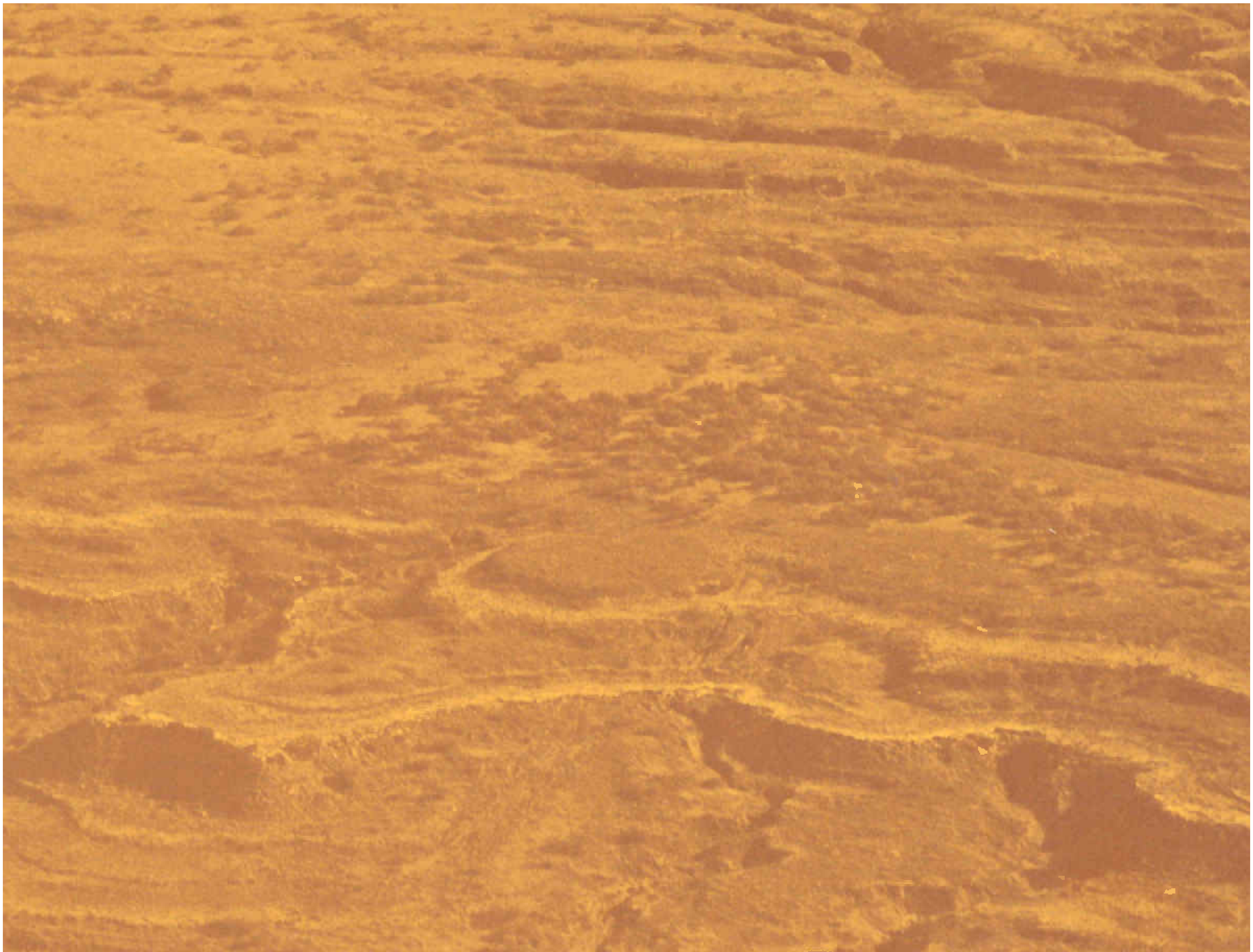
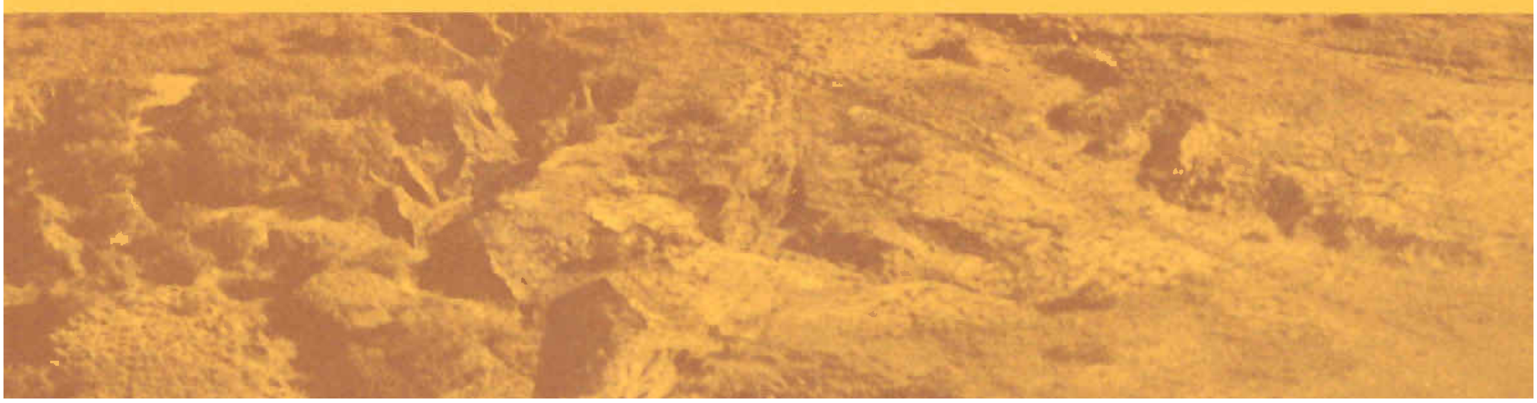


Geologic Field Trips In Oklahoma

Book I:

Introduction, Guidelines, and Geologic History



OKLAHOMA GEOLOGICAL SURVEY
Charles J. Mankin, *Director*
Educational Publication 2

GUIDEBOOK FOR GEOLOGIC FIELD TRIPS IN OKLAHOMA

(PRELIMINARY VERSION)

BOOK I: INTRODUCTION, GUIDELINES, AND GEOLOGIC HISTORY OF OKLAHOMA

KENNETH S. JOHNSON

1971

Facsimile Reprint, 1987

This publication, printed by the Oklahoma Geological Survey, is issued by the Oklahoma Geological Survey as authorized by Title 70, Oklahoma Statutes 1981, Section 3310, and Title 74, Oklahoma Statutes 1981, Sections 231-238. 500 copies have been prepared for distribution at a cost of $684 to the taxpayers of the State of Oklahoma. Copies have been deposited with the Publications Clearinghouse of the Oklahoma Department of Libraries.

Preface

Guidebooks of this series will be prepared and distributed by the Oklahoma Geological Survey in cooperation with the National Science Foundation, the Oklahoma Curriculum Improvement Commission, the Instructional Division, and the Curriculum Section of The Oklahoma State Department of Education. Compilation and preparation of material is financed through a grant from the National Science Foundation (Grant GW-5726), and publication is made possible by funds from Title V, Section 503, of the Elementary and Secondary Education Act of 1965 through The Oklahoma State Department of Education.

Guidebooks are being released as "preliminary versions" so that the changes and additions that users will recommend may be incorporated in a final printing. Field-trip guidebooks are being printed by The Oklahoma State Department of Education and will be issued free within the Oklahoma school system as they are completed (1 every 3 months, approximately). Distribution will be in the region covered by the report and in immediately adjacent areas. All eight preliminary versions should be available by mid-1972, at which time they will be revised, based on users' comments, and a final version of the series will be printed for wider distribution. The tentative schedule for completion of preliminary guidebooks is as follows: Northwest, March 1971; Southwest, May 1971; North-Central, August 1971; South-Central, October 1971; Northeast, January 1972; Southeast, April 1972; and Panhandle, July 1972.

Please send comments and recommendations for improvement of guidebooks to: Editor, Oklahoma Geological Survey, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73069. A limited surplus of this preliminary guidebook is available, and copies may be purchased for 25 cents from the offices of the Oklahoma Geological Survey. Oklahoma teachers who have not received a copy may obtain one free from: Director of Curriculum, The State Department of Education, 310 Will Rogers Building, Oklahoma City, Oklahoma 73105.

Cover Description

Aerial view of gypsum and shale layers forming badlands topography in Beckham County, southwestern Oklahoma.

Editor for this series: Carol R. Patrick, *Associate Editor*, Oklahoma Geological Survey

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GUIDEBOOK FOR GEOLOGIC FIELD TRIPS IN OKLAHOMA

(PRELIMINARY VERSION)

BOOK I: INTRODUCTION, GUIDELINES, AND GEOLOGIC HISTORY OF OKLAHOMA

KENNETH S. JOHNSON

A project supported by:

Oklahoma Geological Survey

National Science Foundation

Oklahoma Curriculum Improvement Commission
and
Curriculum Section of Instructional Division
Oklahoma State Department of Education
Leslie Fisher, *State Superintendent*

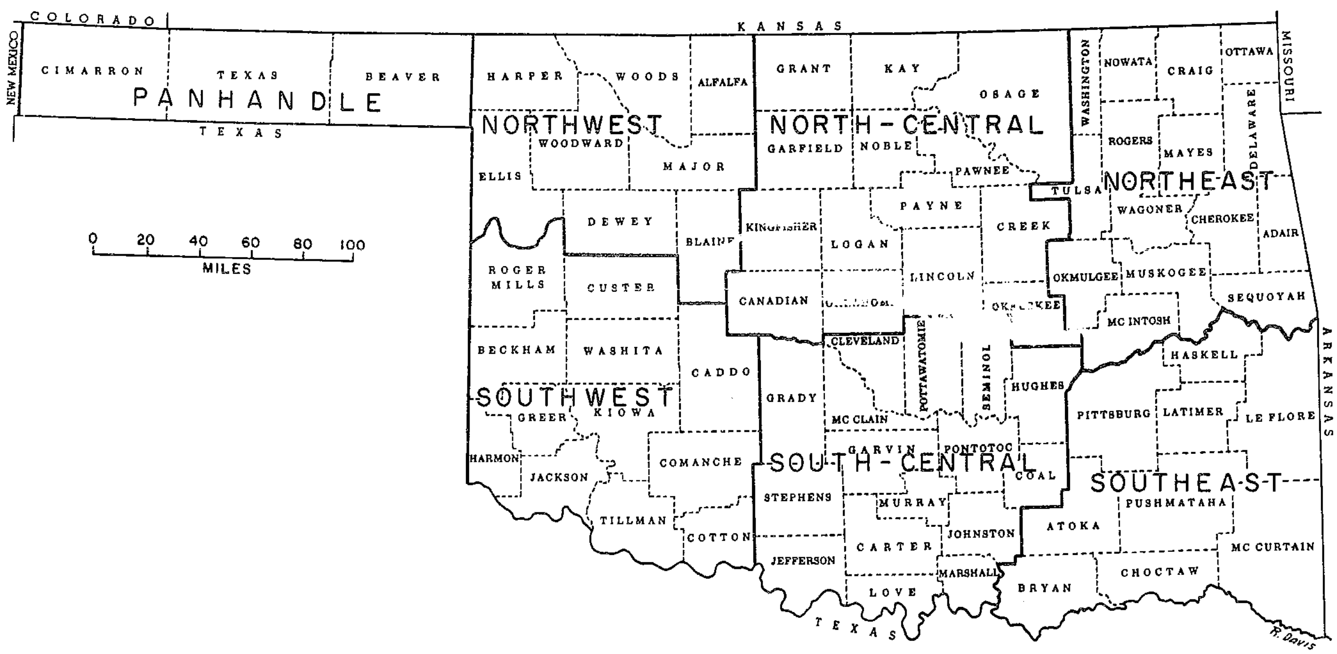


Figure 1. Outline of seven regions in Oklahoma for which separate geologic guidebooks are being prepared.

GUIDEBOOK FOR GEOLOGIC FIELD TRIPS IN OKLAHOMA

(PRELIMINARY VERSION)

BOOK I: INTRODUCTION, GUIDELINES, AND GEOLOGIC HISTORY OF OKLAHOMA

KENNETH S. JOHNSON[1]

INTRODUCTION

Earth science is taught to an ever-increasing number of secondary-school students in Oklahoma each year, and for many students this course will be their only organized study of the Earth and man's environment. Most teachers want to include geologic field trips in their course, and in order to help teachers make plans for such field activities near their home town, this series of nontechnical field-trip guidebooks has been prepared. Although designed for earth science and geology groups, the guidebooks will be useful in general science and geography classes when various aspects of the Earth are discussed. The guidebooks can also be used for excursions taken by small private groups, families, and individuals.

For this series the State is divided into seven regions of nearly equal size (fig. 1), and a separate guidebook will be available on each region. Each guidebook begins with a brief introduction to the geology of the region and follows with descriptions of 20 to 25 sites in the region where fundamental ideas in geology, environmental geology, conservation, and natural-resource development can be studied. Students need not travel great distances for geologic trips but instead can be shown interesting features illustrating geologic processes in "their own back yard."

Sites described are uniformly distributed throughout each region, and 3 to 5 sites can be visited during a 1-day trip. The choice of which stops to make and the order in which they are made is left up to the person conducting the trip. The field-trip director may wish to conduct a half-day trip to only 1 or 2 sites early in the semester to acquaint students with field-studies activities and later lead one or more longer trips to more distant locations. Another idea would be to spend a full day at one site, with students making a thorough investigation of one or more problems.

Geologic information in this series is intended to give the teacher sufficient background to direct student field studies, although it may also be used directly by students in preparation for field trips. This information includes an introduction to the geologic history of Oklahoma (in this guidebook), which sets the stage for the regional guidebooks; an introductory section in each guidebook describing the geology of the region; and finally, a detailed description of local geology at each site. References to more complete geologic information are included in all guidebooks.

Although field trips may be made with a trip leader describing and explaining the local geology at each site, students may also profit from taking the active role of investigating a site on their own. In such an inquiry-oriented field trip, students make their own observations, collect data, analyze evidence, and draw their own conclusions. Some general introductory information about a site may be necessary if students lack experience in field studies. Group participation should be encouraged through question-and-answer discussions.

If students are not able to recognize the field problems at a site, the teacher should suggest some types of investigation. As the study progresses, the teacher may need to ask leading questions and provide clues. Questions may be posed to small groups of students, allowing them time to discuss the problem among themselves and reach a joint conclusion. Questions can be directly or indirectly related to the problem being discussed or can be related to hypothetical situations. The field trip and studies should be related to class readings and lab work, when possible, and students should start to realize that information in textbooks and our knowledge of Earth history are based on investigations similar to those they are conducting. Often students benefit from having their observations and materials they have collected on field trips serve as a basis for subsequent classroom discussion in order to reinforce learning from actual field experiences and encourage group participation.

Certain activities and studies can be conducted at almost every stop, but the types and depth of investigation are matters that the teacher can best work out for a given situation. Possible activities for student investigation of a site include:

1. Recording a description of the rocks in the student's own terms. Although the student will

[1]*Geologist*, Oklahoma Geological Survey.

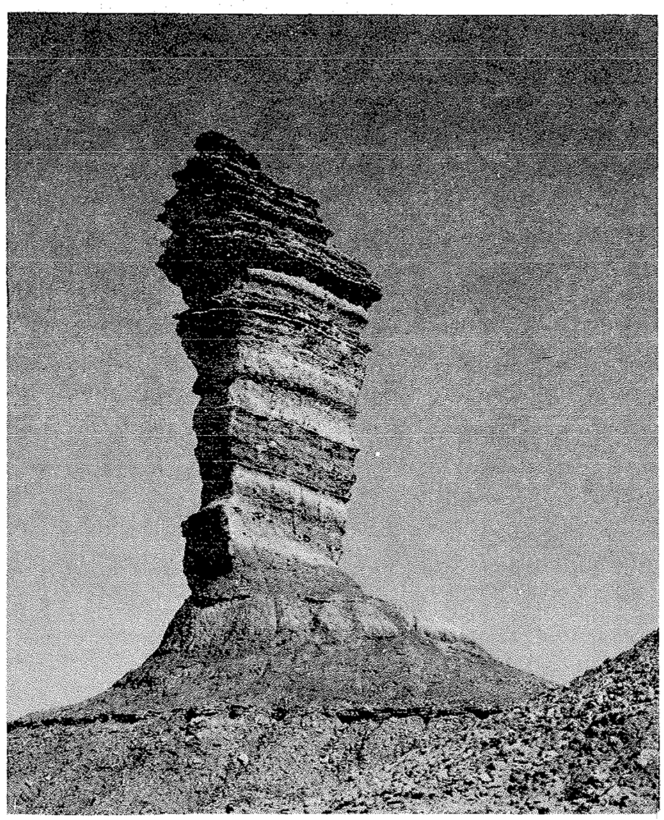
probably not include everything, the kinds of things that should be recorded are type of rock, color, texture, minerals present, thickness and character of bedding, sedimentary structures (crossbedding, ripple marks, nodules, etc.), fossils, weathering character, resultant soil, topographic expression, vertical and lateral changes in rock units, folds, faults, joints, fractures, dip of rock layers, and any unique features.

2. Drawing generalized illustrations of cross sections (most important in showing spatial relationships in geology), outcrop sketches, geologic maps, and topographic maps.
3. Noting how man has modified the site and any environmental implications of this modification.
4. Evaluating rocks and minerals of the area in relation to their potential use by man.
5. Collecting and labeling specimens for lab examination and for school or private collections.
6. Laboratory examination of specimens by microscopic study, density measurements, solubility in acid, and comparison with rocks and fossils collected elsewhere.
7. Preparation of a geologic report (individual or group effort) that simply, and in the students' own words, describes field observations, methods of analysis, results of analysis, and conclusions. Illustrations can be an important part of the report. Student methods of examination and interpretations will vary, but this is to be expected. Some of the sites have been studied for years by professional geologists, who still disagree on interpretation of data.

Geologic observations can also be made and recorded at many other sites of modern sedimentation or erosion in fields and at streams, rivers, or lakes not listed in this series. Students derive a great deal of benefit from observing the deposition of sediments that would subsequently become rock through compaction and cementation. Features easily examined at streams or lakes include meandering streams, braided streams, shoreline processes, flood plains, alluvial fans, stream terraces, deltas, landslides, mudcracks, ripple marks, crossbedding, and stratification of sediment. Erosional features that can be seen in most fields or pastures with rolling topography or steep slopes include soil development, weathering, wind erosion, water erosion, gullies, and man-made contours. Some small features are suitable for long-term studies because changes can be noted during several visits.

Comprehensive guidelines to the procedures and techniques of systematic field study are being prepared as a series of field guides under the auspices of the Earth Science Curriculum Project. Different guidebooks cover such aspects of earth science as layered rocks, rock weathering, streams, mountains, and igneous rocks. Each booklet contains sections on subject review, preparation for field study, field-trip activities, sampling and recording techniques, and subsequent lab and class activities. Booklets are being published by Houghton Mifflin Company, 6626 Oakbrook Boulevard, Dallas, Texas 75235, and should be available by late November 1970.

Maps and geologic reports are available on most sites for use as background data. Topographic maps of Oklahoma may be purchased from the Oklahoma Geological Survey, 830 Van Vleet Oval, Room 163, Norman, Oklahoma 73069, or from the U.S. Geological Survey, Federal Center, Denver, Colorado 80225. An *Index to Topographic Maps of Oklahoma* is available free from either address. Geologic maps and reports referred to may be examined at any geological library in the State or may be purchased from the issuing agency or organization.



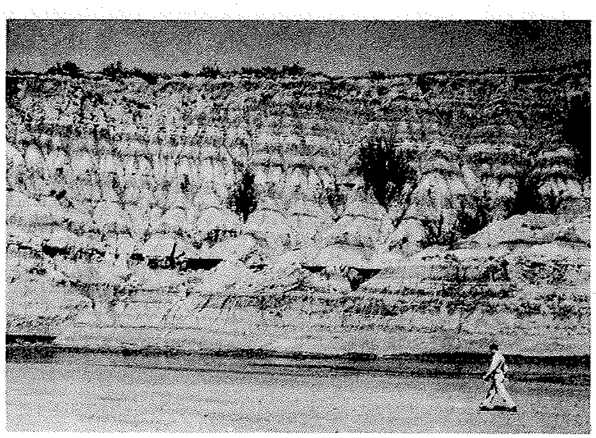
Chimney Rock in northwest Oklahoma is a unique erosional remnant.

Guidelines for Conducting a Geologic Field Trip

In planning a geologic field trip, the teacher should make a pre-trip excursion to check on roads, gates, and access to each site and to become familiar with features worth investigating at each site. During this first visit you should determine the best approach for your group in studying the site, the materials needed to make the study, what dress to suggest to students (long pants, boots if needed), whether measurements should be made and samples collected for follow-up work in lab, approximate time needed for field study, and potential dangers to which you must alert students and adult assistants.

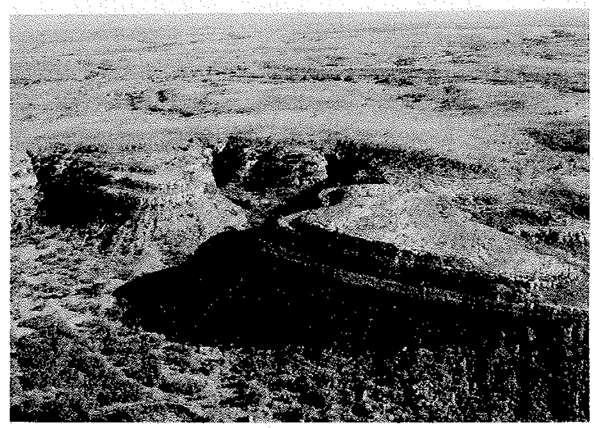
Permission must be obtained from owners or operators before bringing students onto private land and into active mines or quarries. Landowners and mining companies at field-trip sites have shown a willingness to allow educational groups on their land for study purposes, but they should be contacted at least 1 or 2 weeks in advance. If a stop is planned on State or federal lands, discuss your plans in advance with the park superintendent so he can make suitable arrangements for your group and advise you on collecting samples. The name, address, and telephone number of persons to contact is given in the description of each site. Thank-you notes sent after each trip would help maintain good relations for future trips.

Please emphasize to the students that when entering private land they are *guests*, and any property damage, litter, or carelessness may make all groups unwelcome in the future. Of special concern is possible damage to fences, gates, mining tools and equipment, and farming equipment. Gates must be left as they were found on arrival--open or closed. Oklahoma's landowners and mining companies have always been exceptionally helpful and cooperative with scientific and educational groups, and we all have a responsibility to see that this cordial relationship is not jeopardized.



Escarpment of well-layered sedimentary rocks exposed in area of intense erosion.

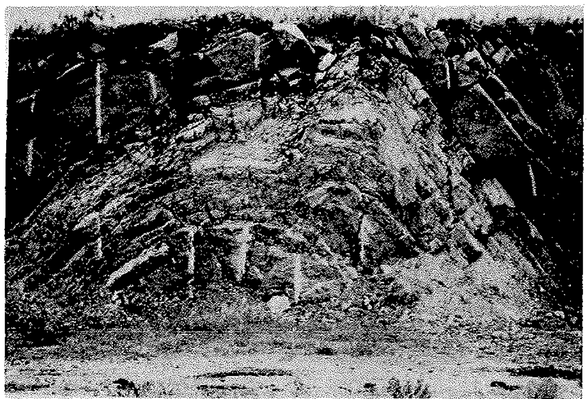
Following is a list of items and suggestions for the teacher that should be considered in planning and conducting a geologic field trip.



Aerial view showing layers of gypsum (white) and shale in rugged lands of western Oklahoma.

PRE-TRIP PLANNING

1. Select sites you wish to visit and make a pre-trip excursion to familiarize yourself with each stop and ask permission to bring your group.
2. Arrange transportation facilities, usually private car, school bus, or charter bus. Your school bus may be satisfactory transportation for most trips in your own or nearby regions.
3. One teacher should be in each vehicle. On bus trips, a second teacher or parent should be in the middle or back of each bus; their presence will reduce discipline problems in the bus.
4. A student-to-adult ratio of 10 or 15 to 1 is recommended for adequate supervision.
5. If you charter a bus, call for rates and services of several bus lines in your area. With a speaker system in the bus, you can show points of interest and lead a general discussion between field-trip stops. A bus with built-in toilet means you do not have to organize your trip around planned rest stops. Forewarn the bus company representative that the driver should bring his lunch if you plan to eat where he cannot buy lunch. Ask the representative how late you may cancel due to rain.
6. Information on travel agenda, conduct, and rules should be given to students before going on the trip.
7. Be certain that all parents and school administrators receive general information about the field trip, in-



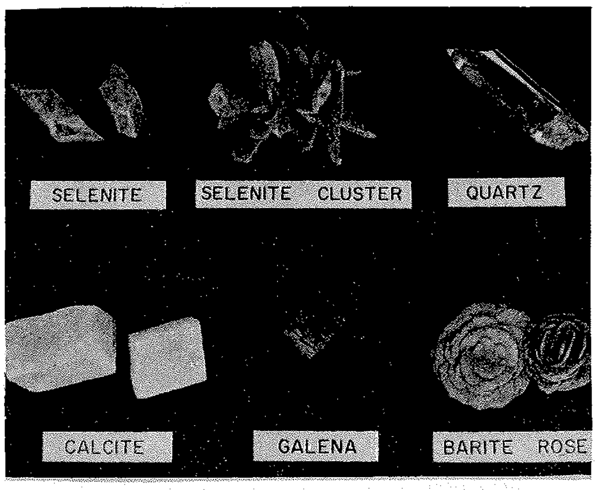
Sedimentary rock layers that were originally horizontal are here folded to form an anticline ("up-fold").

cluding where, when, and why it is being taken. You may need the principal's permission before planning a trip.

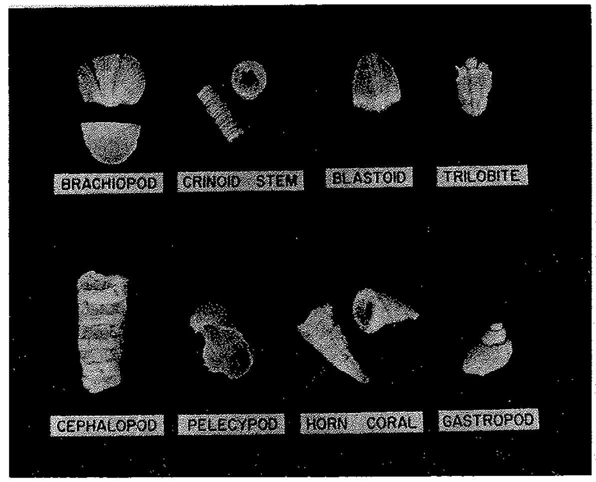
8. A first-aid kit should be taken, and someone, perhaps the school nurse, who knows how to use it should be along on the trip.
9. You may want to collect a little extra money (25-50¢) above the anticipated cost of the trip from each student. It can be returned when expenses are paid, but if the actual cost is higher than anticipated, you may find it difficult to collect the extra money after the trip is over.
10. If possible, a car should be driven as well as the buses to provide emergency transportation.
11. Make alternate plans in case the trip must be rescheduled due to inclement weather. Light or medium rain may not be sufficient reason for cancellation, depending on the trip destination and how the trip is to be conducted.
12. You may want to provide copies of some simple text or illustrations for groups of students to take on the field trip.
13. You may need a portable loudspeaker if your group numbers more than 75 or 100.
14. Investigate some type of trip insurance for students if they are not already insured. This is available at low cost.
15. Teachers might consider teachers' liability insurance, which can be provided at low cost as part of a home-owners insurance policy. Discuss this with your insurance agent and/or a representative of the company holding your home-owners policy. Members of the Oklahoma Education Association are automatically covered by liability insurance. A letter of release signed by a parent is not a legal document, and a parent can still sue a teacher and instigate court action if the child is injured during the trip.
16. Consider the good and bad points of making the trip optional to students. On optional trips you will have only students who want to be there, and, hence, should be able to have more concentrated learning activity and fewer discipline problems. Compulsory attendance, however, gives the entire class a common learning experience and may awaken interest in some students who did not seem to have any. Occasionally, such actual field experience has brought out interest in problem students who have not otherwise taken full advantage of previous educational opportunities.

LEADING FIELD TRIPS

1. Be careful when on private property. Damaged fences, gates, and equipment will make all groups unwelcome in the future.
2. Teachers and chaperons assisting you should be fully aware that they need to help protect both students and property. Due to lack of specific training, most adults must be informed by you of potential dangers and of ways they can assist you; otherwise, they tend to come along and enjoy the field trip as though they were students. Some of the potential dangers that should be watched for are barbed wire, flying rock chips, splinters, passing traffic, sunburn, poison ivy, and chiggers.
3. Discipline should not be strict, except on safety measures. A high noise level is expected, and constructive vocal exchange of ideas about the study is beneficial. However, activity that may be injurious, such as throwing of objects, misuse of tools, and extending arms out of windows, must be curbed immediately.
4. Student dress should be informal. Dungarees or other durable clothes are suitable for boys and girls. Sneakers, boots, or rubbersoled shoes are needed to prevent slipping on rocks.
5. Items commonly taken on trips are hammers, picks, cameras, notebooks, and bags or boxes for carrying samples.
6. Samples may be collected at nearly all sites, but this should be discussed with the landowner in advance.
7. Outdoor activity enhances youthful appetites, and students should bring plenty of lunch, as they usually don't have enough food. Mid-morning snacks may work out well.
8. Avoid taking large groups of young students into town for lunch. Such an excursion will encourage added problems that may be difficult or impossible to handle.



Crystals collected in various parts of Oklahoma.

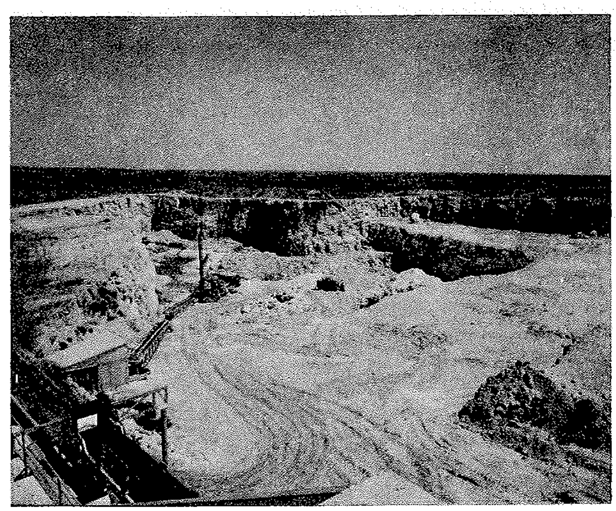


Fossils of various ages found in Oklahoma.

9. Drinks for noontime should be brought along if they are not available at your lunch stop. Bus companies may provide water coolers.
10. Be sure to clean up the lunch area afterwards so groups will be welcome again.

SAFETY MEASURES

1. Stress the specific dangers at each site before students leave the bus. Students should then exit buses and go directly to the trip leader for any additional information.
2. Teachers and parents should be stationed at appropriate places at each stop to keep students from entering dangerous areas. You should indicate these places to both adults and students at each stop. Walks to potentially dangerous places can be taken by small groups in a semi-organized manner.
3. Students are not to stand at the top edge of quarry walls, climb vertical ledges, or climb on unsafe rock-refuse piles. The danger here is that rocks knocked loose might fall on the students below or a student might slip and fall. Beware of standing at the base of steep quarry walls; the danger of falling rock and of landslides is high.
4. Quarrying equipment, farm equipment, and private property must not be disturbed or touched.
5. Rock throwing should never be permitted.
6. Take along a first-aid kit, and be sure someone in the group knows how to use it.
7. Bus windows should remain closed throughout the trip to keep bottles, rocks, etc., inside the bus.
8. You alone are responsible for stressing safety before and during the trip, because only you know the potential danger areas and dangerous acts.



Gypsum quarry in western Oklahoma. Raw materials of construction and industry are commonly mined in open pits.

Geologic History of Oklahoma

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 sandstones and shales were laid down at the same time as alluvial and deltaic deposits near the ancient seas. When these areas were later 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. 2). 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. Principal sites of sedimentation were in great elongate basins that subsided more rapidly than adjacent areas and received sediments 10,000 to 40,000 feet thick. The major sedimentary basins were confined to the southern half of the State and include the Anadarko, Arkoma, Ardmore, Marietta, and Hollis basins and the Ouachita basin in the site of the present Ouachita Mountains.

Rocks of every geologic period (table 1) are present in Oklahoma. Nearly 99 percent of all 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 surface in 46 percent of the State (fig. 3). Other outcrops are Pennsylvanian (25 percent), Tertiary (11 percent), Cretaceous (7 percent), Mississippian (6 percent), Ordovician (1 percent), and Cambrian (1 percent); Precambrian, Silurian, Devonian, Triassic, and Jurassic each cover less than 1 percent of the State. Not included in these estimates are the Quaternary river, terrace, and lake deposits that overlie pre-Quaternary rock in about 25 percent of the State.

PRECAMBRIAN AND CAMBRIAN IGNEOUS ACTIVITY

The oldest rocks known in Oklahoma are Precambrian granites and rhyolites formed 1.05 to 1.35 billion years ago. Pre-existing rocks into which these granites were injected have been destroyed by erosion, metamorphism, or complete melting in magma, although remnants deep underground may exist 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 south-

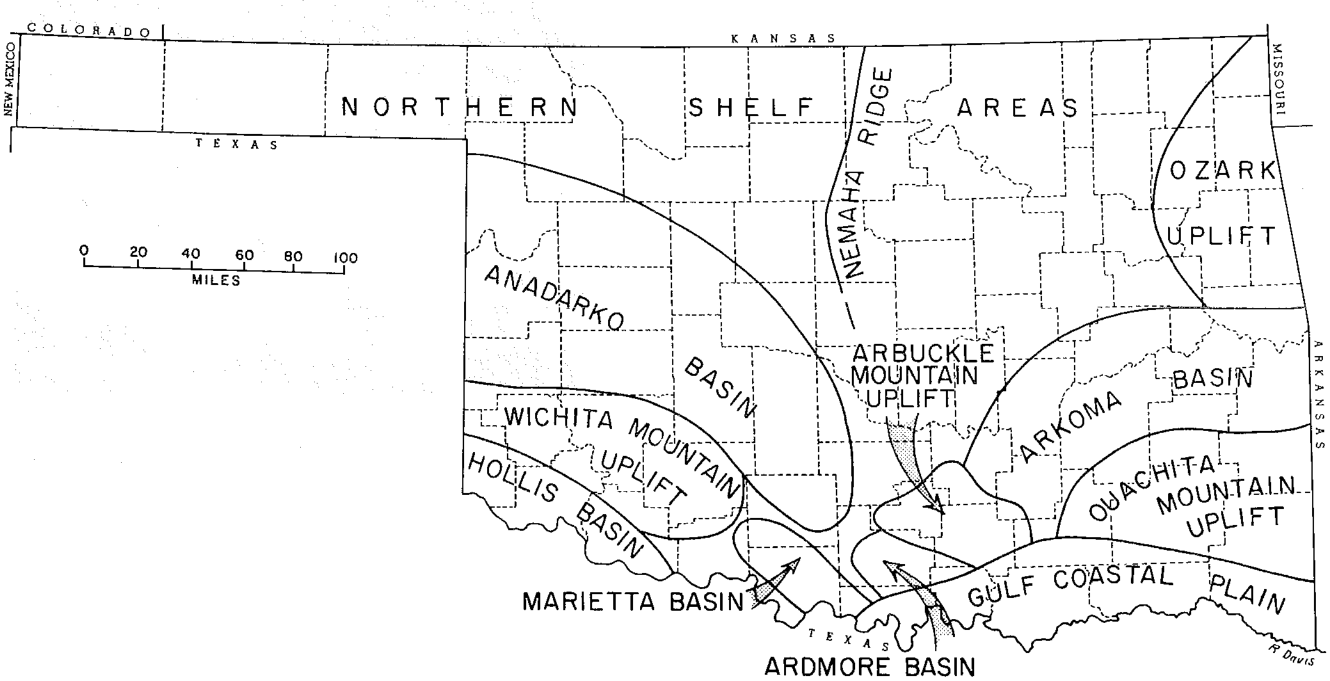


Figure 2. Major geologic provinces of Oklahoma.

western 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 Cambrian igneous rocks underlie all of the State and are the floor or "basement" upon which younger rocks rest (fig. 3). The top of the "basement rock" is about 1,000 feet below the Earth's surface in the Ozark uplift of the northeast and plunges to greater depths to the south and southwest toward the great basins of southern Oklahoma, where it is locally 30,000 to 40,000 feet underground (fig. 4). Adjacent to the basins, "basement" rocks have been uplifted above sea level in two major fault blocks and are exposed now in the Wichita and Arbuckle Mountains.

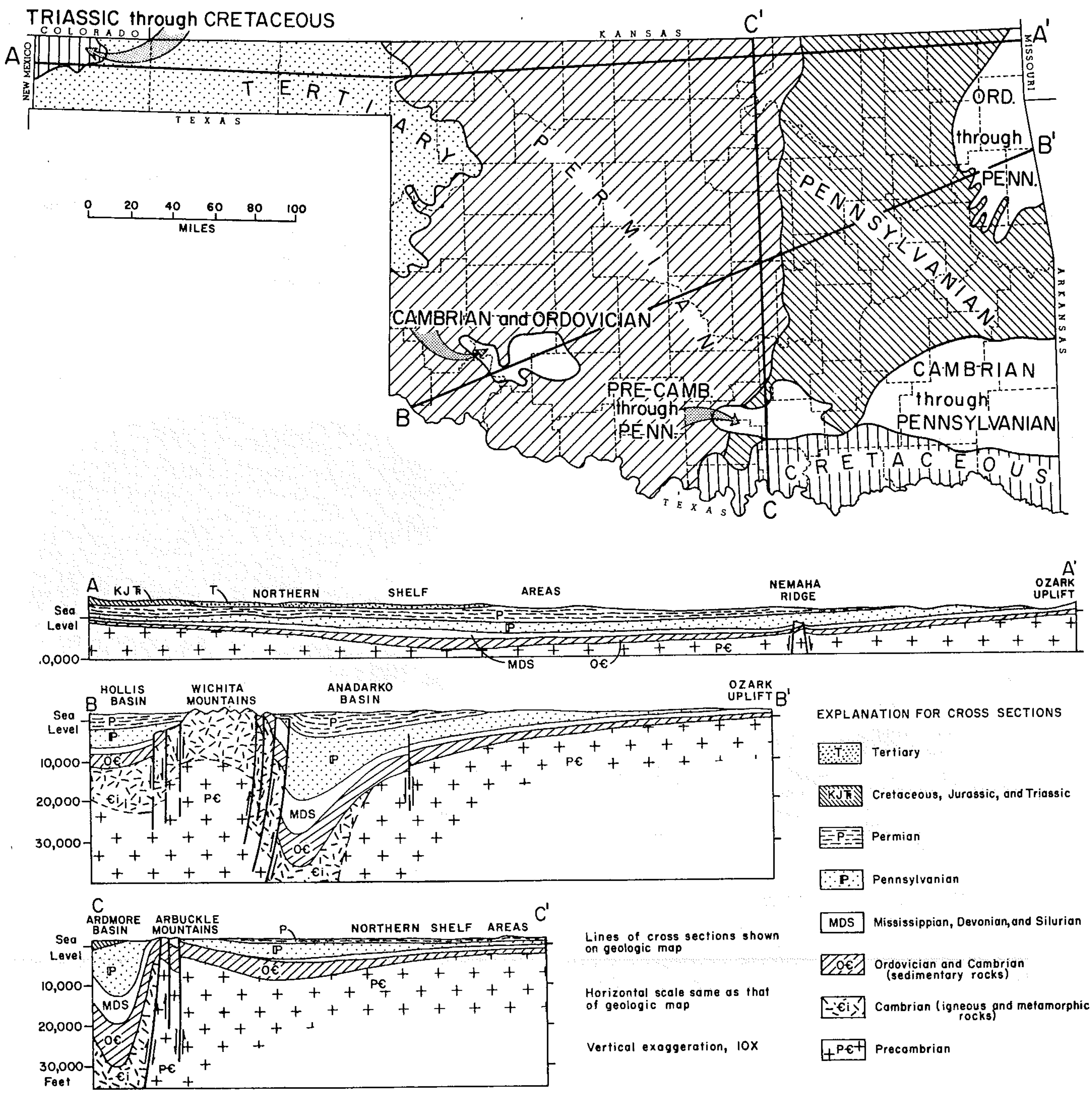


Figure 3. Generalized geologic map and geologic cross sections of Oklahoma. Cross sections follow lines A-A', B-B', and C-C' on map.

TABLE 1. GEOLOGIC TIME SCALE COMPARED TO A CALENDAR YEAR

Geologic Era	Geologic Period	Beginning (1,000,000 years ago)	Comparative Date[1]	Day	Hr.	Min.
CENOZOIC	Quaternary	1	December	31	22	03
("recent life")	Tertiary	70	December	26	7	44
MESOZOIC	Cretaceous	135	December	21	1	12
("middle	Jurassic	180	December	17	9	36
life")	Triassic	220	December	14	3	44
PALEOZOIC	Permian	270	December	10	2	24
("ancient	Pennsylvanian	320	December	6	1	04
life")	Mississippian	350	December	3	14	40
	Devonian	400	November	29	13	20
	Silurian	430	November	27	2	56
	Ordovician	490	November	22	4	37
	Cambrian	600	November	13	16	00
PRECAMBRIAN		4,500	January	1	0	00

[1]Determined by Arthur J. Myers.

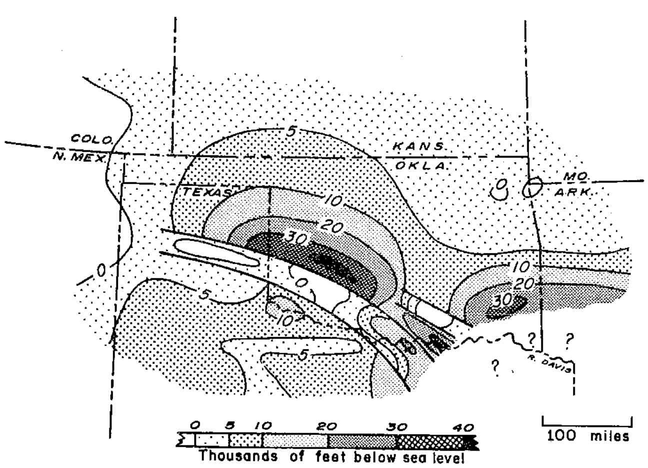


Figure 4. Generalized contours showing elevation (below sea level) of eroded top of Precambrian and Cambrian basement rocks in Oklahoma and parts of surrounding states.

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 lay below sea level, and shallow seas covered all of the State during various parts of the Paleozoic Era. The first sea invasion was in the Late Cambrian and moved across the State from the east or southeast. The basal Reagan Sandstone, 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 extend over the entire State (fig. 5). The thickness of these sediments increases southward from about 2,000 feet in northern shelf areas to 10,000 feet in the Anadarko basin, Ardmore basin, and Arbuckle Mountain region. In all but the southeast, limestone and dolomite (for example, Arbuckle Group and Viola Limestone) are the major rock types, with sandstone (for example, Simpson Group) and shale (for example, Sylvan Shale) less abundant. Sediments of the Ouachita basin, however, include thick units of black shale and sandstone, along with lesser amounts of limestone and chert.

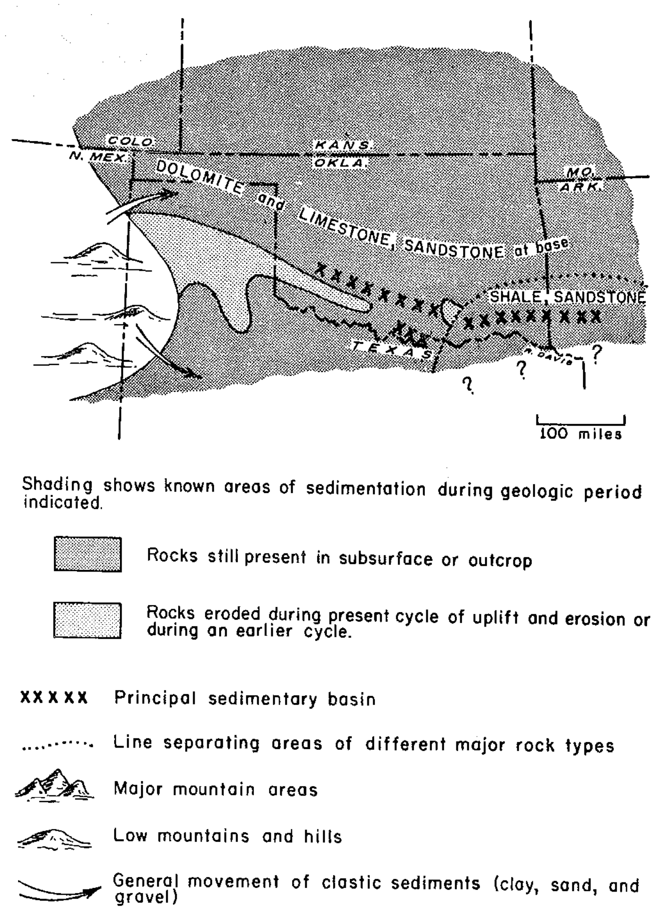


Figure 5. Late Cambrian-Ordovician paleogeography ("ancient geography") of Oklahoma.

SILURIAN AND DEVONIAN PERIODS

Except for the Ouachita basin, Silurian-Devonian sediments consist of limestone and dolomite of the Hunton Group overlain by the black Woodford or Chattanooga Shale (fig. 6). The Hunton Group (Silurian-Early Devonian) is commonly 100 to 500 feet thick (maximum, 800 feet) and has been eroded from the northern shelf areas. Following widespread uplift and erosion, the Late Devonian to Early Mississippian Woodford Shale was deposited in essentially the same areas as the Hunton and also northward into Kansas. The pre-Woodford unconformity is one of the most conspicuous unconformities in the State: 500 to 1,000 feet of strata were removed by erosion over broad areas, and the Woodford or younger Mississippian sediments rest on rocks principally of Ordovician and Silurian age. The Woodford is commonly 50 to 200 feet thick but reaches 600 feet 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 to 1,000 feet.

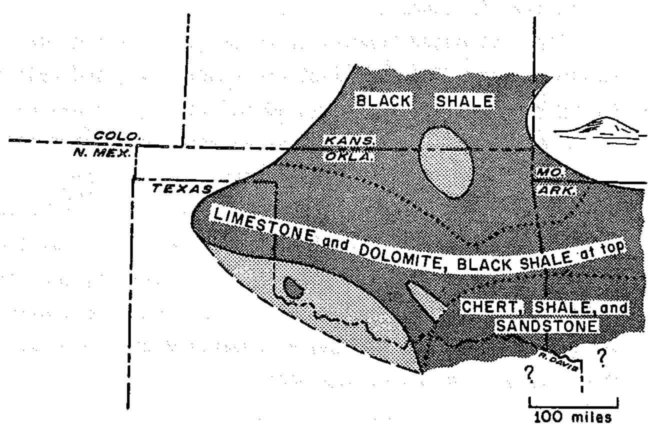


Figure 6. Silurian-Devonian paleogeography of Oklahoma.

MISSISSIPPIAN PERIOD

During the first half of the Mississippian Period, shallow seas covered all of Oklahoma (fig. 7). Limestone and interbedded chert were the dominant sediments 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.

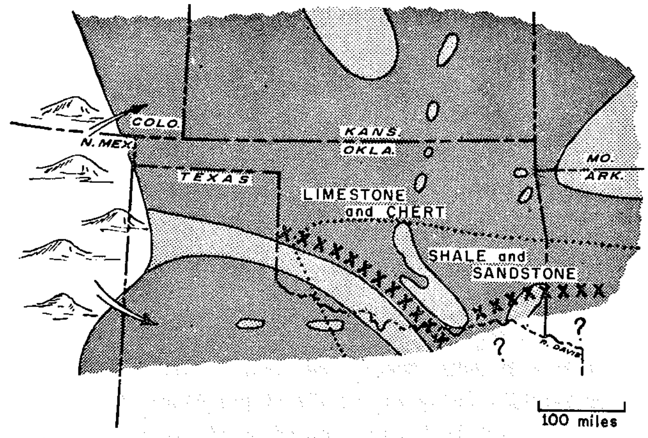


Figure 7. Mississippian paleogeography of Oklahoma.

In the last half of the Mississippian Period, shale and sandstone were the dominant sediments, with major sites of deposition being rapidly subsiding basins in southern Oklahoma. Principal formations of southern Oklahoma (excluding the Ouachitas) 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 to 6,000 feet in the Ardmore and eastern Anadarko basins and nearby areas. The greatest thickness of Mississippian strata is the 10,000 feet of interbedded sandstone and shale making up the Stanley Group of the Ouachita basin. Mississippian strata in central and north-central Oklahoma have been largely removed by Early Pennsylvanian uplift and erosion, and the remaining rocks are generally 200 to 600 feet of cherty limestones that thicken to the west and are 5,000 feet thick in the western Anadarko basin.

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 called the "Ancestral Rockies." Rocks deposited earlier in the Wichita, Arbuckle, and Ouachita Mountain 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 are also present. They are commonly

2,000 to 5,000 feet thick but are as much as 16,000 feet thick in the Anadarko basin, 15,000 feet in the Ardmore basin, 13,000 feet in the Marietta basin, and 18,000 feet in the Arkoma basin.

The Pennsylvanian Period is subdivided into five epochs of time: Morrow (oldest), Atoka, Des Moines, Missouri, and Virgil (youngest). Orogenies occurred in all epochs, but different areas were affected to different degrees by each pulse.

The major Pennsylvanian orogeny, commonly called the Wichita orogeny (Morrow and early Atoka), was characterized by strong folding and uplift of pre-Atoka rocks and resulted in 10,000 to 15,000 feet of uplift in the Wichitas and the Criner Hills south of Ardmore (fig. 8). Conglomerate and granite wash were commonly deposited near major up-

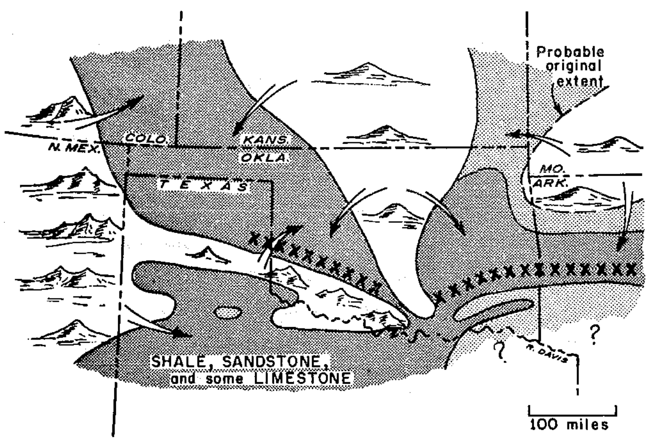


Figure 8. Early Pennsylvanian (Morrow-Atoka) paleogeography of Oklahoma.

lifts, 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 (Nemaha ridge) extending northward from the Oklahoma City area into Kansas. Morrow and Atoka uplift was accompanied by erosion that removed part or all of the pre-Pennsylvanian sediments 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 uplift in the Ouachita Mountains began in Atoka time and were strongest during the Des Moines Epoch (fig. 9): these are referred to as the Ouachita orogeny. In a series of movements lasting through the remainder of the Pennsylvanian Period, the thick sequence of sediments in the Ouachita basin was thrust northward perhaps 50 miles to its present position. In

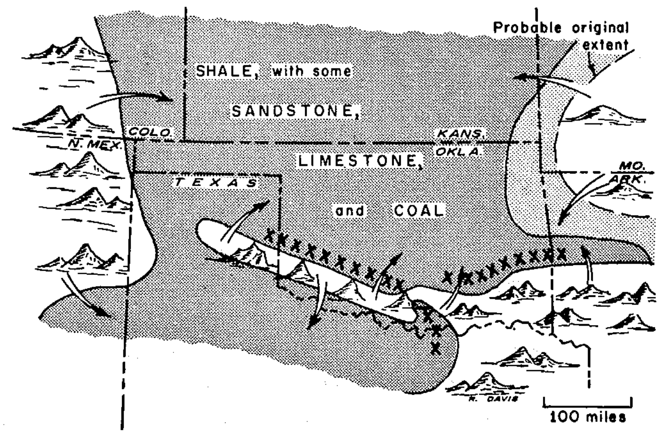


Figure 9. Middle Pennsylvanian (Des Moines) paleogeography of Oklahoma.

deforming the Ouachita trough, basinal downwarping shifted northward into the Arkoma basin during Atoka and Des Moines time and then ceased with folding and faulting of the Arkoma basin. Of special importance in the Arkoma basin and northeast Oklahoma are the coal beds formed during Des Moines time by decaying trees and other plant matter that accumulated in swamps.

The last major Pennsylvanian orogeny, called the Arbuckle orogeny, was one of strong compression and uplift during Virgil 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.10). Much of the thrusting in the Ouachita Mountains is believed to have also occurred in late Virgil 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.

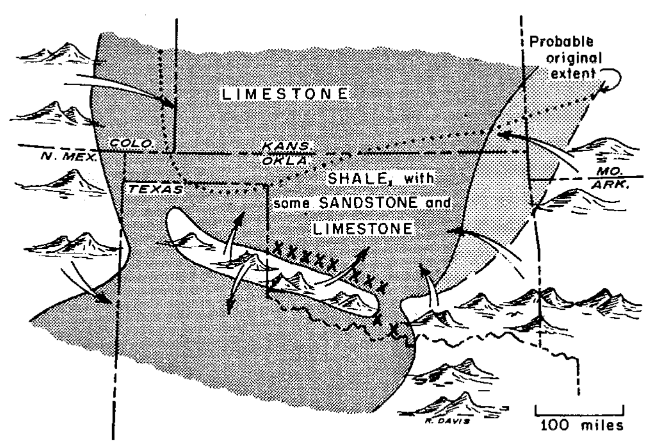


Figure 10. Late Pennsylvanian (Missouri-Virgil) paleogeography of Oklahoma.

PERMIAN PERIOD

Following the period of mountain building, an Early Permian shallow inland sea covered western Oklahoma (fig. 11), extending northward from western Texas to Nebraska and the Dakotas. The climate was warm and dry, and thick units 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 Anadarko basin and northern shelf areas. Alluvial, deltaic, and nearshore marine deposits of red sandstone and shale interfinger with the marine red shale, anhydrite, limestone, dolomite, and salt that are typical of the middle of the broad Permian sea. Most outcrops are red shales, although thin limestones and dolomites are present in north-central Oklahoma and crossbedded sandstones such as the Garber are common in central and south-central areas. The red color so common in Permian rocks results from a stain of red iron oxides (chiefly hematite) deposited with the sand and mud.

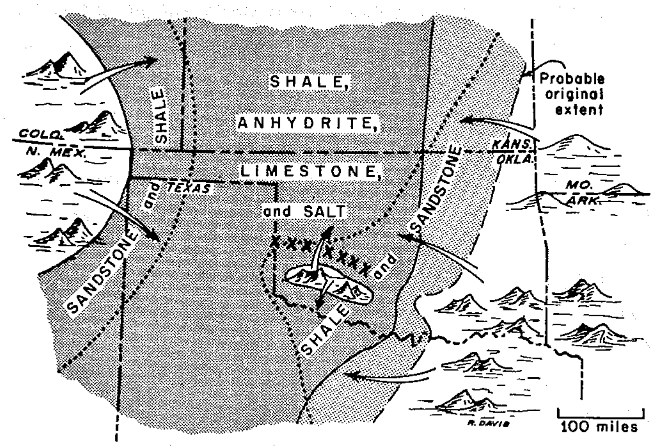


Figure 11. Early Permian paleogeography of Oklahoma.

By Late Permian time the Wichitas were covered with sediment and the mountains of the east were largely worn down (fig. 12). 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 subsurface. The Rush Springs Sandstone is deeply eroded to form canyon lands in much of western Oklahoma and is important as a fresh ground-water aquifer. Thickness of the entire Permian sequence is generally 1,000 to 5,000 feet but reaches 6,000 to 6,500 feet in deeper parts of the Anadarko basin.

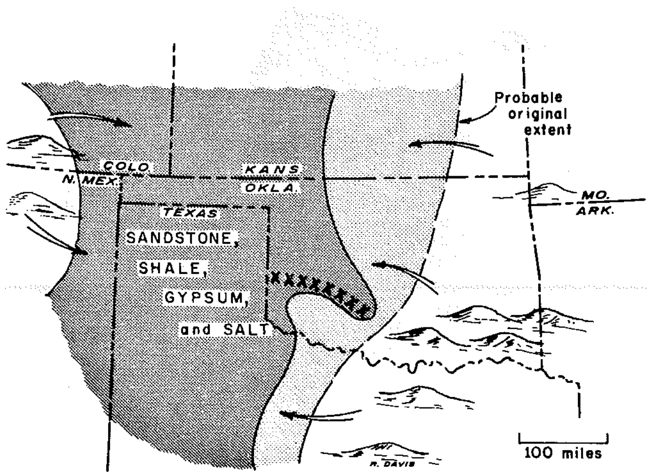


Figure 12. Late Permian paleogeography of Oklahoma.

TRIASSIC AND JURASSIC PERIODS

Most of Oklahoma was apparently above sea level during the Triassic and Jurassic Periods (fig. 13). 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 recently deposited Permian sediments cropped out. Triassic-Jurassic strata of the Panhandle are chiefly red and gray in color, and their thickness is typically 200 to 600 feet. The Ouachitas in the southeast were probably an area of low mountains and hills. Sands eroded from the Ouachitas were carried to the early Gulf of Mexico, which nearly reached into Oklahoma during the Jurassic. Triassic-Jurassic strata southeast of Oklahoma are limestone, sandstone, shale, and evaporites that now are covered by later Cretaceous sediments of the Gulf Coastal Plain.

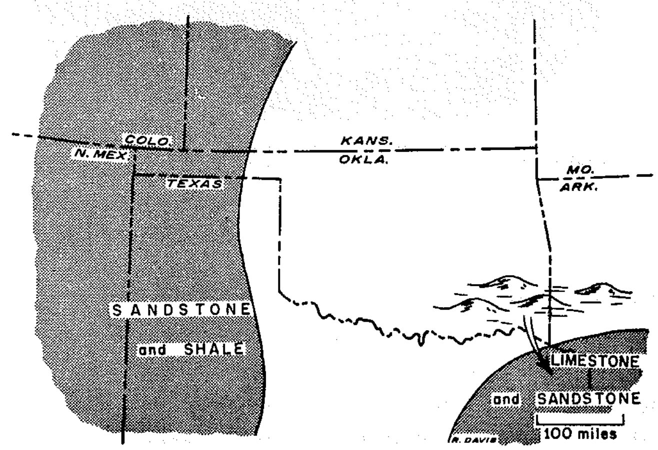


Figure 13. Triassic-Jurassic paleogeography of Oklahoma.

CRETACEOUS PERIOD

Cretaceous seas covered all but northeastern and eastern Oklahoma (fig. 14). The ancestor of the Gulf of Mexico extended up to and across the southern part of the State, and shallow seas spread northward in the last great inundation of Oklahoma and the western interior of the United States. Shale, sandstone, and limestone are generally 450 feet thick in the Panhandle and as much as 2,000 to 3,000 feet 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 by orogeny in Late Cretaceous and Early Tertiary time imparted an eastward tilt to the entire State and caused withdrawal of the sea.

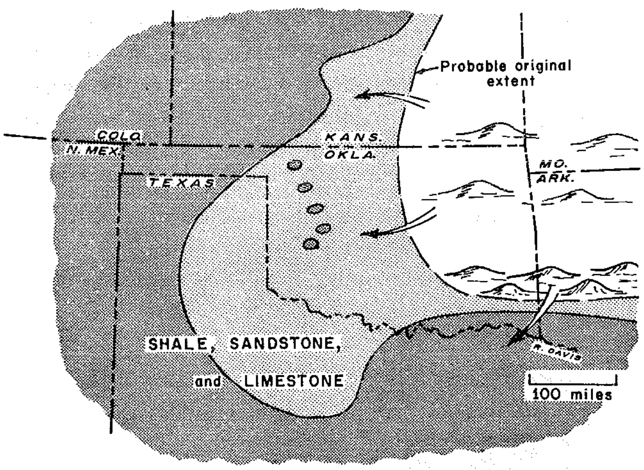


Figure 14. Cretaceous paleogeography of Oklahoma.

TERTIARY PERIOD

The State's 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. 15), and the shoreline gradually retreated southward through the remainder of the period. Sediments in the southeast include marine and nonmarine sand, gravel, and clay. In Late Tertiary time, a thick blanket of sand, clay, and gravel eroded from the Rocky Mountains was laid down across the High Plains and farther east by a system of coalescing major rivers and lakes. These deposits, principally the Ogallala and Laverne Formations, are generally 200 to 600 feet thick in western Oklahoma and originally may have extended across central Oklahoma.

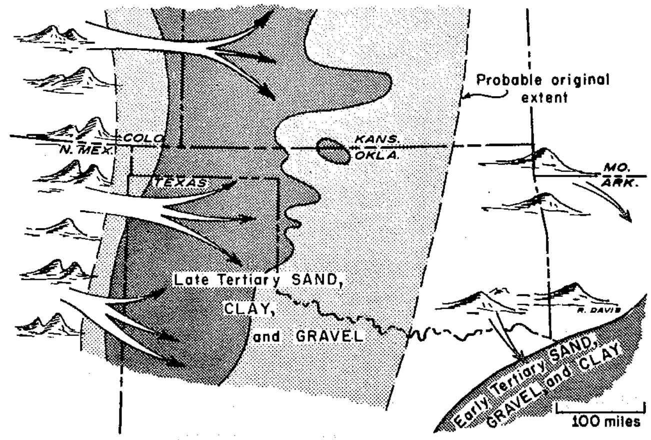


Figure 15. Tertiary paleogeography of Oklahoma.

QUATERNARY PERIOD

The Quaternary Period 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 southward from Canada 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. 16). Major 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 above the present flood plain.

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 are then carried

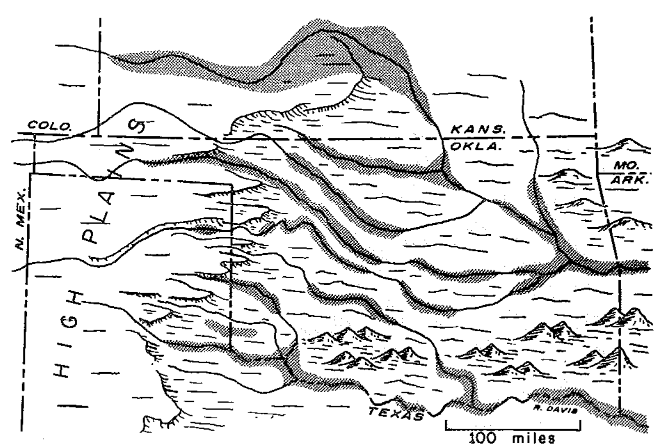


Figure 16. Major rivers of Oklahoma and principal deposits of Quaternary age.

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 are typically 25 to 100 feet thick. Finding Pleistocene terraces 100 feet to more than 300 feet above modern flood plains attests to the great amount of erosion and downcutting performed by major rivers in the past 1 million years.

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