Notes for the Acrobat Version of PP901

Professional Paper 901 contains a history of geologic maps of the conterminous USA and a description of the compilation of the 1974 map. Presently, PP901 remains out of print and no longer available. For this CD-ROM publication, digital versions of PP901 in several different formats were prepared.

The Acrobat version of PP901 was created by scanning the original book and converting to searchable text with optical character recognition software. The illustrations were saved as bitmaps. The entire book is present in this Acrobat document.

The original book was typeset with two columns per page. In the interest of legibility on the computer display screen, the Acrobat document has been reformatted to display the columns sequentially, one column at a time, each column now filling an entire 8.5”x11” page width. For this reason, the Acrobat page breaks may differ from the original. The original page breaks are depicted by page numbers surrounded by asterisks at the top of each “original” page as in *Page 1*. Also, most of the hyphens in words continued on the next line have been eliminated.

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EXPLANATORY TEXT TO ACCOMPANY THE GEOLOGIC MAP OF THE UNITED STATES

By Philip B. King and Helen M. Beikman

Geological Survey Professional Paper 901

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EXPLANATORY TEXT TO ACCOMPANY THE GEOLOGIC MAP OF THE UNITED STATES

By Philip B. King and Helen M. Beikman

INTRODUCTION

The U.S. Geological Survey has published a new Geologic Map of the United States (exclusive of Alaska and Hawaii) on a scale of 1:2,500,000, which was compiled between 1967 and 1971 by Philip B. King and Helen M. Beikman, with geologic cartography by Gertrude J. Edmonston. The map replaces the now outdated Geologic Map of the United States on the same scale, which was compiled by George W. Stose and Olof A. Ljungstedt and was issued by the U.S. Geological Survey in l932.

This report is intended to supplement the new map and to provide background information to assist its user in interpreting it. It describes the historical antecedents of the map and the sources from which the map was compiled and discusses various general topics related to it. Succeeding reports will amplify the necessarily brief descriptions of the map units which appear in its legend and will deal at length with specific geological problems in the United States, insofar as they relate to representation of the features in map form.

PREVIOUS GEOLOGIC MAPS OF THE UNITED STATES

SOURCES OF INFORMATION

Source data for previous geologic maps of the United States are plentiful, so we have chosen here to present a narrative account, describing the circumstances under which the maps were prepared and commenting on their more interesting features, rather than list details which the reader can find in the published sources. Maps that appeared before the mid-188O's have been listed and annotated by Marcou and Marcou (1884, p. 23-32) and have been described at length by C. H. Hitchcock (1887); Jillson (1950) has extended the listing to 1946. In our account we have ignored many maps that appear in these published lists as being merely reprints in the same or slightly different form by a single author, or copies of such maps in textbooks and other media. Much information on the circumstances of geologic maps published by the U.S. Geological Survey can be found in the Annual Reports of the Survey. Interesting contemporary reviews of some of the maps are cited in "Geologic literature on North America, 1785-1918" (Nickles, 1923). For our narrative, we have obtained background information from Merrill's "Contributions to the history of American Geology" down to 1880 (1906), and from biographies of later geologists, such as the Memorials of the Geological Society of America, Darrah's "Powell of the Colorado" (1951), Stegner's "Beyond the Hundredth Meridian" (1954), and Willis's autobiographical "A Yanqui in Patagonia" (1947, especially p. 30-35). Copies of most of the maps referred to here are in the files of the Library of the U.S. Geological Survey, and we are indebted to Mark Pangborn, curator of these maps, for his generous assistance.

MAPS PUBLISHED BEFORE 1860

Efforts to portray on a map the geology of what is now the United States extend back more than two centuries. The first recorded attempt is a "Mineralogic map, showing the nature of the terrains of Canada and Louisiana" ("Carte minéralogique où l'on voit la nature des terrains du Canada et de la Louisiane"), by the French geologist Jean Étienne Guettard, published in 1752, at a time when a large part of the region was still French territory. Whether he visited North America is not certain, and most of his information was compiled from reports of French officers. A belt of marl and clay is shown extending from the Gulf of Mexico to Cape Breton Island, and thence inland toward Quebec. Between it and the coast is a sandy belt, and west of it a schistose and metalliferous belt. Different signs and annotations indicate the places where rocks and minerals were reported between the Atlantic Coast and the Rocky Mountains.

Aside from this primitive effort, the first geologic map of the United States is that published by William Maclure in 1809, of which a revised version appeared in 1817. Maclure was a Scotsman

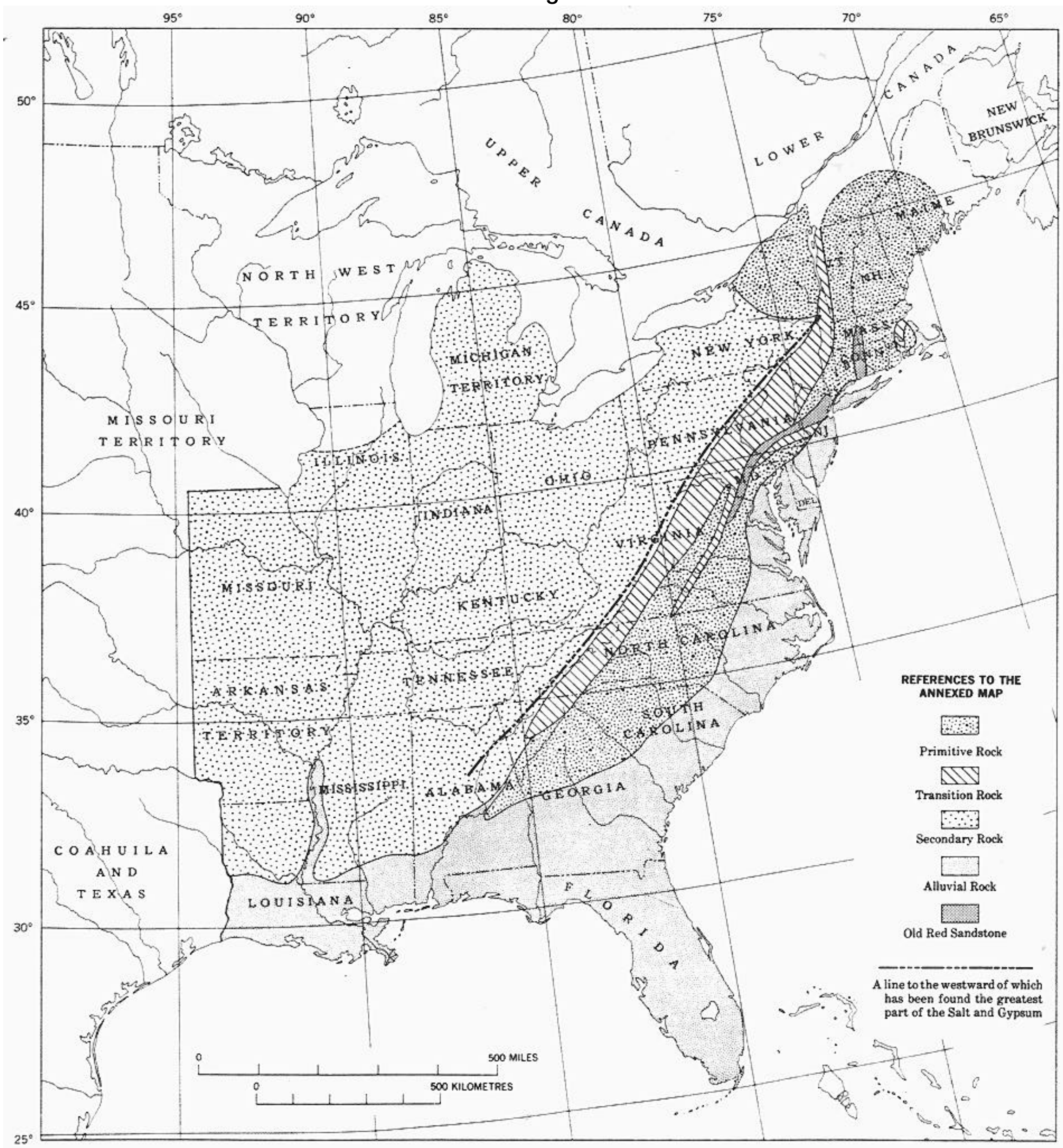

Figure 1.—Geology of the United States as represented by Maclure (1817). Original map in color. Note: To facilitate comparison of figures 1 through 4, the original geological representations have been replotted on the same projection and base. State and national boundaries are retained as they existed at the times of publication; in figures 3 and 4 the geography west of the Mississippi River and within the coastlines is retained as on the originals.

who came to America as a merchant and after his retirement became interested in the sciences; for 22 years he was president of the Philadelphia Academy of Natural Sciences. To

assemble his map, he traveled widely through what was then the United States, and especially the part east of the Mississippi River. Both editions of his map were accompanied by an explanatory text, including "remarks on the effect produced on the nature and fertility of the soils by the decomposition of the different classes of rocks."

In accord with the prevailing thinking of his day, Maclure classified the rocks on Wernerian principles, dividing them into Primitive, Transition, Secondary or Floetz (including a unit of Old Red Sandstone), and Alluvial. On the map of 1817, a line is marked along the Appalachians "to the westward of which is found the greatest part of the Salt and Gypsum." In modern terms, his "Primitive Rock" corresponds to the Precambrian and other crystalline rocks of the Adirondack Mountains, New England, and the Piedmont Province; his "Transitional Rock" to the folded Paleozoic of the Appalachians; his "Secondary Rock" to the flat-lying Paleozoic farther west; his "Old Red Sandstone" to the Triassic Newark Group; and his "Alluvial Rock" to the Cretaceous and Tertiary deposits of the Coastal Plain.

No significant geologic maps of the whole United States appeared for many years after Maclure's publication, but important maps of parts of the region were made. The most notable was that by James Hall which accompanied his classic Part 4 of "Geology of New York" (1843), dealing with the western part of the State and establishing the fundamentals of Paleozoic stratigraphy in a large part of the country. The map includes not only Hall's survey in New York but also his reconnaissance observations farther west and represents in fair detail the Northern States as far south as Virginia and as far west as the Mississippi River on a scale of 1:1,850,000. In addition, geology was also sketched on maps showing the routes of some of the exploring expeditions, such as that of Major S. H. Long's expedition to the Rocky Mountains (James, 1823), and David Dale Owen's to the northern Middle Western States (1843).

In 1845, Sir Charles Lyell published an account of his epochal travels in North America in 1841 and 1842, which was accompanied by a "Geological Map of the United States, Canada, etc., compiled from the State Surveys of the U.S. and other sources" on a scale of 1:7,620,000. (The sources of the map are described at length at the end of the book: v. 2, p. 198-219.) Wernerian concepts had by now disappeared, and the rocks were divided into conventional systems and series (Hypogene, Potsdam, Lower Silurian, Upper Silurian, Devonian, Coal Measures, New Red Sandstone, Cretaceous, Eocene, Miocene, and others). These are shown in much detail westward as far as the Mississippi River, and more vaguely for several hundred miles farther west. The map illustrates vividly the improvements that had been made in representation since the last Maclure map of 1817, as a result of geological mapping in the United States during the intervening 28 years.

Between 1845 and 1853 the territory of the United States was extended northward, southward, and westward to its present conterminous limits by various acquisitions, which greatly expanded the field for geological exploration and mapping and also enlarged the problem of making a geological map of the United States.

Between 1853 and 1858, Jules Marcou produced a succession of geological maps of the United States, the later ones extending to the Pacific Coast. Marcou was a Frenchman, who came to this country as a protege of Louis Agassiz and became a controversial figure. His representation of the western country was based in part on his service with some of the exploring expeditions for the Pacific Railroad, but to an even greater extent on freehanded extrapolation and speculation. His maps received harsh reviews from his none-too-friendly American colleagues (Hall, 1854; Blake, 1856), one of whom stated that "there is here a disregard of published results and an audacious attempt at generalization that has seldom been equalled." Viewed from a distance of more than a century, one can deplore Marcou's failure to use available data yet commend his bold attempt to present the general geological aspect of the western country, which his contemporaries had been reluctant to do.

James Hall, one of Marcou's critics, in collaboration with J. P. Lesley, compiled a geological map of the region west of the Mississippi for the report of the United States and Mexican Boundary Survey (Hall and Lesley, 1857), based not only on the results of the boundary survey, but also on the Pacific Railroad surveys and other expeditions. Their map represented only the areas of outcrop that had been identified or reasonably inferred and left the remaining areas uncolored. Thus, no regional picture emerges, such as the one attempted by Marcou.

Less commendable than these was a contemporary map of the United States by Edward Hitchcock, professor of geology at Amherst College, which accompanied his "Outlines of the geology of the globe, and of the United States in particular" (1854). This map was made by combining Lyell's geologic map of the eastern part of the country with the representation of the western part from Boué's "Geological Map of the World," with a few emendations—with such absurd results that the map would not deserve notice except for the eminence of its author.

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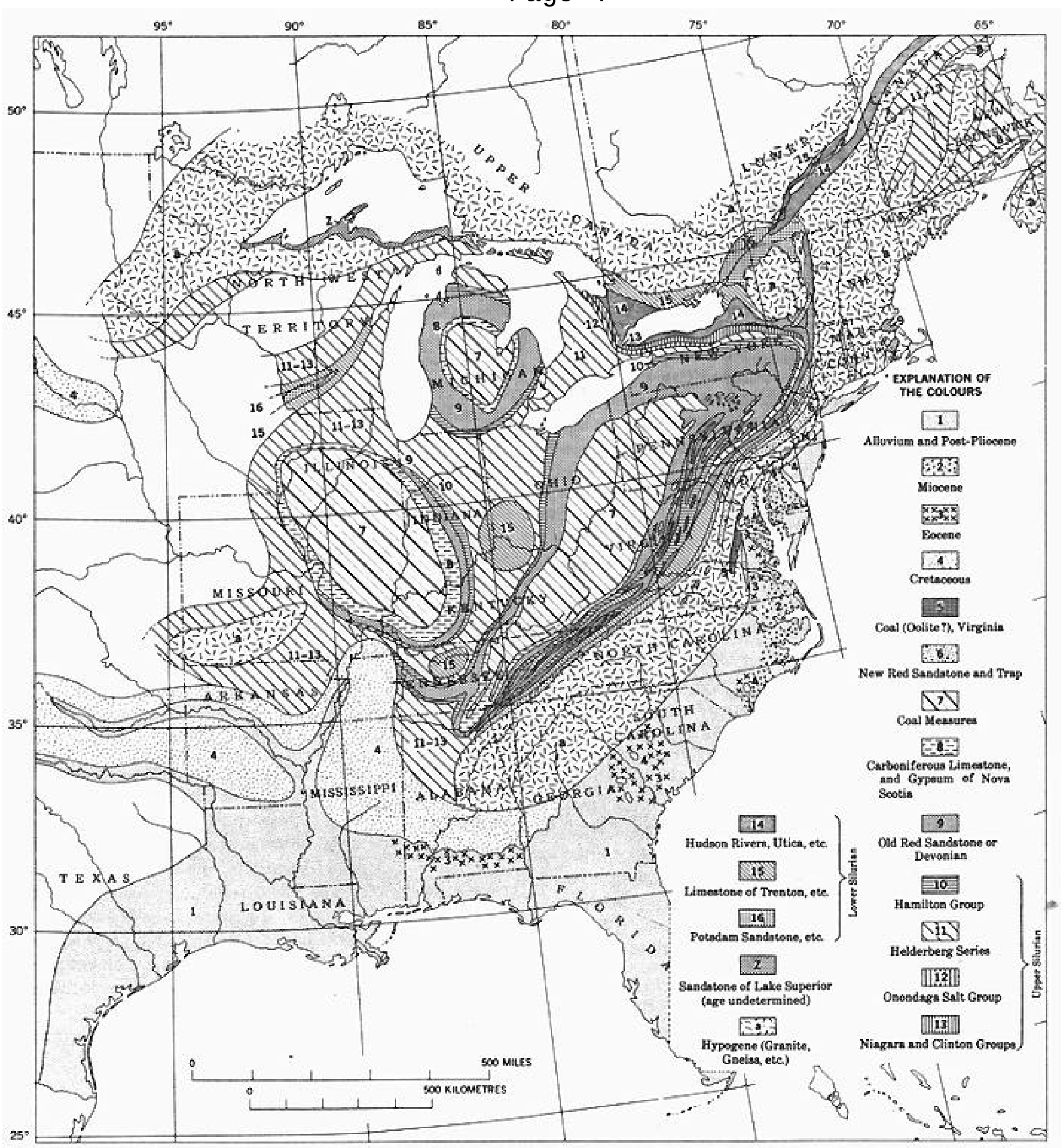

Figure 2.—Geology of the United States and adjacent parts of Canada as represented by Lyell (1845). Original map in color.

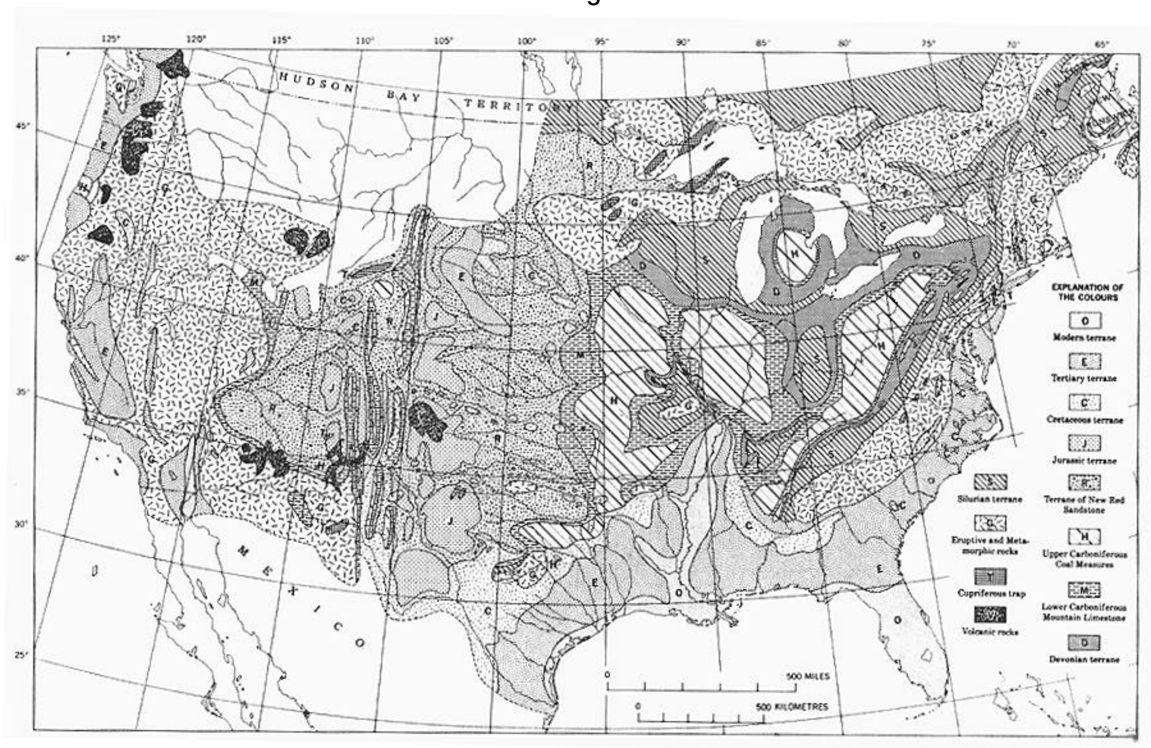

Figure 3.—Geology of the United States and adjacent parts of Canada as represented by Marcou (1855) Original map in color.

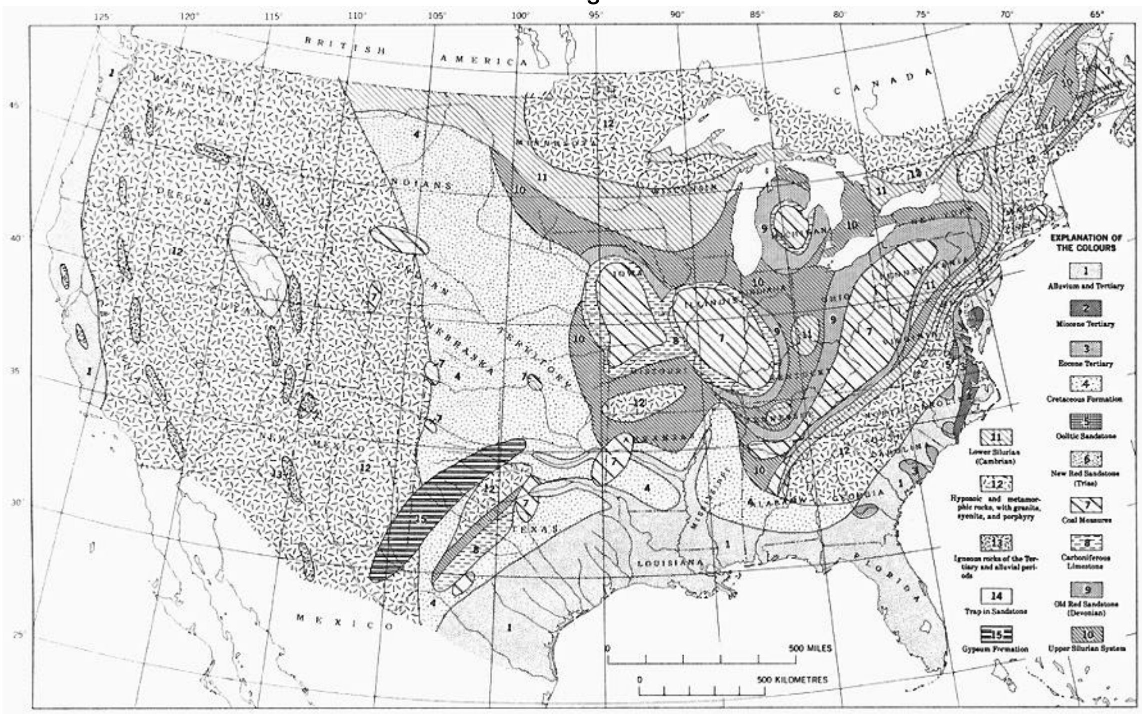

Figure 4.—Geology of the United States and adjacent parts of Canada as represented by Edward Hitchcock (1854). Original map in color.

MAPS BETWEEN 1860 AND 1880

After the Civil War period, notable improvements were made in geological map publishing, as color lithography replaced the former laborious method of coloring printed geological maps by hand. Also, representation of the western country passed from the realms of fantasy to fact as a result of mapping by the Territorial Surveys and other official organizations.

A noteworthy product of this period is the geologic map (scale 1:1,584,000) that accompanied Sir William Logan's report on "The Geology of Canada" (Logan and others, 1863; the map is dated 1866, but was not issued until 1869). It included not only Canadian territory, but also the part of the United States north of the fortieth parallel and east of the ninety-sixth meridian, based on data supplied by James Hall (see footnote 1).

Footnote 1. This map is highly praised by C. H. Hitchcock (1887, p. 478-481), who notes that it was omitted from the listing by Marcou and Marcou (1884), and comments that this "must be compared to the celebrated performance of Hamlet where, owing to infelicitous circumstances, the part of Hamlet was omitted!"

As a result of the new surveys assembling a reasonably expressive geologic map of the whole country became possible. Compilation of such a map on a scale of 1:7,000,000 was made by Charles H. Hitchcock and William P. Blake and appeared in various official reports, notably in the "Statistical Atlas of the United States" that accompanied the report of the Ninth Census of 1870 (1874), a volume which also contains an explanation by the compilers of their sources and methods. Hitchcock was the son of Edward Hitchcock and was himself an eminent New England geologist; Blake had had long experience in western exploration and was at the time professor at California College (the predecessor of the University of California). Aside from the many virtues of the map, one can note adversely that they assigned the granites and other plutonic rocks in the Sierra Nevada and eastward into the Great Basin to the "Archean"; this echoed the conclusion of the geologists of the Fortieth Parallel Survey and many contemporaries, even though a reviewer (Anonymous, 1873) had requested that those in the Sierra Nevada be transferred to the Triassic and Jurassic. More curious is the complete omission of the Idaho batholith, or broad granitic terrane, of central Idaho; its area is represented as being geologically like the Great Basin, consisting of half a dozen strips of Cambrian and Archean rocks, separated by strips of Cenozoic.

Hitchcock himself also published privately a geologic wall map of the United States (1881) on a scale of 1:1,226,200, measuring 13 feet long and 8 feet high——the largest geologic map of the whole country that has ever been issued. Although the geographic base of this map is much more detailed that that of the smaller geologic maps by Hitchcock and Blake, the geologic representation shows no greater refinement, nor indeed was any possible from information available at the time (compare Anonymous, 1881).

MAPS BETWEEN 1880 AND 1930

In 1882, 3 years after the U.S. Geological Survey was organized, it was instructed by Congress "to complete a geological map of the United States." This gave the Survey authority to conduct geological investigations in all parts of the country, and it also obligated the Survey to prepare a national geologic map. In the summer of 1883, Director J. W. Powell instructed W J McGee to compile such a map in time for Congressional hearings the following spring; the map was published in the Fifth Annual Report of the Survey (McGee, 1885b) on a scale of 1:7,115,000, with the title "Map of the United States exhibiting the present status of knowledge relating to the areal distribution of the geological groups." Although the published map states that it was "compiled by W J McGee," he gives generous credit in his administrative report to the assistance of C. H. Hitchcock for his "experience and skill in geologic cartography, his extended personal knowledge of American terranes, and his familiarity with American geological literature" (McGee, 1885a, p. 35).

On McGee's map the two-thirds of the country east of the one hundred and third meridian is completely colored, but in the western third only the areas mapped by the various Territorial Surveys are colored, the remainder being left blank. As McGee explains (1885a, p. 38),

Much of the western part of the United States remains unexplored geologically; repeated efforts were made to gain access to the unpublished material of the now suspended Geological Survey of California, and to establish correspondence with the State Geologist of Oregon, but without success; the maps prepared by the earliest western explorers can seldom be accurately coordinated with those recently published, either geographically or geologically; and it became necessary to leave the following States and Territories either partially or wholly uncolored: Arizona, California, Idaho, Montana, Nevada, New Mexico, Oregon, Texas, Utah, Washington.

On completion of this work for McGee, Hitchcock obtained permission from Director Powell to fill in the remaining western part of the map from less exact data, and the results were published in the Transactions of the American Institute of Mining Engineers (Hitchcock, 1887), with an explanatory text. His additions to the Survey map closely resemble the representation on the earlier maps by Hitchcock and Blake, but there are changes and refinements.

In 1894 the U.S. Geological Survey published a revised version of the official map, again with the authorship of McGee and on the same scale as before, entitled "Reconnaissance map of the United States, showing the distribution of the geologic systems so far as known."

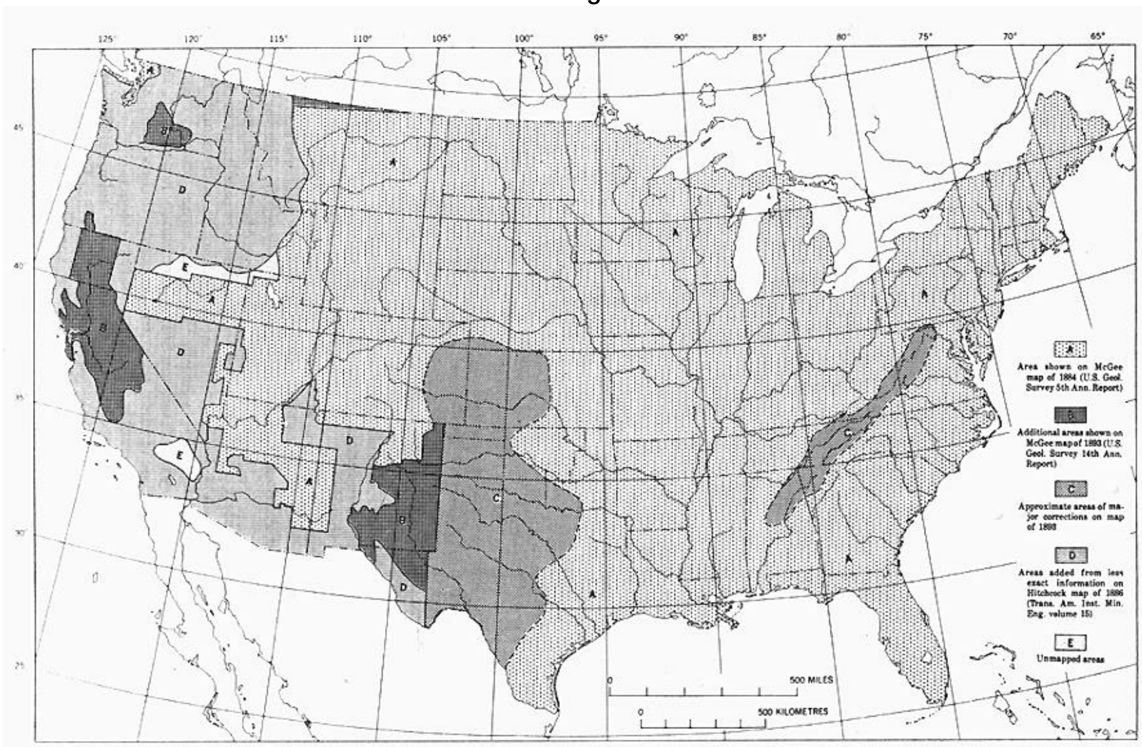

Figure 5.——Index map showing areas represented geologically on McGee map of 1885, areas added or revised on the McGee map of 1894, and additional coverage based on less exact information on the C. H. Hitchcock map of 1887.

Important improvements were made in the previously colored area east of the one hundred and third meridian, especially in the Great Plains from Kansas to Texas, and in the Appalachians. Parts of the area farther west that had hitherto been left blank were filled in, especially in the Sierra Nevada and elsewhere in California, but based on new mapping by U.S. Geological Survey personnel, as the results of the Geological Survey of California had never been obtained. Unfortunately, the compilers of the revised map chose to group the volcanic and plutonic rocks in the Sierra Nevada and elsewhere in the west into a single "igneous" unit, thus ignoring fundamental distinctions for which many data were already available. Representation of the bedrock in the northern tier of States and Territories was also obscured by overprinting a pattern of glacial deposits.

When McGee transferred to the Bureau of American Ethnology in 1894, responsibility for national geologic maps devolved on Bailey Willis as Map Editor. In 1895 his staff was augmented by

George W. Stose as geologist and Olof A. Ljungstedt as cartographer. Shortly afterwards, when Willis became Geological Assistant to Director C. D. Walcott, Stose became Map Editor; nevertheless, Willis and Stose continued their collaboration for many years. Willis was part of a Survey committee on a Geologic Map of the United States, and plans were formulated for a new map which was to be on a scale of 1:2,500,000. Stose assembled a manuscript copy of such a map which formed part of the Survey exhibit at the Louisiana Purchase Exposition in St. Louis in 1904, but attempts to put it into more permanent form were hindered because of lack of an adequate geographic base and the need for more large-scale geologic maps of the States to serve as source material.

Also, the impending Tenth International Geological Congress to be held in Mexico in 1906 indicated the need for a Geologic Map of North America, and Willis and his assistants quickly produced a preliminary version of this map on a scale of 1:5,000,000 with the cooperation of the Governments of Canada and Mexico, which was published by the Congress as "Carte Géologique de l'Amérique du Nord" (Willis, 1906). It then appeared more desirable to perfect this preliminary rendering of North American geology than to continue on the proposed Geologic Map of the United States. An improved version of the Geologic Map of North America was virtually completed by 1910 and published in 1911 under the authorship of Willis and Stose; it was also included as a companion to Willis' monumental "Index to the Stratigraphy of North America" in Professional Paper 71 (1912).

On the Geologic Map of North America of 1912 extensive areas north and south of the United States could not be adequately represented on account of lack of geological knowledge, and some areas in Alaska, northern Canada, and Central America were left uncolored. However, the geology of the United States and southern Canada were shown in much detail; the part in the United States no doubt included the data thus far assembled for the postponed Geologic Map of the United States. For the succeeding 20 years the North America map was the standard reference work for United States geology——including King's student days between 1920 and 1929.

THE GEOLOGIC MAP OF THE UNITED STATES OF 1932

For a considerable period after Willis left the Survey, Stose had to devote his efforts to the preparation or editing of State Geologic Maps on larger scales, although the eventual objective of a Geologic Map of the United States was not forgotten. Actual compilation of this map began in 1927 and was accelerated by the decision of the Fifteenth International Geological Congress held in South Africa in 1929 to hold its Sixteenth Congress in the United States in 1933. Work proceeded with sufficient rapidity that printed copies of the map were distributed to participants of this Congress in the summer of 1933 (but with a publication date of 1932).

Stose assumed primary responsibility for preparation of the map. He compiled the Appalachian part, in which he had long been interested, and supervised the compilations of his associates; initial compilations of many areas outside the Appalachians were made by O. A. Ljungstedt, who was not a professional geologist but who had had long experience as a geologic cartographer in the Map Editor's office. Stose traveled widely to obtain manuscript data, especially from State Maps that were in process of compilation. Nevertheless, adequate source maps were still lacking for much of the northwestern part of the country, so Stose and Ljungstedt, with the aid of local specialists, made original compilations of Nevada, Idaho, Oregon, and Washington on scales of 1:1,000,000 or larger. In addition, Anna I. Jonas (later Mrs. G. W. Stose) was added to the staff to complete a reconnaissance of the Piedmont province which she had already begun in connection with preparation of a Geologic Map of Virginia.

The resulting map, attractively printed in many colors, served as a reference work on the geology of the United States for the succeeding forty years; it was reprinted in 1960 when the stock of the original printing was exhausted. The map represents the best summary that could be made in its time, not only of the areal geology of the country, but also of the prevailing geological philosophy. Any apparent imperfections that we might now see in the map should be viewed in this context.

Many geologic features of the country were poorly coordinated at the time; consequently greater emphasis was given to rock-stratigraphic than to time-stratigraphic units. The geology is treated in terms of nine geological subdivisions or provinces, shown on an index map, for each of which there is a separate legend. The sequences in some of the provinces are very different—for example, those in the Lake Superior region and the Coastal Plains—but others partly overlap in age, and correspondence between these from one legend to another is not always clear.

Some of the stratigraphic classifications have changed since 1932, resulting in improvements in representation not possible at the time. Thus, the "Carboniferous System" is now divided into the Mississippian, Pennsylvanian, and Permian Systems, creating changes in letter symbols, coloring, and even to some extent in geological concepts. Also, separation of the Paleocene from the Eocene has clarified relations in the northern Rocky Mountains and Great Plains, where the two series have different depositional patterns and areal distributions; it has also disposed of the so-called "Laramie question" that had plagued American geology since the days of the Hayden Survey (Merrill, 1906, p. 647-658), traces of which still lingered in 1932.

Many improvements have also been made in correlation of the nonfossiliferous crystalline rocks, by means of radiometric dating. Classification of the Precambrian on the 1932 map was made on the basis of the now-discredited "Archean" and "Algonkian" Systems, with results that are no longer acceptable. The ages of Phanerozoic plutons are now known with greater precision. The so-called "Carboniferous" granites shown in the Southern Appalachians on the 1932 map are now known to be of many Paleozoic ages, mostly pre-Carboniferous. Similarly, the so-called "Jurassic" granites of the Western States are now known mainly to be Cretaceous (for which no provision was made on the 1932 legend), and to be Jurassic only in small part.

The crystalline rocks of the Piedmont province were poorly known in 1932, and only small parts of them had been mapped in detail. By the time of compilation, Arthur Keith's rendering of the province for the North America map of 1912 was no longer useful, so Jonas undertook a new reconnaissance. Because of the need to cover a large area rapidly, her reconnaissance was made on the basis of a general theory, outlined in a contemporary journal article (Jonas, 1932). The theory involved, among other things, correlation of large parts of the Piedmont rocks with the Glenarm Series of supposed "Algonkian" age (which had been studied in some detail in Maryland and Pennsylvania) and a concept of regional belts of retrogressive metamorphism above throughgoing low-angle thrusts, in which the already-formed crystalline rocks were further altered into mylonites and diapthorites. The Piedmont province is better known now as a result of extensive field surveys, and only parts of these concepts have been substantiated by later work; much greater complexity and many more local peculiarities have been discovered.

Similar problems existed in New England in 1932, where the sequences and ages of the crystalline rocks were still unresolved over large areas, and where they were considered to be largely

Precambrian. B. K. Emerson (1917) had indeed made perceptive age assignments in Massachusetts, but his rendering of this small area had to be suppressed in favor of the overall picture.

Elsewhere in the country, large areas had already been adequately portrayed on State Maps (at least for purposes of the 1:2,500,000 scale), and few differences in gross geologic patterns have arisen in the intervening years. Differences in detail have resulted from changes in stratigraphic classification, from greater precision in surface mapping, and from more extensive subcrop data in the heavily drift covered region of the Northern Interior States.

THE GEOLOGIC MAP OF THE UNITED STATES

HISTORY OF THE PRESENT PROJECT

By 1955, it had become apparent that the Geologic Map of the United States of 1932 had passed its peak of usefulness, and plans were made by the U.S. Geological Survey for a new and greatly revised map. Philip B. King was asked to undertake this project, and facilities for the work were set up at the Menlo Park office of the Survey.

A considerable interval elapsed, however, before the project could be activated. King had to complete reports on other projects, and he contributed much time to reviewing work that was being done by others who were revising the Tectonic Map of the United States (Cohee, 1962) and the Geologic Map of North America (Goddard, 1965). In preparation for the project, however, he traveled widely in the United States to visit U.S. Geological Survey field parties and to join formal geological excursions.

A further postponement occurred in 1960, during the Twenty-first International Geological Congress in Copenhagen, when the U.S. Geological Survey accepted responsibility for preparing a Tectonic Map of North America at the request of the Subcommission for the Tectonic Map of the World. King was assigned the task of compilation of this map; only after its completion, in 1967, could actual work on the Geologic Map of the United States be started.

The long delay that followed inception of the project, although unfortunate, resulted ultimately in a better product. Acceptable modern geologic data for many parts of the country did not become available until the mid-196O's and even later. During the delay, new State Maps were published covering extensive parts of the country, and U.S. Geological Survey personnel completed new mapping of hitherto poorly known territory, such as Nevada and eastern Oregon. Many more radiometric dates became available, so age assignments of the Precambrian rocks, the Phanerozoic plutons, and the Cenozoic volcanics could be made with greater confidence.

Also, a competent staff had been assembled. Gertrude J. Edmonston, who had assisted in completion of the Tectonic Map of North America as geologic cartographer, continued these duties on the United States map. Helen M. Beikman was enlisted as geologist and fellow-compiler and prepared nearly half of the eventual product.

A first draft of the compilation was nearly completed early in 1970, after which Beikman left the project to begin work on a companion Geologic Map of Alaska. Several areas, however, were still left in a tentative state or uncolored, pending receipt of additional information, or further review of outstanding problems. Final decisions on the Piedmont province, the State of Texas, the Precambrian of the country, and the Cenozoic volcanic rocks of the Western United States were thus postponed.

In the last half of 1970 and during 1971 King and Beikman traveled widely to obtain additional information on these matters. Representation of the Precambrian was clarified at a Geological Society of America Penrose Conference in Wyoming and during subsequent deliberations of a special panel on the Precambrian of the U.S. Geological Survey under the chairmanship of Max D. Crittenden. A visit to the offices of the Texas Bureau of Economic Geology was made to complete the compilation for Texas, and several journeys were made to the Southeastern States to obtain data on the Piedmont Province. These journeys were supplemented, especially for the Piedmont province, by extensive correspondence and literature review. Data on the volcanic rocks of the West were obtained mainly from the Geological Survey staff at Menlo Park.

Geological plotting of the eastern half of the map was completed in July 1971 and of the western half in February 1972, after which each was reviewed by appropriate Survey geologists, whose corrections were incorporated in the final map. The completed map and legend were transmitted for publication in midsummer of 1972, and a hand-colored manuscript copy formed a part of the U.S. Geological Survey's exhibit at the Twenty-fourth International Geological Congress in Montreal in August l972.

SOURCES OF THE GEOLOGIC MAP

During the course of our compilation we consulted all pertinent geologic maps and texts, including State geologic maps. We also obtained large amounts of unpublished data, revisions, and criticisms from our colleagues on the staffs of the U.S. Geological Survey, the State Geological Surveys, universities, and other research institutions. To all these kind friends, collaborators, and contributors we express our deepest thanks and appreciation.

The sources from which the map was compiled are summarized below alphabetically by States and are cited further at various places in the ensuing text. For each State, the first entry is the most recently published State Geologic Map, customarily on a scale of 1:250,000 or smaller. The data taken from all these maps, especially from the older ones, have been somewhat modified and revised, those from the older maps the most extensively, on the basis of sources listed in the following order: (l) Regional maps on scales of 1:250,000 or smaller. (2) Detailed maps of quadrangles, counties, or other small areas on scales of 1:24,000 to 1:62,500, which are summarized rather than specifically cited. (3) Other maps and reports in geological journals and elsewhere, published and unpublished. (4) Significant reviews and corrections by U.S. Geological Survey colleagues, and others.

Alabama.—Geologic Map of Alabama, 1926, by G. I. Adams, Charles Butts, L. W. Stephenson, and C. W. Cooke: Alabama Geological Survey, scale 1:500,000. Northern Alabama Paleozoic area (including Valley and Ridge province): Verified, or modified in detail from county maps of Alabama Geological Survey published after 1960. Piedmont province: Remapped from: R. D. Bentley and T. L. Neathery, 1970, Geology of the Brevard zone and related rocks of the Inner Piedmont of Alabama: Alabama Geol. Society 8th Ann. Field Trip Guidebook; approx. scale 1:500,000. Also manuscript map of province furnished through the courtesy of P. E. LaMoreaux, State Geologist, Alabama Geol. Survey, 1970; scale l:l,000,000. Coastal Plain: Revised from: W. H. Monroe, 1945, Geologic map of the Upper Cretaceous formations in central Alabama, in C. W. Carlston, Ground-water resources of the Cretaceous area in Alabama: Alabama Geol. Survey Spec. Rept. 18; scale 1:500,000. F. S. MacNeil, 1946, Geologic map of the Tertiary formations of Alabama: U.S. Geol. Survey Oil and Gas Inv. Prelim. Map 45; scale 1:500,000. Minor data from county maps of Alabama Geol. Survey.

Arizona.—Geologic Map of Arizona, 1969, by E. D. Wilson, R. T. Moore, and J. R. Cooper: U.S. Geol. Survey; scale 1:500,000. Radiometric dates of Precambrian rocks compiled by Maureen G. Johnson, U.S. Geol. Survey.

Arkansas.—Geologic Map of Arkansas, 1929, edited by H. D. Miser and G. W. Stose; scale 1:500,000. Northwestern Paleozoic area: Manuscript map summarizing data assembled for the new Geologic Map of Arkansas, by B. R. Haley and E. R. Glick, U.S. Geol. Survey; scale 1:2,500,000. Additional fault data from C. G. Stone, Arkansas Geol. and Conserv. Div. Southwestern Cretaceous and Tertiary area: Little modified from map of 1929. Eastern Cenozoic area (Mississippi Embayment): Map showing Quaternary deposits, in manuscript 1971, by R. T. Saucier, Waterways Exp. Sta., Vicksburg, Miss.; scale 1:1,000,000. Geologic map (of) alluvial valley floor; sedimentary rocks underlying Recent alluvium, in H. N. Fisk, 1944, Geological investigation of the alluvial valley of the lower Mississippi River: Mississippi River Commission, Vicksburg, Miss., pl. 10, sheet 1; scale 1:500,000; with modifications from later data.

California.—Geologic Map of California, 1958-69, by C. W. Jennings and others, California Div. Mines and Geol., 2-degree atlas sheets; scale 1:250,000. Revisions from: Geologic Map of California, in manuscript 1972, by C. W. Jennings and others, California Div. Mines and Geol.; scale 1:750,000. Maps and other data in: E. H. Bailey, editor, 1966, Geology of northern California: California Div. Mines and Geol. Bull. 190; and W. R. Dickinson and Arthur Grantz, 1968, Proceedings of conference on geologic problems of San Andreas fault system: Stanford Univ. Pubs. Geol. Sci., v. 11. Also, P. E. Hotz, 1971; Geology of lode gold deposits in the Klamath Mountains, California and Oregon: U.S. Geol. Survey Bull. 1290, pl. 1; scale 1:500,000. J. E. Evernden and R. W. Kistler, 1970, Chronology of emplacement of Mesozoic batholithic complexes in California and western Nevada: U.S. Geol. Survey Prof. Paper 623 (for radiometric ages on plutonic rocks). Maps and other data, partly unpublished, from P. E. Hotz, E. H. Bailey, W. P. Irwin, L. D. Clark, P. C. Bateman, J. G. Vedder, and T. W. Dibblee, Jr., of U.S. Geol. Survey, and B. M. Page of Stanford University.

Colorado.—Geologic Map of Colorado, 1935, compiled by W. S. Burbank, T. S. Lovering, E. N. Goddard, and E. B. Eckel: U.S. Geol. Survey; scale 1:500,000. Geologic maps of 2-degree quadrangles, scale 1:250,000, issued as U.S. Geol. Survey Misc.

Inv. Maps, as follows: Moab, 1964, by P. L. Williams, Map I-360; La Junta, 1968, by G. R. Scott, Map I-629; Trinidad, 1969, by R. B. Johnson, Map I-558; Cortez, 1972, by D. D. Haynes and others, Map I-629. Great Plains, eastern Colorado: Few changes, except for revised age assignments. Rocky Mountains and Colorado Plateau, western Colorado: Compiled by Helen M. Beikman and Philip B. King from published and unpublished data of U.S. Geol. Survey geologists. Radiometric ages of Precambrian rocks and of Cretaceous-Tertiary instrusives from: Z. E. Peterman and C.E. Hedge, 1968, Chronology of Precambrian events in the Front Range, Colorado: Canadian Jour. Earth Sci., v. 5, no. 3, pt. 2, p. 749-756; and written communications by Ogden Tweto. Final review and correction of compilation by Ogden Tweto, U.S. Geol. Survey, December 1971.

Connecticut.—See New England.

Delaware.—See Maryland.

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Kentucky.—Geologic Map of Kentucky, 1954: Kentucky Geol. Survey Ser. 9; scale 1:1,000,000. Supplemented by Geologic Map of Kentucky, 1929, by W. R. Jillson: Kentucky Geol. Survey Ser. 6; scale 1:500,000. Revised map compiled by Helen M. Beikman, using where available 7 1/2-minute quadrangle maps, scale 1:24,000, published by U.S. Geol. Survey in 1962 and later; and where not available the two State Maps. Tertiary units of Mississippi Embayment from Geologic Map of Jackson Purchase Region, Kentucky, 1972, compiled by W. W. Olive, in Kentucky Geol. Society Field Conf. Guidebook; scale 1:250,000.

Louisiana.—Generalized Geological Map of Louisiana, 1959, L. W. Hough, State Geologist: Louisiana Geol. Survey; scale approx. 1:1,500,000. Supplemented by two earlier State Maps: Geologic Map of State of Louisiana, 1946, compiled by W. E. Wallace, Jr.: Shreveport Geol. Society; scale 1:500,000. Geological Map of Louisiana, in manuscript 1948, compiled by Rufus LeBlanc, Shell Oil Co.; scale 1:500,000. Mississippi Embayment: Map showing Quaternary deposits, in manuscript 1971, by R. T. Saucier, Waterways Exp. Sta., Vicksburg, Miss.; scale 1:1,000,000. Geologic map (of) alluvial valley floor; sedimentary rocks underlying Recent alluvium, in H. N. Fisk, 1944, Geological investigation of the alluvial valley of the Mississippi River: Mississippi River Comm., Vicksburg, Miss., pl. 10, sheet 2: scale 1:500,000. Outcrops of Citronelle Formation (Pliocene): From J. A. Doering, 1956, Review of Quaternary surface formations of Gulf Coast region: Am. Assoc. Petroleum Geologists Bull., v. 40, p.

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Missouri.—Geologic Map of Missouri, 1961, compiled by M. H. McCracken and others: Missouri Div. Geol. Survey and Water Res.; scale 1:500,000.

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Nevada.—No adequate published State Map available. Compiled by Philip B. King from: Manuscript sheets for Geologic Map of Nevada, by J. H. Stewart and J. E. Carlson, U.S. Geol. Survey, in preparation 1974; scales 1:250,000 and 1:500,000. County geologic maps by geologists of U.S. Geol. Survey and Nevada Bur. Mines, published since 1960 as Nevada Bur. Mines Bulletins, as U.S. Geol. Survey Misc. Inv. Maps, or in manuscript; scale 1:250,000.

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E-an Zen, W. S. White, J. B. Hadley, and J. B. Thompson, Jr., editors, 1968, Studies of Appalachian geology; Northern and Maritime: Interscience Pub., New York; especially on nappes and gneiss domes in New Hampshire, Massachusetts, and eastern Connecticut (J. B. Thompson, Jr., and others; H. R. Dixon and L. W. Lundgren, Jr.) and on Maine (P. H. Osberg and others; J. C. Green and V. C. Guidotta; A. M. Hussey II). (4) Manuscript maps on northern and southeastern Maine, supplied by Louis Pavlides, E. L. Boudette, D. B. Stewart, and D. R. Wones; distribution of Paleozoic volcanic rocks in New England, compiled by D. W. Rankin; all of U.S. Geol. Survey, 1971. (4) Radiometric dates in eastern Massachusetts and vicinity from R. E. Zartman and R. F. Martin, 1971, Radiometric age (Late Ordovician) of the Quincy, Cape Ann, and Peabody Granites from eastern Massachusetts: Geol. Soc. America Bull., v. 82, p. 937-958; also oral communications from R. E. Zartman, 1971. Original compilations reviewed and corrected by: John Rodgers of Yale University and James Skehan of Boston College, 1969 and 1971; and by K. G. Bell, H. R. Dixon, Richard Goldsmith, D. S. Harwood, N. L. Hatch, L. R. Page, D. W. Rankin, E-an Zen, and others of U.S. Geol. Survey, 1971.

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South Carolina.—No adequate published State Map available; partial maps as follows: W. C. Overstreet and Henry Bell III, 1965, Geologic map of the crystalline rocks of South Carolina: U.S. Geol. Survey Misc. Inv. Map I-413; scale 1:250,000. W. C. Overstreet and Henry Bell III, 1965, Geologic map and inferred age relations of the crystalline rocks of South Carolina, in The crystalline rocks of South Carolina; U.S. Geol. Survey Bull. 1183, pl. 1; scale 1:500,000. C. W. Cooke, 1936, Cretaceous and Tertiary formations of South Carolina, in Geology of the Coastal Plain of South Carolina: U.S. Geol. Survey Bull. 867, pl. 2; scale 1:500,000. Piedmont province: Extensively revised from publications of South Carolina State Devel. Board Div. of Geol., including: Detailed maps by R. D. Hatcher, Jr., and V. S. Griffin, Jr., in north-western South Carolina, and reconnaissance maps elsewhere. County and quadrangle maps by D. T. Secor, H. D. Wagener, J. R. Butler, J. F. McCauley, and others. Coastal Plain: Revised from data compiled by S. D. Heron for Geological Highway Map of the Mid-Atlantic Region, 1970: Am. Assoc. Petroleum Geologists Geologic Highway Map Ser. 4; scale approx. 1:2,000,000.

South Dakota.—Geologic map (of) South Dakota, 1953, compiled by B. C. Petsch: South Dakota Geol. Survey; scale 1:500,000. Supplemented by Geologic Map of South Dakota, 1951, compiled by N. H. Darton: U.S. Geol. Survey; scale 1:500,000. Subdrift geology east of Missouri River from R. F. Flint, 1955, Pleistocene geology of eastern South Dakota: U.S. Geol. Survey Prof. Paper 262, fig. 4. Precambrian of Black Hills area revised from data of R. W. Bayley, U.S. Geol. Survey open-file map, 1972.

Tennessee.—Geologic Map of Tennessee, 1966, by W. D. Hardeman, R. A. Miller, and G. D. Swingle; Tennessee Div. Geol.; scale 1:250,000. Tertiary units of Mississippi Embayment area, western Tennessee, revised by W. S. Parks, Water Resources Div., U.S. Geol. Survey, written communication, November 1971.

Texas.—Geologic Map of Texas, 1937, by N. H. Darton, L. W. Stephenson, and Julia Gardner: U.S. Geol. Survey; scale 1:500,000. Extensively revised as follows (letter symbols refer to): (A) Eastern, northern, and westernmost Texas, where available, from sheets of Geologic Atlas of Texas, 1965-72, by V. E. Barnes and others: Texas Univ. Bur. Econ. Geology; scale 1:250,000. (B) Llano region, central Texas, from manuscript maps by V. E. Barnes, F. B. Plummer, and others, Texas Univ. Bur. Econ. Geology; scales 1:125,000 and 1:250,000. (C) Edwards Plateau region from manuscript maps by F. E. Lozo, Jr., Shell Oil Co.; scale 1:250,000. (D) South Texas Coastal Plain compiled by Helen M. Beikman from manuscript data for Geologic Atlas of Texas; manuscript maps by D. H. Eargle, U.S. Geol. Survey; Geologic Map of Texas, 1937; and other sources. (E) Trans-Pecos region compiled by Philip B. King from published quadrangle maps of Texas Univ. Bur. Econ. Geology and U.S. Geol. Survey, and from personal knowledge. (F) Northwestern Texas, where not otherwise covered, from Geologic Map of Texas, 1937, with revisions of Paleozoic area by D. H. Eargle, U.S. Geol. Survey.

Utah.—Geologic Map of Utah, 1961-63, compiled by W. L. Stokes, J. H. Madsen, Jr., and L. F. Hintze: Utah State Land Board and Univ. of Utah; scale 1:250,000. With additions and corrections by M. D. Crittenden and H. T. Morris, U.S. Geol. Survey, 1970-71.

Vermont.—See New England.

Virginia.—Geologic Map of Virginia, 1963, compiled by R. C. Milici, C. T. Spiker, Jr., and J. M. Wilson: Virginia Div. Min. Res.; scale 1:500,000. Valley and Ridge and Blue Ridge provinces.—Minor revisions only. Piedmont province.—Extensive revisions as follows: North of James River revised by M. W. Higgins from maps by D. L. Southwick, J. C. Reed, Jr., S. K. Neuschel, and others, and by extrapolations based on reconnaissance. South of James River revised in part by Philip B. King from published and unpublished maps by D. W. Rankin, G. H. Espenshade, J. F. Conley, O. T. Tobisch, and Lynn Glover III. Coastal Plain.—No revision.

Washington.—Geologic Map of Washington, 1961, compiled by M. T. Huntting, W. A. Bennett, V. E.

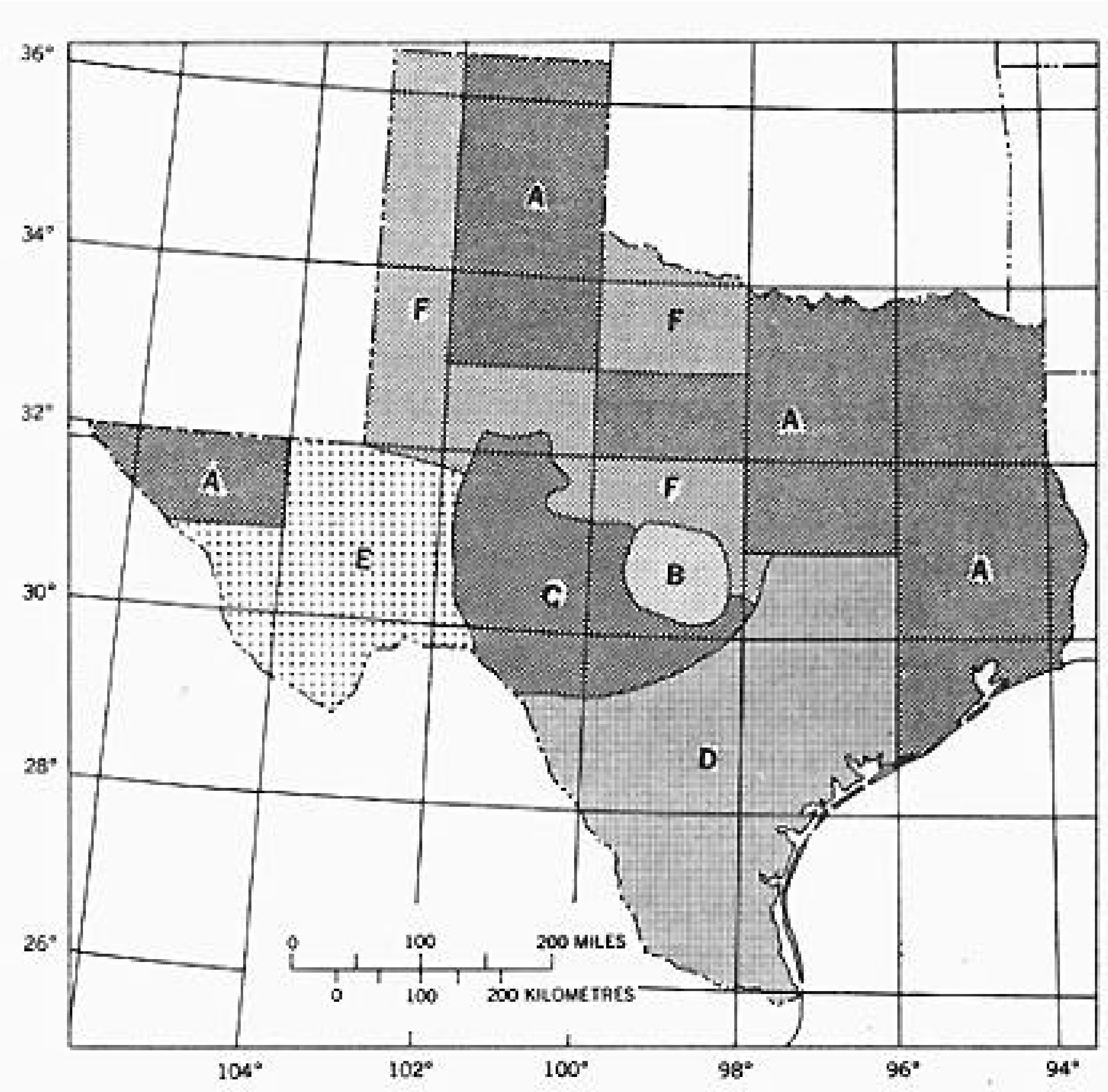

Figure 6.—Index map of Texas, showing areas covered by different sources used on the Geologic Map. Letter symbols are explained on page 16.

Livingston, Jr., and W. S. Moen: Washington Div. Mines and Geol.; scale 1:500,000. Extensively revised by Philip B. King, as follows: Olympic Peninsula, northwestern Washington: From published and unpublished maps by W. M. Cady, R. W. Tabor, H. D. Gower, P. D. Snavely, Jr., and others of U.S. Geol. Survey. Coast Ranges, southwestern Washington: From published quadrangle maps by Holly Wagner, E. H. Wolfe, H. D. Gower, P. D. Snavely, Jr., and others, U.S. Geol. Survey. Volcanic rocks, southern Cascade Range: Revised by C. A. Hopson, Univ. of California, Santa Barbara, written communication, February 1972. Prevolcanic rocks, northern Cascade Range: Peter Misch, 1966, Tectonic evolution of northern Cascades of Washington State, in Symposium on the tectonic history and mineral deposits of the western Cordillera: Canadian Inst. Min. and Geol. Spec. Volume 8, p. 101-148. Maps and other data, in part unpublished, by D. F. Crowder, F. W. Cater, R. W. Tabor, and C. A. Hopson. Northern and northeastern Washington: A. B. Griggs, 1966, Geologic map of western half of Spokane quadrangle, Washington and Idaho: U.S. Geol. Survey Misc. Geol. Inv. Map I-464; scale 1:250,000. General and detailed maps, in part unpublished, by C. D. Rinehart, J. F. Fox, Jr., R. G. Yates, F. K. Miller, G. E. Becraft, and others, U.S. Geol. Survey. Columbia Plateau: R. C. Newcomb, 1970, Tectonic structure of the main part of the basalt of the Columbia River Group, Washington, Oregon, and Idaho: U.S. Geol. Survey Misc. Geol. Inv. Map I-587; scale 1:500,000.

West Virginia.——Geologic Map of West Virginia, 1968, compiled by D. H. Cardwell, R. B. Erwin, and H. P. Woodward: West Virginia Geol. and Econ. Survey; scale 1:250,000.

Wisconsin.——Geologic Map of Wisconsin, 1949, Wisconsin Geol. and Nat. Hist. Survey; scale 1:1,000,000. Precambrian rocks, edge of Cambrian overlap, and faults revised from: C. E. Dutton and R. F. Bradley, 1970, Lithologic, geophysical, and mineral commodity maps of Precambrian rocks of Wisconsin: U.S. Geol. Survey Misc. Geol. Inv. Map I-631; scale 1:500,000; especially sheets 3 and 5. In the main Precambrian area of northern Wisconsin, contacts of Precambrian units extrapolated by Philip B. King beyond their extent as mapped by Dutton and Bradley.

Wyoming.——Geologic Map of Wyoming, 1955, compiled by J. D. Love, J. L. Weitz, and R. K. Hose: U.S. Geol. Survey; scale 1:500,000. Revised in part, as follows: Precambrian rocks from published and unpublished data by R. W. Bayley, Harry Granger, R. C. Pearson, and others, U.S. Geol. Survey, and R. S. Houston, Univ. of Wyoming. Heart Mountain fault, northwestern Wyoming: From W. G. Pierce, U.S. Geol. Survey, 1972. Volcanic rocks, Yellowstone National Park: From Geologic Map of Yellowstone National Park, 1972, by geologists of U.S. Geol. Survey: U.S. Geol. Survey Misc. Geol. Inv. Map I-711; scale 1:125,000. W. R. Keefer, 1972, The geological story of Yellowstone National Park: U.S. Geol. Survey Bull. 1374, pl. 1; scale approx. 1:500,000; and written communication from R. L. Christiansen, U.S. Geol. Survey, November 1970. Tertiary sedimentary rocks revised by J. D. Love, written communication, January 1971. Compilation of Wyoming reviewed by J. D. Love, U.S. Geol. Survey, and staff of Dept. Geol., Univ. of Wyoming, written communication, January 1971.

Phanerozoic metamorphism.——Areas of Phanerozoic metamorphism in western United States, from many sources; in Appalachian region from B. A. Morgan, 1972, Metamorphic map of the Appalachians: U.S. Geol. Survey Misc. Geol. Inv. Map I-724; scale 1:2,500,000.

Limits of Pleistocene glacial deposits.—Glacial Map of the United States East of the Rocky Mountains, 1959, R. F. Flint, chairman, Geol. Soc. America; scale 1:1,750,000. Major revisions, based on later data, made by Roger B. Morrison, U.S. Geol. Survey, 1974, as follows: Montana and North Dakota from R. W. Lemke and R. B. Colton. South Dakota, Nebraska, Kansas, Missouri, and Iowa from the respective State Geological Surveys. Indiana from R. V. Ruhe, Indiana University. Ohio and Kentucky from Jane L. Forsyth, Bowling Green State University. Pennsylvania, New Jersey, and New York from C. S. Denny, U.S. Geol. Survey.

Subsea bathymetry.—Subsea contours compiled by Philip B. King and Gertrude J. Edmonston from the following sources, the locations of which are indicated in: (l) and (2) International map of the World, United States, scale 1:1,000,000, by the U.S. Geol. Survey. Sheet NL-10, Cascade Range, 1951. Sheet NK-10, Mount Shasta, 1951. Sheet NI-11, Los Angeles, 1952. Subsea contours in metres. (3) State of California, base map with shaded relief and offshore contours, by the U.S. Geol. Survey, 1968, scale 1:1,OOO,OOO. Contours in fathoms, converted to metres. (4) D. C. Krause, 1965, Tectonics, bathymetry, and geomagnetism of the southern continental borderland west of Baja California, Mexico: Geol. Soc. America Bull., v. 76, fig. 1, p. 260. Mercator projection; contours in metres. (5) and (6) Bathymetry of the northeast Pacific, by Scripps Institution of Oceanography and Underseas Surveillance Oceanographic Center, 1970. Sheets l and 2. Mercator projection; contours in fathoms converted to metres. (7) Submarine topography of the Gulf of California by R. L. Fisher, G. A. Rusnak, and F. P. Shepard, in T. H. vanAndel and G. G. Shor, Jr., editors, Marine geology of the Gulf of California: Am. Assoc. Petroleum Geologists Mem. 3, 1964. Mercator projection; contours in fathoms, converted to metres. (8) Elazar Uchupi, 1968, Map showing relation of land and submarine topography. Mississippi Delta to Bahia de Campeche; U.S. Geol. Survey Misc. Inv. Map I-521. Elazar Uchupi, 1966, Map showing relation of land and submarine topography, DeSoto Canyon to Great Bahama Bank: U.S. Geol. Survey Misc. Geol. Inv. Map I-475. Both maps, scale 1:1,000,000, contours in metres. (9) Elazar Uchupi, 1965, Map showing relation of land and submarine topography, Nova Scotia to Florida: U.S. Geol. Survey Misc. Geol. Inv. Map I-451. Scale 1:1,000,000, contours in metres. (1O) R. M. Pratt, 1968, Physiography and sediments of the deep-sea basin, in Atlantic continental shelf and slope of the United States: U.S. Geol. Survey Prof. Paper 529-B, pl. 1. Mercator projection, contours in metres. (11) U.S. Naval Oceanographic Service, Contoured position plotting sheet BG-895. Mercator projection; contours in fathoms, converted to metres.

USES OF THE GEOLOGIC MAP

Sometimes, when we explain to nongeologists our project for a Geologic Map of the United States, we are dismayed when asked, "What good is it?" We compilers, enmeshed in our many problems of assembling, collating, and generalizing the source data for the map, find it difficult to produce a ready answer to this question. Nevertheless, the values and uses of an accurate Geologic Map of the United States are manifold, not only to geologists, but to the public at large.

First of all, of course, the map displays the rocky foundations on which our country is built and is a summation of the nearly two centuries of investigation of this foundation by a succession of geologists. It is thus a reference work that present and future geologists of the country can consult and is of prime importance in the education of earth scientists in schools and colleges. Further, it can be consulted by geologists in other countries and continents who wish to learn about the geology of the United States; they will compare the map with similar national or continental maps of their own countries.

In terms of resources useful to man, the Geologic Map lays out accurately the major regions of bedrock in the United States upon which many facets of our economy depend. It illustrates the areas of stratified rocks that are the sources of most of our fuels, and the areas of crystalline, plutonic, and volcanic rocks that contain important parts of our mineral wealth. The map shows areas of complex folding and faulting, parts of which are still tectonically unstable and subject to earthquake hazards. To some extent the bedrock represented on the map also influences the surface soils, which are of interest in agriculture and engineering works.

Beyond this, the practical value of the map is less tangible, although it can be an important tool for the discerning user. Clearly, the map will not pinpoint the location of the next producing oil well or the next bonanza mine, nor will it give specific advice for the location of a dam or a reactor site; these needs can only be satisfied on maps on much larger scales, designed for specific purposes. Nevertheless, the sapient exploration geologist can find upon it significant regional features not apparent to the untrained user. Many great petroleum pools occur in stratigraphic traps, or "wedge belts of porosity," caused by overlap or truncation, the regional occurrence of which can be seen on the map. Important mineral deposits cluster along regional tectonic trends or chains of plutons of specific ages. Finally, the Geologic Map will be used in national planning activities in conjunction with other national maps showing environmental features such as climate, vegetation, and land use—for the location of power transmission corridors, highways, National Parks, wilderness areas, reclamation projects, and the like.

METHODS OF COMPILATION

Many people, including a surprising number of trained geologists, ask the question: How does one go about compiling a geologic map of the United States (or any small-scale regional geologic map)? No doubt various methods of compilation are possible, yet some general principles apply to all, if an acceptable product is to be obtained. We can explain our own methods, which we have evolved through trial and error.

First of all, compilation involves geological comprehension and human skill; no mechanical shortcuts

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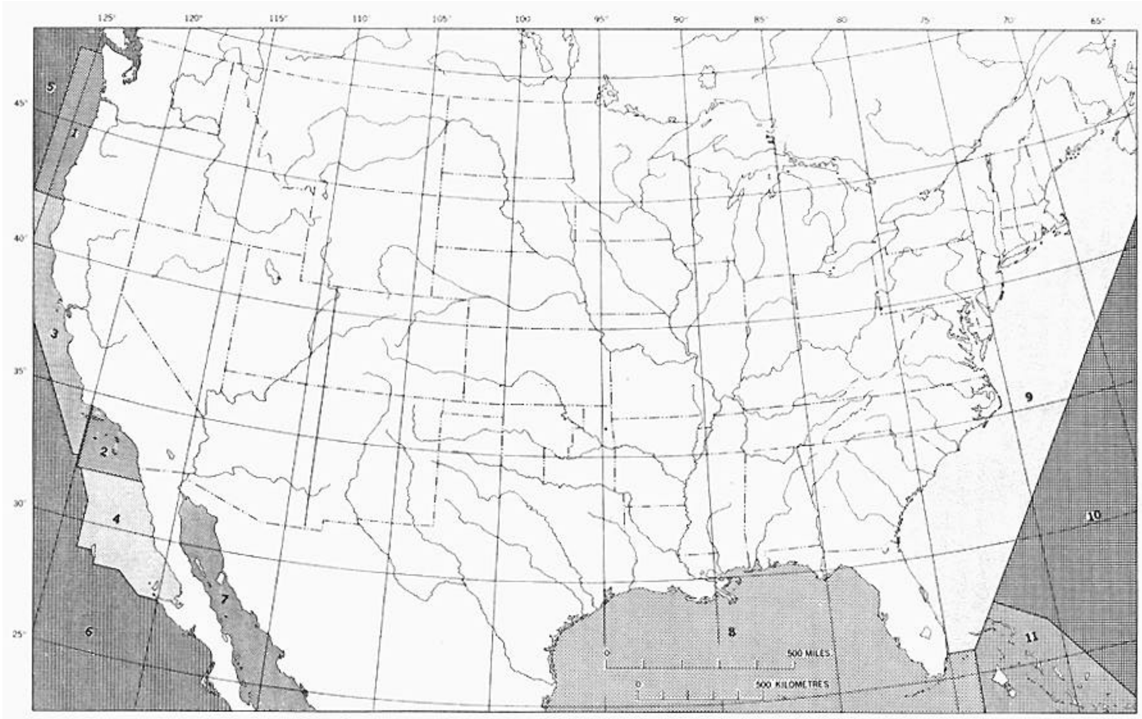

Figure 7.—Index map of the United States, showing areas covered by the different sources used for the subsea contours on the Geologic Map. Numbers are explained on page 18.

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are possible. High-altitude or satellite imagery is undoubtedly valuable for interpreting the geology of other planets, or even of poorly known regions of the earth, but it is merely of peripheral interest in regions where large amounts of ground data are available, as in the United States. Such images illustrate the broad geomorphic features and tectonic lineaments, but they reveal little of the nature, relations, or sequences of the rocks from which these features are made; also, in the United States, wide areas covered by the imagery show more of the soil, vegetation, and the works of man than of the fundamental geology. Further, there appears to be little value in reducing large-scale data into small-scale data by computer. We are not familiar with the details of research that has been done on this matter, but it is our impression that the computer simply reduces selected lines from the source maps in a manner that could be done as well by photography. Precision of linework is attained, but there is no generalization that would make the product comprehensible.

We begin instead, where possible, with geologic source maps on medium scales, approximately between 1:500,000 and 1:250,000, or five to ten times our final scale of 1:2,500,000. A certain amount of generalization has already been made on these medium-scaled geologic maps, yet they still retain much of the original geology in manageable form. Where only the raw geologic data are available, on scales of 1:24,000 to 1:62,500, it has been necessary for us to make our own generalization to the medium scale before proceeding further. On the other hand, source materials on scales of 1:1,000,000 or smaller are ordinarily ill adapted for our purpose, unless they cover areas of very simple geology. On these, the hand of another compiler has been interposed between us and the sources; we must accept on faith his judgment as to what should be represented rather than making judgments of our own.

Beginning with the ideal medium-scaled source maps, we make an effort to comprehend the geological meaning of the area represented—its geologic history, stratigraphy, and tectonics—in order to determine what features can most appropriately be selected for use on the final map. We then trace these features on clear plastic. Some items on the original maps can easily be sacrificed, such as subdivisions within gross stratigraphic units, convolutions of contacts produced by erosion or topography, little faults unrelated to the gross tectonic pattern, patches of some ubiquitous lava or gravel scattered over bedrock, and strips of river alluvium. Other items should be emphasized or even exaggerated, such as inliers of Precambrian rocks amidst younger rocks, and the lay of formations and contacts produced by folding and faulting.

Something should be said about the rock units selected for tracing. The compiler of each State Map or other source map classifies the rocks in a manner most appropriate for his area, but which may be inappropriate for an adjoining State or area. In compiling a Geologic Map of the United States it would be a simple matter merely to accept and copy without coordination the classifications in the different areas, but this would not result in a meaningful representation for the whole country. The compiler of a national map must therefore have in mind what he wishes to achieve in a unified classification for the country and make his tracings accordingly—although this tentative classification may have to be more or less modified as the work proceeds.

These tracings are then reduced photographically and replotted. Ordinarily the reduction is to some intermediate scale—1:1,000,000 in regions of complex geology, and 1:2,000,000 in regions of simpler geology. The results are expressive for their scales, but when a further reduction is made to the final 1:2,500,000 scale, it is obvious that still greater sacrifices will be necessary.

The final generalization is always painful to the compiler, because he is thoroughly aware of the significant geological features he wishes to portray, yet has very little space in which to do so. He is constrained by the limits of legible printing of lines and colors, and by the eventual user's limits of comprehension. Reduction and generalization of the geology to the 1:2,500,000 scale brings it down to about the limit at which actual ground features can be represented; on smaller scales the compiler must indulge in fantasy. On the 1:2,500,000 scale he must endeavor to retain some grasp of reality and to present a digest of the significant aspects of the geology.

For some complex areas this is not possible, even on the 1:2,500,000 scale. For these areas King recalls the sage advice of Nelson Horatio Darton, a master compiler of an earlier generation: Do not attempt to show details of geologic pattern or structure; show merely "what is there"——patches of the significant formations, not necessarily arranged in any meaningful picture. In parts of the United States Map, especially in the Basin and Range province of the Western States, we reluctantly have cast our ideals aside and resorted to this drastic procedure, producing within the mountain ranges a crazy quilt of colored patches of selected units, leaving the user to consult maps on larger scales for the actual details.

CONTENTS OF THE GEOLOGIC MAP

The present Geologic Map of the United States follows the same format as the preceding Geologic Map of the United States of 1932. Ideally, both have been de-

signed to represent the geological features that the user could find if he should visit any locality within its limits, that is, the bedrock formations that lie at the surface at that locality. In many parts of the country, especially in the arid regions of the Southwest, this is literally true. In other parts of the country there are lesser or greater departures from this ideal, owing mainly to concealment of the bedrock by surficial material.

Thus, the geologic map is primarily a bedrock map and not a surficial geology map. Surficial geology maps represent in much detail the surface geology and materials, mainly of Quaternary age, that overlie the bedrock and classify them as to kind and origin. Bedrock is shown, at most, only in actual outcrops; hence, these maps can give little hint as to the fundamental bedrock pattern and structure. Making a surficial geology map is a worthy enterprise in itself but one with which we are not involved; such maps of all or large parts of the country have already been prepared by others (Thorp and Smith, 1952; Flint, 1959).

Consequently, the Geologic Map of the United States does not represent the glacial and other deposits of Pleistocene age that blanket large parts of the Northern Interior States, and loess or drifted sand which are extensive in other places. In such areas our representation of the bedrock must perforce be a subcrop or subdrift map sometimes based more on the results of drilling and geophysical data than on outcrops. In the Northern Interior States we have marked the limits of the later and earlier glaciations to suggest areas in which the bedrock is likely to be extensively concealed. The Geologic Map does, however, represent the Quaternary deposits along the Atlantic and Gulf Coasts and in intermontane areas in the West, where they are essential features of the bedrock pattern. Details of procedure are discussed at several places further on (see p. 31).

The Geologic Map of the United States is not a tectonic map. Tectonic maps classify the surface bedrock according to its tectonic rather than its stratigraphic evolution, and they sometimes represent rocks and structures at considerable depths beneath the surface. They also symbolize the folding and faulting to which the rocks have been subjected and classify the faults as to kind and origin. Again, the making of a tectonic map is a worthy enterprise in itself with which we are not here involved (although King has been so involved in the past); tectonic maps of the United States and of North America have already been published (Longwell, 1944; Cohee, 1962; King, 1969).

Nevertheless, the bedrock patterns on a geologic map have tectonic implications, and these should not be slighted. Where the rocks have been folded, the folding should be emphasized by the patterns of the formations, and where the formations have been displaced by faults, the faults should be represented. Some small-scale geologic maps have omitted faults entirely; others have shown them only where they offset a map unit. On the present map, faults are shown not only to explain offsets of the map units, but for their own sake, to illustrate the structural grain of the region (see p. 28).

The Geologic Map of the United States is not constructed according to any particular tectonic principle or theory——the permanence of continents, the oceanization of continental material, continental accretion, continental displacement, plate tectonics, or the like. If such theories have a place on maps, it is on tectonic rather than geologic maps. A geologic map should present a reasonably factual statement of the bedrock that actually exists on the continent. It contains the data on which a theoretician can build, if he chooses, and hopefully it provides constraints for the more exuberant manifestations of theoretical geology.

The Geologic Map of the United States represents only the geology of the continental territory of the United States; the geology of the continental territory of Canada and Mexico within the limits of the geographic base is not represented. National geologic maps of Canada and Mexico have been published (Geological Survey of Canada, 1969; Sanchez Mejorada and Lopez Ramos, 1968). For our own edification, we have plotted on our copy of the United States Map the geology of Canada and Mexico within the limits of the base, as shown on the national maps of those countries. The results are interesting, and the general fit across the international boundaries is satisfactory, but there are problems in detail of classification and unification that it would be presumptuous for us to attempt to resolve.

Finally, the map does not represent the offshore geology on the continental shelves and continental slopes. Geologic maps of variable quality have been made of parts of the offshore areas by marine geologists (see footnote 2), but the geology of other parts is still imperfectly known; accurate representation of all the offshore areas of the United States is still a project for the future. On the Geologic Map we have, however, represented the positions of the continental shelves and slopes by means of the first 200-metre contour, and of 500-metre contours thereafter, and with this guidance the user can, if he wishes, mark whatever additional data meet his fancy. The sources from which the contours were compiled have been listed earlier (see p. 18).

Footnote 2. See, for example, the geologic map of the sea bottom in the North Atlantic and Gulf of Mexico adjacent to North America by Emery and Uchupi (1972, fig. 87)

CLASSIFICATION OF THE ROCK UNITS

The general plan of classification of the rock units on the Geologic Map of the United States is illustrated by

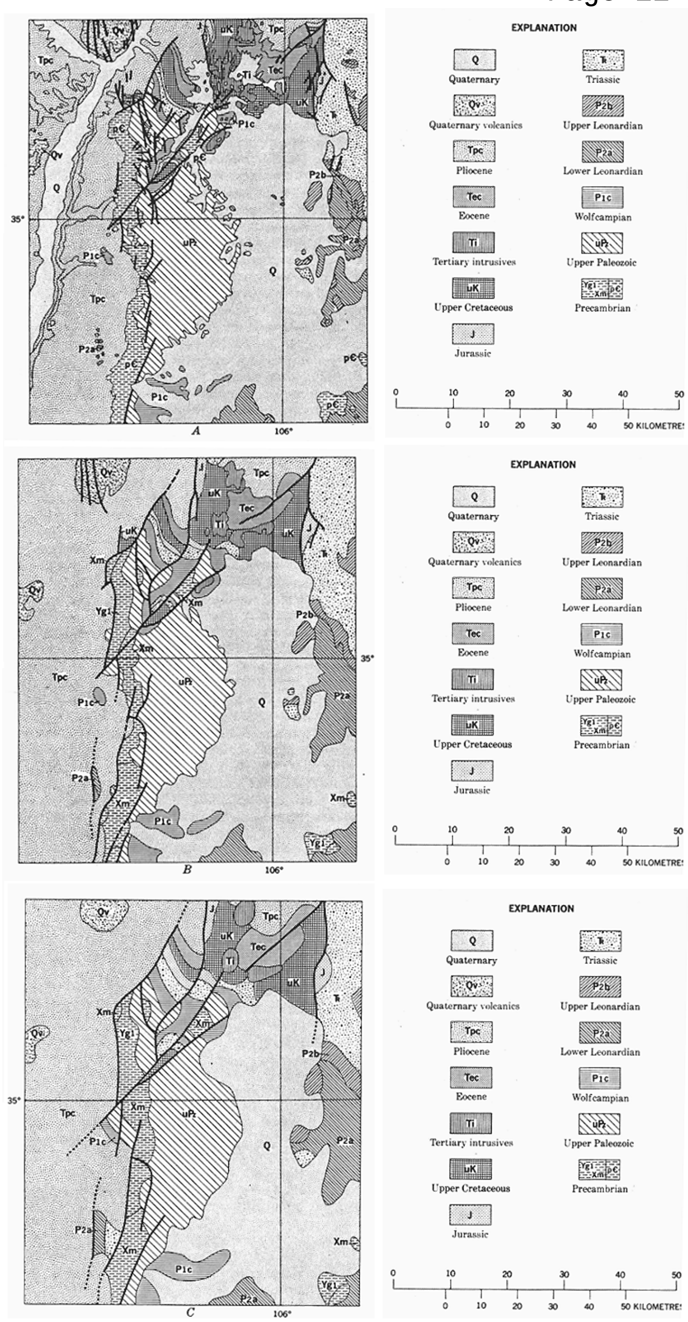

Figure 8.—Geologic maps of the Sandia Mountains, N.M., to illustrate the process of generalizing data for the Geologic Map of the United States. A, Representation of the area on the primary source, the Geologic Map of New Mexico of 1965; original scale 1:500,000. B, The area when generalized, somewhat revised, and replotted on a scale of 1:1,000,000. C, The area as shown on the Geologic Map of the United States, a further generalization from B; original scale 1:2,500,000. The representation in C appears crude by comparison with A and B, but contains the maximum detail possible for publication scale.

the map legend. The legend of the present map differs from that of the previous map of 1932 in that all items are combined into a single tabulation, rather than being broken up into separate tabulations for each of the geologic provinces. This change is now possible because of the progress that has been made during the intervening 40 years in correlation and coordination of the geology of the country.

On the legend, the Phanerozoic rock units are classified according to both age and kind. (The Precambrian rocks are treated in a similar manner so far as possible, but they have special problems and will be treated in a later report.) Rocks of approximately the same age are shown at the same horizontal level in the legend——for example, Lower Cretaceous strata and Lower Cretaceous granitic rocks. Successive vertical columns show different kinds of rocks. Classification begins in the first column with what might be considered as the "normal stratified sequence," largely marine and obeying the classic laws of superposition, and in succeeding columns proceeds to various groupings of the units, then to other facies of similar age such as continental and eugeosynclinal, to contemporaneous volcanic and plutonic rocks, and finally to the metamorphic equivalents of the others.

The classification of the rock units is, if possible, time-stratigraphic——that is, units which are of approximately the same geologic ages at all places, such as systems, series, and stages. Rock-stratigraphic units, which may be of different ages from place to place, are used only where they illustrate some special geologic feature, or where the age classification is uncertain. Unlike the legend for the Geologic Map of 1932, very few formations and other specific stratigraphic units are mentioned; discussion of these will be taken up in later reports.

The first column of the normal stratified sequence lists the smaller subdivisions that are used on the map, commonly series or groups within the systems. Ordinarily, these can be shown on a map of this scale only in regions of simple geology, where the systems occupy wide outcrop bands. Places where such subdivisions can be represented differ from one system to another, hence the first column does not represent a sequence that occurs in a single region. In general, the Paleozoic systems can be divided in most detail in the Eastern Interior Region, the Permian in the Western Interior, the Cretaceous in the Western Interior and the Atlantic and Gulf Coastal Plains, and the Tertiary in the Coastal Plains. In a few places, the rocks of the time-stratigraphic units dip so gently, or are so thick, that they occupy areas too broad to express the geologic features adequately, and smaller subdivisions are desirable. The Lower Ordovician of the Ozark Plateau, and the Montana Group in the northern Montana plains are thus further divided into units O1a and b, and uK3a and b, respectively.

Most of the geologic systems that form wide outcrop bands can be divided on the map into three or four comprehensive time-stratigraphic units, but the situation is less satisfactory in the Permian. The Permian dips gently and forms wide outcrops in the Midcontinent Region, New Mexico, and northern Arizona. The Permian forms smaller, less continuous areas in western Texas, but the rocks here are of fossiliferous marine facies and are the basis for the standard subdivision of the system. In each of these areas the Permian can be subdivided in some detail. Especially impressive is the long belt of outcrop in the Midcontinent Region, from north-central Texas to Nebraska, where six subdivisions can be traced, to a large extent on continuity of outcrops. Nevertheless, the obvious subdivisions in each area are not necessarily correlative, and their correlation is in part controversial. In the Permian, unlike other systems, recourse therefore had to be made to "operational units," which are illustrated in a diagram in the lower part of the legend. Permian stratigraphic problems will be treated at greater length in a later report.

In the remainder of the United States, the geologic systems must be shown as single map units, or several systems must be combined, as shown in the second and third columns of the legend. Map units that combine the systems into more comprehensive groupings are both a necessity and a plague to the compiler. In strongly deformed regions, where the strata are turned up steeply, outcrop bands of even the major units become very narrow, and the niceties of stratigraphic differentiation, appropriate for areas of simpler geology, are out of the question.

In the Eastern United States, we therefore resort to hybrids—DS for Devonian and Silurian, OC for Ordovician and Cambrian, and the like. This means either that the two systems form outcrop bands too narrow to be separated successfully on a map of this scale, or else that the two systems form a homogeneous body of rocks. In making our compilations we have discovered that some geologists have used the hybrids in another sense——DS for Devonian or Silurian when they are not certain which. Where possible, we have avoided this second

meaning and have made arbitrary decisions; if the weight of evidence is more toward a Devonian than a Silurian age, the unit is mapped as Devonian; if we are in error, the error can be corrected later.

In the Cordilleran region of the Western United States, even this hybridization is insufficient, and we have resorted to the more general groupings of lPz, uPz, and lMz, for lower Paleozoic (Cambrian to Devonian), upper Paleozoic (Mississippian to Permian), and lower Mesozoic (Triassic and Jurassic), respectively. This usage will make stratigraphers and other precisionists unhappy; it will fail to reveal to them, for example, the nearly complete absence of the Silurian in most of the Rocky Mountains, or the Triassic in the Sierra Nevada. The alternative would have been to resort to complex letter combinations, varying from one part of the map to another, such as CD (Carboniferous and Devonian), DSO (Devonian, Silurian, and Ordovician) and DC (Devonian, Silurian, Ordovician, and Cambrian) used on the Geologic Map of North America of 1965 (Goddard, 1965)——each requiring a separate color on the map and box in the legend.

Within the Paleozoic areas of the West, the Cambrian and Permian at the base and top of the sequence occupy significantly large areas in a few places, and are of interest both stratigraphically and structurally. These large areas are separately shown; elsewhere the two systems are merged with the lower and upper Paleozoic.

Following the normal stratigraphic sequence are columns for various facies. In the Tertiary deposits of the West it is important to distinguish between marine and continental deposits——the marine Tertiary along the Pacific and Gulf Coasts, and the continental Tertiary of the interior, which forms wide areas in the Great Plains and the intermontane basins of the Rocky Mountains. Problems multiply in the pre-Tertiary rocks, and consistent separation of continental deposits becomes impossible. How should one classify coal measures, red beds and evaporites, or sheets of fossil sand dunes, all of which form broad units in normal stratified sequences, which are continental in a sense, yet have at least some tenuous marine connections? In general, these are not shown as continental deposits on the map. In the pre-Tertiary rocks, only the more obvious continental deposits are so indicated——Cretaceous adjoining orogenic areas in the Rocky Mountains, Jurassic in the Northern Interior, Permian near the Wichita Mountain axis in Oklahoma, and Devonian in the Northern Appalachians.

Another facies that is separated comprises the eugeosynclinal deposits. Modern tectonic studies indicate that "eugeosynclinal" is a broad generic term that embraces many specific kinds of rocks formed in different environments——marginal seas, island arcs, deep-sea trenches, and ocean floors. Be that as it may, the eugeosynclinal suite embraces rocks markedly different from the usual marine and continental deposits of the interior of the continent——immature clastic sediments, cherts, and large volumes of volcanics and volcaniclastic sediments. While the generic characters are plain, separation into specific varieties is likely to be subjective and would, further, unduly clutter representation on the scale of the Geologic Map of the United States.

Eugeosynclinal deposits are represented in the coastward parts of the Appalachians (where they are of lower Paleozoic age), and the Cordillera (where they are of Paleozoic and Mesozoic ages). In addition, eugeosynclinal deposits of Tertiary age, very much like those of the earlier ages, occur in the Olympic Peninsula of northwestern Washington and are separately mapped. Differentiation of rocks of eugeosynclinal facies emphasizes important structural features in the United States, as where they have been thrust for many miles over normal marine carbonate rocks of similar age in the Northern Appalachians and the Great Basin.

Volcanic rocks likewise form stratified or quasistratified sequences, which are equivalent to, or merge laterally into the stratified sedimentary sequences. Those of Cenozoic age occur primarily in the Cordilleran region of the Western States, where they are areally extensive and offer the greatest opportunities for classification and subdivision. On the present map, we have intentionally avoided use of the units Tv and QPv of the 1932 map, for undifferentiated volcanic rocks, believing that the data are now sufficient, or nearly so, to permit a meaningful regional subdivision. Basis for classification is primarily by age (based on fossils and radiometric data), but felsic or siliceous varieties are differentiated where data are available; in addition, several other compositional varieties are shown in the Pacific Northwest. Details of classification of the Cenozoic volcanic rocks will be considered in later reports.

In the pre-Tertiary systems, volcanic rocks are distinguished in few places. They unquestionably form large volumes of the eugeosynclinal deposits, but as these are in part volcanic by definition, their volcanic components can generally be surmised. In the lower Paleozoic eugeosynclinal deposits of the Appalachians, however, volcanic rocks form well-marked entities, the areally more extensive of which are separately mapped.

Among the plutonic rocks, granitic varieties are the most extensive and the most amenable to classification by age, mainly on the basis of radiometric data but partly on their geologic relations to the country rocks. Mafic varieties are less extensive and are not subdivided in detail. The ultramafic rocks are a class by

themselves and are not designated by age; large parts of them, at least, are fragments of mantle material of enigmatic age which have arrived at their present positions by tectonic rather than magmatic processes.

Metamorphic rocks are indicated primarily by overprints on the parent rock units, except in parts of the Piedmont province of the Appalachians and in the Cascade Range of the Pacific Northwest, where the ages of the parent rocks are as yet undetermined; such rocks are designated as "metamorphic complexes." The metamorphic overprint is not used in the Precambrian rocks; the designation of certain units as "orthogneiss" or "paragneiss" seems sufficient to indicate their metamorphic nature.

Rocks shown as "metamorphic" are primarily those of amphibolite grade or higher, that is, with garnet, kyanite, sillimanite, and other diagnostic minerals. Rocks that have been altered to greenschist grade, with chlorite, biotite, and similar diagnostic minerals, are not represented as metamorphic. Near the West Coast, in California and Oregon, upper Mesozoic eugeosynclinal rocks (uMze, Ke) have been subjected to high-pressure low-temperature metamorphism, producing various blueschist minerals. In this domain regionally metamorphosed rocks containing glaucophane, lawsonite, and pumpellyite are shown as metamorphic; lower grade rocks with laumontite and similar minerals are not. In a few places on the map the metamorphic overprint is used to express geologically significant metamorphic rocks or metamorphic contrasts, without regard to mineral content; thus some of the rocks of the Olympic Mountains, Wash., are shown as metamorphic, even though they are low grade mineralogically.

SYMBOLIZATION OF ROCK UNITS

On the Geologic Map itself, the rock units are differentiated by colors, patterns, and letter-number symbols. Of these, the colors present the greatest problems and hence will be dealt with in most detail.

Colors on a geologic map have two facets—geological philosophy and the technology of lithography and printing. The latter need not concern us greatly here, as it is a matter of the techniques of producing colored maps; these change from generation to generation, although the general results are much the same. The geological philosophy is more fundamental, and one upon which there are still significant differences of opinion and usage.

One can, if one wishes, produce an empirical representation, in which the choice of colors on the map has no general meaning—usually for the purpose of creating contrasts between map units, thereby enhancing legibility. An excellent example is the Geologic Map of Pennsylvania (Gray and others, 1960), in which the colors are used unsystematically, yet eloquently portray the structure and stratigraphy of the State. This method is best adapted to large-scale maps, or regional maps of restricted areas, and would be inappropriate for the Geologic Map of the United States.

The best alternative is to match the orderly sequence of rock units from oldest to youngest with an orderly sequence of prismatic colors (consult the Munsell color notation system, which has been adopted by the American Standards Association). As stated by Willis (1912, p. 27):

Let it be agreed that the sequence red, purple, violet, blue, green, and yellow shall be adopted to represent the succession of formations, groups, or series of sedimentary rocks from older to younger and let the order of colors be invariable according to the principle stated above, no matter what part or how much of the geologic column is represented. Then red will always represent something older than that which is shown in purple, or violet, or blue, etc. Blue will always be older than that shown in green or yellow. In looking at any geologic map thus colored the student would at once know which were the older and which were the younger sedimentary rocks. The essential features of the sequence and structure would be immediately obvious.

Most systems of coloring geologic maps use this general principle, although with greater or lesser departures from it, as we shall see.

Efforts to achieve a systematic scheme for coloring geologic maps are nearly a century old, and their history is pertinent. By the 1870's, the proliferation of geological investigations in both Europe and North America made obvious the need to systematize results—in stratigraphy, mineralogy, paleontology, and the making of geologic maps. This led to the convening of the First International Geological Congress in Paris in 1878, the results of which were inconclusive. Decisions were therefore deferred until the Second Congress (Bologna) in 1881 and the Third Congress (Berlin) in 1885 (see footnote 3). Only the results that pertain to the making of geologic maps need concern us here; many of the recommendations made on the other subjects have only historical interest.

Footnote 3. The results have been published in the respective reports of the first three congresses, in which the official language was French. For the American reader, they were usefully summarized by the secretary of the American Committee, Persifor Frazer (1888). In addition, G. K. Gilbert (1887) presented a lengthy critique of the results of the Third Congress.

The prime need at the time was a comprehensive scheme of symbolization for use on a Geologic Map of Europe, then being compiled by an international committee. Although some geologists protested that the results were provisional and experimental and applied only to the European project (Frazer, 1888, p. 95), there were misgivings by others at the time that they would crystallize into a permanent general usage (Gilbert, 1887, p. 432)—a foreboding that has been amply justified by subsequent events. Immediately thereafter, the color scheme adopted by the 1881 and 1885 Congresses was used by C. H. Hitchcock (1887, p. 466-467)

for coloring his Geologic Map of the United States (see p. 7), and today it is commonly referred to as the "International system" by European geologists, who have urged its adoption on a worldwide basis.

Meanwhile, however, J. W. Powell was appointed second Director of the U.S. Geological Survey in March 1881, and in his first official report, written a few months later, announced a scheme of stratigraphic nomenclature, map coloring, and patterns to be used thenceforth in Survey publications (Powell, 1882, p. xliii-liii) even though: "On the 26th of September next (1881) a congress of geologists of the world will assemble at Bologna, Italy, to confer on this subject. It is unfortunate that advantage cannot be taken of the deliberations of so great a body of savants in the publication of these monographs, but the exigencies of the work will not permit of longer delay even for so important a purpose" (p. xlii). Viewed from the perspective of nearly a century the justification for this precipitate action seems specious; it was probably dictated by immediate political problems in Washington (see footnote 4). Somewhat later he presented the methods used by the U.S. Geological Survey to an international audience in a paper at the Berlin Congress (Powell, 1888, especially p. 236-239), delivered in his behalf by W J McGee.

Footnote 4. Stegner (1954, p. 271-272) presents some interesting speculations on the circumstances.

The scheme proposed by Powell has laid the groundwork for usage in publications of the U.S. Geological Survey to the present time. Detailed specifications for usage in these publications were promulgated in 1890, after areas of diverse geology in many parts of the country had been sampled by mapping, and after conferences with 18 of the leading Survey geologists of the time (Powell, 1890, p. 56-79); they differ in detail from the original proposal of 1881, but the broader features remain the same. Thus, Powell's original map colors, with subsequent elaborations, have become the United States, or "American color system."

The principal differences between the "American" and the "International" color systems are in the stratified sedimentary rocks; the intrusive and volcanic rocks in both systems are shown in more brilliant tints, with a preference for the reds and oranges. The two systems are compared in table 1; the original proposal for each is followed by samples of subsequent usage, including that on the present Geologic Map of the United States.

The reasons for the differences between the two systems are ably explained by Willis (1912, p. 24-26):

The European international color scheme embodies the results of prolonged consideration by the international committee who were charged by the Geological Congress with the duty of preparing the map of Europe. In it can be recognized some elements of the French usage, particularly *in the colors employed for the Mesozoic and Tertiary terranes. German influence appears in the selection of tones for the Paleozoic terranes, and the familiar association of gray with Carboniferous and of pink with the ancient crystalline schists is an obvious result of general practice. So also is the use of strong brilliant colors for the igneous rocks. The writer is not definitely informed regarding the discussion of principles through which the result was reached, but a study of the color schemes in the light of what is published concerning the controlling principles, it would seem that the committee recognized (l) established usage, (2) the order of prismatic colors from purple through blue and green to yellow for that portion of the scheme relating to the Triassic and post-Triassic terranes, and (3) the arbitrary principle that Mesozoic terranes should be distinguished from Paleozoic by a very decided contrast of light and shade, the Paleozoic terranes being indicated by dark colors.*

The European color scheme is exceedingly well adapted to delineate the geology of Europe and would apply very well to that portion of western North America in which the Mesozoic and Tertiary formations occupy large areas in contrast to the Paleozoic terranes, as they do in Europe also. The color scheme thus commends itself through the beautiful appearance of the map. It must not be forgotten, however, that Europe represents a special form of geologic structure. The continent is made up of extensive areas of Mesozoic and Tertiary strata surrounding relatively small exposures of Paleozoic terranes. This arrangement of younger strata about older nuclei is, from the standpoint of the cartographer, the most important feature which the continent presents. The committee with good reason sought to emphasize the fact and through that emphasis the map of Europe gains in expression and educational value. The greater part of the map is easily legible, being covered only by the light colors which are used for the Mesozoic and Tertiary, and the difficulties which arise in attempting to read the geology of the minor Paleozoic areas are not forced upon the attention.

But the international scheme is unfitted to lands in which the Paleozoic terranes predominate and are minutely subdivided, for the density of the colors selected for the

Paleozoic would produce a map that would offend good taste and be illegible. Moreover, inasmuch as the range of prismatic colors from purple, blue, and green to yellow is preempted in the European color scheme for Mesozoic and Tertiary terranes and the reds assigned to the ancient crystalline and eruptive rocks, the choice of colors remaining available for the Paleozoic is much too limited for satisfactory discriminations. This is at once evident on an examination of the Paleozoic areas as represented on the international map——such, for instance, as the coal fields of Belgium and France, or the peninsula of Brittany, or Wales and Scotland. Although the distinctions are limited to a few great systems they are recognizable only on close inspection and the areas are indistinguishable from one another at a little distance. A geologic map of eastern North America printed in these dark colors with so little difference of hue or shade would fail to present adequately the great Appalachian zone as distinguished from the broad plateaus of the coal measures and the domelike uplifts of the Cincinnati axis. In the Precambrian also the number of formations recognized in North America is greatly in excess of those distinguished in Europe, and the simplicity of the European scheme renders it insufficient to delineate the geology of the Lake Superior region and the Canadian Shield.

The validity of Willis' evaluation is substantiated by the results of attempts to apply the so-called "International system" to continents where the gross geologic structure and surface distribution of the geologic systems differ significantly from those of Europe. The inadequacy of the "International system" for Australia is lamentably evident on the otherwise beautifully printed sheets for this part of the Geological Map of the World (Bureau of Mineral Resources, Geology, and

TABLE 1.—*Comparison between "American" and "International" systems of coloring stratified rocks on maps*

System	American color system			International color system		
	U.S. Geol. Survey 2d Ann. Rept. 1881[1]	U.S. Geol. Survey Folio 227 1945[2]	Geologic Map of United States 1974[3]	2d and 3d Internat. Geol. Cong. Bologna and Berlin 1881, 1885[4]	Eastern Siberia 1964[5]	Geologic Map of France 1968[6]
Quaternary	Gray	Brownish yellow	Gray Pale yellow	Undecided	Gray	Gray
Tertiary	Yellow	Yellow ocher	Light yellow Pale brown Pale flesh Dark yellow Greenish yellow	Yellow	Light yellow Yellow Greenish yellow	Light yellow Dark yellow Orange yellow
Cretaceous	Green	Olive green	Olive green Yellow green Cool green	Green	Green	Green
Jurassic		Blue green	Blue green	Blue	Blue	Blue
Triassic		Peacock blue	Peacock blue	Violet	Violet	Violet and purple
Permian	Blue	Light blue	Cool blue	Gray	Warm brown	Gray
Pennsylvanian		Blue	Gray		Dark gray	Dark gray
Mississippian			Warm blue			
Devonian	Purple	Blue gray	Blue	Brown	Cool brown	Brown
Silurian		Blue purple	Purple	Greenish gray	Olive green	Olive gray
Ordovician		Red purple	Rose and pink		Pale green	Olive green
Cambrian		Brick red	Red and coral		Rose	Warm brown
Precambrian	Brown	Brownish red Gray brown	Yellow brown Brown Bluish gray Brick red	Rose	Brown	Pale brown

[1]Powell, 1882, p. xi–lv.
[2]Butts, 1945, specifications of folio series on inside covers ("Geologic Atlas of the United States").
[3]King and Beikman, 1974, this report and map.
[4]For summary, see Frazer, 1888.
[5]Kransky, 1964.
[6]Service de la Carte Géologique du France, 1968.

TABLE 1. Comparison between "American" and "International" systems of coloring stratified rocks on maps.

Geophysics, 1965). The Tectonic Map of the country (Tectonic Map Committee, Geological Society of Australia, 1971) and recent maps of individual states use an approximation of the "American system" and produce a much clearer picture of the regional geology. It is of interest to compare the systems of Europe and the United States with that adopted on the Geological Map of Canada (Geological Survey of Canada, 1969); as in the "American system" it follows a prismatic scale, but the blue colors are extended downward to the base of the Paleozoic, reserving the red, orange, and brown colors for the Precambrian, in which rocks of many kinds and ages must be differentiated.

The colors used on the present Geologic Map of the United States conform as far as possible to the traditional "American system," in which the prismatic scale of colors embraces the whole geological sequence, from earliest Precambrian into the Quaternary. Some departures are necessary, it is true, due to modern methods of lithography, and to obtain greater emphasis of some units. (Similar freedom has been exercised within the so-called "International system," as is evident in the last two columns of table 1. In order to clarify the growing complexity of the Precambrian sequence, the rocks of division X are separated from the prevailing reds and browns of the other divisions by the use of tints of bluish gray; and the Oligocene and Miocene Series of the Tertiary are distinguished from the prevailing yellows of the others by the use of flesh and pale-brown tints.

Traditionally, on geologic maps published by the U.S. Geological Survey, the meaning of colors has been enhanced by the use of patterns, as explained in the text that accompanied all the folios of the Geologic Atlas: "Patterns composed of parallel straight lines are used to represent sedimentary formations deposited in the sea, in lakes, or in other bodies of standing water. Patterns of dots and circles represent alluvial, glacial, and eolian formations. Patterns of triangles and rhombs are used for igneous formations. Metamorphic rocks of unknown origin are represented by short dashes irregularly placed; if the rock is schist the dashes may be arranged

in wavy lines parallel to the structure planes." Use of patterns was more feasible with the older methods of lithography than the methods used at present, in which it is more practical to use flat tints; but they can still be achieved by overprints on the flat colors——as has been done on recent maps of the U.S. Geological Survey and on maps published in the Soviet Union and elsewhere. One need only to study a map without patterns to become painfully aware of their mnemonic value; not even the use of vivid, contrasting colors for plutonic rocks and lavas (as on the Geologic Map of France, 1968) conveys the distinctions as clearly and immediately as do patterns.

On the Geologic Map of the United States, overprinted patterns are used to indicate plutonic rocks, metamorphic rocks, and some of the volcanic rocks. For the granitic class of plutonic rocks we have used the "short dashes irregularly placed" (there is no better descriptive term for this excellent and expressive pattern); it implies massive crystalline rocks, so that its former use in the folios for metamorphic rocks has become inappropriate. The pattern is superposed on a color expressing the age of the granitic pluton (which can now be determined from radiometric data). For metamorphic rocks a dense halftone overprint is substituted; the "random dashes" of earlier maps were too weak to differentiate these rocks clearly. For the volcanic rocks we use various v-patterns, a simplified form of the "rhombs and triangles" of the folios.

It is most desirable that colors on a map be identified by letter/number symbols to assist the user in comparing the map with its legend. The handicap of a colored map without symbols is at once apparent to the user of the otherwise excellent sheets of the 1:200,000 Geologic Map of Switzerland, in whose complex parts there are many small patches and bands of color that he must endeavor to match with one of an assortment of similar colors in the legend.

The simplest form of symbolization is by numbers, which are appropriate where there are only a few units, but confusing when they number 50 or more, as on some Canadian maps. Being entirely noncommittal, numbers have no mnemonic value——an advantage or a disadvantage, depending on the circumstances.

Much more common are single or multiple letters, or letters combined with numbers, several systems of which have been used——no one better than the other. In the specifications for the Geologic Map of Europe adopted by the International Geological Congress, geologic ages of strata were expressed by roman lowercase letters, modified by suffixed numbers, and different kinds of eruptive rocks were shown by Greek letters. On many other geologic maps, including those of the U.S. Geological Survey, general age is expressed by capital roman letters representing the geological systems, modified by suffixed lowercase letters. The symbols used on the Geologic Map of the United States resemble those of the latter system; variants are introduced by prefixing the initials l, m, and u (for "lower," "middle," and "upper"), to avoid complicating the suffix, and by use of suffixed numerals rather than letters for the smaller age divisions, reserving lowercase letters for descriptive modifiers, such as c for "continental" and v for "volcanic." Throughout, we have avoided long strings of modifying suffixed letters, which often become annoying acronyms. The only exceptions are the symbols for Tertiary eugeosynclinal deposits of the Olympic Peninsula, Wash.——Tmoe and Toee, for "Tertiary Miocene-Oligocene eugeosynclinal" and "Tertiary Oligocene-Eocene eugeosynclinal." Not all the units shown on the Geologic Map require qualification by a lowercase suffixed letter. Many of them represent a whole geologic system (or several systems); for these, the capital letters alone are sufficient.

REPRESENTATION OF FAULTS

As indicated earlier (p. 21), faults are shown on the Geologic Map of the United States, not only to explain offsets of map units, but for their own sake, to express the structural grain of the area. The density of faults represented on the geologic map thus equals that which would appear on a tectonic map of the country, but they are marked simply as faults, not as low-angle or high-angle thrust faults, normal faults, or strike-slip faults; for this information the user should consult the appropriate tectonic map.

By the method adopted, faults are shown not only at contacts between map units, but within map units. Some of these are major faults with large displacements. In Arkansas, the great frontal thrusts of the Ouachita Mountains all lie within the combined Atokan and Morrowan Series (Pennsylvanian1), which is here more than 4 miles thick; the lower part of the unit is displaced against the upper, as would be evident on a more detailed map. Other faults within map units are themselves minor, but are components of major structures; those lying in the volcanic units of eastern Oregon are merely a sampling of the dense swarms that appear on maps of larger scale, which are arranged in regional sets of several directions.

In the Basin and Range province of the Western United States we have made a special effort to represent range-front faults where geomorphic evidence (steep mountain faces, even base lines, and the like) requires their existence; more timid compilers often fail to show them, thereby creating the illusion of an unfaulted terrane. Commonly, the range-front fault lies a short distance out from the foot of the range beneath the al-

luvium; on a large-scale map it would be shown as a dotted line parallel to and closely adjacent to the bedrock contact of the range. On the small scale of the present Geologic Map, only the fault itself is shown, and the bedrock contact is not.

Although the faults on the geologic map are unclassified, their patterns suggest something of their geometry. For example, in the Taconic region of eastern New York State, an array of sinuous fault traces (many closing on themselves) expresses flat or gently dipping thrusts and contrasts strongly with the straight or angularly bent traces of the high-angle faults of the Adirondack uplift and those on the borders of the belts of Triassic rocks.

Low-angle thrust faults geometrically like those in the Taconic area of eastern New York State are components of the internal structure of the ranges in the Great Basin section of the Basin and Range province. They are older than the range-front faults just mentioned, which greatly disrupt them. The major low-angle thrusts of the Great Basin section are recognizable from range to range by distinctive rocks on their upper and lower plates, but their original continuity is difficult to represent on the geologic map because of the confusing array of other rocks and structures; dotted lines are used in a few places to suggest the obvious connections.

The regional extent of these faults is indicated on the accompanying figure, which shows the inferred traces of the frontal thrusts of the Sevier orogenic belt in Utah (of mid-Cretaceous age), of the Roberts thrust in north-central Nevada (of late Devonian-early Mississippian age), and of the Golconda thrust a little farther west (of late Permian-early Triassic age). On large-scale maps the experienced eye could detect each of these by its characteristic "trademark," but these "trademarks" are necessarily blurred on the much generalized, small-scale Geologic Map of the United States. Nevertheless, even on this map the different segments of the Roberts thrust are apparent from the juxtaposition of

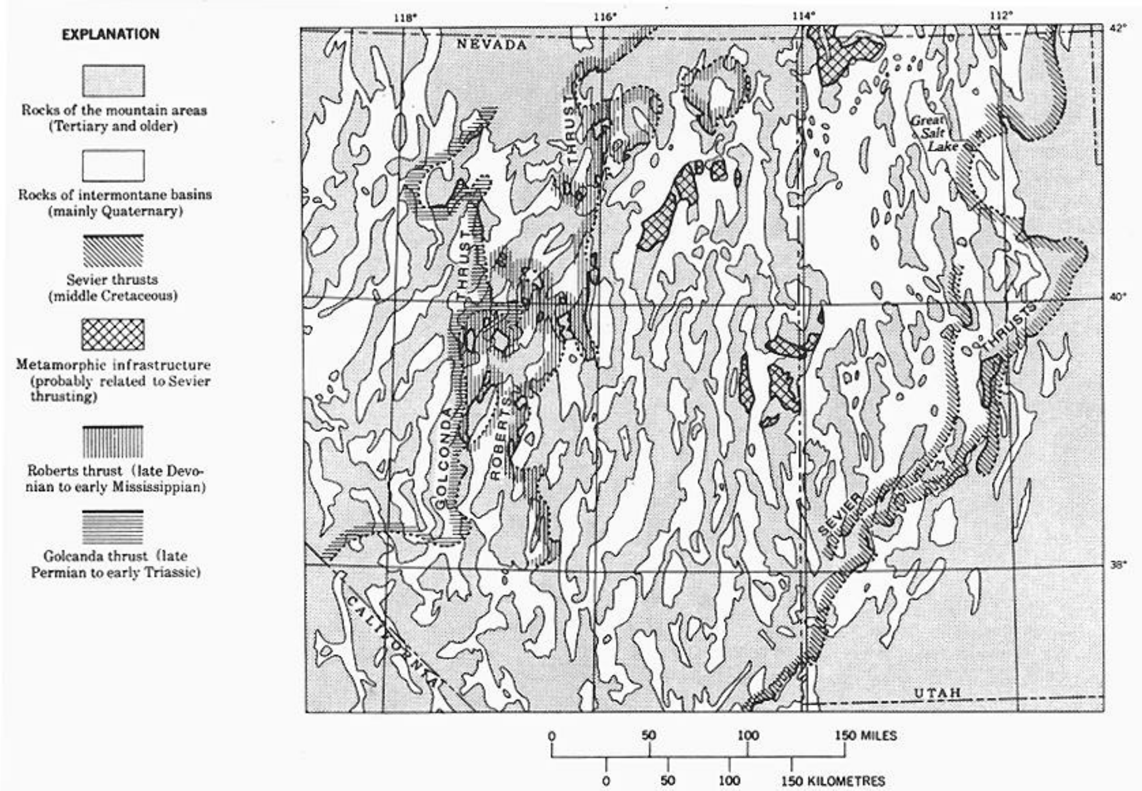

FIGURE 9.—Map of the Great Basin in Nevada and Utah, showing regional extent of major low-angle thrust faults that are represented on the Geologic Map of the United States as exposed fragments in the mountain areas. The thrusts involve only the Paleozoic and Mesozoic strata, whereas the mountain areas also include plutonic and stratified rocks younger than the thrusting.

eugeosynclinal lower Paleozoic rocks (lPze) and normal lower Paleozoic rocks (lPz) on its upper and lower plates.

Explanation is needed of the nearly circular fault traces of small to medium diameters which appear in places on the Geologic Map. They are of multiple origins, some being the rims of calderas (produced by terrestrial volcanism), others the edges of astroblemes (produced by extraterrestrial impact). Parts of these are shown by dashes, not to imply that they are hypothetical but to suggest that the marginal faulting around the central structure is discontinuous. As with the other faults, they are not further symbolized on the geologic map. Moreover, they are shown only where they conspicuously affect the surface bedrock pattern. Many more calderas and astroblemes could be represented on a tectonic map, but they would not conspicuously affect surface geology; such calderas are old, worn down, and largely buried, and the astroblemes are little structures within single map units. We have made one exception of the great caldera rim in Yellowstone National Park, nearly 40 mi (65 km) in diameter, even though it is extensively concealed by ash-flow tuffs and rhyolite

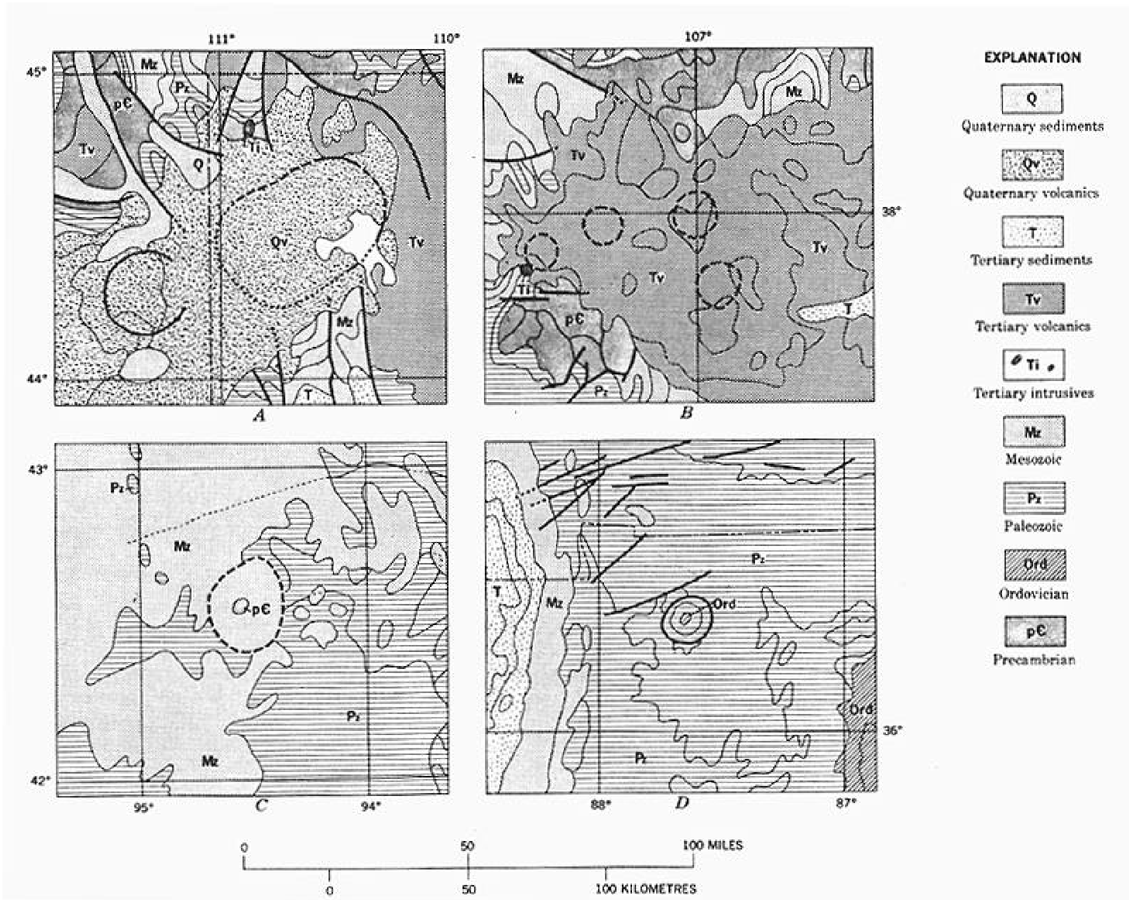

FIGURE 10.—Circular faults shown on the Geologic Map of the United States. A and B are associated with calderas, C and D with astroblemes. A, Yellowstone and Island Park calderas northwestern Wyoming and adjacent Montana. B, Calderas in San Juan Mountains, Colorado. C, Monson structure, central Iowa. D, Wells Creek Basin, west Tennessee. Contacts are the same as on the Geologic Map, but units are grouped in the legend.

flows resulting from the eruption; it is one of the major structural features of the United States and should not be ignored.

REPRESENTATION OF CONTACTS

Throughout the Geologic Map of the United States, contacts between map units (where not faulted) are represented by fine solid lines except where one set of map units merges with another along the strike; here the colors of the two are juxtaposed without a contact line. A conspicuous example is in northwestern Iowa and south-western Minnesota, where subdivisions of the Upper Cretaceous that are separately shown to the west give place eastward to undifferentiated Upper Cretaceous. Along the outcrop belts in the folded Appalachians, subdivisions of the Paleozoic systems similarly give place along the strike to undivided systems, but these features are of smaller areal extent, and are only apparent on close inspection of the map.

A "state-line unconformity" occurs between North and South Dakota, in an area of heavy drift cover where the contact between the Colorado and Montana Groups of the Upper Cretaceous (uK2 and uK3) fails to match by several counties on the bedrock maps of the respective States, the contact has been reconciled by sketching across the state line. Other "state-line unconformities" (discrepancies between map units as represented in adjoining States) abounded on our initial compilations but were resolved upon inquiry.

Subdivisions of the Eocene Series in the Mississippi Embayment of western Tennessee and the Atlantic Coastal Plain of southwest Georgia are inaccurately located; in Tennessee the contact between Te2 and Te3 is concealed by a blanket of Pleistocene loess, and in Georgia by residuum. The location of the contacts between the Eocene and the Oligocene (To) and the Oligocene and the Miocene (Tm) in Georgia are also in doubt. Drilling beneath these blankets is insufficient to clarify the actual bedrock pattern, and for want of better information we have projected the contacts hypothetically across them.

The southwestern part of the Blue Ridge province of northern Georgia was inadequately mapped at the time of compilation, but a hypothetical contact between supracrustal rocks (Z) and basement rocks (Ym) was mapped. For a more accurate representation, see the new Geologic Map of Georgia (in press, 1974).

Dotted lines, expressing contacts buried by younger deposits, are used sparingly on the Geologic Map, for the most part to indicate connections between closely adjacent areas of outcrop but also in southwestern Minnesota and in the Mississippi Embayment.

Those in Minnesota are boundaries between Precambrian units beneath a blanket of Upper Cretaceous strata and glacial drift, as shown on the Bedrock Geologic Map of Minnesota (Sims, 1970), and are supported by a variety of drilling and geophysical data.

Those in the Mississippi Embayment are contacts between various series of the Tertiary and subdivisions within the Eocene Series buried beneath the Quaternary deposits of the alluvial valley of the Mississippi River. The Quaternary deposits (Pleistocene and Holocene) are several hundred feet thick and are an essential feature of the bedrock pattern. The Tertiary units are exposed on each side of the alluvial valley and are connected beneath it in subcrop, where they are represented by dotted lines. These lines explain buried features of interest, especially the large outliers of Jackson Group (Te3) north of the normal belt of outcrop, where they are preserved in the downwarp of the Desha basin. The extent of the Tertiary units in subcrop is well known from many drill data, which were first assembled by Fisk (1944, pl. 10); representation on the Geologic Map includes some later refinements.

In the areas on the Geologic Map where extensive subcrop is represented by dotted contacts, it is clarified by letter symbols of the buried units in parentheses.

SUBCROP GEOLOGY

The present Geologic Map of the United States, like the map of 1932, is intended to represent bedrock rather than surficial deposits. The map shows principally the distribution of the Tertiary and older rocks, and the surficial deposits of the country are largely of Quaternary age. Quaternary deposits are shown on the map where they are thick enough, or tectonically significant enough, to be an essential part of the bedrock pattern. In some parts of the country, bedrock is represented even where the cover of surficial deposits is extensive and outcrops are sparse; here, outcrops must be supplemented by drill and geophysical data to produce a subcrop map. The most extensive area of such surficial cover is in the part of the Northern Interior States subjected to continental glaciations during Pleistocene time, but smaller areas occur elsewhere outside the glacial limits.

NORTHERN INTERIOR STATES

In the Northern Interior States the extent of the surficial cover is suggested on the geologic map by lines showing the limits of the latest (Wisconsin) glaciations and of the older glaciations. Concealment of the bedrock is greatest in the area of the Wisconsin glaciations, but it is nearly equalled in a few parts of the area of the older glaciations.

The extent of the concealment is illustrated by the accompanying maps of eastern South Dakota. West of the Missouri River there is little surficial cover, and the bedrock is mapped from outcrops. East of the

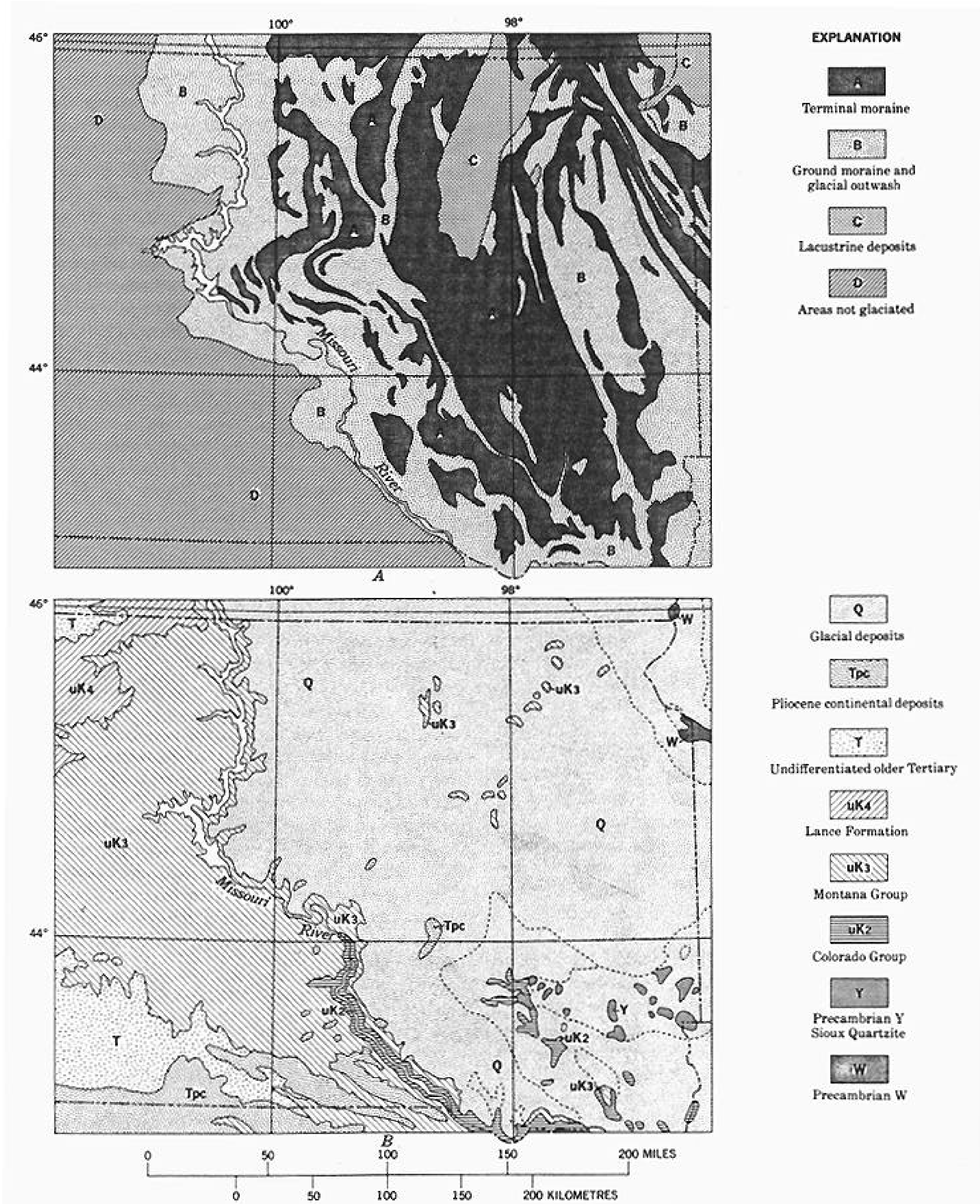

FIGURE 11.—Maps of eastern South Dakota, to illustrate problems of representing bedrock geology in areas with extensive cover of surficial deposits. A, Surficial, or Quaternary glacial deposits, generalized from Flint (1959). B, Bedrock geology as shown on Geologic Map of the United States. Outcrops of bedrock east of Missouri River are from Geologic Map of South Dakota of 1953; contacts elsewhere, shown by dotted lines, are those shown on the Geologic Map of the United States and are subcrop representations based on subsurface data.

river the cover of Wisconsin glacial deposits is nearly complete, including massive terminal moraines, and intervening areas of ground moraine, outwash, and lacustrine deposits. Bedrock emerges only in a few places along the streams, with two or three outcrops to a county at most, and in some counties none at all.

Most of the glaciated region in the Northern Interior States is a terrane of gently dipping Paleozoic strata that had been dissected into a dendritic pattern by stream erosion prior to the glaciations. The contacts between the map units show the crenulations characteristic of such dissection, including long narrow projections of older units into areas of younger, which express preglacial stream valleys, now filled and obliterated.

Especially striking examples of these features occur along the Ordovician-Silurian contact in western Ohio and eastern Indiana. Segments of preglacial stream valleys have been known in this region from water-well drilling since the turn of the century, but only in the last few decades has it been recognized that they are all parts of a single major river system, quite different from the present major Ohio River system (Horberg, 1945, p. 356-359; Janssen, 1952). The master stream was the Teays River, named for a now-empty valley near Charleston, W. Va. (Tight, 1903, p. 50). Its headwaters were the present New and Kanawha Rivers, which drain from the Appalachian Highlands. Northwest of the present Ohio River, the valley of the Teays passes under glacial deposits and has no surface expression, but it can be traced in subcrop across Ohio and Indiana (where it and its tributaries produced the crenulations in the above-noted Ordovician-Silurian contact), and into central Illinois, where it joined the ancestral Mississippi River near the present course of the Illinois River.

Other preglacial valleys in northwestern Missouri are illustrated on an inset map accompanying the Geologic Map of Missouri (McCracken and others, 1961) and produce crenulations in the contacts between Pennsylvanian map units unrelated to modern drainage. Another crenulation, on the Precambrian-Cambrian contact in central Wisconsin, has been shown on many earlier geologic maps and was thought to have been produced by the ancestral Wisconsin River; however, modern reviews of the subcrop data indicate that this valley, if it exists, does not penetrate the top of the Precambrian in this manner (Dutton and Bradley, 1970, sheet 5).

In the northern two-thirds of Minnesota the prevailing terrane is Precambrian rather than Paleozoic, and in its western part the amount of surficial cover again requires recourse to subcrop mapping. On the Geologic Map of 1932, this part was mostly represented as Quaternary, for want of better data. Much more information on the bedrock is available now, from drilling and geophysical surveys, so the patterns of Precambrian units can be extended westward across the State to join the Precambrian in the valley of the Red River

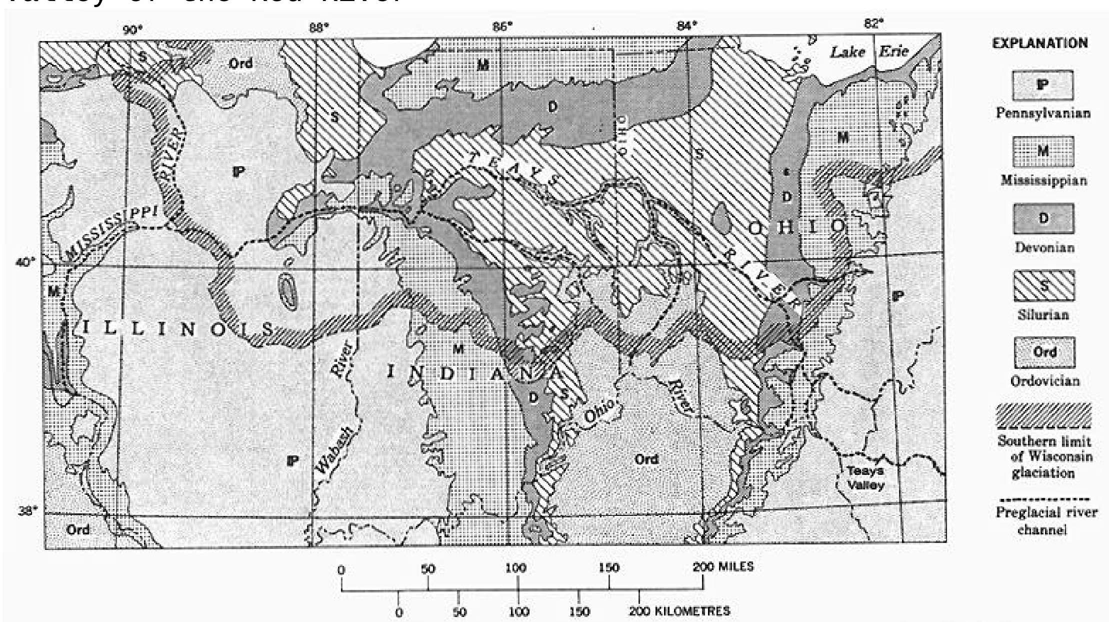

FIGURE 12.—Generalized geologic map of eastern Middle Western States, to show relation of subcrop geology of preglacial river systems. Preglacial drainage compiled from Tight (1903), Horberg (1945), and other sources.

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shown on the bedrock geologic map of North Dakota (Sims, 1970; Carlson, 1969).

The situation is complicated by the fact that in part of northern Minnesota a thin sheet of unconsolidated Cretaceous deposits intervenes between the Pleistocene and the Precambrian. These deposits are the Coleraine Formation (Sloan, 1964, p. 8-15), which has been exposed in mine workings on the south flank of the Mesabi Range and is known elsewhere from drilling and sparse natural outcrops. Part of the formation is marine, and its fossils indicate that it is equivalent to the Upper Cretaceous Colorado Group (uK2) that occurs in North and South Dakota to the west.

We believe that, for purposes of the Geologic Map of the United States, the feature of primary interest in northern Minnesota is the Precambrian bedrock, and we have accordingly extended it in subcrop across most of this part of the State. The Pleistocene deposits can be sacrificed without regret, even though they attain thicknesses of many hundreds of feet in places. Omission of the Cretaceous Coleraine Formation is less defensible, and under other circumstances it should perhaps be represented, yet to do so here would greatly obscure the essential Precambrian pattern. We have

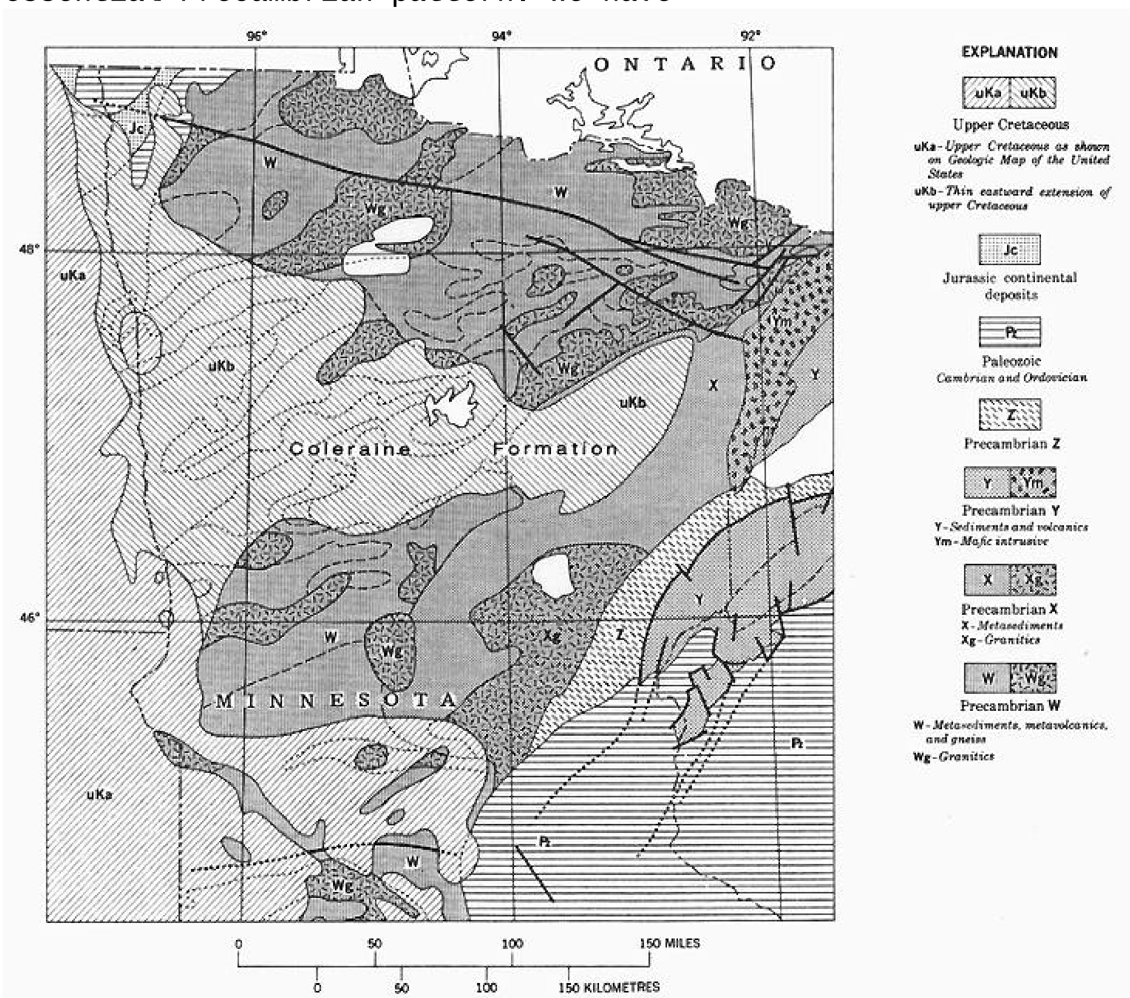

FIGURE 13.—Geologic map of northern Minnesota, showing the extent of thin Upper Cretaceous deposits (Coleraine Formation) that are not represented on the Geologic Map of the United States. Compiled from Sloan (1964) and Sims (1970).

therefore classified the Cretaceous with the Pleistocene as part of the overburden on the Precambrian subcrop but have shown its known extent in.

EOLIAN DEPOSITS

In several places outside the glaciated area of the United States, eolian deposits of Pleistocene and younger age cover areas so extensive that the bedrock beneath them is represented in subcrop (see Thorp and Smith, 1952).

In northwestern Nebraska an area of about 20,000 square miles was shown as Quaternary on the Geologic Map of 1932, on the authority of N. H. Darton and G. E. Condra. This is the Sand Hills region, whose dunes and drifted sand, or Sand Hills Formation, lie on the Pliocene continental deposits of the Ogallala Formation (Tpc), from which they were ultimately derived (Reed and others, 1965, p. 199). Although the Nebraska Sand Hills are a prominent geomorphic feature of the Great Plains, they are merely surficial cover and hence are omitted from the present Geologic Map.

East of the alluvial valley of the Mississippi River, in Mississippi, Tennessee, and Kentucky, the Tertiary bedrock of the uplands is mantled by loess, a windblown dust derived from the alluvial valley, when it was in its braided-channel phase during the late Pleistocene, and before it entered its present meander-belt phase (Krinitzsky and Turnbull, 1967, p. 7-9; Snowden and Priddy, 1968, p. 129-140). The loess is as much as 100 feet (30 m) thick in the bluffs next to the alluvial valley but thins irregularly eastward to a featheredge. On the State geological maps the loess belt is shown as about 25 miles (40 km) wide in Mississippi and more than 50 miles (80 km) wide in Tennessee; it actually extends east of the alluvial valley for 100 to 150 miles (160-250 km), but the remainder is thinner and less continuous (Thorp and Smith, 1952). Although the Mississippi Valley loess is appropriately shown on the State geologic maps, it would be inappropriate on the Geologic Map of the United States. In Tennessee it conceals the Claiborne-Jackson contact (Te2-Te3).

In southeastern Washington and adjacent States another loess deposit, the Palouse Formation, extensively covers the basalts of the Columbia River Group (Tmv) and was probably derived during Pleistocene time from the front of the Cordilleran ice sheet to the north (Richmond and others, 1965, p. 238). On the Geologic Map of Washington (Huntting and others, 1961), much of this part of the State is mapped as Quaternary, including not only the

Palouse (Qce), but also various units of glacial outwash and stratified drift, so that the true bedrock pattern is not apparent. Actu-

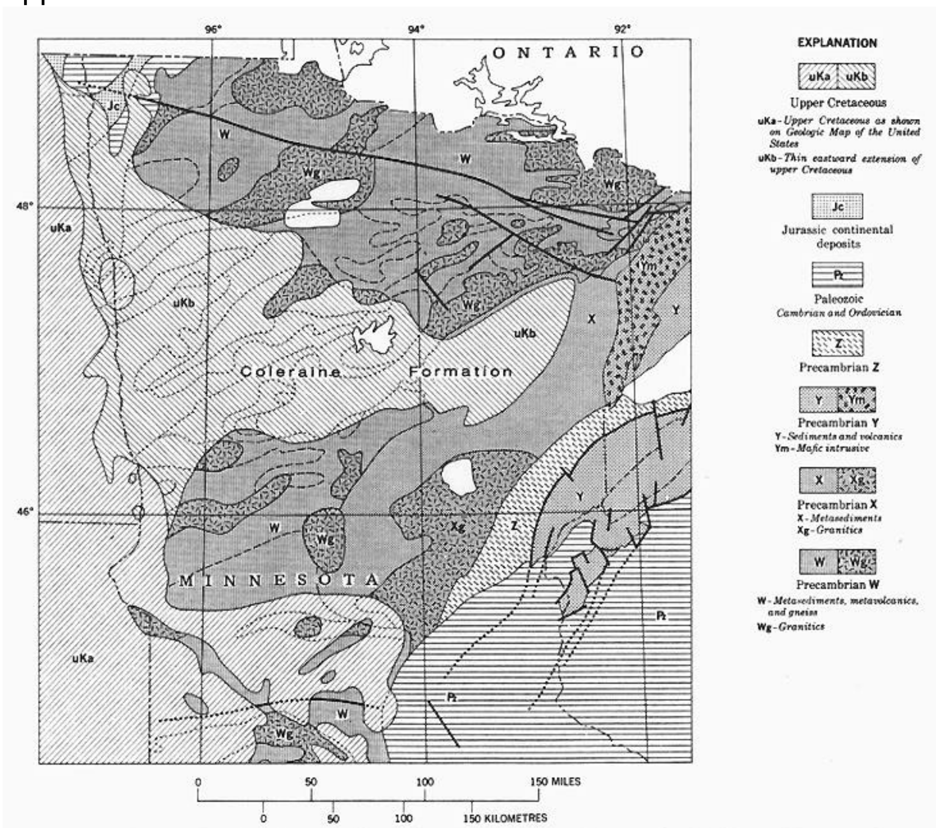

FIGURE 14.—Map of western Nebraska, showing bedrock geology as represented on the Geologic Map of the United States, superposed on which are the areas of Quaternary sand dunes and drifted sand (Sand Hills Formation) as represented on the Geologic Map of the United States of 1932 and by Thorp and Smith (1952).

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ally, the Palouse Formation is a surficial cover on the Columbia River Group in the uplands, whereas the other Quaternary deposits occur in structural depressions where they lie on older Pleistocene and on Tertiary deposits. On the Geologic Map of the United States we have therefore omitted the Quaternary deposits in the uplands but have retained those in the depressions, in the same manner as shown by Newcomb (1970).

ATLANTIC COASTAL PLAIN

In the Atlantic Coastal Plain, from South Carolina northward to New Jersey, we have followed the usage on the Geologic Map of 1932 and have shown the Quaternary only in the coastal areas and represented the inland areas as bedrock of Miocene age and older. Actually, Pleistocene and possible Pliocene deposits cover parts of the surface of the inland areas, in places to such an extent that representation of the older strata must be by subcrop mapping.

The surficial deposits are shown separately on the Geologic Map of Maryland (Weaver and others, 1968) and as overprints on the geologic maps of New Jersey and Virginia (Lewis and Kümmel, 1910-12; Milici and others, 1963); map data for the other States are less definite. The deposits have been variously interpreted as between marine and continental, as to whether they are classifiable according to altitude (that is, whether they formed on surfaces representing different stands of the sea during the Pleistocene), their relation to glaciation, and their relation to crustal warping; the place for resolution of these problems should be on a surficial geology map, rather than on the Geologic Map of the United States.

On the source maps, the older surficial deposits are better defined than the younger, as they form erosional remnants and outliers on the higher divides of the country. One of them, the Brandywine Formation is preserved on the uplands between Chesapeake Bay and the Potomac River in southern Maryland. Another, the Bridgeton Formation, is extensive in southern New Jersey, and a little farther north are smaller remnants of the apparently older Beacon Hill Formation. All of these are alluvial or fluviatile deposits whose ages are speculative at best. The Brandywine may be Pliocene (Hack, 1955, p. 25-40), as well as the Beacon Hill; the Bridgeton may be early Pleistocene, yet it is not clearly separable from the presumably younger Pensauken Formation (Richards, 1965, p. 130-131). These formations resemble in origin and geographic habit the Citronelle Formation of the Gulf Coast (differentiated on the Geologic Map as a continental deposit of Pliocene age, Tpc), although they are not necessarily of the same age. There is something to be said for showing the deposits in Maryland and New Jersey in the same manner as the Citronelle, but to do so would obscure the already small-scaled pattern of the bedrock outcrops, and it would be difficult to know how far to extend them because their correlation with surficial deposits in other parts of the Coastal Plain is uncertain; they are therefore omitted.

RADIATING STRIKES

In closing this general discussion of the Geologic Map of the United States, a few remarks should be made about a curious feature (or pseudofeature) apparent to anyone who views the map from a little distance—the "radiating strikes" or belts of outcrop which fan out in all directions from the Arbuckle Mountains uplift in the southern Midcontinent Region of southern Oklahoma. The feature was observed years ago by Arthur Keith (see footnote 5) on the basis of the general mapping available at the time; it is much more apparent on the Geologic Maps of the United States of 1932 and 1974.

Footnote 5. Arthur Keith, lecture at University of Texas, Austin, while visiting professor, 1926. We have been unable to find a reference to the subject in his publications.

The "radiating strikes" involve a number of disparate geological elements that can be sorted out as follows:

(1) Strikes of belts of Pennsylvanian and Permian strata in the Prairie Plains homocline, across Oklahoma into Kansas on the north, and into north-central Texas on the south.

(2) Tectonic features of Paleozoic age that cross the homocline transversely in Arkansas and Oklahoma. East of the Arbuckle area they include the south flank of the Ozark uplift and folds and faults in the Arkoma basin and Ouachita Mountains. West of the Arbuckle area they include the axes of the Anadarko basin and the Wichita Mountains uplift.

(3) Strikes of homoclinal belts of Cretaceous rocks on the north and west flanks of the East Texas embayment in the Gulf Coastal Plain.

The southern Midcontinent Region is geologically and tectonically complex, with many features of different ages crossing each other or superposed, only parts of which are revealed in the surface bedrock pattern; abundant subsurface data indicate many other features and in places quite a different history than would be inferred from the surface geology alone. Hence, many of the "radiating strikes" are illusory, or coincidental at most. The only truly valid features are the radiating strikes of the belts of Pennsylvanian and Permian strata in the Prairie Plains homocline. Their convergence toward the Arbuckle Mountains uplift indicates that tilting of the strata near the uplift was more

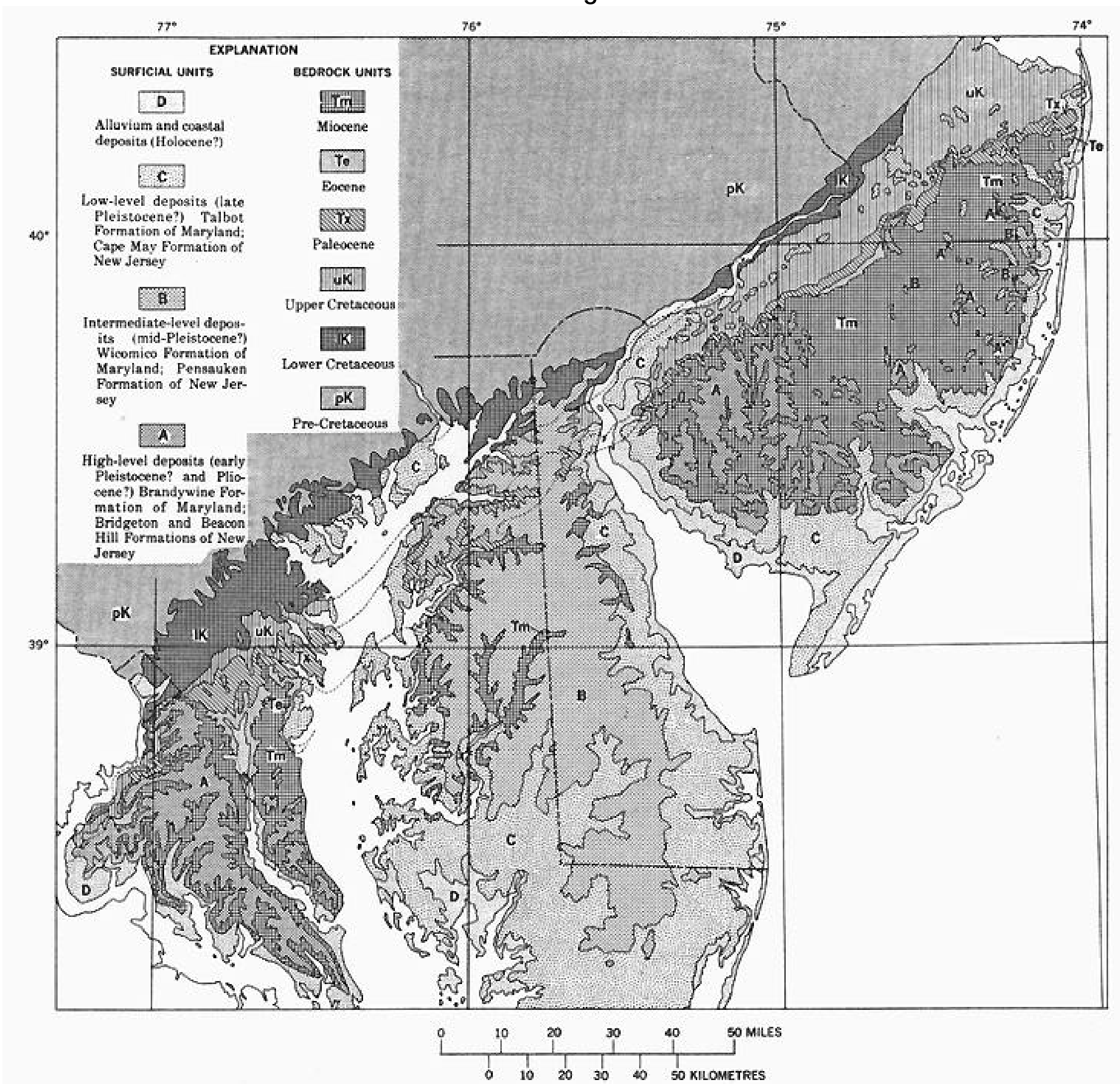

FIGURE 15.—Geologic map of the Atlantic Coastal Plain in Maryland, Delaware, and New Jersey, showing the relation of the bedrock units that appear on the Geologic Map of the United States to surficial deposits of Quaternary and late Tertiary age. Compiled from state geologic maps and from Owens (1967).

steeply westward than farther north or south—although even where steepest it amounts to no more than a few feet per mile.

Despite the questionable nature of this feature it has recently been exploited by Burke and Dewey (1973, p. 420-421), with the aid of some subsurface data, as a triple or quadruple rift junction in the continental plate produced by global tectonic movements during late Paleozoic time (styled the "Dallas junction"). The merits of this proposal remain to be evaluated.

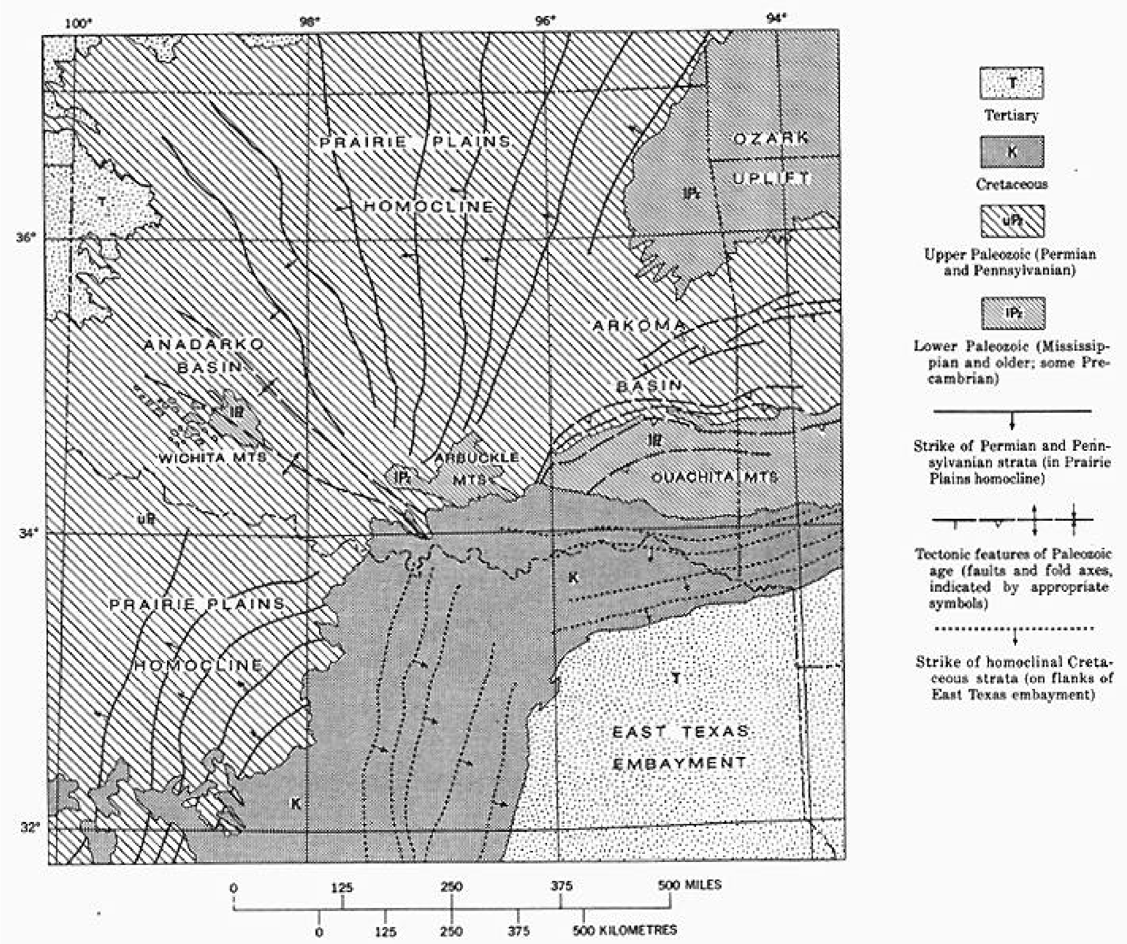

Figure 16.—Map of the southern Midcontinent Region in Oklahoma, Arkansas, and Texas, showing "radiating strikes" in Paleozoic and Cretaceous rocks. Lines are generalized from contacts shown on Geologic Map of the United States.

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