discovered. Many

Wilson, L. R., 1996, A geological history of Oklahoma's vegetation, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 81–96.

of the earlier described fossil plant species are based upon a few or fragmentary specimens. Later studies often have shown that some of these species are actually morphological parts which occur together on more complete specimens. Many fossil leaves have been incorrectly assigned to natural families or genera, and later studies of the specimens have revealed closer affinities. These and other problems are apparent in Oklahoma paleobotanical studies, and it is necessary to compare many fossil specimens with the species types before a comprehensive treatment of the fossil flora can be written. Many of the plant megafossil species collected in Oklahoma have been known previously and their types are in the collection of the United States National Museum or in European collections.

There are many laboratory techniques in paleobotanical work. Petrified fossil wood studies require thin sections of the specimens. These must be cut transversely, radially, and tangentially to the growth axis and the sections must be examined with the compound microscope for morphological structures. Ground thin sections and parlodion peels are commonly used in petrifaction studies. Leaves and other herbaceous structures are often removed from their rock matrices and placed on microscope slides for venation and detailed cellular studies. This is accomplished by cellulose peels and treatment with acids. Shales and sandstones containing plant fragments may be dissolved with hydrochloric and hydrofluoric acids, and after careful washing, the fragments can be removed for study under a stereobinocular microscope. Sometimes it is desirable to treat the fragments with nitric acid or Schulze's solution and a mild base in order to observe the cellular structure. The study of carbonaceous deposits such as coal and black shales normally requires the removal of the calcium carbonate with hydrochloric acid, then the silica with hydrofluoric acid, and finally a maceration of the carbonaceous material with Schulze's solution and a weak solution of ammonium hydroxide, or with potassium hydroxide. Details of these techniques are found in many paleobotanical publications, and reference can be found to some of the more recent ones in Wilson (1960).

THE HISTORICAL RECORD

Hugh Miller wrote in the *Testimony of the Rocks* (1857, p. 502), "We see only detached bits of that green web which covered our earth ever since the dry land first appeared but the web itself seems to have been continuous throughout all time." This quotation is especially appropriate for the oldest geological formations where only fragments of algae or woody structures have been found in marine deposits. Direct evidence of a land vegetation in the oldest Paleozoic periods is almost nil, but the evolutionary stages or morphological complexities of the Silurian land plants indicate an ancestry of even greater antiquity. The evolutionary status and the abundance of the Lower Cambrian invertebrates indicate that the same type of ancestral antiquity is apparent for the animal kingdom. Because it is an ecological fact that where there exists an animal community there also exists some form of plant life which serves as a source of food for the animals, it can be assumed that plant communities were also present in the Cambrian Period. Such is the evidence for the early existence of plant life in the seas and possibly on the lands. An explanation for the lack of terrestrial vegetation in the early Paleozoic fossil record may be found in the fact that no extensive continental deposits are known to be older than Devonian. Those that must have existed are either deeply buried or were located in diastrophically positive areas and were subsequently eroded. We must realize that the fossil record of the plant or animal kingdom is at best an infinitely small representation of the life that existed on the earth at any one instant of time; nevertheless that record is complete enough to serve the academic scientist in his many quests and the stratigrapher and economic paleontologist in their search for geologic order and natural resources. Whereas the animal paleontologists have mostly concerned themselves with marine faunas and have largely neglected the continental faunas, most plant paleontologists have studied the continental floras and neglected the marine floras. The reason lies in the presence of a greater number of marine animal fossils for the animal paleontologist and the greater number of continental plant fossils for the plant paleontologist. The result of these differences in paleontological studies has led to disagreements when marine and continental time scales have been compared. With further development of the science of palynology, at least some irregularities of correlation will be resolved because within many marine fossil assemblages there occurs an abundance of spores and pollen that are also present in continental deposits of comparable age. Thus spores and pollen transported from the lands are "common denominators" where separate and as yet unrelated marine and terrestrial fossil biotas seem to suggest different ages.

Text-figure 1 shows the stratigraphic distribution of vascular plants constructed from a world study of paleobotanical records. Table 1 is a summary of Oklahoma's vegetational history as it is presently known.

Precambrian

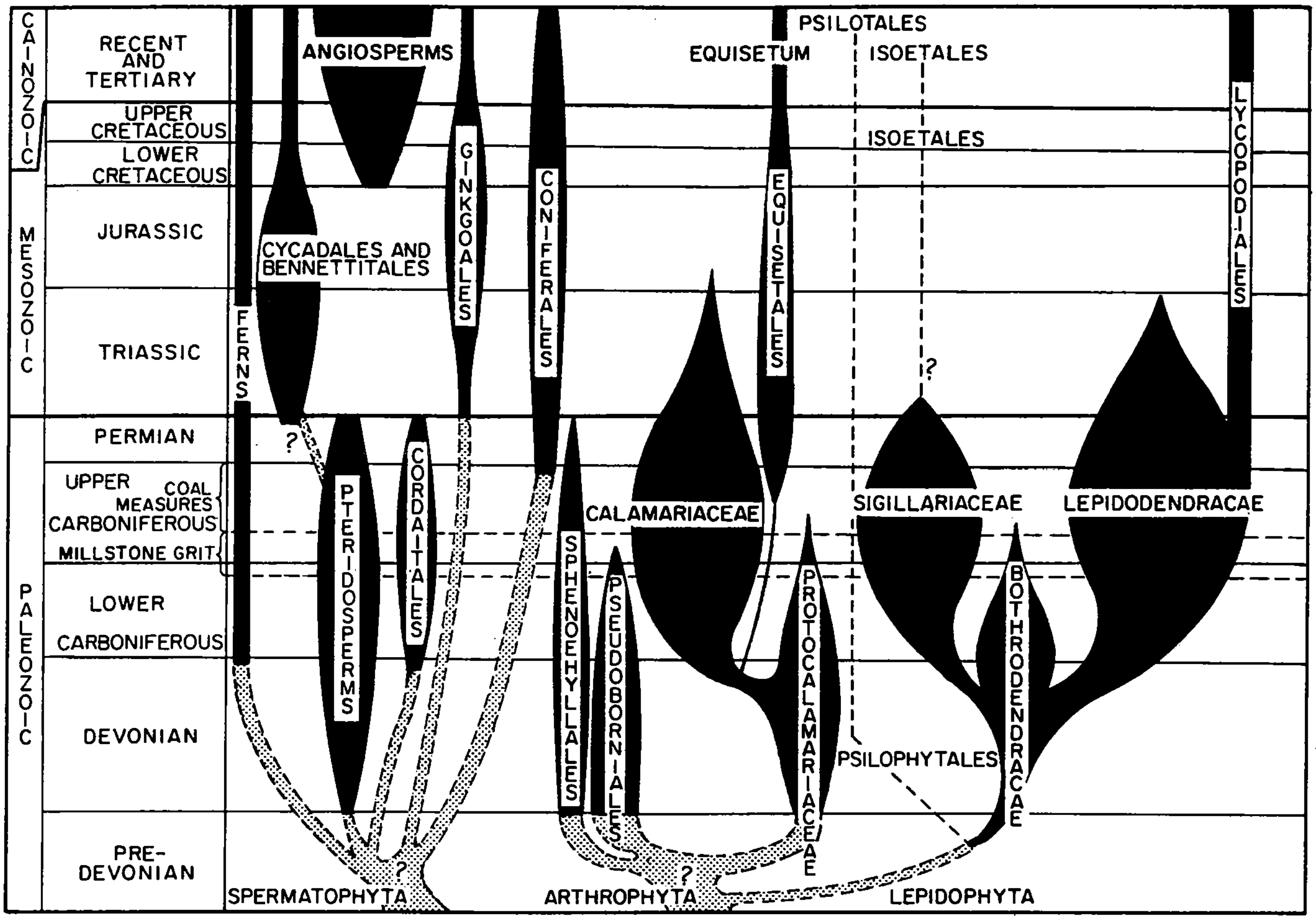
Fossils of primitive algae occur in the late Precambrian rocks of Minnesota, Montana, and several other places in the world but as yet no conclusive evidence is known for such fossils in the Precambrian rocks of Oklahoma. Some of the sedimentary rocks of southern Oklahoma which may prove to be of late Precambrian age, may contain objects that were formed by primitive blue-green algae or bacteria.

Cambrian Period

The Cambrian rocks of Oklahoma are generally too coarse to have been a good preserving medium for algae; however, there occur in the Collier Shale thin siliceous beds containing structures which superficially simulate algae.

Ordovician Period

During the Ordovician Period the sea waters over Oklahoma deepened and extensive calcium carbonate deposits were formed. In the shallower parts of the marine environment, extensive algal colonies developed. The Arbuckle Limestone of the Arbuckle Mountains contains excellent "heads" of *Cryptozoon poliferum* (Plate I, Figure 4) and



Text-figure 1. Distribution of vascular plants in geological time (from Crookall, 1929, pl. I).

colonies of blue-green algae. Many of these show no definite cellular structures in thin sections examined under the microscope. Their identification is generally based on the growth forms or shapes of the colonies. Some of the best examples are to be seen on the pathway just below the "Lookout" at Turner Falls. A photograph of one such colony is shown on Plate I, Figure 5. In the McLish Formation, also in the Arbuckle Mountains, there occurs a "Birdseye" limestone of algal origin. The structure and occurrence of these was described by Ham (1954). The Simpson Group limestones contain *Solenopora* cf. *compacta*, "Fucoids," and *Ischadites iowensis*, all illustrated on Plate I. Until recently the last named fossil was considered to be an animal related to the sponges.

Silurian Period

Few algae are known at present from the Silurian rocks of Oklahoma, but a search should reveal a number of species. Certain of the oolitic deposits in the Chimneyhill Formation apparently were formed by unicellular algae.

Devonian Period

With the advent of Devonian time the first unquestioned land floras occur in Oklahoma. The most spectacular are large fragments of silicified *Callixylon* wood found in the Woodford Formation of the Ada vicinity. Text-figure 2 shows a reconstructed stump, located on the campus of East Central State College at Ada. This specimen, probably the largest *Callixylon* that has been discovered, is a fitting memorial to Dr. David White, one of America's great phytogeologists, and to Mr. John Fitts, who had the foresight to ensure the preservation of the remarkable fossil. Arnold (1934) studied the wood of the *Callixylon* from Oklahoma and named the species *Callixylon whiteanum*. Considerable significance can be attached to the occurrence of *Callixylon* in the Woodford Formation for until that geological time no plants of terrestrial nature are known to have lived in Oklahoma. All *Callixylon whiteanum* fragments appear to have been recovered from marine shales and seem to be further restricted to the lower 30 or 40 feet of the Woodford Formation. *Callixylon* wood is abundant, and undoubtedly the living tress formed an extensive Devonian forest in the Ada vicinity until the sea encroached upon the land (Wilson, 1958). A microscopic study of the Woodford shales has revealed an abundant spore flora in the same zone in which the *Callixylon* wood occurs (Plate VI, Figures 21–24). These spores, like the fossil wood, indicate the existence of a nearby terrestrial

Table 1. — Summary of Oklahoma's Vegetation History

	Geological Time	*Physical Conditions*	*Nature of Paleobotanical Records*	*Dominant Vegetation*
Cenozoic	Pleistocene	Cool to warm Erosion, Glaciation north of Oklahoma	Peat, silt, volcanic ash Relict communities	Prairie types Oak-hickory Beech (?)-maple Pine-hemlock (?) Spruce-pine
	Pliocene	Cool to warm Erosion	River deposits, volcanic ash Seeds	Conifers, dicots, monocots (prairie types)
	Miocene	Cool to warm Erosion	Inferred from adjacent states	Ferns, conifers, dicots, monocots
	Oligocene	Cool to warm Erosion	Inferred from adjacent states	Ferns, cycads, conifers, dicots, monocots
	Eocene	Warm Erosion	Inferred from adjacent states	Ferns, cycads, conifers, dicots, monocots
	Paleocene	Cool to warm Erosion	Inferred from adjacent states	Ferns, cycads, conifers, dicots, monocots
Mesozoic	Cretaceous	Warm Marine and coal swamps	Coal, shale, limestone Wood, leaves, spores, reefs	Algae, ferns, cycads, conifers, dicots, monocots
	Jurassic	Erosion, continental deposition	Inferred from adjacent states	Algae, ferns, cycads, conifers,
	Triassic	Erosion Marine in West	Inferred from adjacent states	Ferns, cycads, conifers
Paleozoic	Permian	Cool to warm Marine in west, deltaic in central	Redbeds, shale, sandstone Leaves, spores, pollen, reefs	Algae, lycopods, ferns, *Calamites*, pteridosperms *Cordaites*, conifers
	Pennsylvanian	Warm Marine and coal swamps	Coal, shale Leaves, seeds, wood, spores, pollen, reefs	Algae, lycopods, ferns *Calamites*, pteridosperms, *Cordaites*, conifers
	Mississippian	Warm Marine and coal swamps	Coal, shale Leaves, seeds, wood, spores, pollen, reefs	Algae, lycopods, ferns *Calamites*, cordaites
	Devonian	Warm Marine	Shale Wood, leaf tissue, spores	Algae, ferns, *Callixylon*, *Tasmanites*
	Silurian	Warm Marine	Shale, limestone	Algae
	Ordovician	Warm Marine	Shales Reefs, spores (?)	Algae
	Cambrian	Warm Marine	Shale	Algae
	Precambrian		Inferred	Algae

environment, but the distance and direction of that land area on which the forest and other vegetation grew is not known.

The sporelike fossil, *Tasmanites* (Plate VI, Figure 21), which occurs in the dark-colored and black shales of the Devonian and Mississippian Periods, is probably better known to geologists than *Callixylon*. These structures, now allied to the algae, often occur in countless numbers in a shale sample. Associated with *Tasmanites* is another sporelike body, *Quisquilites buckhornensis* (Plate VI, Figure 22), which too is thought to be an alga. This form was described by Wilson and Urban (1963) and has been observed in Devonian deposits of Canada and South America.

During the closing time of the Devonian Period in southern Oklahoma the Woodford Sea withdrew, and as this occurred, the terrestrial vegetation again invaded the region. This is shown also by the presence of an abundant spore flora in the top of the Woodford Formation.

Mississippian Period

The Mississippian rocks, like the Devonian, are mainly of marine origin, but they contain a greater abundance of fossil spores and megascopic plant fragments. At present more than 200 species of spores are known from the Caney, Goddard, and Springer Formations. These originated from terrestrial plants that lived along the shores of the Mississippian seas in Oklahoma. Four typical spores of this period are illustrated on Plate VI, Figures 17–20. Plant megafossils are locally abundant in the Caney Shale of southern Oklahoma, but their preservation is rather poor. Seldom can one assign more than a generic name to these fossils. The common forms are *Lepidodendron* and *Calamites*, genera that became abundant in the Pennsylvanian Period.

Pennsylvanian Period

The conspicuous forms of plant life in the Pennsylvanian Period were the Lycopsida (so-called clubmosses), the Sphenopsida (scouring rushes), the Filicineae (ferns), the Pteridospermae (seed-ferns), and the Cordaitales, a group of primitive and extinct gymnosperms whose straplike leaves superficially resemble those of some living cycads. The relative importance of these groups of plants in geologic time is shown in Text-figure 1. The first three have descendants in the present world flora but all are minor elements.

The Pennsylvanian vegetation of Oklahoma was abundant and at times probably comparable to that of the present tropics in density and growth habit, but certainly not in composition. Because of its abundance and good preservation, more is known about Oklahoma's Pennsylvanian vegetation than of any other geological period in the State's history, except that of the present. These plant fossils are associated with the extensive coal deposits in the eastern part of Oklahoma. Many of the shales above the coal seams contain remarkably well-preserved leaves and other plant parts, whereas the coals, except in those of low volatility in the Arkoma basin, contain an extensive flora of fossil spores and pollen. Examples of these fossils are illustrated on Plates II–IV and on Plate VI, Figures 13–16.

Probably all of Oklahoma and much of the world had a low relief during Pennsylvanian time, and minor rises or drops in sea level flooded or exposed wide areas of land. Swamps containing dense vegetation developed along the shore lines and contributed to the formation of peat, which upon burial and alteration became coal. In Oklahoma probably more than 40 distinct coal seams are present, and each is evidence of a former forest now converted to a carbonaceous deposit. These seams vary from less than 1 inch to as much as 10 feet in thickness.

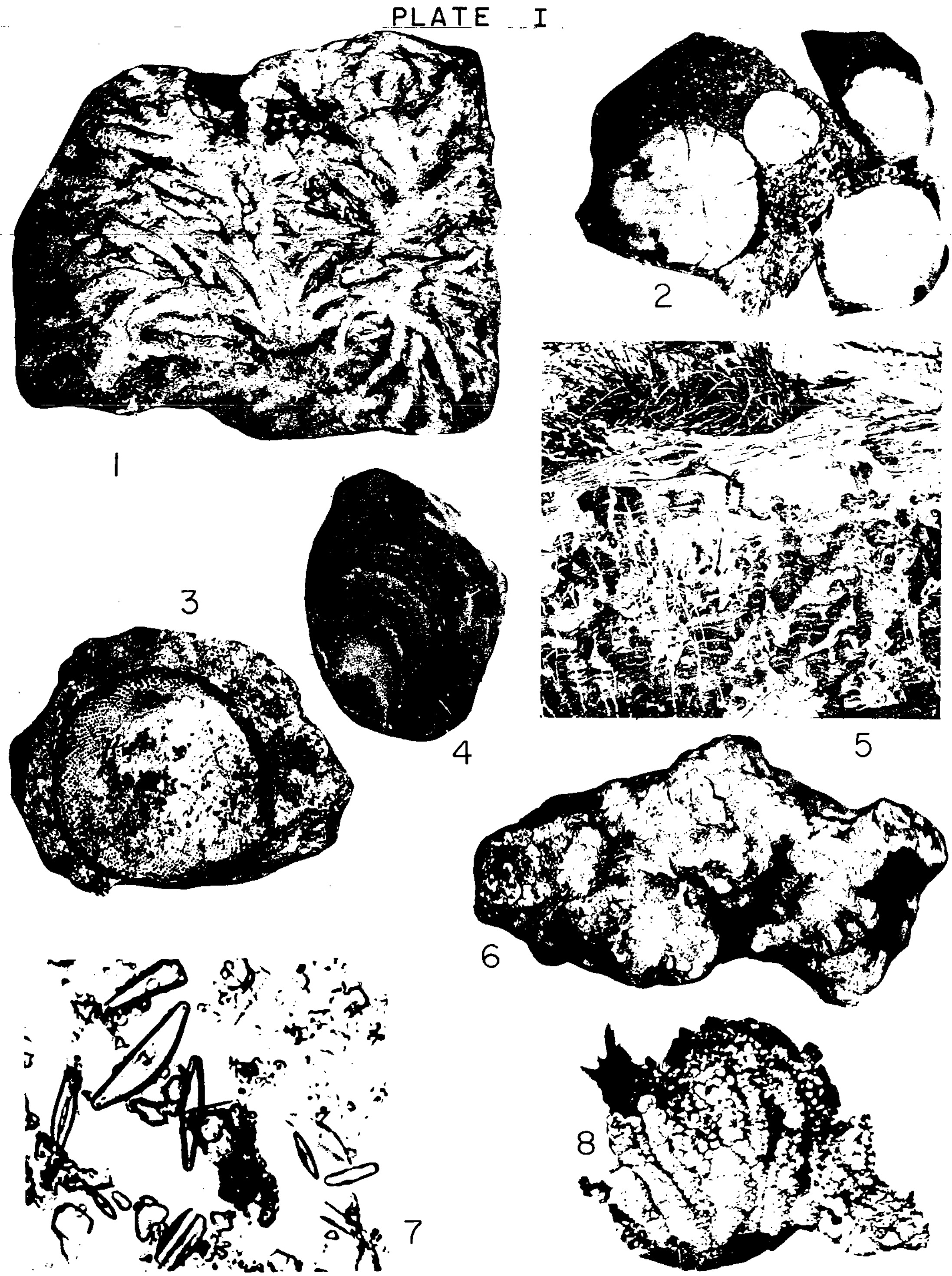


Plate I

Fossil algae and mosses from Oklahoma.

Figure 1. "Fucoids", Bromide Formation, Ordovician.
Figure 2. *Solenopora* cf. *compacta* (Billings). Top of the Simpson Group, Ordovician.
Figure 3. *Ischadites iowensis* Owen, Bromide Formation, Ordovician. This fossil was formerly thought to be a fossil sponge.
Figure 4. *Cryptozoon* cf. *proliferum* Hall. Upper Arbuckle Limestone, Ordovician.
Figure 5. *Collenella?*, Arbuckle Formation, Ordovician. Exposed below "Lookout" at Turner Falls.
Figure 6. Blue-green algae from the Morrison Formation, Jurassic.
Figure 7. Diatoms associated with travertine formation at Turner Falls, Pleistocene.
Figure 8. Mosses encrusted with travertine. Such structures occur in some of the oldest travertine deposits at Turner Falls, Pleistocene.

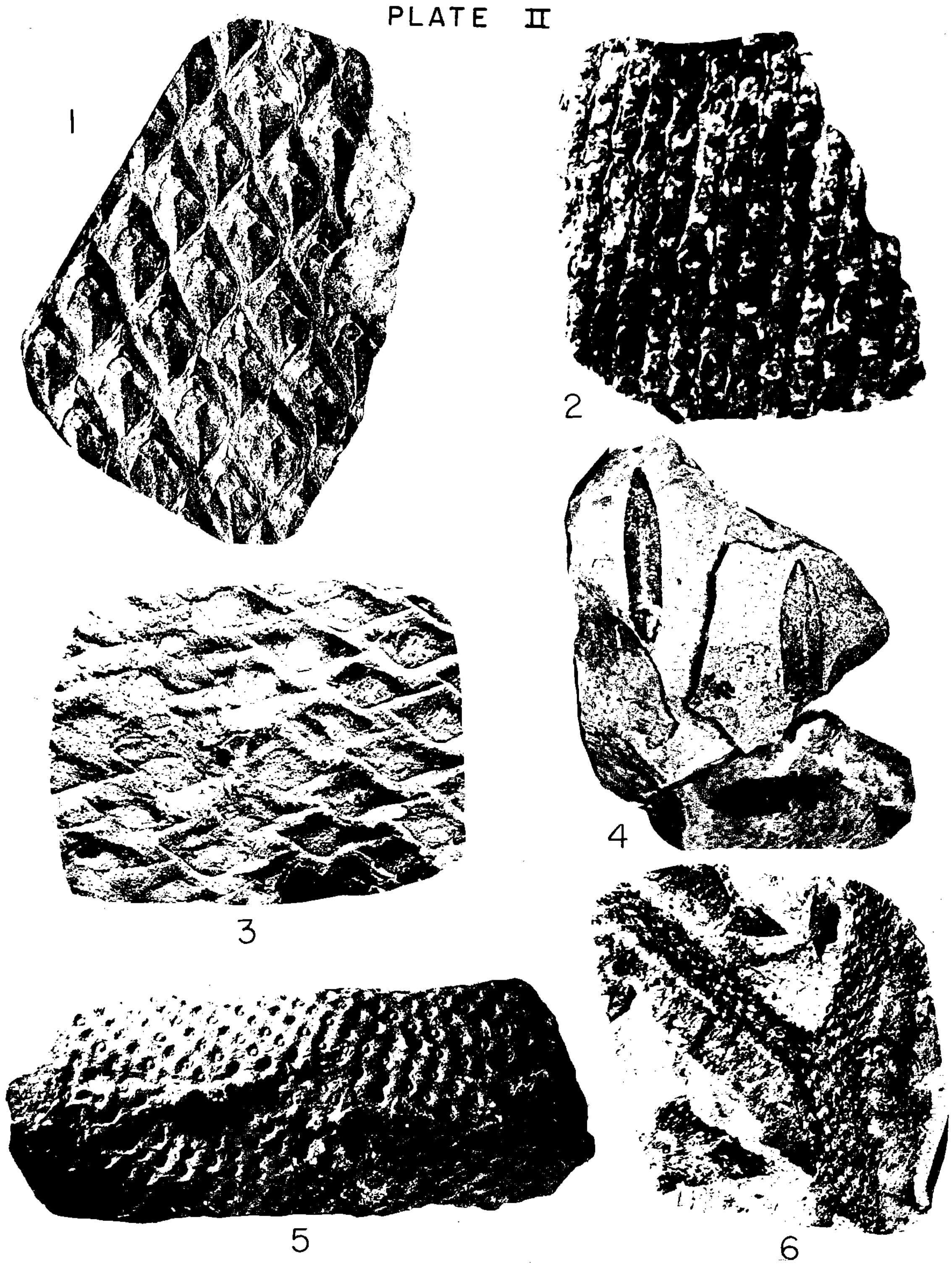


Plate II

Fossil Lycopsida from the Pennsylvanian rocks of Oklahoma.

Figure 1. *Lepidodendron aculeatum* Sternberg. Impression of bark showing leafbase scars.

Figure 2. *Sigillaria* sp. Impressions of bark showing leafbase scars.

Figure 3. *Lepidophloios* sp. Impression of bark showing leafbase scars.

Figure 4. *Lepidophyllum* sp. Leaves of *Lepidodendron*.

Figure 5. *Stigmaria ficoides* (Sternberg) Brongniart. Root of *Lepidodendron*, *Sigillaria*, and other arborescent Lycopsida, showing rootlet scars.

Figure 6. *Lepidodendron* sp. Branch showing leafbase scars.

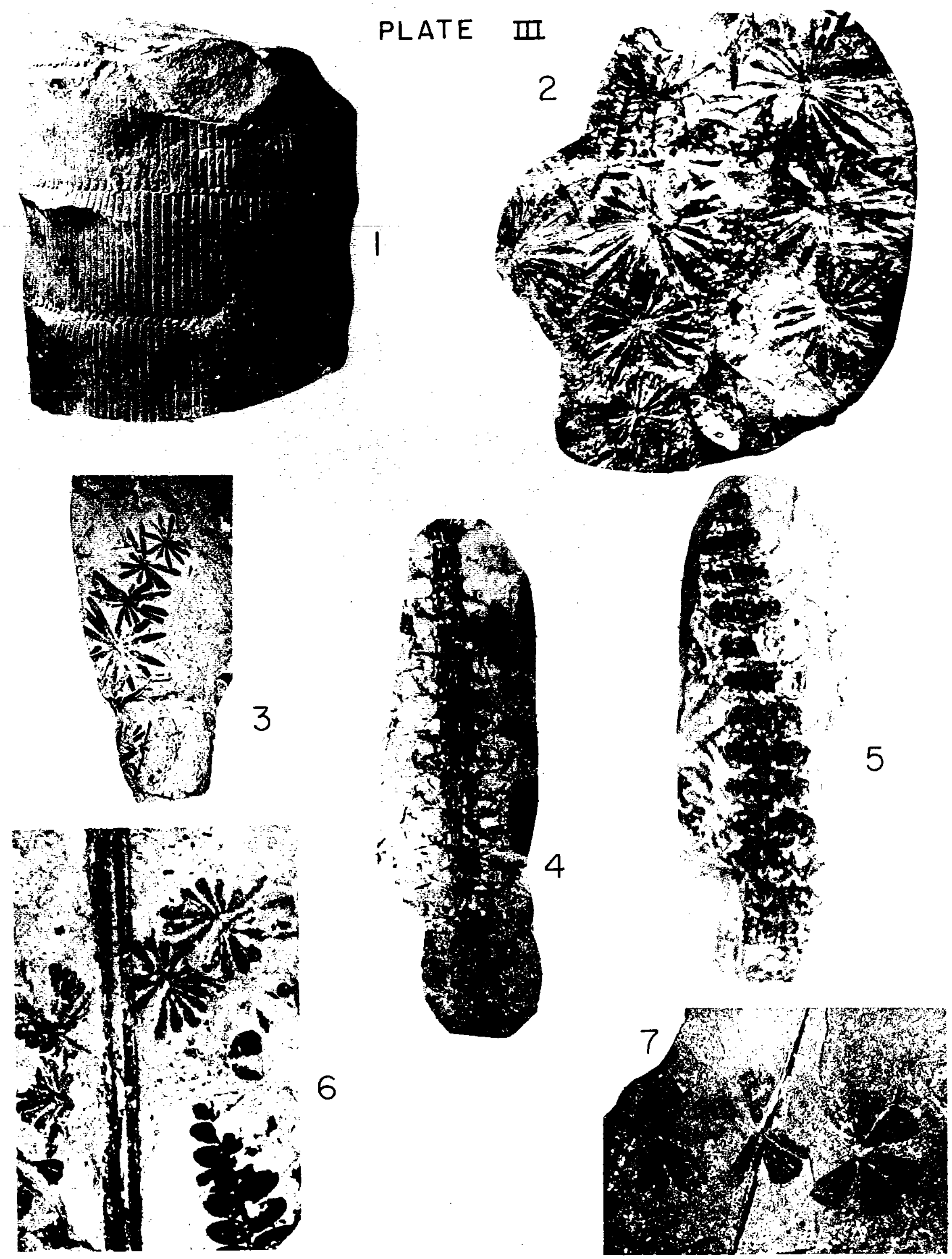


Plate III

Fossil Sphenopsida from the Pennsylvanian rocks of Oklahoma.

Figure 1. *Calamites suckowi* Brongniart. Internal cast of stem.
Figure 2. *Annularia stellata* (Schlotheim) wood. Leaves of *Calamites*.
Figure 3. *Annularia* sp. Leaves of *Calamites*.
Figure 4. *Cingularia* sp. *Calamites* branchlet?
Figure 5. *Calamostachys* sp. Cone of *Calamites?*
Figure 6. *Annularia sphenophylloides* (Zenker) Gutbier. Leaves of *Calamites*. The straplike leaf is *Lepidophyllum* and the "fern leaf" is *Neuropteris*.
Figure 7. *Sphenophyllum emarginatum* (Brongniart) Koenig.

Plate IV

Fossil Cordaitalean and fernlike leaves from the Pennsylvanian rocks of Oklahoma.

Figure 1. *Cordaianthus* cf. *gemmifer* Grand 'Eury. Two catkin-like structures on left. The fern is a species of *Pecopteris*.
Figure 2. *Cordaites* sp. Fragment of a leaf.
Figure 3. *Tripterospermum* sp. seed.
Figure 4. *Neuropteris* sp. Leaflet.
Figure 5. *Neuropteris* sp. Pinna or portion of a leaf.
Figure 6. *Pecopteris* sp. Portion of a leaf.
Figure 7. *Alethopteris serlii* (Brongniart) Goeppert. Portion of a leaf.
Figure 8. *Pecopteris* sp. A portion of a leaf.
Figure 9. *Trigonocarpus* sp. Seed of a Pteridosperm. (Seed-fern).

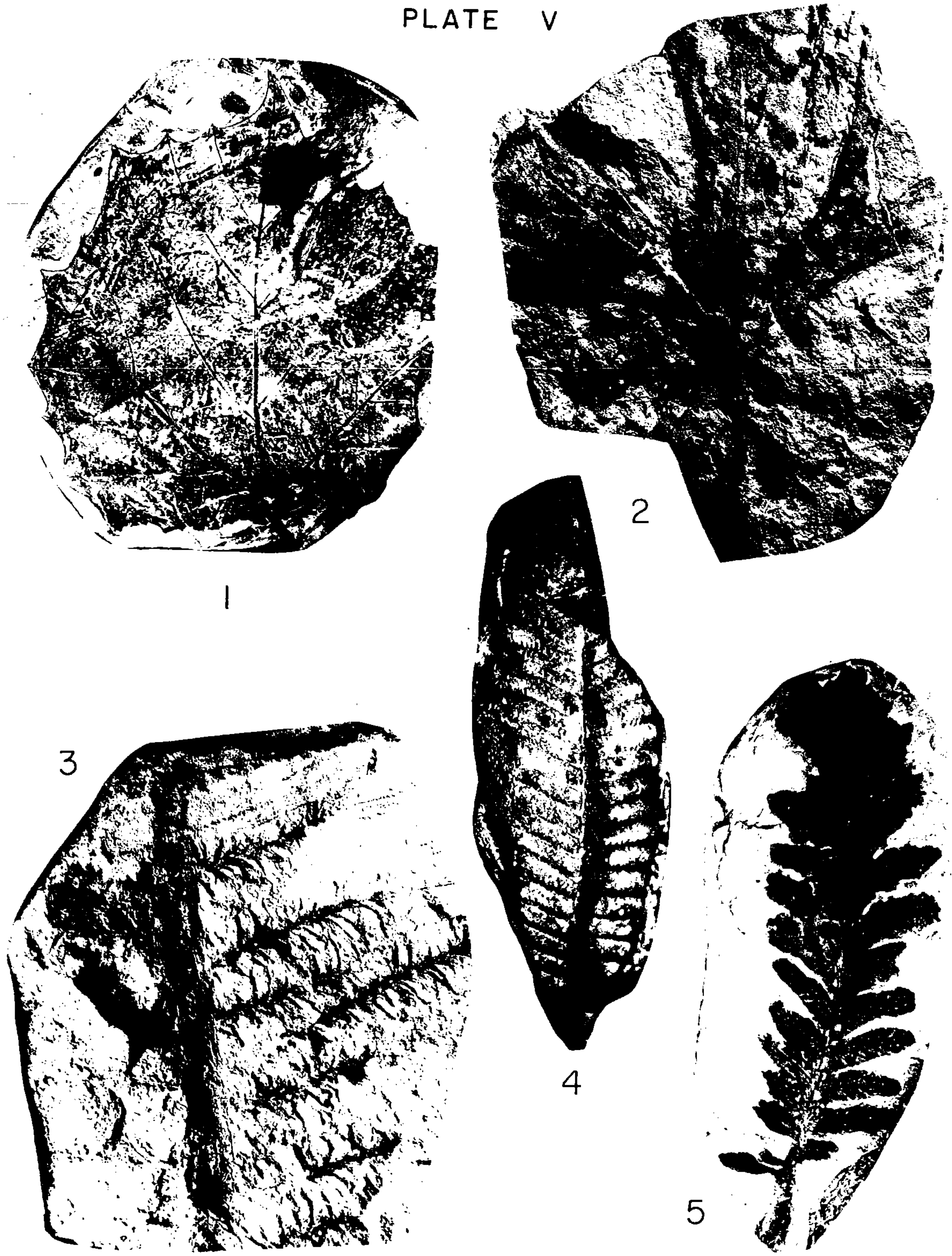


Plate V

Fossil plants from the Permian and Tertiary of Oklahoma.

Figure 1. *Platanus* sp., sycamore. Pliocene.
Figure 2. *Acerites* sp., maple. Pliocene.
Figure 3. *Walchia* sp., a conifer. Permian.
Figure 4. *Gigantopteris* sp., fern. Permian.
Figure 5. *Callipteridium* sp., fern. Permian.

The climate of the Pennsylvanian Period in Oklahoma and probably over much of the earth was tropical or subtropical. Evidence for this theory is the absence of seasonal growth rings in most of the Pennsylvanian fossil woods. There are, however, several reports of Pennsvlvanian tree trunks showing seasonal growth rings; one of these is by Goldring (1921), who described such a log from northern Oklahoma.

Fossil logs and wood fragments are abundant in some parts of the Pennsylvanian System of Oklahoma, but few last a great length of time after their exposure because many are petrified by the quick-weathering pyrite or calcium carbonate. Wood that is petrified by the process of silicification is resistant to weathering and may have excellently preserved cellular structure. One of the best examples of preserved cellular structure is the fossil wood of *Cordaites michiganensis* described by Tynan (1959) from a coal seam located near Beggs, Oklahoma. This species of *Cordaites* was originally observed in Michigan, and its occurrence in Oklahoma is an indication of the extensiveness of the Pennsylvanian forest species.

Another remarkable silicified log is located in the Wintersmith Park at Ada, Oklahoma. This log is a *Dadoxylon*, a cordaitelean, closely related to *Cordaites*, but whose internal structure is not well enough preserved to permit positive identification with that genus. The character that gives the Ada log its fame is the fact that it is the largest *Dadoxylon* known. It is 58 feet long and approximately 2 feet in diameter at the top end. Because neither end is preserved, its original length can only be estimated. A conservative guess might be that the tree was between 80 and 90 feet tall. A search has been made of paleobotanical records to determine if any larger specimen of Pennsylvanian tree exists. It was discovered that a tree of *Dadoxylon brandlingii* was found in a quarry near Newcastle, England, in 1831 which measured 78 feet long. Inquiries were made at the Hancock Museum in Newcastle and at the British Museum in London to determine if the log is still in existence. Information recently received from the British Museum indicates that the log was not preserved and all that remains of it are several microscope thin sections in the collection in London. Consequently the city of Ada possesses the largest known *Dadoxylon* log, and the people of Ada have taken steps to preserve it from destruction. They also are planning to place a bronze marker on it.

Some fossil logs and stumps are merely sand or clay casts of cavities left after the wood had been buried and decayed; however many of these are remarkably good replicas of the former tree parts. Probably the best known specimen of this type in Oklahoma is the fossil stump near the entrance to the grounds of the Rock Island railroad station at El Reno (Branson, 1958). This fossil was approximately 8 feet tall when first moved to El Reno and slightly more than 3 feet in diameter, but has suffered some subsequent destruction. The fossil is probably a species of *Lepidodendron*, but one cannot be certain because no bark markings are present. The roots have markings upon them which indicate that the tree was a lycopsid rather than a *Calamites* or a *Cordaites*. This specimen was moved to El Reno from 1 mile southeast of Alderson, Pittsburg County, Oklahoma. It was found March 14, 1914, at a depth of 40 feet in the No. 9 shaft of the Rock Island Coal Mining Company. The stratigraphic position of the fossil was in the basal part of the Savanna Formation or the upper part of the McAlester Formation.

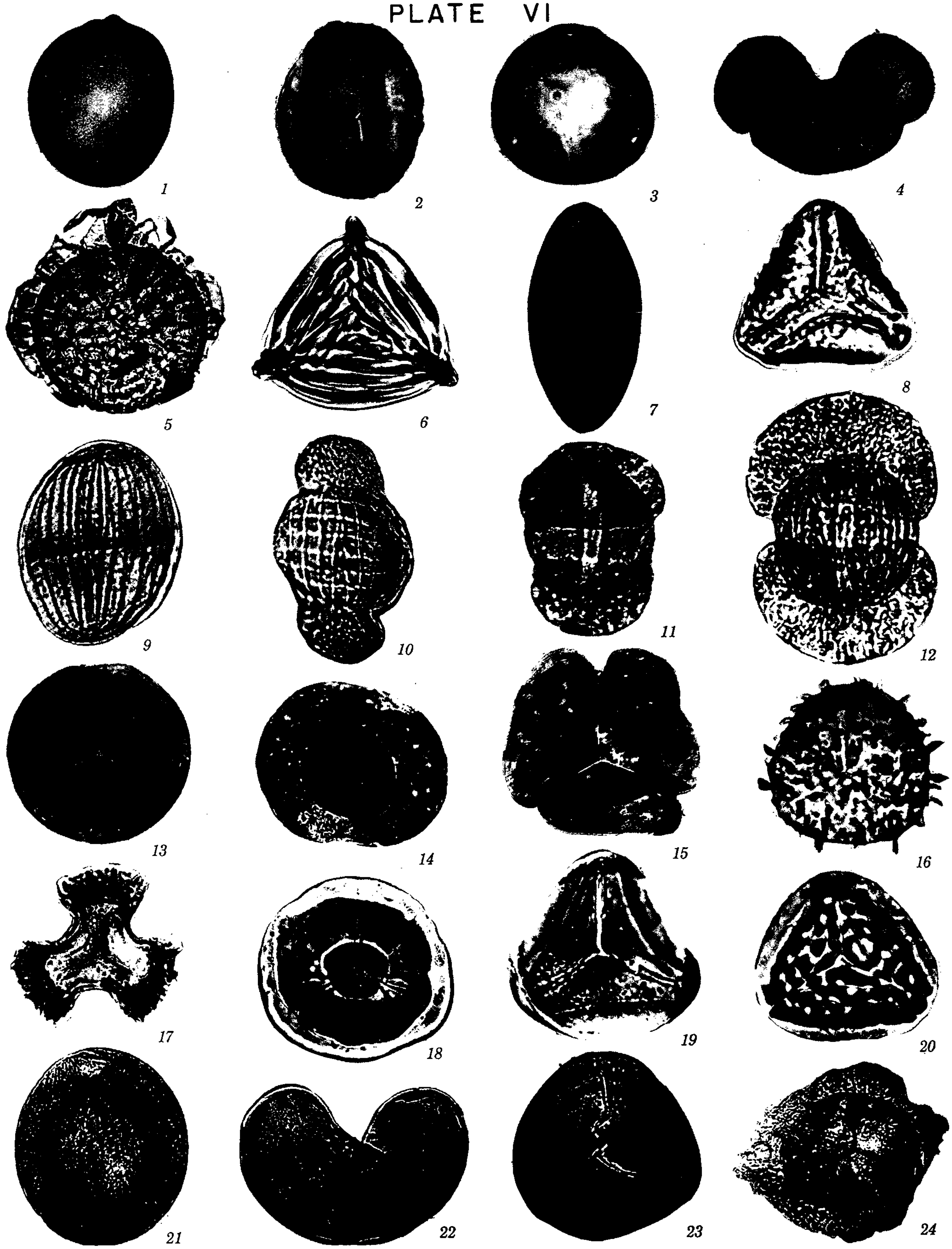
Although fossil leaves, stems, roots, and seeds are the more conspicuous plant remains in the Pennsylvanian rocks, it is from studies of the plant microfossils that we get the detailed history of coal swamps. When coal samples are studied microscopically, literally millions of fossil spores and pollen are commonly observed. If these samples are studied successively from the bottom to the top of a seam, the assemblages of microfossils are found to change in type and thus reveal the vegetational develop-

Plate VI *(opposite page)*

Characteristic plant microfossils from Paleozoic, Mesozoic, and Cenozoic rocks of Oklahoma.

Figures 1–4. Pleistocene
Figure 1. *Phleum* sp., 36 microns. Grass pollen.
Figure 2. *Quercus* sp., 34 microns. Oak pollen
Figure 3. *Carya* sp., 38 microns. Hickory pollen.
Figure 4. *Pinus* sp., 68 microns. Pine pollen.
Figures 5–8. Cretaceous
Figure 5. *Balmeisporites* cf. *B. glenelgensis* Cookson and Dettmann, 125 x 140 microns. Aquatic fern spore?
Figure 6. *Appendicisporites* cf. *A. tricornatus* Weyland and Greifeld, 48 x 50 microns. Fern spore.
Figure 7. *Schizosporis* cf. *S. parvus* Cookson and Dettmann, 36 x 75 microns. Fern spore?
Figure 8. *Gleicheniidites* sp., 32 x 33 microns. Fern spore.
Figures 9–12. Permian
Figure 9. *Vittatina costabilis* Wilson, 50 x 64 microns. Ephedran pollen?
Figure 10. *Hamiapollenites saccatus* Wilson, 43 x 71 microns. Gymnosperm pollen.
Figure 11. *Lueckisporites virkkiae* Potonié and Klaus, 34 x 59 microns. Conifer pollen.
Figure 12. *Strotersporites communis* Wilson, 88 x 128 microns. Conifer pollen.
Figures 13–16. Pennsylvanian
Figure 13. *Vestispora profunda* Wilson and Hoffmeister, 64 microns. Affinity unknown.
Figure 14. *Endosporites ornatus* Wilson and Coe, 112 microns. Lycopsid spore.
Figure 15. *Alatisporites* sp., 89 microns. Affinity unknown.
Figure 16. *Raistrickia* sp., 74 microns. Fern spore.
Figures 17–20. Mississippian
Figure 17. *Tripartites* sp., 32 x 32 microns. Fern spore?
Figure 18. *Knoxispora* sp., 52 x 53 microns. Fern spore?
Figure 19. *Rotaspora* sp., 56 x 56 microns. Fern spore?
Figure 20. *Savitrisporites* sp., 39 x 40 microns. Fern spore?
Figures 21–24. Devonian
Figure 21. *Tasmanites* sp., 272 x 339 microns. Alga.
Figure 22. *Quisquilites buckhornensis* Wilson and Urban, 52 x 108 microns. Alga.
Figure 23. *Hymenozonotriletes* sp., 57 x 57 microns. Fern spore?
Figure 24. *Hymenozonotriletes* sp., 48 x 57 microns. Fern spore?

PLATE VI



Text-figure 2. Oklahoma's oldest known fossil tree, *Callixylon whiteanum*, from the Woodford Formation of Devonian age. It is at least 350 million years old and is representative of the first forest trees of the world. Pieces of the tree were replaced by flinty silica that preserved the wood structure in great detail, so that the fragments could be reconstructed as shown. Picture taken at the entrance to East Central State College, Ada, Oklahoma.

ment that took place in the coal swamp. The same technique is used in the study of Recent peat deposits to reveal their history and that of the surrounding forests. Pollen from the upland is blown by the winds into the swamps where it settles on the peat and is preserved. An analysis of the microfossil assemblages indicates that many Pennsylvanian swamps began with a fern type of vegetation. As the peat accumulated, a clubmoss community became dominant, and this was succeeded by cordaitelean trees and other plants of similar growth habit. In a number of coal seams the spore assemblage changes abruptly at the top and becomes dominated by a spore known as *Densosporites*. This spore may be from an herbaceous type of clubmoss. The abruptness of the spore assemblage change and its close association with marine sediments that covered the coal swamp suggests that *Densosporites*, in part, may represent a plant community of strand line type. Not all coal seams contain the complete spore and pollen succession outlined above. There are indications that in some cases retrogression occurred after the second stage and that there was a return of the initial type of vegetation before the swamp was inundated by the rise of the sea level. These fluctuations in spore associations may provide valuable information regarding the instability of the Pennsylvanian coast lines when further studies have been completed. At present, the sequences of microfossil succession are serving as stratigraphic criteria for the identification of coal seams over short areal distances.

Permian Period

The extensive redbeds of Oklahoma contain a rather meager plant megafossil flora, but locally these may be abundant. The best specimens have been discovered in the Oklahoma City area and northward toward the Kansas state line. Probably the best known are *Walchia*, a conifer (Plate V, Figure 3), *Gigantopteris* (Plate V, Figure 4), and *Callipteridium* (Plate V, Figure 5). The last two were fern-like plants and suggest a swamp environment, whereas the first probably grew on the swamp borders and on the upland where, in favorable habitats, it formed forests. The abundance of red shales, red sandstones, salt, and gypsum deposits in Oklahoma strongly suggests a climate that was warm and dry, possibly of a desert type. However, the local abundance of fossil plants indicates that, at least near some of the Permian shore lines, there were conditions that permitted the growth of plants with tropical or subtropical characteristics. The conifers were many and varied, as is indicated by the abundance of pollen present in the Flowerpot and Blaine Shales (Wilson, 1962). Several of these pollen types are illustrated on Plate VI, Figures 9–12. In this assemblage of plant microfossils are pollen grains belonging to the Ephedraceae, a family of gymnosperms that exists today mainly in desert regions. Fern and other spores that also occur in the shale suggest the presence of coastal swamps adjacent to the conifer forests. The discovery of these palynological fossils in rocks of Oklahoma will lead to a better understanding of Permian stratigraphy because many of the same types of spores and pollen occur in the German, Indian, Australian, Russian, and African deposits of near and similar ages.

Triassic Period

The Triassic rocks of Oklahoma crop out in a limited area in Cimarron County near Black Mesa. These are known as the Docum Group, and although they are finely stratified green, brown, and red shales, they have not yielded plant fossils of any type. Although no Triassic plant fossils are presently known from Oklahoma, the vegetation of the State during that time was probably similar to that of the Permian in abundance of conifers because these seem to have dominated the world flora. The most complete representation of Triassic plants near Oklahoma is in the Petrified Forest of Arizona. Here the dominant vegetation appears to have been coniferous, but other elements such as ferns and ephedrans were also present. The latter are indicated by the presence of spores and pollen grains in the shales.

Jurassic Period

Jurassic rocks in Oklahoma, like those of the Triassic, crop out in the Panhandle region. These are sandstones, shales, and some limestones belonging to the Exeter and Morrison Formations.

Plant fossils are not known to be abundant in the Morrison rocks of Oklahoma, but further exploration should reveal considerably more because some of the deposits are fresh-water lake sediments. Oogonia of two species of Charaphytes, a fresh-water alga, have been found, and near Black Mesa other algae occur as massive structures in the limestones (Plate I, Figure 6). Silicified wood fragments are common in some areas, but all appear to lack cellular structures necessary for identification. Small unidentified fragments of roots, stems, and a few small leaves have been reported by Stovall (1943, p. 70). The Morrison Formation of Oklahoma has also yielded fossils of dinosaurs, crocodiles, turtles, fish, ostracodes, and gastropods. The occurrence of this rich fossil fauna in the Morrison Formation should make the discovery of an equally rich fossil flora an assured fact.

Cretaceous Period

The Cretaceous Period begins the rise of the modern floras. Just as abruptly as did the first of Oklahoma's land floras appear in the Devonian rocks, so the first of Oklahoma's angiosperm (flowering plants) floras appeared. The Devonian land plants were already highly evolved forms when they first appeared and indicate an ancestry of great antiquity. Also, the first angiosperms are advanced types and indicate a longer ancestry than is known from the rocks. The place and time of origin of the angiosperms is one of the mysteries of paleobotany. In recent years evidence has been accumulating which suggests that the angiosperms possibly have evolved in a tropical climate and are as ancient as Triassic or earlier time.

The Cretaceous floras of Oklahoma consist of many tropical ferns, cycads, conifers, and angiosperms. These fossils are known from the rocks of the Dakota Group in western Oklahoma and the Woodbine Formation of the southern part of the State. When other Cretaceous deposits of Oklahoma are studied for plant fossils, a great wealth of information about the Cretaceous time can be expected.

The plant megafossils from southern Oklahoma, at present, consist of coalified logs and a few leaf impressions. Many more specimens should be found and these will complement the palynological discoveries by adding species to the flora that are not normally encountered as pollen grains.

The Dakota angiosperm megafossils of Cimarron County were described by Noe (1925). He reported one species of monocotyledon, five species of dicotyledons, and some unidentified seeds and branches. The dicotyledons are *Salix* (willow), *Quercus* (oak), *Platanus* (sycamore), and two species of *Sterculia* (varnish tree). The Dakota flora is one of the richest Cretaceous floras of North America and probably of the world. It consists of more than 500 species in the following natural plant groups: 7 species of ferns, 10 cycads, 15 conifers, and the remainder are angiosperms. Many genera of these angiosperms are living today but in reduced number of species. For example, in Dakota time there were 11 species of tulip trees and 12 species of sassafras, whereas today there is one species of each. A few other genera represented in the Dakota flora are as follows: 8 species of willows, 18 poplars, 20 oaks, 10 magnolias, 7 hollies, 23 figs, 7 persimmons, and more than 12 azaleas. This flora reached as far north as Greenland and as far south as central Argentina. The palynology of the Dakota Group is poorly known. Potter (1963) has recently described the palynology of an Oklahoma coal seam in the top of the Omadi Formation of Cimarron County and reported a larger number of tropical ferns and conifers than is known to be present from the Dakota Formation megafossils.

The palynology of the Upper Cretaceous Woodbine Formation in Bryan County, Oklahoma, described by Hedlund (1962) reveals a large number of tropical fern species, a few conifer, and angiosperm pollen grains. Some of these microfossils are illustrated on Plate VI, Figures 5–8.

Tertiary Period

At the close of the Cretaceous Period the Mesozoic Era came to an end. At this time the earth experienced extensive mountain building, continental uplift, withdrawal of the seas from the continents, climatic changes, and great migrations of faunas and floras which resulted in the extinction of many plant and animal species. These changes were all a part of the Laramide Revolution, but it must not be construed that they took place within a short period of time. The revolution should be thought of as the cumulative effects over several million years of structural unrest which was probably not much more intensive than is presently taking place.

Plant and animal communities always exist in sensitive balance to their environments. The change of any ecological factor will cause others to be influenced, and the biology of the plant and animal community will in turn be affected. This will result in changes in the composition of the communities by an increase or decrease in the number of organisms and species. If the species living under unfavorable conditions can move to a more equable environment, they will migrate; but if that is not possible, they will become locally or entirely extinct. The history of the dinosaurs and many other forms terminated during the worldwide diastrophic activity which marks the close of the Cretaceous Period. Those species with considerable adaptability then became the dominant forms of the Tertiary. In the animal kingdom the mammals and the insects rose rapidly to places of importance, and in the plant kingdom the herbaceous angiosperms invaded and partially dominated nearly every terrestrial and numerous aquatic environments. At about this time certain insects and angiosperm plants became mutually associated, and insect pollination replaced wind pollination to a great extent. This relationship further aided the evolution of plant life, and many complex and specialized floral structures developed. The changes were not all within the plant kingdom: The insects, too, developed structural adaptations, and the bees, ants, and wasps developed social organization with highly specialized functions for their members. It appears also that parasitism attained new complexities in the Tertiary, with the life cycles of many parasitic organisms becoming intimately related to the life cycles of more than one host. Marked increase in the abundance of certain fungus spores in the Upper Cretaceous and Tertiary rocks is evidence of the complex nature of these parasites. The evolutionary problems of the Tertiary are many and are more geological in background than has been commonly recognized.

During the Paleocene time, the earliest epoch of the Tertiary Period, the climate was cooler than just previous in the Cretaceous Period. The continent of North America stood higher above the seas and consequently the climate would be more varied. In the north were floras different from those in the south, and the fossil record is not as extensive as in the Cretaceous. Oklahoma appears to be without Paleocene sediments because, as an area, it was undergoing erosion and therefore would normally be without fossil deposits. However, adjacent to Oklahoma, in Arkansas and Missouri, are deposits of the Midway Formation, which contain an abundance of fossil spores and pollen. Also, to the west, in Colorado, are other Paleocene deposits containing similar fossils. From these it is reasonable to assume that Oklahoma had an abundant vegetation of a warm-moist type. Cypress swamps with subtropical ferns and lowland forests containing oak, hickory, and many unidentified angiosperms and some pines could have been the typical vegetation of Oklahoma in early Tertiary time.

Evidence secured from fossil plants and animals of Texas, Arkansas, and Alabama indicate that the climate of the Eocene became warmer and probably more subtropical than during the Paleocene (Berry, 1917; Ball, 1931; Sharp, 1951; Wodehouse, 1933). Palms, tropical ferns, figs, and many southern hardwood tree species are found as megafossils. Fossil spores and pollen, too, are abundant and corroborate other paleontologic evidence. Oklahoma has no recognized Eocene deposits, but the fossil plant remains south, east, northwest, and west of the State are of subtropical to warm-temperate types; therefore we may conclude that here too were similar floral assemblages.

The Oligocene–Miocene floras are also lacking in Oklahoma but are abundant in Texas and Colorado. These suggest a cooler climate but warm-temperate types are still abundant.

In the Panhandle of Oklahoma and in Kansas are extensive Pliocene deposits which contain fossil leaf impressions and amazing quantities of seeds in fluvial sediments. The leaves are of cool- to warm-temperate trees (Berry, 1918), and the seeds are of the plains type of grasses and other plants (Chaney and Elias, 1936). During the Pliocene, the Great Plains were beginning to take on the floristic aspect of the present, but this was interrupted several times during the next geologic epoch.

Pleistocene Palynology

The Pleistocene covers an estimated one million years; this is 1/70 ± 2 million years of the Cenozoic, the era to which the Pleistocene is assigned. "Pleistocene" means *most recent* and includes the present as well as glacial time. By some geologists the postglacial time is called the Recent, and by others it is the first period of the Psycozoic Era. Regardless of terminology, we are dealing here with the events that began approximately one million years ago. These cover four stages of glaciation, three recognized interglacial stages, and a postglacial time (the Recent) that may or may not be an interglacial stage.

The boundary between the Pliocene and the Pleistocene is nowhere marked except possibly in some marine deposits (Ericson and others, 1963). Most sedimentary deposits that are supposedly continuous across this time boundary show no stratigraphic break. Most paleontology is inconclusive and transitional from one epoch into the other. The one feature of the Pleistocene that separates it from the Pliocene is the event of extensive glaciation. At its maximum, glacial ice covered 32% of the earth's land, affected another 10% with outwash and fluvial deposits, and caused a drop of several degrees Fahrenheit in the average temperature over the earth. However, glaciation spread slowly and was restricted to limited areas; thus it could not cause a physical or biotic change that would be recognized on all parts of the earth. Only at the height of a glacial stage would the maximum effect of a glacial climate be felt. Nevertheless, probably the best criterion for recognizing the Pleistocene Epoch is the climatic change which brought about glaciation and which, in turn, affected physical geology and faunal and floral distribution. The cause or causes of glaciation are still being speculated and need not be reviewed here. However, the important physical events of the Pleistocene were rise of the youngest mountains, general uplift of the continents, and active volcanism. These events disrupted faunal and floral communities, caused migration, and possibly, through isolation of areas, brought about extinction of some biotic elements. These changes evolved slowly and probably at no greater speed than the mountain building, volcanic activity, and climatic shifts now in progress.

The world stratigraphy of the Pleistocene is still not firmly established, and in the table below only that of North America and Europe are compared.

Central North America	Alps
Wisconsin Glacial	Würm Glacial
Sangamon Interglacial	Riss/Würm Interglacial
Illinoian Glacial	Riss Glacial
Yarmouth Interglacial	Mindel/Riss Interglacial
Kansan Glacial	Mindel Glacial
Aftonian Interglacial	Günz/Mindel Interglacial
Nebraskan Glacial	Günz Glacial

At the present time we recognize certain large aspects of plant distribution. These plant assemblages are roughly tropical, subtropical, temperate, and boreal. Their recognition is important in paleobotany as well as in the field of palynology, for each has an historical background and these backgrounds did not begin with the Pleistocene. A general summation of these problems may be stated as follows:

1. The present distribution of floras is a reflection of their climatic requirements and their historical migrations.

2. Each flora is made up of elements whose origin dates from certain geological periods. The following elements are part of the present floral composition but are the evolved forms: Bryophytes (Silurian or older), Lycopsids (Devonian or older), Sphenopsids (Devonian or older), Filicineae (Devonian or older), conifers (Mississippian or older), and angiosperms (Jurassic or older).

3. Composition of Pleistocene palynological deposits varies with geography, climate, and historical events.

Oklahoma's Pleistocene vegetation can be considered almost nomadic in nature, for it has been actively on the move for most of the epoch. Although the southernmost extention of the glaciers did not come closer than northern Missouri, the influences have been felt in the State. Temperatures dropped to about the average of northern Minnesota, rainfall was greater, the rivers transversing the State from west to east carried great loads of gravel, sand, and clay, and the forests with their animal inhabitants were of more northern aspects.

The distribution of the four glacial drifts indicates that at least that many times there were major migrations southward, and between each glacial stage the forests returned northward. Peat in Florida and Texas, of at least Wisconsin age, contains pollen of spruce and fir in the lowest levels of the deposits, and much of the Oklahoma blue clay, generally associated with elephant bones, contains the same northern tree pollen. These deposits are probably all proglacial in age, and the pollen indicates that the northern coniferous forests had been forced southward into Texas and farther. Oklahoma's forests contained spruce, fir, pine, and northern hardwoods during the proglacial times, and it is quite reasonable to assume that the vegetation types during the interglacial stages were grasslands, oak-hickory, and pine forests, of which the present is a good example.

No interglacial deposits containing plant fossils are known in Oklahoma; consequently it is necessary to refer to deposits in Missouri, Iowa, Minnesota, Wisconsin, and Illinois for information. Those interglacial deposits contain northern forest species, but also many contain oak, elm, and hickory pollen. Assemblages of forest trees like the last three indicate a climate not greatly different from the present in northeastern Oklahoma. One of the difficulties that arises when comparing the vegetation of the interglacial stages is the great difference in the duration of these and that of Recent or postglacial time. Various estimates place the last retreat of the glacial ice from the United States as somewhere between 12,000 to 10,000 years ago or even less. Whatever is the correct estimate, postglacial time is recognized as only a fraction of that of other stages when one learns that the Aftonian interglacial stage is estimated to have lasted 200,000 years, the Yarmouth 300,000 years, and the Sagamon 120,000 years. Fluctuations of climate and details of vegetation history during the entire time of these earlier stages have not been determined, and it may not be possible to do so from the known deposits.

The history of Oklahoma's vegetation during the last 10,000 years, or slightly more, may be outlined as follows. While the last Wisconsin glacial ice lay to the north, possibly in Iowa, forests of spruce, pine, and a few northern hardwoods covered the State. Prairies were probably nonexistent in Oklahoma at that time. When the Wisconsin glacial ice retreated from the United States, the spruce-pine forests migrated north of Oklahoma and oak, hickory, elm, maple, and the southern pines covered the State. Prairies began to enter Oklahoma from the southwest and spread northeastward. The forest trees also spread northward except in certain favorable physiographic areas, where they remained and became the isolated plant communities such as are now present in the Caddo Canyons. The northeastward spread of the prairies continued until several thousand years ago, just before the climate began to change toward cooler and more moist conditions. The height of climatic temperature occurred approximately 3,000–4,000 years ago and is variously named. Some of these names are "Climatic optimum," "Xerothermic period," and "Hypsithermal." This event is recognized in nearly all parts of the world, and in Oklahoma the fact that some of the soils appear to be out of phase with the climate is taken as evidence that warmer temperatures occurred in postglacial time. It is conceivable that much of Oklahoma during this "xeric" period was semi-desert and that the vegetation was largely long grass, short grass, and cactus with here and there some relicts of the earlier vegetation growing in favorably protected areas. With the return to cooler temperatures and greater moisture, the migrations of the plants and the animals were reversed. These migrations are apparently still in process and will continue toward forest development as long as the present climatic trend exists. Oklahoma is presently a great complex of vegetation because it is the transition area between the southern and northerm plains and prairie vegetation in the central and western parts of the State, the transition area between the prairie grasses and mixed hardwood forests in northeastern Oklahoma, and the Coastal Plain vegetation of cypress and palmetto in the southeast corner.

One final chapter in Oklahoma's history of vegetation includes man, because he has been responsible for the destruction of the natural sod and the invasion of many weed species. It is unnecessry to dwell upon man's part in the development of Oklahoma's dustbowl of the 1930s other than to cite this as part of the human influence. Man's part in accelerating plant evolution is more theoretical than is his part in the destruction of natural plant communities, but it is also a part of the latter activity. One of the recognized factors in the evolution of organisms is the appearance of "new ground" and unpopulated areas. In the geologic past, such areas appeared with the drop of sea level, extensive volcanism, erosion, deposition, and glaciation. When these geological processes are accompanied by changes of climate and are of considerable duration, then floral and faunal migrations occur and genetic mixing, isolation, and adaptations develop which result in new and aggressive biotic elements. In the last million or more years there have been four glacial stages and intervening interglacial stages, great climatic changes, rising and falling of the sea levels, and volcanism. Finally, man has come into the geologic picture as a disturber of natural habitats and the seed bearer of the youngest and most aggressive vegetation, the so-called weeds. When these plants which appear to have evolved in the Late Tertiary compete for "new ground" with the older or native vegetation, they dominate and smother all other types. The inference that may be gathered from this is that the weeds represent the vegetation of the future. The following facetious verse subtly indicates why:

"Roses are red and violets are blue,
But they don't get around like dandelions do."

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Experiments in Geologic Processes for Earth Science Teachers

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INTRODUCTION

Laboratory exercises in solid earth science (geology and geophysics) should serve as preparation for actual field studies or as analogies to processes that cannot be readily or easily observed in the field. Manuals of laboratory exercises abound for college-level courses. The laboratory exercises focus mostly on teaching standard methods (reading geologic maps, learning minerals and rocks, etc.) that a practicing geologist or geophysicist must know. Such laboratory manuals that cater to college courses in solid earth science, therefore, tend to be full of necessary but sometimes dull exercises. Most K–12 teachers of solid earth science need but a few laboratory exercises that have the following attributes: easy to prepare and conduct by individuals or small groups; inexpensive; quick to execute with predictable results; safe; and perhaps most important, engaging and fun for the students. Novel experiments for older students, in high school and college, can infuse a course with more interesting activities than the conventional lab exercises.

We present here a few laboratory exercises that we have conducted for K–12 and college students that illustrate some important aspects of solid earth science, that are quick, easy (relatively but variably) inexpensive, safe with normal precautions, and fun (as evidenced by student responses). This is by no means an exhaustive or complete list of exercises. They stem mostly from our own individual expertise and experiences. As we devise others, or learn from K–12 teachers of their own experiments, we hope to expand this into a thorough compilation of methods and applications.

EXPERIMENTS IN EARTH SCIENCE FOR PUBLIC SCHOOL TEACHERS

The ten earth science experiments presented in this article are designed to introduce younger students to their natural surroundings and encourage their curiosity about the planet we live on. These activities are designed so that a student will make closer, keener observations and develop his or her deductive reasoning abilities.

Matter

Part I. The student examines salt crystals with a hand lens and then dissolves the salt in a small pan of water. The solution is heated or allowed to evaporate over several days. The remains are examined and compared to the salt before it was dissolved in the water. A before-and-after data table is useful to collect this information and to make comparisons. The student should also describe the differences observed.

Result. After dissolving and recrystallizing, the salt crystals will be smaller, but they will have the same shape as before dissolving—a cube.

Part II. The student looks at a piece of granite, some crushed granite, and some quartz sand. On a data table, the similarities and differences are listed. The teacher's questions should include, Are any of the sand grains similar to any of the granite fragments? How is the salt similar to the sand? How is it different? What would happen to the sand if it was put into water? How can the words *element, mineral, compound, solution, mixture, crystal,* and *rock* be applied to these two activities?

Result. The sand grains are the same as the white (or grayish white), glassy quartz crystals of the granite. The salt grains and the sand grains are both white and have the form of crystals, although their shapes are different. (These facts may not be obvious to the student as the sand grains may be rounded and/or have yellow staining.) The salt will dissolve in water, but the sand will not.

What's the Matter?

Matter is anything that has mass and occupies space. Matter includes all known materials: elements, mixtures, chemical compounds.

The *mass* of an object is the amount of matter it contains. To find how much mass an object has is easy: just weigh it.

The *volume* of a object is the amount of space it occupies. The volume of an object can be found by multiplying the measurement of its length by the measurement of its

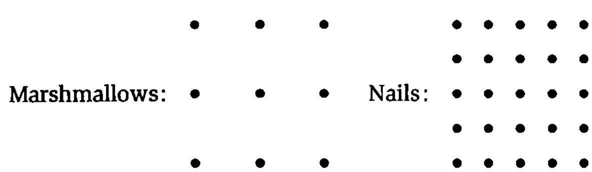
Egger, C.; and London, D., 1996, Experiments in geologic processes for earth science teachers, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 97–102.

width times the measurement of its height, if the object has smooth sides that can be measured. If the object is an irregular shape, such as a rock, its volume can be measured by dropping it into a graduated cylinder of water and observing the increased water level. (Remember, 1 mL is the same as 1 cm^3.)

The mass and the volume are both needed to calculate the *density* of an object. Dividing the volume into the mass yields the density:

$$\frac{\text{Mass (in grams)}}{\text{Volume (in cubic centimeters)}} = \text{Density (in grams per cubic centimeter)}$$

To practice measuring and calculating density, the student may use the following items: a block of wood, a marble, a rock, a ball bearing, etc. The teacher can convey differences in density by asking the class which is more dense—a pound of marshmallows or a pound of nails? They both weigh the same, but the marshmallows occupy more space. What does this mean? The teacher can "draw" an explanation of the density of the marshmallows and the nails by using dots to represent their internal structures:



The teacher can demonstrate a 500 mL graduated cylinder carefully and very slowly filled (by maintaining smooth, laminar flow down the cylinder side) with different colored liquids, each with a different density: clear water, yellow salad oil, brown corn syrup, red alcohol, and blue salt water. These liquids will layer themselves according to the density of each substance. Another colorful demonstration of density differences is a bottle with blue water and yellow salad oil: shake these liquids together until both are mixed and then allow the mixture to separate.

There are many toys and items sold commercially that demonstrate the concept of density, such as a lava lamp, a "Magic Window" filled with two different colors of "sand," or colored droplets falling one at a time through another liquid (glycerin?) or making waves as they rock back and forth.

The density of water can be calculated. The student weighs a known volume of water in a beaker and subtracts the weight of the beaker from the total weight so that the weight is only for the water. What is the density of water? (1 g/cm^3 = 1 g/mL at 4 °C.) This value is important to know because scientists often compare the density of an object to that of a standard substance—typically, water. *Specific gravity* is the ratio between the mass of some substance and the mass of an equal volume of water. It tells whether a substance is heavier or lighter than water and is a convenient property for comparison of various substances. Specific gravity is especially useful in mineral identification.

Sink or Float

The student constructs a flat-bottomed boat from a 10 cm square of aluminum foil. The boat is floated in fresh water; the student makes a mark indicating the level of the water surface on the side of the boat as it floats. Fresh water is then added to the boat, drop by drop, until it sinks. The student counts the number of drops used to sink the boat.

Then the procedure is repeated, except this time the student floats the boat in brine instead of in fresh water. Which substance did the boat float higher in? Did it take more drops of fresh water to sink the boat when it was floating in fresh water or in brine? (The brine, because it is more dense.)

After completing both the fresh-water and brine tests, the student folds the aluminum boat into a compact square and drops it into the fresh water and then into the brine. What happens? (The aluminum square sinks.) Why? (It is more dense than the water.) Why didn't the aluminum sink when it was a boat? (The shape allowed air to occupy part of the volume of the boat, enabling it to float.) The student should explain his or her results.

Crystal-growing Activity

Crystals are solid bodies with atomic patterns that have been repeated until the resulting accumulation is large enough to be seen. The student will create crystals at home and describe their growth and shape. Here is the procedure:

Dissolve two cups of sugar into one cup of boiling water. Pour the solution into a small jar. Suspend a thread from a stick placed across the jar's mouth. On the bottom of the thread, tie a heavy plastic button, sugar cube, etc. Place the thread into the solution so that it does not touch the bottom or sides of the jar. Let the solution cool slowly for 24 hours, then examine it. Reexamine the experiment once each day for one week, noting the growth of the crystals. What has caused the crystals to grow (or not to grow)? This same process can be used to grow other types of crystals, such as salt, Epsom salts, copper sulfate, etc. What crystal shapes have been formed?

Result. The crystals grew from a supersaturated solution of sugar or other compound because of slow cooling in a largely undisturbed environment. The atoms arranged themselves in a definite pattern over and over again until the accumulation that they formed was big enough to see.

What Do Mineral Crystals Look Like?

This activity will help to reinforce the student's understanding of the six different crystal systems. The student constructs crystal-system models and then compares the models to actual mineral samples. Straws, toothpicks, tinker toys, model kits, etc., may be used for the construction of the crystal systems. The student will use as a guide the one-dimensional diagrams from textbooks or a printed worksheet to construct a three-dimensional crystal shape. Then the student is given a group of crystals, such as quartz, calcite, halite, etc., and asked to place them next to the correct model that has just been constructed. Can the student see how the axes give the crystal its shape? Then the student should place each crystal on a sheet of paper and trace around it. The crystal axes should then be drawn in on each of the tracings, and the appropriate crystal system should be added as a label.

Result. The student uses two-dimensional (2-D) diagrams to construct three-dimensional (3-D) models and then compares the actual 3-D crystals to the models. After matching the crystals to the correct models, the process of tracing the crystal and drawing the axes reduces the crystals to 2-D again. Not all crystals are perfect examples of their crystal system, but using the best ones available will help the student have success.

Find a Mineral

This activity uses a kit from Ward's Natural Science Establishment (1996; see the reference at the end of this article).

The student is given a cupful of gravel composed of quartz, feldspar, mica, sulfur, calcite, apatite, fluorite, galena, garnet, hematite, magnetite, pyrite, and talc. The components of the gravel are to be separated into like groups, according to color, shape, texture, hardness, and any observed special properties. The student makes a data table on which to describe each group. Then, using the mineral identification table included in the kit, the student identifies each group. What other properties would have been helpful for identification of these groups? (Answers will vary, but might include magnetism, results of an acid test, crystal shape, etc.) Was color a good identifier? Why or why not? (No, because different specimens of the same mineral can be different colors.) A piece of granite is in the kit. Does it resemble any of the separated groups? (Quartz, feldspar, and mica are in granite.)

Mineral Identification Lab

At each testing station, seven tests are to be performed on six unknown mineral specimens to determine their identities. The tests determine color, streak, luster, fracture and/or cleavage, hardness, reaction to acid, and specific gravity. The tests can be done in any order. There are instructions and a mineral identification table in all earth science textbooks.

Color. The six minerals are to be identified from only their colors.

Streak. The six minerals are to be identified according to their streaks made on a tile streak plate.

Luster. The luster of each of the six minerals should be described. Can the student identify any of the minerals from only its luster?

Fracture and/or cleavage. All the cleavage planes and/or fracture surfaces for each of the six given minerals are to be identified. This test is difficult, as the student may misidentify a crystal face as a cleavage plane.

Hardness. By using a fingernail, a penny, a nail, and a glass plate, the student can determine the approximate hardness of the six minerals.

Acid. The student should wear goggles to do this test. One drop of 15% hydrochloric acid is placed on each sample. A reaction—fizzing—indicates the presence of a carbonate. How many minerals had a reaction? The student should use water to carefully wash the acid into a plastic container for waste disposal in accordance with the Environmental Protection Agency's regulations (not down the drain).

Specific Gravity. Weigh each sample in the air. Weigh each sample in a beaker of water. Subtract the weight in water from the weight in air (remember to subtract the beaker's weight and the water's weight first). Divide the loss of weight (the difference) into the weight in air to obtain the specific gravity.

Result. As a postlab activity, the teacher should review the correct answers with the students. Ask them which is the best or most accurate test to identify a mineral. Does one need several tests to be more accurate? (Yes.) Is color or streak a better test? (Streak.) Why? (Because it shows the mineral's true color and never changes.) Have the students write a paragraph or more about the use of mineral properties to identify a mineral. Have them include other mineral tests that they think would be useful to help identify minerals.

Rock Groups

Construct a rock-texture chart (Fig. 1), dividing it into three texture groups: coarse-grained rocks, fine-grained rocks, and glassy rocks. The students are given ten rocks to be divided into the three groups. Further divide the rocks of each texture by grain shape or grain arrangement.

Now, construct a rock-cycle diagram (Fig. 2) by using the three classifications of rocks. Label the processes creating each of the texture types on the diagram. Match the ten rocks to the rock-cycle diagram and their type of formation. Write a paragraph describing how a rock's physical characteristics help to identify it.

Location of Rock Types and Ages in Oklahoma

The teacher can use a geologic map of Oklahoma to construct an original simplified map showing five rock ages. Prepare a set of five handouts, each showing the outline of one of the five rock ages, as follows: (1) The outline map for rocks of Precambrian age is the same as the outline of the whole State, because Precambrian rocks underlie the younger rocks throughout the State. (2) Paleozoic rocks form the next age group and cover all of the State that doesn't have Precambrian rocks exposed at the surface. (3) Mesozoic rocks are next; they cover all of the

ROCKS

Coarse-Grained	Fine-Grained	Glassy
Sandstone	Limestone	Obsidian
Granite	Basalt	
Conglomerate	Shale	
Breccia	Slate	
	Gneiss	

Figure 1. Chart of rock textures (modified from Addison-Wesley, 1996, p. 213).

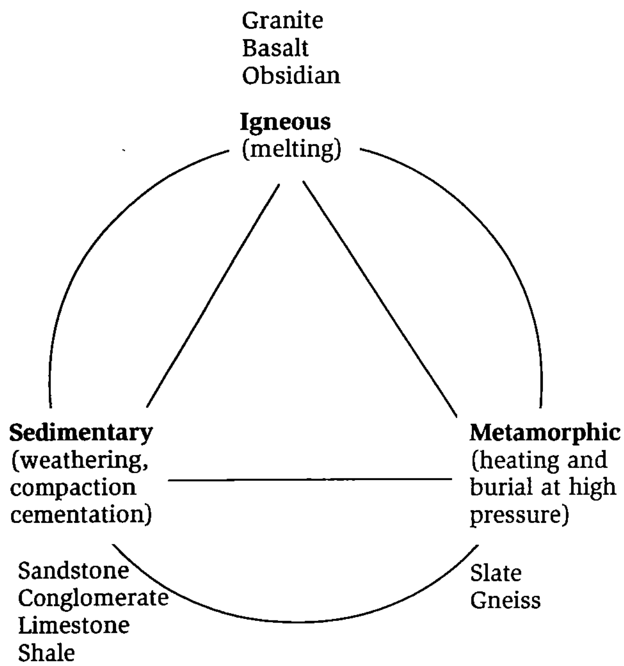


Figure 2. Rock cycle.

State that doesn't have either Paleozoic or Precambrian rocks exposed at the surface. (4) The next group is formed by the Tertiary rocks, and (5) the group after that is formed by the Quaternary rocks.

Each student receives a set of the handouts showing the extent of the five age groups, colored pencils, and scissors. On each sheet, the area for only one rock age is present; the rest of the sheet is to be cut away and discarded. This rock age cutout is then color-coded and put aside until all five cutouts are ready to be assembled. When all five are completed, assemble them by overlaying each sheet, one on top of the other, with the oldest rock layer on the bottom and the youngest on the top. Label the ages and types of rock on each sheet and make a legend on the top page. The result can be glued together or stapled at the corners to create a geologic map of Oklahoma. This is a good activity to introduce the study of Earth history and fossils.

EXPERIMENTS IN CRYSTAL GROWTH FOR HIGH SCHOOL AND COLLEGE STUDENTS

Minerals are rightly termed the building blocks of earth materials, and a basic knowledge of their properties is essential to solid earth sciences. Minerals represent the naturally occurring crystalline materials; there are many synthetic crystalline materials that are not known to exist in nature. Both natural minerals and other synthetic crystals play very large roles in our technological society.

An introductory exercise in mineralogy would be one in which students learn the physical properties of minerals as diagnostic tools. Lists of important physical properties and their attributes can be found in any textbook on mineralogy (for college or lay person). Most minerals occur as small grains in rock, and samples of rock are usually broken free of the Earth for inspection. The properties of minerals that are most evident, therefore, are those that appear on broken surfaces: color, luster, cleavage or fracture, hardness, twinning, and shape (habit and form). Several of the exercises presented above involve the recognition of these common physical attributes.

Nothing is more fundamental to solid earth science than understanding how crystals grow. In common rocks, minerals precipitate from fluids (liquids, gases, solutions, etc.) by one of three means: cooling, evaporation, or reaction by mixing. Each of these processes can be demonstrated in the lab with reference to natural examples (hand specimens or field occurrences).

Growth by Cooling

Experiment 1 for Igneous Rocks. Melt 0.3 g of moth crystals, Thymol, or melting point standard (available from science supply houses) onto large microscope slides. Cover with cover glass, and place on a hot plate set at a temperature to melt the substance but not cause fuming. Allow the compound to melt completely. The melted medium should flow to edges of the cover glass and fill the covered space between glass and slide. Transfer the slide mount to black (for moth crystals) or white (colored standards) paper and watch crystals form as the liquid cools. Better displays with magnification include transparency projector (visible to large groups), microfiche card reader (visible to small groups), or petrographic microscope (visible to individual).

What Happens. Initial heating transforms crystalline solid to liquid. Cooling reverses that process, and when heat is removed from liquid, the greater association of atoms favors formation of a denser phase, crystals in this case. (When some liquids are cooled faster than they can form crystals, they solidify to glass.) In the above experiments, crystals develop a growth habit that is characteristic of rapid crystallization—radial growth of many elongate crystals, which form sunbursts as they grow in two dimensions (a plane, as a bedding or fracture surface). Rapid crystallization in a three-dimensional situation forms puffballs of spherical crystal aggregates.

Application. Growth by cooling simulates the solidification of igneous rocks from magma.

Natural Examples. Igneous rocks can be found in the Wichita igneous province of southwestern Oklahoma, where some in fact have textures similar to those grown in this lab (Fig. 3). There are additional exposures of igneous rocks within the Arbuckle Mountains (Colbert Rhyolite) and in the vicinity of Mill Creek to Tishomingo.

Pyrite dollars are representative of rapid 2-D growth as seen in this experiment; snowflake obsidian, whose black background is a glass, contains spherical 3-D radial aggregates of cristobalite and feldspars.

Experiment 2 for Vein Fillings. Fill a large glass beaker or jar (about 500 mL) one-half full of rock salt (coarse salt or salt blocks from ranching feed stores work better than table salt). Add hot tap water to make a thick crystal slurry and stir. Continue to add hot tap water and stir until beaker contains about ⅔ solution and ⅓ crystals. Let the mixture stand until the crystals settle to the bottom of the beaker; then decant the hot solution off into a smaller clean beaker (about 250 mL) until it is nearly full. As the solution cools, watch crystals of salt form on the sides of the beaker and grow inward.

Application. The experiment replicates the precipitation of minerals dissolved in aqueous solutions as they cool en route toward the Earth's surface. Simple as the process and its result are, mineral precipitation by cooling solutions is responsible for much of the mineral formation in sedimentary and metamorphic rocks. When crystals precipitate along open fractures in rock, analogous to the walls of the beaker, the rock material that precipitates forms a vein.

Natural examples. Veins filled with quartz (mostly southeastern Oklahoma, especially McCurtain County) and calcite (Arbuckle Mountains) are common products of cooling solutions. Some small calcite-filled veins can be seen in rock exposures along I-35 in the Arbuckle Mountains. Collecting trips for vein quartz in southeastern Oklahoma are privately available.

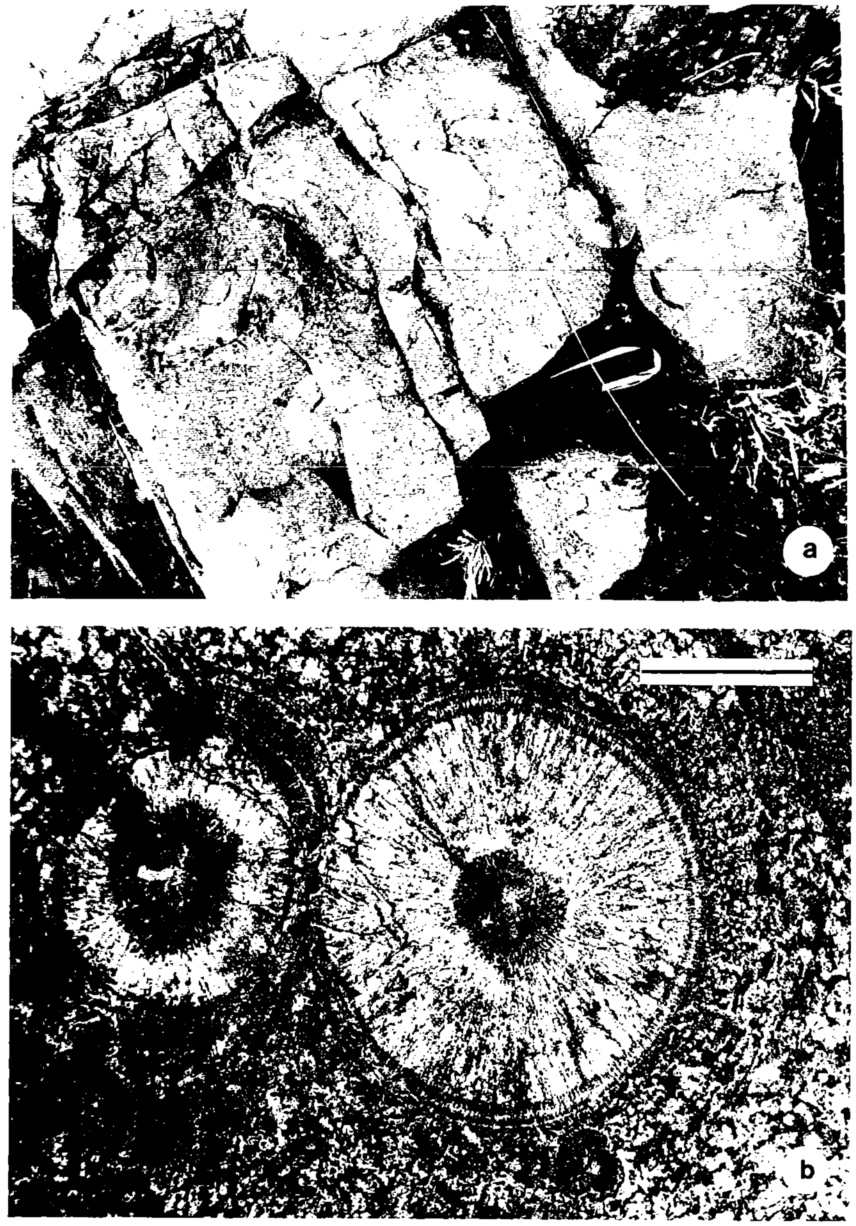


Figure 3. Outcrop (a) and detail (b) of spherical crystal growth from granitic melt; Wichita Mountains, southwestern Oklahoma (photographs courtesy of John P. Hogan). Bar scale in (b) represents 2 cm.

Growth by Evaporation

Experiment 3. Fill a large glass beaker or jar (about 500 mL) one-half full of epsomite (Epsom salts). Add cold tap water to make a thick crystal slurry and stir. Continue to add cold tap water and stir until the beaker contains about ⅔ solution and ⅓ crystals. Let the mixture stand until the crystals settle to the bottom of the beaker; then decant the room-temperature solution off into a smaller clean beaker (about 250 mL) until it is one-half full. Cover the small beaker with cheesecloth, and let the beaker stand in an open but not drafty location indoors. Slow evaporation will lead to the growth of a few clear epsomite crystals in the bottom of the beaker. These turn white slowly when exposed to air.

Application. Minerals formed by evaporation of brines produce various types of salt minerals, the most common of which is halite. These are found mostly in deserts, where capillary action pulls ground water toward the surface with hot, dry air. This wicking action causes salts to precipitate from the ground water, sometimes making a hard, salt-encrusted layer called *caliche.*

Natural Examples. In Oklahoma, the gypsum crystals found in the Salt Plains Refuge near Jet form by evaporation of calcium- and sulfate-rich ground water just below the surface.

Growth by Mixing

Experiment 4. Fill a large glass beaker, jar, or tall graduated cylinder (about 500 mL) approximately ⅔ full of tap water; add about 50–100 g of epsomite (Epsom salts). The solution should be clear and not saturated with salt. In another smaller beaker, dissolve about 10 g of barium chloride ($BaCl_2$, available from science supply houses) into *distilled* water; again, the solution should not be saturated. With an eyedropper or pipette, add the barium chloride solution by drops to the epsomite solution. Upon contact, clouds of very fine white barite crystals will precipitate and eventually settle to a layer at the bottom of the beaker.

Application. Many reactions that precipitate minerals in metamorphic and sedimentary rocks occur by mixing aqueous solutions with different chemical properties (solutes, pH, oxidation state, etc.). Mixing occurs, for example, when ground water from one rock flows into another rock and mixes with its fluids. If the two rock types are very different, the ground water derived from one is likely also to be chemically different from that derived from the other, and upon mixing of the two ground waters, reaction will occur that either dissolves or precipitates minerals. This type of mixing experiment provides an example of what is known as salting out, in which a reaction among soluble components produces another compound with very low solubility. In this case, the reaction is

$$BaCl_2 \text{ (aqueous)} + MgSO_4 \text{ (aqueous)} = BaSO_4 + MgCl_2 \text{ (aqueous)}$$

in which barite represents the insoluble mineral.

Applications. Barite roses, the official rock of Oklahoma, may originate from some type of mixing reactions. The host for the barite roses is the Garber Sandstone, a good and porous aquifer. One hypothesis would be that two types of ground water from different sources flowed into the Garber, mixed, and locally deposited barite in the pore spaces of the sandstone. Another good possibility is that reduced (oxygen-poor) ground water containing both barium and reduced sulfur (e.g., H_2S) mixed with more oxidizing water near the surface, and the oxidation of sulfide to sulfate triggered the precipitation of barite.

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Considerations in Stimulating Students' and Teachers' Interest in Geology and Rockhounding

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INTRODUCTION

The future path of our children is formed while they are students in the fourth through eighth grades.

Every child, and adult, has a love and desire to have and hold the beautiful colored and patterned rocks Mother Nature has created for us. Our interest may vary over the years, but it is always there, just waiting for a spark to kindle the desire to get involved with nature again. I hope to inspire us to rekindle that spark in others today.

This paper addresses the need to adjust our approach to introducing students of various levels to rockhounding and geology. The involvement of government agencies, clubs, and associations must be increased to support the teachers in their endeavors to stimulate students. Practical methods for the teachers, as well as tips for the practitioner, provide details on the required adjustments. The suggested approaches aim to cement the learning of the classroom with a tangible benefit for the student.

Associated benefits for the rockhound or geologist and the community at large are given.

STUDENTS

We have a variety of students whose educational needs and means of learning differ (see Table 1). The children of the electronic age, brought up with computers and video games, have become impatient individuals with very short attention spans. Adults in adult-education programs are keen to develop practical skills for upgrading their current qualifications or learning new skills in hopes of improving their employability. Yet, they face pressures of time in holding down existing jobs, running families, and coping with today's stresses. Our seniors, although not faced with such time pressures, may suffer from the inability to retain new learning for any great length of time.

We can provide these students with a better appreciation of our natural resources and ecology, and we can aim to stimulate an interest in geology and rockhounding. One way we can achieve these goals is to provide a hands-on, practical approach to learning.

The students will benefit from getting closer to nature—to touch and feel how the rocks and Earth patterns are developed and how Mother Nature has blended the natural colors together. We can help our students develop a better understanding of how the world works and how the pieces, just as the patterns seen in rocks and minerals, fit together. This knowledge can then be related to life experiences; for example, how a company works or how people should work together.

For example, gem and mineral clubs can help, and some are helping, to achieve these goals by (1) getting students involved in rockhound meetings, workshops, and shows; (2) giving talks at schools (Fig. 1), and (3) taking students on field trips. By adding a more hands-on experience in teaching these students, we can possibly interest them in choosing a career path that could lead to geology, mining, jewelry, or other related fields.

TABLE 1.—OKLAHOMA SCHOOL ENROLLMENT

All grades 1 through 12 (1994–95 school year)		599,456
Grades 4 through 8 (1994–95 school year)		
4th grade	47,929	
5th grade	48,831	
6th grade	49,524	
7th grade	49,377	
8th grade	47,549	
Total		243,210
Adult education (1993–94 school year)		31,719
Seniors		412,000

Note: Student enrollment data provided by Oklahoma State Department of Education. Number of seniors provided by American Association of Retired Persons, Oklahoma State Director.

TEACHERS

We should now turn our attention to the teachers. They are the ones who choose to discuss geology and rockhounding in the classroom.

The majority of students in the fourth through eighth grades are sincerely interested in rocks, minerals, and geology. However, many of the teachers are unfamiliar with rocks and minerals. These teachers have limited resources to call on for reference material. Our teachers need help in the classroom; they need advice from experts ready and willing to share their knowledge and experience.

Groves, L. E., 1996, Considerations in stimulating students' and teachers' interest in geology and rockhounding, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 103–106.

Figure 1. L. E. "Verne" Groves shows a piece of Brazilian agate, part of his rock collection, to Puterbaugh Middle School students Vena Ashalintubbe and Ben Miler. Groves was a guest speaker at the school to describe his hobby and part-time business to science classes. Photo courtesy of *McAlester News Capital and Democrat.*

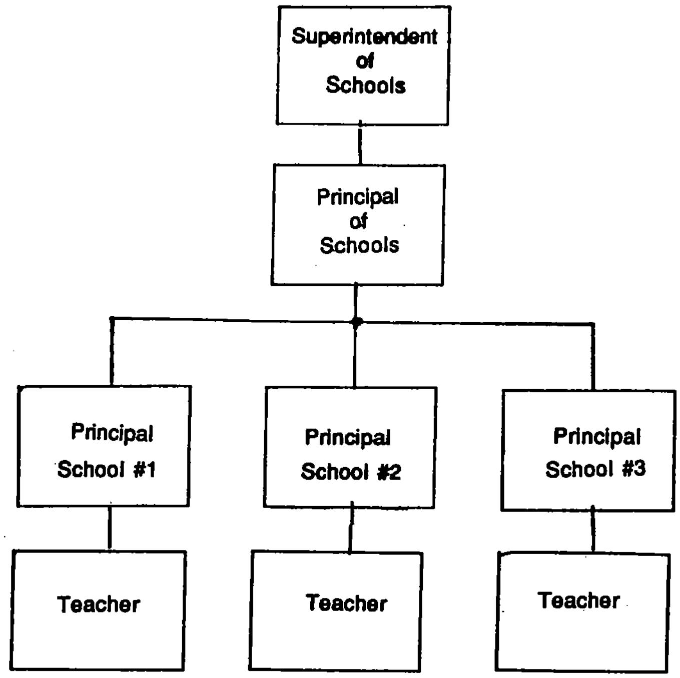

Figure 2. Diagram showing school hierarchy.

However, the teacher must account for the number of hours each subject is taught, whether through lecture or workbook exercise. These hours must also include examination time. Therefore, to include an outside speaker in the classroom, the teacher must first obtain permission. The approval of an outside speaker depends on cost, qualifications of the speaker, fit of the talk into the curriculum, and class schedule and speaker availability.

Given these factors, a teacher's request is often rejected. To overcome the lack of approval requires a serious commitment on the part of the teacher. The teacher must revise and resubmit the request often before approval is granted by higher levels of authority (Fig. 2). Once approval is obtained, the teacher must now contact outside groups for help. Normally, the teacher already has a speaker in mind. If not, the teacher faces the daunting task of finding someone.

A number of organizations are available: local, State, and Federal agencies and numerous clubs and associations. Organizations the teacher could contact are shown in Figure 3. Some of these organizations, however, may be unwilling to assist. They provide many reasons: no budget, lack of time, work and knowledge are incompatible, assistance is not approved by the organization, and "who wants to talk to a bunch of kids?"

On the other hand, there are a few organizations and individuals who would welcome the opportunity to talk to the students. These very same organizations may be unaware that their services are needed or would be appreciated. Thus we end up with teachers needing help and not knowing where to turn, and organizations and individuals willing to help and not knowing whom to contact.

The groups, clubs, and other organizations desiring to help the teacher can pursue a number of routes to contact the teacher. One way is to contact the State educational

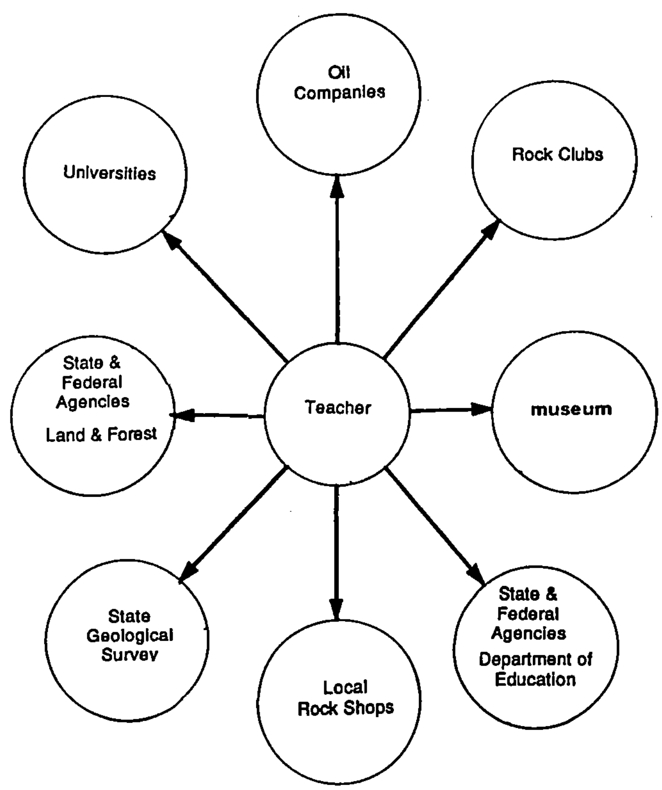

Figure 3. Diagram showing potential contacts a teacher can make for assistance in geology and rockhounding.

office and obtain a listing of schools, teachers, and subjects taught by each teacher. This is a time-consuming method.

A more efficient way for individuals is to send each school a list of your qualifications and areas of expertise. Once there is commitment on both sides to present the talk, the individuals, groups, or organizational representatives can meet and discuss the presentation with the teacher.

The following items should be considered: (1) scheduling the length of the talk, the hour of day, and the setup time, (2) number of students in the class, (3) educational level of the students, (4) physically or mentally challenged students with special needs, and (5) provision of reference materials or other handouts. With the meeting details successfully accomplished, the speaker should be interested not only in the material being presented, but also in all aspects of the students.

For the actual presentation, the speaker must remember the following: (1) Be on time; you have only a limited amount of time to set up, give the talk, answer questions, and remove any materials after class time. (2) Do not patronize the students. Do not talk down to the students regardless of age or grade level. (3) Use simple explanations; however, provide enough detail to keep the topic interesting.

There are additional possibilities for increasing the interest of the teacher and the students: (1) Invite the class to visit your facility. Be realistic about your ability to have this visit be successful and worthwhile. Set up a date and time with the teacher. (2) Set up a field trip whereby you can link the theoretical classroom discussion to the practical hands-on learning (Fig. 4). (3) Pick a nearby location where an abundance of interesting geologic material can be found in a very short time. On the field trip, remember to link the theoretical to the practical knowledge. Some points to consider:

- How and where to find specific rocks.
- How to remove the rock specimens without damaging the surrounding environment.
- How rocks and minerals are formed in the area. Discuss their specific characteristics, i.e., patterns, chemistry, colors, mineral composition, etc.
- How rocks and minerals are shaped and have been shaped by the area's geologic history and climate.
- Most important of all, stress the importance of working together.

Each student should find or take back at least one choice specimen to the classroom. To cement this new learning, you can return to the classroom and turn the

Figure 4. Digging for quartz crystals near Hochatown are nearly 60 fifth graders and sponsors from Edmond Doyle and William Gay elementary schools in McAlester, Oklahoma. Cephis Hall guided the students and answered many questions about crystals and timber harvesting. When back at school, the students will make jewelry from their finds. Photo courtesy of *McCurtain Daily Gazette.*

specimens into projects, just as we rockhounds and geologists return with specimens to make into jewelry items or to study an area's geologic development.

By helping the students and teachers benefit from this experience, the individual rockhound or geologist gains the pleasure and excitement of watching the students exploring and learning new things about their environment, the gratification felt from being part of the passing on of knowledge, and the fun and backaches of field trips.

CONCLUSION

From the above, it is clear that we rockhounds and geologists can expand the students' learning by a more practical approach, develop their appreciation of nature, stimulate their interest in a geologic or related career, help teachers enhance their curriculum, and enjoy ourselves by giving something back to the community. If we work together, all of us will benefit.

Two last questions I leave you with for consideration:

- What are you, geologists and rockhounds, doing to help teachers present geologic and other material to students?
- What are you doing, teachers, to get help to present geologic and other materials to the students?

ACKNOWLEDGMENTS

This paper and the related talk would not have been possible without the determination and help of the children from the fifth grades at William Gay and Edmond Doyle Schools and their teachers, Cindy Douthitt and Neil Dawson.

A special thanks to Carol Wiebe, McAlester School System art teacher, who contacted me with an idea. Together we developed the idea into reality. The reality involved three schools and 75 fifth- and sixth-grade students and teachers.

None of this would have been possible without Cephis Hall, rockhound and guide at Broken Bow, Oklahoma, who obtained permission from the Weyerhaeuser Corporation, Idabel, Oklahoma, for these school children to hunt crystals on the Weyerhaeuser property.

Credit for the editorial and art work goes to Melba W. Benson, Educator/Consultant. My daughters, Lois Finch and Aline Groves, were invaluable in getting this paper on the computer. The line drawings are the result of S. Henry's hard work.

The opinions expressed and content can only be blamed on me!

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Advertising and Promoting Rockhounding and Earth Science Activities

Tom Creider and Jim Buratti
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The following is an edited transcript of the presentation made by the speakers Tom Creider and Jim Buratti and their responses to questions from the audience.

Tom Creider: I would like to reemphasize a couple of points concerning State parks that were made yesterday in our session. State parks in Oklahoma have several primary purposes as part of our mission statement, and one is obviously to serve the public, especially the outdoor-recreating public, with opportunities for recreation and for enjoyment and pleasure. Also, the parks provide a place of protection for some parts of Oklahoma's natural heritage or natural history. And it is in that context that we try to serve the public, through interpretative programs conducted by our naturalists and other staff and through materials that we present on trails and literature leaflets. We try to help educate the public as they are enjoying these natural assets so that they come away with a better appreciation and understanding of Oklahoma's uniqueness and our rich natural heritage.

Oklahoma has many very special geologic resources. Some of those are evident in the parks as you visit; others may not be quite as obvious, particularly to someone like myself who is not extensively trained in geology. Our department welcomes the opportunity to work with any of you, either individuals or organizations, as you see fit to work with us to provide better educational leaflets and trail guides or to help us develop trails that take the visitor to some fascinating geologic areas in the parks.

I know that a lot of our naturalists have some training in the geology of their park, but, quite frankly, most have a background in plant and animal science. I think that we want to take a more holistic approach as we interpret these state parks to the public, and obviously the particular geologic setting is the reason why certain plants and animals are found where they are in the State. Therefore we welcome the opportunity to have parks become more widely used as classrooms—as outdoor classrooms, if you will. We welcome your expertise in assisting us to that end, maybe by being an occasional volunteer or a presenter for a school group or in the evenings at a campfire program. So, if you or your club have an interest in helping out, we would really appreciate your letting me know.

Jim Buratti: Let me start off with a story. There were two guys rocking on the porch one day, just talking about life in general. And one said to the other, "I wonder if there's baseball in heaven?" The guy looked at him real strange. He responded, "What are you thinking about?" The first guy said, "Well, you know, we're getting up in age, and I've always wondered if there's baseball in heaven. It wouldn't be fair to us. Look at what our backgrounds are. We both played little-league baseball, we played high-school baseball, we played in college, and we're both lucky enough to be major-league baseball players."

Well, that particular day they made a pact that the first one to pass on would try to get word back to the other about whether there was baseball in heaven. A couple of weeks went by, and one of the gentlemen passed on. And his friend, a couple of days later, was sitting on that porch. He was rocking and thinking about his friend, and he was thinking about life, but in the back of his mind, he still had that question, "Is there baseball in heaven?"

Finally, he looked up into the sky, and he saw a vision. He looked really close, he listened, and it was his friend. His friend started talking to him, and he said, "I have good news and I have bad news. The good news is 'thank goodness there's baseball in heaven.' The bad news is 'you're the starting pitcher this Sunday.'" It's probably the same thing that we have in tourism. I can talk in general about the problems that we face in tourism.

About five years ago we did a Gallup Poll Survey in Oklahoma to ask people about their vacation plans and whether or not they vacation in their home state. A neighboring state had done a similar survey; their survey showed that 69% of their people said "Yes, we will vacation in our state this year." So we had that result for comparison. We asked the same question to both in-state and out-of-state people, and we found the amazing fact that when our survey came back, 81% of the people in Oklahoma said, "No, there isn't anything to do here." And that's really the problem that we've been working on for the past five years.

Now I always tell people that we also have to be realistic. If you rockhounds think about it, I guess at one time we did have something better than the Rocky Mountains

Creider, T.; and Buratti, J., 1996, Advertising and promoting rockhounding and earth science activities, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 107–110.

here. We didn't have it in the same form, I guess, as the Rocky Mountains today. Today we don't have the Rocky Mountains, and we don't have the Pacific Ocean. If we get beyond that fact, really what we're trying to do is to try to convince people, both in-state and out-of-state, that "Yes, there are things to do in Oklahoma." Your group today is a good example. But you know that someone will stand up at a civic club or some other meeting and tell me, "I've lived in Oklahoma all my life, and I know there's nothing to do here." And I ask such people a couple of questions: "Have you ever dug for selenite crystals in the Great Salt Plains State Park?" They say, "No." "On a beautiful, crystal-clear morning did you every stay in a cabin next to the river that runs through Beavers Bend State Park?" They say, "No." "Have you every been to the Will Rogers Memorial in Claremore?" And they say, "Oh, yes—36 years ago my school class went there on a field trip." In 36 years it's changed just a little bit. And if you make out a list of all the things you like to do—I don't care what your background is or what your wants or desires are—those things are probably available in one form or fashion in Oklahoma.

In simplistic terms, what I'm always trying to do is encourage travel in Oklahoma. Let's say the average person, for example, takes five weekend trips in a year. What's happening right now is that they're going to Branson, they're going to San Antonio, they're going to Dallas, they're going to Eureka Springs, they're going to Kansas City. Just imagine for a moment the economic impact to Oklahoma if every Oklahoman took at least one weekend trip in Oklahoma. I'm not saying, "Don't ever travel anyplace else again." You and I know that if we look closely (and you know we have the largest constitution in the country), there's probably a line in there that makes it illegal to travel out of state. We'll just have to look into that a little bit closer.

All right! Here's audience participation! How many of you have seen the commercials "Oklahoma Native America" before? If you said "No," I can tell you the reason. Either you don't watch television (and there's nothing wrong with that), or you've been out of the country. So I think that recently, we've done a better job of trying to get word out on tourism. In fact, I was just telling Tom Creider that I was in beautiful Cordell last night, and I was asking some folks there the same question. Some guy stood up and asked, "You're talking about those Oklahoma Native Americans?" I said, "No. The campaign is Oklahoma Native America." Yes, it is a play on words. We can't deny that. But also we're talking about things that are native to Oklahoma. And I said, "If you have a disagreement with that, all I can tell you is that in all the things the Tourism Department has tried to generate interest, it is the most successful campaign that we've ever done."

The first year that we started the Oklahoma Native America campaign, we had a 400% increase in the number of people who inquired about Oklahoma. And obviously, as we send them literature, we are trying to convert them to be interested in coming to Oklahoma. Since then, our set of commercials has won first place nationally in two of the last three years. Somebody said: "Yea, we beat out Texas!" Yes, and we also beat out California, New York, Michigan, Florida, you name them—two of the last three years.

Oklahoma's biggest problem in years past has been that we do not sell ourselves effectively. I tell people there are advantages and disadvantages to living anywhere, and I have a long list of disadvantages about living in Oklahoma. But I also have a list of advantages. And I've decided that it's more advantageous to live in Oklahoma than it is to live anyplace else. Now I've been here only eighteen and a half years. Tom Creider promised me that when I am here for twenty years, I'm going to get that little "Okie" pin. So I guess I've got a year and a half before I get my "Okie."

We all have to do a better job of selling Oklahoma. And that is what we have not done. We are never going to be the number one tourist state in the country; it's never going to happen. I can give you that in writing. We don't want to be. Somebody said, "If we could just get Disney World here." I don't want it. Let it stay in south Florida. Yes, it's a great economic impact, but there are a lot of disadvantages to a place like that. What we want to do is just show people the things that we do have.

Somebody telephoned me in the office recently; he was trying to promote a festival and told me, "I'm not getting very much publicity. I'm not getting very much help." And I started asking questions. I said, "Have you done this?" "No." "Have you done that?" "No." "Have you done this?" "No." And I said, "Well, I can see your problem." And the guy said to me, "Well, you know I'm only a volunteer." And my line back to him was, "I didn't know that because you're a volunteer, someone gave you a license to continue to do things wrong year after year. Just because you're a volunteer doesn't mean 'it doesn't really matter.'"

There are a couple of things that your group or organization can do. As I travel across the State, the two things that I hear from people who are promoting a tourist activity, whether it's in Guymon or Idabel or Oklahoma City, are (1) "We're the best-kept secret," and (2) "We don't have any money." As a group, what you need to do is have a plan. When I spoke to the Oklahoma Municipal League (which includes mayors, city administrators, council members, and all those folks) recently, I said, "It's amazing, when you put in a sewer system, you have a very nice plan—schematics, whatever you call it." "And then," I said, "when it comes to tourism, you don't even have a piece of paper. You don't have a plan."

Even if you're only a volunteer organization, or you don't have a lot of money, a plan still can be developed. It's just a plan about how to get the information out. Several speakers at this workshop distributed handouts with information about rockhounding, fossil collecting, and similar activities. Right? I've never seen them before. What I'm trying to do is to get groups like yours to put together an effective public-relations campaign. And you don't have to have a four-year degree in public relations; just try to do some very simple things. These flyers you have are an example. They're great, but if they don't get into the right hands, you're not going to get the kind of publicity that you're seeking.

Since I've been doing the show "Discover Oklahoma," I've been trying to get people to send information packets to me. They don't have to be beautiful, four-color brochures. I tell people, if you have to get a piece of paper and a crayon, send the information.

The kind of flyers I get in my office generally are about a function or festival that's going on, the name of it, the time, the date, maybe directions to get there, and if there's a cost. Now, that photocopied flyer is a great beginning for notifying the general public, but if you're trying to generate publicity about something, a barebones flyer may not be a very effective selling tool.

Have you ever heard the old term, "what's your shtick"? You need a shtick, you know. You've got to convince somebody that there's a reason to look at your announcement. It's almost the same thing if you have a festival or event—the first thing you have to do is show there is a reason for somebody to come. And it's the same with your organization when you need to get more people interested and involved.

Another important point is to put out a decent packet of information. People always ask me, "Well, what's a decent packet; what do you mean?" Let's say on the average, as an editor for a newspaper, or for a TV or radio station, I get a hundred announcements a month with information about a festival, an event, some sort of tourist attraction, bed and breakfast, or restaurant, or whatever. With a hundred of them, what I might do is spread them out on a table. I'm looking for the one that's going to sell me. What's the reason for me wanting to go here or there? So you have to go back to that shtick. In other words, what is it? I'll give you an example again. Sometimes it's also just a little creativity. And this group has some very interesting items that could be used. Just think creatively.

A number of years ago I lived in Atlanta, Georgia, and I happened to work at a media outlet. A particular group wanted me to come to their place, but I wasn't really interested at the time. I got invited to so many things that it was a pleasure to stay home one night. The invitation in question happened to be to a new seafood restaurant that was about to open: it was a big place, they spent a lot of money on it, and they probably sent me their little press release. I still just wasn't interested. I didn't want to go. Finally one day the mailman came into my office, which was unusual. Mailmen usually just dropped mail off at the front desk. And he said he had a special thing that was mailed to me. This group had gotten a boat oar, and they had burned my name into it, stuck some stamps on it, and mailed it to me. Remember I said it doesn't take a lot of money to be creative. I don't think that I'll forget that boat oar the rest of my life. You bet, I went to their grand opening. And they ended up getting more publicity than probably any other story I had done in a number of years, just because of their creativity.

Anybody know where Covington is? Over there by Enid. The largest cactus collection in the entire Midwest is in Covington, Oklahoma. There's a guy there who has this cactus collection, and most people don't know it. I gave him a bit of advice to make his flyer stand out above the hundred pamphlets I get each month. "What would it take for you, when you mail out your publicity, to send a little cactus in the mail?"

Well, for your group—a little gem, some sort of a rock. Where do you think the recipients are going to put that shiny stone? Right on their desk!

Now, each of these ideas, individually, I can't say is guaranteed. It still has to be a combination of things. But remember the hundred packets that I receive. Wouldn't it be nice, when you send out a little packet, that at least your packet will stand out from the hundred packets on my table? That's really all you're trying to do. What does it take? A little rock.

There's an asparagus farm in Stidham, Oklahoma, and this guy has about 40 acres of asparagus growing. His products are available all over the country now. It's amazing. It's one of those things you wouldn't know, but he is probably one of the top ten asparagus growers in the United States, and his products are available even in places like Neiman Marcus. I was kidding him one day, and I said, "If nothing else, mail some asparagus to somebody. Even if you have to go ahead and get a box of dirt, it's going to stand out in some form or fashion." Get a box of dirt and say to the recipient, "Here, you can plant your own asparagus." It's just those little efforts of creativity that sometimes can get you a little more publicity.

Another important point is reaching the right person with your announcement. There are about 700 tourism employees in the State, when you count all the parks and resorts and all our facilities across the State. It always amazes me that people who are trying to get publicity—whether it's through the "Discover Oklahoma" program or through the Tourism Department—go ahead and mail it to "Oklahoma Tourism, Will Rogers Building, Oklahoma City." How much extra effort would it take to pick up the phone and find out to whom it should be mailed? A lot of times, just pick up the phone and ask me; I can probably tell you. If you're trying to get this kind of publicity or that kind of publicity, well it's the same thing that I'm trying to do. If I can get all the towns and the festivals around the State to actually send the information to the proper person, can you imagine how much better off we'd all be in trying to generate publicity? If you send information to the right person in the Tourism Department, maybe you'll send it to the right person at the *Tulsa World*, the *Daily Oklahoman*, Channel 2 in Tulsa, or Channel 5 here in Oklahoma City, or even *Southern Living Magazine*. As I said, it doesn't take a four-year degree to figure out some of those little items that you can do.

It's the same thing with the information centers. Some of your brochures probably are available at these centers. You know, we had 1.5 million people go through the information centers last year. I can tell you right now, 92% of them don't care about what you're doing or what you're involved with. But look what 8% of that total is. There are a lot of people who are traveling across the country who are interested in rockhounding. So why not ask me to help you, as an organization? I'd like to get more information from you; I'd like to be more involved, to be able to help promote the things that you are doing. But I'm only interested if it would be of interest to a tourist. If a tourist can't do it, I'm not interested.

There are things going on that a tourist can do, however; right now we are promoting bus trips around Oklahoma. Just last week we took a group to southeast Oklahoma, and who would ever have imagined it. All we did was promote a bus trip on "Discover Oklahoma." We had people call in and sign up. On this two-day trip they paid $149.00 each. We had 213 people sign up and go with us on a bus trip to southeast Oklahoma. I even see the potential of doing some eco-tourism; we'll go down to the Arbuckles, and maybe look at the ecological or geologic background of what's there. I think there's a potential to do those kinds of trips.

All right, here's the other part of the audience participation. How many of you have ever seen a show called "Discover Oklahoma"? If you haven't seen it, there are two deputies who would like to escort you from the building. Now, why do I say that, kiddingly, of course? All I'm trying to do is say that if you watch the show, you are going to learn more about Oklahoma. If you went down to Texas and said the things about Texas that we say about Oklahoma around here, the Texans would kick your teeth out. And really all we're trying to get you to do is to talk positively about Oklahoma.

Who's got some questions to ask?

Question from audience: Does the Department have any funds for supporting a brochure or advertising Oklahoma?

Jim Buratti: Generally, the answer is "No." Probably the number one question we get asked all the time is just exactly what you are asking. Organizations or groups want financial help to do this or to do that. However, let me tell you about how we do support advertising. The State Tourism Department puts out a book called *A Vacation Guide*. We print 500,000 copies a year. What we do for the private sector is include their ads at one-third of the cost of what it would be if a private company were doing it. So that's one example. As another example of our support, although we will not write your brochure, we do have people in our office who commonly will look over your plans and will try to provide suggestions or ideas.

Tom Creider: Jim Buratti is referring to items that the agency produces at its cost and then gives to the public without charge. But there may be some possibilities of support from state parks, admittedly on a limited budget. What I'm talking about is producing booklets or leaflets that focus on the geology, minerals, and fossils of Oklahoma, or one part of Oklahoma. We are looking toward producing materials with the help of organizations like yours. We are interested in supporting development of printed materials that are interpretive. We want to provide them at a park or a nature center, for a nominal charge; they would not be free materials.

We would like you to help prepare the text. We could have some illustrations or photographs, probably black and white because of a limited budget. If we can get the ball rolling, it might generate enough proceeds that we would be able to support future printing of such leaflets and booklets.

Question from audience: There is an existing Oklahoma Fossil and Rock brochure that the Stillwater Club has put out. Is there any chance of getting it reprinted?

Tom Creider: That was a four-color, slick folder that we last produced in 1990. This was one of the items that, because of budget restrictions, was not reproduced by the agency. I'm visualizing something like that plus a little more text material, so that if we charged a quarter for it, a person would be getting more than just one piece of paper. Maybe we could have a booklet format and maybe expand on that.

Question from audience: Is there a budget for something like that?

Tom Creider: Well, the budget for it will have to come out of the Parks Department. Just like everybody else, we're scrambling for money. I think if we could start with a project where we do in-house printing, then our costs are relatively small. We could charge for it, start developing some cash flow, produce reprints, and build on that. That is my suggestion.

Topographic Map Reading

James R. Chaplin
Oklahoma Geological Survey
Norman, Oklahoma

INTRODUCTION

Mineral, rock, and fossil collecting is an outdoors activity that combines the excitement of the hunt, the joy of discovery, and the intellectual satisfaction that comes with unraveling a part of the Earth's history. A topographic map of the collecting site or area is essential for recording collecting localities. It is important to note accurately on each bag containing specimens, or in a field notebook, the geographic location (section, township, range, county, state [or, alternatively, the latitude and longitude, plus county and state]) and a statement as to how to get to the locality. The record should also include the date, the elevation, and, if possible, the name of the rock formation and the stratigraphic level within the formation from which the specimen was collected.

The recording of all of this information is critical in order to ensure, if necessary, reproducible field data at some later date for other collectors and/or for the scientific community. Unless these data are recorded, the collecting of geologic specimens is no more scientific than the collecting of postage stamps. Remember that the accurate identification, labeling, and displaying of one's specimens are further testimony to competence as an amateur geologist or paleontologist.

What Is a Topographic Map?

A *topographic map* is a graphic representation of the three-dimensional configuration of the Earth's surface plotted to a definite scale on a two-dimensional surface. The distinguishing characteristic of a topographic map is the portrayal of the shape and elevation of the Earth's terrain.

Topographic maps usually portray both natural and artificial features. They show and name works of nature including mountains, valleys, lakes, rivers, plains, and vegetation. They also identify the principal nonnatural works, such as roads, boundaries, major buildings, and transmission lines.

The United States Geological Survey (USGS), a unit of the Department of the Interior, has been actively engaged in the making of several series of standard topographic maps of the United States and its possessions since 1882. Some sources where topographic quadrangle maps can be purchased are listed in Appendix 1.

Use of Topographic Maps

Topographic maps are of prime importance in planning airports, highways, dams, pipelines, transmission lines, industrial plants, and other types of construction. Topographic maps are also an essential part of geologic and hydrologic research, of mineral investigations, and of studies on the quantity and quality of potable water. In addition, they facilitate the study and application of flood controls, soil conservation, and reforestation.

Users of topographic maps have a distinct advantage in the pursuit of outdoor activities such as rock, mineral, and fossil collecting as well as hunting, fishing, hiking, and spelunking. Topographic maps are also extremely valuable in genealogy, particularly in locating family cemeteries, and revealing changes in the names and boundaries of places (Anonymous, undated reference [d]).

USGS 7.5-MINUTE QUADRANGLE MAPS

Map Information

The information used to identify the map is generally found in the space outside the border of the map. This information tells briefly how the map was constructed, where it is located, the agency that prepared it, where the quadrangle is located, and other information to make the map more useful (Fig. 1). The following discussion of map format focuses principally on USGS 7.5-minute quadrangle maps. These maps are the most popular and useful maps for plotting collecting localities.

Map Name

Each quadrangle is identified in both the upper-right and lower-right corners by quadrangle name (Fig. 1). The state or states the quadrangle is located in will also be identified in the upper-right corner along with the quadrangle series (7.5-minute) and the map type (topographic) (Fig. 2). The name of the quadrangle is taken generally from some town or feature within the boundaries of the mapped area.

Cooperative Credit

Cooperative credit is generally given in the top center of the map if the map was produced in a cooperative arrangement between states or municipalities and the U.S. Geological Survey.

Chaplin, J. R., 1996, Topographic map reading, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 111–124.

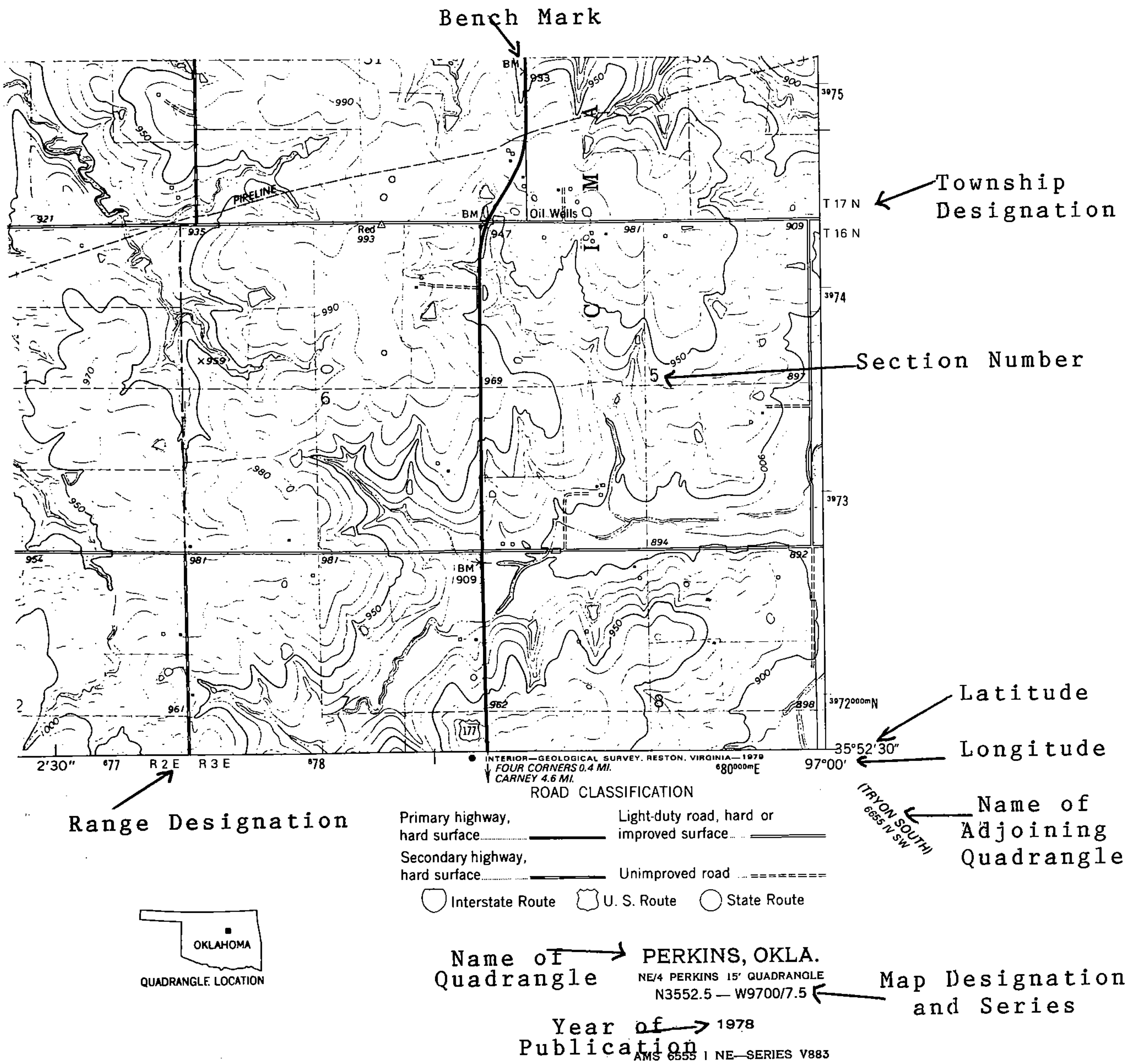


Figure 1. Some information that is shown in the margins of U.S. Geological Survey topographic quadrangle maps. In particular, the method of labeling (1) section numbers, townships, and ranges and (2) latitude and longitude should be noted (see Figs. 3–6 for further explanation). Also shown is a bench mark location (BM) and the elevation at that point (933 ft) (see text for further explanation).

Adjoining Quadrangle Maps

The names of all adjoining quadrangle maps are shown in parentheses at the corners and centers of the sides of the map (Fig. 1).

Location

Longitude and latitude coordinates are given at each corner of the map (Fig. 1). In addition, tick marks ⅓ and ⅔ of the way along each margin of the map give intermediate longitude and latitude coordinates. These marks, in effect, divide the map into nine smaller quadrangles, each one-ninth of the original area, for ease in locating individual points.

Public-land-survey coordinates for townships and ranges are also labeled along the map margins to identify the locations of each township and range (described in detail below; see Fig. 1). Both of these methods of map location are discussed in more detail below.

Credit Legend

In the lower-left margin of the map is the list of credits to show methods and responsibilities for the preparation of the map. It usually includes the following: (1) name of mapping agency, (2) name of editing and publishing agency, (3) mapping procedures, and (4) informative and explanatory notes (Fig. 2).

Margin Data

The upper-left corner of the map notes the publishing agency. The upper-right corner of the map gives the name of the quadrangle, the state (or states) and county (or counties), and the map series (Fig. 2).

Just below the map borderline in the lower-right corner of the map, the following information is provided: (1) the quadrangle name, (2) year of publication and revision if completed, (3) the map designation and series, (4) quadrangle location on a small-scale map of the state containing the mapped area, and (5) the general road classification that is used to designate different classes of roads (Fig. 1).

In the center of the lower margin are the map scale and contour interval (C.I.) (Fig. 2). Additional information, arranged from top to bottom, includes the following: (1) publication scale in ratio form, (2) bar scale in both English and metric units, (3) statement of contour interval, (4) vertical datum (maps published after 1975 show "National Geodetic Vertical Control Datum of 1929"), (5) map accuracy statement, and (6) sources of published quadrangle maps.

Declination Diagram

Just to the left of the center of the lower margin (between the credit legend and the bar scale) are two north arrows: geographic or true north and magnetic north. All maps use a true-north meridian for orientation, and by convention almost all maps have true north at the top of the map. The true-north meridian is a line oriented toward the north geographic pole.

The north magnetic pole doesn't coincide with the true or geographic pole, and in addition, the position of the north magnetic pole is constantly changing. The angular difference between these two directions is the *magnetic declination,* which is taken, to the nearest 0.5°, from the latest isogonic chart for the year of the field survey or revision (i.e., the angle between the star [true north] and the arrow labeled MN [magnetic north] in Fig. 2). The arrow for magnetic north is referred to as the north arrow of the map. The *declination diagram* enables the user to orient the map correctly. All compass needles point toward the north magnetic pole (located in the upper Hudson Bay region), making the magnetic-north arrow the easiest one to use for orienting in the field.

Magnetic north can be either east or west of true north. When true and magnetic north are in the same direction, the declination is zero. The line of zero declination passes through Lake Michigan and off the western coast of Florida. On the east side of the zero declination line, a compass will point west of true north. This effect is called "westerly declination." On the west side of the line, a compass will point east of true north. This effect is called "easterly declination." As an example, if one was using a compass in Texas, where the declination line is 8°, the magnetic needle would point 8° to the east of the true-north pole. Or, if one was in Maine, where the declination is 19°, the magnetic needle would point 19° to the west of the true-north pole. Maps and directions are usually based on true north, and it is usually desirable to have one's compass read true north, especially for those who use a compass in the field to plot geologic or other data on a base map (e.g., a USGS 7.5-minute quadrangle map). On some compasses (e.g., a Brunton), adjustment for declination is easily accomplished by rotating the compass's graduated circle with the slotted screw that extends through the side of the case.

MAP SCALES AND MAP MEASUREMENTS

Map scale is simply the proportion between the distance on the map and the actual distance on the ground. The scale expresses the size relationship between the features shown on the map and the same features on the Earth's surface. Map scales are shown in the center, at the bottom margin of topographic maps (Fig. 2).

Fractional Scale or Representative Fraction (R.F.)

Map scale is generally expressed as a ratio or fraction—e.g., 1:24,000 or 1/24,000. The representative fraction (R.F.) is the numerical ratio between linear measurements on a map and their corresponding distances on the ground. The R.F. is simply a fraction that can be used for any dimension desired, as long as the units in the numerator and denominator are the same. The numerator, usually 1, represents map distance; the denominator, a large number, represents ground distance. Thus the scale 1:24,000 states that any unit, such as 1 in. or 1 ft, on the map represents 24,000 of the same units on the ground. This statement could also be expressed as 1 inch represents 24,000 in. or 2,000 ft (Fig. 2). Units of measure in the English and metric systems and the means of converting from one system to the other are in Appendix 2.

Graphical Scale

A convenient way of representing map distance is by a graphical scale. A graphical scale is a diagram on the map that illustrates the units of distance on the map. Bar scales are the most common type of graphical scale on topographic maps. To use them, one simply measures the length on the map of the feature in question. String can be used if the feature is curved or sinuous; marks on the edge of a piece of paper suffice for straight lengths. Then the ground distance can be read by laying the string or paper on the bar scale (Fig. 2).

Verbal or Stated Scale

A verbal or stated scale is simply a means of verbally communicating the map scale. For example, the scale of 1:24,000 could be verbally expressed as "1 in. equals 24,000 in." Another way would be simply to state that on the map, "1 in. equals 2,000 ft" or "1 in. equals 0.6 km."

MAP CLASSIFICATION

Maps are classified generally according to publication scale, and each scale series is intended to fulfill a specific type of map need. Table 1 shows the contrasts between some selected large-, medium-, and small-scale maps.

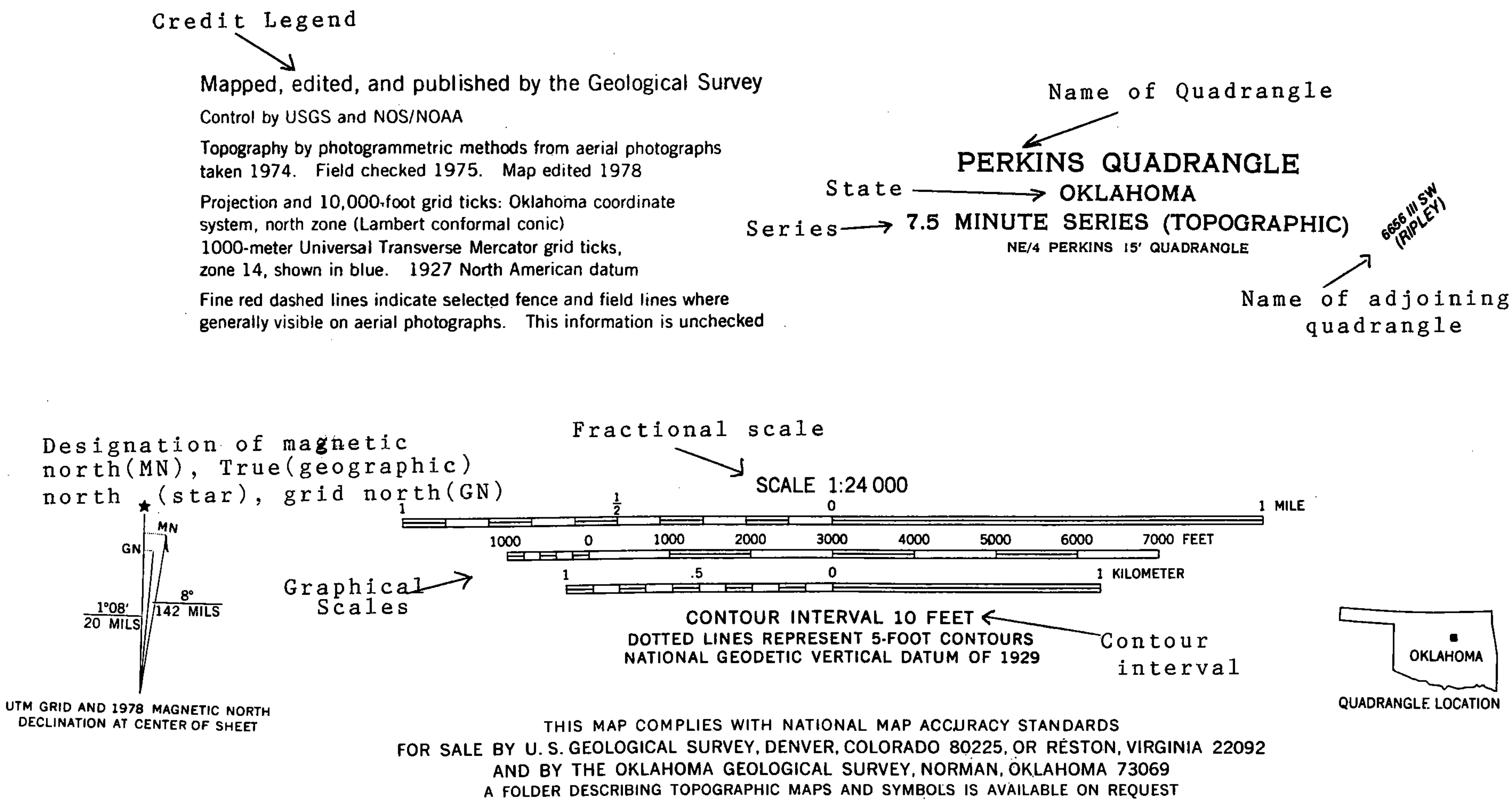


Figure 2. Some information that is shown in the margins of U.S. Geological Survey 7.5-minute topographic quadrangle maps. In particular, the declination diagram in the lower-left corner and the fractional and graphical scales should be noted (see text for further explanation).

TABLE 1.—USGS MAP SERIES AND THEIR ESSENTIAL CHARACTERISTICS

Series	Scale	1 in. represents	Standard quadrangle size[a]	Map area (approx. sq. mi.)	Paper size[b] (inches)
7.5-minute	1:24,000	2,000 ft	7.5 x 7.5 min	49–70	22 x 27[c]
15-minute	1:62,500	~1 mi	15 x 15 min	197–282	17 x 21[c]
U.S. 1:250,000	1:250,000	~4 mi	1° x 2°	4,580–8,669	34 x 22[d]
U.S. 1:1,000,000	1:1,000,000	~16 mi	4° x 6°	73,734–102,759	27 x 27

Note: Modified from U.S. Geological Survey brochure (Anonymous, 1969).
[a]Latitude x longitude.
[b]East-west (width) by north-south (length).
[c]South of latitude 31°, 7.5-minute sheets are 23 x 27 in.; 15-minute sheets are 18 x 21 in.
[d]North of latitude 42°, sheets are 29 x 22 in. Alaska sheets are 30 x 23 in.

Large-scale maps, such as 1:24,000 (i.e., those whose scale has a small denominator and thus a large quotient or result) are especially useful for highly developed areas or rural areas where detailed information is needed for construction or other purposes. Medium-scale maps, for example 1:62,500, may be adequate for rural areas where less detailed planning or other map-intensive activities are necessary. Small-scale maps, 1:250,000 and smaller, cover very large areas on a single sheet and are useful in regional planning or interpretation. Remember that large-scale maps show more detail and small-scale maps show less detail. For collectors, 7.5-minute (1:24,000) quadrangle maps are probably the most useful.

LOCATING FEATURES ON A MAP

Coordinates: Longitude and Latitude

To facilitate the location of points, most maps have a coordinate or grid system. The most familiar and widely used system of coordinates is latitude and longitude. By international agreement, the Earth's surface is divided into a series of north-south and east-west grid lines. The north-south lines are called *lines of longitude* (abbreviated *long*), or *meridians*. They represent segments of arc on the Earth's equator measured in *degrees, minutes,* and *seconds.* The line of zero longitude, the *prime meridian,* passes through Greenwich, England. All other longitude lines are measured as east or west of the prime meridian to the 180° line of longitude (which generally corresponds to the *International Date Line*). Meridional lines converge toward the *north* or *south poles* from the *equator* (Fig. 3).

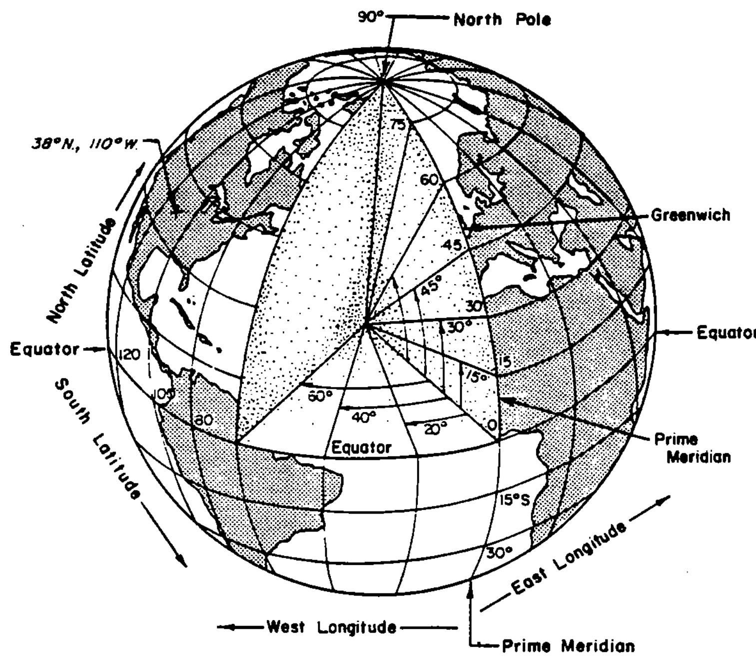


Figure 3. Longitude and latitude coordinates and their relationship to the Earth's surface (Thomson, 1980).

The east-west lines of the grid system are called *parallels of latitude* (abbreviated *lat*). Parallels of latitude circle the globe parallel to the equator, which is lat 0°. Degrees of latitude are measured north or south of the equator up to lat 90° N and lat 90° S at the north and south poles, respectively. The system of latitude lines also divides the Earth into two hemispheres, the *Northern Hemisphere* and the *Southern Hemisphere.* Parallels always lie in a true east-west direction, are always parallel to each other, and are always about 70 mi apart.

This grid system of meridians (longitude lines) and parallels (latitude lines) thus provides a means of accurately designating the location of any point on the globe. For increased accuracy in locating a point, a degree may be divided into 60 subdivisions known as minutes (indicated by the notation ′). A minute may be divided into 60 subdivisions known as seconds (indicated by the notation ″). Thus, a position description might read lat 64°32′32″E, long 44°16′18″S.

Positions given in latitude and longitude may be plotted on topographic maps by measuring along the sides to the proper latitude and across the bottom or top for the longitude. Lines drawn across the map will then intersect at the proper position. Because so few latitude and longitude tick marks are furnished along the margins of the maps, it is necessary either to measure distances between marks and divide by the number of minutes in order to obtain the distance covered by each minute or to simply estimate distances along the margins, accepting the possibility of error.

The following information is useful in plotting positions in latitude and longitude: (1) All latitudes in North America are north and increase toward the top of a map. (2) All longitudes in North America are west and increase toward the west on a map. (3) The length of a degree of latitude (always measured along the north-south direction) is 60 nautical miles, but since each nautical mile is 6,080.2 ft in length, the equivalent in statute miles is slightly more than 69 mi. (4) The length of a degree of longitude is 60 nautical miles *only at the equator* and decreases as the poles are approached. This is the reason why standard topographic quadrangles of areas in the United States, although measuring 7.5 minutes of latitude by 7.5 minutes of longitude, are rectangular in shape instead of square. Since meridional lines converge toward the north or south poles from the equator, the area bounded by parallels and meridians is not a true rectangle. USGS quadrangle maps are also bounded by meridians and parallels, but on the scale at which they are drawn, the convergence of the meridional lines is so slight that the maps appear to be true rectangles.

The USGS standard quadrangle maps embrace an area bounded by 7.5 minutes of latitude and 7.5 minutes of longitude. These quadrangle maps are called 7.5-minute quadrangles. Other maps published by the USGS are 15-minute quadrangles, and a few of the older ones are 30-minute quadrangles (see Table 1).

Metes and Bounds

In the Atlantic Coast States and certain others, such as Texas and Kentucky, land was surveyed and pieces of land are described by a system known as *metes and bounds*. In this system, the surveyor selected a point along the perimeter of a parcel of property, such as a prominent tree, rock, river bend, etc. He then traced a line around the edge of the property, following one compass direction for a certain distance, then another direction for a specific distance, and so on until he returned to the original point. This system has proved unsatisfactory owing to the impermanence of the arbitrary points and to the inexact original measurements. Plots of land in these areas rarely have regular patterns of shape, and boundary lines seldom follow cardinal compass directions. Road patterns in these states clearly show the absence of a consistent rectangular type of survey.

Coordinates: Township and Range System

For purposes of locating property lines and land descriptions on legal documents, another system of coordinates is used in most states and some parts of Canada. Since April 26, 1785, when a committee headed by Thomas Jefferson developed a plan that the Continental Congress adopted for dividing land into a series of rectangles, the public land of 30 states has been or is being surveyed under a system of standard townships and ranges (Land Office Grid System). The original 13 states, Kentucky, Tennessee, Texas, and the Vincennes area and Clark and Floyd Counties in Indiana use a separate system. The land grid system is tied into the latitude and longitude coordinate system, but functions independently of it. The country is subdivided into a series of north-south lines and east-west lines to form a grid. Certain parallels of latitude (east-west lines) are called *base lines*, and certain meridians of longitude (north-south lines) are called *principal meridians* (Fig. 4). The country is then marked off into a series of north-south strips called *ranges*, which are exactly 6 mi wide, to the east and west of the principal meridian. The land is also divided into a series of east-west strips, also exactly 6 mi wide, to the north and south of the base line. The lines bounding these north-south and east-west strips subdivide the land into a series of squares, called *townships*, each township being 6 mi on a side, and including an area of 36 sq mi. This method of subdivision is shown in Figure 4.

The ranges are numbered east and west from the principal meridian. The first subdivision east of the principal meridian is designated range one east (R. 1 E.); the second, range two east (R. 2 E.); etc. The first subdivision to the west is called range one west (R. 1 W.); the second, range two west (R. 2 W.); etc. The townships are likewise numbered north and south of the base line. The first subdivision north of the base line is called township one north (T. 1 N.); the second, township two north (T. 2 N.); etc. The first subdivision to the south is called township one south (T. 1 S.); the second, township two south (T. 2 S.); etc.

In Oklahoma (excluding the Panhandle; see Fig. 5), the base line is at lat 34°30′N, a line passing through Davis, Sulphur, and Duncan. All townships north of this line are designated T. 1 N., T. 2 N., etc., and those to the south as T. 1 S., T. 2 S., etc. The principal meridian is the Indian Meridian at long 97°15′W passing just west of Pauls Valley. Townships east of this line are designated R. 1 E., R. 2

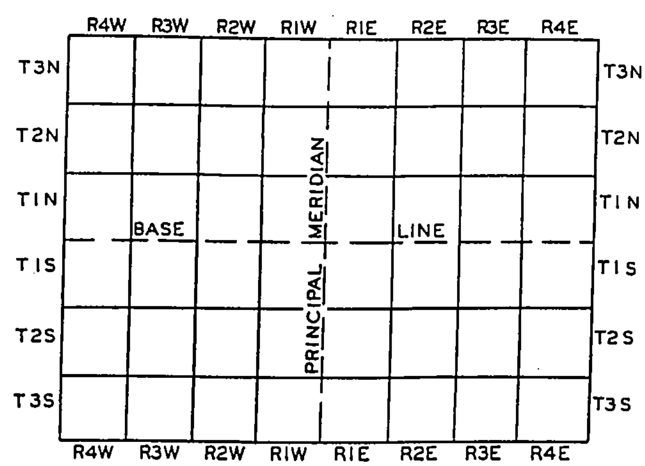
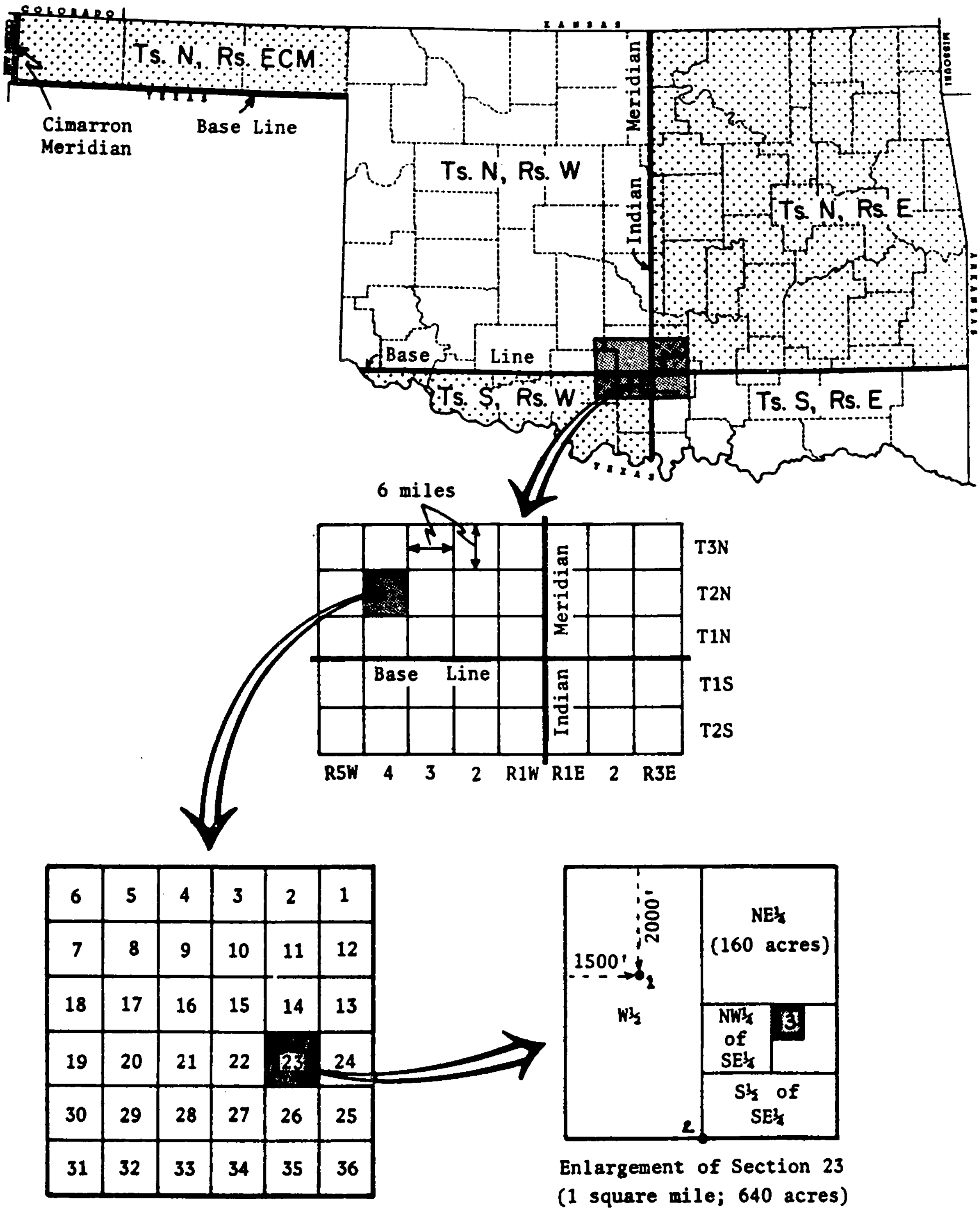


Figure 4. Designation of townships and ranges.

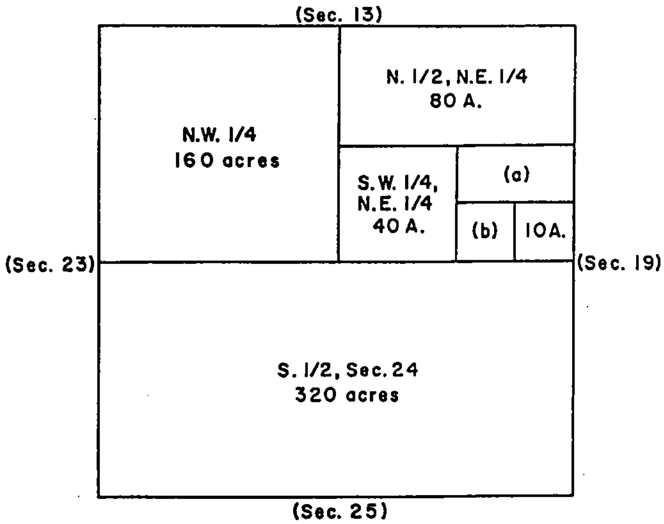


1- 1500'E & 2000'S NW cor. sec. 23, T. 2 N., R. 4 W.

2- center South line sec. 23, T. 2 N., R. 4 W.

3- NW¼ NE¼ SE¼ sec. 23, T. 2 N., R 4 W.

Figure 5. Land subdivision by the Bureau of Land Management for the State of Oklahoma. In the lower-right diagram are three examples of legal descriptions of land parcels.



(a) N. 1/2, S.E. 1/4, N.E. 1/4, Sec. 24, 20 A.
(b) S.W. 1/4, S.E. 1/4, N.E. 1/4, Sec. 24, 10 A.

Figure 6. Subdivision of a section into various sizes and their areas in acres (abbreviated A.). Underneath the diagram are two examples of legal descriptions of land parcels.

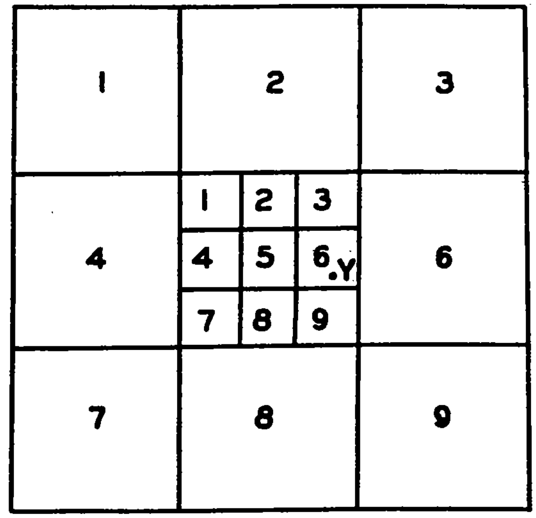


Figure 7. Rectangle method of map location (from Huffman, 1955). Point Y is located in 5,6.

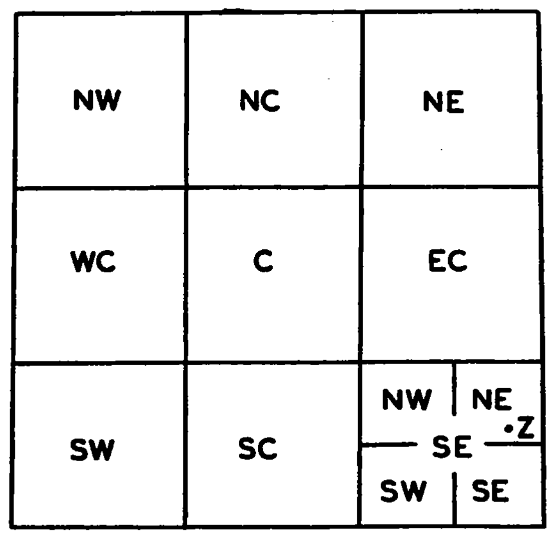


Figure 8. More recent rectangle method of map location (from Huffman, 1955). Point Z is located in the NE¼ of the SE rectangle.

E., etc.; those to the west are designated as R. 1 W., R. 2 W., etc. This series of numbering townships and ranges usually stops at the state boundaries.

Each state with this type of land survey system is therefore divided into a series of squares or townships, each 6 mi on a side. Each township is likewise divided into 36 sections (or 36 sq mi). The line separating sections is called a section line. The method of numbering sections within a township is shown in Figure 5. Each section consists of 640 acres of land. A half section has 320 acres; a quarter section has 160 acres; one-half of a quarter section has 80 acres; one-fourth of a quarter section has 40 acres, etc. (Fig. 6). A typical location designation of a point by this method might read SW¼NE¼SE¼ sec. 3, T. 7 N., R. 2 W., meaning the southwest quarter of the northeast quarter of the southeast quarter of section 3, township 7 north, and range 2 west. Figures 5 and 6 show legal descriptions of some selected land parcels by this method of location. This method should be used in designating collecting localities and other location points.

Rectangle Method

A less accurate, but more rapid method of location is called the *rectangle method*. In this method, the margins of the map and the fractional lines of latitude and longitude are used to form nine principal rectangles. These may be indicated by numbers or by letters as shown in Figure 7. Each of the nine rectangles may be further subdivided into nine smaller rectangles as shown in Figure 7. This process may be repeated on the smaller rectangles if a more precise location is desired. To express location, the number of the largest unit is given first, followed by the next smaller, etc. Thus point Y in Figure 7 is located in 5,6.

A newer technique involves the use of letters to designate the nine rectangles as NW (northwest), NC (north-central), NE (northeast), WC (west-central), C (central), EC (east-central), SW (southwest), SC (south-central), and SE (southeast). Point Z in Figure 8 is located in the NE¼ of the SE rectangle.

FEATURES SHOWN ON TOPOGRAPHIC MAPS

The features shown on topographic maps may be divided into three general groups: (1) culture, works such as roads, railroads, land boundaries, and similar features, (2) water features, including lakes, ponds, rivers, canals, swamps, and the like, and (3) relief that includes hills, valleys, and mountains.

Map Symbols

Interpreting the colored lines, areas, and other symbols is the first step in using topographic maps. Symbols are the graphic language of topographic maps. Their shape, size, location, and color all have significance. Some map symbols are pictographs that resemble the objects they represent, but the brown lines are abstractions and represent a third dimension (shape and elevation of the terrain) on flat paper. Standard topographic map symbols used by the U.S. Geological Survey appear in Figure 9. Individual houses may be shown as small black squares. For larger buildings, the actual shapes are mapped. Churches, post offices, schools, and other landmark buildings are shown on most topographic maps.

Map Colors

Colors on topographic maps are used to distinguish the various classes of map features. There are six basic colors: *Black* is used for artificial features, such as roads, buildings, names and political boundaries. *Blue* is used for water features, such as lakes, rivers, canals, and glaciers. *Green* is used to show wooded areas with typical patterns to indicate vineyards or orchards. *Red* is used to emphasize important roads, built-up urban areas, and property lines. *Purple* has recently been used as an interim revision technique for updating maps; all classes of features depicted on an interim revision edition are shown in purple. *Brown* is used for the shape and elevation of the land surface as portrayed by contour lines.

Map Topography

Elevation is the vertical distance of a point above a reference plane (e.g., on topographic maps, this plane is mean sea level, M.S.L.) (Fig. 10). The elevations of many points on the map—such as road intersections, summits of hills, and lake levels—are given. These are called spot elevations and are accurate to within the nearest foot or meter. More precisely located and more accurate in elevation are bench marks (points located on the ground by permanently fixed brass plates) that are marked by crosses and elevations, preceded by the letters BM, printed in black on the map (Fig. 1).

Height refers to the difference in elevation between the top of an object (e.g. hill, tower, etc.) and its base (Fig. 10). *Relief* is the difference in elevation between the highest point and the lowest point on the map or in the area (Fig. 10).

The great utility of topographic maps is that they show the shape and elevation of the land surface by means of contour lines. A *contour line* is an imaginary line on the Earth's surface connecting points of equal elevation. A contour line may also be described as a line traced by the intersection of a level surface with the ground. The shoreline is, in effect, a contour line representing zero elevation or sea level.

Contour lines are brown on standard USGS maps. To help the user determine elevations, *index contours* are wider and printed heavier (a thick brown line). Elevation values are printed in several places along the index contours.

The contour interval (C.I.) is usually constant for a given map (see Fig. 2) and may range from 5 ft for flat terrain to 50 or 100 ft for a mountainous region. Remember that the contour interval (C.I.) is a vertical distance, not a horizontal distance. Below are several general statements (rules) regarding contour lines.

1. All contour lines are shown in brown.
2. Every fifth contour line is a thick brown line with its elevation marked at some point on the line.
3. All points on the same contour line are of equal elevation.
4. All contours form closed lines, either on the given quadrangle or when that quadrangle is joined to one or more quadrangles.
5. Contour lines generally do not intersect or cross because it is impossible for one point to have two different elevations. There are two exceptions: (a) In the case of a vertical cliff, the contours are superimposed (merge) on top of each other, and (b) in the case of an overhanging cliff, the higher contours must cross over the lower.
6. Closed contours appearing on the map as ellipses or circles represent hills or knobs (Fig. 11).
7. Closed contours with hachures, short lines pointing downslope, represent closed depressions (e.g., sinkholes, strip pits, quarries, etc.) (Fig. 12). The elevation of the outermost hachured contour line in a series is the same as that of the adjacent, unhachured contour, unless otherwise marked.
8. *The elevation of a hill* (vertical distance above sea level) is determined by the value of the last closed contour that encloses the hill. The elevation of the top of a hill is slightly greater than (>) the value of the uppermost closed contour, but less than (<) the value of one additional contour. The elevation of the hill marked by an X in Figure 11 is therefore greater than 250 ft (>250 ft) but less than 275 ft (<275 ft).
9. The *elevation of the bottom of a depression* is determined in the same manner. In this case, the elevation is less than the innermost closed contour that encircles the depression, but greater than the value of one additional depression contour. Thus, the elevation of Y in Figure 12 is >75 ft but <100 ft.
10. The *height of a hill* (distance above surroundings) is determined by counting the number of closed contour intervals. Since neither the top nor the base of a hill lies directly on a contour, the height is greater than the number of contour intervals, but less than the number of contour intervals plus 2 ($N + 2$). Thus, the height of the hill (X) shown in Figure 13 is >20 ft but <40 ft.
11. The *depth of a depression* is determined by counting the number of closed contours involved. Since neither the bottom of the depression nor its rim lie exactly on a closed contour, the depth is always greater than the number of contour intervals and less than the number of contour intervals plus 2 ($N + 2$). The depth of the depression (Y) shown in Figure 13 is therefore >20 ft but <40 ft.
12. Hill and valley contours go in pairs, that is, the same contour is encountered twice—once in going up a hill (or down a valley) and again in going down the other side of the hill (or up the other side of the valley).

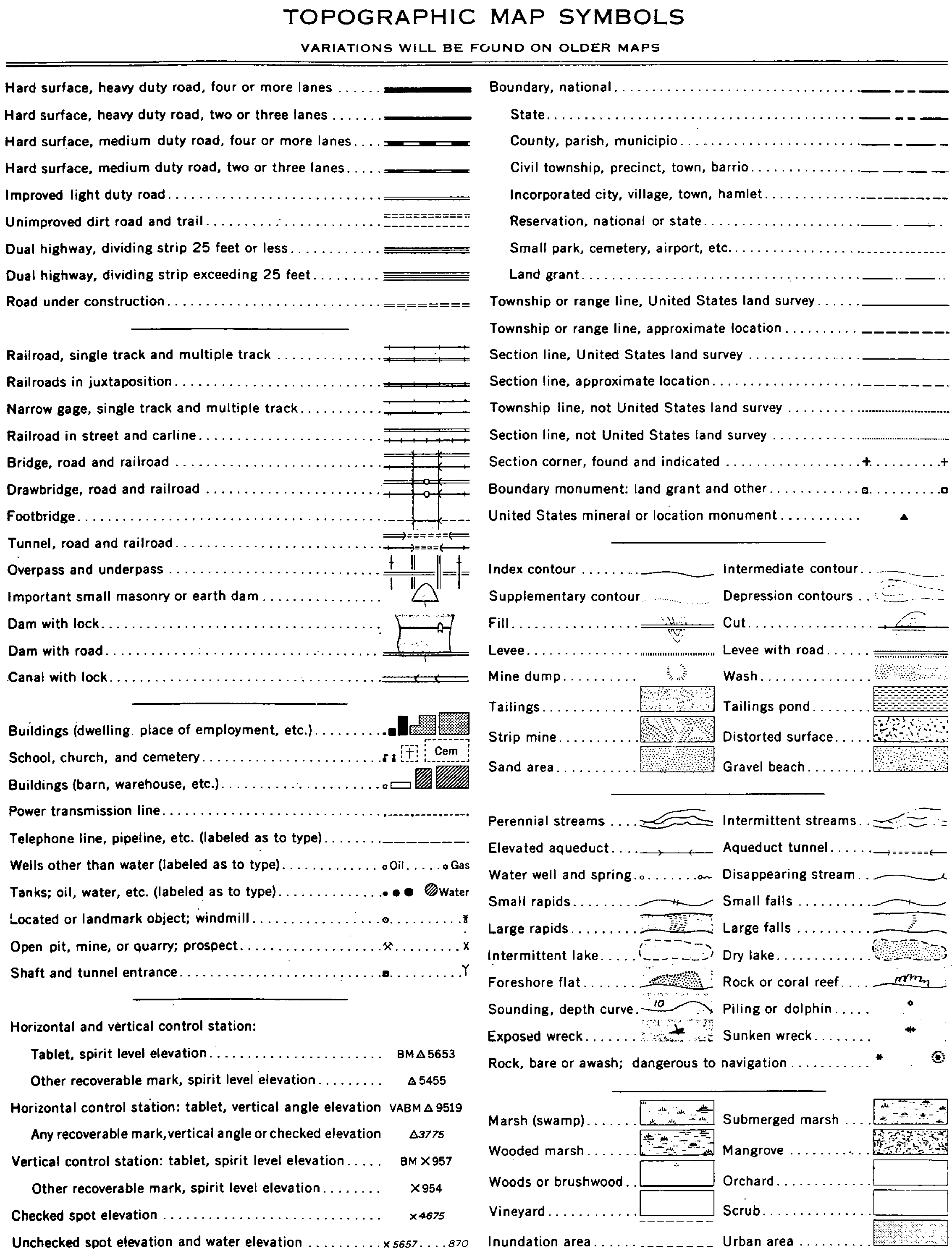


Figure 9. Standard topographic map symbol sheet used by the U.S. Geological Survey.

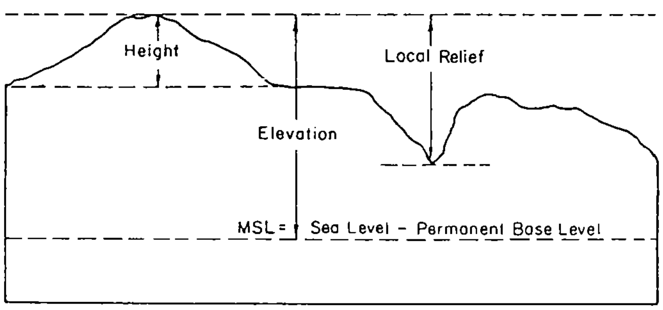


Figure 10. Cross section showing the relationships among the terms *relief, height,* and *elevation* (Thomson, 1980).

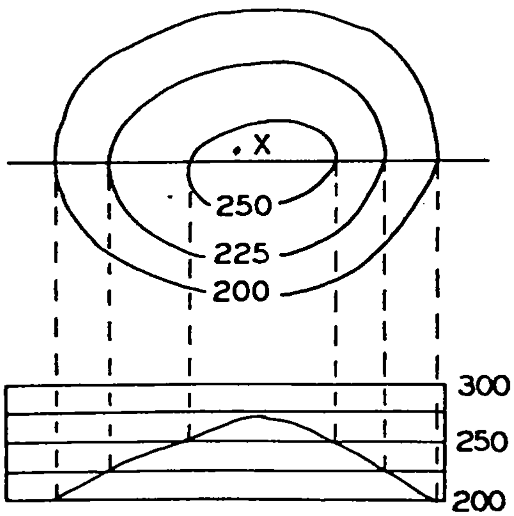


Figure 11. Determining the elevation of a hill by counting the number of closed contours (from Huffman, 1955). C.I. = 25 ft. The elevation of the hill marked by an X is >250 ft but <275 ft.

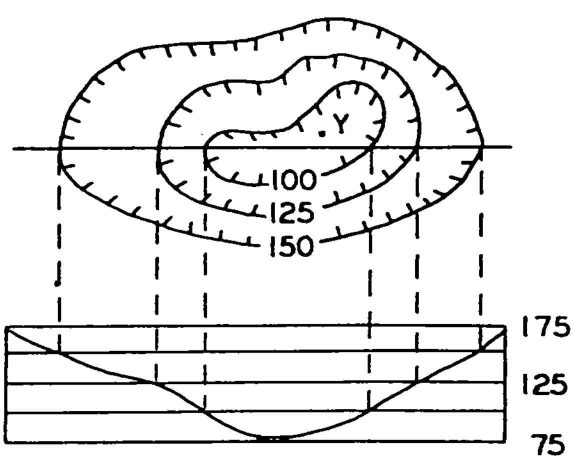


Figure 12. Determining the elevation of the bottom of a depression by counting the number of closed contours (from Huffman, 1955). C.I. = 25 ft. The elevation of point Y is >75 ft but <100 ft.

13. *Steepness of slope* is indicated by the spacing of successive contours. Steep slopes are shown by closely spaced contours, gentle slopes by widely spaced contours—provided map scale and contour interval are the same for both cases (Fig. 14).

14. When contour lines cross streams, they bend upstream; that is, the segment of the contour line near the stream forms a "V" shape with the apex pointing in an upstream direction (Fig. 15).

In Figure 15, all lettered arrows point toward the low side of the contour that the arrow crosses. This fact can be ascertained from the following lines of evidence. *Arrow A:* The contour line of lower stated elevation (420 ft, as opposed to 440 ft) is on the side that the arrow points to. *Arrow B:* Apex of V at the stream crossing points upvalley (upstream). *Arrow C:* Land on the inside of a closed contour is on the high side. *Arrow D:* Toward water (a stream in this example) is downhill. *Arrow E:* Hachures are on the downhill side of a depression contour.

Some general observations that can be noted in studying Figure 15: (1) The contour interval (C.I.) is 20 ft. (2) The closed contour on the map appearing as a circle (letter C) represents a hill. (3) The elevation of the depression contour (E) is 500 ft. (4) The elevation of point A can be stated as >420 ft, but <440 ft. (5) The elevation of point D is >380 ft, but <400 ft. (6) The general slope of the land shown in the sketch is relatively uniform.

SUMMARY

The wide range of information provided by topographic maps makes them extremely useful to professional and recreational map users alike. Topographic maps are the most useful guides in rock, mineral, and fossil collecting. Used in conjunction with a geologic map of a particular area, a topographic map is a collector's most faithful friend for satisfying field explorations.

An important function of a map is to provide the means of defining the location of a point or area so that a specific position can be found again at a later date, communicated to others, or recorded for scientific, legal, or political purposes. A great many collecting localities are listed as "about 1 mi northwest of Smithville crossroads," which seems a fairly precise location, all things considered, but if the area is heavily wooded and several roads lead in the general direction, one begins to experience the frustrations that all collectors have suffered at one time or another in looking for nebulous localities. Designating localities by using distances (noted in feet, yards, or miles) in reference to easily found, conspicuous points on maps (e.g., prominent peaks or hilltops, stream branches, villages, etc.) is a commonly used practice, but not a particularly accurate method for designating collecting localities.

A concerted effort should therefore be made to record an accurate geographic description of the collecting locality with respect to latitude and longitude and/or section, township, and range, as well as county and state, from the appropriate topographic map, as discussed in this paper.

In addition, one of the most important steps in collecting rocks, minerals, and fossils is recording as much information as possible about the specimens found. Keeping a

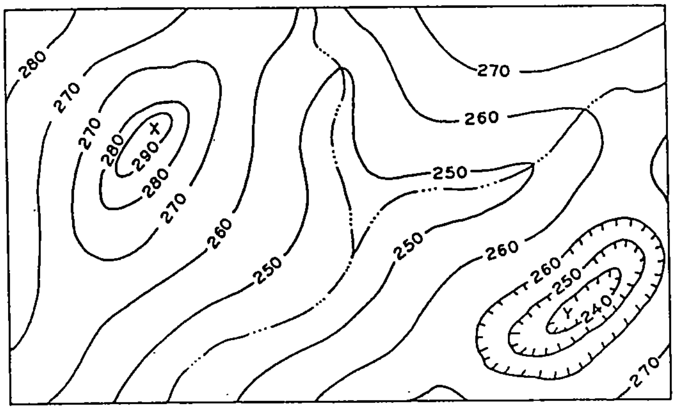


Figure 13. Map showing the method of determining the height of a hill and the depth of a depression (from Huffman, 1955). The height of the hill (X) is >20 ft but <40 ft. The depth of the depression (Y) is also >20 ft but <40 ft. (Note that both have the same number of closed contours.)

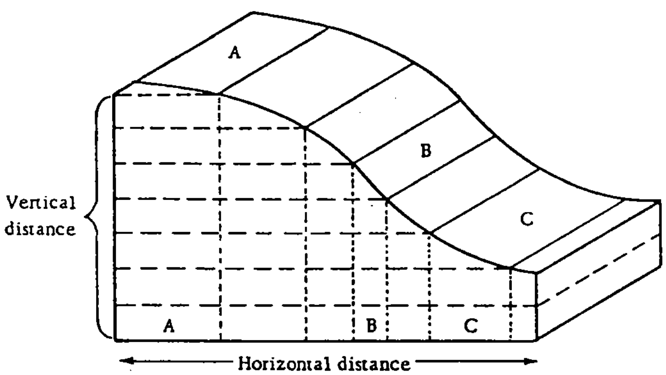


Figure 14. Schematic diagram showing the relationship of slope to spacing of contour lines (from Romey and others, 1967). Although vertical spacing between contours is constant, horizontal spacing is uneven: There is a general lack of contour lines on a relatively flat area (A). The contour lines on a steeply sloped land surface are closely spaced (B). The contour lines are widely spaced on a gently sloping land surface (C).

detailed record of everything known about a given specimen and collecting site is important, especially should the collector wish to return to the site for further study or collecting work. The keeping of detailed field notes distinguishes the dedicated collector from the casual amateur or rank beginner in any of the collecting areas: rocks, minerals, and fossils.

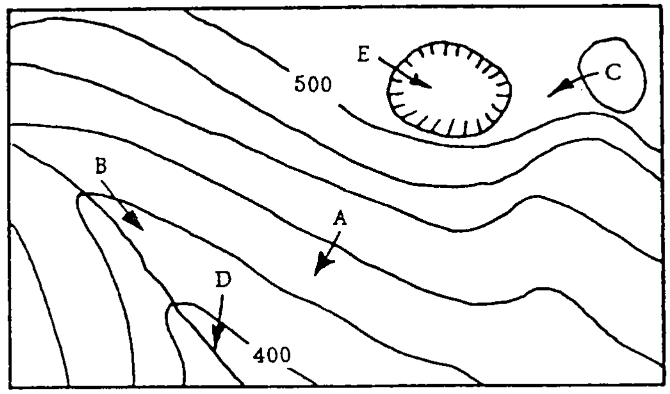


Figure 15. Contour sketch showing criteria for recognition of slope direction (from Romey and others, 1967).

SELECTED REFERENCES

Portions of the information and illustrations included in this paper are adapted primarily from the following sources.

Anonymous, 1969, U.S.G.S. principal map series and their essential characteristics: U.S. Geological Survey, 2 p.

Anonymous, 1981, Map scales: U.S. Geological Survey, 2 p.

Anonymous, 1987, Finding your way with map and compass: U.S. Geological Survey, single sheet.

Anonymous, undated (a), Oklahoma—index to topographic and other map coverage: U.S. Geological Survey, single sheet.

Anonymous, undated (b), Topographic map symbols: U.S. Geological Survey, 4 p.

Anonymous, undated (c), Topographic mapping: U.S. Geological Survey, 20 p.

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Zumberge, J. H.; and Rutford, R. H., 1983, Laboratory manual for physical geology: Wm. C. Brown, Dubuque, Iowa, 187 p.

APPENDIX 1.—SOME SOURCES OF TOPOGRAPHIC QUADRANGLE MAPS

The following is a list of some local and regional sources for purchasing topographic quadrangle maps.

OKLAHOMA

SOURCE:

Oklahoma Geological Survey
Publications
Energy Center
100 East Boyd Street, Room N-131
Norman, Oklahoma 73019–0628
405-360-2886

Each state has an index to topographic and other map coverage. These are free upon request from the respective map agencies listed. These indexes show the names for all 7.5' topographic maps in the respective states. Maps must be ordered from agencies by quadrangle name.

1. Index to topographic map coverage of Oklahoma – Free upon request
2. 7.5' Topographic quadrangle maps of Oklahoma – Cost $3.25 + postage
   (1 inch on the map = .4 mile [2,083 feet] on the ground surface)
3. County Map Series: 1:100,000 scale metric topographic maps of Oklahoma
   a. 30 x 60 minute quadrangle map series (1 cm on the map = 1 kilometer on the ground surface; 1 inch = 1.6 miles)
   b. Maps show:
      - Contour elevations in meters
      - Highways, roads, other man-made features
      - Woodland areas
      - Geographic names
      - 10-meter contour interval
   c. Cost $4.00 plus postage

REGIONAL MAP COVERAGE

SOURCE:

Map Distribution
U.S.G.S. Map Sales — 303–202-4700
Box 25286
Federal Center, Building 810
Denver, Colorado 80225

1. Index to topographic and other map coverage of all states west, and including Colorado, Wyoming, Montana and Texas – Free upon request
2. 7.5' Topographic quadrangle maps – Cost $4.00 each + $3.50 shipping and handling per order

Rolla ESIC
U.S. Geological Survey — 314–341-0856
1400 Independence Road
Rolla, Missouri 65401

1. Indexes to topographic and other map coverage of all states east of Montana, Wyoming, Colorado, and Texas – Free upon request
2. 7.5' Topographic quadrangle maps – Cost $4.00 each + $3.50 shipping and handling per order

APPENDIX 2.—UNITS OF MEASURE IN THE ENGLISH AND METRIC SYSTEMS, AND THE MEANS OF CONVERTING FROM ONE SYSTEM TO THE OTHER

A. English units of linear measurement

12 inches	= 1 foot
3 feet	= 1 yard
1 mile	= 1,760 yards, 5,280 feet, 63,360 inches

B. English units of area

1 square mile = 640 acres

C. Metric units of linear measurement

10 millimeters = 1 centimeter
100 centimeters = 1 meter
1,000 meters = 1 kilometer

D. Conversion of English Units to Metric Units.

Symbol	When you know	Multiply by	To find	Symbol
in.	inches	2.54	centimeters	cm
ft.	feet	30.48	centimeters	cm
yd.	yards	0.91	meters	m
mi.	miles	1.61	kilometers	km

E. Conversion of Metric Units to English Units.

Symbol	When you know	Multiply by	To find	Symbol
mm	millimeters	0.04	inches	in.
cm	centimeters	0.4	inches	in.
m	meters	3.28	feet	ft.
m	meters	1.09	yards	yd.
km	kilometers	0.62	miles	mi.

Using Professional Literature as a Guide to Rockhounding

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Ada, Oklahoma

INTRODUCTION

The purpose of this paper is to provide information on how to use professional geologic literature to locate sites for collecting minerals, fossils, and rocks. The paper is divided into three parts: (1) definition of professional geologic literature, (2) where to find professional geologic literature, and (3) evaluation and use of professional geologic literature.

DEFINITION OF PROFESSIONAL GEOLOGIC LITERATURE

For purposes of this paper, *professional geologic literature* is defined as published or unpublished work prepared by specialists with a degree in geology, engineering geology, geophysics, or earth science. The work typically has been edited and reviewed (sometimes called "refereed") by someone proficient in the geological sciences.

Professional literature falls into two categories, technical and nontechnical. Technical literature includes works that are to be used by earth scientists or other professional people well versed in the language of technical writing. Examples of technical professional literature include such publications as U.S. Geological Survey bulletins, monographs, and professional papers; state geological survey bulletins, circulars, geologic maps, guidebooks, special publications; professional journals such as the *American Association of Petroleum Geologists Bulletin*, the *Geological Society of America Bulletin*, the journal *Palaeontology*, and the *Journal of Sedimentary Petrology*; textbooks used by geology departments in colleges and universities; and reports by industry scientists—to name just a few.

Nontechnical literature includes such books as *The Rock Book* and *The Fossil Book* by Fenton and Fenton (1940, 1958); *Fossils, A Guide to Prehistoric Life* by Rhodes and others (1962); *Rocks and Minerals* by Zim and Shaffer (1957); educational publications by state geological surveys; certain guidebooks by state geological surveys; and certain articles in various rockhound magazines available through subscriptions.

Of special interest to rockhounds prospecting in Oklahoma are two older books: *Catalog of 100 Rocks, Minerals, and Fossils from Oklahoma* (Ham, 1942) and *Common Minerals, Rocks, and Fossils of Oklahoma* (Ham and Curtis, 1960). These are available from the Oklahoma Geological Survey (OGS) as reprints.

A new book titled *Guide to Resources for Earth Science Information in Oklahoma* (Suneson, 1996) has recently been released by the Oklahoma Geological Survey. This book points the reader to many nontechnical publications and other sources.

WHERE TO FIND PROFESSIONAL LITERATURE

The best place to start looking for informative geologic literature is in a library. Some small libraries may not have books on geology, but most, if not all, public libraries in larger cities as well as college and university libraries have geology books on their shelves.

Research literature can be located in a library through use of call numbers, either by the Library of Congress classification or the Dewey Decimal System classification. Interlibrary loan services are available so that research materials not found in one library may be borrowed from other libraries.

On the University of Oklahoma (OU) campus, the Lawrence S. Youngblood Energy Library houses the combined geology and geophysics collections of the Oklahoma Geological Survey and the University of Oklahoma (Fig. 1). More than 90,000 cataloged volumes going back to the late 1800s and more than 200,000 map sheets are contained in the library. A computerized online public catalog named OLIN (Oklahoma Library Information Network) lists most of the books held by the University Libraries; these books are accessible by title, author, subject, and key words. Access to OLIN is available in the Youngblood Library. Holdings in the collection can also be accessed through book and map card catalogs.

Assistance is available for those unfamiliar with library use. Browsing often yields good results. Photocopiers are available in the library. Information on acquiring a borrower's permit is available at the Youngblood Library counter.

For those wishing to start a geologic library of their own, books and maps can be purchased by mail order

Hemish, L. A.; and Shaha, B., 1996, Using professional literature as a guide to rockhounding, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 125–128.

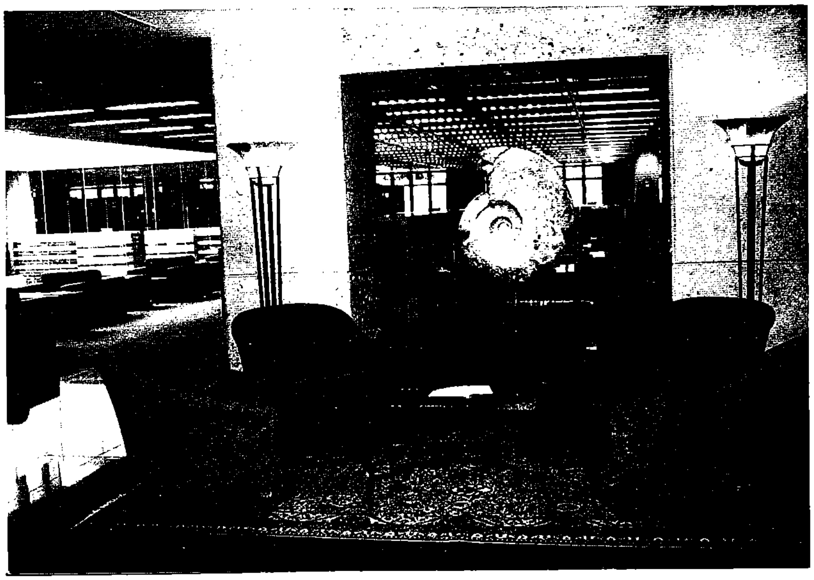

Figure 1. View of the entrance to the Youngblood Energy Library, Sarkeys Energy Center, University of Oklahoma, Norman, Oklahoma.

from such government organizations as the U.S. Geological Survey or the various state geological surveys, as well as through private publishing companies. Some bookstores carry both old and new geologic literature.

The Oklahoma Geological Survey distributes a free catalog ("List of Available Publications") that provides information about new OGS publications as well as older publications that are in print. Books and maps can be ordered by mail or purchased from the OGS Publication Sales Office, now located at 1218-B West Rock Creek Road in Norman (Figs. 2, 3). Out-of-print documents are available in photocopied form if requested.

Organizations such as the Oklahoma City Geological Society, the Tulsa Geological Society, and the Ardmore Geological Society are other good sources of professional geologic literature.

Another place to find useful professional literature is in the libraries of rock and mineral clubs. Locations of collecting sites for specific local or regional areas may have been recorded and filed for future use by club members. Personal communication with experienced rockhounds can provide the information needed to locate the best geologic literature available.

USING AND EVALUATING THE LITERATURE

Once the literature is in hand, how do you use it? Because of a keen interest in the science, most rockhounds have a good working knowledge of geology. Therefore, reading and evaluating professional publications are relatively easy for them.

First, a specific objective must be established. Is there a geographic area that is of prime importance for a collecting excursion? Are you looking for a specific rock, mineral, or fossil? Are you limiting your search to a certain geologic age, or to a certain rock unit? The book(s) and/or map(s) must be selected to fit your interests and needs.

After the literature has been selected, how can you benefit the most from its use? First, scan the index. Then read the information about your topic in the text. Look at the figures, figure captions, plates, and measured sections—they often give specific locations for economic rocks and minerals or illustrated fossils. From whichever book is selected one should choose locations that fit rock units of the geologic age one wants to investigate.

Make use of any geologic maps that are generally part of a professional publication. Study the map explanation and acquaint yourself with the outcrop patterns of each rock unit shown. When in the field, if collectible specimens can't be located at the site named in the text, or shown on the map, work laterally along the outcrop belt, paying par-

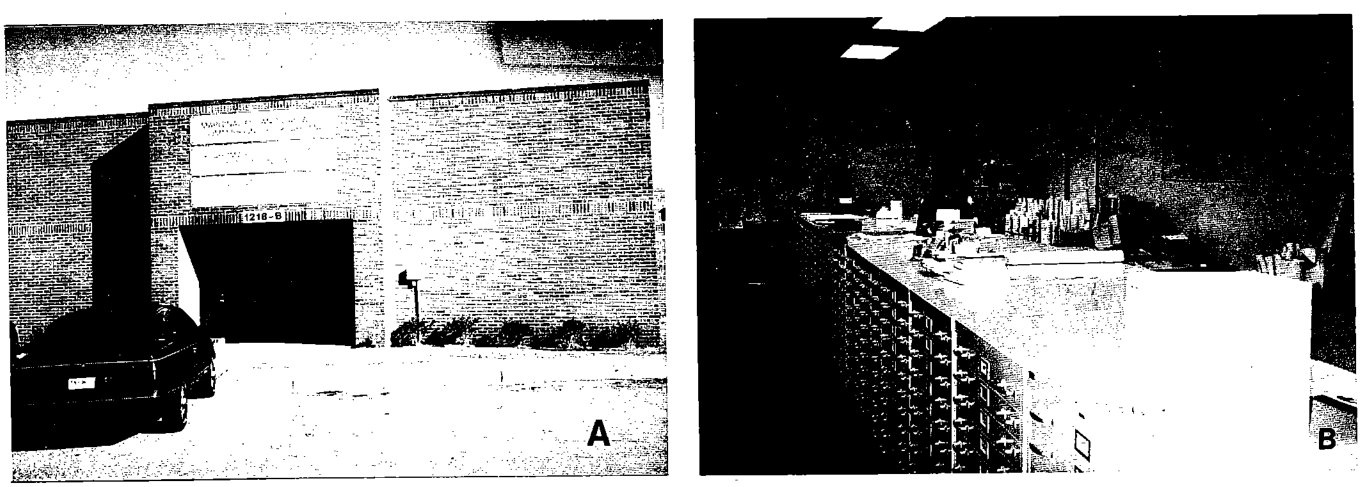

Figure 2. Exterior view (A) and interior view (B) of the Oklahoma Geological Survey Publication Sales Office at 1218-B West Rock Creek Road, Norman, Oklahoma; phone (405) 360-2886.

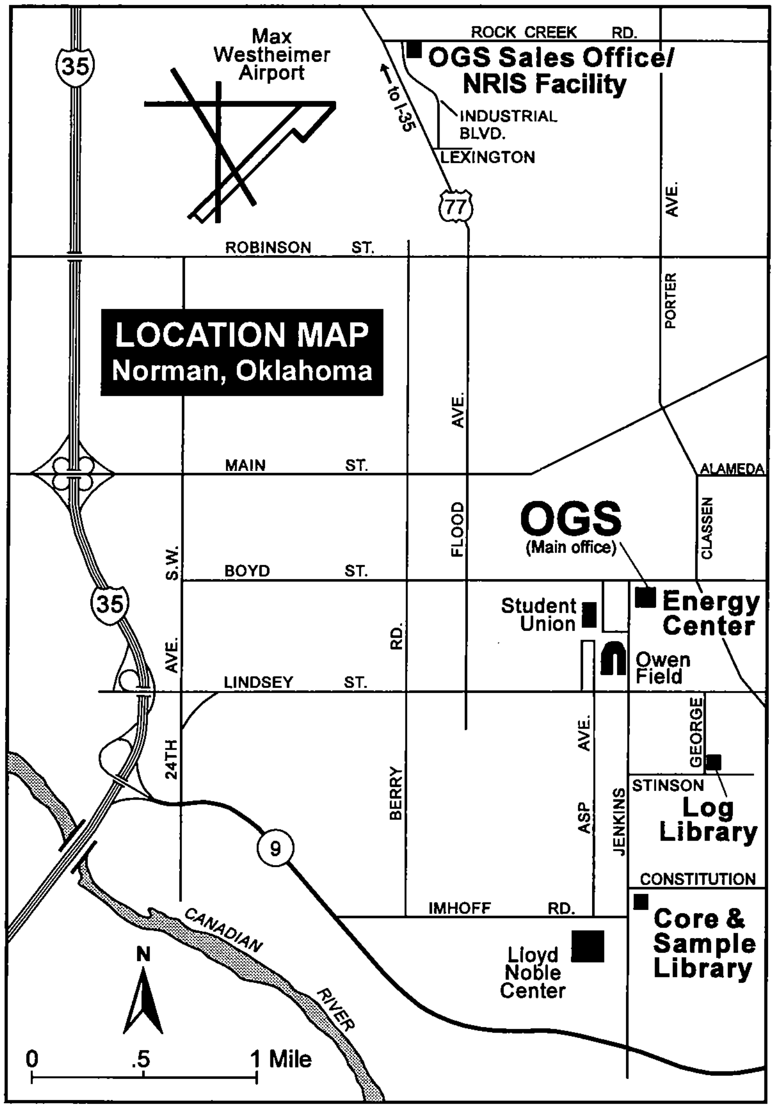

Figure 3. Location map for Oklahoma Geological Survey facilities in Norman, Oklahoma: Main Office, at 100 E. Boyd; Publication Sales Office, at 1218-B West Rock Creek Road; Log Library, at 1425 George Avenue; and Core and Sample Library, at 2725 S. Jenkins.

ticular attention to creeks, road cuts, railroad cuts, spillways below dams, and quarries. Be able to recognize map symbols (shown in the map explanation) that show where old mines, pits, and quarries are located.

Many books will indicate both the variety and relative abundance of fossils or minerals at the location specified. Remember that the professional geologist uses the fossils in a rock unit to determine the identity of the unit. The collector, then knowing the identity of the unit, goes to it in the field to find a specific fossil. The professional might be satisfied with a part of a fossil that is identifiable, whereas the rockhound is searching for the perfect specimen for his or her collection. The literature seldom indicates the quality. Some places have well-preserved fossils—others have only broken pieces.

Some of the early literature is amazingly accurate. However, ongoing processes of change are constant, and locations that were once good collecting sites may no longer exist. Cliffs erode, creeks change their courses; railroad and road cuts may have been eliminated, or they may be concealed by an overgrowth of vegetation. Buildings or new highways may have been constructed on good collecting sites.

The professional literature will usually give township, range, section, and where in that section specimens occur. To determine land ownership at a selected site, visit the county clerk's office. The name and address of the owner will be provided. Permission should be secured by talking to the landowner, preferably in person, before entering onto private property for collecting purposes.

Locations given in some literature, particularly older literature, may be incorrect. The given locations may be mislocated by a section, or perhaps as much as one full township; so, don't always expect to walk directly to the indicated spot. Careful searching, inspection of all outcrops in an indicated area, and persistence will often lead the collector to the mislocated site.

Consultation of even the most recently published literature may not lead to collectible specimens. If a measured section from a geologic report indicates a potentially good collecting site, and subsequently that site is visited, results may be disappointing. Earlier visitors to the site may have already gleaned the outcrop, and collectible material may not be available without extensive excavation.

The time spent looking for good locations can be shortened by communicating with experienced collectors who have made good use of available professional literature. Following their directions can give valuable leads on where to look, as well as where not to look. Formations of the same age at different locations may not yield material everywhere that is well preserved. In some areas, stratigraphically higher or lower units may yield the best-preserved material.

A county highway map, usually available at the local county clerk's office, can be used to hand trace the productive formations from a geologic map. Section numbers and all roads are well shown on these county maps. Points of reference for easily accessible areas can be determined. A hand trace is usually adequate to locate roads that will provide access to good locations, as determined from the geologic map. Searching should be limited to the area drawn on the county map.

In time, thorough research of the literature and published geologic maps combined with careful search in the field allows the rockhound to make a personalized map. By constant updating and color coding to mark good collecting sites, along with notes of phone numbers of land owners, a rockhound's map takes on its own character. Use and evaluation of the professional literature have ultimately produced a rockhound's treasure map!

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Keeping a Field Notebook

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INTRODUCTION

An important but often overlooked element in the successful fossil-collecting or rockhounding expedition is the field notebook. Although field geologists would not dream of working in the field without a book to record their observations, findings, and analyses, the rockhound or collector often relies only on maps and memory to find a good collecting locality and to evaluate what has been observed and found. The benefits of keeping a field notebook to the rockhound, fossil collector, or educator are many. Advantages include conducting more successful expeditions, making better finds, classifying the specimens more accurately, returning successfully to the same locations, and developing a deeper understanding of geologic processes. Although many may think that the geologist makes entries in the notebook only while at the outcrop, ideally, the field notebook is used before, during, and after the field work. Using the field notebook to plan the trip, as well as to analyze findings after the trip is over, will contribute to the trip's success.

DESCRIPTION OF THE FIELD NOTEBOOK

Ideally, a field notebook is a bound book with numbered pages. If the pages, ink, and pencils are waterproof, the accidental loss of valuable data can be avoided. The notebook should be small enough to be carried comfortably in a backpack or pocket, but not so small that it is impossible to make sketches of the outcrop and the fossils or mineral specimens collected there. Entries can be made with pen or pencil. Colored pencils can be used effectively to denote lithology changes, or changes in structure or composition of fossil assemblages. Numbered pages allow cross-referencing and they also enable the individual to continue notes, observations, or analyses in a different book or on separate pages.

PLANNING

The most effective use of the field notebook begins before the field work ever commences. Using the notebook as a place to work out ideas, to record observations from previous trips, and to list anticipated findings can help prepare the individuals to make the most of each stop. The primary functions of planning can be broken down into brainstorming, organizing, and anticipating phases. A key to success is to accomplish these phases before one ever leaves on the field trip.

The first step of the initial planning phase is to identify the goal or objectives of the field trip and to write them on the first page, along with the date. For example, if the objective of the field trip is to find examples of *Texa gryphaea* in the Cretaceous Kiamichi Shale in southeastern Oklahoma, then this should be clearly stated. Similarly, if the goal is to find a good location in central Oklahoma where elementary-age school children can collect barite crystals (rose rocks) in the Permian Garber-Wellington Formation, this also should be clearly stated.

After a goal has been defined, it is necessary to determine the stops or collecting localities that best help one achieve the field-trip objectives. A list of potential or prospective collecting locations should appear in the section under goals or objectives or on the pages following that section. Each prospective collecting location should be numbered, and space left at each entry in the book for further data and planning. Once a list of potential collecting locations has been developed, the location should be marked on a topographic or geologic map (Fig. 1). The spot location, with section, township, range, and county, should be recorded in the field notebook next to the number of the location.

In order to minimize confusion and frustration in finding the localities, it is a good idea to look at county and state road maps or topographic maps to determine the best way to get to the locations. This information should be entered into the field notebook as well. If the numbered localities on a map correspond to those in the field notebook, much confusion can be avoided.

Perhaps the most important step in the planning stage is to anticipate what will be found at each location. This process will enable the individual to more readily identify fossils or mineral specimens, and it will encourage a fuller, deeper understanding of the geology of the area. This can add to the overall appreciation of the experience and make it more educational and enlightening to those who may accompany the individual on the field trip. This is especially true in the case of science education, where the better the teacher's understanding, the richer and more fruitful the experience will be for the students.

In the space next to each proposed stop, the individual should make a list of the fossils or minerals that are expected to occur there. Then, a sketch or a photograph of each can be placed next to the items in the list. This procedure will clarify the objective in the individual's mind

Nash, S. S., 1996, Keeping a field notebook, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 129–134.

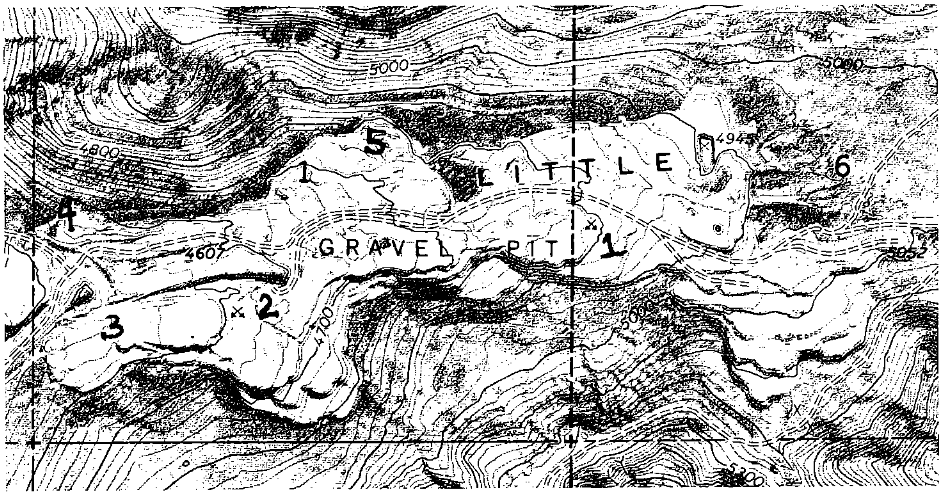


Figure 1. Number proposed collecting locations and mark them on a topographic or geologic map.

and make it less likely that good specimens will be overlooked.

At this point, it is extremely useful to start a new section in the field notebook that begins where the planning section ends. This is the brainstorming section, and the objective is to develop an analytical approach to the field project that will enable the rockhound to move beyond the role of observer and/or collector to a deeper understanding of earth science that may result in the discovery of even better collecting localities than the ones originally proposed.

It is important that the brainstorming section be as fluid and free-associative as possible. With the relaxation of structure, one can more easily make connections and draw conclusions. This is not the time or place to worry about grammar or coherency. The main objective is to think intuitively and to find creative solutions to the problem of deducing where the best outcrops might occur. Virtually any question or observation relating to the anticipated field trip is within the scope of this section. To get started, the rockhound should contemplate the following questions and enter possible answers in the field notebook:

1. Speculate why the minerals or fossils are occurring in the collecting localities. Write down your thoughts.
2. What makes your proposed collecting localities good? Is there a particular zone within a formation? What is it? Answer in the field notebook, and think of new locales that might fit the criteria of the others. Write them down.
3. What was the depositional environment? What evidence can you find in the field?

RECORDING LOCATIONS AND LITHOLOGIES

On the day of the field trip, a well-organized, well-thought-out field notebook can make the difference between a successful trip and a disappointing one in which everyone returns home empty-handed. The value of maintaining a field notebook during the trip is twofold. First, it helps one keep good records of the trip so that the best possible identification and analysis of the fossils or mineral specimens are possible. Second, a good field notebook allows one to return to the same locations in the future—especially if they are difficult to find or are obscured—and thus guarantees repeatability of results. Another benefit is that it relieves the worker from having to rely too much upon memory. Observations made in the notebook can be examined later—geologic, geomorphic, and geographic analyses are possible if good data are collected and recorded on site. For example, one might study channel development and point-bar deposition or speculate regarding the depositional environment or paleoecology of the site at the time when the fossilized organisms thrived.

As in the case of the planning stage, a methodical, but not inflexible, step-by-step approach is best. Each location should have a separate place in the field notebook for notes, observation, and sketches (Fig. 2). Plenty of blank space should be left at the end of each entry for later comments, analysis, or ideas. The comments and observations can be placed somewhere within three general categories: location, lithology, and findings. The findings include fossils and/or mineral specimens, and the field notebook entry for those will be dealt with in the next section. This section will look at the two initial categories: location and lithology.

Location

Simply put, the location is an accurate description of the stop that enables a person to return to the place. Since this is the primary way in which collecting places are identified, it is important to make sure that the numbers in the field notebook are consistent with the numbers on the map. After the field trip is over, it is often useful to develop a table of contents or an index in which the site number and the field-notebook page number appear together. At the beginning, however, simply make a separate entry in the field notebook for each stop or collecting location (Fig.

The Field Notebook — A Typical Page

Stop Number:

Name of topographic or geologic map:

Spot location (legal description):

Nearby roads:

Formation at outcrop:
  name:
  lithological description:

Sketch of outcrop:

Description of fossils or minerals:
  Specimen 1:

  Sketch:

  Specimen 2:

  Sketch:

Regional geology:

Figure 2. Each stop is an opportunity to collect and record data in the field notebook.

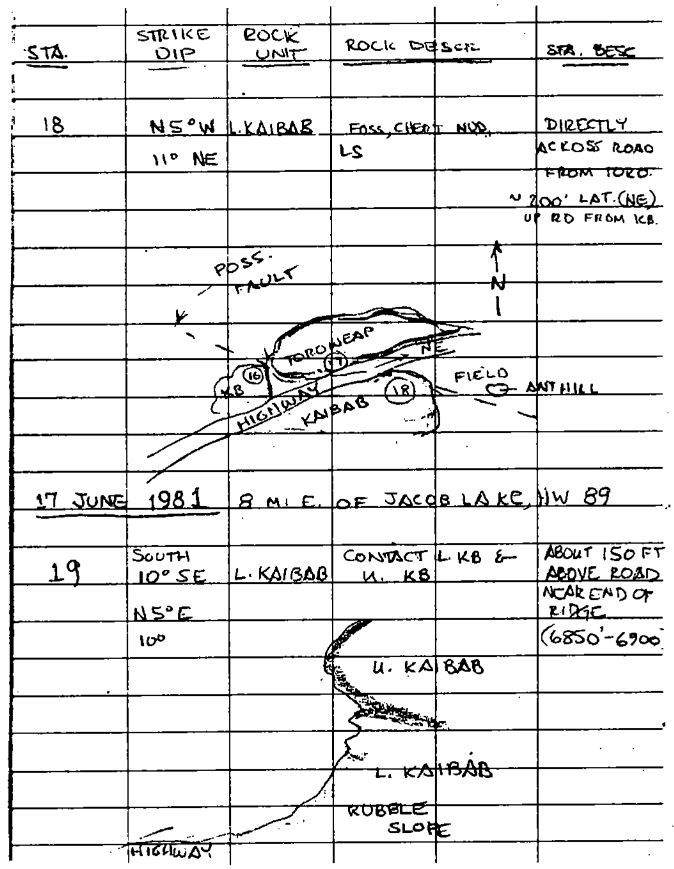


Figure 3. Describe the location and make a sketch of the area. Draw a map view first and then a cross section that includes the formation of interest.

3). Write the number on the topographic or geologic map on the spot location, and then, in the field notebook, describe the location as specifically as possible, with section, township and range, and county.

To make the description as useful as possible and to pinpoint the site, include "ground truth" data from the site, including the mileage from nearest intersection, signposts, and landmarks or other cultural markers. Include a date and perhaps time. This latter, seemingly inconsequential detail is in fact very useful, particularly if some of the cultural markers are seasonal and therefore transitory. For example, a collecting locality for Cretaceous ammonites near Lake Texoma may be adjacent to a marina or campsite that is closed during the winter. In that case, many of the signs and landmarks present during the summer simply may not exist during the winter months. If one is relying on those seasonal cultural landmarks to find the site, one will face an difficult and confusing task. Mileage markers, roads, and permanent structures are better indicators. Also, it is important to describe conditions at the outcrop as well, since the outcrop may not be as exposed during certain times of the year. Sometimes the best time to find fossils or mineral specimens is after a heavy rain, when differential erosion reveals new layers or cleans up the specimens by washing away the matrix.

Lithology

The goal of this section is to make the field worker more aware of the geologic setting and thus develop a working understanding of the nature and occurrence of the desired fossils and/or minerals. Such an understanding will prove useful when trying to determine where new, perhaps yet undiscovered localities might exist. It also helps the field worker gain a broader view of the overall geologic system, which includes depositional environment, paleoecology, sedimentation, and stratigraphy (Fig. 4). In addition, making such observations increases one's analytical skills and makes comparison between sites more accurate.

Entries in the field notebook about the lithology should follow the data on the location. The following list is a guideline that can be modified depending on the individual's objectives or the nature of the outcrop:

1. Describe the lithology as completely as possible.
2. Include all recognizable, distinguishable strata.
3. Record the sequence and sketch the stratigraphic section as it appears at this location. On the sketch, indicate which layer contains collectible rocks, minerals, or fossils.
4. Describe texture, minerals present, color, and other distinguishing characteristics.

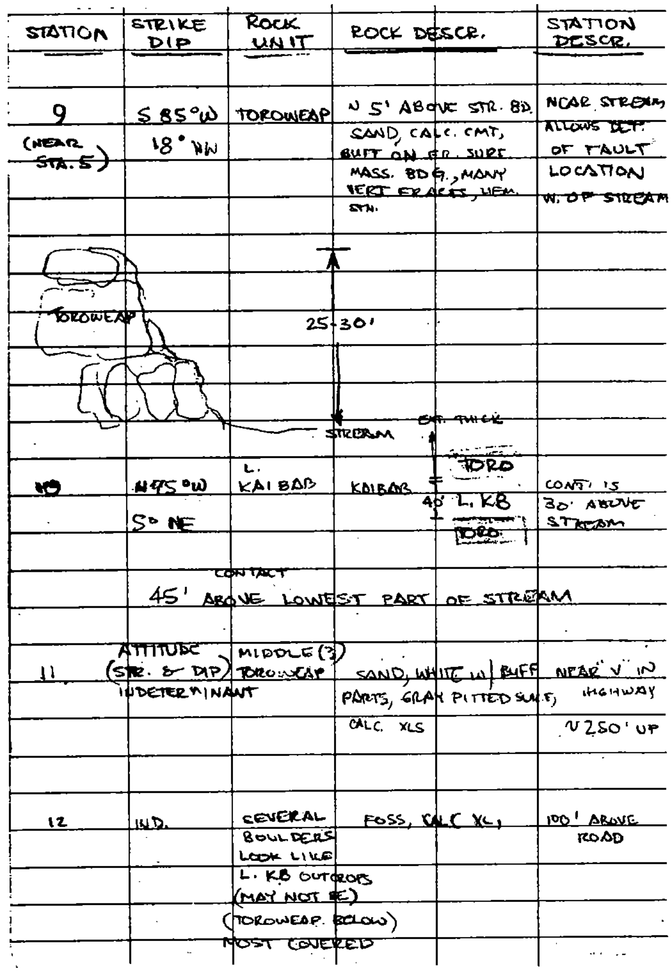


Figure 4. Include lithological descriptions of the formations.

5. Look at a geologic map or publication to determine the formation name. Write that down.
6. If possible, make a note of where the target zone (the zone containing collectible rocks and minerals) occurs nearby.

With a field notebook that contains careful and relatively detailed notes on the lithology, location, and the overall geologic setting, the field worker can more easily return to the same location in the future or analyze the occurrence and find analogous (and perhaps even better) locations in the same area.

DESCRIBING THE FINDS

Without good records, all the interesting fossils and mineral specimens that one finds on a trip will be reduced to an unidentifiable, undifferentiable mass. Perhaps general classification is possible, particularly if one's memory is good, but little else can be done if all the day's finds are simply thrown into a common box to be sorted through later. Good labeling and description techniques can avert that collecting disaster. In addition, the careful observation that is required to make the entries will help the field worker develop analytical skills so that he or she is more able to locate and identify good specimens while at the outcrop.

The importance of good records cannot be understated. It is imperative to have good records in order to identify, classify, and map the fossil and mineral specimens. Good records help the field worker get the most from the finds and possibly locate other excellent collecting sites.

The following procedures will help the field worker classify the finds more accurately.

Fossils

1. Label each fossil with site number.
2. Assign the fossil a number and put it in a separate container or bag.
3. Record each fossil in the field notebook. Enter a brief description and sketch (Fig. 5).
4. Make a preliminary attempt to identify the fossils.
5. Record the name of the reference book or geological survey publication that contains useful references to the fossils.
6. Make a list of all fossils in the outcrop, even those not collected.
7. Record the formation name.
8. Estimate the proportion of different fossils found (for example, 20% trilobites, 60% crinoids, 20% brachiopods).

Minerals

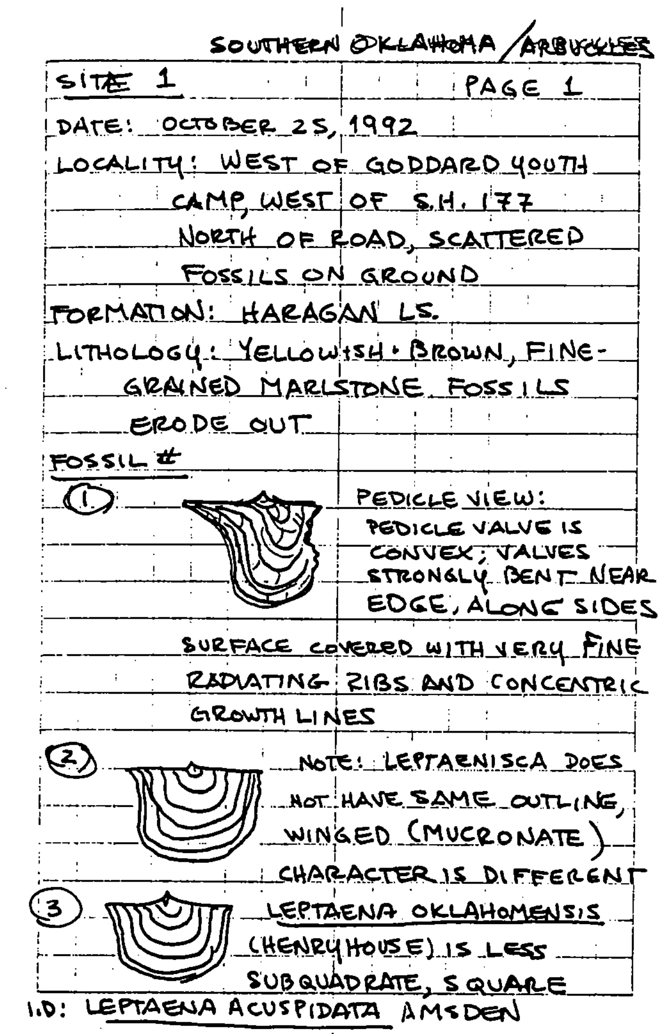
1. Label each mineral specimen and record it in the field notebook.
2. Place each mineral specimen in an individual container and label the container.
3. Describe where each specimen was found in the formation and indicate location on a sketch of the outcrop.
4. Record the formation name.
5. Attempt a preliminary identification of the mineral and record its distinguishing characteristics.
6. Describe the matrix.
7. Evaluate the geologic and topographic map to propose other prospective sites that appear to be similar to this one.

SPECIMEN CLEANING, PREPARATION, AND THE FIELD NOTEBOOK

Cleaning and preparation present an opportunity for the field worker to either create chaos of what has been so systematically found and organized, or to more accurately classify the specimens, and thus develop a deeper understanding of the depositional environment, regional geology, and the geologic history of the area.

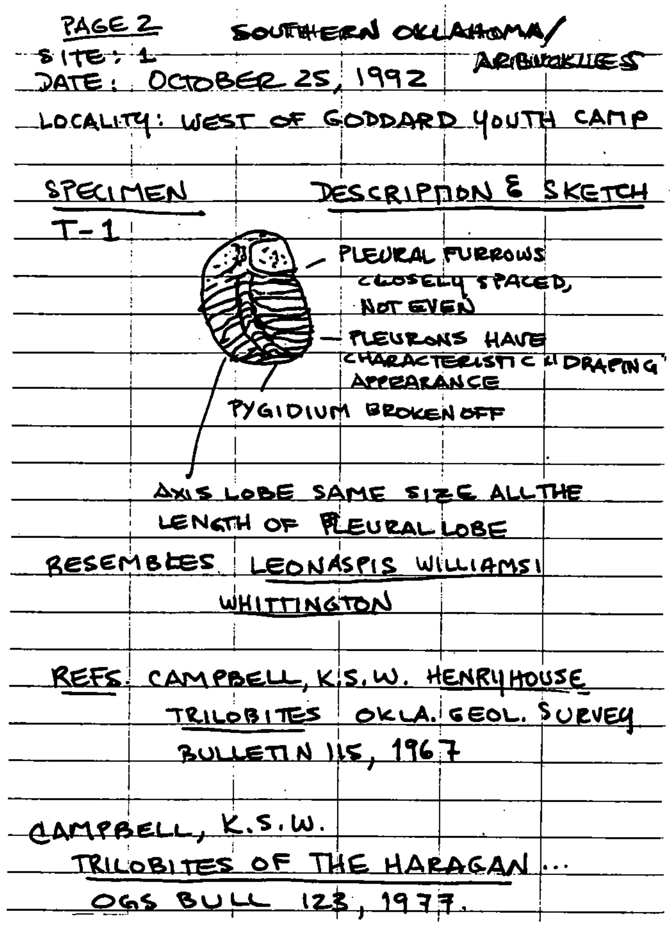
Following a few simple procedures will insure that the specimens are not misplaced or mislabeled. A systematic procedure should include these steps:

1. Clean fossils or mineral specimens from one locality at a time.
2. Double-check the label with description in the field notebook.
3. Add descriptions and observations to the notebook entry after the specimens have been cleaned.



SOUTHERN OKLAHOMA / ARBUCKLES
SITE 1 PAGE 1
DATE: OCTOBER 25, 1992
LOCALITY: WEST OF GODDARD YOUTH CAMP, WEST OF S.H. 177 NORTH OF ROAD, SCATTERED FOSSILS ON GROUND
FORMATION: HARAGAN LS.
LITHOLOGY: YELLOWISH • BROWN, FINE-GRAINED MARLSTONE. FOSSILS ERODE OUT
FOSSIL #
1 PEDICLE VIEW: PEDICLE VALVE IS CONVEX; VALVES STRONGLY BENT NEAR EDGE, ALONG SIDES
SURFACE COVERED WITH VERY FINE RADIATING RIBS AND CONCENTRIC GROWTH LINES
2 NOTE: LEPTAENISCA DOES NOT HAVE SAME OUTLINE, WINGED (MUCRONATE) CHARACTER IS DIFFERENT
3 LEPTAENA OKLAHOMENSIS (HENRYHOUSE) IS LESS SUBQUADRATE, SQUARE
I.D: LEPTAENA ACUSPIDATA AMSDEN

Figure 5. Record each fossil in the field notebook. Enter a brief description and sketch.



PAGE 2 SOUTHERN OKLAHOMA / ARBUCKLES
~~SITE: 1~~
DATE: OCTOBER 25, 1992
LOCALITY: WEST OF GODDARD YOUTH CAMP
SPECIMEN DESCRIPTION & SKETCH
T-1
PLEURAL FURROWS CLOSELY SPACED, NOT EVEN
PLEURONS HAVE CHARACTERISTIC "DRAPING" APPEARANCE
PYGIDIUM BROKEN OFF
AXIS LOBE SAME SIZE ALL THE LENGTH OF PLEURAL LOBE
RESEMBLES LEONASPIS WILLIAMSI WHITTINGTON
REFS. CAMPBELL, K.S.W. HENRYHOUSE TRILOBITES OKLA. GEOL. SURVEY BULLETIN 115, 1967
CAMPBELL, K.S.W. TRILOBITES OF THE HARAGAN... OGS BULL 123, 1977.

Figure 6. Try to make accurate and specific classification of specimens.

4. Work with additional reference books to classify and categorize fossils and minerals. Write the bibliographic information in the notebook.
5. Attempt more accurate and specific classifications. Modify sketches (Figs. 6 and 7).
6. Compare the fossils and minerals of one locality with those of another.

The specimen-cleaning phase can also be a time to consider adding other items of interest to the field notebook. This contemplation provides the rockhound or field worker an opportunity to develop more interests and to gain a wider, more comprehensive appreciation of the resources of the area she or he is working in. This will allow the field worker to find innovative uses for the notebook. For example, the field notebook can be used as source material for creative writing, personal essays, economic development ideas, and vacation planning. With those possibilities in mind, it can be useful to include the historical facts and items of interest about areas near the collecting localities, brief socio-cultural backgrounds, details about nearby ghost towns and boom towns, lists of predominant industries and natural resources, an overview of economic trends, and information about or descriptions of parks and recreation centers.

OTHER SOURCES OF GUIDELINES FOR FIELD NOTEBOOKS

Textbooks on field geology often provide helpful guidelines and procedures to follow when keeping a field notebook. Some of the recommendations may not be applicable to the rockhound or fossil collector since the textbooks focus more on geologic field mapping than on rockhounding. Nevertheless, they can be useful. Perhaps the most well known is Frederic H. Lahee's *Field Geology* (1961), a long-time standard that has appeared in many editions since its initial publication in 1916. An updated approach can be found in Terry S. Maley's *Field Geology Illustrated* (1994), which gives good examples of field mapping problems as well as tips for logging the data into a field notebook. F. Moseley's *Methods in Field Geology* (1981) provides guidelines for organizing field notes and diagrams, primarily while one is still in the field or each evening after returning home or to base camp. Perhaps the

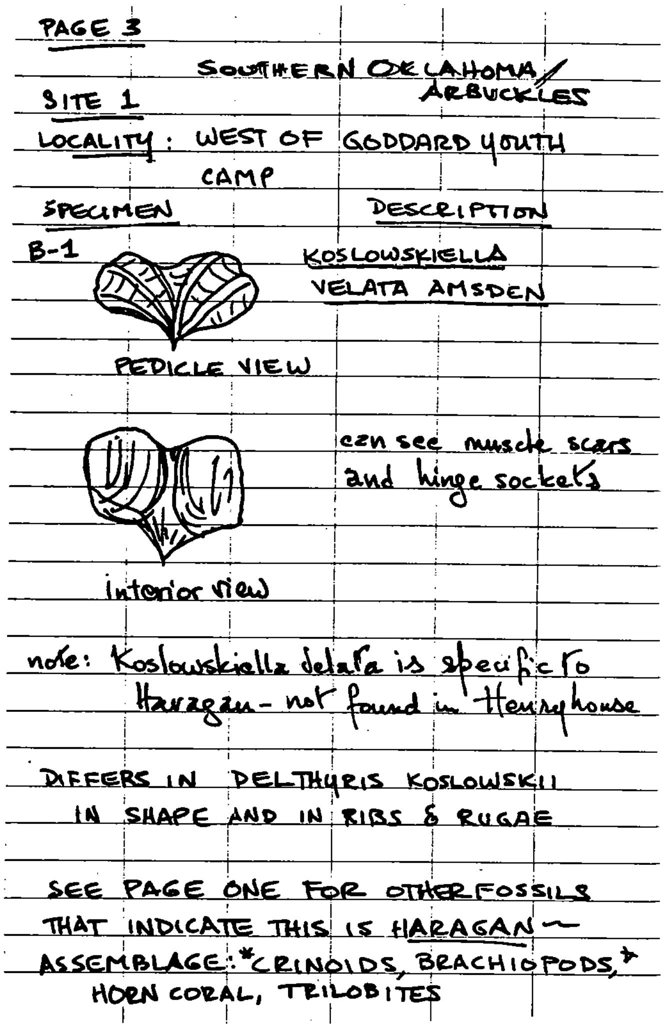


Figure 7. Analyze specimens closely and attempt preliminary classification of the formation, with consideration given to the depositional environment, the fossil assemblage, and published information.

most useful and comprehensive guide to keeping a field notebook appears in I. M. Simpson's *Fieldwork in Geology* (1977), which emphasizes good planning, record-keeping, and organization in the data-collection and data-analysis phases. Some rock and mineral field guides also contain suggestions for keeping notes; these include *The Audubon Society Field Guide to North American Rocks and Minerals* (1978) by Charles Wesley Chesterton, *A Field Guide to Rocks and Minerals* (1960) by Frederick H. Pough, and *The Rock-Hunter's Field Manual: A Guide to Identification of Rocks and Minerals* by D. K. Fritzen (1959).

CONCLUSION

The experienced field geologist, rockhound, or fossil collector realizes the importance of a good field notebook in planning field trips, collecting on-site data, and classifying specimens. The geologist benefits immediately from more successful expeditions. There are future benefits as well, and they include better identification of specimens, a fuller understanding of the geology, better information for displays and reports, more accurate information for science-education purposes, and an increased likelihood of successful future field trips.

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Resources for Amateur Collectors and Rockhounds Available from Universities, Museums, and State and Federal Agencies in Oklahoma

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INTRODUCTION

The relationship between amateur fossil and mineral collectors, sometimes known as rockhounds, and professional geologists and land managers varies, but is generally one of mutual respect and benefit. There are many instances in which collectors have discovered sites or materials that have proved interesting and/or important to geologists, and some collectors have donated material that has significantly improved the quality of comparative research collections. On the other hand, some technical geologic literature has provided collectors with a wealth of potential collecting sites and enabled accurate descriptions of collectors' fossil and mineral specimens. Many geologists are also willing, if not eager, to share their knowledge with collectors of all ages. Most managers of public lands recognize the multiple-use philosophy, and unless collectors damage or deface public lands or remove protected materials (especially vertebrate fossils and cultural, historical, and archaeological materials), these managers allow and even encourage amateur collecting.

Information on geology, specimen identification, and collecting rocks, minerals, and fossils in Oklahoma is available to amateur collectors from universities, museums, and State and Federal agencies. Much of this information is free or inexpensive, although some takes a fair amount of time to access. Most of the resources described here focus on identifying specimens and learning more about their geologic occurrence, rather than answering specific questions such as "Where can I go to find beautiful rose rocks?" or "Where is the best place to collect ammonites?" Local collectors or rockhound clubs are generally the best place to learn about collecting sites. However, if an individual has the time, knowledge, and inclination to look through the technical literature, meet with professional geologists, learn how to use topographic maps, etc., excellent and little-collected localities can be found.

This brief paper is designed to bridge the gap between the professional geologist and amateur collector or rockhound. Most geologists are relatively familiar with the resources available at universities and government agencies; however, many collectors may not be. Some of the information below might also be of interest to earth science educators, mostly because they typically have a need for inexpensive teaching materials. *Time* is probably the most important element in using the resources described here; collectors must have time and patience, be it to properly identify an unknown specimen or to search for a new collecting site.

This paper summarizes parts of a book recently published by the Oklahoma Geological Survey titled *Guide to Resources for Earth Science Information in Oklahoma* (Suneson, 1996). The book lists all the university and college faculty involved in the earth sciences, museums with earth science displays, and State and Federal agencies with earth science interests. In addition, the book contains lists of state parks with geologic displays, active mines and quarries that permit tours, rock and mineral shops, continuing-education courses, nontechnical books and articles, geoscientists throughout the state who are willing to work with the public and educators, professional geological organizations, and amateur rock, mineral, and gem clubs and societies.

OKLAHOMA UNIVERSITIES AND COLLEGES

There are three comprehensive universities in Oklahoma with large geology departments: the University of Oklahoma (OU) in Norman, Oklahoma State University (OSU) in Stillwater, and the University of Tulsa (TU) in Tulsa. The resources of interest to collectors at all three are generally similar. These universities have geology faculty members, many of whom are willing to discuss fossil and mineral identifications with collectors. A phone call to the department, with a request to speak to someone knowledgeable in rocks, minerals, and/or fossils, is generally the best way to start. In some cases, the faculty member may request a photograph of a specimen or that the specimen be mailed or brought in. If the specimen is unique or extremely unusual, the faculty member may ask where it came from because he/she may be interested in collecting more or noting its geologic occurrence. In no case will a

Suneson, N. H., 1996, Resources for amateur collectors and rockhounds available from universities, museums, and State and Federal agencies in Oklahoma, *in* Johnson, K. S.; and Suneson, N. H. (eds.), Rockhounding and earth-science activities in Oklahoma, 1995 workshop: Oklahoma Geological Survey Special Publication 96-5, p. 135–139.

faculty member refuse to return specimens sent for identification. Some identifications are relatively easy and others more difficult; and some take long simply because the faculty member may have other, more pressing commitments. All three comprehensive Oklahoma universities have faculty members who can identify rocks and minerals; OU and OSU also have paleontologists on staff who can identify invertebrate fossils. Vertebrate fossils and fossil plants typically can be identified by staff members at the Sam Noble Oklahoma Museum of Natural History (see the section on Oklahoma museums).

In addition to hand-specimen identifications by faculty members, collectors may want to have more sophisticated tests run on their mineral specimens; these include detailed crystallographic measurements using an X-ray diffractometer (OU, OSU, TU) or a chemical analysis using an electron microprobe (OU, TU). These tests require trained personnel and analytical-machine time; as a result, the tests can be quite expensive ($100 per hour). Some fossil and/or mineral specimens may be looked at through binocular or petrographic microscopes and thus identified; sample-preparation costs can be moderate. Some faculty members maintain research or teaching collections that can be used to compare known with unknown specimens.

There are many smaller colleges and universities throughout Oklahoma. Some of these have small geology or physical science departments or, in some cases, a single individual. Faculty members in these departments typically are willing to identify rock, mineral, and fossil specimens brought to them by collectors. In some cases, faculty members in other departments or on the staff are willing to do hand-specimen identifications.

An important resource available at all the colleges and universities in Oklahoma, but particularly at the comprehensive universities, is the libraries. The most complete geological library in the State is the Laurence S. Youngblood Energy Library located in the Sarkeys Energy Center at OU. It has an excellent collection of technical and popular books and journals. In addition, the library has a complete set of topographic maps of all 50 states and all U.S. Geological Survey and state geological survey geologic maps. Nonuniversity individuals may purchase a "user's card" for $50.00, which allows them to borrow books and journals from any of the OU libraries. People living in the Oklahoma City area may apply for a "borrower's permit" (free) that allows them to borrow books and journals only from the Youngblood Energy Library. The use of books, journals, and maps in the library is free, and copying machines are available.

The Edmon Low Library on the OSU campus also has a large collection of technical and popular books and journals on geology as well as geologic maps and a complete set of Oklahoma topographic maps. Nonuniversity individuals may purchase a "courtesy card" that allows access to the library databases (i.e., "card catalogs") at a cost of $20 for six months; however, borrowing privileges for Oklahoma residents are free. The McFarlin Library at TU also has a wealth of geologic literature. Nonuniversity individuals wishing to use that library may do so for $65 for six months or $100 per year. To borrow material from the McFarlin Library costs $130 for six months or $200 per year. Topographic maps of Oklahoma are available at the Tulsa City/County Library. Noncounty residents may purchase a library card for $20 per year. The topographic maps may be borrowed by businesses only; individuals may photocopy the maps for private use.

Back issues of rockhound magazines are available at some of the libraries at the colleges and universities in Oklahoma. Most of the collections are large, but incomplete. Issues of *Gems and Minerals* and *Jewelry Making, Gems and Minerals* are available at Southwestern Oklahoma State University in Weatherford and the University of Central Oklahoma in Edmond. *The Mineralogist* is available at Phillips University in Enid and the Youngblood Energy Library at OU in Norman. *Lapidary Journal* is available at the Tulsa City/County Library. *The Mineralogical Record* is available at the Youngblood Energy Library at OU in Norman. *Rock and Gem* is available at Southwestern Oklahoma State University in Weatherford. *Rocks and Minerals* is available at the Youngblood Energy Library at OU in Norman.

OKLAHOMA MUSEUMS

There are over 50 museums in Oklahoma that have displays related to geology. Many of these museums are an important source of information for the amateur collector. Some sell mineral and fossil specimens as well as books on geology. Many typically display properly identified specimens that enable the collector to determine what he/she has; in some cases, the museum curator can identify specimens or will allow access to stored research collections. Although museums typically give the general location of where a particular specimen was collected, these locations are rarely detailed enough for the collector. Curators of small museums will sometimes tell collectors where they collected particular specimens, but this is generally not the case.

Many of the small museums in Oklahoma are privately operated; some are parts of businesses that sell rocks, minerals, and fossils. The owners and operators of these businesses and museums typically are very knowledgeable about local geology, collecting sites, and locally collected specimens. Other museums in the State are affiliated with colleges and universities; these can range from formal displays in rooms, to display cabinets in halls, to what might be more properly termed "research collections." One or more faculty members typically are in charge of the displays or collections, and they may be able to help in identifying fossil or mineral specimens.

In Oklahoma, the best place to have vertebrate fossils identified is the Sam Noble Oklahoma Museum of Natural History (at OU) in Norman. The museum has a large comparative collection, and the paleontologists there are extremely knowledgeable and willing to work with the public in identifying bones. In general, they will ask for a photograph of the specimen, or that an individual mail it or bring it to them for identification. If the particular specimen is unique or extremely rare, they may ask where it came from in order that they might conduct a scientific excavation. The Sam Noble Oklahoma Museum of Natural

History also has an extensive paleobotany collection; the paleobotanist on staff is able to identify plant fossils.

STATE AGENCIES

The Oklahoma Geological Survey, which is located on the OU campus in Norman, is the primary research and public-service agency that serves as a source of geologic information in the State. The geological staff is able and willing to identify rocks, minerals, and fossils for the public; some staff members specialize in invertebrate fossils, others in minerals. Some of the geologists can suggest areas that are accessible to the public for collecting minerals or fossils. The publication sales office in the north part of Norman sells a large number of technical books and maps on the geology of Oklahoma; these may be useful to the amateur collector who is interested in a particular area and is willing to take the time to understand some of the technical terms. The publication sales office also has numerous popular publications (e.g., field-trip guides, photocopies of books on collecting in Oklahoma, handouts); some are for sale and some are free. The best way to learn what publications are available is to write for a free "List of Available Publications" or check with the nearest university library; many have Oklahoma Geological Survey publications. In addition to geologic reports and maps, the publication sales office has all the topographic maps of the State available for sale.

All 50 states in the United States have an agency that studies geologic, earth science, and earth resources issues. In some states, these agencies are geological surveys; in other states, they may be called bureau or division of mines, department of natural or mineral resources, or conservation division. Regardless of what they are called, these state agencies are an excellent source of information on the geology, rocks, minerals, and fossils in their particular state.

Two less-used resources in the State are the Oklahoma Department of Mines and the State Parks Division of the Oklahoma Department of Tourism and Recreation, both of which are in Oklahoma City. The Department of Mines has maps showing the locations of old, abandoned, and active mines in the State. Refuse piles, quarry walls, and dumps of some of these may be good places to collect minerals and fossils; however, most are on private land and require permission to gain access. Some rangers and naturalists at the state parks are interested in geology and may be able to direct individuals to areas outside the parks where collecting is permitted. (Collecting is not allowed in any of Oklahoma's state parks without a written permit.)

FEDERAL AGENCIES

There are six Federal agencies in Oklahoma that have some degree of jurisdiction over the management of public lands and/or an interest in the geologic resources on those lands. Of these, the U.S. Bureau of Land Management manages very little land in Oklahoma, although it is responsible for vast tracts of public lands in the western states. Most of the large lakes and waterways in Oklahoma are managed by the U.S. Bureau of Reclamation (7 lakes) or the U.S. Army Corps of Engineers (23 lakes, 2 waterways). The U.S. Forest Service manages the Ouachita National Forest in southeast Oklahoma. The U.S. Fish and Wildlife Service manages the Great Salt Plains National Wildlife Refuge in north-central Oklahoma. The U.S. Geological Survey has a small water-resources division in Oklahoma City but does not manage any Federal lands; however, it does have some literature of interest to collectors.

All of the Federal agencies have similar philosophies with regard to amateur collecting on the public lands under their management, and all are required to act under a number of Federal laws and guidelines (Organic Act of 1897, Preservation of American Antiquities Act of 1906, Federal Land Policy and Management Act of 1976, Archaeological Resources Protection Act of 1979, Federal Cave Resources Protection Act of 1988). The agencies attempt to distinguish between legislation and policy, as well as determine what is legally permissible compared to what is practical. All of the Federal agencies require that permits be obtained before collecting vertebrate fossils and that the collection of petrified wood be limited to 250 lb per person per year. The agencies do not allow individuals to collect on archaeological, cultural, or historic sites in their jurisdiction.

Perhaps the two most important aspects of the Federal response to collecting on Federally managed lands are (1) that the agencies make a distinction between commercial collectors and amateur collectors and (2) that the agencies distinguish between significant surface disturbance and casual surface collecting. Obviously, there are many areas of unclear and perhaps controversial interpretation of Federal laws with regard to collecting on public lands.

The U.S. Army Corps of Engineers allows amateur collecting on most public lands managed by them, but requests that individuals or groups check with local project managers to determine accessibility to desired sites. The Corps has geologists in their district office in Tulsa who are willing to talk with collectors; however, they are generally not able to point out specific sites.

The Ouachita National Forest encourages amateur collecting on land managed by them, but suggests that interested individuals purchase a land-ownership map to distinguish public from private lands. Also, collecting of any kind is not allowed in officially designated "wilderness areas." Like the other Federal agencies, the Forest Service distinguishes between casual collecting by amateurs and commercial operations. The Ouachita National Forest has a geologist in their Hot Springs, Arkansas, office who can recommend good areas for collecting and/or gold panning. There are also offices in Heavener and Talihina where land ownership can be determined.

The U.S. Geological Survey (USGS) has published a large amount of technical literature on the geology and mineral resources of the United States; some of this literature can be used by the amateur collector with the time and desire to wade through the language and sheer volume of material. In addition, the USGS publishes the topographic maps (all scales) that are so critical for locating or relocating good collecting sites. All the major universities

TABLE 1.—EARTH SCIENCE RESOURCES AVAILABLE TO COLLECTORS IN OKLAHOMA

		Specimen Identification						Literature and Maps			
		Rocks and Minerals		Fossils				Books and Journals			
	Phone Number	Hand Specimen	Analytical	Invertebrate	Vertebrate	Plant	Collecting Sites	Technical	Popular	Topographic Maps	Access to Public Lands
Colleges and Universities											
University of Oklahoma											
School of Geology and Geophysics	(405)325-3253	X	X	X							
Youngblood Energy Library	(405)325-6451							X	X	X	
Oklahoma State University											
School of Geology	(405)744-6358	X	X	X							
Edmon Low Library	(405)744-9729							X	X	X	
University of Tulsa											
Department of Geosciences	(918)631-2091	X	X								
McFarlin Library	(918)631-2873							X	X		
Smaller Colleges and Universities	a	X	P	X	P	P		P	P		
Tulsa City/County Library	(918)596-7977							P	P	X	
Museums	a	X		X	P	P	X				
Sam Noble Oklahoma Museum of Natural History	(405)325-4712	P		P	X	X					
State Agencies											
Oklahoma Geological Survey	(405)325-3031	X		X			X			X	
Oklahoma Department of Mines	(405)521-3859						X				
Oklahoma State Parks	a						X		X		
Federal Agencies											
U.S. Bureau of Land Management, Tulsa	(918)621-4100										X
U.S. Bureau of Reclamation, Oklahoma City	(405)231-4515										X
U.S. Army Corps of Engineers, Tulsa	(918)669-7366										X
U.S. Forest Service, Hot Springs, Arkansas	(501)321-5202						X				X
U.S. Fish and Wildlife Service, Great Salt Plains	(405)626-4794						X				
U.S. Geological Survey, Denver, Colorado	b							X	X	X	

Note: X—available; P—possibly available.
[a]Consult phone book for individual locations.
[b]Address only (see text).

in Oklahoma have the USGS literature; some of it can still be purchased directly from the USGS. The USGS publishes a large number of general-interest publications, several of which concern rock, mineral, and/or fossil collecting. A list of these publications may be obtained by writing to the USGS Branch of Distribution, Box 25286, Denver, CO 80225.

The U.S. Fish and Wildlife Service actively promotes selenite-crystal digging and collecting at the Great Salt Plains National Wildlife Refuge in Alfalfa County. Collecting is restricted to certain areas and only during certain times of the year (April through October).

SUMMARY

There are a number of resources available to amateur collectors and rockhounds in Oklahoma at colleges and universities, public and private museums, and State and Federal government agencies. Some of these resources (1) are able to identify unusual or unknown specimens, (2) provide information on collecting sites, (3) provide general information on geology and/or rockhounding, and (4) provide information on access to public lands. Table 1 is a general guide that lists the organizations that can be considered a resource to collectors, the phone numbers of those organizations, and the resource (or "service") those organizations provide.

REFERENCE CITED

Suneson, N. H., 1996, Guide to resources for earth science information in Oklahoma: Oklahoma Geological Survey Educational Publication 5, 76 p.