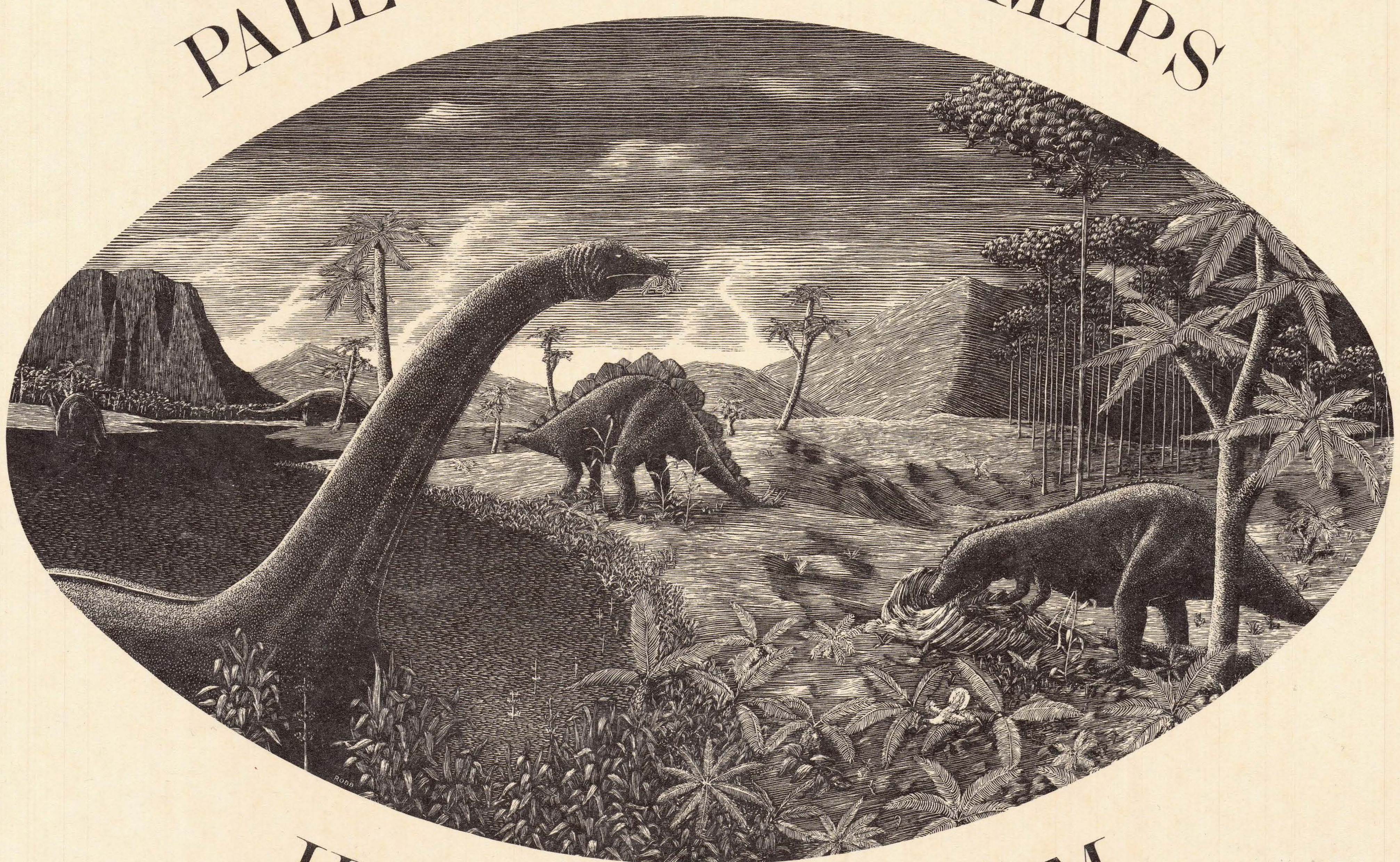
DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

PALEOTECTONIC MAPS



JURASSIC SYSTEM

By
Edwin D. McKee, Steven S. Oriel, Vernon E. Swanson,
Marjorie E. MacLachlan, James C. MacLachlan, Keith B. Ketner,
June Waterman Goldsmith, Ruth Young Bell, and Dolores J. Jameson
With a separate section on paleogeography by Ralph W. Imlay

PUBLISHED BY THE U. S. GEOLOGICAL SURVEY
WASHINGTON, D. C.
1956

CONTENTS

TABLE 1.—ASSIGNMENT OF UNITS TO INTERVALS USED IN THIS FOLIO

Stratigraphic units	Areas	Intervals of folio maps A	B	C	D
Amador group	East-central California		X		
Arapien shale	Central Utah		X		
Arvison formation	North-central California	X			
Aztec sandstone	Eastern and southern Nevada	X			
Bagley andesite	North-central California	X			
Bicknell sandstone	Northeastern California		X		
Bilk Creek sandstone member of Wanakah formation.	Durango-Ouray area of southwestern Colorado.			X	
Bluff sandstone	Eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.			X	
Bossier formation	Western Gulf Coast				X
Brushy Basin member of Morrison formation.	Eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.				X
Buckner member of Haynesville formation.	Eastern Texas to Alabama			X	
Canyon Springs member of Sundance formation.	Eastern Wyoming; western South Dakota, northwestern Nebraska.		X		
Carmel formation	Western Wyoming; Idaho, northern Utah; eastern and southern Utah, western Colorado; northeastern Arizona.		X		
Colpitts group	East-central Oregon		X		
Combe sandstone	Northeastern California				X
Cotton Valley group	Eastern Texas to Alabama				X
Cow Springs sandstone (lower part).	Northwestern New Mexico; northeastern Arizona.			X	
Cow Springs sandstone (upper part).	Northwestern New Mexico; northeastern Arizona.				X
Curtis formation	Western Wyoming; Idaho, northern Utah; eastern and southern Utah, western Colorado.			X	
Dewdney Creek formation	North-central Washington				X
Donovan formation	East-central Oregon	X			
Dothan formation	Southwestern Oregon			X	
Dunlap formation	Western Nevada	X			
Entrada sandstone	Western Interior region		X		
Entrada sandstone, *lower sandy member.*	Northeastern Arizona.		X		
Entrada sandstone, *middle silty member.*	Northwestern New Mexico; northeastern Arizona.		X		
Entrada sandstone, *upper sandy member.*	Northwestern New Mexico; northeastern Arizona.		X		
Exeter sandstone	Eastern Colorado, western Oklahoma, northeastern New Mexico.		X		
Fant andesite	Northeastern California	X			
Foreman formation	Northeastern California			X	
Franciscan formation	Western California				X
Galice formation	Southwestern Oregon			X	
Gypsum Spring formation	Eastern Wyoming and western South Dakota.		X		
Hardgrave sandstone	Northeastern California	X			
Haynesville formation	Eastern Texas to Alabama			X	
Hinchman sandstone	Northeastern California		X		
Hulett member of Sundance formation.	Eastern Wyoming; western South Dakota, northwestern Nebraska.		X		
Izee group	East-central Oregon		X		
Junction Creek formation	Durango-Ouray area of southwestern Colorado.			X	
Kayenta formation	Eastern and southern Utah, western Colorado; northeastern Arizona.	X			
Knoxville formation	Southwestern Oregon; western California.				X
Lak member of Sundance formation.	Eastern Wyoming; western South Dakota, northwestern Nebraska.		X		
Lonesome formation	East-central Oregon			X	
Louann salt	Eastern Texas to Alabama		X		
Malone formation	Western Texas				X
Mariposa slate	East-central California			X	
Milton formation (lower part).	Eastern California	X			
Milton formation (upper part).	Eastern California		X		
Moab tongue of Entrada sandstone.	Eastern and southern Utah, western Colorado.			X	
Monte de Oro formation	North-central California				X
Mormon sandstone	Northeastern California		X		
Morrison formation	Western Interior region				X
Morrison formation (lower unit).	Southwestern Nebraska, western Kansas.			X	
Morrison formation (basal beds).	Eastern Colorado, western Oklahoma, northeastern New Mexico.			X	
Mowich group	East-central Oregon	X			
Myrtle formation (in part).	Southwestern Oregon				X
Navajo sandstone	Northern Utah; eastern and southern Utah, western Colorado; northeastern Arizona; eastern and southern Nevada.	X			
Nooksack formation (lower part).	North-central Washington			X	
Nooksack formation (upper part).	North-central Washington				X
Norphlet formation	Eastern Texas to Alabama			X	
Nugget sandstone	Wyoming; Idaho, northern Utah; western South Dakota, eastern and southern Nevada.	X			
Ocate sandstone	Northeastern New Mexico.		X		
Piper formation	Eastern Montana, North Dakota.		X		
Pony Express member of Wanakah formation.	Durango-Ouray area of southwestern Colorado.			X	
Potem formation	North-central California		X		
Preuss sandstone	Western Wyoming; Idaho, northern Utah.		X		
Ralston formation	Eastern Colorado			X	
Recapture member of Morrison formation.	Eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.				X
Redwater shale member of Sundance formation.	Eastern Wyoming and western South Dakota.			X	
Rierdon formation	Montana and North Dakota		X		
Rogue formation	Southwestern Oregon			X	
Sailor Canyon formation.	Eastern California	X			
Salt Wash member of Morrison formation.	Eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.				X
Sawtooth formation	Western Montana		X		
Schuler formation	Western Gulf Coast				X
Shuksan formation	North-central Washington			X	
Smackover formation	Eastern Texas to Alabama			X	
Stockade Beaver member of Sundance formation.	Eastern Wyoming; western South Dakota, northwestern Nebraska.		X		
Stump sandstone	Western Wyoming; Idaho and northern Utah.			X	
Summerville formation	Northeast Utah and eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.			X	
Sundance formation (lower part).	Eastern Wyoming; eastern Montana, North Dakota; western South Dakota, northwestern Nebraska.		X		
Sundance formation (upper part).	Eastern Wyoming; eastern Montana, North Dakota; western South Dakota, northwestern Nebraska.			X	
Sunrise formation	Western Nevada	X			
Swift formation	Montana and North Dakota			X	
Thompson limestone	Northeastern California		X		
Todilto limestone	New Mexico			X	
Trail formation	Northeastern California	X			
Trowbridge shale	East-central Oregon		X		
Twin Creek formation	Western Wyoming; Idaho, northern Utah.		X		
Twist Gulch member of Arapien shale.	Central Utah		X		
Wanakah formation	Durango-Ouray area of southwestern Colorado; eastern Colorado, northeastern New Mexico.			X	
Werner formation	Gulf Coast		X		
Westwater Canyon member of Morrison formation.	Eastern and southern Utah, western Colorado; northwestern New Mexico; northeastern Arizona.				X
Winsor formation	Southwest Utah			X	

INTERIOR—GEOLOGICAL SURVEY, WASHINGTON, D. C., MR-2978
For sale by U. S. Geological Survey, price $5.00

PALEOTECTONIC MAPS OF THE JURASSIC SYSTEM

INTRODUCTION

Paleotectonic map compilation was begun by the U. S. Geological Survey in July 1952. Work was fully underway by the fall of 1953, and from then on the staff of the paleotectonic map project has consisted of six to seven geologists. The objective of this program is to prepare folios that depict rock thicknesses, generalized lithology, ancient geography, and other regional relations for each of the geologic systems in the United States, and to interpret these data in terms of tectonic evolution.

The Jurassic system is the first for which a synthesis has been prepared in the form of a folio. It was selected for this purpose because it appeared to be well suited for the development of project methods and techniques. Rocks of this system are of current economic interest; they also include a wide variety of types, but they are believed not to be as complex stratigraphically or as extensive as those of most other systems.

Data have been compiled with the objective of developing a permanent, usable file to which new data may continuously be added. The file consists of punch cards arranged by State. A card is prepared for each formation at every locality for which data are available; each card contains the formation name, locality or map number, geologic age, source of data, and a summary of additional data. The punch card files of the paleotectonic map project, located in the Federal Center at Denver, Colo. are open and available for the use of all geologists, except for relatively few data obtained in confidence.

In accumulating information, initial efforts normally are directed toward the published record which is systematically abstracted on the punch cards. Among unpublished materials, the most important are well logs and measured section files. Through the courtesy of sample log companies, oil companies, and university and survey well-log libraries, data from thousands of wells have been made available to the project staff. Other significant contributions of data have come from university theses, from individuals, from State surveys, and from various groups within the U. S. Geological Survey. These data have contributed much toward the solution of local and regional problems.

With few exceptions, all accumulation of data on Jurassic rocks was terminated late in the fall of 1954.

Stratigraphic data were compiled for each State at a scale of 1:1,000,000. They are presented on maps covering nine folded pages in this folio. Seven of the maps are of the United States on a scale of 1:5,000,000. They were prepared as objectively as possible, although a certain amount of interpretation was necessary to make the data, collected from diverse sources, mutually consistent. Also in this folio are two plates made up of maps of a more subjective nature; they represent interpretations of the factual data.

The interpretive maps include a series of nine paleogeographic maps and a summary map (pl. 8) prepared by Ralph W. Imlay. These maps, based upon his extensive and detailed studies of Jurassic faunas and sections, show the positions of shorelines, land masses, and sources of sediments during short time intervals. Other interpretive maps included in the folio are the environmental maps on plate 9. These portray details of depositional environments in certain areas where control points are numerous and data good. These maps are speculative presentations prepared by various members of the project from data compiled in connection with the other maps.

The Jurassic folio represents the cooperative efforts of the entire staff of the paleotectonic map project. Each geologist is responsible for all stages of compilation for a particular region, with coordination by the project chief and general guidance as to scope and procedures from a steering committee of eight appointed by the Chief Geologist. Distribution of assignments among project staff was as follows:

Gulf Coast region
Marjorie E. MacLachlan
Midcontinent region
Steven S. Oriel
Southwest region
Edwin D. McKee
Utah and western Colorado
James C. MacLachlan
Wyoming, Montana, North Dakota, South Dakota
June Waterman Goldsmith
Nevada
Keith B. Ketner
West Coast region
Vernon E. Swanson

The project was directed by James Gilluly in the early stages and by Edwin D. McKee later, with an overlapping interval of joint responsibility. During the early stages, work on Wyoming, Montana, North Dakota, and South Dakota was by Ruth Young Bell and on Utah and Idaho by Dolores J. Jameson.

INDEX TO LOCALITIES AND SOURCES

The index that immediately precedes the map of control points (pl. 1) is designed to enable the reader to determine the precise location and the original source data for each point used on the maps in this folio. Citations, necessarily brief because of the number of control points, include publications and unpublished reports, well logs, sections, and personal communications. The index should not be considered a complete bibliography, although it does include references to all publications used in establishing control points on the maps. The bibliographic reference list for the folio appears at the end of the text.

ACKNOWLEDGMENTS FOR INFORMATION

Many individuals and organizations have generously contributed information in the form of measured sections, well-log data, and other detailed records that were necessary for the successful preparation of this folio. The list of names on the locality index indicates those to whom the project is so indebted. This folio would be incomplete, however, if the names of those who contributed most extensively were not also mentioned here.

- Applin, P. L. and E. R., U. S. Geological Survey, Jackson, Miss.
- Bass, N. W., U. S. Geological Survey, Denver, Colo.
- Callaghan, Eugene, and associates, New Mexico Bureau of Mines and Mineral Resources, Socorro, N. Mex.
- Childs, Orlo, Phillips Petroleum Co., Denver, Colo.
- Chronic, John, University of Colorado, Boulder, Colo.
- Clark, L. W., U. S. Geological Survey, Menlo Park, Calif.
- Craig, L. C., and associates, U. S. Geological Survey, Grand Junction, Colo.
- Danner, W. R., University of British Columbia, Vancouver, B. C., Canada.
- Ferguson, H. G., U. S. Geological Survey, Washington, D. C.
- Hadley, H. D., and associates, Billings Geological Service, Billings, Mont.
- Hallgarth, W. E., U. S. Geological Survey, Denver, Colo.
- Harshbarger, J. W., and associates, U. S. Geological Survey, Holbrook, Ariz.
- Hazzard, R. T., Gulf Oil Co., Shreveport, La.
- Jensen, F. S., The Texas Co., Denver, Colo.
- Kansas Sample Log Service, Wichita, Kans.
- Kelley, V. C., University of New Mexico, Albuquerque, N. Mex.
- Knight, W. H., Union Oil Co., Jackson, Miss.
- Love, J. D., U. S. Geological Survey, Laramie, Wyo.
- Low, J. W., The California Co., Denver, Colo.
- Lynch, W. D., The California Co., Denver, Colo.
- Maher, J. C., U. S. Geological Survey, Tulsa, Okla.
- Mallory, W. W., Phillips Petroleum Co., Denver, Colo.
- Merriam, D. F., Kansas Geological Survey, Lawrence, Kans.
- Misch, Peter, University of Washington, Seattle, Wash.
- Mitchell, J. G., American Stratigraphic Co., Denver, Colo.
- Muller, S. W., Stanford University, Stanford, Calif.
- Northrop, Stuart, University of New Mexico, Albuquerque, N. Mex.
- Ogden, Lawrence, Colorado School of Mines, Golden, Colo.
- Reed, E. C., Nebraska Geological Survey, Lincoln, Nebr.
- Taliaferro, N. L., University of California, Berkeley, Calif.
- Trowbridge, Raymond, Tyler, Tex.
- Wanek, A. A., and associates, U. S. Geological Survey, Albuquerque, N. Mex.

MAP OF CONTROL POINTS (PL. 1)

Plate 1 shows the location of all control points used in the maps that follow. It enables the reader to determine the source of data for any portion of the paleogeologic, isopach, or lithofacies maps. Numbers shown adjacent to control points on the map correspond to numbers in the locality index that precedes it. This map, with the accompanying index, should make it possible for the reader to (1) compare the data used in the preparation of this folio with his own, (2) evaluate the significance of various control points in making later interpretations of his own, and (3) reproduce comparable maps, adding such data as become available in the future.

Another purpose of the map is to indicate, by the density of control points, the relative amount of information available for any area. This provides a basis, when considered together with the quality of data, for evaluating the reliability of various isopach lines. Also significant is the paucity of control points in certain areas, for it calls attention to places where additional geologic studies are needed and where problems remain unsolved.

The accuracy of paleogeologic, isopach, and lithofacies maps is determined by the quantity and spacing of control points and upon the quality of the data available for each point. In regions such as the West Coast or Nevada, for example, points are so widely spaced that interpolation is hazardous. Isopach and lithofacies maps prepared for such areas are unreliable. Consequently, in regions of sparse control, isolated points are shown with explanatory data and rock symbols, but no isopach lines are used.

In other regions, particularly in petroliferous basins where there has been much drilling, sections or wells are too closely spaced in many places to be shown individually on the scale of 1:5,000,000. In general, one point per township is the upper density limit shown on the maps in this folio. Where more data were available, however, they have been compiled on punch cards as confirmation of the validity of composite or selected data.

Where measured sections or wells have been variously interpreted, these interpretations are discussed in the text, although only one may be shown on the maps.

PALEOGEOLOGIC MAP (PL. 2)

The paleogeologic map shows the geology of the surface upon which Jurassic sediments were deposited. It is based upon those control points for which the formation immediately beneath Jurassic rocks has been determined. Areally it is limited to regions in which Jurassic strata are now found. In a few places, however, where Triassic rocks now extend beyond the present limits of the Jurassic, their distribution is indicated by means of symbols but without the use of color.

The base of the Jurassic is difficult to establish in many areas and, therefore, subject to interpretation. In such places the boundary has been selected arbitrarily. Specific boundary problems are summarized below and pertinent evidence cited in the discussion of each region.

ATLANTIC COAST REGION

On Cape Hatteras, N. C., Upper Jurassic(?) rocks encountered in the Esso Standard Oil, Hatteras Light Well No. 1, are reported to be underlain by Precambrian granite (Swain, 1952, p. 66-67). This is the only Jurassic control point available for the region.

GULF COAST REGION

The rocks beneath the Jurassic system in the Gulf Coast region are poorly known. Only around the northern periphery of the Coastal Plain, where they have been penetrated by wells, is information available. Therefore, present knowledge concerning them is restricted to a relatively narrow, semicircular belt extending from Alabama to east Texas.

Igneous rocks of unknown age underlie Jurassic strata in the central part of the Gulf Coast region in many wells. Whether additional Jurassic strata underlie these bodies is not known.

Structural relations in the Gulf Coast region also are far from clear, owing to insufficient data. Whether the Appalachian and Ouachita orogenic belts, for example, connect or cross (King, 1950, p. 666-668) is not known, although P. B. King (written communication) believes that available data suggest a connection.

Alabama and Mississippi, units underlying Jurassic.—In the eastern Gulf Coast region (Alabama) Triassic(?) diabase sills or dikes underlie younger strata at two localities. The extent of the Triassic(?) rocks is not known, but they are represented as occupying a trough comparable in size and shape to the known Triassic troughs of the Atlantic Coast States. Other Triassic deposits, not yet recognized, may be present in the Gulf Coast region (Applin, 1951, p. 15-17.)

Most of the rocks of pre-Jurassic age that have been examined in Alabama and Mississippi are of Pennsylvanian and Ordovician age. Subsurface trends of these strata and adjoining crystallines to the southeast appear to be continuous with surface trends in the southern Appalachians.

Pennsylvanian strata dip to the south and thicken downdip as far south as penetrated (H. R. Wanless, written communication). Where rocks of Ordovician age occur in the small bulge along the contact shown in eastern Mississippi (pl. 2), the absence of Pennsylvanian is attributed to erosion.

Ordovician strata to the south of the Pennsylvanian belt may be part of (1) a thrust sheet on the Pennsylvanian belt, (2) a high-angle fault block, or (3) a normal sequence brought up by a sharp reversal of dip. H. R. Wanless (written communication) believes available evidence favors the first explanation.

Arkansas and Louisiana, units underlying Jurassic.—If the *Werner*[1] and *Louann* formations are of Jurassic age, as discussed under Interval B, the Eagle Mills of this report may be the youngest pre-Jurassic formation in the middle part of the Gulf Coast region. The late Paleozoic age assigned to the unfossiliferous Eagle Mills (restricted), however, is also questionable. The validity of the paleogeologic map in the Gulf Coast region, therefore, as well as that of the summary isopach and the Interval B maps (pls. 3 and 5), depends upon the solution of these stratigraphic problems.

The Morehouse formation, determined on faunal evidence to be of Pennsylvanian age (Imlay and Williams, 1942, p. 1672-1673; Hoffmeister and Staplin, 1954, p 158-159), was partially penetrated in northeastern Louisiana by a single well. Unfortunately, neither its relation to underlying and overlying formations, nor its position relative to the Eagle Mills formation is clear. As a result, three interpretations of its stratigraphic relationships have been suggested, as shown below diagrammatically. The second of these interpretations is followed in this folio.

NE — *Werner* — SW
Eagle Mills \ Morehouse

1. Eagle Mills older than Morehouse

NE — *Werner* — SW
Eagle Mills / Morehouse

2. Morehouse older than Eagle Mills

NE — *Werner* — SW
Eagle Mills | Morehouse

3. Fault of unknown dip and displacement

East Texas, units underlying Jurassic.—Pre-Jurassic rocks in the western part of the Gulf Coast region are arranged in parallel belts that form a southward curving arc. The northwesternmost belt is composed of Cambrian and Ordovician strata; the middle belt consists of rocks of Pennsylvanian age; and the southeasternmost belt is formed of metamorphic rocks, including schist, phyllite, and slate (Morgan, 1952, p. 2272-2273; Goldstein and Reno, 1952, p. 2288-2290). The structural relations of the belts and the age of the metamorphic rocks have not definitely been established. H. R. Wanless (written communication) suggests, however, that in the northeastern part, the metamorphic rocks closely resemble the Stanley shale of Mississippian and Pennsylvanian age in Oklahoma and Arkansas and may be correlative with it. Some geologists believe they are younger.

Lower boundary of Jurassic.—The position of the lower boundary of the Jurassic system, as mentioned above, is believed by some geologists to be above the *Louann* and *Werner* formations (table 2), but by others to be beneath them, at the top of the Eagle Mills (restricted) formation. Because the *Louann* and *Werner* formations consist of unfossiliferous deposits of salt, anhydrite, and red beds and because these formations have not been penetrated very far downdip, the problem remains controversial. The base of the Jurassic system is here assumed to be at the contact of the *Werner* and the Eagle Mills (restricted) formations.

WEST TEXAS

Jurassic rocks in west Texas and adjoining Mexico directly overlie Permian and possibly older Paleozoic formations. The *Briggs formation* of Leonard or younger age underlies Jurassic strata in the Malone-Quitman Mountain area (Huffington, 1943, p. 994).

MIDCONTINENT REGION

In the area from the Front Range of Colorado eastward into western Kansas and western Nebraska, rocks of the Jurassic system rest in many places on those of Triassic age and elsewhere on truncated Permian strata. From southwest to northeast in Kansas, for instance, Jurassic rocks rest upon progressively older strata. In the southwestern corner of that State, they overlie the Dockum group (Triassic), whereas farther east and north, near the Nebraska border in Phillips County, they rest on beds of Leonard (Permian) age.

Kansas and Nebraska, units underlying Jurassic.—Formational boundaries within the Triassic and Permian sequences underlying the Jurassic are recognizable with varying degrees of assurance for different areas. In western Kansas, contacts between Permian units, shown on this map, are determined on the basis of key beds of dolomite, anhydrite, and sandstone within a section of red beds (Moore et al., 1951, p. 36). In Nebraska to the north, however, changes in facies and the presence of many anhydrite lenses make difficult the recognition of the Kansas Permian formations. For this reason, no attempt is made to differentiate Permian units there. Even the Permian-Triassic boundary is difficult to recognize because strata of both ages are composed largely of red beds; peculiarities of boundary configuration may reflect, in part, differences in interpretation by different geologists.

Eastern Colorado, units underlying Jurassic.—In eastern Colorado two principal problems are involved concerning the formations that directly underlie the Jurassic. First, the position of the Permian-Triassic boundary is uncertain throughout this area. Second, the relation of exposed strata (Lykins) along the Front Range to the uppermost Permian strata in the subsurface farther east is obscure. Contributions toward the understanding of these rocks have been made by Condra and others (1950) and by Maher (1953), but the stratigraphic problems involved remain so difficult that the distribution of pre-Jurassic strata in this area is generalized on the paleogeologic map.

Attempts to determine the age of the Lykins formation along the Front Range have thus far given inconclusive results. The only described fossils, from the lower part of the formation, are of Permian age (Richardson, 1915, p. 5). The upper part of the formation —above the locally designated "upper crinkled limestone"— is considered Triassic by some geologists because of its lithologic similarity to the Triassic Chugwater and Spearfish formations in Wyoming and the Black Hills, repectively.

The upper red beds of the Lykins formation are absent near the southern part of the Front Range (south of Perry Park), so in that area the Lykins is considered to be entirely of Permian age. Near the Colorado-Wyoming border, however, the upper red beds attain a maximum thickness of about 700 feet; the Permian-Triassic boundary is believed by some geologists (Lavington and Thompson, 1948, p. 44) to lie within these beds, although others (Johnson, 1945, p. 80) consider the red beds to be entirely of Permian age. Still others (LeRoy, 1946, p. 44) place the boundary at the top of the "upper crinkled beds." No attempt is made on this paleogeologic map (pl. 2) to subdivide the Lykins formation.

Above the Lykins formation in northern Colorado is the Jelm formation of Late Triassic age. In southeastern Colorado and northeastern New Mexico, however, the Lykins is overlain by strata of the Triassic Dockum group (Chinle formation). Because Dockum strata are red beds similar to those of the Lykins formation, they are difficult to distinguish in well cuttings with the result that the position of the Dockum-Lykins contact in many well logs is subject to more than one interpretation. The contact used in preparing this map, therefore, represents only one of several possible selections.

Lower boundary of Jurassic.—The contact at the base of the Jurassic system throughout western Kansas, Nebraska, and eastern Colorado is distinct. Jurassic strata within this region are composed largely of variegated rocks having distinctive pastel colors, especially greens and pinks. They contrast strongly with underlying Triassic and Permian rocks that are dominantly deep red. In southeastern Colorado (central Kiowa County to central Las Animas County and southward), however, the contact is difficult to recognize. White to pink cross-stratified sandstone of the Jurassic Exeter or Entrada sandstone rests upon a similar unit of sandstone, about 200 feet thick, believed to belong to the Triassic Dockum group. The problem of separation in this area has been discussed by Bass and others (1947). In some places the units are not distinguishable, making necessary the omission of the Entrada sandstone from Jurassic isopach and lithofacies maps.

SOUTHWEST REGION

Rocks of Triassic age everywhere underlie the Jurassic strata that extend across northeastern Arizona and northern New Mexico. Furthermore, Triassic strata are present in many places south and west of the present limits of the Jurassic and, at least in southeastern New Mexico, once extended far beyond the area of original Jurassic deposition as indicated by present outcrops (X) and by sections beneath the Cretaceous (△) on plate 2.

Arizona and New Mexico, units underlying Jurassic.—Across much of

[1]Formation names shown in italics are those that have not yet been adopted by the U. S. Geological Survey.

UTAH AND WESTERN COLORADO

Formations included.—The Kayenta formation and Navajo sandstone represent Interval A in central and southern Utah and both extend a few miles into southwestern Colorado. South of the Uinta basin of northeastern Utah ("Jurassic not reached by drill" area) the relations and descriptions for the Southwest region are applicable.

In northwestern Colorado and northern Utah, Interval A is represented by the Navajo, or Nugget, sandstone. Problems of terminology and correlation of the Nugget sandstone are discussed in the section on paleogeology (lower boundary of Jurassic system), Wyoming.

Thickness trends.—A general trend of increasing thickness from Colorado westward to central Utah is notably modified at one place on the Colorado-Utah boundary, near the southeastern margin of the Uinta Basin ("Jurassic not reached by drill" area). From this area of constricted isopach lines, southward along the eastern limits of deposits of Interval A, the Kayenta formation extends farther east than does the Navajo sandstone. North and south of this wedge of Kayenta, the Navajo sandstone forms lobes that project beyond the eastern margin of the underlying Kayenta formation.

Lithofacies trends.—In the area of constricted isopach lines, where the Kayenta formation is the sole representative of Interval A, lithofacies patterns reflect a relatively large proportion of mudstone in the section. Elsewhere the Navajo sandstone dominates and the pattern shows sandstone as the chief constituent in rocks of the interval.

Upper boundary of Interval A.—Except in northwestern Colorado the Navajo sandstone is overlain by the Carmel formation or its equivalent, and the boundary is easily recognized. In northwestern Colorado the Entrada sandstone rests upon the Navajo, and selection of a boundary between them is difficult. Where no selection was made by the author of a measured section, and where adjacent localities indicate the probable presence of Navajo sandstone, the contact has been projected from nearby localities, and the resulting thicknesses have been tentatively assigned to the appropriate unit.

IDAHO AND WYOMING

Formation included.—Interval A is represented in southeastern Idaho and southwestern Wyoming by the Nugget sandstone. The formation consists mainly of red and gray, thick-bedded, cross-stratified sandstone. In a few places, mudstone interbeds are in the lower part of the formation, as in the southwestern part of the Wind River Basin of western Wyoming (Love et al., 1945b).

In southeastern Wyoming and southwestern South Dakota, sandstone beds at the base of the Jurassic section formerly were assigned tentatively to the Nugget sandstone (e.g., Imlay, 1947, p. 229), but they now are considered to be part of the Sundance formation of Interval B (Love et al., 1949; Imlay, oral communication). Unlike the Nugget, which thickens westward, the sandstone beds increase in thickness toward the east and do not fit into a logical regional pattern with the Nugget.

Map trends.—In the southeastern corner of Idaho the rocks of Interval A are 2,000 feet thick, but they thin northward and eastward to a feather edge in central Wyoming. This thinning may be due either to subsequent tilting and beveling or to less deposition eastward. How closely the present limits of the Nugget sandstone coincide with the original margins is not known, but because black mudstone (Fernie formation) to the north is believed to be comparable in age, sandstone of the Nugget may never have extended much beyond its present margins.

Upper boundary of Interval A.—In western Wyoming the Nugget sandstone, which comprises Interval A, is easily distinguished from overlying red mudstone, gypsum, and limestone of the Gypsum Spring correlative at the base of the Twin Creek (Interval B). Farther east in Wyoming, the upper boundary of Interval A is beneath marine sandstones and mudstones of various Upper Jurassic formations. These also contrast lithologically with the Nugget.

WESTERN NEVADA

Lower Jurassic rocks assigned to Interval A in western Nevada comprise two formations separated by a prominent unconformity. The lower formation, called the Sunrise, is marine and is composed of mudstone and limestone; the upper unit, known as the Dunlap formation, consists of both continental and marine sandstone, conglomerate and volcanic rocks. The Dunlap apparently represents a time of crustal disturbance and volcanism in that area and is dated as Middle Lias (Muller and Ferguson, 1939, p. 1621).

The area in which the Sunrise and Dunlap formations were deposited has been referred to as the "Luning Embayment" of Triassic-Jurassic time and is considered to have been a branch of the rapidly sinking eugeosyncline of the Pacific Coast region (Ferguson and Muller, 1949, p. 8). Within this embayment, Lower Jurassic strata attained a thickness of at least 6,250 feet.

WEST COAST REGION

California formations included.—In eastern California (locality 122) J. H. Halsey (oral communication, 1954) has tentatively correlated a unit of predominantly volcanic rocks several thousand feet thick with the Lower Jurassic Dunlap formation of western Nevada. To the northwest (localities 4, 47, 117), the Milton and Sailor Canyon formations are approximately equivalent and probably include several thousand feet of Lower Jurassic rocks.

In a large area in the southern part of the Sierra Nevada (as represented by locality 97), patches of metamorphosed sedimentary rocks in the granodiorite massif have been assigned, in part, an Early Jurassic age, though no substantiating fossils have been found. Lavas and tuffaceous rocks of definite Early Jurassic age have been described both in the Mount Jura area (locality 22) and in north-central California (localities 34, 116).

A thick section of the Jurassic(?) Aztec sandstone in southeastern California is discussed in its relation to strata of the southwest region.

Oregon formations included. — In east-central Oregon (locality 1) some 3,000 feet of detrital rocks, the *Mowich group*, have been dated as middle Early Jurassic. From the other two localities shown on this map (localities 15, 16), fossil collections have tentatively been assigned an Early Jurassic age. One of these collections, from the Snake River Canyon (locality 15), includes a specimen of *Gryphaea* collected by W. R. Wagner and dated by J. B. Reeside, Jr. (written communication); the other collection, from the Mount Vernon quadrangle (locality 16), consists of fragmented ammonites collected by T. P. Thayer and assigned an "Early Jurassic(?)" age by R. W. Imlay (written communication).

Washington formations included.—No rocks of definite Early Jurassic age have been described from Washington. The only formation possibly of this age, as far as known, is a limestone (S. L. Glover, written communication) in which an ammonite of Triassic or Early Jurassic age was found (Waters and Krauskopf, 1941, p. 1366).

Significance of map data.—The limited information available makes attempts to outline the areas of Early Jurassic sedimentation in the West Coast region inadvisable. Apparent absence of these rocks over much of California, Oregon, and Washington may be and probably is due to nondeposition; however, in many places rocks of Early Jurassic age were deposited and either have not been recognized or have been removed by erosion. Further, it may be inferred that in this region of apparently intense, local tectonic activity and volcanism, the distribution of these rocks would be patchy. To project limits of deposition over areas of hundreds or thousands of square miles, therefore, on the basis of one or two outcrops where Lower Jurassic rocks have been identified, is unwarranted; hence the Lower Jurassic map, and subsequent lithofacies maps show only those localities where rocks of corresponding age have been specifically dated. For the above reasons, "0 thickness" points are not indicated on the map for Interval A where the rocks are not known. In most places such figures would be misleading.

INTERVAL B (PL. 5)

Interval B is the second from the base of the four divisions into which the Jurassic system has been divided in this folio. It is considered in broad terms to span the time represented by the Bajocian, Bathonian, and Callovian stages of the European classification.

During Interval B, sediments accumulated in all of the principal Jurassic basins and geosynclines (table 2). In the Gulf Coast region, strata tentatively assigned to this interval consist largely of evaporites and attain a maximum of more than 3,000 feet. Throughout most of the Western Interior basin, although sedimentary deposits of Interval B are relatively thin, they include both continental and marine strata. In the West Coast region, thousands of feet of lavas, tuffs, and sedimentary materials, typical of a rapidly sinking eugeosyncline and similar to those of the preceding Interval A, continued to form.

GULF COAST REGION

Formations included. — Formations assigned to Interval B in this folio are the *Werner*, composed of red beds and anhydrite, and the overlying *Louann*, a thick salt deposit. Unfortunately the age of these formations is far from certain and data concerning their thickness and lithology are scant.

Estimates on the age of the *Werner* and *Louann* formations are based on physical features and on their relations to other rock units, for no fossils have been found. These units, along with the overlying *Norphlet* and the underlying Eagle Mills (restricted) compose the Eagle Mills formation as described by Imlay (1940, p. 8-15; 1943, p. 1422-1440; 1952, p. 973-974). Because the *Norphlet* grades upward into the Smackover of Oxfordian age and is separated from the *Louann* by an unconformity, it is considered as Late Jurassic by Hazzard and others (1947, p. 483-503).

The lower three units included in the original Eagle Mills are interpreted by Hazzard and others (1947, p. 483-503) as Permian(?), although these writers recognize an unconformity between the Eagle Mills (restricted), at the base, and *Werner-Louann* deposits above. The Eagle Mills (restricted) has some lithologic support for a Permian age, but the *Werner* and *Louann*, being unfossiliferous and bounded by unconformites above and below, have yielded no proof of their age. They may be Late Jurassic as inferred by Imlay (1952a, p. 973-974), or Late Permian as suggested by Hazzard and others (1947, p. 483-485), or of intermediate age.

Map data.—Because relatively few wells have penetrated rocks included in Interval B, lithofacies trends cannot be illustrated on the map and thicknesses are shown as isolated figures, most of them too incomplete for the construction of isopach lines (pl. 5). On the other hand, available data show that the zero isopach line forms an arc from Alabama to east Texas, concave toward the south and similar to shoreline trends of later Jurassic deposits. Although a thickness of more than 3,000 feet for strata of this age is reported from northern Louisiana, this thickness is incomplete.

MIDCONTINENT REGION

Formations included and map data.—East of the Colorado Front Range, Interval B is represented by a wedge of Entrada sandstone that thins southward from Wyoming and by a similar sandstone, variously called Ocate, Entrada, or Exeter, extending across southeastern Colorado. Between these areas, in the middle part of eastern Colorado (south of Boulder), the Entrada sandstone is absent (Heaton, 1939, p. 1160). At some localities within this middle area (pl. 5), sandstone lenses at the base of the Jurassic have been described as Entrada, but the validity of their identification seems doubtful. Regularity of stratification, absence of typical truncated-wedge cross-bedding, presence of interbedded mudstone, and poor size sorting suggest that these sandstones are not Entrada. They are interpreted as representing local facies of rocks included in Interval C.

In northwestern Nebraska, marine deposits included in the lower part of the Sundance formation represent Interval B. Members of this unit described by Imlay (1947) in the Black Hills of South Dakota can be traced southward into the subsurface and can be recognized in wells as far south as the center of the Nebraska panhandle (Morrill County). The southernmost limits of these members cannot be recorded accurately.

Upper boundary of Interval B.—In eastern Colorado, the boundary marking the upper limit of strata referred to Interval B is at the top of the Entrada, Ocate, or Exeter sandstone. Through most of the southern Colorado region this boundary is distinct, as the well-sorted sandstone beds of these formations are overlain by mudstones and evaporites of later age. Locally, however, difficulties in picking the contact are encountered, for in some places sandstone resembling that in the Entrada is present at the base of the overlying rock sequence.

In Nebraska the contact between strata of Interval B and those of the overlying interval is considered to be at the top of the Lak member of the Sundance formation. Where that member is absent, the contact is placed at the top of the Hulett sandstone member. The Redwater shale member of the Sundance formation is the overlying unit.

SOUTHWEST REGION

Formations included and thickness trends.—Interval B is represented by the Entrada sandstone in northern New Mexico and by the Carmel formation and Entrada sandstone in northeastern Arizona. The southern limit of these deposits forms a line running approximately east-west across New Mexico, slightly north of the center, but in Arizona the line swings northwestward. Deposits in the basin north of this line have a maximum thickness of more than 800 feet about midway along the Arizona-Utah boundary. This area appears to have been at the southern end of the axis of a trough that was transgressed by the sea during Carmel deposition. Deposits of this time interval are, in general, progressively thinner eastward and, across the eastern half of New Mexico, they form a broad sheet of sediment less than 100 feet thick.

Lithofacies trends.—Trends on the lithofacies maps (pl. 5) indicate that sections consist almost exclusively of sandstone along the southwestern and southern margins of the region and across most of northern New Mexico. There is a notable increase in amount of mudstone farther north in Arizona, immediately west of the Arizona-New Mexico State line. This increase culminates in the Carrizo Mountain area in extreme northeastern Arizona where locally there is more mudstone than sandstone. The increase in percentage of mudstone is explained, in part, by the presence of the argillaceous Carmel formation here, but not in New Mexico. Even more significant, however, is the distribution of facies in the Entrada sandstone (Harshbarger et al., in press). Throughout most of New Mexico it is represented largely or entirely by the "upper sandy member" and in the western part of the Arizona outcrop area by the "lower sandy member" whereas between these areas, the "middle silty member" prevails.

Origin and source of sediments.—Principal events in the history of Interval B in northern Arizona and New Mexico are indicated in the east-west section (fig. 1). The suggested interpretation is that deposition (Carmel formation) began in the extreme western part of the present outcrop area where sinking along the axis allowed marine waters to advance southward across an expanding basin in Utah. Meanwhile muds were transported northward across Arizona into this basin, accumulating in ponds and lagoons marginal to the sea, or perhaps, as suggested by Harshbarger and others (in press, fig. 29), within the sea itself.

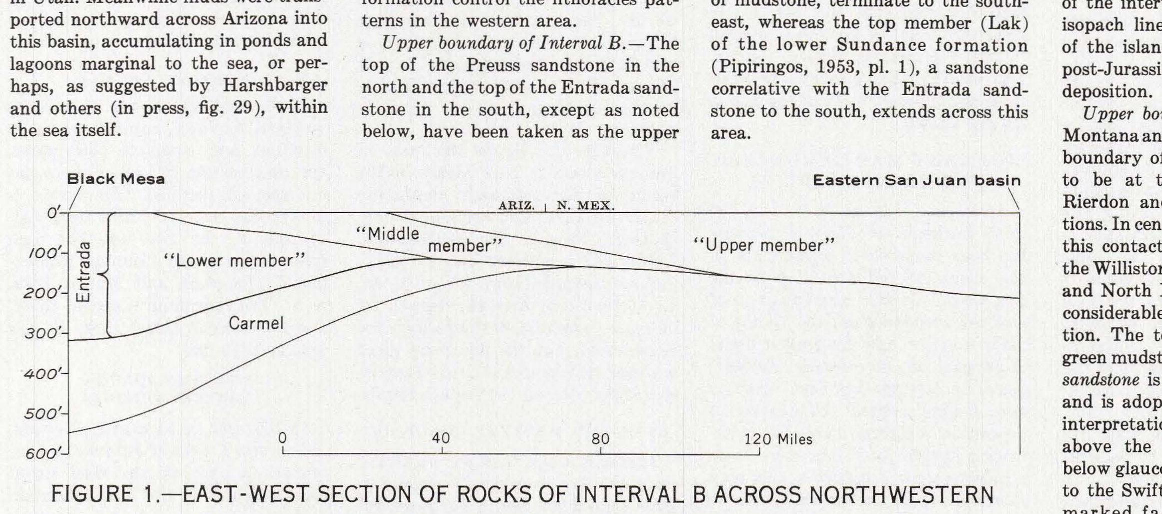


FIGURE 1.—EAST-WEST SECTION OF ROCKS OF INTERVAL B ACROSS NORTHWESTERN NEW MEXICO AND NORTHEASTERN ARIZONA

With the advance of time, sediments of the Entrada sandstone (including Ocate and Exeter sandstones in New Mexico) began to accumulate, and an enlarged basin of deposition allowed them to form a great sheet, consisting mostly of sand, that eventually covered all the marine and marginal deposits of the Carmel, as well as older deposits in adjoining areas. The Entrada sandstone (section *A-A'*, pl. 5) appears to have formed as a series of facies ("members" of Harshbarger) with overlapping relations that result in a shinglelike development from west to east.

Sandstones constituting the "lower sandy member" are interpreted as eolian, at least in the southwest margins of the area, and the sand appears to have been transported northeastward (Harshbarger et al., in press). Mudstones of the "middle silty member" form a facies composed of water-deposited sediments believed to have been introduced into the area adjoining the Arizona-New Mexico boundary from a source to the south. Drainage direction at that time doubtless was controlled by the position of the marine trough in Utah. Eastward from the belt of mudstones, across most of New Mexico, relatively pure sandstones suggest that, as in the west, an eolian environment may have prevailed, though streams may also have been locally important agents of transportation.

Because distribution and structures of the detrital sediments comprising the Carmel formation and Entrada sandstone indicate a source to the south and southwest in Arizona and New Mexico, elevation of the land in those directions has been suggested. Orogenic belts called Mohavia and Chico-Shunie have been indicated by Eardley (1951, pl. 13) to the southwest; a raised area referred to as the Mogollon Highlands is postulated by Harshbarger and others (in press) to the south in New Mexico. Sediments of the Carmel and Entrada are all fine grained, and there seems no reason to consider that an uplift of mountainous proportions occurred at this time. The area must have been exposed sufficiently to furnish a very considerable amount of detritus, however.

Upper boundary of Interval B.—The top of Interval B in Arizona and New Mexico, as recognized in this folio, is the upper boundary of the Entrada sandstone. In some places this boundary is arbitrary, as along the southwest borders where primary structures in the Entrada resemble those of the overlying Cow Springs sandstone, and in parts of northeastern Arizona where the silty facies of the Entrada is similar to the overlying Summerville (Harshbarger et al., in press). Also, in central New Mexico the Entrada sandstone is recorded as having an intertonguing relationship with the Todilto formation above (Silver, 1948, p. 77; Rapaport et al., 1952, p. 27). On the other hand, contacts are sharp in areas where the Summerville rests on the lithologically distinct sandy facies of the Entrada, and where the Todilto limestone rests on the silty facies of the Entrada (Harshbarger et al., in press).

UTAH AND WESTERN COLORADO

Formations included.—Interval B consists of both the Carmel formation and Entrada sandstone in the southern half of Utah. Although the Carmel formation underlies the Entrada sandstone for a short distance into Colorado, through most of western Colorado the Entrada sandstone alone represents the entire interval. In central Utah most of the Arapien shale (Twelvemile Canyon member and lower part of the Twist Gulch member) represents Interval B. The Twin Creek formation and the Preuss sandstone are included in Interval B in northern Utah.

Thickness trends.—In central Utah a deep trough developed during Interval B, as shown by isopach lines on plate 5. More than 5,000 feet of sediments were deposited in north-central Utah. The thick section extends southward to south-central Utah, gradually thinning to about 1,000 feet near the southern end of the belt. Eastward from the trough, rocks of Interval B are spread in a thin sheet across eastern Utah and western Colorado. As indicated on plate 5, the present limit of the Entrada sandstone may nearly correspond to the original limit of deposition in central Colorado.

Lithofacies trends.—Lithofacies patterns for Interval B in Colorado and eastern Utah contrast with those in central and southwestern Utah (pl. 5). The Entrada sandstone dominates in the eastern area, and marine shales and limestones of the Twin Creek formation, Arapien shale, and Carmel formation control the lithofacies patterns in the western area.

Upper boundary of Interval B.—The top of the Preuss sandstone in the north and the top of the Entrada sandstone in the south, except as noted below, have been taken as the upper boundary of Interval B in Utah and western Colorado. Along the Colorado-Utah State line the uppermost part of the Entrada is the Moab tongue. In areas where this tongue is distinguishable from the main body of the Entrada, it has been assigned to Interval C and the upper boundary of Interval B placed at its base.

In south-central and southwestern Utah several interpretations of the stratigraphic section are possible. Three sections (fig. 2), in generalized form, serve to demonstrate the various interpretations. They are, from east to west, (1) the Halls Creek section (locality 32), (2) the Pine Creek section (locality 120) and (3) the Cannonville section (locality 26).

The Halls Creek section as given by Hunt (1953, p. 67) is used in this folio, without alteration, as a standard for comparison with the sections to the west.

Correlation between the Halls Creek and Pine Creek sections may be made in three ways as shown in figure 3. L. C. Craig (written communication) prefers the version attributed to him in the diagram, but he considers that the correlation by C. C. McFall (Craig, written communication) may be correct. The third correlation, adopted in this folio, is a compromise between these two. It is not in conflict with available field data, according to Craig, and appears to best fit the isopach and lithofacies trends developed in adjacent areas.

The Cannonville section as described by Gregory (1951, p. 57) has been revised by Bissell (1954, p. 64) and by Craig (written communication) as shown in figure 4. Correlations between Cannonville and Pine Creek, as preferred by Craig and as used in this folio, are indicated in figure 4.

IDAHO, WYOMING, AND SOUTH DAKOTA

Formations included.—Rocks of Interval B (table 2) include the Twin Creek limestone and Preuss sandstone in Idaho and western Wyoming, the Gypsum Spring formation and the lower part of the Sundance in eastern Wyoming and western South Dakota. Although the Gypsum Spring formation is not commonly distinguished in southwestern Wyoming, it is represented by red beds and brecciated limestone in the basal part of the Twin Creek limestone.

Rocks of Interval B in South Dakota are difficult to correlate with confidence because of facies changes, and their eastern limits are not accurately known. The wide spacing of wells in that area results in a sparsity of data. As a result, members of the Sundance formation as recognized in the Black Hills (Imlay, 1947, p. 232-234) can be recognized in wells only a short distance east of the outcrop area. A pink mudstone, recognized in many wells, is used in this paper for correlation with the Lak member in the lower part of the Sundance. In other wells a conglomeratic sandstone, underlying glauconitic mudstone and sandstone, is considered equivalent to the lower part of the Sundance and permits tentative correlation.

Thickness trends.—Rocks of Interval B increase in thickness from east to west across South Dakota and Wyoming, attaining maximum thickness in a north-trending belt near the Idaho-Wyoming boundary. Complex structural relations exaggerate the rate of westward thickening in this belt; sediments originally deposited in separate areas are now piled upon each other in west-dipping, imbricate, thrust sheets. Present spatial relations, therefore, are abnormal.

A minor trend in isopach lines, apparent where rocks of Interval B have a thickness of 200 feet or less, as in eastern Wyoming, shows an east-west preferred orientation. The significance of this trend is not as yet understood.

Lithofacies trends.—Belts of similar rock percentages, as shown by the lithofacies symbols on plate 5, parallel isopach lines. In western Wyoming they trend generally north; in eastern Wyoming and South Dakota, approximately east. Regional changes in the thickness of various rock units, rather than changes in facies within units, are responsible for most east-west lithofacies variations in Wyoming. North-central Wyoming, for example, has a high percentage of gypsum in the Gypsum Spring formation. This rock is also in western Wyoming, but it is masked on the lithofacies map by the proportionally more abundant limestone and mudstone of the overlying Twin Creek limestone.

A relative increase in the proportion of sandstone in southeastern Wyoming reflects stratigraphic overlap, rather than facies change in a single stratigraphic unit. The lower members of the Sundance formation, dominantly of mudstone, terminate to the southeast, whereas the top member (Lak) of the lower Sundance formation (Pipiringos, 1953, pl. 1), a sandstone correlative with the Entrada sandstone to the south, extends across this area.

In South Dakota, facies changes in rocks tentatively assigned to Interval B involve an eastward increase in the proportion of sandstone. In many places, furthermore, the sandstone is conglomeratic.

Upper boundary of Interval B.—In much of Wyoming and southeastern Idaho, the upper boundary of Interval B is placed arbitrarily at the contact between the red sandstones of the Preuss or Lak units and the overlying green Stump sandstone or Redwater shale member of the Sundance formation. In general, this boundary is readily recognized by a marked color change. In some parts of central Wyoming, however, it is determined by an upward change from nonglauconitic mudstone and limestone to glauconitic mudstone and sandstone (Love et al., 1945b).

In the Black Hills region of South Dakota, the boundary between Intervals B and C is marked by a disconformity that separates the Hulett or Lak members from the overlying Redwater shale member of the Sundance formation.

MONTANA AND NORTH DAKOTA

Formations included.—Interval B in Montana and North Dakota includes the Sawtooth, Piper, Gypsum Spring, and Rierdon formations and strata listed as basal Jurassic. Because the Williston basin is still in the early development stage from the petroleum point of view, problems in stratigraphic nomenclature are numerous. Many geologists, on the basis of well samples, subdivide Middle Jurassic rocks into the Sawtooth, Piper, and Gypsum Spring formations, in descending order. The type localities of the three formations are widely separated, however, and their strata may be approximately equivalent (Imlay, 1952a, p. 967-969). Moreover, the Gypsum Spring formation, according to some geologists (Love, written communication), pinches out near the Wyoming-Montana border, northward from the type locality. Rocks from the subsurface in Montana have been called Gypsum Spring and are shown to underlie Piper limestone; they probably should be assigned to the basal part of the Piper formation (Imlay et al., 1948).

In northwestern Montana, the Sawtooth formation is used for rocks that have been called Grouse and Davidson. The age of these rocks and their relation to the Gypsum Spring formation in Wyoming have not been established. Although the rocks may be older than the Gypsum Spring, they are tentatively assigned to Interval B in this folio.

In the Dakotas, the name Gypsum Spring formation is used for rocks correlative with the Piper formation. Rocks assigned to the Sawtooth formation in Wyoming have not been recognized. Predominantly sandstone, it is included in the upper member of the Piper formation by others (Imlay et al., 1948).

Thickness trends.—Rocks of Jurassic Interval B are absent in a small area in central Montana, but they increase in thickness away from it. In an easterly direction, in northeastern Montana and northwestern North Dakota, they attain maximum thicknesses of 600 feet. The dominant orientation of isopach lines is northeast-southwest in the west and appears to be related to the inferred island.

Lithofacies trends.—Limestone is the dominant rock type represented by Interval B in Montana and North Dakota, though mudstone is abundant in a few places. Although quantitatively unimportant and largely masked by more abundant rock types, considerable sandstone is in the Sawtooth formation of the Sweetgrass arch in northwestern Montana (Cobban, 1945, p. 1270-1277). This sandstone is significant because of its distribution around an area in which rocks of Interval B are absent, suggesting that an island persisted in that area and was a source of detritus. Sandstone also is present in border areas of southeastern Montana, southwestern North Dakota, and near the eastern limit of deposition in North Dakota. Evaporites occur throughout central Montana and in North Dakota in the lower and upper units of the Piper formation.

The island in central Montana apparently supplied relatively little detritus to the surrounding area during Interval B—an indication that it probably was relatively low. This island seems to have restricted marine circulation during the early and late parts of the interval. The present trend of isopach lines, from which the shape of the island is inferred, may reflect post-Jurassic erosion as well as initial deposition.

Upper boundary of Interval B.—In Montana and North Dakota, the upper boundary of Interval B is considered to be at the contact between the Rierdon and overlying Swift formations. In central and western Montana, this contact is readily recognized. In the Williston basin of eastern Montana and North Dakota, however, there is considerable disagreement on its position. The top of a calcareous, gray-green mudstone beneath the *Vanguard sandstone* is used by many geologists and is adopted in this folio. Another interpretation places the boundary above the *Vanguard sandstone* and below glauconitic sandstone belonging to the Swift formation. Farther east, marked facies changes make the boundary difficult to trace.

WEST COAST REGION

California formations included.—Interval B is well documented at several scattered localities in northern California, particularly in the Potem formation (localities 34, 116), and the Mount Jura section (locality 22). Middle Jurassic fossils have been found 9,500 feet above the base of the Milton formation (locality 4), but the thickness of sediments deposited during Middle and early Late Jurassic time has not been determined.

The Amador group, which is highly variable in lithology and thickness, crops out in long, narrow belts between the Calaveras and Mariposa formations on the western slope of the central Sierra Nevada. Its exact age is not known, but Taliaferro (1943b, p. 284) believes it to extend from late Middle to early Late Jurassic, and R. W. Imlay (written communication) reports a probable Callovian age for ammonites collected by L. D. Clark from the Amador on the Cosumnes River (locality 124). For purposes of this map the entire thickness of the Amador is shown where known, recognizing that the unit may include rocks that are older or younger than the time interval this map represents.

Oregon and western Idaho formations included.—Fossils of Middle and early Late Jurassic age are found in only one area in Oregon (east-central Oregon, locality 1). The age of the thick Dothan formation in southwestern Oregon is generally considered Oxfordian, and hence is not shown on this map, but it may be older, in part, as its lower stratigraphic limit is not known.

Near the town of Mineral in western Idaho (locality 22) fossils of "early Upper Jurassic" age (Lupher, 1941, p. 265) have been found in a carbonaceous shale unit, about 250 feet thick, which is associated with several hundred feet of acidic volcanic rocks (Livingston, 1932, p. 33-34). Farther to the north and northeast in western Idaho (locality 23, 24, and 25) shales, phyllites, and schists that make up the upper member of the Lucile series may be equivalent in part to the fossiliferous unit near Mineral (Cook, 1954, p. 4), but because the correlation is very tentative these rocks are not shown on any but the total thickness map of the Jurassic.

Washington formations included.—Predominantly volcanic rocks of Middle Jurassic age, named the Harrison Lake formation, have been described on the west side of Harrison Lake in southern British Columbia by Crickmay (1930b), and a patch of this formation is shown on the north edge of American Sumas Mountain in northern Washington (locality 7). Farther to the east (locality 6), Peter Misch (written communication) has tentatively correlated a thick sequence of andesites, andesite breccias, and some intercalated sediments that underlie the Upper Jurassic and Lower Cretaceous *Nooksack formation*, with Crickmay's Harrison Lake formation.

Significance of available data.—A regional picture of distribution, general thickness, and lithology of rocks included in Interval B in the West Coast region can be based on sketchy evidence only. The most obvious generalization to be drawn from available data is that volcanism was active, certainly in a large part of California, in western Idaho, and probably in southwestern Oregon and northern Washington. Thousands of feet of basic lava, tuff and agglomerate, graywacke, argillite, and chert accumulated in central and east-central California; and several thousand feet of andesitic rocks probably were laid down in Washington during this time also. The limits of this eugeosynclinal area, however, cannot as yet be defined.

Volcanic rocks in the Jurassic sequence of western Idaho indicate that this area was part of the eugeosyncline that included the West Coast region and much of western Nevada. Furthermore, they suggest volcanism possibly related to emplacement of the Idaho batholith.

INTERVAL C (PL. 6)

During the third and next to highest interval (C) into which the Jurassic system has been divided in this folio, sedimentation was extensive, and basins and geosynclines were active. Rocks of this interval, for the most part, correlate with the Oxfordian stage in Europe (table 2).

Sedimentary rocks of Interval C include thick marine deposits accumulated in an off-shore environment in the Gulf Coast region, extensive marine and continental deposits of the Western Interior basin, and a thick sequence of geosynclinal materials in the West Coast region. Deposits of a Mexican seaway at this time accumulated close to the border of the United States adjoining west Texas.

Marine deposits of the Western Interior basin are the result of a major transgression of the sea across this area from the north. The extent of the sea's advance was comparable to that during Interval B and, like it, covered major parts of the basin. During early stages of this interval, widespread evaporite deposits accumulated in shallow waters south and east of the marine areas.

GULF COAST REGION

Formations included.—Four formations in the Gulf Coast region are considered to belong to Interval C. In ascending order these are the *Norphlet*, Smackover, Buckner (of questionable rank) and Haynesville. These rock units appear to be closely related lithologically and consist largely of limestone, mudstone, and evaporites. Along the northern margins of deposition, pre-Late Jurassic erosion removed varying amounts of these deposits, including all of the Haynesville in places and both Haynesville and Buckner in others.

Correlation of strata within Interval C is uncertain partly because well data are relatively sparse, especially in the thick sections downdip (toward the south). Although many wells have been drilled to the Smackover formation, few have penetrated the entire unit. Furthermore, in the Haynesville-Buckner sequence stratigraphic relations are obscure, particularly in east Texas. Time planes cannot be recognized anywhere within this sequence.

Thickness trends.—The isopach map illustrates that deposits of Interval C thicken southward all along the arc from Alabama to eastern Texas, reaching a total thickness of from 3,000 to 4,000 feet at the southernmost localities for which data are available. The thickness apparently continues to increase downdip though confirmatory data are not as yet available beyond the limits shown (section *D-D'* in east Texas). An exception is illustrated by the generalized section *E-E'* in northeastern Texas. Thicknesses of formations as interpreted by Swain (1949, p. 1216) at station 29 indicate that along the line of that section a lens is present, thinning toward both the present basinward margin and the shoreward side.

Lithofacies trends.—The lithofacies map (pl. 6) indicates scattered areas of sand concentration along the shoreward margin of the basin. These places are interpreted as areas adjoining the mouths of streams that introduced large loads of detrital sediments. Also apparent on this map are high percentages of limestone in most of the thick, seaward deposits and considerable proportions of anhydrite and red beds in intermediate areas. Moderate proportions of limestone are in many near-shore areas, suggesting an absence of nearby sources of detrital matter and conditions of quiet deposition.

These broad relationships appear on sections *D-D'* and *E-E'* west of the present Mississippi River, but they seem to prevail in areas to the east, judging from the very few available data.

The shoreline of the marine Mexican embayment during Interval C probably paralleled the present Rio Grande above the Big Bend.

WEST TEXAS

Rocks of Oxfordian age (Interval C), although present in northern Mexico, have not been reported by local geologists from nearby areas in West Texas. The strata in northern Mexico consist of 3,000 feet of sandstone, mudstone, and limestone and are assigned to the La Gloria formation.

MIDCONTINENT REGION

Rocks included.—Strata of Interval C are more extensive east of the Colorado Front Range than has generally been recognized. In many places detrital rocks, considered in this paper to be representative of the interval, previously have been assigned to the overlying Morrison formation; in other places, gypsiferous deposits in similar stratigraphic positions have been included in the underlying Lykins formation. Where rocks of this unit have been distinguished from the sandstones above and below, many different names have been used for the same sequence, for example, Curtis, Ralston, Summerville, Sundance, Todilto, and Wanakah. Those strata in western Kansas described by Merriam (1955, p. 32) as the "lower unit of the Morrison formation" also are correlated with rocks of this interval.

Several distinct facies are recognized in rocks assigned to Interval C east of the Front Range. Their approximate time equivalence has been established through the tracing of a distinctive key bed at the upper boundary of the unit. Evaporites—anhydrite and limestone—comprise much of the unit within the Denver basin and southward to the New Mexico boundary. Arkosic conglomerate of equivalent age is the dominant lithology at Cañon City, Colo., but eastward from there, the section contains increasing amounts of gypsum (Lawrence Ogden, written communication). Mudstone and marlstone are the principal constituents of the facies farther north at Ralston Creek, Colo., (LeRoy, 1946, p. 47-51; Van Horn, written communication), and similar rocks are described by Pipiringos (1953, p. 34) as "member D of the Sundance formation" in the southern Laramie Basin on the Colorado-Wyoming border and by James Mitchell (written communication) from the vicinity of Greeley in Weld County, Colo. Other distinctive facies of this interval are marine mudstone in the Nebraska Panhandle, traceable northward into rocks of the Redwater shale member, Sundance formation, in the Black Hills, and the alternating sandstone and mudstone sequence of Cimarron County in northwestern Oklahoma.

Included in Interval C are some sandstone beds of unknown age in south-central Nebraska (Furnas County) and in adjacent parts of Kansas. These rocks underlie evaporites recognized as part of Interval C. They have been referred to by some stratigraphers as the basal Jurassic sandstone. Because this sandstone is separated from the main sheet of Entrada sandstone lying considerably to the west, and in the absence of data bearing on its age, the reference of this sandstone to Interval C must be considered tentative.

Thickness and lithofacies trends.—Strata of Interval C have a fairly uniform thickness, ranging from 100 to 200 feet, throughout the Denver basin and in most of the adjoining areas (pl. 6), but they are absent in a small area in northwestern Nebraska.

Significant trends appearing on the lithofacies map (pl. 6) include the distribution pattern of anhydrite and limestone. These evaporites appear to be concentrated in parallel bands that reflect a change in relative proportions of evaporites to carbonates. In each set of bands, a calcareous facies is consistently north of a corresponding anhydrite facies—interpreted as a result of calcareous sediments being deposited closer to the source of saline waters than the anhydrites.

A second trend apparent on the lithofacies map (pl. 6) is the increase in percent of detrital components both to the east and southeast, near the pinchout of deposits, and to the west, adjacent to the present Front Range of Colorado. This trend suggests sources in two directions. Support for the thesis of an eastern source is the conclusion by Merriam (1955, p. 41) that in western Kansas distribution and position of detrital materials indicates northwest-flowing streams.

In northwestern Nebraska, where the lithofacies map shows an absence of strata belonging to Interval C, two interpretations are apparent. Either this area was a barrier to depositing agents and no sediments accumulated there, or, having originally been formed across the region, the sediments subsequently were removed. This map indicates the presence of mudstones, probably marine, to the southeast of the questionable area—a strong suggestion that the region of marine accumulation to the north was once continuous over this area.

Upper boundary of Interval C.—East of the Front Range of Colorado the boundary between rocks of Interval C and the overlying rocks of Interval D, as recognized in this investigation, is a key stratigraphic horizon. This horizon has long been used by petroleum geologists, but has not been referred to in print until recently. It is located at the top of one or more very thin beds of chalcedony that are believed to be restricted to a constant stratigraphic position over an extensive area. The chalcedony is red or white in most places, but locally is of other colors.

Significance of chalcedony bed.—Usefulness of the chalcedony as a time indicator was suggested when its persistent occurrence at the top of, or immediately above, anhydrite deposits was noted in many well-sample logs in eastern Colorado. The stratigraphic value of the chalcedony has been corroborated by independent studies of Ogden (1954, p. 914) and of Merriam (1955, p. 38). Whether the beds represent the top of Interval C or the base of Interval D is uncertain, but in this work they are assigned to the older interval. The basal part of the Morrison formation, which consists of lenticular sandstone in some places, but elsewhere mudstone, is recognized as resting on chalcedony throughout most of the region.

Evidence concerning the age of the chalcedony beds is meager. The only fossils found in them are some well-preserved charophytes reported by Peck (G. R. Scott, written communication) to be closely related to the European species *Clavator pecki* of Kimmeridgian age, and some undiagnostic fresh-water gastropods, all from the vicinity of Kassler, Colo. Stratigraphic evidence, on the other hand, suggests an earlier age for the chalcedony. It has been recognized in the type section of the Sundance formation (Interval C) in the Laramie basin (Pipiringos, 1953, p. 38) and in the upper part of the Redwater shale member, Sundance formation, in the northern part of Colorado and in the Nebraska Panhandle. Moreover, in western Kansas the chalcedony appears to be more closely related to the anhydrite than to overlying detrital beds of the Morrison (Merriam, 1955, p. 32). For these reasons, the chalcedony beds are considered uppermost deposits of Interval C in this folio.

The chalcedony beds extend from northwestern Nebraska through western Kansas and eastern Colorado, southward into westernmost Oklahoma, northern Texas Panhandle, and northeastern New Mexico. They may extend as far south in New Mexico as Tucumcari (Quay County), for siliceous deposits near the base of the Morrison formation that are described from that area (Dobrovolny and Summerson, 1946), are possibly correlative. In a few localities, the chalcedony beds are absent, making difficult the recognition of a boundary between Intervals C and D. Also, locally, problems involving the distinction between bedded chalcedony of Interval C and detrital fragments of chalcedony in conglomeratic beds of the overlying Morrison have been encountered in well samples.

Wide lateral distribution and limited stratigraphic range of the chalcedony beds, as suggested by Ogden (1954, p. 916), may be the result of volcanic ash deposition. The volcanic origin of these beds has not yet been established through petrographic study, but some support for the idea is furnished by the presence of embayed quartz crystals. Moreover, montmorillonite and tuffaceous material in the Morrison formation of eastern Colorado (Keller, 1953, p. 103; Mook, 1916, p. 124) have been attributed to volcanoes, and these may well have been active as early as the time when the chalcedony beds were formed.

SOUTHWEST REGION

Formations included.—Strata of Interval C in northern New Mexico are referred to as the Wanakah formation in the northeastern part, the Todilto limestone in the central area, and the Todilto and Summerville formations in the west. In the southwestern and northwestern parts of the New Mexico area, the Cow Springs sandstone and the Bluff sandstone, respectively, intertongue with the Summerville formation. In northern Arizona, the Cow Springs sandstone is the principal unit that has been recognized, except in the extreme northeastern corner where the Summerville is overlain by the Bluff sandstone.

Thickness trends.—The region occupied by deposits of Interval C is more restricted than that of either the underlying or overlying intervals (pl. 6). In the southeast near Tucumcari (Quay County), N. Mex., strata of this time interval have not been distinguished (Dobrovolny and Summerson, 1946) but may be present. At the other geographic extreme, in the western and southern parts of the Navajo Reservation, Ariz., these units are absent from Jurassic sections. Between the two areas, strata of Interval C are relatively thin, attaining a maximum thickness of slightly more than 300 feet along the Arizona-Utah boundary and in northwestern New Mexico near the Colorado boundary. These places of maximum thickness reflect an approach toward the axis or center of the trough of deposition in Utah.

Lithofacies trends.—Areas of extensive evaporite deposits (Todilto, Wanakah) that were formed early in Interval C are indicated on the lithofacies map (pl. 6). Both gypsum and limestone deposits are shown across the central and western parts of northern New Mexico, but, unfortunately, extension of the limestone unit westward to the Arizona boundary is not apparent. In that area, the limestone (Todilto) is overlain by such a thickness of detrital sedimentary rocks (Summerville formation and Cow Springs sandstone)—making the limestone proportionately so small a part of the total section—that it is obscured on the map.

Significance of evaporite deposits.—Whether the evaporite basin in northeastern New Mexico and eastern Colorado was once connected to the south with the basin that extends westward across New Mexico, is not known. No data are available from the critical area north of Santa Fe, part of which has not been penetrated and part of which contains only pre-Jurassic rocks. The area of gypsum accumulation is much more limited than that of limestone in western and central New Mexico and, as should be expected in a nearly landlocked basin, is concentrated near the central part.

The location of the connection or connections between waters of the New Mexico evaporite basin and marine waters that must have been continually replenishing them is not easy to determine. Harshbarger and others (in press) suggest that a strait or channel may have joined the evaporite basin with that of the Curtis sea in northeastern Arizona. A second possible connection is between the evaporite basin of New Mexico and the similar basins of western Colorado, which in turn may have been connected with the Curtis sea farther west. A third possible connection is northeastward from the present San Juan basin area to the large evaporite basin of eastern Colorado which apparently had, at its northern end, connections with the "upper Sundance" sea (pl. 6).

Detrital rocks of Interval C show a transition eastward from all sandstone in Arizona to a belt containing mostly sandstone but 20 to 50 percent mudstone (western and southern parts of the San Juan basin, New Mexico), and farther east to a belt of over 50 percent mudstone (eastern and southeastern parts of the San Juan basin). This change in facies probably is best explained as the result of extensive sand deposits, considered to be eolian, being introduced from the southwest to form the Cow Springs and Bluff sandstones, which intertongue to the east and northeast with water-laid deposits of the Summerville formation. Deposits of the Summerville formation, formed largely of silts in the lower part and sandy above, appear to have been derived from the southwest but they cover a surface that drained toward a marine basin (Curtis formation) in Utah to the northwest. The upward increase in sand probably indicates the effect of a progressive northwestward filling of the basin under regressive conditions.

Upper boundary of Interval C.—The contact between the Morrison and Summerville formations is considered to be the upper boundary of rocks of Interval C throughout much of northwestern New Mexico and northeastern Arizona. Where Interval C is represented by the Cow Springs sandstone instead of the Summerville, however, in the southern and southwestern parts of the Navajo Reservation, Ariz., the boundary problem is serious because the Cow Springs is equivalent to both the Summerville (in part) and the Morrison formations. In such areas, the assignment of strata to either interval for the purpose of preparing isopach and lithofacies maps is done by projecting the boundary from areas where it is established and assigning the appropriate proportions of the formation to each interval.

In the central and eastern parts of northern New Mexico, there is considerable question whether the Summerville formation (Interval C) is represented by some of the detrital rocks currently assigned to the Morrison formation. On the east side of the San Juan basin (Rio Arriba County), for instance, the Summerville deposits are recognized in subsurface records although the formation is moderately thick on the opposite side of the basin. Further south in the Laguna-Lucero area, the Summerville may have correlative units in the "buff shale and brown buff sandstone members of the Morrison formation" described by Kelley and Wood (1946). In Quay County of eastern New Mexico, it may be represented by the deposits immediately below the chalcedonic beds in the Morrison (Dobrovolny and Summerson, 1946) as suggested by stratigraphic relationships in eastern Colorado to the north.

UTAH AND WESTERN COLORADO

Formations included.—In northwestern Colorado the Curtis formation represents Interval C. Locally in west-central Colorado, the Wanakah formation, with the Pony Express and Bilk Creek members, is recognized and in this folio is assigned to Interval C. In southwestern Colorado, Interval C is composed of a basal limestone unit, a middle shale unit, and an upper sandstone unit. These units are variously described as the (1) Wanakah formation (Read et al., 1949), (2) Wanakah formation and Junction Creek sandstone (Craig, written communication), (3) Wanakah formation and "white sandstone member of the Morrison formation" (Wood et al., 1948). The name Pony Express is used by most geologists for the basal limestone unit, and it corresponds to the Todilto limestone of New Mexico.

In southwestern Colorado and southeastern Utah, the Moab sandstone member of the Entrada sandstone, Summerville formation, and Bluff sandstone are assigned to Interval C. Westward, in south-central and southwestern Utah, the Summerville formation and Winsor formation represent Interval C (see discussion above on the upper boundary of Interval B, Utah and western Colorado). In central Utah the Curtis and Summerville formations and, to the north, the Curtis formation alone, represent the interval. In north-central Utah the upper part of the Twist Gulch member of the Arapien shale is assigned to Interval C.

Thickness trends.—The thickness trends of Interval C resemble those of Interval B (cf. pls. 5 and 6) with a relatively thick trough in central Utah and a thin sheet of sediments extending eastward into Colorado. A belt of thick deposits trends eastward from south-central Utah to south-central Colorado, marking the area in which eolian sands of the Cow Springs, Bluff, and Junction Creek sandstones accumulated.

Lithofacies trends.—Sandstones are dominant in southern Utah and southwestern Colorado and grade northward into finer grained detrital rocks in northwestern Colorado and central Utah. Another area of dominant sandstone in northern Utah is shown by the few control points there, but its trends are not well established. Evaporites are sufficiently thick in central Colorado and northeastern Utah, to be evident in the lithofacies patterns. Elsewhere, rocks of Interval C include evaporites, but their presence is masked on lithofacies maps by thicker detrital rocks. In north-central Colorado a belt of normal marine oölitic limestone marks the former extent of marine waters, which may have connected with the evaporite basin to the southwest.

Upper boundary of Interval C.—The base of the Morrison formation is used as the upper limit of Interval C. In southwestern Utah the Morrison formation does not extend as far west as do rocks of Interval C, therefore, Cretaceous rocks rest on rocks of Interval C. The upper boundary of Interval C is placed at the top of the Winsor formation.

In north-central Colorado the Morrison formation seems to be conformable with the underlying Curtis formation. Both the basal Morrison and the Curtis formation contain interbedded limestone and sandstone units. The position of the contact between Morrison and Curtis formations and, consequently, of the upper boundary of Interval C, is dependent upon recognition of marine limestones or glauconitic sandstones which are assigned to the Curtis formation (Baker et al., 1936, p. 19).

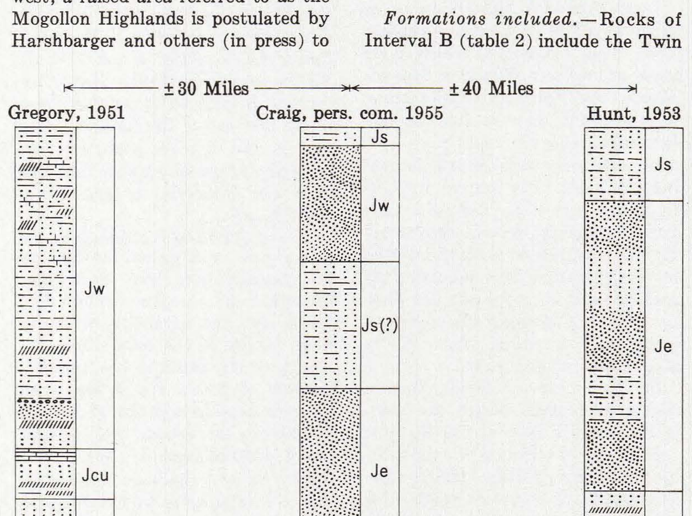


FIGURE 2.—SECTIONS IN SOUTH-CENTRAL UTAH AS ORIGINALLY DESCRIBED

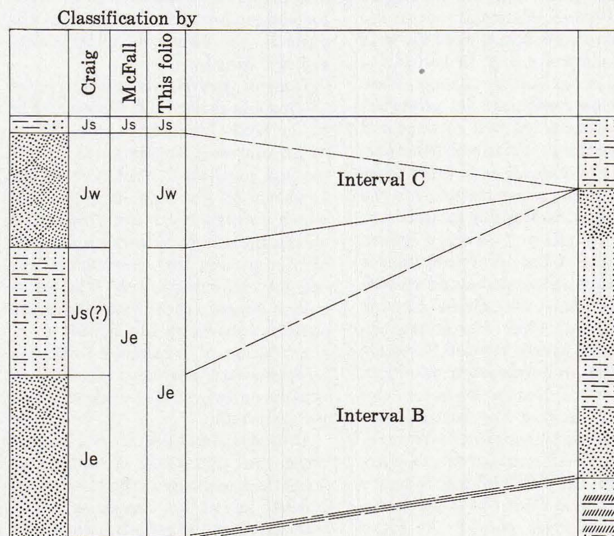


FIGURE 3.—CORRELATIONS BETWEEN PINE CREEK AND HALL'S CREEK

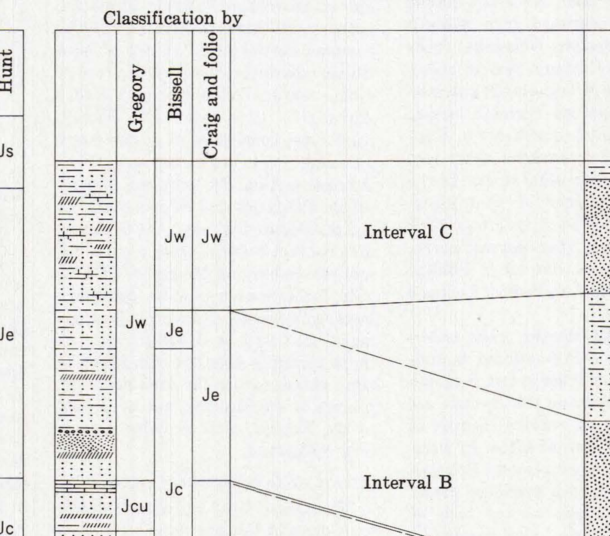


FIGURE 4.—CORRELATIONS BETWEEN PINE CREEK AND CANNONVILLE

much since Mook's (1916) comprehensive study.

Extensive collections of the fauna and flora of the Morrison formation have been made, largely in the early days, on the east flank of the Front Range, but until the past decade or so, interest in these fossils was almost exclusively biological and study of them contributed little towards clarification of detailed stratigraphic relations.

Thickness and lithofacies trends.—The Morrison formation ranges from 200 to 400 feet in thickness on the east flank of the Front Range and thins irregularly toward the east. In the subsurface of a small area in northwestern Nebraska, the formation is absent. Trends in thickness over most of the region are not uniform. These irregularities are explained by post-Morrison erosion as demonstrated in Oklahoma by an angular unconformity that truncates successive units in the upper part of the Morrison formation within a relatively short distance (Schoff and Stovall, 1943, p. 63-65).

Alignment of areas of maximum and minimum thickness in the Morrison formation is similar on both sides of the Front Range in Colorado. These belts of varying thickness trend northwest (pl. 7), strongly suggesting that they were continuous across this area in Jurassic time. They also coincide with trends evident on the lithofacies map (pl. 7). In the northwest-trending belts of thinning, the formation is sandier than in corresponding thicker belts. The significance of this pattern is not understood.

A second trend that is apparent on the lithofacies map of Interval D is the notable increase in percentage of sand southeastward toward the pinchout of the formation in southwestern Kansas and southeastern Colorado. This suggests a source of sediment to the southeast.

Localities of considerable coarse detrital sediment in northwestern Nebraska appear to be related to an adjoining area to the north and east in which the Morrison is absent and from where sediments presumably were furnished by a pre-Morrison source. Local areas of relatively abundant sandstone in northeastern Colorado, however, cannot readily be explained; and the haphazard distribution of limestone and marlstone east of the Front Range shows no readily apparent relationship to other features of sedimentation.

Upper boundary of Interval D.—In this folio the top of Interval D and of the Jurassic system is assumed, in the absence of conclusive evidence to the contrary (Waagé, 1955, p. 47-48), to coincide with the boundary between the Morrison formation and the Lytle formation of the Dakota group. This formational boundary, however, is an elusive one, difficult to recognize consistently. The difficulty arises because conglomeratic beds are not present everywhere at the base of the Lytle and because the formations contain similar, dominantly red, variegated silty claystones and lenticular sandstones (Waagé, 1955, p. 21, 23).

Difficulty in recognition of the upper contact of the Morrison formation is perhaps best illustrated by differences of opinion about its position in the type area.

As originally defined by Eldridge (1896, p. 60-61), the Morrison formation is about 200 feet thick and consists in the lower two-thirds of green, drab or gray marls with numerous lenses of limestone. The upper third, however, consists of shales "similar to those . . . of the Jura" [variegated] and sandstones, with either prevailing locally. At the base of the upper third are discontinuous lenses of sandstone, the Saurian sandstone of Eldridge, which locally are conglomeratic and resemble the basal Dakota (Lytle) sandstone in pebble content. The Saurian sandstone, according to Eldridge, is between 16 to 125 feet below the Dakota, although more generally from 50 to 80 feet. Unfortunately, no specific type section was designated or measured by Eldridge.

Eldridge's definition apparently was misinterpreted by Lee (1920, p. 185). Lee believed that Eldridge had included higher beds, which at Morrison, were later found to contain Early Cretaceous plants. He, therefore, revised Eldridge's section and placed the contact at the base of the Saurian conglomerate (1920, p. 184-185; 1927, p. 17, 28, pl. 1) because "No obvious break was found in the section between the plant horizon and the base of the Saurian conglomerate."

In recommending a new type section for the Morrison formation along the Alameda Parkway, Waldschmidt and LeRoy (1944, p. 1100) recognize Lee's misinterpretation and attribute it, in part, to poor exposures at the old type locality. They state that the upper lithic boundary is distinct along Alameda Parkway and "lies with apparent disconformity below the conglomeratic phase of the Dakota." With their choice of the upper contact, the Morrison as measured (1944, p. 1103-1106) is 277 feet thick. The Saurian sandstone of Eldridge (1896, p. 61) presumably is absent, but the upper, dominantly red variegated claystones and lenticular sandstones are 113 feet thick.

Waagé (1955, p. 23-26) reviews the problem of the Morrison-Lytle contact and concludes that both the old and the new type sections of the Morrison have indefinite upper contacts. He points out that whereas Lee places the Morrison-Dakota contact at the base of the Saurian sandstone in the Morrison section (1920, p. 185), he places the contact at the base of the Lytle sandstone, 98 feet stratigraphically higher, in the Turkey Creek section (Lee, 1927, p. 28), 1.8 miles to the south.

Of the revised type section Waagé states (1955, p. 25) that none of the sandstone lenses contains pebbles of chert and quartzite. Waldschmidt and LeRoy's (1944, p. 1100) upper Morrison contact is, according to Waagé, the base of the uppermost sandstone lens in the Lytle formation. Waagé's top of the Morrison is stated (1955, p. 25) to lie between 35 and 55 feet below Waldschmidt and LeRoy's top (1944, p. 1102), and is shown (1955, p. 21) as 45 feet below. The upper, dominantly red variegated claystones [illegible]

contain interstitial clay commonly peppered with ferruginous specks (Waagé, 1955, p. 23).

The boundary, as generally recognized by stratigraphers studying subsurface rocks east of the Colorado Front Range, is placed at the base of thick conglomeratic sandstones assigned to the Dakota group. In many wells the sandstones contain a few thin beds of variegated mudstone. Where the sandstones are thin or absent, the boundary is placed at the base of a dark-gray mudstone that overlies the uppermost variegated mudstone.

Difficulty in recognizing the Morrison-Dakota boundary in some subsurface sections is responsible for certain local problems. In eastern Colorado, it probably accounts for local anomalies on the isopach and lithofacies map (pl. 7). In north-central Kansas (Phillips County) and northward through the center of Nebraska, it makes uncertain the recognition of eastern limits of the Morrison formation. In that area, well samples from the questionable part of the section consist of interbedded sandstone, conglomerate, and mudstone, which have been interpreted by some (Merriam, 1955, p. 37) as Morrison deposits that are abnormally coarse because of proximity to source, and by others as normal continental deposits at the base of the Dakota group. Thus, the position of the eastern margin of the Morrison formation is queried on plate 7 and is regarded as tentative.

SOUTHWEST REGION

Formations included.—The 0-isopach line for rocks of Interval D in Arizona and New Mexico (pl. 7) marks the present southern and southwestern limits of the Morrison formation and its correlative—the Cow Springs sandstone (in part). As shown on the map, however, the original area of deposition during this interval probably extended considerably to the south and southwest of the zero isopach line, sediments having been removed from the bordering areas by pre-Dakota erosion. The line suggesting the former limit of deposition is believed to be conservative and possibly should be considerably south of the position indicated.

Thickness trends.—As illustrated on the isopach map (pl. 7), thicknesses of the Morrison formation across the eastern half of northern New Mexico are rather uniformly between 300 and 400 feet, but starting near the center (west of Santa Fe) and striking northwestward is an axis along which the deposits are thickest. In the northwest corner of the State a maximum thickness of nearly 1,000 feet is encountered. Southwestward from this axis, across the Navajo Indian Reservation in Arizona, the thickness diminishes to a feather edge in a relatively short distance. The northwest trend of the axis is approximately parallel to, but farther east than, that of the underlying Summerville formation, suggesting a continued eastward migration of the center of basin downwarping that prevailed during earlier Jurassic time. Marine waters did not fill any part of this trough during Interval D as they had earlier.

Lithofacies trends.—A series of lithofacies belts trending northwestward constitutes the general pattern for Interval D in northern Arizona and New Mexico. In the southwestern part of the area, strata of this age (Cow Springs) consist of sandstone only, but to the northeast in New Mexico a minor amount of mudstone is present in all sections (Morrison). Sandstone of the Morrison formation in this area includes appreciable amounts of conglomerate. Farther east this belt grades into another in which the percentage of mudstone is greater than that of sandstone; and beyond, in eastern New Mexico sections in some localities are composed almost entirely of mudstone. One notable exception to the eastward trend from sandstone to mudstone is in north-central New Mexico near the Colorado border where the Morrison consists almost entirely of sandstone. In a belt extending southward from this area sandstone dominates over mudstone.

Interpretation of the lithofacies trends described above involves the following concepts: (1) a principal source of sand was from the southwest, the sand being introduced under eolian conditions (Harshbarger, et al., in press); (2) muds, sands, and some gravels were transported northward or northwestward across western New Mexico by streams forming alluvial plain and fan deposits (Craig et al., 1951, p. 43); (3) a source of sediments was the ancient Uncompahgre-San Luis Highlands of southern Colorado as indicated by the belt of sand extending southward midway across northern New Mexico; (4) an area or areas of ponding and quiet water developed in northeastern New Mexico where the formation is composed largely of mud; (5) a minor source of sediments was to the east and southeast of the present area of Morrison deposits as indicated by a local increase in sand in these directions along the border areas.

Evidence that source areas to the south were uplifted during Morrison deposition is furnished by conglomeratic sandstones and stringers of pebble conglomerate in all members of this formation in western New Mexico. Pebbles as much as 4 inches in diameter are present in the Westwater Canyon member and granitic fragments are reported from the Recapture member. The source of these materials, which probably was in west-central New Mexico, has been referred to as the Mogollon Highlands by Harshbarger and others (in press). Most likely the uplift was the beginning of major crustal disturbances, the record of which is prominent in southern Arizona beneath deposits of Early Cretaceous age (McKee, 1951, p. 495). That movement continued or was renewed in very late Jurassic or Early Cretaceous time is suggested by the progressively greater southward truncation and beveling of Morrison and Cow Springs deposits accomplished prior to Dakota deposition. Probably these movements were related to the major disturbances farther west that are ascribed to the Nevadan [illegible]

Early Cretaceous age overlies the Morrison, but lithologic contrasts make the contact relatively easy to find.

UTAH AND WESTERN COLORADO

Formation included.—In Utah and western Colorado Interval D consists of the Morrison formation. In north-central Utah the interval may possibly be represented by conglomerate beds now assigned to the Indianola group or Kelvin formation of Cretaceous age. These beds are not included in Interval D in this folio.

Thickness trends.—The prominent thick troughs in central Utah evident on maps of Intervals B and C, did not continue into Interval D. Instead, the sediments of the Morrison formation are spread across the area as irregularly thick and thin deposits. In southeastern Utah a thick sheet of the Morrison formation probably represents the original, or nearly complete, accumulation for the interval. The rather abrupt thinning to the west probably is the result of pre-Cretaceous erosion.

In north-central Utah rocks of this interval are shown on plate 7 as 2,000 feet thick, but they are absent within a relatively short distance northwestward. As indicated by broken lines on the cross section *A-A'*, the very thick section may contain beds of Early Cretaceous age. Where Interval D is not represented in north-central Utah, lower beds of the conglomeratic sequence assigned to the Indianola group and Kelvin formation may be equivalent to the Morrison formation. If so, the Morrison formation would increase in thickness, gradually, from east to west in northern Utah and would become more coarse to the west. A source area might then be postulated for the Morrison formation in northwestern Utah.

Lithofacies trends.—Rocks of Interval D are dominantly sandstone in southern and in north-central Utah. These two areas of coarser sediment are probably a result of proximity to source, but in western Utah, the original limit of deposition of Interval D is not known. Elsewhere in Utah and western Colorado finer grained sediments of this interval are randomly distributed as patches of mudstone or sandy mudstone with minor accumulations of evaporites, three of which are shown by lithofacies patterns on plate 7.

Upper boundary of Interval D.—The contact between the Morrison formation and Cretaceous strata is the upper boundary of the Interval. In west-central Colorado and in central Utah Lower Cretaceous strata of the *Buckhorn* and Cedar Mountain formations have been differentiated from the Morrison formation in recent measured sections (Stokes, 1952, p. 1768). Some older sections were revised by Craig (personal communication) to conform to this usage (localities 47, 81, and 191); consequently, the upper boundary of the interval is lower than originally indicated in some published sections.

In north-central Utah, as noted above, basal beds of the Indianola group may be correlative with the Morrison formation, in which case the upper boundary of the interval is incorrectly placed. In this folio, original assignments to the Morrison formation have been followed.

SOUTH DAKOTA, WYOMING, AND SOUTHEASTERN IDAHO

Formations included.—Interval D is represented in South Dakota by the Morrison formation and, in places, the Unkpapa sandstone. Throughout most of Wyoming, also, the interval consists of the Morrison formation. Only in the westernmost part of that state is the Morrison absent. There, and in southeastern Idaho, Interval D probably is represented by the lower part of the Ephraim conglomerate.

The age of the Ephraim conglomerate has long been open to question. Although provisionally assigned to the Early Cretaceous in many reports (e.g., Mansfield, 1927, p. 104) and lacking diagnostic fossils, regional considerations suggest a Late Jurassic age for at least part of this formation (Stokes, 1944, p. 969; Mansfield, 1952, p. 42). A few Jurassic fossils have been found in the lower part of the formation, but the possibility that these may have come from reworked older deposits has not been eliminated (Rubey, oral communication).

Thickness and lithofacies trends.—Isopach lines in South Dakota and the northern half of Wyoming trend slightly west of north. Noteworthy are belts of thickening on the east side of the Black Hills, S. Dak., the east flank of the Big Horn Range, Wyo., and the northwestern part of Wyoming. Moreover, the small north-trending belt of thinning south of the Black Hills and the thinning to the northwest of the Black Hills both parallel the thickening to the east. This belt of thinning, therefore, may have been continuous across the present western margin of the Black Hills.

In southern Wyoming, isopach lines are oriented more irregularly than elsewhere in the state, but nearly easterly trends are prominent locally.

Belts of comparable lithofacies are roughly parallel to isopach trends in South Dakota and northeastern Wyoming. The abundance of coarse detrital rocks on the southeastern side of the Black Hills, along the belt of thickening, is noteworthy and suggests local depositional sources. Possibly these sources were along the western margin of the present Black Hills and also in an area to the south where Morrison rocks are absent.

Lithofacies trends in Morrison strata of southwestern Wyoming are oriented approximately northeast-southwest. Sandstones are more abundant in the section than farther east.

An increase in thickness and in abundance of coarse detrital rocks in the Morrison, from east to west across Wyoming, supports the suggestion that it may be correlated with the lower part of the Ephraim conglomerate. Whatever the age of the Ephraim, however, the source of coarse detrital sediments in the Morrison was relatively nearby to the west.

Upper boundary of Interval D.—Because the age of the Ephraim con- [illegible]

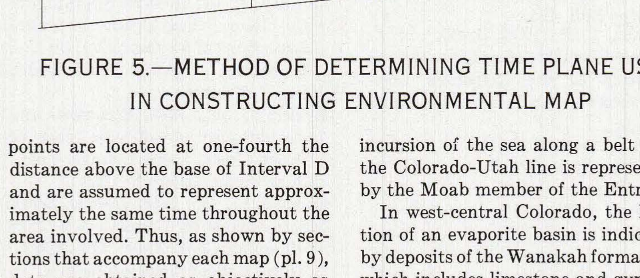


FIGURE 5.—METHOD OF DETERMINING TIME PLANE USED IN CONSTRUCTING ENVIRONMENTAL MAP

REFERENCES CITED

Albritton, C. C., Jr., 1938, Stratigraphy and structure of the Malone Mountains, Tex.: Geol. Soc. America Bull., v. 49, p. 1747-1806.

Anderson, A. L., 1930, The geology and mineral resources of the region about Orofino, Idaho: Idaho Bur. Mines and Geology Pamph. no. 34, 63 p.

Anderson, F. M., 1945, Knoxville series in the California Mesozoic: Geol. Soc. America Bull., v. 56, p. 909-1014.

Anderson, S. B., 1953a, Summary of the Hunt Oil Company Shoemaker No. 1 Well: North Dakota Geol. Survey Circ. 9.

Anderson, S. B., 1953b, Summary of H. L. Hunt Oil Company Oliver Olson No. 1: North Dakota Geol. Survey Circ. 8.

Anderson, S. B., 1953c, Summary of the Ajax Oil Company Bell No. 1 Well: North Dakota Geol. Survey Circ. 10.

Anderson, S. B., 1953d, Summary of the Barnett Gaier No. 1 Well: North Dakota Geol. Survey Circ. 11.

Anderson, S. B., 1953e, Summary of William Herbert Hunt Trust Estate Jo J. and Anna Wald No. 1: North Dakota Geol. Survey Circ. 12.

Anderson, S. B., 1953f, Summary of the Fritz F. Leutz No. 1 Well: North Dakota Geol. Survey Circ. 13.

Anderson, S. B., 1953g, Summary of the Wamste Oil Company, M. O. Lee and Silas Engen No. 1: North Dakota Geol. Survey Circ. 14.

Anderson, S. B., 1953h, Summary of the Alvin Pojilinski No. 1 Well: North Dakota Geol. Survey Circ. 15.

Anderson, S. B., 1953i, Summary of the Henry O. Bakken No. 1: North Dakota Geol. Survey Circ. 16.

Anderson, S. B., 1953j, Summary of the Benhamer Rieser No. 1 Well: North Dakota Geol. Survey Circ. 17.

Anderson, S. B., 1953k, Summary of the McLean County No. 1 Well: North Dakota Geol. Survey Circ. 18.

Anderson, S. B., 1953l, Summary of the General Atlas Carbon Company, Albert Ketterling No. 1: North Dakota Geol. Survey Circ. 19.

Anderson, S. B., 1953m, Summary of the Continental Oil Company No. 1 John Lueth: North Dakota Geol. Survey Circ. 20.

Anderson, S. B., 1953n, Summary of the Elmer Holm No. 1 Well: North Dakota Geol. Survey Circ. 21.

Anderson, S. B., 1953o, Summary of the S. D. Johnson-John Roth No. 1: North Dakota Geol. Survey Circ. 29.

Andrews, Philip, 1936, Geology of the Pinnacles National Monument: California Univ., Dept. Geol. Sci., Bull., v. 24, p. 1-38.

Applin, P. L., 1951, Preliminary report on buried pre-Mesozoic rocks in Florida and adjacent States: U.S. Geol. Survey Circ. 91, 28 p.

Applin, P. L., and Applin, E. R., 1953, The cored section in George Vasen's fee well 1, Stone County, Miss.: U.S. Geol. Survey Circ. 298, 29 p.

Arnold, Ralph, and Anderson, Robert, 1910, Geology and oil resources of the Coalinga district, California: U.S. Geol. Survey Bull. 398, 354 p.

Bachman, G. O., 1953, Geology of a part of northwestern Mora County, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Map 137.

Baker, A. A., 1933, Geology and oil possibilities of the Moab district, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 841, 95 p.

Baker, A. A., 1936, Geology of Monument Valley-Navajo Mountain region, San Juan County, Utah: U. S. Geol. Survey Bull. 865, 106 p.

Baker, A. A., 1946, Geology of the Green River Desert-Cataract Canyon region, Emery, Wayne, and Garfield Counties, Utah: U. S. Geol. Survey Bull. 951, 122 p.

Baker, A. A., 1947, Stratigraphy of the Wasatch Mountains in the vicinity of Provo, Utah: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 30.

Baker, A. A., Dane, C. H., and Reeside, J. B., Jr., 1936, Correlation of the Jurassic formations of parts of Utah, Arizona, New Mexico, and Colorado: U. S. Geol. Survey Prof. Paper 183, 66 p.

Baker, C. L., 1947, Deep borings of western South Dakota: South Dakota Geol. Survey Rept. Inv. 57.

Baker, C. L., 1948, The Pennington-Haakon County central boundary area with general discussion of its surroundings: South Dakota Geol. Survey Rept. Inv. 64.

Baker, C. L., 1951, Well borings in South Dakota, 1948-50: South Dakota Geol. Survey Rept. Inv. 67.

Barlow, J. A., 1950, Geology of the Rawlins uplift, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Bass, N. W., 1946, Subsurface maps of the Rangely anticline, Rio Blanco County, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 67.

Bass, N. W., Straub, C. E., and Woodbury, H. O., 1947, Structure contour map of the surface rocks of the Model anticline, Las Animas County, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 68.

Bauer, E. J., 1952, Geologic map and structure sections of the Wagonhound Creek area, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Bergstrom, J. R., 1950, Geology of the east portion of the Casper Mountain and vicinity: Unpubl. M.A. thesis, Univ. Wyoming.

Bissell, H. J., 1952, Stratigraphy and structure of northeast Strawberry Valley quadrangle, Utah: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 575-634.

Bissell, H. J., 1954, The Kaiparowits region, *in* Intermountain Assoc. of Petroleum Geologists Guidebook, Fifth annual field conference, p. 63-70.

Blair, R. W., 1951, Subsurface geologic cross sections of Mesozoic rocks in northeastern Colorado: U. S. Geol. Survey Oil and Gas Inv. Chart 42.

Blanpied, B. W., and Hazzard, R. T., 1944a, Development in north Louisiana and south Arkansas in 1942: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 257-277.

Blanpied, B. W., and Hazzard, R. T., 1944b, Field and wildcat developments in south Arkansas in 1942: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 326-332.

Blanpied, B. W., and Hazzard, R. T., 1944c, Interesting wildcat wells drilled in north Louisiana in 1942: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 554-561.

Blixt, J. E., 1933, Geology and gold deposits of the North Moccasin Mountains, Fergus County, Mont.: Montana Bur. Mines and Geology Mem. 8.

Brainerd, A. E., Carter, S. L., and Curtis, B. F., 1947, Frannie oil field, Park County, Wyo., *in* Wyoming Geol. Assoc. Guidebook, Field conference in the Bighorn basin, p. 241-246.

Branner, J. C., Newsom, J. F., and Arnold, R., 1909, Description of the Santa Cruz quadrangle, Calif.: U. S. Geol. Survey Geol. Atlas, folio 163.

Brice, J. C., 1953, Geology of the Lower Lake quadrangle, Calif.: California Div. Mines Bull. 166, 72 p.

Burbank, W. S., 1940, Structural control of ore deposition in the Uncompahgre district, Ouray County, Colo.: U. S. Geol. Survey Bull. 906-E, p. 189-265.

Burk, C. A., 1953, Electric log correlation of the Triassic rocks of southeastern Wyoming, *in* Wyoming Geol. Assoc. and Univ. Wyoming Guidebook, Eighth annual field conference, p. 29-33.

Caldwell, J. W., 1953a, Summary of the Continental-Pure Oil Co. Paul H. McCay No. 1: North Dakota Geol. Survey Circ. 21.

Caldwell, J. W., 1953b, Summary of the F. L. Bailey No. 1 Well: North Dakota Geol. Survey Circ. 22.

Caldwell, J. W., 1953c, Summary of the Peter Lenertz No. 1 Well: North Dakota Geol. Survey Circ. 24.

Caldwell, J. W., 1953d, Summary of the Emma Kleven No. 1 Well: North Dakota Geol. Survey Circ. 33.

Callahan, J. T., 1951a, Geology of the Glen Canyon Group: Plateau, v. 23, p. 49-57.

Callahan, J. T., 1951b, The geology of the Glen Canyon group of the Echo Cliffs region, Ariz.: Unpubl. M.S. thesis, Univ. Arizona, 91 p.

Camp, C. L., 1942, Ichthyosaur rostra from central California: Jour. Paleontology, v. 16, p. 362-371.

Carlson, C. E., 1949, Areal geology and stratigraphy of the Red Fork-Powder River area, Johnson County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Carpenter, C. B., and Schroeder, H. J., 1943, Magnolia oil field, Columbia County, Ark. Part 1. Petroleum engineering study: U. S. Bur. Mines Rept. Inv. 3720.

Cater, F. W., Jr., and Wells, F. G., 1953, Geology and mineral resources of the Gasquet quadrangle, California-Oregon: U. S. Geol. Survey Bull. 995-C, p. 79-133.

Chapman, R. T., 1951, Haynesville field, Claiborne Parish, La., *in* Reference report on certain oil and gas fields of north Louisiana, south Arkansas, Mississippi, and Alabama, v. 3, no. 1, p. 18-28: Shreveport, La., Shreveport Geol. Soc.

Clark, S. G., 1930, The Milton formation of the Sierra Nevada of California: Ph.D. thesis, California Univ. [Berkeley], 206 p.

Clements, T. D., 1950, Some formations exposed in the Cuyama Gorge, Branch Mountain quadrangle, Calif. [abstract]: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 2378.

Cobban, W. A., 1945, Marine Jurassic formations of Sweetgrass Arch, Mont.: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1262-1303.

Condra, G. E., Reed, E. C., and Scherer, O. J., 1950, Correlation of the formations of the Laramie Range, Hartville uplift, Black Hills, and western Nebraska: Nebraska Geol. Survey Bull., 13A.

Cook, E. F., 1954, Mining geology of the Seven Devils region: Idaho Bur. Mines and Geology Pamph. no. 97, 22 p.

Cook, E. F., 1954(?), Geology of Pine Valley Mountains, Utah: Washington Univ. [Seattle] thesis.

Cooper, H. T., 1951, Geology of the Western Seminoe Mountains: Unpubl. M.A. thesis, Univ. Wyoming.

Craig, L. C., Holmes, C. N., Cadigan, R. A., Freeman, V. L., Mullens, T. E., and Weir, G. W., 1951, Preliminary report on the stratigraphy of the Morrison and related formations of the Colorado Plateau region: U. S. Geol. Survey Trace Elements Inv. Rept. 180.

Crickmay, C. H., 1930a, The Jurassic rocks of Ashcroft, British Columbia: California Univ., Dept. Geol. Sci., Bull., v. 19, p. 23-74.

Crickmay, C. H., 1930b, The structural connection between the Coast Range of British Columbia and the Cascade Range of Washington: Geol. Mag., v. 67, p. 482-491.

Crickmay, C. H., 1931, Jurassic history of North America, its bearing on the development of continental structure: Am. Philos. Soc. Proc., v. 70, no. 1, p. 15-102.

Crickmay, C. H., 1932, A new Jurassic ammonite from the Coast Ranges of California: Am. Midland Naturalist, v. 13, p. 1-11.

Crickmay, C. H., 1933, Mount Jura investigation: Geol. Soc. America Bull., v. 44, p. 895-926.

Crittenden, M. D., 1951, Geology of the San Jose-Mount Hamilton area: California Dept. Nat. Res., Div. Mines Bull. 157.

Crowell, J. C., 1952, Geology of the Lebec quadrangle, Calif.: California Dept. Nat. Res., Div. Mines Special Rept. 24.

Cushman, J. A., and Todd, Ruth, 1948, A foraminiferal fauna from the New Almedan district, California: Cushman Lab. Foram. Research Contr., v. 24, pt. 4, p. 90-98.

Dane, C. H., 1935, Geology of the Salt Valley anticline and adjacent areas, Grand County, Utah: U. S. Geol. Survey Bull. 863, 184 p.

Dane, C. H., 1948, Geologic map of part of eastern San Juan Basin, Rio Arriba County, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 78.

Darton, N. H., 1904, Comparison of the stratigraphy of the Black Hills, Bighorn Mountains, and Rocky Mountain front range: Geol. Soc. America Bull., v. 15, p. 379-448.

Darton, N. H., 1928, "Red beds" and associated formations in New Mexico: U. S. Geol. Survey Bull. 794, 356 p.

Dehlinger, Peter, 1952, Geology of the Southern Ridge basin, Los Angeles County, Calif.: California Dept. Nat. Res., Div. Mines Special Rept. 26.

Deiss, Charles, 1943, Stratigraphy and structure of southwest Saypo quadrangle, Mont.: Geol. Soc. America Bull., v. 54, p. 205-262.

Del Mauro, G. L., 1953, Geology of Miller Hill and Sage Creek area, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Dibblee, T. W., Jr., 1950, Geology of southwestern Santa Barbara County, Calif.: California Dept. Nat. Res., Div. Mines Bull. 150.

Diller, J. S., 1898, Roseburg folio, Oregon: U. S. Geol. Survey Geol. Atlas, folio 49.

Diller, J. S., 1901, Coos Bay folio, Oregon: U. S. Geol. Survey Geol. Atlas, folio 73.

Diller, J. S., 1903, Description of the Port Orford quadrangle (Oreg.): U. S. Geol. Survey Geol. Atlas, folio 89.

Diller, J. S., 1908, Geology of the Taylorsville region, California: U. S. Geol. Survey Bull. 353, 128 p.

Diller, J. S., and Kay, G. F., 1924, Description of the Riddle quadrangle: U. S. Geol. Survey Geol. Atlas, folio 218.

Dobrovolny, Ernest, and Summerson, C. H., 1946, Geology of northwestern Quay County, N. Mex.: Geologic map and stratigraphic sections of Mesozoic rocks: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 62.

Donner, H. F., 1949, Geology of the McCoy area, Eagle and Routt Counties, Colo.: Geol. Soc. America Bull., v. 60, p. 1215-1247.

Downs, G. R., 1947, Mesozoic stratigraphy of the Bighorn basin area, *in* Wyoming Geol. Assoc. Guidebook, Field conference in the Bighorn basin, p. 131-141.

Duce, J. T., 1924, Geology of parts of Las Animas, Otero, and Bent Counties: Colorado Geol. Survey Bull. 27, pt. 3, p. 73-102.

Dunbar, R. O., 1944, Como Bluff anticline, Albany and Carbon Counties, Wyo.: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 1196-1216.

Eardley, A. J., 1944, Geology of the north-central Wasatch Mountains, Utah: Geol. Soc. America Bull., v. 55, p. 819-894.

Eardley, A. J., 1951, Structural geology of North America: New York, Harper & Brothers, 624 p.

Eldridge, G. H., 1896, Mesozoic geology, *in* Emmons, S. F., Cross, Whitman, and Eldridge, G. H., Geology of the Denver basin in Colorado: U. S. Geol. Survey Mon. 27, p. 51-150.

English, W. A., 1926, Geology and oil resources of the Puente Hills region, southern California: U. S. Geol. Survey Bull. 768, 110 p.

Erdmann, C. E., 1948, [illegible] Lothian area, Liberty County, Mont.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 87.

Erwin, H. D., 1934, Geology and mineral resources of northeastern Madera County, Calif.: California Jour. Mines and Geology, v. 30, p. 7-78.

Everhart, D. L., 1950, Quicksilver deposits of the Cachuma district, Santa Barbara County, Calif.: California Jour. Mines and Geology, v. 46, p. 509-532.

Fairbanks, H. W., 1904, Description of the San Luis quadrangle, Calif.: U. S. Geol. Survey Geol. Atlas, folio 101.

Fenneman, N. M., 1905, Geology of the Boulder district, Colorado: U. S. Geol. Survey Bull. 265, 101 p.

Ferguson, H. G., and Muller, S. W., 1949, Structural geology of the Hawthorne and Tonopah quadrangles, Nev.: U. S. Geol. Survey Prof. Paper 216, 55 p.

Fidlar, M. M., 1949, Clay Basin gas field, Daggett County, Utah, *in* The oil and gas possibilities of Utah, by G. H. Hansen and M. M. Bell: Utah Geol. Mineralog. Survey, p. 261-267.

Fidlar, M. M., 1950, Church Buttes gas field, Sweetwater, and Uinta Counties, Wyoming, *in* Wyoming Geol. Assoc. Guidebook, Southwest Wyoming, p. 111-113.

Fiedler, W. M., 1944, Geology of the Jamesburg quadrangle, Monterey County, Calif.: California Jour. Mines and Geology, v. 40, p. 177-250.

Finlay, G. I., 1916, Description of the Colorado Springs quadrangle, Colo.: U. S. Geol. Survey Geol. Atlas, folio 203.

Finley, E. A., 1951, Geology of Dove Creek area, Dolores and Montezuma Counties, Colo.: U. S. Geol. Survey Oil and Gas Inv. Map OM 120.

Foster, H. L., 1947, Paleozoic and Mesozoic stratigraphy of northern Gros Ventre Mountains and Mt. Leidy highlands, Teton County, Wyo.: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 1537-1593.

Frebold, Hans, 1953, Correlation of the Jurassic formations of Canada: Geol. Soc. America Bull., v. 64, p. 1237-1238.

Fulkerson, D. H., 1951, Geology of a part of the west flank of the Bighorn Mountains north of Bigtrails, Washakie County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Gardner, L. S., 1944, Phosphate deposits of the Teton basin area, Idaho and Wyoming: U. S. Geol. Survey Bull. 944-A, p. 1-36.

Gardner, L. S., Hendricks, T. A., Hadley, H. D., and Rogers, C. P., Jr., 1945, Mesozoic and Paleozoic rocks in the mountains of south-central Montana: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 18.

Gardner, L. S., Hendricks, T. A., Hadley, H. D., and Rogers, C. P., Jr., 1946, Stratigraphic sections of upper Paleozoic and Mesozoic rocks in south-central Montana: Montana Bur. Mines and Geology Mem. 24.

Gealey, W. K., 1951, Geology of Healdsburg quadrangle, Calif.: California Dept. Nat. Res., Div. Mines Bull. 161.

Gianella, V. P., 1936, Geology of the Silver City district and the southern portion of the Comstock Lode, Nevada: Nevada Univ. Bull., v. 30, no. 9.

Gilluly, James, 1929, Geology and oil and gas prospects of part of the San Rafael swell, Utah: U. S. Geol. Survey Bull. 806-C, p. 69-130.

Gilluly, James, 1937, Geology and mineral resources of the Baker quadrangle, Oregon: U. S. Geol. Survey Bull. 879, 119 p.

Gilluly, James, and Reeside, J. B., Jr., 1928, Sedimentary rocks of the San Rafael swell and some adjacent areas in eastern Utah: U. S. Geol. Survey Prof. Paper 150-D, p. 61-110.

Glaessner, M. F., 1949, Foraminifera of Franciscan (California): Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1615-1617.

Goebel, L. A., 1950, Cairo field, Union County, Ark.: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 1954-1980.

Goldstein, A., Jr., and Reno, D. H., 1952, Petrography and metamorphism of sediments of Ouachita facies: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 2275-2290.

Gould, C. N., 1907, The geology and water resources of the eastern portion of the Panhandle of Texas: U. S. Geol. Survey Water Supply Paper 191, 70 p.

Granger, A. E., 1953, Stratigraphy of the Wasatch Range near Salt Lake City, Utah: U. S. Geol. Survey Circ. 296, 14 p.

Granger, A. E., and Sharp, B. J., 1952, Geology of the Wasatch Mountains east of Salt Lake City, *in* Utah Geol. Soc. Guidebook no. 8, Geology of the Central Wasatch Mountains, Utah, p. 1-37.

Gregory, H. E., 1938, The San Juan country, a geographic and geologic reconnaissance of southeastern Utah: U. S. Geol. Survey Prof. Paper 188, 123 p.

Gregory, H. E., 1950a, Geology of eastern Iron County, Utah: Utah Geol. Mineralog. Survey Bull. 37.

Gregory, H. E., 1950b, Geology and geography of the Zion Park region, Utah and Arizona: U. S. Geol. Survey Prof. Paper 220, 200 p.

Gregory, H. E., 1951, The geology and geography of the Paunsaugunt region, Utah: U. S. Geol. Survey Prof. Paper 226, 116 p.

Gregory, H. E., and Moore, R. C., 1931, The Kaiparowits region, a geographic and geologic reconnaissance of parts of Utah and Arizona: U. S. Geol. Survey Prof. Paper 164, 161 p.

Hadley, H. D., Gardner, L. S., and Rogers, C. P., Jr., 1945, Graphic sections of Mesozoic and Paleozoic rocks that underlie the basin areas in south-central Montana: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 15.

Halsey, J. H., 1953, Geology of parts of Bridgeport quadrangle, California, and Wellington quadrangle, Nevada: Ph.D. thesis, California Univ. [Berkeley].

Hansen, G. H., and Bell, M. M., 1949, The oil and gas possibilities of Utah: Utah Geol. Mineralog. Survey.

Hardy, C. T., and Zeller, H. D., 1953, Geology of the west-central part of the Gunnison Plateau, Utah: Geol. Soc. America Bull., v. 64, p. 1261-1278.

Harrison, E. P., 1949, Geology of the Hagan Coal Basin: Unpubl. M.S. thesis, Univ. New Mexico.

Harshbarger, J. W., 1949, Petrology and stratigraphy of Upper Jurassic rocks of central Navajo Reservation, Arizona: Unpubl. Ph.D. dissertation, Univ. Arizona.

Harshbarger, J. W., Repenning, C. A., and Irwin, J. H., in press, Jurassic stratigraphy of the Navajo country: U. S. Geol. Survey Prof. Paper.

Harshbarger, J. W., Repenning, C. A., and Jackson, R. L., 1951, Jurassic stratigraphy of the Navajo country: New Mexico Geol. Soc. Guidebook, South and west sides, San Juan basin, 2nd field conference, p. 95-99.

Hazzard, R. T., Spooner, W. C., and Blanpied, B. W., 1947, Notes on the stratigraphy of the formations which underlie the Smackover limestone in south Arkansas, northeast Texas, and north Louisiana: Shreveport Geol. Soc. 1945 Ref. Rept., v. 2, p. 483-503.

Heaton, R. L., 1939, Contribution to Jurassic stratigraphy of Rocky Mountain region: Am. Assoc. Petroleum Geologists Bull. v. 23, p. 1153-1177.

Heikkila, H. H., 1953, Horseshoe Creek area, Teton County, Idaho, *in* Intermountain Assoc. Petroleum Geologists Guidebook, Fourth annual field conference, p. 93-94.

Herald, F. A., 1951, Occurrence of oil and gas in northeast Texas: Texas Univ. Bull. 5116, 449 p.

Herold, C. L., 1939, Geology of the Salinas and Jamesburg quadrangles, Monterey County, Calif. [abstract]: Geol. Soc. America Bull., v. 50, p. 1951.

Hewett, D. F., 1931, Geology and ore deposits of the Goodsprings quadrangle, Nev.: U. S. Geol. Survey Prof. Paper 162, 172 p.

Heyl, G. R., 1948, The Grayhouse area, Amador County, Calif., *in* Copper in California: California Dept. Nat. Res., Div. Mines Bull. 144, p. 85-91.

Heyl, G. R., Cox, M. W., and Eric, J. H., 1948, Penn zinc-copper mine, Calaveras County, Calif., *in* Copper in California: California Dept. Nat. Res., Div. Mines Bull. 144, p. 61-84.

Heyl, G. R., and Eric, J. H., 1948, Newton Copper Mine, Amador County, Calif., *in* Copper in California: California Dept. Nat. Res., Div. Mines Bull. 144, p. 49-60.

Hiestand, T. C., 1947, Basin oil and gas field, Big Horn County, Wyo., *in* Wyoming Geol. Assoc. Guidebook, Field conference in the Bighorn basin, p. 234-240.

Hinds, N. E. A., 1935, Mesozoic and Cenozoic eruptive rocks of the southern Klamath Mountains, Calif.: California Univ., Dept. Geol. Sci. Bull., v. 23, p. 313-380.

Hoffmeister, W. S., and Staplin, F. L., 1954, Pennsylvanian age of Morehouse formation of northeastern Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 158-159.

Hoots, H. W., 1931, Geology of the eastern part of the Santa Monica Mountains, Los Angeles County, Calif.: U. S. Geol. Survey Prof. Paper 165-C, p. 83-134.

Hubbell, R. G., 1954, Stratigraphy of the Jelm, Nugget, and Sundance formations of northern Carbon Co., Wyoming: Unpubl. M.A. thesis, Univ. Wyoming.

Hubert, J. F., 1954, Structure and stratigraphy of an area east of Brush Creek, Eagle County, Colo.: M.S. thesis, Colorado Univ.

Hubley, M. D., 1948, Beaver Creek field, Fremont County, Wyo., *in* Wyoming Geol. Assoc. Guidebook, Third annual field conference, p. 160-165.

Huddle, J. W., Mapel, W. J., and McCann, F. T., 1951, Geology of the Moon Lake area, Duchesne County, Utah: U. S. Geol. Survey Oil and Gas Inv. Map OM 115.

Huddle, J. W., and McCann, F. T., 1947, Geologic map of Duchesne River area, Wasatch and Duchesne Counties, Utah: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 75.

Hudson, Ben, 1949, Tisdale Anticline: Wyoming Geol. Assoc. Guidebook, Fourth annual field conference in the Powder River Basin, p. 83-84.

Huffington, R. M., 1943, Geology of the North Quitman Mountains, trans-Pecos, Tex. Geol. Soc. America Bull., v. 54, p. 987-1047.

Hunt, C. B., Averitt, Paul, and Miller, R. L., 1953, Geology and geography of the Henry Mountains region, Utah: U. S. Geol. Survey Prof. Paper 228, 234 p.

Hunt, V. G., and O'Connor, V. P., Jr., 1954, Developments in east Texas in 1953: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 1196-1207.

Imlay, R. W., 1939, Paleogeographic studies in northeastern Sonora [Mex.]: Geol. Soc. America Bull., v. 50, p. 1729.

Imlay, R. W., 1940, Lower Cretaceous and Jurassic formations of southern Arkansas and their oil and gas possibilities: Arkansas Geol. Survey Inf. Circ. 12.

Imlay, R. W., 1943, Jurassic formations of Gulf region: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 1407-1533.

Imlay, R. W., 1945, Jurassic fossils from the Southern States, No. 2: Jour. Paleontology, v. 19, p. 253-276.

Imlay, R. W., 1947, Marine Jurassic of Black Hills area, South Dakota and Wyoming: Am. Assoc. Petroleum Geologists Bull., v. 31, p. 227-273.

Imlay, R. W., 1950, Jurassic rocks in the mountains along the west side of the Green River basin, *in* Wyoming Geol. Assoc. Guidebook, Southwest Wyoming, p. 36-48.

Imlay, R. W., 1952a, Correlation of the Jurassic formations of North America, exclusive of Canada: Geol. Soc. America Bull., v. 63, p. 953-992.

Imlay, R. W., 1952b, Marine origin of Preuss sandstone of Idaho, Wyoming, and Utah: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 1735-1753.

Imlay, R. W., 1953, Characteristics of the Jurassic Twin Creek limestone in Idaho, Wyoming, and Utah, *in* Intermountain Assoc. Petroleum Geologists Guidebook, Fourth annual field conference, p. 54-62.

Imlay, R. W., 1954, Marine Jurassic formations in the Pryor Mountains and Northern Bighorn Mountains, Montana, *in* Billings Geol. Soc. Guidebook, Fifth annual field conference, p. 54-64.

Imlay, R. W., Gardner, L. S., Rogers, C. P., Jr., and Hadley, H. D., 1948, Marine Jurassic formations of Montana: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 32.

Imlay, R. W., and Williams, J. S., 1942, Late Paleozoic age of Morehouse formation of northeastern Louisiana: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 1672-1673.

Jenkins, C. E., 1950, Geology of the Bates Creek-Corral Creek area, Natrona County, Wyo.: Unpubl. M. A. thesis, Univ. Wyoming.

Johnson, J. H., 1945, A résumé of the Paleozoic stratigraphy of Colorado: Colorado School Mines Quart., v. 40, no. 3.

Jones, J. C., Smith, A. M., and Stoddard, C., 1931, The preliminary survey of the Scossa Mining District, Pershing County, Nev.: Nevada Univ. Bull., v. 25, no. 4.

Kansas Geol. Soc., 1940, Fourteenth Annual Field Conference, Guidebook, p. 85-86.

Keller, W. D., 1953, Clay minerals in the type section of the Morrison formation: Jour. Sed. Petrology, v. 23, p. 93-105.

Kelley, V. C., and Wood, G. H., Jr., 1946, Lucero uplift, Valencia, Socorro, and Bernalillo Counties, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 47.

Kew, W. S. W., 1919, Geology of a part of the Santa Ynez River district, Santa Barbara County, Calif.: California Univ., Dept. Geol. Sci. Bull., v. 12.

Kew, W. S. W., 1924, Geology and oil resources of a part of Los Angeles and Ventura Counties, Calif.: U. S. Geol. Survey Bull. 753, 202 p.

Kiilsgaard, T. H., [illegible] and coal of the [illegible] District, Teton County, Idaho: Idaho Bur. Mines and Geology Pamph. 92.

King, P. B., 1947, Carta geologica de la parte septentrional de la Republica Mexicana: Universidad National Inst. Geol., Geod., Cartas Geol. y Mineras no. 3.

King, P. B., 1949, Regional geologic map of parts of Culberson and Hudspeth Counties, Tex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 90.

King, P. B., 1950, Tectonic framework of southeastern United States: Am. Assoc. Petroleum Geologists Bull., v. 34, p. 635-671.

King, R. E., and Adkins, W. S., 1946, Geology of a part of the lower Conchos Valley, Chihuahua, Mexico: Geol. Soc. America Bull., v. 57, p. 275-294.

King, P. B., King, R. E., and Knight, J. B., 1945, Geology of Hueco Mountains, El Paso and Hudspeth Counties, Tex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 36.

Kinney, D. M., 1951, Geology of the Uinta River and Brush Creek-Diamond Mountain areas, Duchesne and Uintah Counties, Utah: U. S. Geol. Survey Oil and Gas Inv. Map OM 123.

Kinney, D. M., and Rominger, J. F., 1947, Geology of the Whiterocks River-Ashley Creek area, Uintah County, Utah: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 82.

Kirkham, V. R. D., [illegible], Geology and oil possibilities of central and southeastern Idaho: Idaho Bur. Mines and Geology Bull. [illegible]

Kirkham, V. R. D., [illegible], Geology and oil possibilities of Bingham, Bonneville, and Caribou Counties, Idaho: Idaho Bur. Mines and Geology Bull. 8, 116 p.

Knight, W. H., 1949, The geology of the western part of Flat Top anticline, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Koenig, A. J., 1952, Geologic map and structure sections of the Troublesome Creek Basin, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Krampert, E. W., 1947, Hamilton Dome, Hot Springs County, Wyo., *in* Wyoming Geol. Assoc. Guidebook, p. 229-233.

Kummel, Bernhard, 1954, Triassic stratigraphy of southeastern Idaho and adjacent areas: U. S. Geol. Survey Prof. Paper 254-H, p. 165-194.

Laird, W. M., 1941, Selected deep well records: North Dakota Geol. Survey Bull. 12.

Laird, W. M., and Anderson, S. B., 1952, Price Kline No. 1 Well: North Dakota Geol. Survey Circ. 6.

Landes, K. K., and Keroher, R. P., 1939, Geology and oil and gas resources of Logan, Gove, and Trego Counties, Kans.: Kansas Geol. Survey Min. Res. Circ. 11.

Lasky, S. G., 1947, Geology and ore deposits of the Little Hatchet Mountains, Hidalgo and Grant Counties, N. Mex.: U. S. Geol. Survey Prof. Paper 208, 101 pages.

Lavington, C. S., and Thompson, W. O., 1948, Post-Mississippian stratigraphy, *in* Guide to the geology of central Colorado: Colorado School Mines Quart., v. 43, no. 2., p. 36-52.

Lawson, A. C., 1914, Description of the San Francisco district: U. S. Geol. Survey Atlas, folio 193.

Lee, W. T., 1901, The Morrison formation of southeastern Colorado: Jour. Geology, v. 9, p. 343-352.

Lee, W. T., 1902, The Morrison shales of southern Colorado and northern New Mexico: Jour. Geol. v. 10, p. 36-58.

Lee, W. T., 1912, Coal fields of Grand Mesa and the West Elk Mountains, Colo.: U. S. Geol. Survey Bull. 510, 237 p.

Lee, W. T., 1920, Type section of the Morrison formation: Am. Jour. Sci., 4th ser., v. 49, p. 183-188.

Lee, W. T., 1927, Correlation of geologic formations between east-central Colorado, central Wyoming, and southern Montana: U. S. Geol. Survey Prof. Paper 149, 80 p.

LeRoy, L. W., 1946, Stratigraphy of the Golden-Morrison area, Jefferson County, Colo.: Colorado School Mines Quart., v. 41, no. 2.

Lindgren, Waldemar, 1896, Description of the Pyramid Peak quadrangle, Calif.: U. S. Geol. Survey Geol. Atlas, folio 31.

Lindgren, Waldemar, 1900, Description of the Colfax quadrangle, Calif.: U. S. Geol. Survey Geol. Atlas, folio 66.

Lindgren, Waldemar, and Turner, H. W., 1894, Description of the Placerville quadrangle: U. S. Geol. Survey Geol. Atlas, folio 3.

Livingston, D. C., 1932, A major overthrust in western Idaho and northeastern Oregon: Northwest Sci., v. 6, no. 2, p. 31-36.

Longwell, C. R., 1928, Geology of the Muddy Mountains, Nev., with a section through the Virgin Range to the Grand Wash Cliffs, Ariz.: U. S. Geol. Survey Bull. 798.

Longwell, C. R., 1949, Structure of the northern Muddy Mountain area, Nevada: Geol. Soc. America Bull., v. 60, p. 923-967.

Love, J. D., Denson, N. M. and Botinelly, Theodore, 1949, Geology of the Glendo area, Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 92.

Love, J. D., Duncan, D. C., Bergquist, H. R., and Hose, R. K., 1948, Stratigraphic sections of Jurassic and Cretaceous rocks in the Jackson Hole area, northwestern Wyoming: Wyoming Geol. Survey Bull. 40.

Love, J. D., Thompson, R. M., Johnson, C. O., and others, 1945a, Stratigraphic sections and thickness maps of Lower Cretaceous and nonmarine Jurassic rocks of central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 13.

Love, J. D., Tourtelot, H. A., Johnson, C. O., and others, 1945b, Stratigraphic sections and thickness maps of Jurassic rocks in central Wyoming: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 14.

Lovering, T. S., 1934, Geology and ore deposits of the Breckenridge mining district, Colorado: U. S. Geol. Survey Prof. Paper 176, 64 p.

Lupher, R. L., 1941, Jurassic stratigraphy of central Oregon: Geol. Soc. America Bull., v. 52, p. 219-270.

Maher, J. C., 1953, Permian and Pennsylvanian rocks of southeastern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 913-939.

Malek-Aslani, M., 1950, Geology of the southern Perry Park, Douglas County, Colo.: Unpubl. M.S. thesis, Colorado School of Mines, 93 p.

Malek-Aslani, M., 1952, Geology of the Beulah area, Pueblo County, Colo.: Unpubl. M.S. thesis, Colorado School of Mines.

Mansfield, G. R., 1920, Triassic and Jurassic in southeastern Idaho and neighboring regions: Am. Jour. Sci., 4th ser., v. 50, p. 53-64.

Mansfield, G. R., 1927, Geography, geology, and mineral resources of part of southeastern Idaho: U. S. Geol. Survey Prof. Paper 152, 453 p.

Mansfield, G. R., 1952, Geography, geology, and mineral resources of the Ammon and Paradise Valley quadrangles, Idaho: U. S. Geol. Survey Prof. Paper 238, 92 p.

Maravich, M. D., 1941, Geology of Freezeout Mountain-Bald Mountain area, Carbon County, Wyo.: Am. Assoc. Petroleum Geologists Bull., v. 25, p. 883-897.

McCabe, W. S., 1948, Elk Basin anticline, Park County, Wyoming, and Carbon County, Montana, [illegible]

McDavid, J. D., 1953, Geology of Muddy Creek area, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

McKee, E. D., 1951, Sedimentary basins of Arizona and adjoining areas: Geol. Soc. America Bull., v. 62, p. 481-506.

McKnight, E. T., 1940, Geology of the area between Green and Colorado Rivers, Grand and San Juan Counties, Utah: U. S. Geol. Survey Bull. 908, 147 p.

McLaughlin, T. G., 1942, Geology and ground-water resources of Morton County, Kans.: Kansas Geol. Survey Bull. 40, 126 p.

McLaughlin, T. G., 1943, Geology and ground-water resources of Hamilton and Kearny Counties, Kans.: Kansas Geol. Survey Bull. 49, 220 p.

McLaughlin, T. G., 1946, Geology and ground-water resources of Grant, Haskell, and Stevens Counties, Kans.: Kansas Univ., Geol. Survey Bull. 61.

McLaughlin, T. G., 1955, Geology and ground-water resources of Baca County, Colo.: U. S. Geol. Survey Water Supply Paper 1256, 232 p.

Meholin, G. L., Totten, R. B., Tarver, J. H., and Ptasynski, Harry, 1953, East-west cross section Union County, New Mexico to Ellis County, Oklahoma: Panhandle Geol. Soc. Cross Section.

Merriam, D. F., 1955, Jurassic rocks in Kansas: Am. Assoc. Petroleum Geologists Bull., v. 39, p. 31-46.

Mohr, C. L., 1938, Geological notes; The I.T.I.O.-Olson no. 1 Arbes test, Bent County, Colo.: Mines Mag., v. 28, p. 14-15, 16, 18.

Monroe, W. H., 1954, Geology of the Jackson area, Mississippi: U. S. Geol. Survey Bull. 986, 133 p.

Monroe, W. H., and Toler, H. M., 1937, The Jackson gas field and the State deep test well: Mississippi Geol. Survey Bull. 36.

Moody, C. L., 1917, The breccias of the Mariposa formation in the vicinity of Colfax, Calif.: California Univ., Dept. Geol. Sci. Bull., v. 10, p. 383-420.

Mook, C. C., 1916, A study of the Morrison formation: New York Acad. Sci. Annals, v. 27, p. 39-191.

Moore, R. C., Frye, J. C., Jewett, J. M., Lee, Wallace, and O'Connor, H. G., 1951, The Kansas rock column: Kansas Univ., State Geol. Survey Bull., v. 89.

Morgan, H. J., Jr., 1952, Paleozoic beds south and east of Ouachita folded belt: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 2266-2274.

Morgan, J. K., 1951, Geology of the Otter Creek area, Washakie County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Moritz, C. A., 1951, Triassic and Jurassic stratigraphy of southwest Montana: Am. Assoc. Petroleum Geologists Bull., v. 35, p. 1781-1814.

Muller, S. W., and Ferguson, H. G., 1939, Mesozoic stratigraphy of the Hawthorne and Tonopah quadrangles, Nev.: Geol. Soc. America Bull., v. 50, p. 1573-1624.

Neely, Joseph, 1937, Stratigraphy of the Sundance formation and related Jurassic rocks in Wyoming and their petroleum aspects: Am. Assoc. Petroleum Geologists Bull., v. 21, p. 715-770.

Nelson, L. A., 1950, Franklin Mountains, *in* West Texas Geol. Soc. Guidebook, 1950.

North Dakota State Geol. Survey Circ. 5, 2d rev., and 1st suppl., 1952.

Northrop, S. A., Sullwold, H. H., Jr., McAlpin, A. J., and Rogers, C. P., Jr., 1946, Geologic maps of a part of the Las Vegas basin and of the foothills of the Sangre de Cristo Mountains, San Miguel and Mora Counties, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 54.

Norton, G. H., 1938, The oil fields of Scott and Finney Counties, Kans., *in* Kansas Geol. Soc. Guidebook, Twelfth annual field conference, along the Front Range of the Rocky Mountains, Colorado, p. 73-76.

Norton, G. H., 1939, Permian red beds of Kansas: Am. Assoc. Petroleum Geologists Bull., v. 23, p. 1751-1819.

Nowels, K. B., 1925, Navajo Reservation development: Oil and Gas Jour., p. 255-264, 300.

O'Brien, J. C., and Braun, L. T., 1952, Mines and mineral resources of Glenn County, Calif.: California Dept. Nat. Res., Div. Mines Bull. 48, p. 29-54.

Ogden, Lawrence, 1954, Rocky Mountain Jurassic time surface: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 914-916.

[illegible]

Pack, R. W., 1920, The Sunset-Midway oil field, California: U. S. Geol. Survey Prof. Paper 116, 179 p.

[illegible]

Pierce, W. G., and Andrews, D. A., 1941, Geology and oil and coal resources of the region south of Cody, Park County, Wyo.: U. S. Geol. Survey Bull. 921-B, p. 99-180.

Pipiringos, G. N., 1953, Correlation of marine Jurassic and related rocks in the Laramie basin, Wyoming: Wyoming Geol. Assoc. Guidebook, Eighth annual field conference, p. 34-39.

Prescott, G. C., Jr., 1951, Geology and ground-water resources of Lane County, Kans.: Kansas Geol. Survey Bull. 93.

Proctor, P. D., 1953, Geology of the Silver Reef (Harrisburg) mining district, Washington County, Utah: Utah Geol. and Mineralog. Survey Bull. 44.

Rapaport, Irving, Hadfield, J. P., and Olson, R. H., 1952, Jurassic rocks of the Zuni uplift, New Mexico: U. S. Atomic Energy Commission, Division of Raw Materials, RMO-642, Technical Information Service, Oak Ridge, Tenn.

Read, C. B., and Andrews, D. A., 1944, The upper Pecos River and Rio Galisteo region, New Mexico: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 8.

Read, C. B., Wilpolt, R. H., Andrews, D. A., Summerson, C. H., and Wood, G. H., Jr., 1944, Geologic map and stratigraphic sections of Permian and Pennsylvanian rocks of parts of San Miguel, Santa Fe, Sandoval, Bernalillo, Torrance, and Valencia Counties, north-central New Mexico: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 21.

Read, C. B., Wood, G. H., Wanek, A. A., and Mackee, P. V., 1949, Stratigraphy and geologic structure in the Piedra River Canyon, Archuleta County, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 96.

Reeside, J. B., Jr., and Bassler, Harvey, 1922, Stratigraphic sections in southwestern Utah and northwestern Arizona: U. S. Geol. Survey Prof. Paper 129-D, p. 53-77.

Regan, L. J., Jr., and Hughes, A. W., 1949, Fractured reservoirs of Santa Maria district, California: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 32-51.

Renick, B. C., 1931, Geology and ground-water resources of western Sandoval County, New Mexico: U. S. Geol. Survey Water-Supply Paper 620, 117 p.

Richards, P. W., and Rogers, C. P., Jr., 1951, Geology of the Hardin area, Big Horn and Yellowstone Counties, Mont.: U. S. Geol. Survey Oil and Gas Inv. Map OM 111.

Richardson, G. B., 1915, Description of the Castle Rock quadrangle, Colo.: U. S. Geol. Survey Geol. Atlas, folio 198.

Richmond, G. M., 1945, Geology and oil possibilities at the northwest end of the Wind River Mountains, Sublette County, Wyo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 31.

Rinehart, Ira, 1950, Rinehart's Yearbook; a statistical and graphical summary of well information: Rinehart Oil News Co., Dallas.

Ritzma, H., 1949, Geology along the southwest flank of the Sierra Madre, Carbon County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Roth, R. I., 1949, Paleogeology of the Panhandle of Texas: Geol. Soc. America Bull., v. 60, p. 1671-1687.

Rubey, W. W., 1955, Early structural history of the overthrust belt of western Wyoming and adjacent states, *in* Wyoming Geol. Assoc. Guidebook, Field conference in the Green River basin, p. 125-126.

Sanborn, A. F., 1952, Geology and paleontology of a part of the Big Bend quadrangle, Shasta County, Calif.: Ph.D. thesis, Stanford Univ.

Sanders, C. W., 1934, Geology of Two Buttes dome in southeastern Colorado: Am. Assoc. Petroleum Geologists Bull., v. 18, p. 860-870.

Schlocker, J., Bonilla, M. G., and Imlay, R. W., 1954, Ammonite indicates Cretaceous age for part of Franiciscan group in San Francisco Bay area, California: Am. Assoc. Petroleum Geologists Bull., v. 38, p. 2372-2381.

Schmitt, G. T., 1952, Regional stratigraphic analysis of middle and upper marine Jurassic in northern Rocky Mountains: Unpubl. Ph.D. thesis, Northwestern Univ.

Schmitt, G. T., 1953, Regional stratigraphic analysis of middle and upper marine Jurassic in northern Rocky Mountains-Great Plains: Am. Assoc. Petroleum Geologists Bull., v. 37, p. 355-393.

Schoff, S. L., 1939, Geology and ground-water resources of Texas County, Okla.: Oklahoma Geol. Survey Bull. 59.

Schoff, S. L., 1943, Geology and ground-water resources of Cimarron County, Okla., with a section on Mesozoic stratigraphy by J. W. Stovall: Oklahoma Geol. Survey Bull. 64.

Schulze, J. D., 1954, The pre-Dakota geology of the northern half of the Canon City embayment, Colorado: Unpubl. M.S. thesis, Univ. Oklahoma.

Schwartz, C. B., 1948, Fouke oil and gas field, Miller County, Ark., *in* J. V. Howell, ed., Structure of typical American oil fields, v. 3, p. 5-23; Tulsa, Okla., Am. Assoc. Petroleum Geologists.

Sears, W. A., 1949, Geology of the Deer Creek-Smith Creek area, Converse and Natrona Counties, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Sellards, E. H., Adkins, W. S., and Plummer, F. B., 1932, The geology of Texas, v. 1, Stratigraphy: Texas Univ. Bull. 3232.

Sheridan, David, 1950, Permian, Triassic, and Jurassic stratigraphy of the McCoy area, west central Colo.: Unpubl. M.A. thesis, Colorado Univ.

[illegible]

Silver, Caswell, 1948, Jurassic overlap in western New Mexico: Am. Assoc. Petroleum Geologists Bull., v. 32, p. 68-81.

Smith, G. O., and Calkins, F. C., 1904, A geological reconnaissance across the Cascade Range near the forty-ninth parallel: U. S. Geol. Survey Bull. 235, 103 p.

Smith, J. F., Jr., and Ray, L. L., 1943, Geology of the Cimarron Range, N. Mex.: Geol. Soc. America Bull., v. 54, p. 891-924.

Smith, W. D., and Allen, J. E., 1941, Geology and physiography of the northern Wallowa Mountains, Oreg.: Oregon Dept. Geology and Min. Industries Bull. 12.

Southeastern Geological Society, Mesozoic Committee, [illegible]

Spencer, A. C., and Paige, Sidney, 1935, Geology of the Santa Rita mining area, New Mexico: U. S. Geol. Survey Bull. 859, 78 p.

Spieker, E. M., 1946, Late Mesozoic and early Cenozoic history of central Utah: U. S. Geol. Survey Prof. Paper 205-D, p. 117-160.

[illegible]

Stokes, W. L., 1944, Morrison formation and related deposits in and adjacent to the Colorado Plateau: Geol. Soc. America Bull., v. 55, p. 951-992.

Stokes, W. L., 1952, Lower Cretaceous in Colorado Plateau: Am. Assoc. Petroleum Geologists Bull., v. 36, p. 1766-1776.

Strassberg, Morton, 1953a, Summary of Evans Production Co. Johnson No. 1: North Dakota Geol. Survey Circ. 23.

Strassberg, Morton, 1953b, Summary of the Samedan Oil Company Vaughn Hanson No. 1: North Dakota Geol. Survey Circ. 25.

Strassberg, Morton, 1953c, Summary of the Argyle Royalty Co. Baukol Noonan No. 1: North Dakota Geol. Survey Circ. 26.

Strassberg, Morton, 1953d, Summary of Lion Oil Co. No. 1 Sebelius: North Dakota Geol. Survey Circ. 27.

Strassberg, Morton, 1953e, Summary of Deep Rock-Stanolind No. 1 J. Brusich: North Dakota Geol. Survey Circ. 28.

Strassberg, Morton, 1953f, Summary of Phillips Petrol. Co. Olivia Saude No. 1: North Dakota Geol. Survey Circ. 30.

Strassberg, Morton, 1953g, Summary of Zach Brooks Drilling Co. Edwin Berentson No. 1: North Dakota Geol. Survey Circ. 31.

Strassberg, Morton, 1953h, Summary of the Carter Oil Co. North Dakota State No. 1: North Dakota Geol. Survey Circ. 32.

Strobell, J. D., in press, Geology of the Carrizo Mountains, Ariz. and N. Mex.: U. S. Geol. Survey Prof. Paper.

Swain, F. M., 1944, Stratigraphy of Cotton Valley beds of northern Gulf Coastal Plain: Am. Assoc. Petroleum Geologists Bull., v. 28, p. 577-614.

Swain, F. M., 1949, Upper Jurassic of northeastern Texas: Am. Assoc. Petroleum Geologists Bull., v. 33, p. 1206-1250.

Swain, F. M., 1952, Ostracoda from wells in North Carolina, Part 2, Mesozoic ostracoda: U. S. Geol. Survey Prof. Paper 234-B, p. 59-93.

Swain, F. M., and Peterson, J. A., 1952, Ostracodes from the upper part of the Sundance formation of South Dakota, Wyoming, and southern Montana: U. S. Geol. Survey Prof. Paper 243-A, p. 1-17.

Swinney, C. M., 1949, The geology and petrology of the Sonora quadrangle, California: Ph.D. dissertation, Stanford Univ., 90 p.

Taliaferro, N. L., 1941, Geologic history and structure of the central Coast Ranges of California: Calif. Div. Mines Bull. 118, pt. 2, preprint, p. 119-163.

Taliaferro, N. L., 1942, Geologic history and correlation of the Jurassic of southwestern Oregon and California: Geol. Soc. America Bull., v. 53, p. 71-112.

Taliaferro, N. L., 1943a, Franciscan-Knoxville problem: Am. Assoc. Petroleum Geologists Bull., v. 27, p. 109-219.

Taliaferro, N. L., 1943b, Manganese deposits of the Sierra Nevada, their genesis and metamorphism, *in* Manganese in California: California Dept. Nat. Res., Div. Mines Bull. 125, p. 277-332.

Taliaferro, N. L., 1951, Geology of the San Franciscan Bay Counties, *in* Geologic guidebook of the San Francisco Bay Counties: California Dept. Nat. Res., Div. Mines Bull. 154, p. 117-150.

Thalmann, H. E., 1943, Upper Cretaceous age of the "Franciscan" limestone near Laytonville, Mendocino County, Calif. [abstract]: Geol. Soc. America Bull., v. 54, p. 1827.

Thomas, C. R., Huddle, J. W., McCann, F. T., Raman, N. D., and Johnson, C. O., 1944, Structure contour map of the Rangely anticline, Rio Blanco and Moffat Counties, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 7.

Thomas, C. R., McCann, F. T., and Raman, N. D., 1945, Mesozoic and Paleozoic stratigraphy in northwestern Colorado and northeastern Utah: U. S. Geol. Survey Oil and Gas Inv. Prelim. Chart 16.

Thomas, H. D., and Krueger, M. L., 1946, Late Paleozoic and Mesozoic stratigraphy of Uinta Mountains: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 1255-1293.

Thomas, H. E., and Taylor, G. H., 1946, Geology and ground-water resources of Cedar City and Parowan Valleys, Iron County, Utah: U. S. Geol. Survey Water-Supply Paper 993, 210 p.

Thorup, R. R., 1943, Type locality of the Vaqueros formation, *in* Geologic formations and economic development of the oil and gas fields of California: California Dept. Nat. Res., Div. Mines Bull. 118, p. 463-466.

Threet, Richard, 1954(?), Geology of Red Hills area, Iron County, Utah: Washington Univ. [Seattle] thesis.

Tillieux, H. O., 1951, Logansport field, De Soto Parish, La., Panola, and Shelby Counties, Tex., *in* Reference report on certain oil and gas fields of north Louisiana, south Arkansas, Mississippi, and Alabama, v. 3, no. 1, p. 29-41: Shreveport, La., Shreveport Geol. Soc.

Tonking, W. H., 1953, Geology of the Puertecito quadrangle, Socorro County, N. Mex.: New Mexico Bur. Mines and Min. Res., map.

Towse, Donald, 1952, Summary of the Carter Oil Company Thompson No. 1 Well: North Dakota Geol. Survey Circ. 7.

Trager, H. H., 1940, Dorcheat Pool, Columbia County, deepest in Arkansas: Am. Assoc. Petroleum Geologists Bull., v. 24, p. 738-740.

Travis, R. B., 1952, Geology of the Sebastopol quadrangle: California Dept. Nat. Res., Div. Mines Bull. 162.

Trites, A. F., and Thaden, R. E., in press, Geology of the White Canyon area, San Juan County, Utah: U. S. Geol. Survey Bull.

Trotter, J. F., 1954, Geology of the Nowood Creek-Tensleep area, Washakie County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

U. S. Geol. Survey, 1935, Geologic map of Colorado, by the U. S. Geological Survey in cooperation with the Colorado State Geological Survey Board, and Colorado Metal Mining Fund, compiled by W. S. Burbank and others, edited by G. W. Stose.

U. S. Geol. Survey, Nov. 4, 1954, Tritylodontoids discovered in the New World: U. S. Department of Interior, Information Service Press release.

Veatch, A. C., 1911, Coal deposits near Pinedale, Navajo County, Ariz.: U. S. Geol. Survey Bull. 431, p. 239-242.

Vestal, J. H., 1950, Petroleum geology of the Smackover formation of southern Arkansas: Arkansas Res. and Devel. Comm., Div. Geology, Inf. Circ. 14.

Vine, J. D., and Hail, W. J., Jr., 1950, Geology of the Hobson area, Montana: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 108.

Waagé, K. M., 1955, Dakota group in northern Front Range foothills, Colorado: U. S. Geol. Survey Prof. Paper 274-B, p. 15-51.

Wagner, W. R., 1945, A geological reconnaissance between the Snake and Salmon Rivers north of Riggins, Idaho: Idaho Bur. Mines and Geology Pamph. no. 74, 16 p.

Waldschmidt, W. A., and LeRoy, L. W., 1944, Reconsideration of the Morrison in the type area, Jefferson County, Colo.: Geol. Soc. America Bull., v. 55, p. 1097-1114.

Walton, P. T., 1946, Ellis, Amsden, and Big Snowy group, Judith basin, Mont.: Am. Assoc. Petroleum Geologists Bull., v. 30, p. 1294-1305.

Walton, P. T., 1947, Oregon basin field, Wyoming, *in* Wyoming Geol. Assoc. Guidebook, Field conference in the Bighorn basin, p. 210-222.

Wanek, Leonard, 1953, Geology of an area east of Wolcott, Eagle County, Colo.: M.S. thesis, Colorado Univ., 62 p.

Warn, G. F., 1953, Montezuma section, *in* Panhandle Geol. Soc. Guidebook, Field trip of the Raton basin region and the Sangre de Cristo Mountains of New Mexico, p. 35.

Waters, A. C., and Krauskopf, K. B., 1941, Protoclastic border of the Colville batholith [Wash.]: Geol. Soc. America Bull., v. 52, p. 1355-1418.

Weaver, C. E., 1920, The mineral resources of Stevens County: Washington Geol. Survey Bull. 20.

Weaver, C. E., 1945, Geology of Oregon and Washington and its relation to occurrence of oil and gas: Am. Assoc. Petroleum Geologists Bull., v. 29, p. 1377-1415.

Weeks, H. J., 1925, Oil and water possibilities of parts of Delta and Mesa Counties, Colo.: Colorado Geol. Survey Bull. 28.

Weeks, W. B., and Alexander, C. W., 1942, Schuler field, Union County, Ark.: Am. Assoc. Petroleum Geologists Bull., v. 26, p. 1467-1516.

Weimer, R. J., 1949, Geology of the Whiskey Gap-Muddy Gap area, Wyoming: Unpubl. M.A. thesis, Univ. Wyoming.

Welder, G. E., 1954, Geology of the Basalt area, Eagle and Pitkin Counties, Colo.: M.A. thesis, Colorado Univ.

Welles, S. P., 1953, Jurassic plesiosaur vertebrae from California: Jour. Paleontology, v. 27, p. 743-744.

Welles, S. P., 1954, New Jurassic dinosaur from the Kayenta formation of Arizona: Geol. Soc. America Bull., v. 65, p. 591-598.

Wells, F. G., and others, 1940, Preliminary geologic map of the Grants Pass quadrangle, Oreg.: Oregon Dept. Geology and Min. Industries.

Wells, F. G., and Cater, F. W., Jr., 1950, Chromite deposits of Siskiyou County, Calif.: California Dept. Nat. Res., Div. Mines Bull. 134, p. 77-127.

Wells, F. G., Hotz, P. E., and Cater, F. W., Jr., 1949, Preliminary description of the geology of the Kerby quadrangle, Oreg.: Oregon Dept. Geology and Min. Industries Bull. 40.

Wells, F. G., Walker, G. W., and McIntyre, J. M., 1951, Pre-Cretaceous stratigraphy of the northern Klamath Mountains [abstract]: Geol. Soc. America Bull., v. 62, p. 1514.

Wells, F. G., and Walker, G. W., 1953, Geology of the Galice quadrangle, Oreg.: U. S. Geol. Survey Geol. Quadrangle Map GQ 25.

Wheeler, H. E., Scott, W. F., and Thompson, T. L., 1949, Permian-Mesozoic stratigraphy in northeastern Nevada [abstract]: Geol. Soc. America Bull., v. 60, p. 1928.

Wieland, G. R., 1929, A new cycad from the Mariposa slates: California Univ., Dept. Geol. Sci. Bull., v. 18, p. 303-323.

Williams, Howel, 1949, Geology of the Macdoel quadrangle: California Dept. Nat. Res., Div. Mines Bull. 151.

Wilpolt, R. H., McAlpin, A. J., Bates, R. L., and Vorbes, G., 1946, Geologic map and stratigraphic sections of Paleozoic rocks of Joyita Hills, Los Piños Mountains, and northern Chupadera Mesa, Valencia, Torrance, and Socorro Counties, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 61.

Wilson, I. F., 1943, Geology of the San Benito quadrangle, Calif.: California Jour. Mines and Geology, v. 39, p. 183-270.

Wilson, R. F., 1955, The stratigraphy and sedimentology of the Moenave and Kayenta formations, Vermilion Cliffs region, Utah and Arizona: Unpubl. Ph.D. dissertation, Stanford Univ.

Wise, R. A., 1952, Eastern Front Range and foothills geology of central Jefferson County, north-central Colo.: Unpubl. Ph.D. dissertation, Colorado School of Mines.

Wold, J. S., 1952, Report on Worland field, Wyoming, *in* Wyoming Geol. Assoc. Guidebook, Seventh annual field conference, southern Bighorn basin, Wyo., p. 117-120.

Wood, G. H., Jr., Kelley, V. C., and MacAlpin, A. J., 1948, Geology of southern part of Archuleta County, Colo.: U. S. Geol. Survey Oil and Gas Inv. Prelim. Map 81.

Wood, G. H., Jr., Northrop, S. A., and Griggs, R. L., 1953, Geology and stratigraphy of Koehler and Mount Laughlin quadrangles and parts of Abbott and Springer quadrangles, eastern Colfax County, N. Mex.: U. S. Geol. Survey Oil and Gas Inv. Map OM 141.

Woodring, W. P., and Bramlette, M. N., 1950, Geology and paleontology of the Santa Maria district: U.S. Geol. Survey Prof. Paper 222, 185 p.

Wrobleske, J. L., 1953, The stratigraphy and sedimentation of the Popo Agie, Nuggett, and Sundance formations in central Wyoming: Unpubl. M.A. thesis, Univ. Wyoming.

Zakis, W. H., 1950, Geology of the east flank of the Bighorn Mountains near Dayton, Sheridan County, Wyo.: Unpubl. M.A. thesis, Univ. Wyoming.

Zakis, William, 1952, Table Mesa oil field San Juan County, N. Mex., *in* Four Corners Geol. Soc. Guidebook, Geological symposium of the Four Corners region, p. 89.

Zeni, Milton, 1953, Geology of Sheep Creek anticline, Bear Lake County, Idaho, *in* Intermountain Assoc. Petroleum Geologists Guidebook, Fourth annual field conference, p. 80-82.

TABLE 2.—GENERALIZED CORRELATION CHART SHOWING STRATIGRAPHIC UNITS IN MAJOR JURASSIC DIVISIONS

Map intervals	European stages	WESTERN INTERIOR REGION: Western Wyoming	Eastern Wyoming	Western Montana	Eastern Montana, North Dakota	Idaho, northern Utah	Eastern and southern Utah, western Colorado	Durango-Ouray area of southwestern Colorado	Northwestern New Mexico	Northeastern Arizona	Eastern Colorado, western Oklahoma, northeastern New Mexico	Southwestern Nebraska, western Kansas	Western South Dakota, northwestern Nebraska
Interval D	Portlandian												
	Kimmeridgian	Morrison formation	Morrison formation	Morrison formation	Morrison formation	Morrison formation	Morrison formation: Brushy Basin member; Westwater Canyon member; Recapture member; Salt Wash member; Bluff sandstone	Morrison formation; Junction Creek formation	Morrison formation: Brushy Basin member; Westwater Canyon member; Recapture member; Salt Wash member; Cow Springs sandstone (upper part); Bluff sandstone	Cow Springs sandstone (upper part); Morrison formation: Brushy Basin member; Westwater Canyon member; Recapture member; Salt Wash member; Bluff sandstone	Morrison formation	Morrison formation	Morrison formation
Interval C	Oxfordian	Stump sandstone; Curtis formation	Sundance formation (upper part): Redwater shale member	Swift formation	Sundance formation (upper part); Swift formation	Stump sandstone; Summerville formation; Curtis formation	Winsor formation; Summerville formation; Curtis formation; Moab tongue (of Entrada)	Wanakah formation (restricted); Middle shale member; Bilk Creek ss. member; Pony Express member	Wanakah formation; Cow Springs sandstone (lower part); Summerville formation; Todilto limestone	Cow Springs sandstone (lower part); Summerville formation	chalcedonic beds; basal beds of Morrison formation; Wanakah formation; *Ralston formation*	chalcedonic beds; lower unit of Morrison formation; Sundance formation	Sundance formation (upper part): Redwater shale member
Interval B	Callovian	Preuss sandstone; Entrada sandstone	Sundance formation (lower part): Lak member; Hulett member; Stockade Beaver member; Canyon Springs member	Rierdon formation	Sundance formation (lower part); Rierdon formation	Twin Creek member; Preuss sandstone; Entrada sandstone; Carmel formation	Entrada sandstone	Entrada sandstone	Entrada sandstone: *upper sandy member*; *middle silty member*	Entrada sandstone: *middle silty member*; *lower sandy member*; Carmel formation	Ocate ss.; Exeter ss.; Entrada ss.		Sundance formation (lower part): Lak member; Hulett member; Stockade Beaver member; Canyon Springs member
	Bathonian	Twin Creek formation; Carmel formation	Gypsum Spring formation	Sawtooth formation	Piper formation	Arapien shale; Twin Creek formation	Carmel formation						Gypsum Spring formation
	Bajocian												
Interval A (Lias)	Toarcian	Nugget sandstone	Nugget sandstone			Navajo sandstone; Nugget sandstone	Navajo sandstone; Nugget sandstone			Navajo sandstone			
	Pliensbachian												
	Sinemurian						Kayenta formation			Kayenta formation			
	Hettangian												

Map intervals	European stages	NEVADA: Eastern and southern Nevada	Western Nevada	WEST COAST REGION: North-central Washington	Southwestern Oregon	East-central Oregon, western Idaho	Western California	North-central California	Northeastern California	East-central California	Eastern California	TEXAS: West Texas	GULF REGION: East Texas to Alabama
Interval D	Portlandian			*Nooksack formation* (upper part); *Dewdney Creek formation*	Knoxville formation; Part of Myrtle formation	*Lonesome formation*	Knoxville formation; Part of Franciscan formation	Monte de Oro formation	*Combe sandstone*			Malone formation	Cotton Valley group: Schuler formation; Bossier formation
	Kimmeridgian			*Shuksan formation*									Haynesville formation: Buckner member
Interval C	Oxfordian			*Nooksack formation* (lower part)	Galice formation; Rogue formation				Foreman formation	Mariposa slate; Amador group			Smackover formation; *Norphlet formation*
Interval B	Callovian			unnamed volcanic rocks	Dothan formation	*Trowbridge shale*; unnamed shale and volcanic rocks (Idaho)			Hinchman sandstone; Bicknell sandstone				*Louann salt*; *Werner formation*
	Bathonian										Milton formation (upper part); Sailor Canyon formation (upper part)		
	Bajocian					*Izee group*; *Colpitts group*			unnamed volcanic rocks; Mormon sandstone; Thompson limestone				
Interval A (Lias)	Toarcian	Aztec sandstone; Navajo sandstone; Nugget sandstone	Dunlap formation			*Mowich group*		Potem formation	Fant andesite				
	Pliensbachian					*Donovan formation*		Bagley andesite	Hardgrave sandstone		Milton formation (lower part); Sailor Canyon formation (lower part)		
	Sinemurian		Sunrise formation					*Arvison formation*	Trail formation				
	Hettangian												

INDEX TO LOCALITIES AND SOURCES (PL. 1)

Citations of sources of data used in compilation of the maps fall into five categories (see below). Complete bibliographic data for publications and unpublished formal reports (such as theses) are listed under References Cited at the end of the text. An asterisk (*) denotes that the source of data is the files of an individual or organization and, therefore, is not listed in the bibliography.

I. Published data are shown as: author's name; year of publication; page, plate, or figure on which data used are found.

II. Unpublished reports and theses are referred to in the same manner as I, except that the date given is the date of work completion.

III. Unpublished measured sections from the files of individuals are indicated by: asterisk, name of individual; year section was measured (if known, otherwise date is omitted).

IV. Unpublished measured sections in the files of organizations are cited as follows: name of organization; asterisk, representative consulted; year section was measured (if known).

V. Unpublished well logs are shown as follows: name of company drilling; well number; farm name. Asterisk, name of individual or organization consulted for interpretation of well; year samples were examined (if known).

Abbreviations used in the index include the following:

AmStrat.	American Stratigraphic Company
Bd.	Board
Bu.	Bureau
Chem.	Chemical
Confid.	Confidential
Corp.	Corporation
Devel.	Development
Drlg.	Drilling
Eng.	Engineer(s)
Explor.	Exploration
fig.	figure
G.	Geologic(al), geologist(s)
Gen.	General
Illum.	Illuminating
Ind.	Industry
Lab.	Laboratory
Lbr.	Lumber
Mtn.	Mountain
Nat.	Natural
Natl.	National
NPRR	Northern Pacific Railroad
p.	page
PI	Petroleum Information
pl.	plate
Ref.	Refining
rept.	report
SE	Southeastern, southeast
sec.	section
Serv.	Service
Soc.	Society
Surv.	Survey
SW	Southwestern
Terr.	Territory
Univ.	University
UPRR	Union Pacific Railroad
USGS	U. S. Geological Survey

Alabama

1-3. SE G. Soc., 1949, sec. E-E'.
3. Applin, 1951, p. 22.
4. Imlay, 1943, fig. 3, 4, p. 1445-8, 1455, 1463-5.
4. *Imlay, 1953.
7. Shreveport G. Soc., 1947, pl. 1.
9. Humble 1 Williams. *Knight, W.
10. Nelson Explor. 1 Smith Lbr. *Dixie G. Serv.
11. Humble 2 Williams. *Knight, W.
12. Carter 1 James. *Knight, W.
13. Southern Nat. Gas 1 Morgan Estate. *Knight, W.
14. Danciger 1 York. *Knight, W.
15. Gulf 1 Sellers. *Knight, W.

22. Hazzard et al., 1947, p. 483-503.
23. Imlay, 1945, p. 254.
24. Vestal, 1950, table 9.
25. Vestal, 1950, table 11.
26. Vestal, 1950, table 9.
26. Hazzard et al., 1947, p. 483-503.
27. Shreveport G. Soc., 1947, pl. 5-A.
28-30. Vestal, 1950, table 9.
30. Hazzard et al., 1947, p. 483-503.
31. O'Meara 1 Wood Heirs. *Confid., 1946.
32. Vestal, 1950, table 9.
33. Carter 1 Orr. *Imlay, R. W.
33. Shreveport G. Soc., 1947, pl. 5.
34. Vestal, 1950, table 9.
35. Vestal, 1950, table 10.
36. Vestal, 1950, table 9.
37. Shreveport G. Soc., 1947, pl. 6-A.
37. Hazzard et al., 1947, p. 483-503.
38. Swain, 1944, p. 586.
39. Vestal, 1950, table 9.
40. Blanpied & Hazzard, 1944b, p. 332.
41. Vestal, 1950, table 9.
41. Hazzard et al., 1947, p. 483-503.
42. Sohio 1 Daniels Fee. *Imlay, R. W.
43. Tidewater-Seaboard 1 Graves. *Imlay, R. W.
45. Vestal, 1950, table 10.
46. Vestal, 1950, table 9.
47. Swain, 1944, p. 587.
48-49. Imlay, 1940, table 11.
50. Phillips 1 Arnold. *Imlay, R. W.
51. Shreveport G. Soc., 1947, p. 63-6.
53. Modisette et al. 2 Union Saw Mill. *Imlay, R. W.
56-58. Shreveport G. Soc., 1947, pl. 5.
59-61. Shreveport G. Soc., 1947, pl. 6.
63-64. Shreveport G. Soc., 1947, pl. 2.
65-68. Blanpied & Hazzard, 1944b, p. 330.
69. Blanpied & Hazzard, 1944b, p. 331.
69. Swain, 1944, p. 586.
70. Swain, 1944, p. 590.
70. Blanpied & Hazzard, 1944b, p. 331.
71. Carpenter & Schroeder, 1943, p. 24.
71. Swain, 1944, p. 586.
72. Swain, 1944, p. 589.
73. Swain, 1944, p. 588.
74-75. Swain, 1944, p. 587.
76. Swain, 1944, p. 589.
77. Rinehart, 1950, p. 6.
78. Imlay, 1943, p. 1423.
79. Swain, 1944, p. 587.
80. Amerada 1 Bradley Lbr. Co. *Imlay, R. W.
81. Ohio Taylor. *Imlay, R. W.
82. Gutousky et al. 1 Mills. *Imlay, R. W.
83. Fohs 1 Craig. *Imlay, R. W.
84. Erwin & Leach 3 Bodcaw. *Imlay, R. W.
85. Phillips 1 Marsden. *Imlay, R. W.
86. Phillips 1 Godfrey. *Imlay, R. W.
87. Blanpied & Hazzard, 1944a, p. 259.
88. Hazzard et al., 1947, p. 486.
89. Hazzard et al., 1947, p. 487.

California

2. Travis, 1952, p. 10-16.
3. *Imlay, 1955.
3. Taliaferro, 1942, p. 90-92.
4. Taliaferro, 1942, p. 99-101.
4. Lindgren, 1900.
5. Gealey, 1951, p. 19-20.
6. Crittenden, 1951, p. 30, 41, 42.
8. Williams, 1949, p. 19.
18. Dibblee, 1950, p. 21-23.
19. *Robinson, G. D., 1953.
20. Woodring & Bramlette, 1950, p. 12-13.
22. Diller, 1908, p. 35-57, 87, 88.
25. Arnold & Anderson, 1910, p. 46-62.
26. Pack & English, 1915, p. 126-127.
33. Andrews, 1936, p. 30.
34. Hinds, 1935, p. 325-336.
35. Wieland, 1929, p. 303-323.
37. Kew, 1919, p. 6-8.
38. Moody, 1917, p. 383-420.
39. Lawson, 1914, p. 5-8.
41. Fairbanks, 1904, p. 2-3.
43. Branner et al., 1909, p. 2.
47. Lindgren, 1896.
48. Lindgren & Turner, 1894.
54. Hoots, 1931, p. 90.
55. Pack, 1920, p. 22.
57. Wells & Cater, 1950, p. 81-83.
58. O'Brien & Braun, 1952, p. 32-33.
60. Everhart, 1950, p. 513, 516, 517.
63. Wilson, 1943, p. 224, 252.
64. Wilson, 1943, p. 198-199.
66. Fiedler, 1944, p. 180, 191-192.
77. Heyl & Eric, 1948, p. 52-53.
78. Heyl et al., 1948, p. 61-84.
79. Heyl, 1948, p. 98-99.
83. Dehlinger, 1952, p. 5.
84. Crowell, 1952, p. 6.
88. Taliaferro, 1943b, p. 282-284.
91. Kew, 1924, p. 6-10.
95. English, 1926, p. 11-17.
97. Erwin, 1934, p. 20-21.
101. Thorup, 1943, p. 463-465.
102. Herold, 1939, p. 1951.
103. Clements, 1950, p. 2378.
104-106. Anderson, 1945, p. 909-1014.
106. *Frick, 1954.
107-114. Anderson, 1945, p. 909-1014.
115. Swinney, 1949.
116. Sanborn, 1952.
117. Clark, 1930.
118. Brice, 1953.
121. Crickmay, 1932, p. 1-11.
122. Halsey, 1953.
123. Cater & Wells, 1953, p. 92-104.
124. *Clark, L. D., 1954.
125. *Ehrreich, A., 1954.
126. Regan & Hughes, 1949, p. 48-51.
128. *Frick, J. D., 1954.

INDEX TO LOCALITIES AND SOURCES (PL. 1)

Citations of sources of data used in compilation of the maps fall into five categories (see below). Complete bibliographic data for publications and unpublished formal reports (such as theses) are listed under References Cited at the end of the text. An asterisk (*) denotes that the source of data is the files of an individual or organization and, therefore, is not listed in the bibliography.

I. Published data are shown as: author's name; year of publication; page, plate, or figure on which data used are found.

II. Unpublished reports and theses are referred to in the same manner as I, except that the date given is the date of work completion.

III. Unpublished measured sections from the files of individuals are indicated by: asterisk, name of individual; year section was measured (if known, otherwise date is omitted).

IV. Unpublished measured sections in the files of organizations are cited as follows: name of organization; asterisk, representative consulted; year section was measured (if known).

V. Unpublished well logs are shown as follows: name of company drilling; well number; farm name. Asterisk, name of individual or organization consulted for interpretation of well; year samples were examined (if known).

Abbreviations used in the index include the following:

AmStrat.	American Stratigraphic Company
Bd.	Board
Bu.	Bureau
Chem.	Chemical
Confid.	Confidential
Corp.	Corporation
Devel.	Development
Drlg.	Drilling
Eng.	Engineer(s)
Explor.	Exploration
fig.	figure
G.	Geologic(al), geologist(s)
Gen.	General
Illum.	Illuminating
Ind.	Industry
Lab.	Laboratory
Lbr.	Lumber
Mtn.	Mountain
Nat.	Natural
Natl.	National
NPRR	Northern Pacific Railroad
p.	page
PI	Petroleum Information
pl.	plate
Ref.	Refining
rept.	report
SE	Southeastern, southeast
sec.	section
Serv.	Service
Soc.	Society
Surv.	Survey
SW	Southwestern
Terr.	Territory
Univ.	University
UPRR	Union Pacific Railroad
USGS	U. S. Geological Survey

Alabama

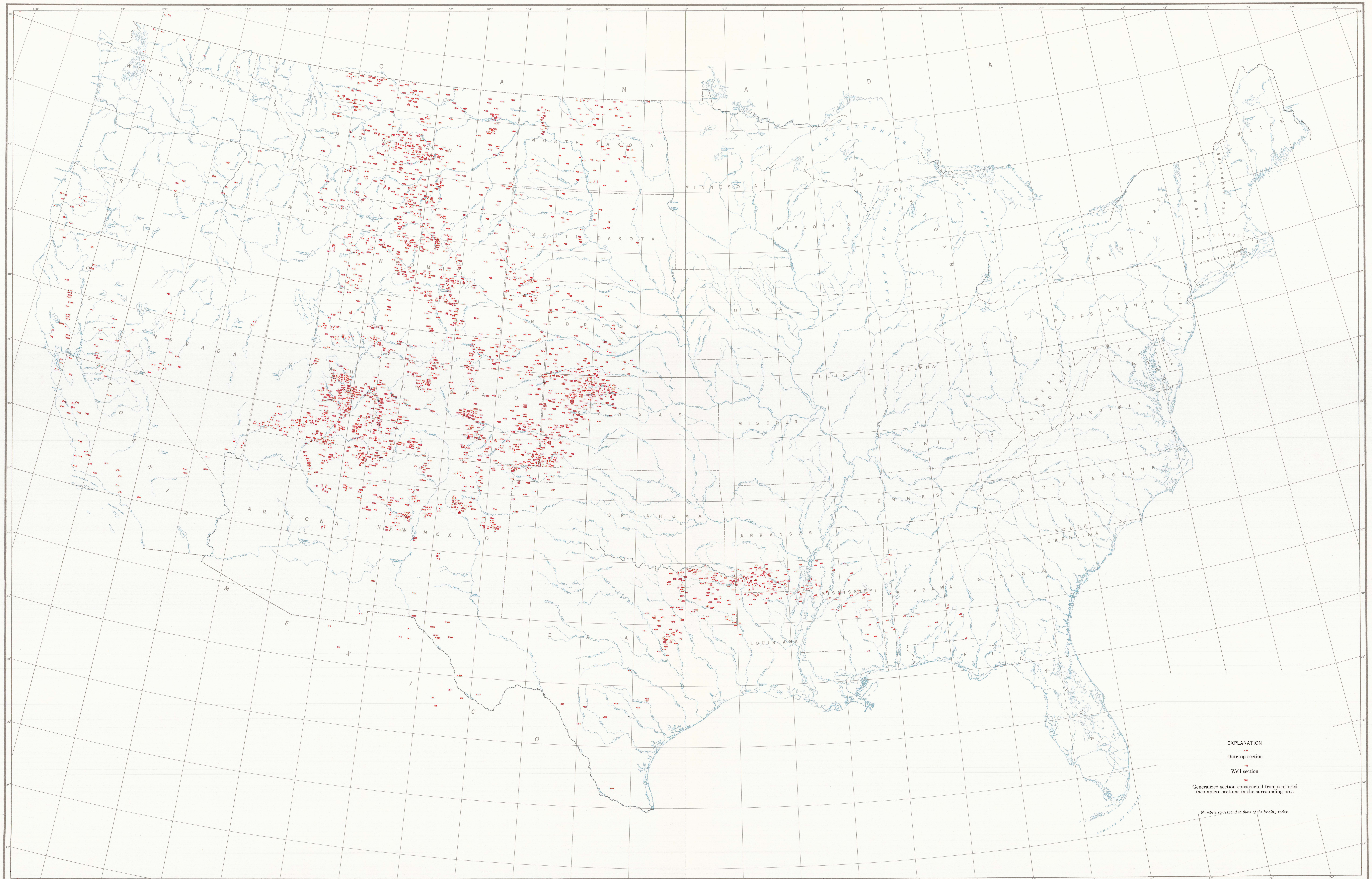
1-3. SE G. Soc., 1949, sec. E-E′.
3. Applin, 1951, p. 22.
4. Imlay, 1943, fig. 3, 4, p. 1445-8, 1455, 1463-5.
4. *Imlay, 1953.
7. Shreveport G. Soc., 1947, pl. 1.
9. Humble 1 Williams. *Knight, W.
10. Nelson Explor. 1 Smith Lbr. *Dixie G. Serv.
11. Humble 2 Williams. *Knight, W.
12. Carter 1 James. *Knight, W.
13. Southern Nat. Gas 1 Morgan Estate. *Knight, W.
14. Danciger 1 York. *Knight, W.
15. Gulf 1 Sellers. *Knight, W.
16. Gulf 1 Hendrix. *Knight, W.
17-20. Applin, 1951, p. 22.
21-22. Applin, 1951, p. 19.
23. Applin, 1951, p. 26.
24. Applin, 1951, p. 19.
25. Applin, 1951, p. 22.

Arizona

1-2. Veatch, 1911, p. 241.
3-5. Harshbarger et al., 1951, pl. 2.
6-7. Harshbarger et al., 1951, p. 103, pl. 2.
8. Harshbarger et al., in press, sec. 6.
9. Harshbarger et al., in press, sec. 1.
10-11. USGS, *Harshbarger, J. W., 1954.
12. Baker et al., 1936, p. 20, pl. 3.
12. Callahan, 1951a, fig. 2.
13. USGS, *Harshbarger, J. W.
14. Baker et al., 1936, p. 30, fig. 7.
15. USGS, *Craig, L. C.
15. USGS, *Harshbarger, J. W.
16. Callahan, 1951a, fig. 2.
17. Callahan, 1951b, p. 55.
18. Callahan, 1951b, p. 64.
19. Callahan, 1951b, p. 68.
20. Callahan, 1951b, p. 72.
21. Callahan, 1951b, p. 76.
22. Callahan, 1951b, p. 79.
23. Harshbarger et al., in press, sec. 2.
25-43. USGS, *Harshbarger, J. W.
44. Harshbarger, 1949, sec. 22.
45. Harshbarger, 1949, sec. 17.
46. Harshbarger, 1949, sec. 16.
47. Harshbarger, 1949, sec. 14.
48. Harshbarger, 1949, sec. 12.
49. Harshbarger, 1949, sec. 27.
50. Harshbarger, 1949, sec. 28, 29.
51. Harshbarger, 1949, sec. 32.
52. Harshbarger, 1949, sec. 33.
53. Harshbarger, 1949, sec. 30.
54. Harshbarger, 1949, sec. 31.
55. Strobell, in press, sec.
56. Sinclair 1 Navajo. USGS, *Harshbarger, J. W.
57-62. Strobell, in press, sec.
63. *Lowell, 1954.
65-67. Strobell, in press, sec.

Arkansas

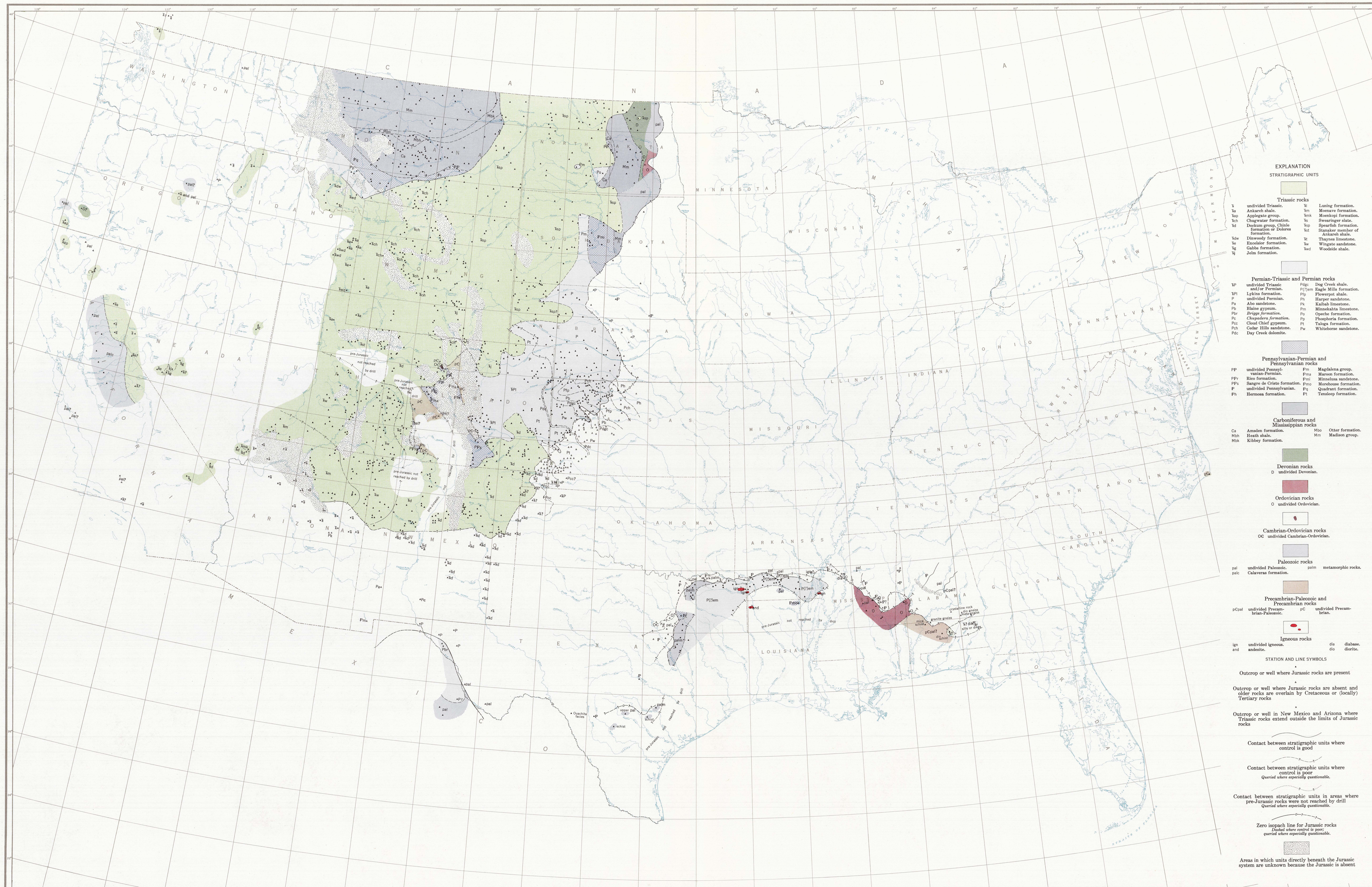
1. Schwartz, 1948, p. 5-23.
2. Shreveport G. Soc., 1947, pl. 6-A.
3-4. Vestal, 1950, table 9.
6-7. Imlay, 1943, fig. 3.
8. Imlay, 1943, fig. 3, p. 1430.
9. Imlay, 1943, fig. 3.
10. Weeks & Alexander, 1942, p. 1476-1482.
10. Goebel, 1950, p. 1954-1980.
10. Swain, 1944, p. 599.
11. Swain, 1944, p. 586.
11. Trager, 1940, p. 739.
12. Swain, 1944, p. 587.
13. Hazzard et al., 1947, p. 483-503.
13. Vestal, 1950, table 9.
14. Standard La. 1 McKean. *Imlay, R. W.
15. Ohio Garner. *Imlay, R. W.
17. Phillips 1 Asken Unit. *Imlay, R. W.
18. Standard La. 1 Phillips. *Imlay, R. W.
18. Imlay, 1945, p. 254.
20. Hazzard et al., 1947, p. 483-503.
20. Vestal, 1950, p. 8.
21. Shreveport G. Soc., 1949, sec. A-A′.
21. Hazzard et al., 1947, p. 483-503.
21. Vestal, 1950, p. 8.
22. Vestal, 1950, table 8.
22. Hazzard et al., 1947, p. 483-503.
23. Imlay, 1945, p. 254.
24. Vestal, 1950, table 9.
25. Vestal, 1950, table 11.
26. Vestal, 1950, table 9.
26. Hazzard et al., 1947, p. 483-503.
27. Shreveport G. Soc., 1947, pl. 5-A.
28-30. Vestal, 1950, table 9.
30. Hazzard et al., 1947, p. 483-503.
31. O'Meara 1 Wood Heirs. *Confid., 1946.
32. Vestal, 1950, table 9.
33. Carter 1 Orr. *Imlay, R. W.
33. Shreveport G. Soc., 1947, pl. 5.
34. Vestal, 1950, table 9.
35. Vestal, 1950, table 10.
36. Vestal, 1950, table 9.
37. Shreveport G. Soc., 1947, pl. 6-A.
37. Hazzard et al., 1947, p. 483-503.
38. Swain, 1944, p. 586.
39. Vestal, 1950, table 9.
40. Blanpied & Hazzard, 1944b, p. 332.
41. Vestal, 1950, table 9.
41. Hazzard et al., 1947, p. 483-503.



LOCATION OF CONTROL POINTS

Scale 1:5 000 000

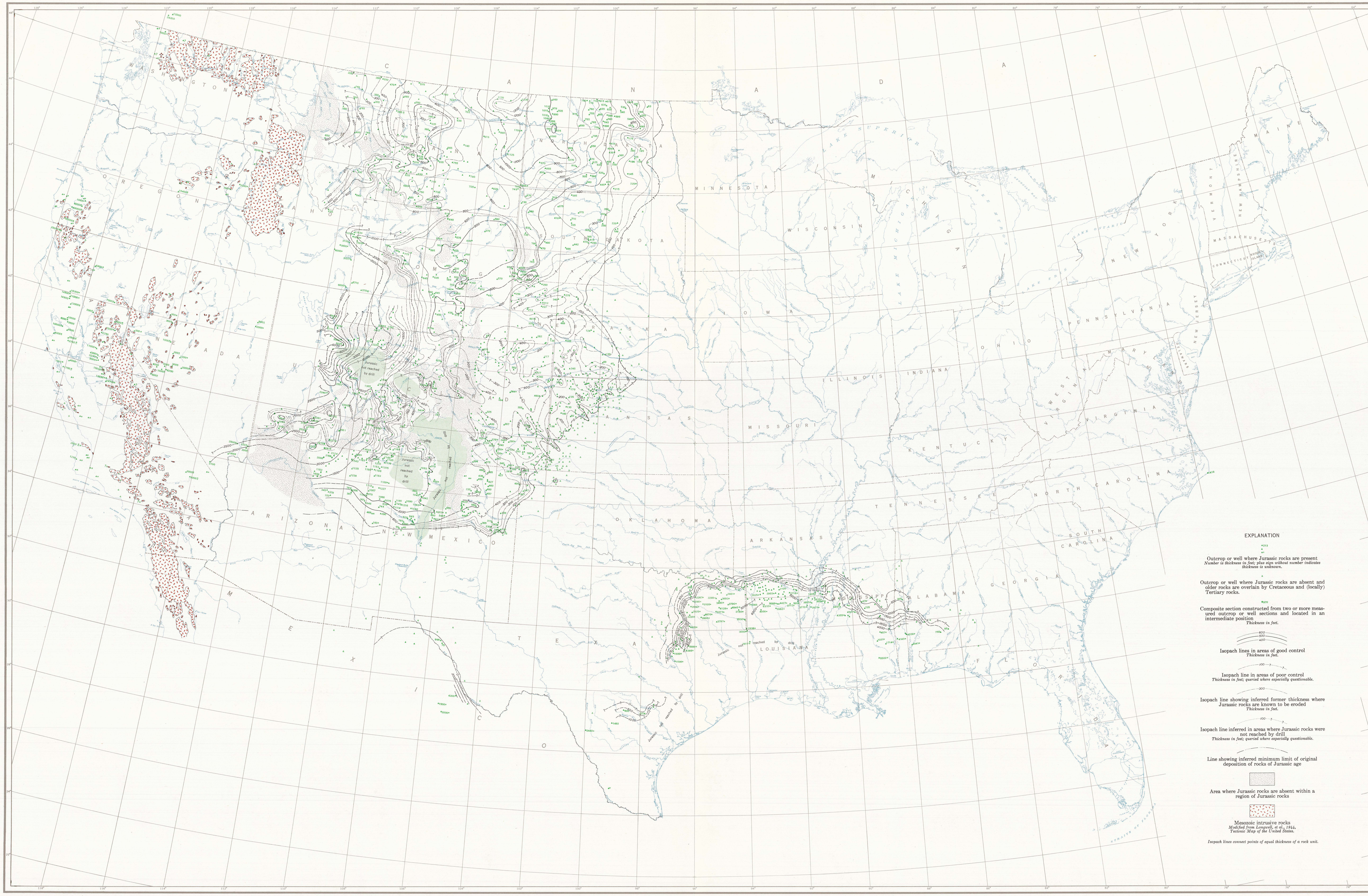
1956



GEOLOGIC UNITS DIRECTLY BENEATH JURASSIC SYSTEM

Scale 1:5 000 000

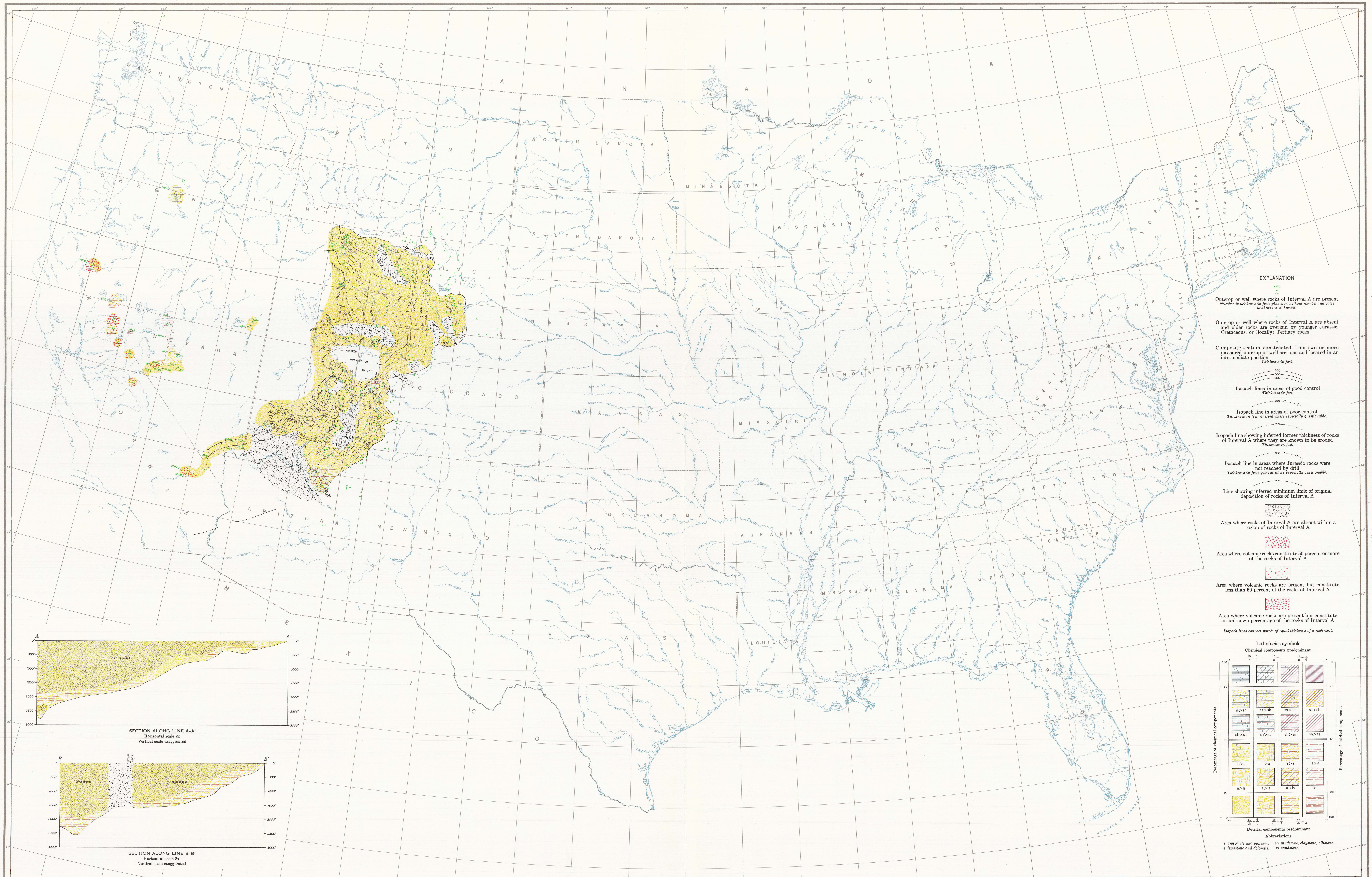
1956



SUMMARY OF JURASSIC ROCK THICKNESSES

Scale 1:5 000 000

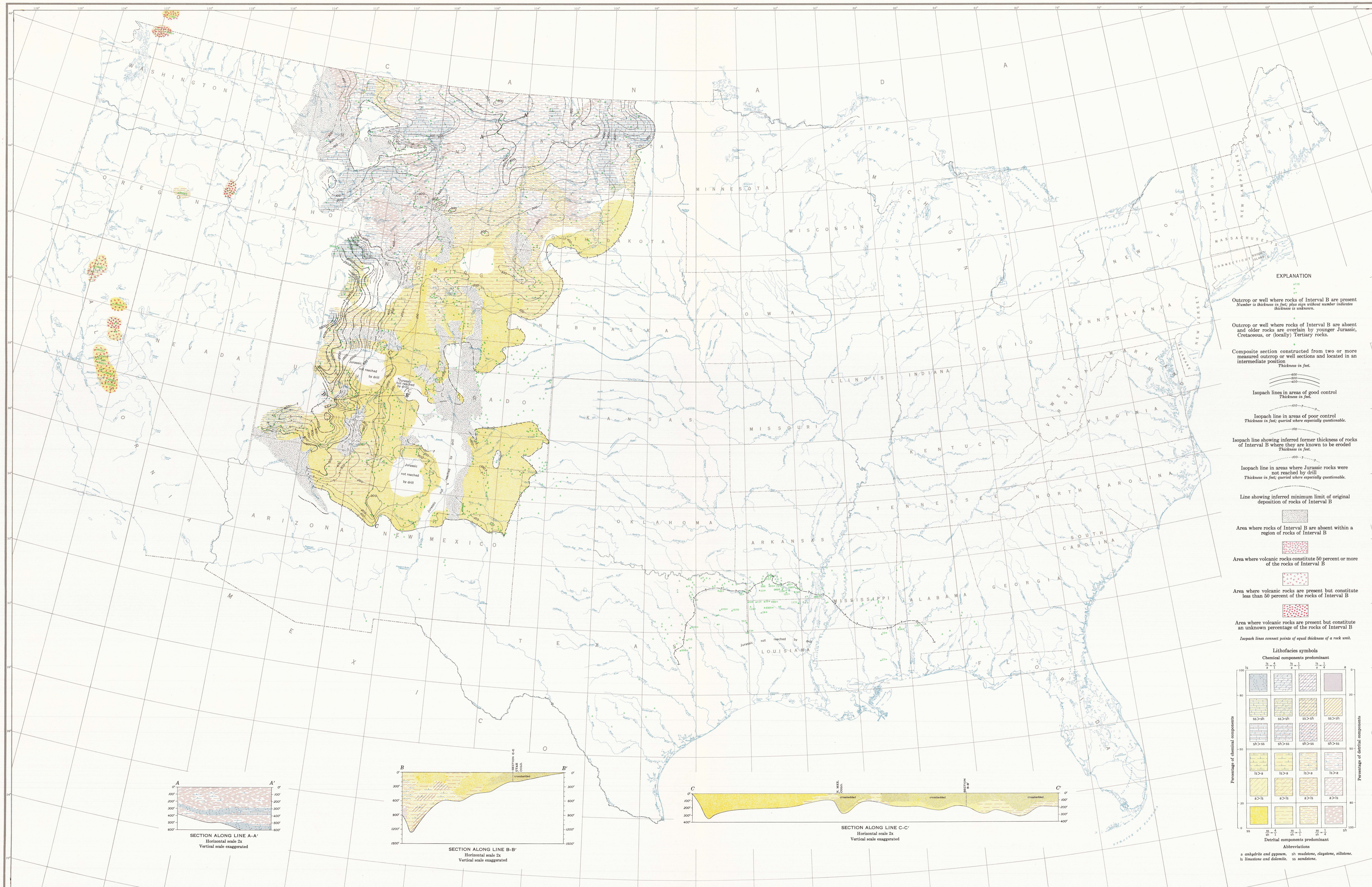
1956



LITHOFACIES AND THICKNESSES, INTERVAL A

Scale 1:5 000 000

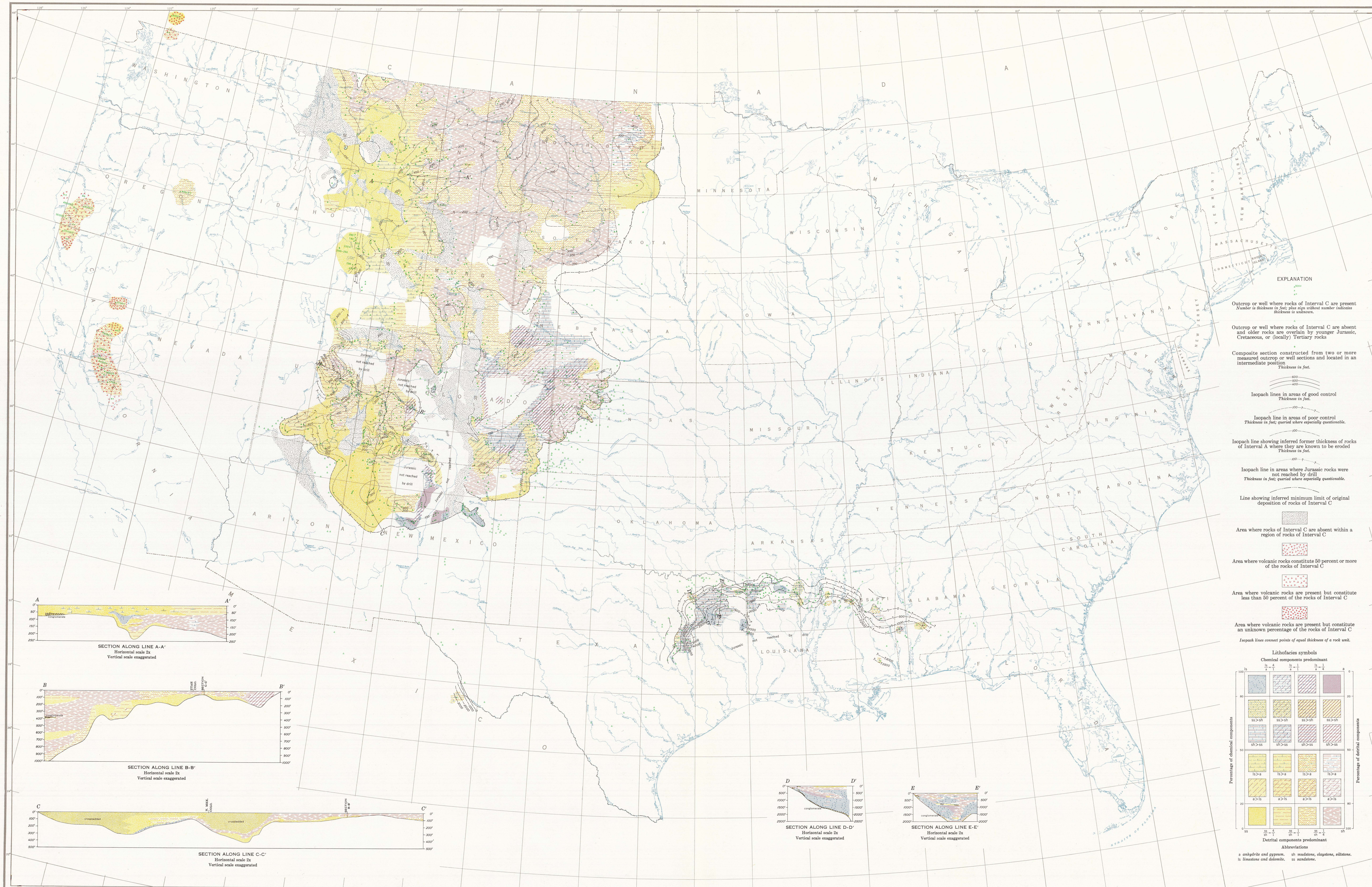
1956



LITHOFACIES AND THICKNESSES, INTERVAL B

Scale 1:5 000 000

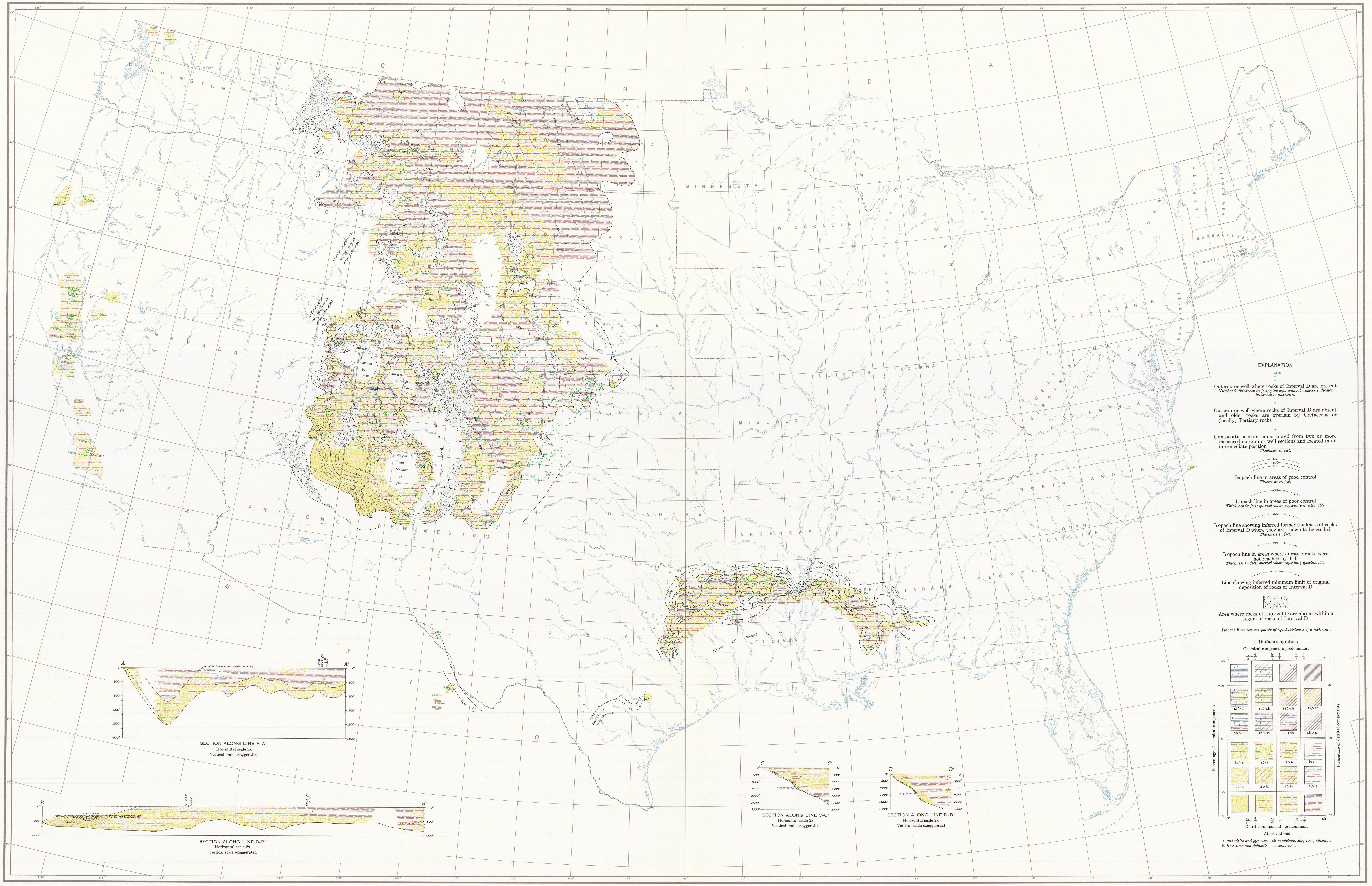
1956



LITHOFACIES AND THICKNESSES, INTERVAL C

Scale 1:5 000 000

1956



LITHOFACIES AND THICKNESSES, INTERVAL D

Scale 1:5 000 000

1956

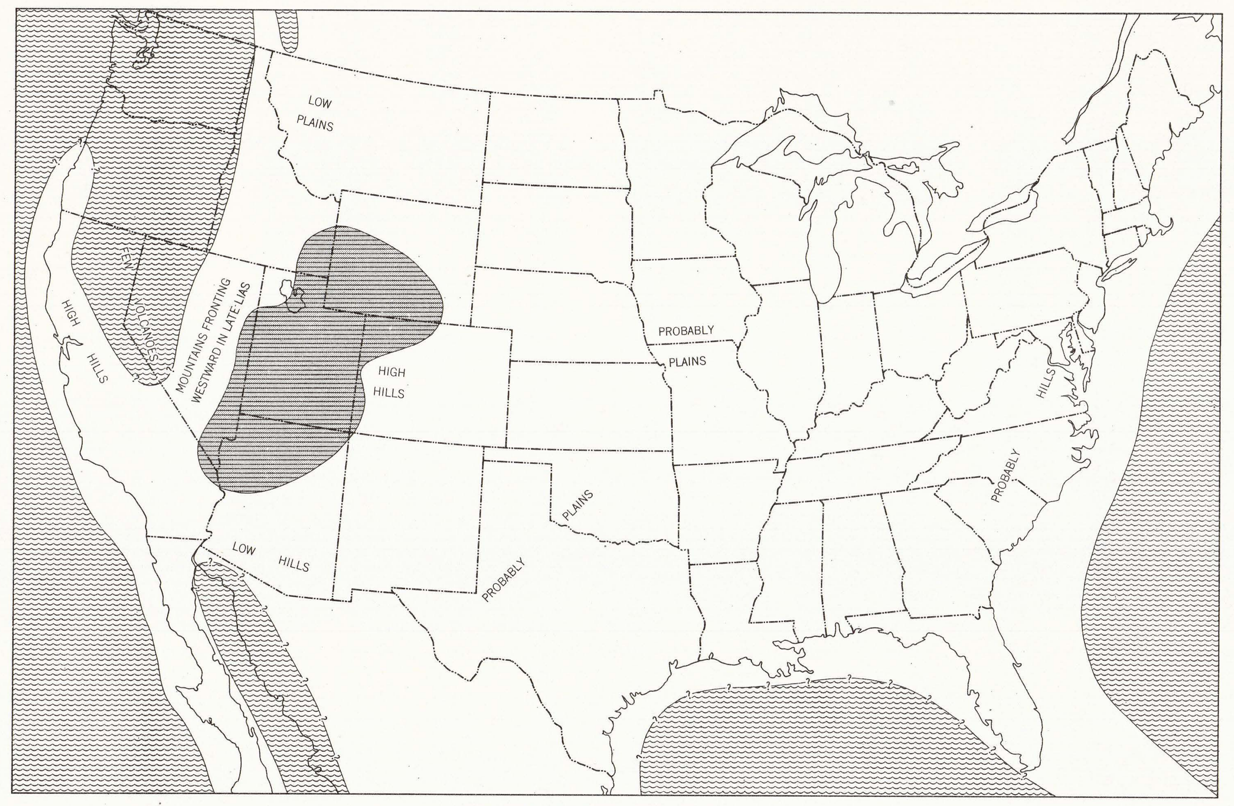


FIGURE 1.—EARLY JURASSIC (LIAS)

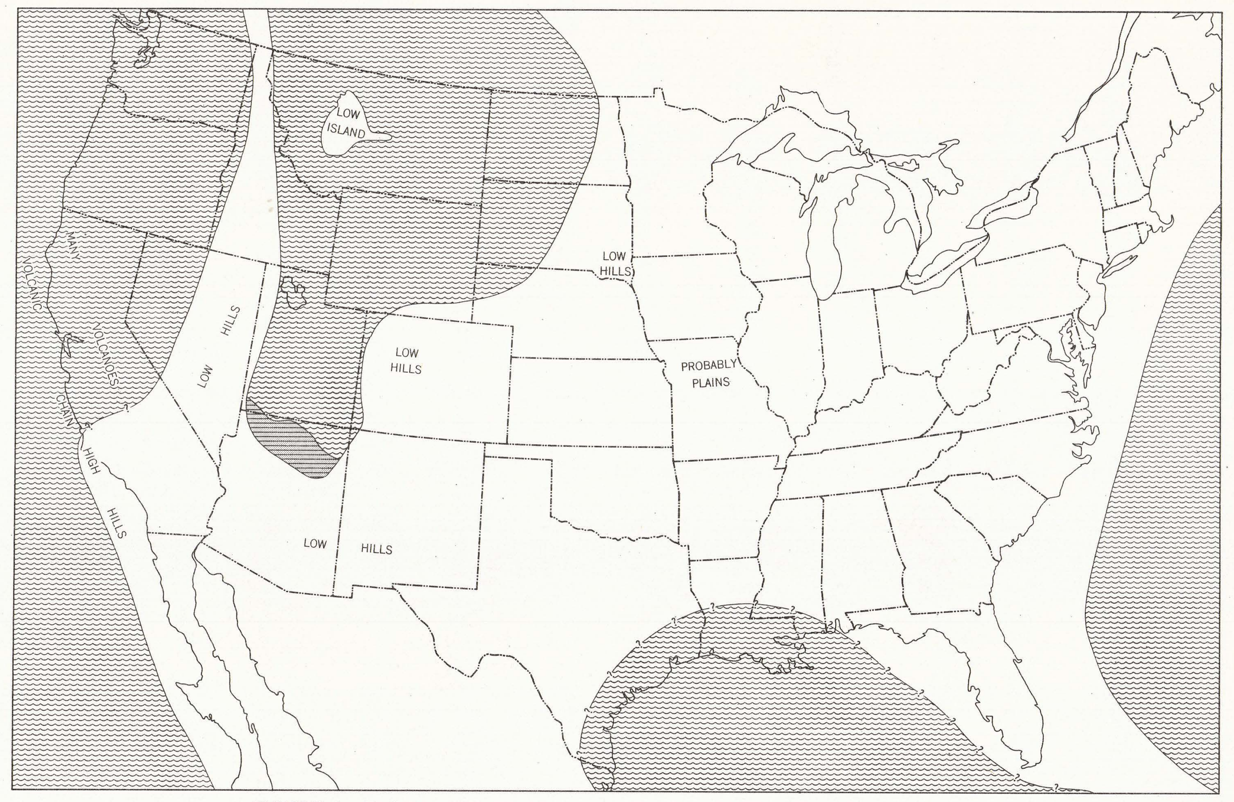


FIGURE 4.—EARLY LATE JURASSIC (EARLY AND EARLY MIDDLE CALLOVIAN)

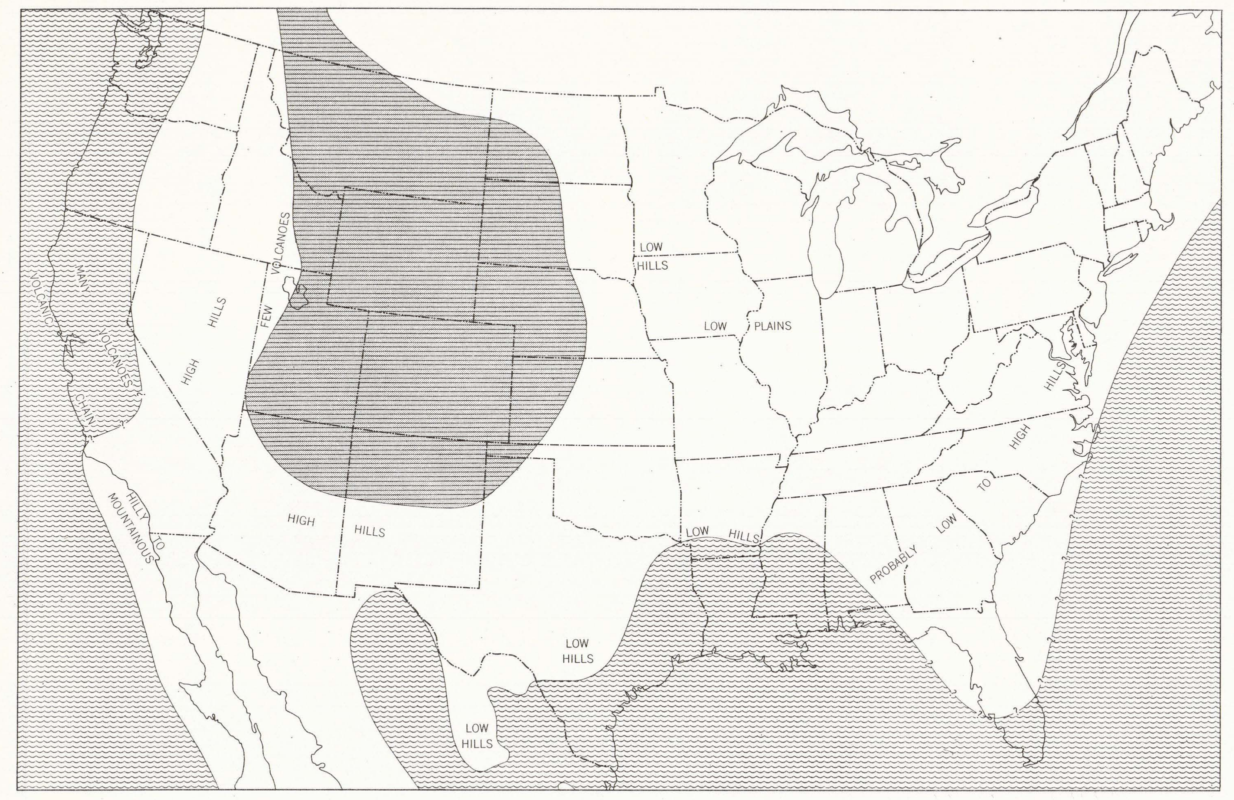


FIGURE 7.—LATE JURASSIC (EARLY KIMMERIDGIAN)

Method of preparation.—The accompanying paleogeographic maps are constructed from available field and laboratory data on the Jurassic of the United States and adjoining countries. Selection of time-rock units represented by each of the nine Jurassic maps is based on recently published correlation charts. Data concerning the extent of the time-rock units were originally plotted on large-scale maps, inferences regarding the physical features were then made, and the resulting interpretations were transferred to the smaller scale maps. These maps were checked by a number of geologists and most of the suggested modifications incorporated in the final maps.

These maps should not be considered final interpretations because many detailed paleontologic, stratigraphic, and ecologic studies remain to be made. They resemble only in a general way those made by Crickmay (1931) yet his maps were reasonable interpretations of the facts as then known and have been very useful. The present maps probably are accurate to within a few miles in certain areas that have been studied intensively, such as parts of the Colorado Plateau. They may be in error as much as two hundred miles in areas such as Nevada or North Dakota. It is hoped that these maps will stimulate criticism and encourage investigation that will be the basis for further development.

The time units selected for the paleogeographic maps are based on events in the Western Interior because the Jurassic of that region has been studied in greater detail than the Jurassic of the Southern States, or of the West Coast, and because the Jurassic rocks in the Western Interior represent a greater variety of environments than equivalent rocks in the other regions. This variety results from three cycles of marine invasion, three of widespread continental deposition, and at least three of widespread erosion. The lobate seas that entered the Western Interior region were much shallower than the broad seas bordering the continent and were subject, therefore, to more conspicuous environmental changes as a result of minor changes in sea level. For example, a relative fall of sea level of a few hundred feet in the Western Interior might have meant the difference between marine and continental deposition over a large area. However, the time units that illustrate most accurately the main events during the Jurassic in the Western Interior appear to correspond very well with the major events in other parts of the United States.

Fig. 1, Early Jurassic (Lias).—During Early Jurassic time only the northern part of the West Coast region was submerged. Continental deposition was widespread in the Western Interior. Sediments deposited in both regions during the earliest part of the Early Jurassic are considerably different lithologically from the later sediments of the Early Jurassic and in many respects are similar to those of the Late Triassic. The sea of the West Coast region became somewhat restricted in the later part of the subperiod, volcanoes arose within or along its borders, and highlands developed along its eastern and southern margins. Simultaneously the drainage direction in the Western Interior changed from southwestward to northward.

Fig. 2, Early Middle Jurassic (Bajocian).—During Bajocian time two seas covered parts of the western United States. One in the Pacific Northwest was a continuation of the Early Jurassic sea but was probably less extensive owing to uplift in Nevada in late Early Jurassic time. The other sea came from the area along the British Columbia-Alberta boundary and spread rapidly eastward into eastern North Dakota and southward into southwestern Utah. This sea must have been extremely shallow at first as its initial deposits over large areas south of northern Montana consisted of red clay and gypsum. These were succeeded in middle Bajocian time by normal marine calcareous sediment and red to gray clay. On these was deposited brownish-red clay that has not yielded diagnostic fossils and may be either latest Bajocian or early Bathonian in age. The distribution of gypsum and red beds appears to be related to the presence of a large island in north-central Montana and to submarine ridges extending southward and eastward from it. In contrast to the red beds and gypsum east of the island, the Bajocian rocks to the west consist mostly of pyritic, phosphatic dark-gray to black shale generally underlain by a few feet of marine pebbly sandstone. The limestone at the base of the Carmel formation in southwestern Utah is assumed to be of Bajocian age although diagnostic fossils have not been found.

Fig. 3, Late Middle Jurassic (Bathonian).—During the Bathonian stage the West Coast region was emergent. Diagnostic Bathonian fossils have not been found there, and in those places where detailed studies have been made no stratigraphic unit that might represent Bathonian time is present. The contact between the Bajocian and Callovian rocks indicates, however, that no appreciable uplift, folding, or erosion occurred during Bathonian time.

In the Western Interior the Bathonian stage probably is represented by a rock sequence less than 300 feet thick, but the faunal evidence of its age is not conclusive. The Bathonian age assignment is based mainly on the faunal and stratigraphic characteristics of the upper member of the Sawtooth formation in western Montana. This member contains the Bathonian to early Callovian ammonites *Arctocephalites* and *Procerites*, grades downward into beds of middle to late Bajocian age, and is overlain with apparent conformity by beds bearing many early Callovian ammonites. Furthermore, it contains many species of pelecypods similar to those in beds of Bajocian and early Callovian age of adjoining areas. The range of many of the most common species of pelecypods and gastropods from Bajocian into Callovian beds has been noted at many places in Montana and Wyoming and constitutes evidence that there was no important interruption in sedimentation there during the Bathonian stage.

The possibility that at least part of the upper member of the Sawtooth formation is of Callovian age must be considered because Frebold (1953) recently recorded the Callovian ammonite *Gadoceras* from beds similar to the Sawtooth formation in southern

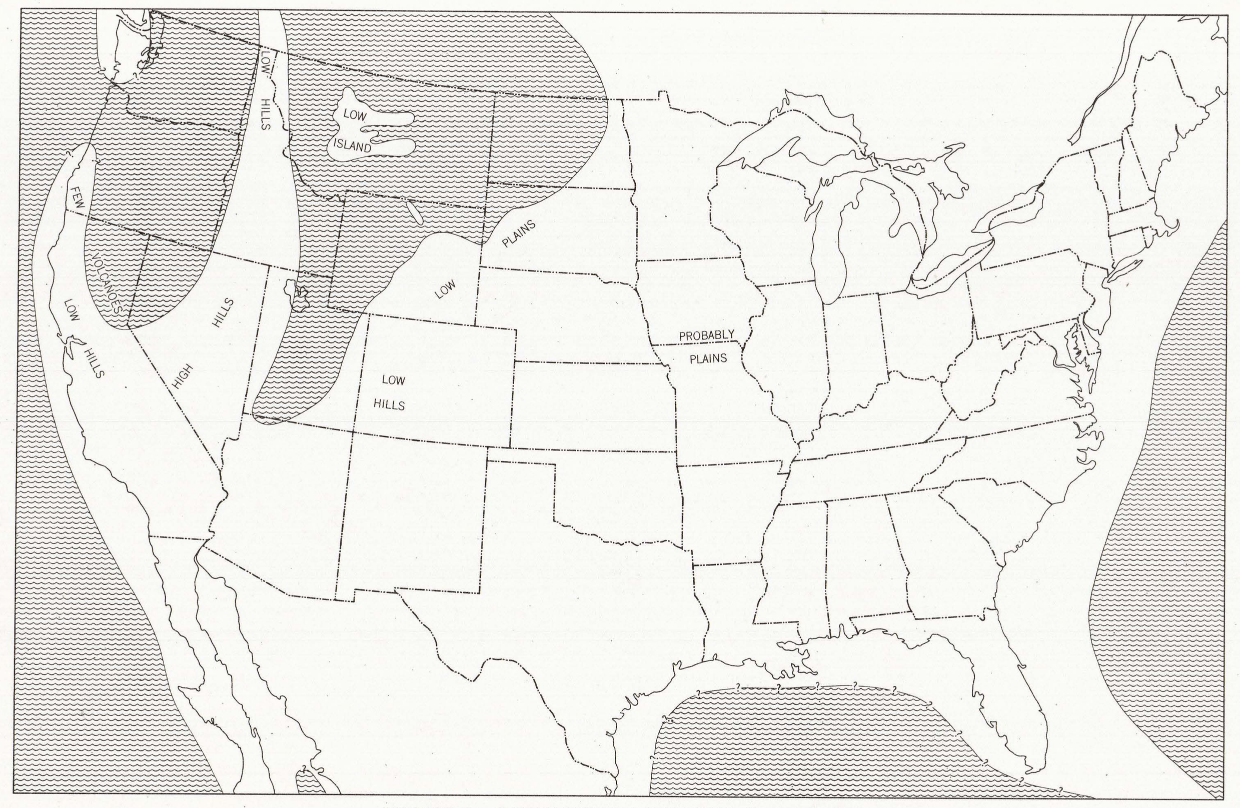


FIGURE 2.—EARLY MIDDLE JURASSIC (BAJOCIAN)

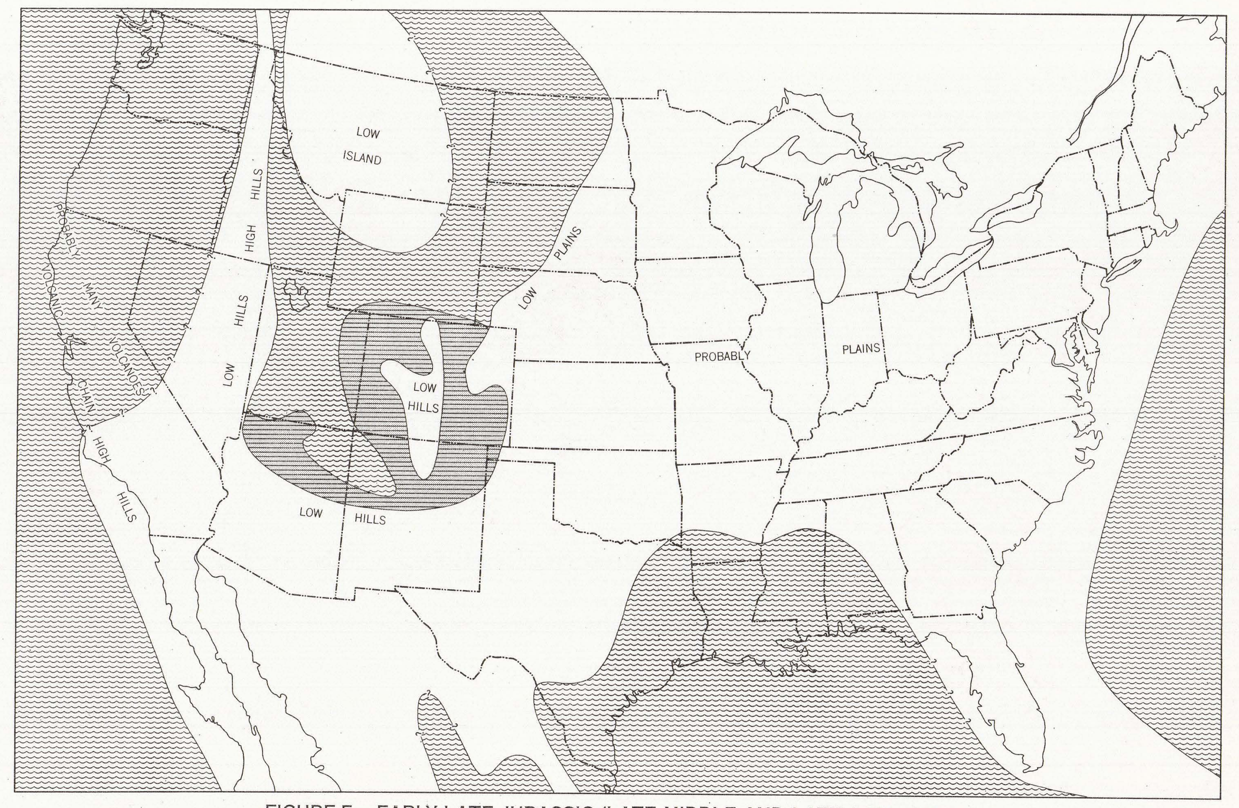


FIGURE 5.—EARLY LATE JURASSIC (LATE MIDDLE AND LATE CALLOVIAN)

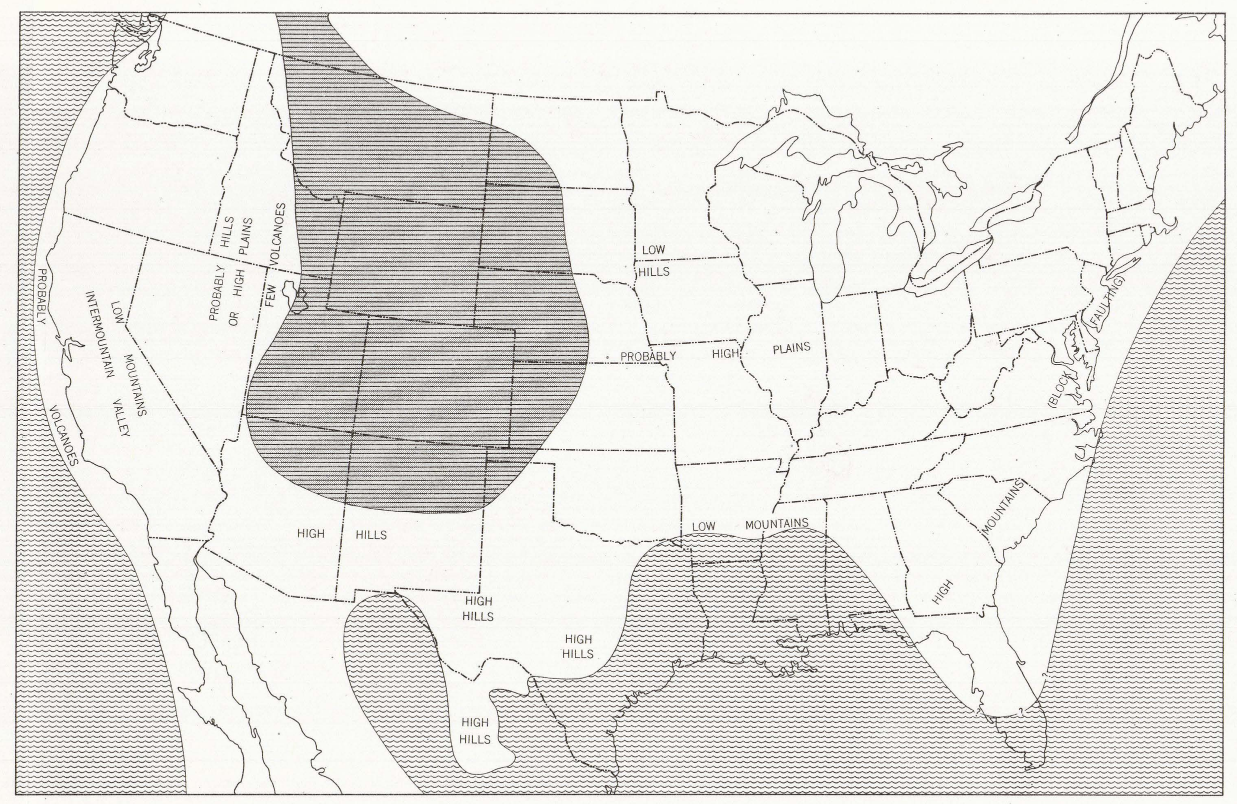
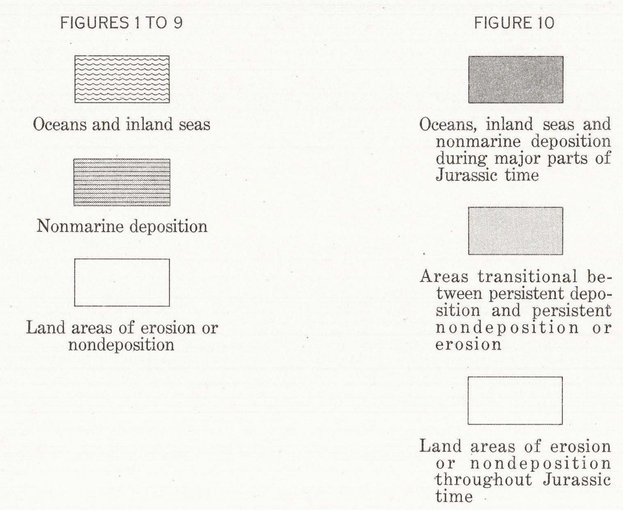


FIGURE 8.—LATE JURASSIC (MIDDLE KIMMERIDGIAN TO EARLY PORTLANDIAN)

EXPLANATION



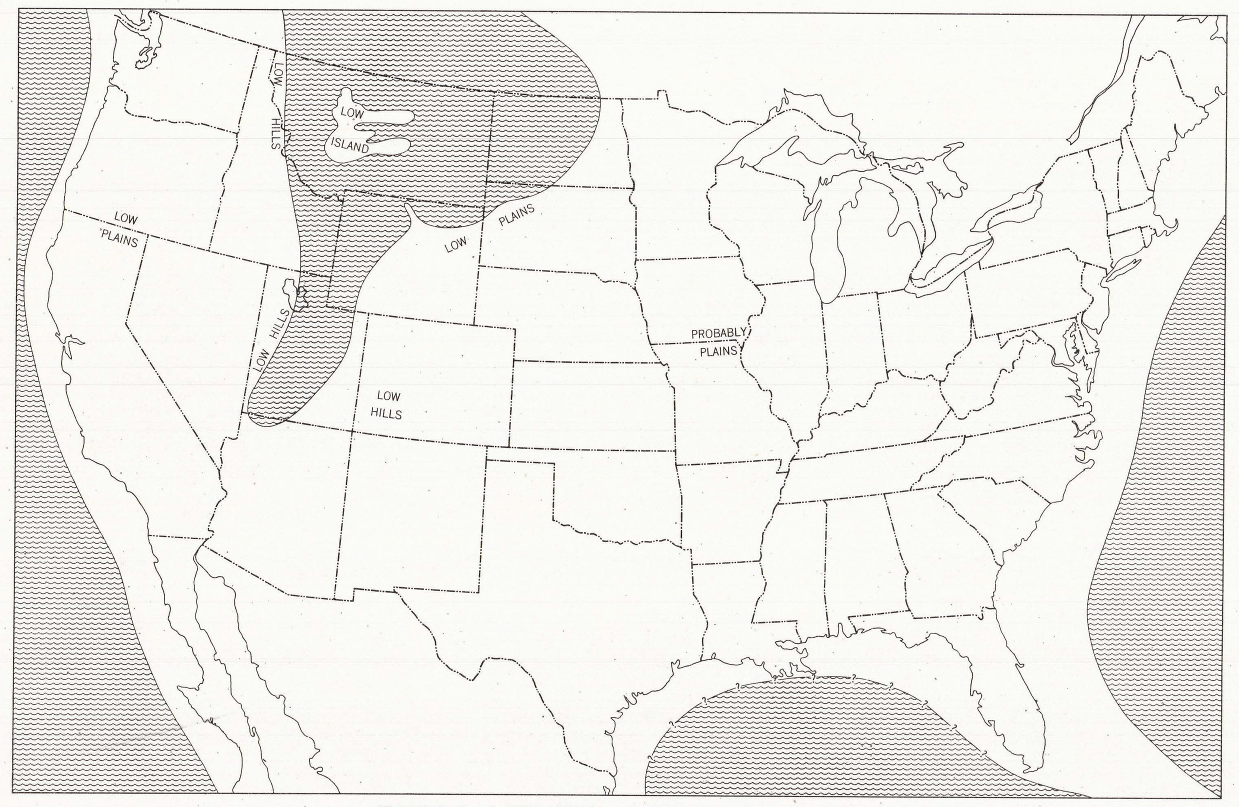


FIGURE 3.—LATE MIDDLE JURASSIC (BATHONIAN)

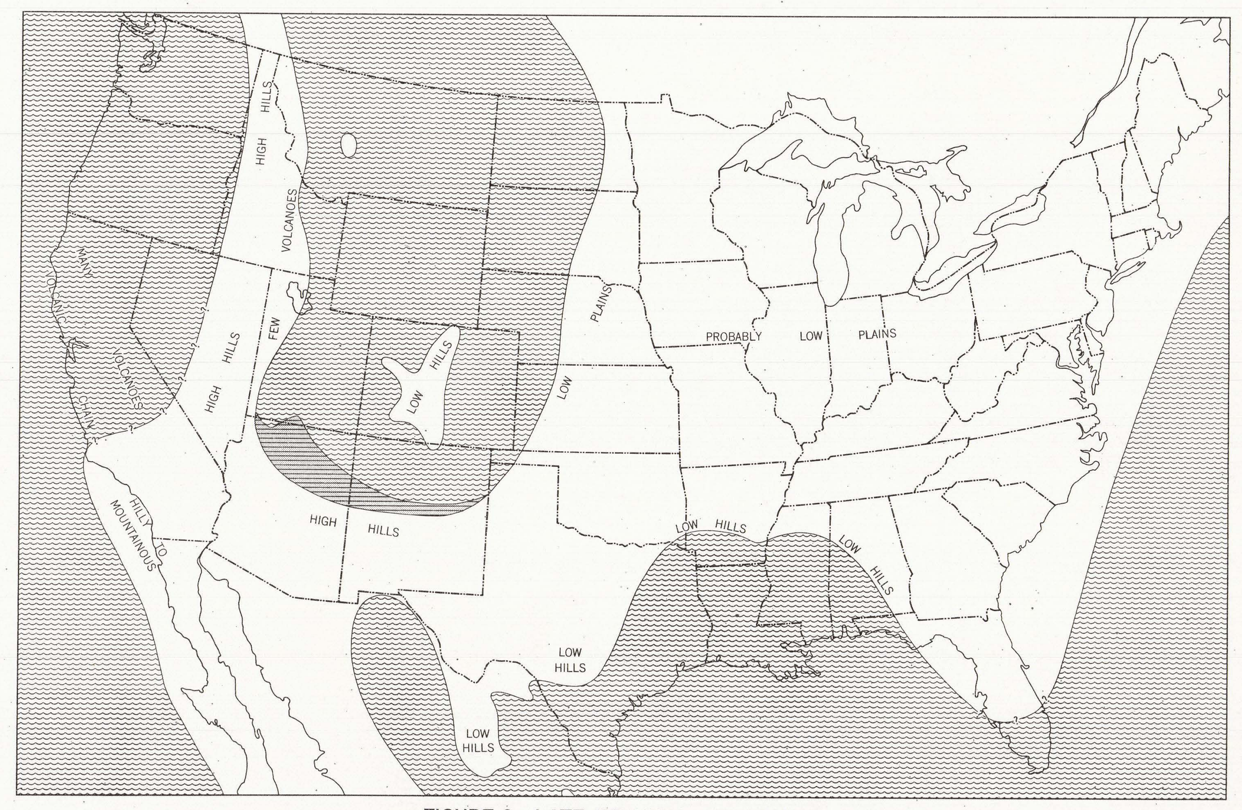


FIGURE 6.—LATE JURASSIC (OXFORDIAN)

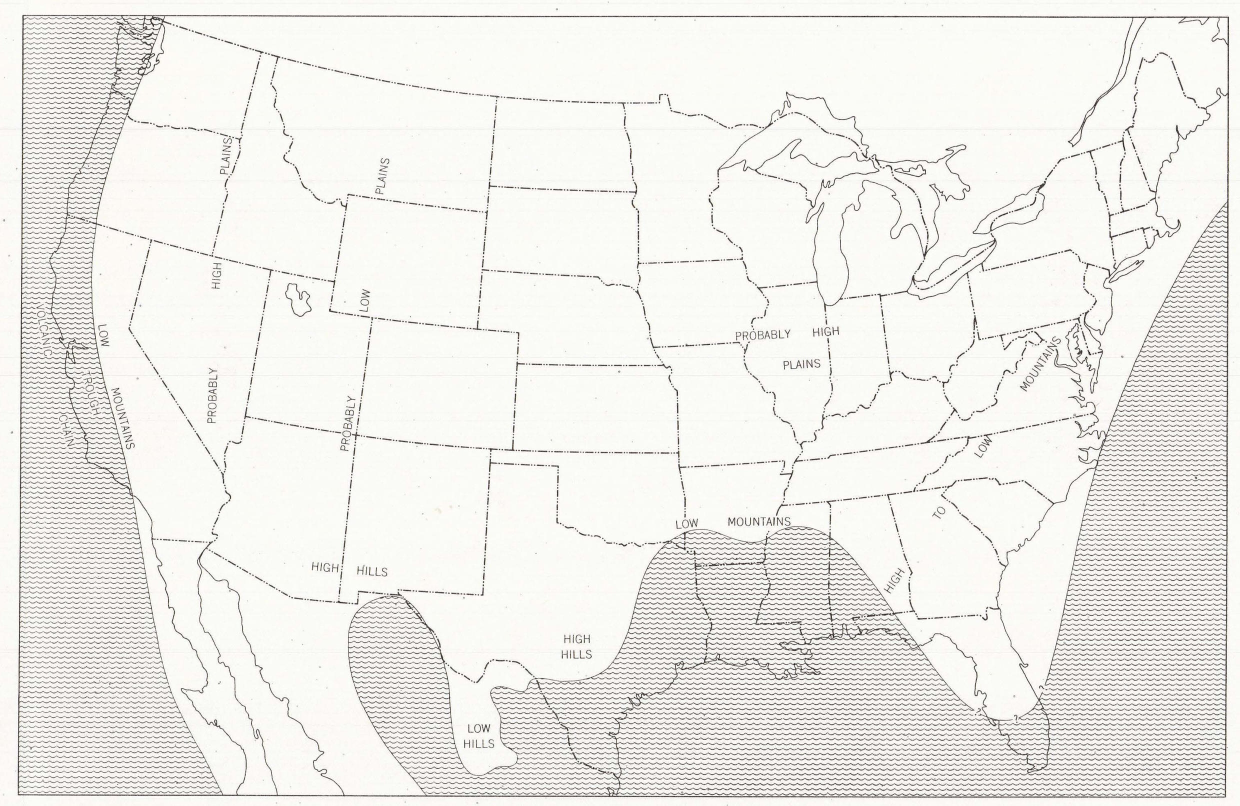


FIGURE 9.—LATE JURASSIC (MIDDLE TO LATE PORTLANDIAN)

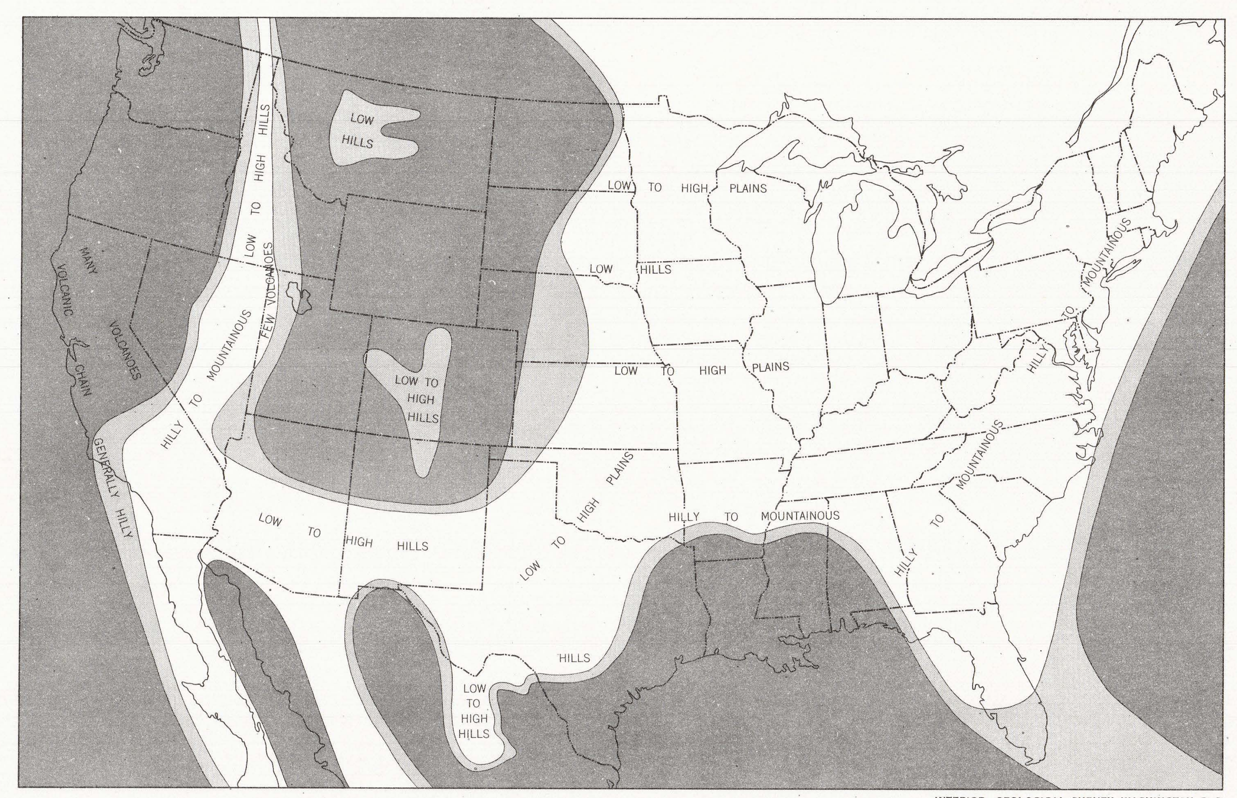


FIGURE 10.—FRAMEWORK OF THE JURASSIC BASINS

PALEOGEOGRAPHIC MAPS OF THE UNITED STATES DURING THE JURASSIC PERIOD

By
Ralph W. Imlay

1956

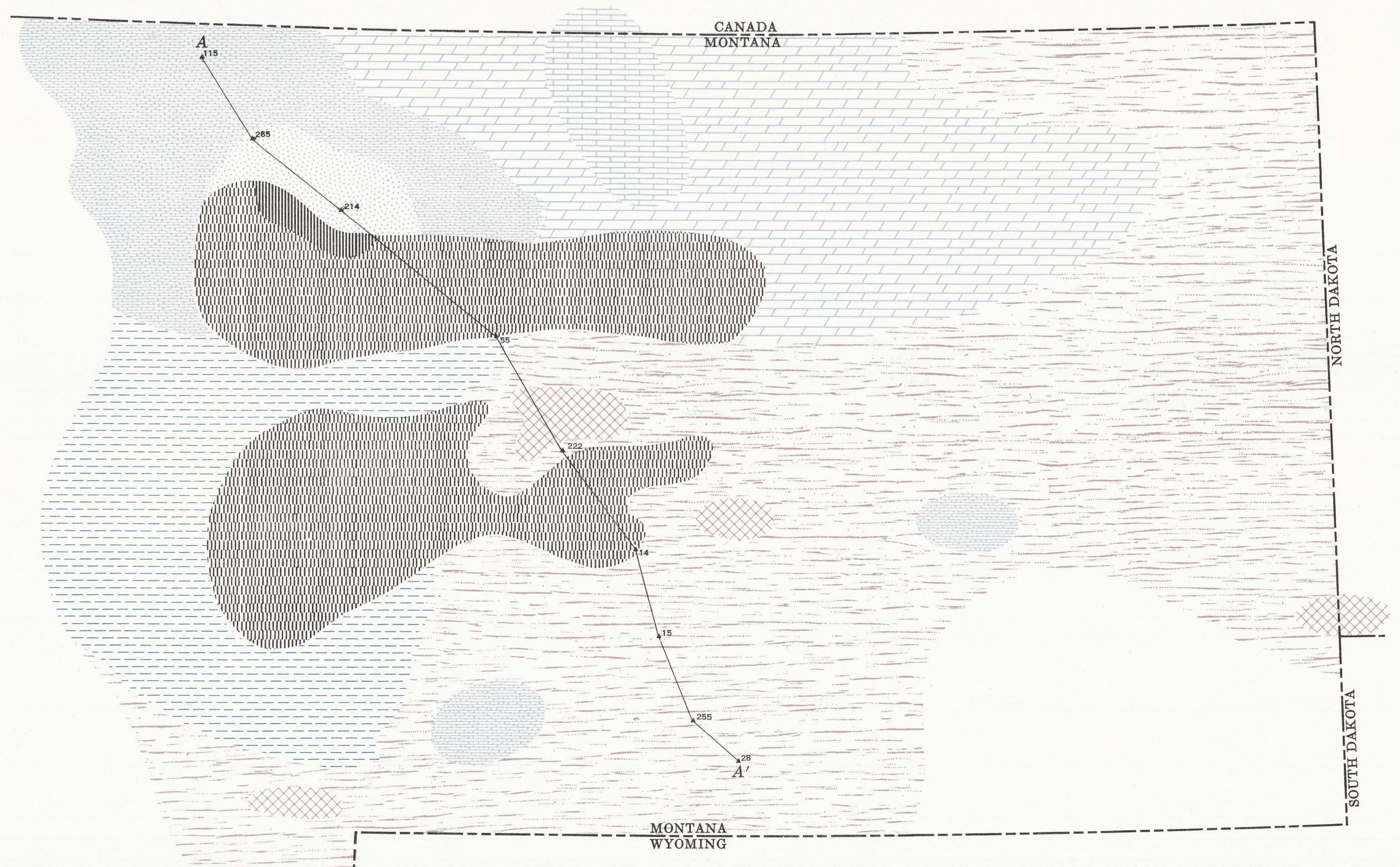
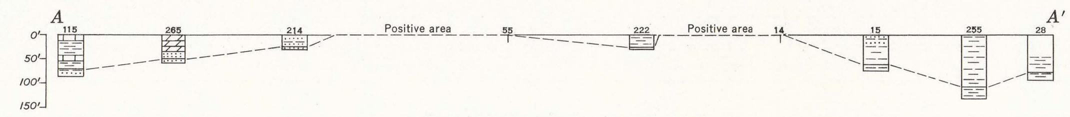


FIGURE 1.—MONTANA AT A TIME DURING DEPOSITION OF THE PIPER AND SAWTOOTH FORMATIONS—LOWER PART OF INTERVAL B

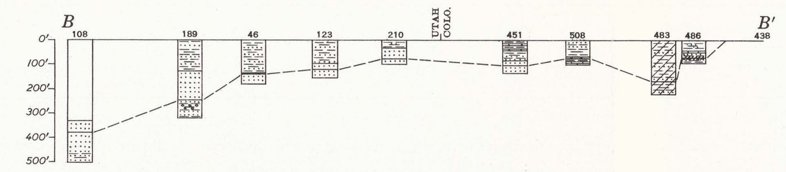
Scale 1:2 500 000

Datum: 1/5 above base of interval B



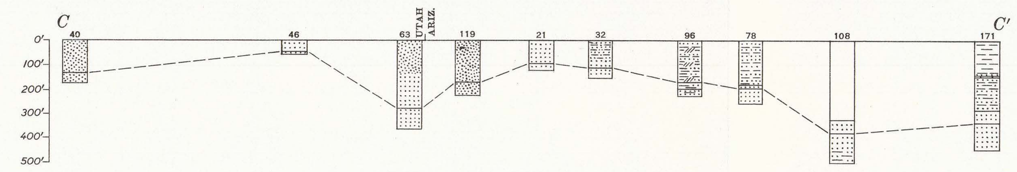
SECTION ALONG LINE A-A′ FROM FIGURE 1

Horizontal scale approximate



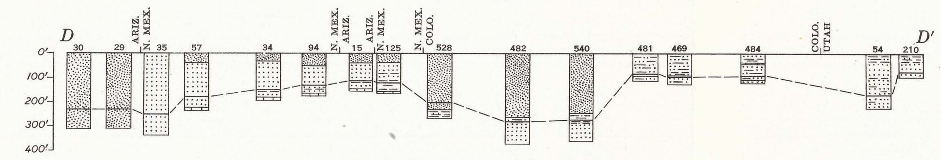
SECTION ALONG LINE B-B′ FROM FIGURE 3

Horizontal scale approximate



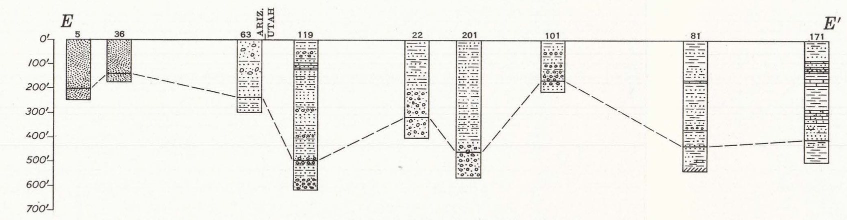
SECTION ALONG LINE C-C′ FROM FIGURE 3

Horizontal scale approximate



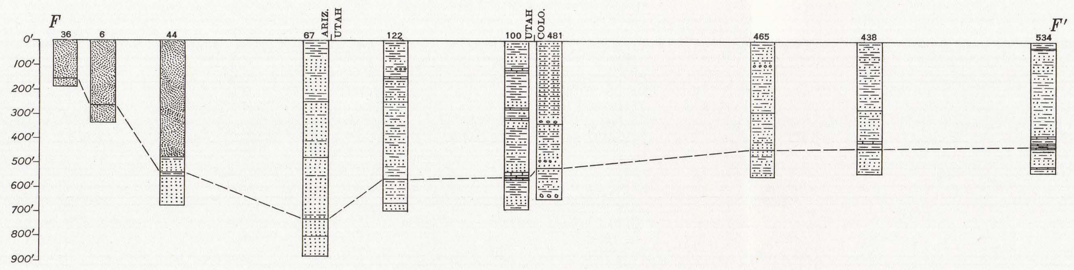
SECTION ALONG LINE D-D′ FROM FIGURE 3

Horizontal scale approximate



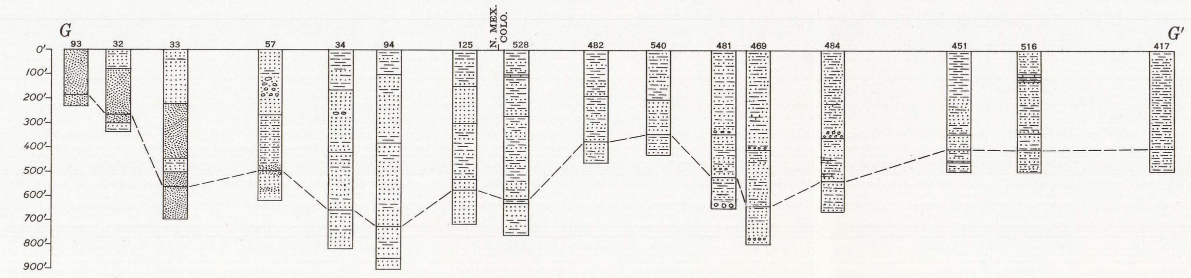
SECTION ALONG LINE E-E′ FROM FIGURE 4

Horizontal scale approximate



SECTION ALONG LINE F-F′ FROM FIGURE 4

Horizontal scale approximate



SECTION ALONG LINE G-G′ FROM FIGURE 4

Horizontal scale approximate

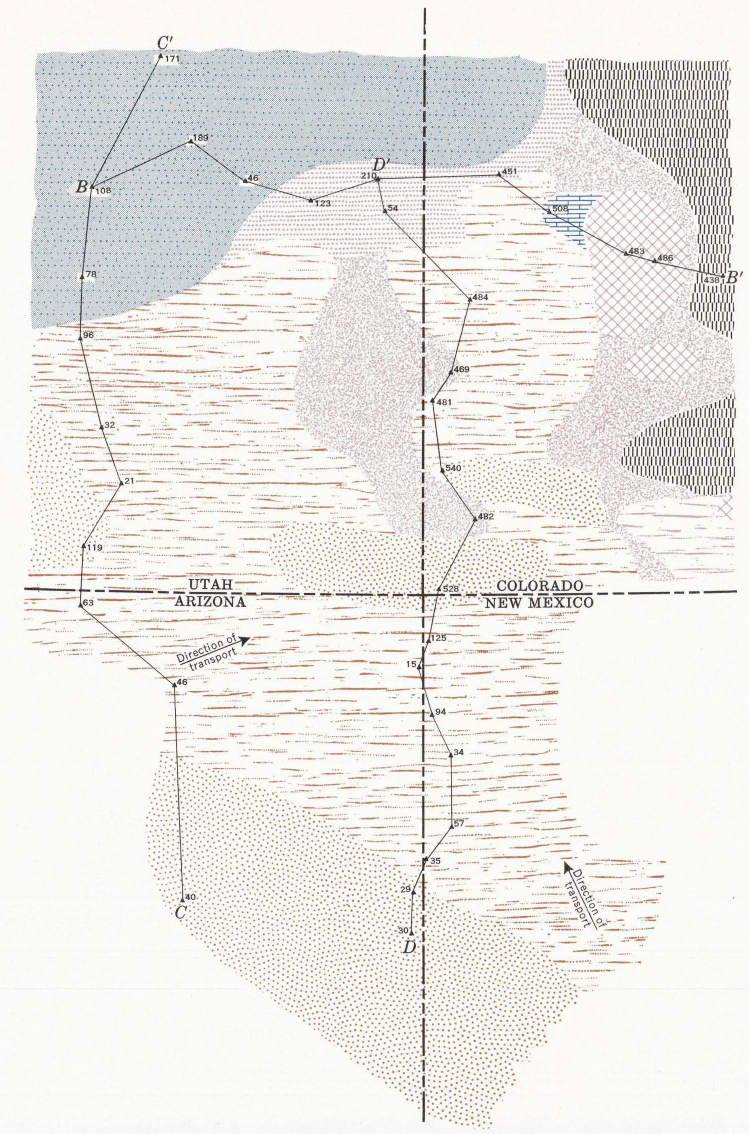


FIGURE 3.—COLORADO PLATEAU AT A TIME DURING DEPOSITION OF SEDIMENTS OF INTERVAL C

Scale 1:2 500 000

Datum: 1/4 above base of interval C

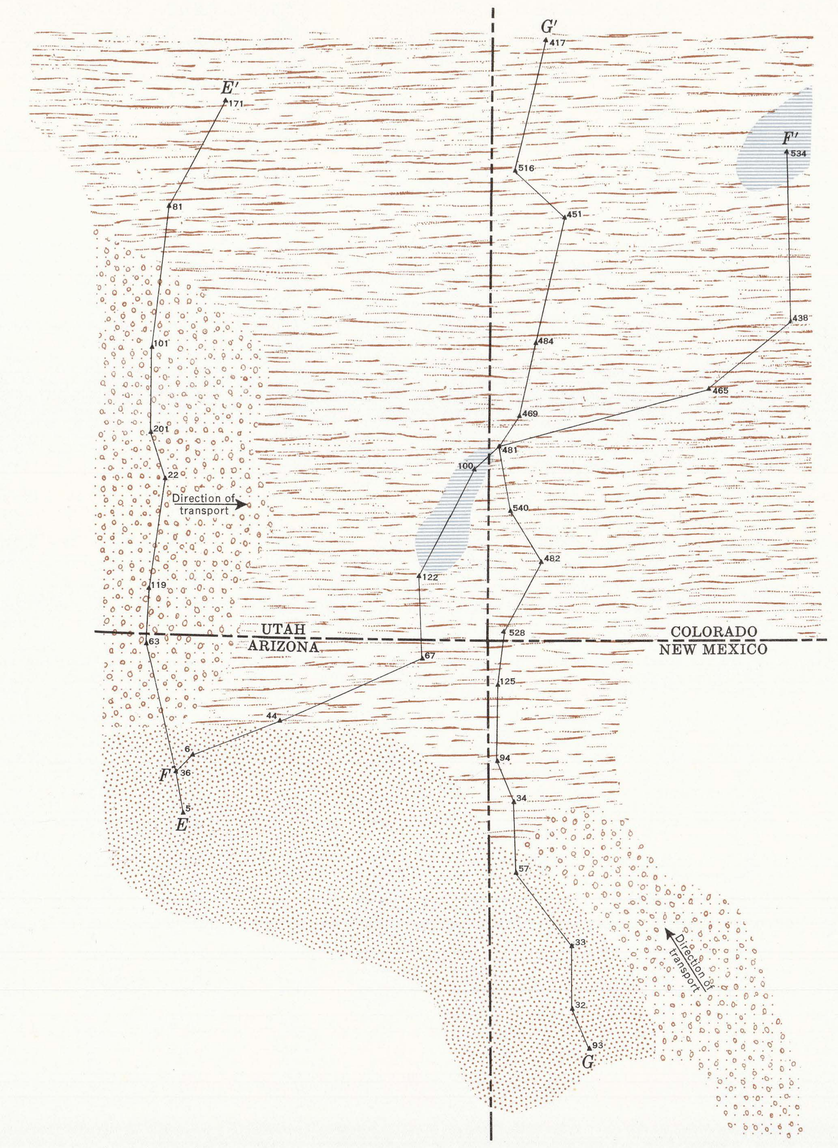


FIGURE 4.—COLORADO PLATEAU AT A TIME DURING DEPOSITION OF SEDIMENTS OF INTERVAL D

Scale 1:2 500 000

Datum: 1/5 above base of interval D

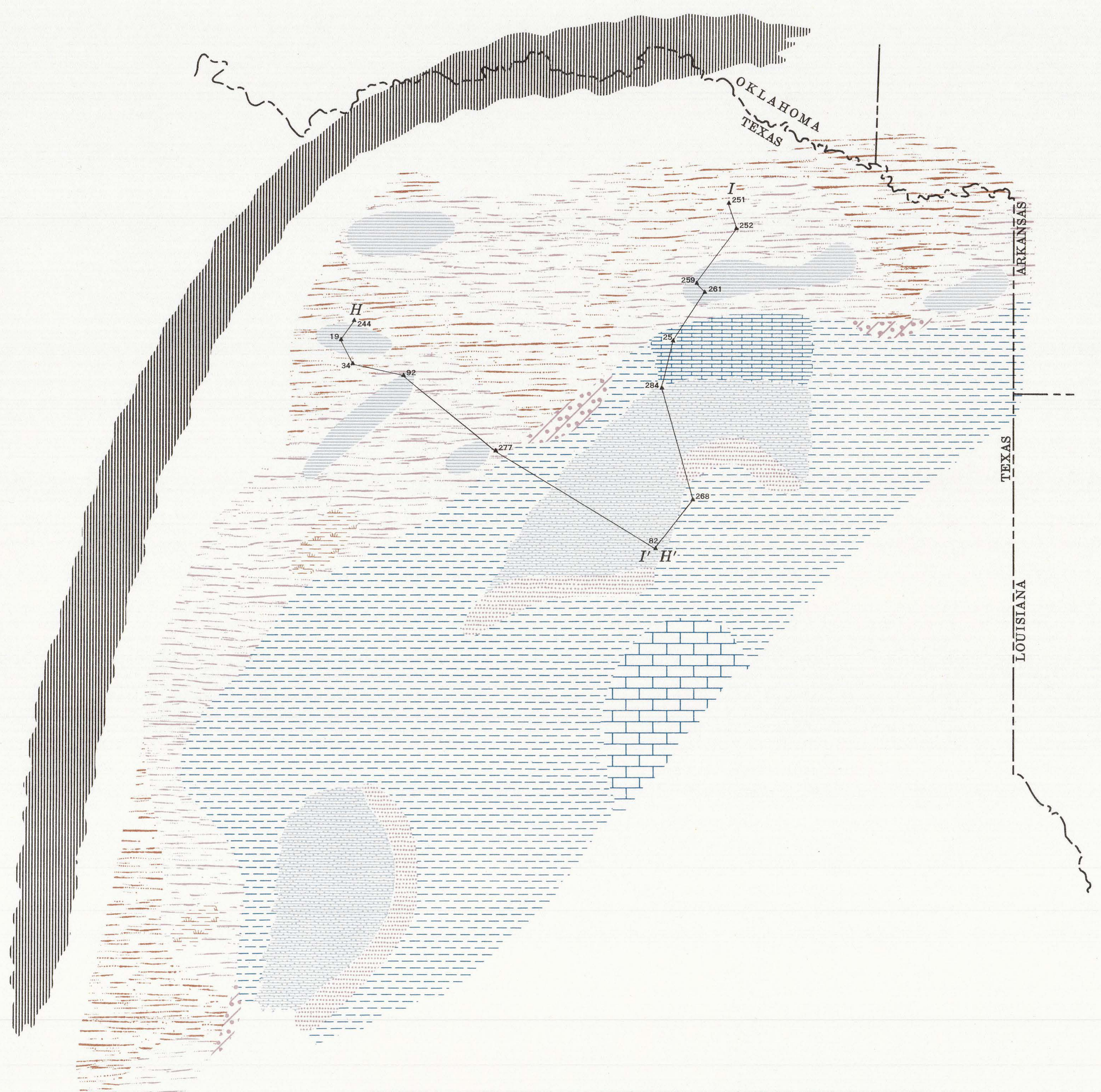
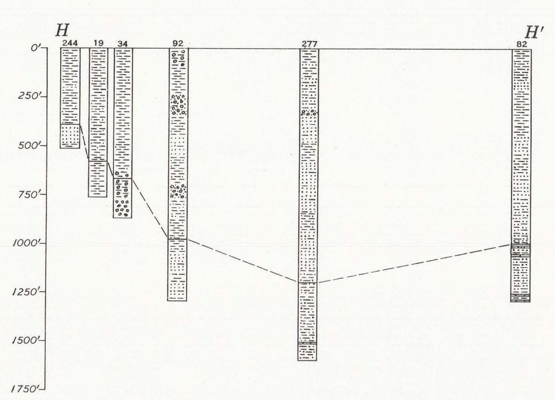


FIGURE 2.—EAST TEXAS AT A TIME DURING DEPOSITION OF THE SCHULER FORMATION—UPPER PART OF INTERVAL D

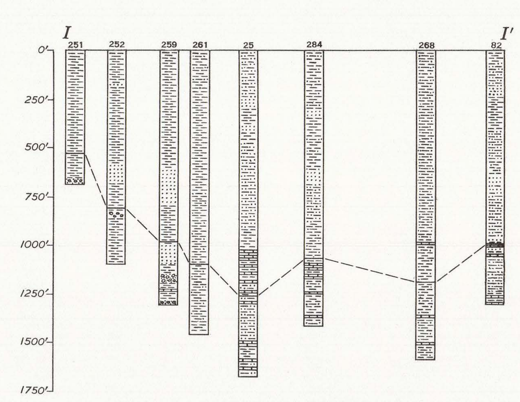
Scale 1:1 250 000

Datum: 1/4 above base of interval D



SECTION ALONG LINE H-H′ FROM FIGURE 2

Horizontal scale approximate



SECTION ALONG LINE I-I′ FROM FIGURE 2

Horizontal scale approximate

ENVIRONMENTAL MAP SYMBOLS

CONTINENTAL AREAS, NONDEPOSITION

- Elevated areas, source of detritals—epeirogenic
- Low positive areas, minor source of detritals

CONTINENTAL AREAS, DEPOSITION

- Dune
- Flood plain or alluvial plain
- Alluvial fan
- Coal swamp
- Playa or lake

MARGINAL AREAS, DEPOSITION

- Delta
- Beach or bar
- Lagoon—evaporite portion
- Lagoon—sand portion
- Flood plain or marginal mudflat
- Playa or lake

MARINE AREAS, DEPOSITION

- Sea, normal circulation—mud
- Near shore—lime
- Sea, normal circulation—normal lime
- Sea, normal circulation—sand
- Near shore—dolomite
- Sea, restricted circulation—black lime
- Sea, restricted circulation—black mud
- Sea, restricted circulation—sand

▲15 Location of well or outcrop used in construction of cross section

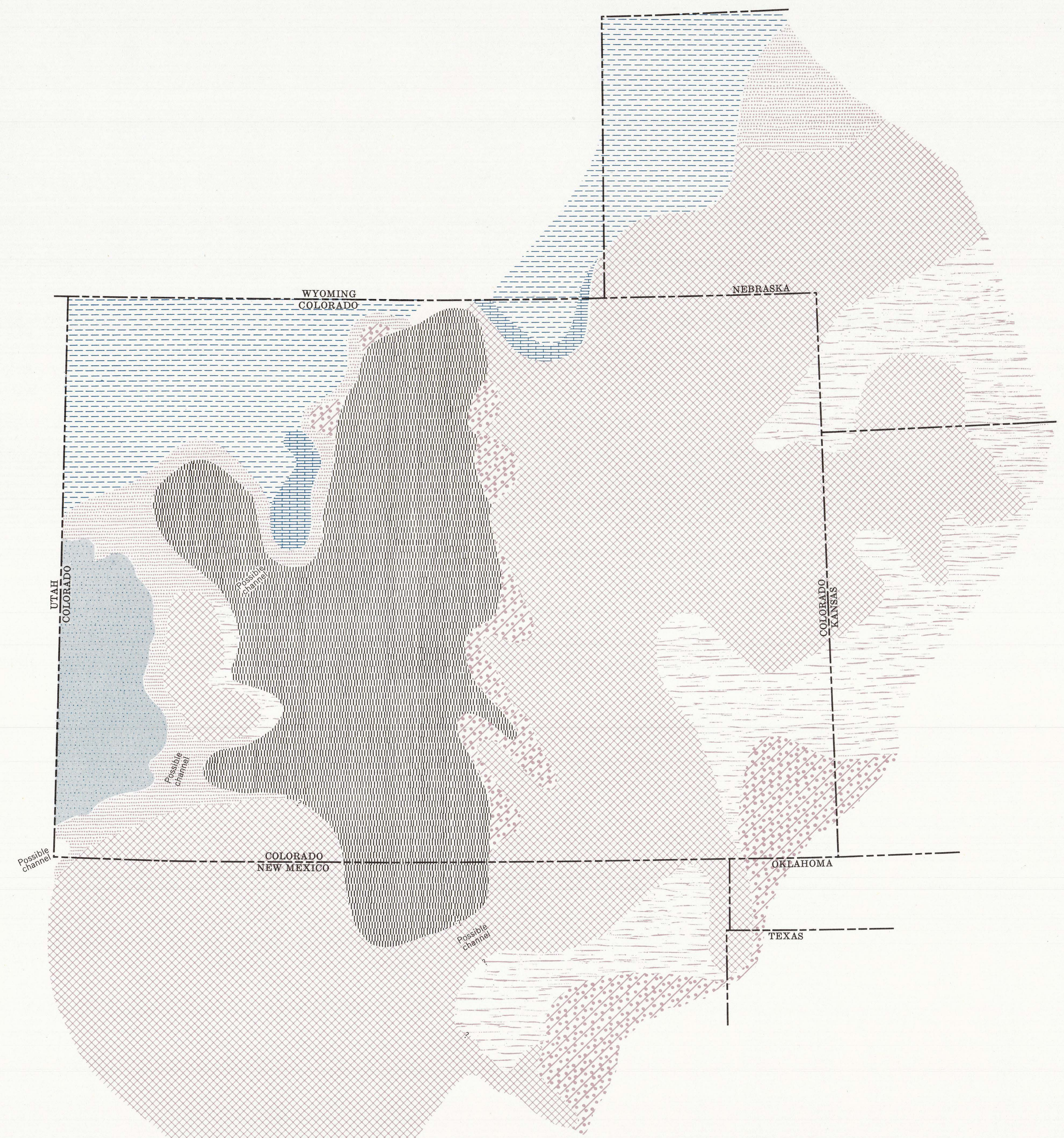


FIGURE 5.—COLORADO PLATEAU-KANSAS-NEBRASKA DURING DEPOSITION OF SEDIMENTS AT BEGINNING OF INTERVAL C

Scale 1:2 500 000

Datum: base of interval C

ENVIRONMENTS OF DEPOSITION OF JURASSIC SEDIMENTS FOR SELECTED TIMES AND PLACES

1956