The components of man's environment may be classified into three broad categories of closely interrelated phenomena: (1) physical features which are provided by nature, such as landforms, their underlying geologic formations and structures, soils, natural vegetation, climate, hydrologic conditions, and mineral resources, (2) cultural features which man has added through living on the earth, such as houses, roads, dams, and cities, and (3) economic-social-political ways of life that characterize segments of man's cultural complex. In *The national atlas of the United States of America* the components of the physical environment are treated first because they constituted the first environmental conditions to confront man on the earth. The area, location, and condition of land, in association with the basic resources of soil and water to provide food and drink, have from prehistoric times to the present greatly influenced the capacity of an area to support human existence.

However, many earth features of natural origin have gradually been modified by mankind. For example, cultivated soils, much of the earth's vegetation cover, and minor topographic features are not exclusively either natural or cultural, but result from man–environment interactions. The man–environment relationships are becoming increasingly significant as population growth accelerates, as technological developments rapidly increase the per capita use of resources, and as pollutants threaten the health and living standards of the Nation. On the other hand, major topographic features generally change slowly, even through geologic time. Consequently man considers them relatively stable elements of his environment and recognizes that they influence the placement of farms, cities, and transportation networks and are often related to the economic-social-political cultural complex of his way of life.

LANDFORMS

The land surface of the United States of America has a great and generally pleasing variety of mountains, plateaus, hills, plains, and minor physical features, arranged in endless combinations. In order to understand better the distributional patterns and relationships of those landforms, geologists, geomorphologists, physiographers, and physical geographers have devised various schemes for classifying and mapping them. The most direct method of showing relief features within Atlas scale limitations is the shading technique used by Richard Edes Harrison on the following three pages. Each feature is drawn to scale, shaped to create a pictorial representation, and structured to show its degree of flatness or slope, its relative height above sea level, and its spatial relationship to other physical features of the landscape. Although shaded relief maps give the reader an easily interpreted image of the landscape and a reasonably good impression of local relief and general elevation, they do not indicate precise elevations above sea level except for points at which spot elevations may have been added to the map.

Two other commonly used means of portraying relief are shown on page 59. On the upper map, contour lines connect points of equal elevation and layer color tints denote areas with elevations that fall between the contour lines. If data are available for accurate contouring and if the contour interval is small enough, the shapes of many landforms may be revealed, but with less visual impact than on an equally well made shaded relief map. On the other hand, the contour lines provide more specific information about elevation than does a shaded relief drawing. Relief shading may be combined with the contour–layer tint technique, but the result creates a false impression of abrupt changes in slope or elevation at the layer tint boundaries and thus destroys the natural gradients which are shown so well by relief shading alone. This effect can be minimized by using inconspicuously fine contour lines and vignetting the colors at the transition zones.

The lower map on page 59 shows relief features by means of a set of stylistic symbols rather than natural forms. That technique, commonly known as physiographic diagraming, was used by Erwin Raisz to emphasize classes of surface forms, whereas Armin K. Lobeck and Guy-Harold Smith used somewhat different schematic symbols to interpret the origin and structure of landforms. In either case, the perspective of symbolization causes the peak or base to be inaccurately placed planimetrically, but at small scales the displacement may not be as critical as the easy recognition and interpretation of the landforms.

In contrast with maps depicting relief features, either pictorially or through symbolization, other maps delineating physiographic regions, provinces, or divisions were developed. Those classics by the famous scholars, John Wesley Powell (1834–1902), Nevin M. Fenneman (1865–1945), and Armin K. Lobeck (1886–1958), are reproduced on page 60. In spite of differences in the dates of map compilation and in the viewpoints of the authors, the similarities of their work are more conspicuous than the differences, because all three classifications are based fundamentally on genetic factors. On the other hand, the land-surface form maps by Edwin H. Hammond (p. 61–64) were developed from an empirical analysis of a selected group of surface characteristics. They do not conform closely in several respects to the earlier works of Powell, Fenneman, and Lobeck, but Hammond's classification serves a different purpose – the classification of land forms for human use.

Land-surface form, geographically interpreted, constitutes a bridge between other physical phenomena, such as geophysical forces and structures, geology, climate, and vegetation, and man's use of the land for a wide range of economic and sociocultural purposes. The land-surface form maps (p. 62–64), unlike the earlier works of Powell, Lobeck, and Raisz, were not designed to relate primarily to genetic factors in surface development. They combine, for any given area, five bits of information: (1) percentage of the area which has a gentle slope of less than 8 percent, (2) local relief, (3) generalized profile, (4) distinctive surface materials, and (5) major lineaments such as streams, crests, scarps, and valley sides. Nevertheless, regionalization of the results on a smaller scale map (p. 61) resembles in many ways the physiographic regions depicted on page 60. Internal differentiations, however, can be readily distinguished on the larger scale, land-surface form maps (p. 62–64) and thus are more useful in evaluating land-use potentials.

GEOPHYSICAL FORCES

The geophysical forces of gravity and magnetism, which play such important roles in reshaping the earth's solid crust, or upper mantle, are also basic in measuring the earth's shape and in establishing both horizontal and vertical geodetic controls for mapping. (See p. 316–318.) They also have important roles in determining the earth's internal structure, in helping to locate underground resources, and in providing directional controls for modern inertial navigation and guidance devices. Gravity anomalies (departures from an ideal, theoretical model) are mapped and explained on page 65. Likewise, on page 68 are maps of horizontal and vertical attractions of magnetic forces in the United States as of 1965. These forces of gravity and magnetism, combined with the tectonic stresses and movements discussed on page 69, result in folding, faulting, and intrusive as well as volcanic movements that cause tremors, or earthquakes within the earth's crust.

When stresses between different parts of the earth's solid crust become strong enough, the rocks break and move along fracture surfaces, and energy in the form of elastic vibrations is released. The energy waves are transmitted as displaced particles which vibrate and displace particles next to them. Several different types of waves are transmitted from the center of movement, and they travel at different speeds from each other, as well as at different rates through different substances. Consequently, careful measurements of the earthquake waves yield clues to the nature of the earth's crust and core.

It is the velocity of earthquake waves rather than their amplitude which causes damage to surface structures, the upper parts of which are snapped by the sudden reversal of fast traveling, high frequency, push-pull waves that first emanate from a zone of crustal movement. Secondary waves, which vibrate at right angles to the push-pull waves, travel more slowly and are not transmitted through liquid or gas. These are commonly known as shaker waves. Long, surface waves are the slowest moving and least damaging of the three common wave types.

Earthquakes result from movements of the earth's crust, but in turn result in landslides, tsunamis (huge waves caused by submarine earthquakes; incorrectly called tidal waves), and vibrations in the air that are often audible as cracking sounds near the center of movement, or as a rumble at greater distances. Several scales have been devised to categorize the intensity of earthquakes (McAdie, Richter, and Mercalli scales, for example), but all range from the minimum wave detectable by sensitive instruments to quakes that cause catastrophic damage to buildings and loss of life over wide areas. For the world as a whole, each year man may expect an average of one great earthquake, 1,000 damaging earthquakes, 100,000 noticeable shocks, and close to 1,000,000 detectable tremors.

Since earthquakes are normally associated with mountainous areas, particularly around the Pacific Basin, it is not surprising that most of the quakes recorded in the United States are in the Pacific Coast and Rocky Mountain States, Alaska, and Hawaii, and fewest are recorded in the great interior and coastal plains.

Comparison of the maps of earthquakes (p. 66–67) and of tectonic features (p. 70–72) readily reveals the close relationship between frequency of earthquakes and zones of tectonic activity. The tectonic map of the United States is, in effect, an architectural drawing in cartographic format of the rocks and structures of the upper part of the earth's crust. The structural platform areas, consisting of the Atlantic and Gulf Coastal Plains, and the extensive interior plains and plateaus, are mapped in subdued colors which reflect their relatively inactive condition. The foldbelts, fault zones, and areas of volcanic origin are mapped in brighter colors to emphasize their more dynamic character. For a more detailed analysis of the tectonics of the country, see page 69.

GEOLOGY

Geology, in the broadest meaning of the term, is the study of the whole earth, but the discipline has been traditionally restricted to the crust of the earth–its origin, composition, structure, and life forms. Historical geology provides keys for deciphering the history of the earth as it is recorded in rocks and structures. Those keys are, however, largely derived from the study of processes which are currently at work and which can be observed and analyzed. The fundamental stages in the geologic history of the areas which constitute the United States are described on page 73, and the extent of continental glaciation, with related lake developments, is mapped on page 76. Geologic regions of the United States, mapped in a highly generalized fashion on pages 74–75, are related to the age of bedrocks in those regions, but may also be interpreted in terms of rock types and origins.

Physical geology draws heavily upon the principles of chemistry and physics to identify and classify minerals and rocks; to understand the earth processes of crustal change through volcanism, diastrophism, weathering, erosion, and sedimentation; and to apply the results to practical problems. Geologists are concerned, for example, with the discovery and extraction of useful materials such as metals, petroleum and natural gas, gem stones, construction materials, and water supplies. Engineering and military geologists are more directly concerned with the feasibility and ultimate safety of construction projects, reservoir sites, disposal of wastes, prediction of earthquakes, landslides, and structural failures of earth materials.

For these types of studies, much more detailed, larger scale mapping is essential, but the broad structural features shown on the tectonic maps of this Atlas (p. 70–72) and combined with the geologic regions (p. 74–75) help to identify priority areas for more intensive study. For example, the pre-Cambrian rocks of the Canadian Shield, northeast of Lake Superior and extending into New York and parts of Wisconsin and northern Michigan, are unlikely sources of petroleum because of the scarcity of organic life which is the basis for petroleum formation. On the other hand, such rocks may yield rich deposits of ores associated with igneous intrusions and diastrophic forces. In contrast, the folded sediments of the Appalachians are rich in coal and petroleum, the limestones of Tennessee and Kentucky afford precarious construction sites because of underground drainage that leaches out caves ("Karstlands and caverns", p. 77).

The basic rocks of geologic regions are modified by weathering, which creates soils and often results in the concentration of residual minerals such as aluminum, gold, and some forms of iron ores. Erosion of the weathered materials by running water, glaciers, winds, gravity, and marine forces results in a wide variety of landforms (such as hills, valleys, mountain peaks, and glacial cirques) which differ even within classes according to their position in a cycle of erosion and which are counterbalanced by corresponding depositional features (such as alluvial fans, deltas, dunes, and coastal plains). People are always in the presence of geologic features, and those who understand the origin of the features will derive more satisfaction from their surroundings and learn to use them to better advantage, even in such simple ways as choosing a homesite free from floods, landslides, earthquakes, insecure foundations, and correspondingly high insurance rates.

MARINE FEATURES

The general outline of the seacoast of the United States as computed by the U.S. Coast and Geodetic Survey, Environmental Science Services Administration (ESSA), Department of Commerce, is 12,383 statute miles in length.

Conversion of coastal lengths to percentages reveals that the Pacific and Arctic coastlines of the United States constitute 70.1 percent of the country's general coastline, but due to narrow continental shelves and relatively few indentations except in southeastern Alaska, they account for only 48.3 percent of the more detailed shoreline. In sharp contrast, the Atlantic and gulf coasts constitute only 29.9 percent of the country's general coastline, but due to broad continental shelves and numerous islands, bars, and deep indentations, they make up 51.7 percent of the detailed shoreline.

The map of coastal landforms (p. 78–79) shows cliffed and flat coastal areas, dominant rock types, and shoreline characteristics such as sandy or rocky beaches, mudflats, swamps, coral, and larger scale insets of the more highly developed areas around Chesapeake Bay, New England, Puget Sound, and San Francisco Bay. Most of the Pacific coast, including Hawaii and Alaska south of the Alaska Peninsula, is characterized by high cliffs and narrow continental shelves. New England and parts of Hawaii and western Alaska have lower cliffs, bordered by narrow and generally rocky or pebbly beaches and broader continental shelves. The South Atlantic and gulf coasts, as well as much of northwestern Alaska, have predominantly flat coastal plains and broad offshore shelves with numerous islands, bars, lagoons, and estuaries. In general, the coastline configuration and shoreline characteristics reflect the tectonic forces and rock compositions of the coastal segments, but many of the detailed features are more intimately related to storms, waves, tides, and currents which in turn affect erosion and deposition processes.

Also of great importance to man is the variety of resources, land uses, and problems of the coastal zone. Human uses of that zone range from recreation to port development, from wildlife sanctuaries to sports and commercial fisheries, from sources of petroleum and natural gas to tidal power stations, and from dumping grounds for sewage and waste to increasingly important sources of desalinated water. It is in the coastal zone that natural hazards such as hurricanes, tsunamis, and floods near the mouths of swollen rivers often develop into catastrophes that take huge tolls in property damage and loss of life and create problems of area rehabilitation as well as raise questions of risk concerning the traditional land uses of deltas, flood plains, and coastal plains. A fact of outstanding significance, however, in evaluating the coastal zones of the United States is that coastal counties already contain more than half of the country's total population, and the National Council on Marine Resources and Engineering Development has predicted that the percentage may reach 75 percent by 1980.

SOILS

Aside from air, soil and water are the two most essential resources of the earth. They were the bases for primitive food and drink and have been subjected to constantly increasing demands as the world's population expanded. To enable a meaningful inventory of soils and to use them more effectively, many attempts have been made to analyze and classify soils.

Fundamentally, soils are related to the upper mantle rocks of the earth's crust from which they have evolved through the physical and chemical processes of weathering and the influence of living organisms. The various stages of soil development reflect different combinations of the effects of parent rock, living organisms, and climatic influences, but given enough time, climate becomes the dominant factor in determining the eventual characteristics of soil and can reduce to uniformity the mature soils of a given climatic region, regardless of their origin.

New soils, however, are largely dependent on the nature of the mantle or parent rock for their content and extend downward as far as organic life penetrates. As the soils mature, they develop vertical profiles in which the top, or A horizon, has the most organic life and, in humid climates, is characterized by leaching. The intermediate, or B horizon, is one of deposition from above, and in some soils is made dense and hard by the additions. The C horizon, or subsoil, is decomposed or disintegrated parent rock, modified only slightly by weathering processes and organic material. Within the horizons, soils may be described by their texture or size of particles (gravel, sand, silt, or clay), by their structure or arrangement of particles, pore spaces, and colloids (such as friable, granular, platy, lumpy, or blocky), and by their chemical qualities of acidity or alkalinity, depending upon the proportion of positive charged hydrogen ions in the gelatinous soil colloids on which vegetation growth is dependent.

Because the interaction of climatic elements (moisture, temperature, and wind) and organic life (particularly vegetation and bacteria) with parent rock minerals is fundamental to the evolution of soils, their classification constitutes a highly complex problem. Chinese records show that Engineer Yu classified soils by color and texture about 2,000 B.C., but the founder of a basis for the modern theories of soil origin and classification was a Russian geologist (V. V. Dokuchaiev) whose school of soil science evolved, between 1870 and 1900, a general philosophy that was modified and developed in the 1920's and 1930's by C. F. Marbut, Chief of the Soil Survey Division, U.S. Department of Agriculture, into a comprehensive scheme of soil classification that was adopted by the U.S. Department of Agriculture in 1938. A detailed account of that classification was published in the U.S. Department of Agriculture, *Soils and men,* Yearbook of Agriculture: 1938.

In that scheme, soils are divided into three orders, known as zonal (well drained), intrazonal (poorly drained), and azonal (too new or on slopes too steep to allow the development of clear profile characteristics). Soil orders are subdivided into suborders, then into great groups, families, series, types, and phases. The great groups of soils, such as podzol, prairie, chernozem, red, yellow, and tundra, are most closely related to climatic conditions. Families of soils are groups of related soil series which have similar horizon characteristics, and which are derived from the same type of parent material. A soil type is a subdivision of a series with a clearly identifiable texture of the A horizons. The phase of a soil type refers to such local characteristics as slope, stoniness, or degree of erosion.

In the 1950's emphasis was shifted toward the care and effective use of soils, and a series of land capability classes, described in the U.S. Department of Agriculture, *Soil,* The Yearbook of Agriculture: 1957, categorized soils suitable for regular cropping, those requiring special management practices, and other categories. During those years, American pedologists also became increasingly aware of the desirability of incorporating into the scheme of soil classification definitions of a more quantitative nature than those adopted by the U.S. Soil Survey in 1938. They presented to the Seventh International Congress of Soil Science in 1960 a group of papers on the concept that soil comprises a continuum on the land surface, subdivisions of which should be described in terms of properties that can be universally observed and measured. The scheme of soil classification adopted by the Congress had been carried through a succession of revisions and developments over a period of years. For purposes of identification, the stages were numbered, and the one adopted was called *Soil classification, a comprehensive system, seventh approximation: 1960.* The Seventh Approximation involves a formidable array of newly coined terms, but it became the basis for the National Cooperative Soil Survey Classification of 1967 which was adopted by the United States, and is used for the soils map in this Atlas (p. 86–87).

In this classification the nomenclature is systematic, and the general soil definitions are grouped in three categories: order, suborder, and great groups. Names of the orders, of which there are ten classes, end in "sol" and have three or four syllables. Suborders, of which there are 40 classes, are more directly related to specific land uses and have names consisting of two syllables, one of which is a prefix and the other a syllable from the order name. Great groups, with 120 classes, have one or more syllables prefixing a suborder name. The great groups are further subdivided into 400 subgroups, 1,500 families, and 7,000 series. Due to the broad international acceptance of the basic philosophy and nomenclature of this new classification, about which further information is provided on pages 85–88, the National Cooperative Soil Survey Classification of 1967 is well on its way toward worldwide use for soils analysis and mapping.

VEGETATION

Vegetation, like landforms, hydrographic features, and soils, is a significant element of the landscape, but it reflects to a large extent other factors of the physical environment, such as climatic conditions, soils, relief, and drainage. Natural vegetation develops without appreciable interference or modification by man, but it may be affected indirectly by manmade fires, pollutants in the atmosphere, domesticated animals, and even changes in surface energy budgets related to cities, reservoirs, and other extensive projects. Potential natural vegetation, as mapped on pages 90–92, is that which might be expected to return through a series of stages if man's interference with the natural regimen were suspended.

For many purposes the actual vegetation cover, such as forests (p. 154–155), rangelands (p. 158–160), and crops (p. 170–172), is more significant. For other purposes, a detailed analysis of vegetation formations, percentages of areas burned over, cut for timber, and converted to other uses, is needed. With traditional techniques of data gathering and processing, it has been virtually impossible to obtain current information of uniform quality for areas as large as the United States of America, or even of its major regions, but the use of remote sensor instrumented high altitude aircraft and satellites during the 1970's may enable the computerization and automated mapping of vegetation conditions and timely updating as changes take place.

Because of the latitudinal extent from Hawaii to Alaska and altitudinal ranges from Death Valley to Mt. McKinley, the United States has a tremendous variety of plants which form a natural resource base of great value. The forests, savannas, grasslands, and desert scrub constitute watershed covers, scenic and recreational settings, and renewable sources of food, clothing, shelter, furniture, fuel, and many other commodities. The conservation of the country's vegetative cover from destruction by fire, consumption, and environmental changes becomes increasingly essential as population and per capita consumption grow. For the economic welfare of the Nation, however, the introduction of new species and the upgrading of rangeland grasses, timber supplies, and crops must be sought, within the tolerance limits of environmental complexes.

CLIMATE

Climate is the characteristic condition of the atmosphere, deduced from a number of observations over a period of years. It is more than an average of statistics pertaining to air temperature, pressure, winds, moisture, and storms, because it includes departures from statistical means and implies a prediction of the probability that certain sets of observations will recur in a given area. The observable components of climate are due primarily to transformations of energy between the atmosphere and the land and sea.

For all practical calculations the sun may be considered the source of the earth's heat energy. In spite of thermal cycles (daily, seasonal, and over periods of years) it appears that the receipt of heat energy from the sun and loss of heat energy from the earth are essentially in balance for the planet as a whole. The solar radiation maps (p. 93) reveal the effects of latitude, altitude, and seasonal shifts of angle of the sun's rays on the amount of incoming radiation for various parts of the United States. Since the lower latitudes and higher altitudes receive more heat energy, due respectively to higher sun angles and thinner atmosphere, heat transfer to areas receiving less insolation takes place by means of winds in the atmosphere and currents in the water. The resultant effects on the distribution of temperature, precipitation, and winds is illustrated by a series of climatic maps on pages 94–116. A special aspect of climate, air pollution, is treated on pages 114–115.

A conspicuous omission from the climatic section of this Atlas is a map of climatic regions.Several widely accepted classifications were considered, including those developed by Köppen, Thornthwaite, and Trewartha. It became apparent, however, that such classifications have been applied on a worldwide basis and that enlargement of segments of small-scale world maps might improve their visibility in a classroom but did nothing to add the detail needed for large-scale analysis of climatic complexes in single countries. Furthermore, existing maps of climatic regions are in many ways inaccurate in detail and misleading because they are oversimplified; the systems portrayed tend to emphasize unduly either the influence of temperature or moisture, the effects of evapotranspiration, or the interpretation of climate through vegetation or soils regions. Several attempts were made to induce experts to produce detailed climatic region maps of the United States, but all of them felt that existing maps were faulty and that it would be premature to make new maps based on the short term statistics available from satellite data. Consequently, it was decided to postpone the inclusion of a climatic regions map until a subsequent edition of the *National atlas.* Those who wish, however, to become better acquainted with the principal climatic classification schemes and maps may find the following list of selected references useful.

General Climatology:

Haurwitz, B., and J.M. Austin, *Climatology,* New York, McGraw-Hill Book Co., 1944, 410 p.

Landsberg, H., *Physical climatology,* DuBois, Pa., Gray Print. Co., 1958, 446 p.

Terjung, W.H., "Physiological climates of the conterminous United States; a bioclimatic classification based on man", *Annals of the Assoc. of Am. Geographers,* v. 56, p. 141–179, 1966.

Trewartha, G.T., *An introduction to climate,* New York, McGraw-Hill Book Co., 1968, 408 p.

U.S. Department of Agriculture, *Climate and man,* Yearbook of Agriculture: 1941, Washington, U.S. Govt. Print. Office, 1941. (Many papers on climate topics; United States climate data.)

Visher, S.S., *Climatic atlas of the United States,* Cambridge, Mass., Harvard Univ. Press, 1954, 403 p.

Köppen System:

Köppen, W., and R. Geiger, *Handbuch der Klimatologie,* Berlin, Gebrüder Borntraeger, 5 v., 1930 and later. (See v. 1, pt. C, 1936, for general analysis of Köppen system of climatology.)

——— *Klima der Erde,* Darmstadt, Germany, Justus Perthe, 1954, map. American distributor, A.J. Nystrom and Co., Chicago.

Wilcock, A.A., "Köppen after fifty years", *Annals of the Assoc. of Am. Geographers,* v. 58, p. 12-28, 1968.

Thornthwaite System:

Thornthwaite, C.W., "The climates of North America, according to a new classification", *Geog. rev.,* v. 21, p. 633-655, 1931.

———"An approach toward a rational classification of climate", *Geog. rev.,* v. 38, p. 55-94, 1948.

Chang, Jen-Hu, "An evaluation of the 1948 Thornthwaite classification", *Annals of the Assoc. of Am. Geographers,* v. 49, p. 24-30, 1959.

WATER

The National Water-Resources Data Network, maintained by the U.S. Geological Survey in cooperation with other Federal agencies and the States, is the chief source of basic water data in this country. The stream-gaging network consists of more than 8,400 stream gaging stations, and the ground-water network, of nearly 30,000 observation wells. In addition, about 2,500 water quality stations are maintained to determine the chemical properties, sediment content, thermal conditions, and pollutants of surface waters.

Although the amount of water which falls upon the 50 States as rain and snow (p. 97–100) exceeds current requirements, the distribution of water does not match the concentration of people, and the amount available for use is diminished by both runoff (p. 118–120) and evaporation (p. 96). Much of the remaining water is rendered unfit for essential uses by sediments and chemicals (p. 124–125). Since water plays an important role in the weathering of rocks and formation of soils, the effects of chemical pollution may be reflected indirectly in soil characteristics and food production. On the other hand, temporary surpluses of water cause damaging floods, increase pollution, and in arid lands leach out alkaline and saline chemicals that are subsequently deposited in concentrated forms that ruin soils for most agricultural uses. It is because of the interrelationships of water with climate, soils, geologic processes, and land-surface forms that this resource is treated in the physical rather than the economic or sociocultural sections of the Atlas. The uses and management problems of water obviously relate to many topics in the economic and socio-cultural sections of the atlas. For a more detailed treatment of the whole scope of water as a resource of primary significance, see page 117.

SHADED RELIEF

Richard Edes Harrison, 1969

Albers Equal Area Projection

SCALE 1:7,500,000

For detailed information on Alaska see page 58

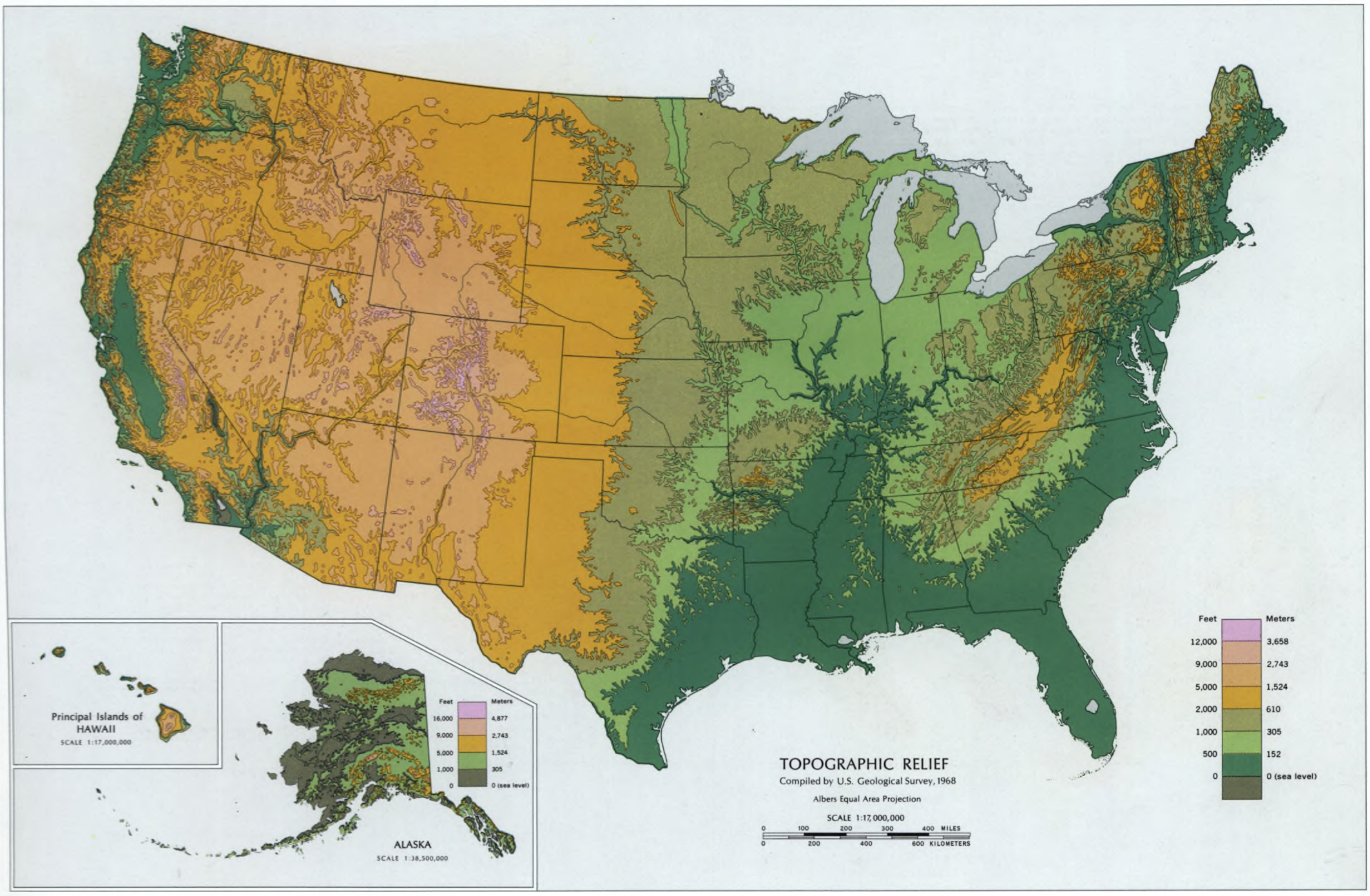
SHADED RELIEF

Richard Edes Harrison, 1969

Albers Equal Area Projection

SCALE 1:7,500,000

0 100 200 300 MILES
0 100 200 300 400 KILOMETERS



TOPOGRAPHIC RELIEF

Compiled by U.S. Geological Survey, 1968

Albers Equal Area Projection

PHYSIOGRAPHIC DIAGRAM

Erwin Raisz, 1954

JOHN WESLEY POWELL, 1834–1902, markedly influenced the work of later geomorphologists by his contributions to the discussion of erosional processes and their effect in the development of landforms.[1] Powell introduced an analytical approach to physiographic studies based primarily upon generic considerations rather than upon empirical evaluations; a radical departure from the then customary methods. In the words of William Morris Davis, Powell "chiefly contributed to laying the foundations of what may be fairly called the American School of Geomorphology."[2] His essay, *Physiographic Regions of the United States,*[3] contains a map showing 16 principal regions of the United States, exclusive of Alaska and Hawaii. The old custom of portraying regions as units of basins was not followed because "the basin unit divides the country into very unequal parts and fails to exhibit the association of great features that are intimately connected in physiographic history."[4]

1 Davis, William M. *Biographical Memoir of John Wesley Powell, 1834–1902,* Natl. Acad. of Sci., v. 8, Feb. 1915. p. 29.

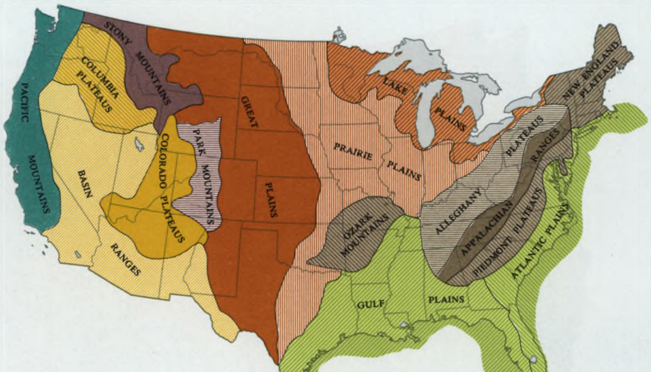
2 ______ ________, p. 37.

3 Powell, John W. *Physiographic Regions of the United States,* Natl. Geog. Soc. Mon., v. 1, no. 3, Am. Book Co., New York, 1895.

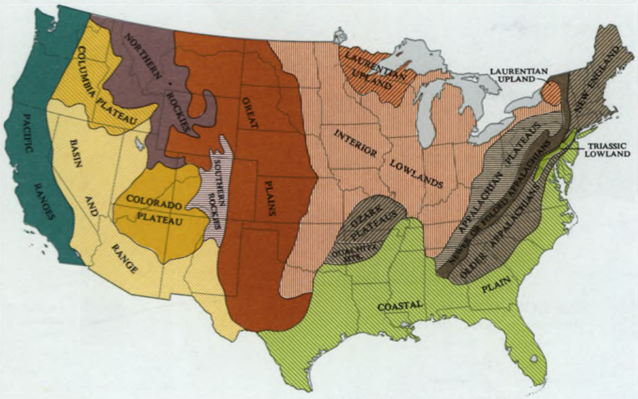
4 ______ ________, p. 65.

Additional References

______ *Physiographic Processes and Physiographic Features,* Natl. Geog. Soc. Monographs, v. 1, nos. 1 and 2, Am. Book Co., New York, 1895.



PHYSIOGRAPHIC REGIONS
John W. Powell, 1895
SCALE 1:34,000,000



PHYSIOGRAPHIC PROVINCES
Armin K. Lobeck, 1932 rev.
SCALE 1:34,000,000

ARMIN KOHL LOBECK, 1886–1958, was equally well-known for his work in geomorphology and physiography. He was particulary effective in making geology understandable to students and laymen. He developed the art of producing perspective views of the terrain from techniques introduced earlier by William Morris Davis. The many publications containing his physiographic maps and diagrams have been and are continuing to be used extensively by students in this country and abroad. In seeking to interpret and classify landforms of the United States, Lobeck first published a map of physiographic provinces in 1922.[1] This early work was subsequently revised, and the regional portrayals resulted in much closer conformity with the work of Fenneman.

1 Lobeck, Armin K. *Physiographic Diagram of the United States,* Small-scale ed., 8 folio pages, Wisconsin Geog. Press, Madison, 1922.

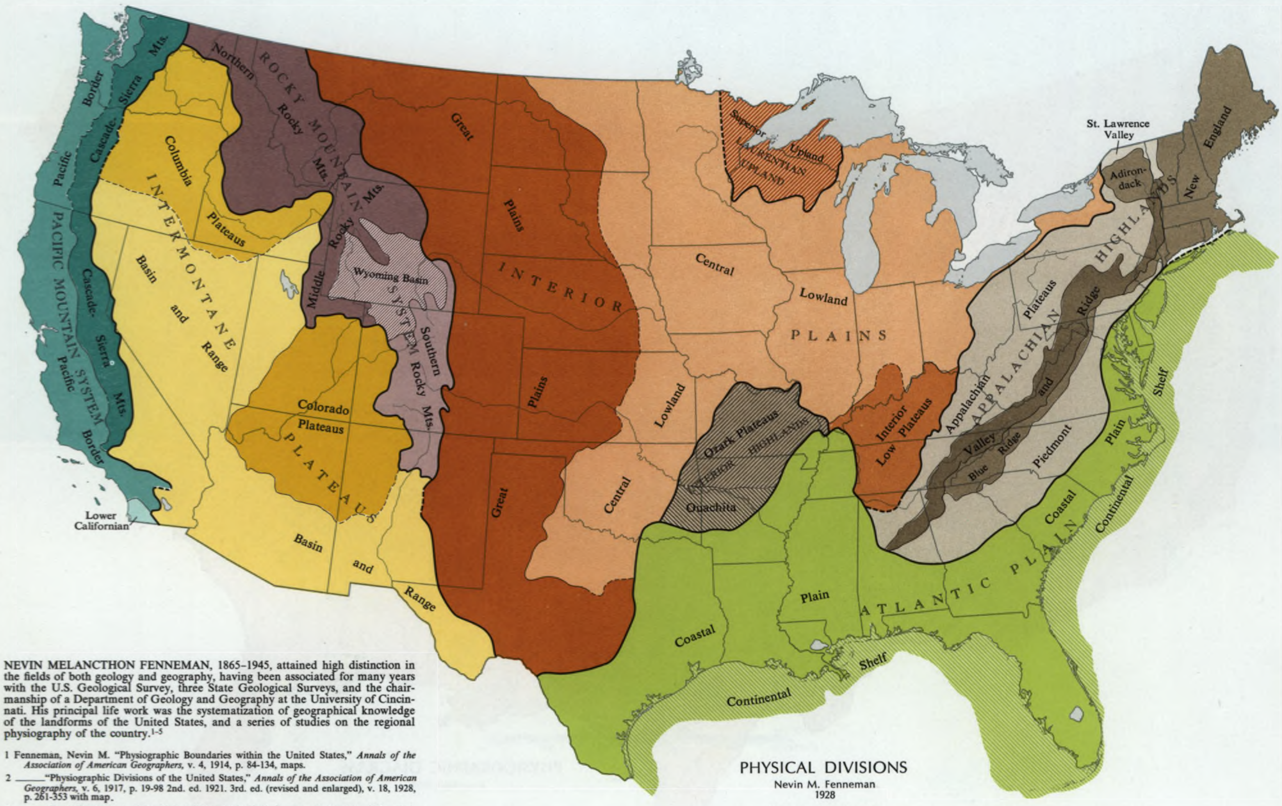
______ "Block Diagrams," *The Journal of Geography,* v. 19, 1920, p. 24-33.

______ *Atlas of American Geology,* The Geog. Press, New York, 1929, 100 sheets.

______ "Airways of America, Guidebook 1, The United Airlines; a Geological and Geographical description of the route from New York to Chicago and San Francisco," *James Furman Kemp Memorial Series, Publication No. 11,* The Geog. Press, New York, 1933.

______ *Geomorphology, An Introduction to the Study of Landscapes,* McGraw-Hill, New York, 1939.

______ *Things Maps Don't Tell Us. An Adventure Into Map Interpretation,* Macmillan, New York, 1956.



NEVIN MELANCTHON FENNEMAN, 1865–1945, attained high distinction in the fields of both geology and geography, having been associated for many years with the U.S. Geological Survey, three State Geological Surveys, and the chairmanship of a Department of Geology and Geography at the University of Cincinnati. His principal life work was the systematization of geographical knowledge of the landforms of the United States, and a series of studies on the regional physiography of the country.[1-5]

1 Fenneman, Nevin M. "Physiographic Boundaries within the United States," *Annals of the Association of American Geographers,* v. 4, 1914, p. 84-134, maps.

2 ______ "Physiographic Divisions of the United States," *Annals of the Association of American Geographers,* v. 6, 1917, p. 19-98 2nd. ed. 1921. 3rd. ed. (revised and enlarged), v. 18, 1928, p. 261-353 with map.

3 ______ *Physical Divisions of the United States,* U.S. Geol. Survey, Washington, 1946, map 1:7,000,000.

4 ______ *Physiography of the Western United States,* McGraw-Hill, New York, 1931, 534 p.

5 ______ *Physiography of the Eastern United States,* McGraw-Hill, New York, 1938, 714 p.

PHYSICAL DIVISIONS
Nevin M. Fenneman
1928
Albers Equal Area Projection

CLASSES OF LAND-SURFACE FORM IN THE UNITED STATES

In contrast to the traditional systems of physiographic regions based upon genetic factors, maps of land-surface form in the United States have been developed by Edwin H. Hammond from an empirical analysis of the land surface. The basic maps of this group are those on pages 62-64, which show the occurrence of landform types defined in terms of a selected group of surface characteristics. The regional map (below) is a more generalized representation, roughly comparable in degree of detail to the regionalizations of Powell and Fenneman. On it the country has been partitioned into ten major divisions, six for the conterminous States and Hawaii, and four for Alaska. The conterminous area is further subdivided into 35 provinces.

Since no specific hierarchy of regional boundaries is established on the larger scale maps, there is no unequivocal basis for combining the small areas into landform regions of larger size. The attempt has been made to reach a compromise between strict adherence to a systematic hierarchical scheme and a mere equalization of subdivision size. Most of the boundaries between provinces on the regional map are also boundaries between surface form classes on the more detailed maps, though a few exceptions occur, chiefly in zones of gradual transition. The user of so generalized a map should keep in mind that the subdivisions vary markedly in homogeneity. Certain of the provinces, such as the High Plains and the Gulf-Atlantic Coastal Flats, contain only minor internal variations, whereas others, such as the Appalachian Highlands, the Middle Rocky Mountains, and the Columbia Basin, are internally quite heterogeneous. Throughout, surface character has been given greater weight than similarity in geologic structure or other specific factors of landform genesis.

The chief aim of the larger scale maps (pages 62-64) is to enable the user to compare and contrast the surface form of different parts of the country in specific terms. To accomplish this aim a small group of surface characteristics was selected to serve as a basis for a meaningful, specific, and cartographically practicable system of landform characterization. Criteria for the selection of characteristics were that they should: 1) be especially effective in conveying a visual image of the surface form; 2) be broadly suggestive of possible relationships to other phenomena of geographical interest, especially potential land use; 3) be capable of being determined readily for broad areas from available map data, and 4) be capable of simple expression.

In accordance with these principles, five properties of land-surface form were selected for use on the maps. These are: 1) percentage of area occupied by surfaces of gentle inclination (less than 8% or 4° 35′); 2) local relief, that is, maximum difference in elevation within a limited area; 3) percentage of gently inclined surface that lies in the lower half of the local relief; 4) percentage of area occupied by sand, ice, and standing water; and 5) pattern of major crests, peaks, and escarpments. The first three characteristics are used as the basis for a simple classification (shown in the map legend on page 63), from which each class of land-surface form is designated by a 3-item code, such as B3a. In this example, the "B" indicates that 50 to 80% of the area is occupied by gentle slopes; the "3" signifies that the maximum local difference in elevation is 300-500 feet; and the "a" means that more than 80% of the gently sloping land lies in the lower half of the elevation range. In areas of very little gentle slope (D) or very low relief and great smoothness (A1), the third designator is omitted. The coded classification for each separate area is shown directly on the map. In addition, different landform classes are distinguished by color to heighten visual perception, colors becoming darker or more intense as roughness increases. For the sake of simplicity, classes that differ only in terms of the position of the gently sloping land in the profile are distinguished by color differences only if the amount of gentle slope is large (A or B) and the local relief is considerable (3 to 6).

Character of surface material and pattern of major features, the fourth and fifth items in the list of properties, are omitted from the classification in order to control the number of classes. However, these properties are shown on the map by overprinted symbols. The occurrence of significant amounts of sand, ice, or standing water is indicated by conventional patterns in blue or black. Major crest lines, peaks, and escarpments are shown by various black symbols indicated in the legend. For each feature shown, the thickness of the symbol is directly proportional to the height of the crest of the feature above its base. No feature that rises less than 300 feet above its base is represented on the map.

Although gentle slope is here defined as an inclination less than 8%, that is not strictly a critical value for land utilization. It does, however, fall in the range within which the difficulty of machine cultivation increases rapidly, erosion of cultivated fields becomes troublesome, easy movement of vehicles becomes impeded, and in general one becomes highly conscious that he is dealing with a sloping surface.

Since local relief is defined as maximum difference in elevation within a local area, it is necessary to specify a fixed size for that local area. Experimentation led to the selection of a unit square six miles across. A unit of this size is neither small enough to cut individual slopes in two nor large enough to embrace areas of excessive diversity, nor to distort local relief figures by adding in long regional slopes.

The class boundary values chosen throughout the classification are essentially arbitrary and have no critical significance. Those for percentage of area in gentle slope and for vertical position of gentle slope afford a conveniently small number of classes with roughly equal class intervals. For local relief the class interval is broadened as the relief increases, following the idea that for most purposes there is progressively less concern with small absolute differences in relief as the relief becomes greater. For surface materials the 10% figure is a reasonable threshold value at which the presence of sand, ice, or water becomes distinctly noteworthy, whereas the 50% value marks the lower limit of predominance of these significant materials.

In delineating the crest, peak, and escarpment patterns, considerable generalization has been necessary. Nearly all isolated features with more than 300 feet of local relief appear on the map, but in areas where high features are closely spaced, only selected ones can be shown. In such areas, features have been selected that display the essential character of the pattern as clearly as possible. The degree of generalization is keyed to the scale and to the requirements for reasonable visual clarity. The smallest region delimited by boundaries and given a coded classification has an area of about 800 square miles. Smaller areas are omitted or absorbed into the adjacent region that they most resemble.

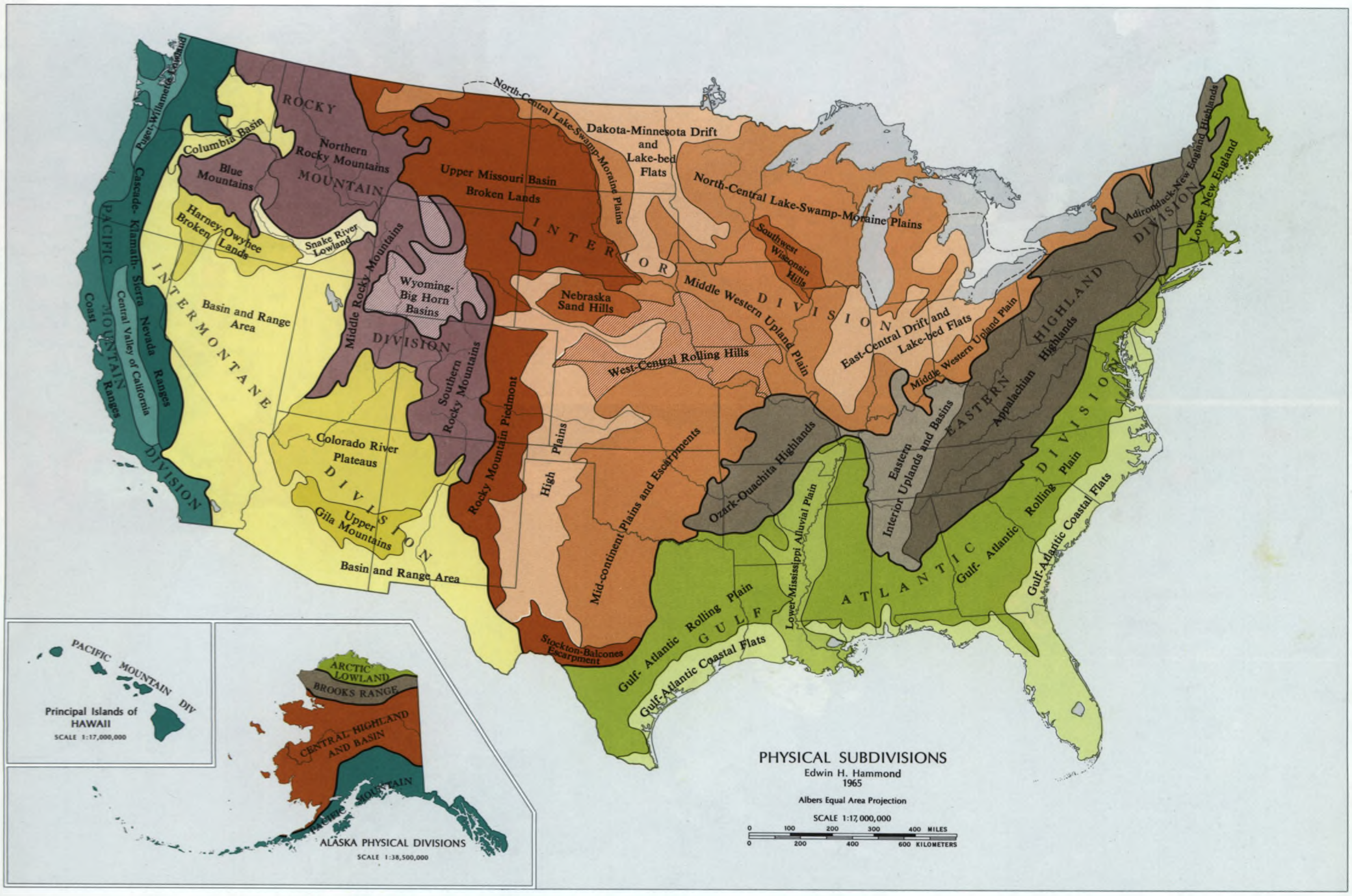
The finished map is believed to be unique in representing the pattern of land-surface variation in the United States as an array of clearly defined types that can occur repetitively and that can be compared and contrasted in terms of specific attributes. Because the scale is rather small and the classification simple, the map is necessarily a highly abstract version of reality, revealing no more than five selected bits of information about any area. As in all maps of natural phenomena based upon systematic classifications, some of the boundaries between areas fall in the midst of zones of gradual transition rather than at points of discontinuity or abrupt gradient.

The shift of emphasis from structure and developmental history to character of the surface form produces significant departure from the earlier maps. By way of example, the Fall Line, which separates the Appalachian Piedmont from the Atlantic Coastal Plain on the Powell and Fenneman maps appears here as a boundary in only a few short segments. Although it represents a major break in geologic structure, it forms a much less fundamental dividing line for surface configuration. The narrower valley floors, more rolling divides, and somewhat higher elevations which distinguish the Piedmont surface from that of much of the inner Coastal Plain are only in places distinctive enough to warrant being set apart by a class boundary. Much the same is true for the southern boundary of Fenneman's Superior Upland, where an important geologic boundary is effectively masked by a cover of glacial drift that imparts a similar configuration to the surface on both sides of the lithologic line.

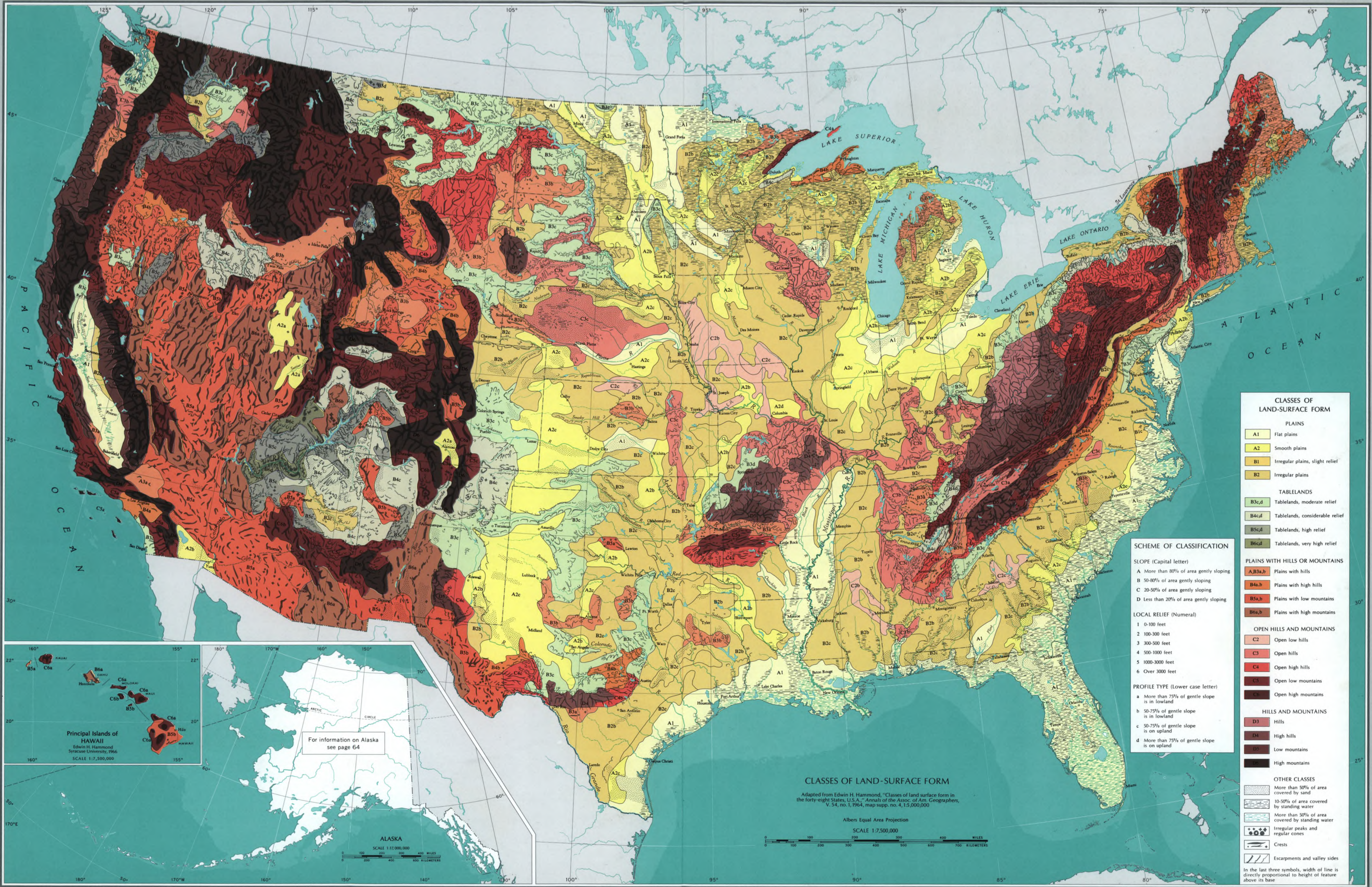
Conversely, the Classes of Land-Surface Form maps emphasize certain other distinctions that the Fenneman and Powell maps do not. Examples may be seen in the separation of the flat, marshy, outer Coastal Plain from the more rolling, better drained inner sections; the recognition of a great variety of relief and roughness in the Appalachian Plateaus area, and the sharp distinctions among different parts of the Central Lowlands. To some degree those represent a finer subdivision made possible by the larger scale, but they also reflect a basic difference of emphasis in the criteria of differentiation.

Although the map is designed to show visually and functionally significant aspects of the terrain and not to indicate genetic factors in surface development, it is not without significance to geomorphologists, because each of the regional differences in surface properties poses a problem of origin. Certain of those problems, especially those of differences in slope and slope profile characteristics, are unusually knotty and have as yet received relatively little attention in systematic regional studies.

A more comprehensive treatment of the subject appears in Edwin H. Hammond's "Analysis of Properties in Land Form Geography: An Application to Broad-Scale Land Form Mapping," *Annals of the Association of American Geographers,* Vol. 54, 1964, pp. 11-23. The author's map of the conterminous States at 1:5,000,000 which accompanied the above-referenced article was adapted to National Atlas scale with the author's assistance, and was extended by him to include Alaska and Hawaii.



PHYSICAL SUBDIVISIONS
Edwin H. Hammond
1965



CLASSES OF LAND-SURFACE FORM

Adapted from Edwin H. Hammond, "Classes of land surface form in the forty-eight States, U.S.A.," *Annals of the Assoc. of Am. Geographers,* V. 54, no. 1, 1964, map supp. no. 4, 1:5,000,000

Albers Equal Area Projection

SCALE 1:7,500,000

Principal Islands of HAWAII
Edwin H. Hammond
Syracuse University, 1966
SCALE 1:7,500,000

For information on Alaska see page 64

SCHEME OF CLASSIFICATION

SLOPE (Capital letter)

- A More than 80% of area gently sloping
- B 50-80% of area gently sloping
- C 20-50% of area gently sloping
- D Less than 20% of area gently sloping

LOCAL RELIEF (Numeral)

- 1 0-100 feet
- 2 100-300 feet
- 3 300-500 feet
- 4 500-1000 feet
- 5 1000-3000 feet
- 6 Over 3000 feet

PROFILE TYPE (Lower case letter)

- a More than 75% of gentle slope is in lowland
- b 50-75% of gentle slope is in lowland
- c 50-75% of gentle slope is on upland
- d More than 75% of gentle slope is on upland

CLASSES OF LAND-SURFACE FORM

PLAINS

A1	Flat plains
A2	Smooth plains
B1	Irregular plains, slight relief
B2	Irregular plains

TABLELANDS

B3c,d	Tablelands, moderate relief
B4c,d	Tablelands, considerable relief
B5c,d	Tablelands, high relief
B6c,d	Tablelands, very high relief

PLAINS WITH HILLS OR MOUNTAINS

A,B3a,b	Plains with hills
B4a,b	Plains with high hills
B5a,b	Plains with low mountains
B6a,b	Plains with high mountains

OPEN HILLS AND MOUNTAINS

C2	Open low hills
C3	Open hills
C4	Open high hills
C5	Open low mountains
C6	Open high mountains

HILLS AND MOUNTAINS

D3	Hills
D4	High hills
D5	Low mountains
D6	High mountains

OTHER CLASSES

░	More than 50% of area covered by sand
≡	10-50% of area covered by standing water
≡	More than 50% of area covered by standing water
●	Irregular peaks and regular cones
～	Crests
/	Escarpments and valley sides

In the last three symbols, width of line is directly proportional to height of feature above its base

CLASSES OF LAND-SURFACE FORM

Edwin H. Hammond
Syracuse University, 1966

Albers Equal Area Projection

SCALE 1:7,500,000

CLASSES OF LAND-SURFACE FORM

PLAINS

A1	Flat plains
A2	Smooth plains
B2	Irregular plains

PLAINS WITH HILLS OR MOUNTAINS

B3b	Plains with hills
B4a,b	Plains with high hills
B5a,b	Plains with low mountains

OPEN HILLS AND MOUNTAINS

C3	Open hills
C4	Open high hills
C5	Open low mountains
C6	Open high mountains

MOUNTAINS

D5	Low Mountains
D6	High mountains

OTHER CLASSES

▤	10-50% of area covered by standing water
▤	More than 50% of area covered by standing water
▩	10-50% of area covered by glaciers
▩	More than 50% of area covered by glaciers
◆	Irregular peaks and regular cones
～	Crests
⌒	Escarpments and valley sides

In the last three symbols, width of line is directly proportional to height of feature above its base

SCHEME OF CLASSIFICATION

SLOPE (Capital letter)

A	More than 80% of area gently sloping
B	50-80% of area gently sloping
C	20-50% of area gently sloping
D	Less than 20% of area gently sloping

LOCAL RELIEF (Numeral)

1	0-100 feet
2	100-300 feet
3	300-500 feet
4	500-1000 feet
5	1000-3000 feet
6	Over 3000 feet

PROFILE TYPE (Lower case letter)

a	More than 75% of gentle slope is in lowland
b	50-75% of gentle slope is in lowland
c	50-75% of gentle slope is on upland
d	More than 75% of gentle slope is on upland

GRAVITY, SEISMOLOGY, AND GEOMAGNETISM

GRAVITY

A knowledge of the earth's gravity field is essential in many branches of science, notably geodesy, geophysics, and space technology. The gravity field reflects the earth's general shape, its internal structure, and the location of underground resources; also, it is the controlling environment for modern inertial navigation and guidance devices.

The value of gravity at a point on the earth's surface does not change appreciably with time and depends mainly on latitude and elevation above sea level. Smaller, yet measurable, are the influences of known topographic masses and water depths, coupled with variations in crustal and subcrustal densities. Measured gravity values are customarily reduced by some standard process and then compared with gravity on an ideal theoretical model; departures from the model are termed "anomalies." Careful study of these anomalies reveals abnormalities in the earth's shape and internal structure. Gravity reductions may be based solely on latitude and elevation of the measurement points (free-air anomalies) or may additionally include allowance for attraction of known topography and water depths (Bouguer anomalies). More refined reduction systems consider the correlation known to exist between visible topography and the supporting structure underneath (isostatic anomalies).

The gravity field of a large geographic area may be conveniently displayed by contouring the anomalies obtained from some system of reduction as described above. The Bouguer form of reduction, employed in the map below, is preferred by most geologists and geophysicists. However, the anomalies must be interpreted with care. Bouguer anomalies allow for the effect of normal topographic attraction —a desirable property when searching for abnormal crustal densities, as in geophysical exploration. The anomalies typically have negative values in elevated land areas and follow the opposite trend in the deep oceans. This phenomenon corroborates the theory of isostasy, which states that for any sizable load on the crust, such as a mountain mass or extended plateau, there is a mass deficiency in the lower part of the crust. Since the Bouguer reduction allows for the attraction of the extra mass above sea level, but not for the compensating deficiency underneath, the Bouguer anomalies on high land will be predominantly negative if the isostatic theory is correct. Isostasy is confirmed by the strongly negative Bouguer anomalies in the western half of the United States, as compared with the eastern half. The gravity map shows anomaly contours in milligals (1 milligal is exactly equivalent to 0.001 cm per sec/sec).

The map below was adapted from *Bouguer gravity anomaly map of the United States.*[1] The Alaska inset was compiled by David F. Barnes, U.S. Geological Survey, in 1967–68, from various sources. The Hawaii inset was adapted from an unpublished map compiled jointly by the University of Hawaii and the U.S. Geological Survey and furnished by the Hawaii Institute of Geophysics.

SEISMOLOGY

The map on pages 66–67 shows major earthquakes in the United States that were recorded up to the end of 1965. When large parts of the United States were comparatively unsettled, it was difficult to secure complete reporting on earthquakes; consequently, exact seismological information has been available only for the last 60 years or so. Nevertheless, practically all the earthquakes of general interest are shown on the map. The Coast and Geodetic Survey publication, *Earthquake history of the United States,* parts I and II,[2] provides a descriptive text about the earthquakes shown on the map and includes regional tables that list the earthquakes chronologically and give the position, affected area, and intensity of each.

More than 85 percent of the world's seismic activity is centered in the circumpacific belt that includes the Pacific coast and western mountain region of the conterminous United States and a large part of Alaska. The California Coast Ranges, the Puget Sound area, and the Aleutian Islands chain are the most active zones. Great earthquakes occasionally occur outside these zones, however; southeastern Missouri and Charleston, S.C., are examples, but many years have elapsed since the occurrence of destructive shocks in these areas. The greater violence and damage associated with Pacific coast and Rocky Mountain earthquakes, as compared with those in the East, are generally attributed to the fact that the center of the disturbance is closer to the center of the earth. Most of the major rock fractures in California appear to be only 10 or 15 miles deep, whereas in other areas the depth may be doubled or tripled and thereby cause less violent motion at the surface.

At the end of 1965 there were about 150 seismograph stations in continuous operation in the United States and approximately 900 stations throughout the world. Some of the principal organizations engaged in seismological work in the United States are the California Institute of Technology, which operates a network of 18 stations in southern California; the University of California, which operates a similar network of 20 stations in northern California; and the Jesuit Seismological Association, which coordinates the work of 27 affiliated stations spread over most of the country. In addition, more than a score of stations are operated independently by universities in connection with their geological and geophysical programs. The Geological Survey operates seismograph stations in Yellowstone National Park, in Utah, and on the island of Hawaii. The Hawaii network is used to study local earthquakes due to volcanic activity. The Coast and Geodetic Survey, in addition to operating a network of 14 stations and cooperating in the maintenance of 16 others, serves as the central point for collation of much of the statistical information collected by these various groups.

GEOMAGNETISM[3]

The earth's magnetic field roughly resembles that of a uniformly magnetized sphere or a small strong bar magnet at the earth's center. The supposed source of the field is a system of fluid motions and concomitant electric currents nonuniformly distributed in the earth's molten metallic core; this system constitutes a self-excited dynamo. The central-magnet model resembles nature more if the magnet is placed off center, but there are still large discrepancies. For practical uses it is necessary to compile charts showing the field determined from magnetic surveys; the local detail is smoothed out, leaving only the broad features shown on page 68. The isogonic chart illustrates the horizontal direction of the field (compass direction) throughout the United States as of 1965. Isogonic lines (in red) connect places where the compass points in the specified direction with respect to true north, this horizontal angle being the magnetic declination. The magnetic field is not generally horizontal but points downward at an angle called the magnetic dip or inclination; the isoclinic chart shows the distribution of dip. Other charts similarly show the total intensity of the field and its horizontal and vertical components. The unit of field intensity is the gamma or nanotesla (100,000 gammas equal 1 oersted or 1 gauss; 10^9 gammas equal 1 tesla, in mks units).

The earth's field is not static but has a long-term secular change, the annual rates of change being depicted by the blue isoporic lines on each of the five charts. Annual rates of change in direction (magnetic declination and magnetic dip) are expressed in minutes of angle per year; rates of change in field intensity are given in gammas per year.

Magnetic charts of the United States are compiled by the U.S. Coast and Geodetic Survey at intervals of 10 years (every 5 years for the isogonic chart) in order to show the continuing but unpredictable changes correctly. The rates of change illustrated by the isoporic lines should not be used for correction, forward or backward in time, over intervals longer than some 5 to 10 years, for the patterns of the isoporic lines themselves often undergo quite drastic changes. Similar magnetic charts of the entire world are compiled by the Coast and Geodetic Survey and published by the U.S. Naval Oceanographic Office.

The magnetic charts reproduced here represent a highly smoothed picture of the magnetic field. They are not suitable for detailed representation of crustal structures. The isogonoic chart serves as the primary source of magnetic-compass information as it is presented on navigation charts, both nautical and aeronautical. The other magnetic charts serve a number of functions, which include the depiction of regional gradients that commonly must be removed from magnetic measurements made by the exploration geophysicist so that the measurements will illustrate magnetic anomalies more readily.

REFERENCES

[1] American Geophysical Union and U.S. Geological Survey, *Bouguer gravity anomaly map of the United States,* Washington, U.S. Geol. Survey, 1964, map 1:2,500,000, conterminous U.S.

[2] U.S. Coast and Geodetic Survey, *Earthquake history of the United States,* pt. I, Washington, U.S. Govt. Print. Off., 1965.

— *Earthquake history of the United States,* pt. II, Washington, U.S. Govt. Print. Off., 1966.

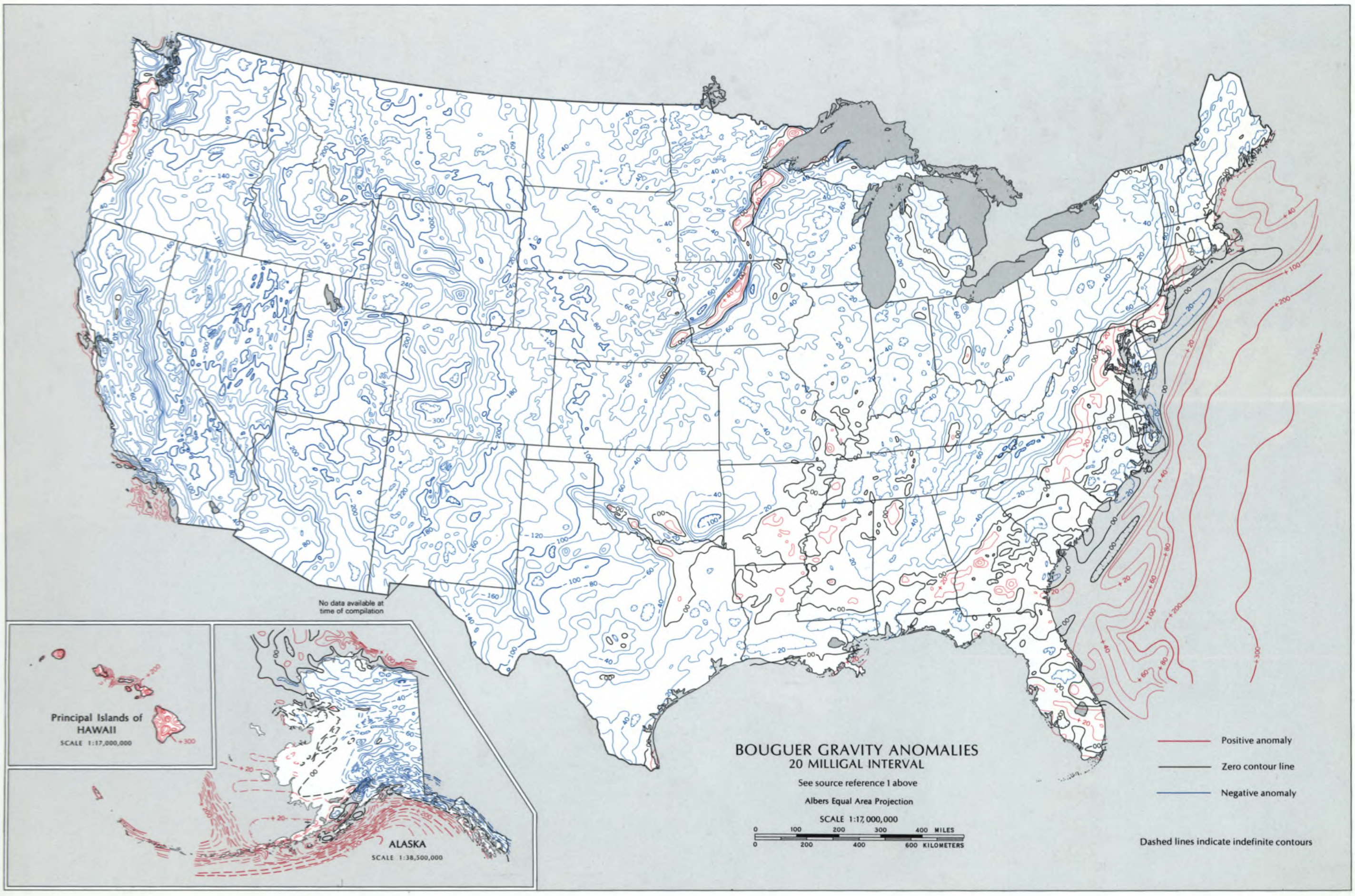
[3] U.S. Coast and Geodetic Survey, *Isogonic chart of the United States, 1965.0,* 3077, Washington, USC&GS, 1965, map 1:5,000,000.

— *Total intensity chart of the United States, 1965.0,* 3077f, Washington, USC&GS, 1965, map 1:5,000,000.

— *Horizontal intensity chart of the United States, 1965.0,* 3077h, Washington, USC&GS, 1965, map 1:5,000,000.

— *Isoclinic chart of the United States, 1965.0,* 3077i, Washington, USC&GS, 1965, map 1:5,000,000.

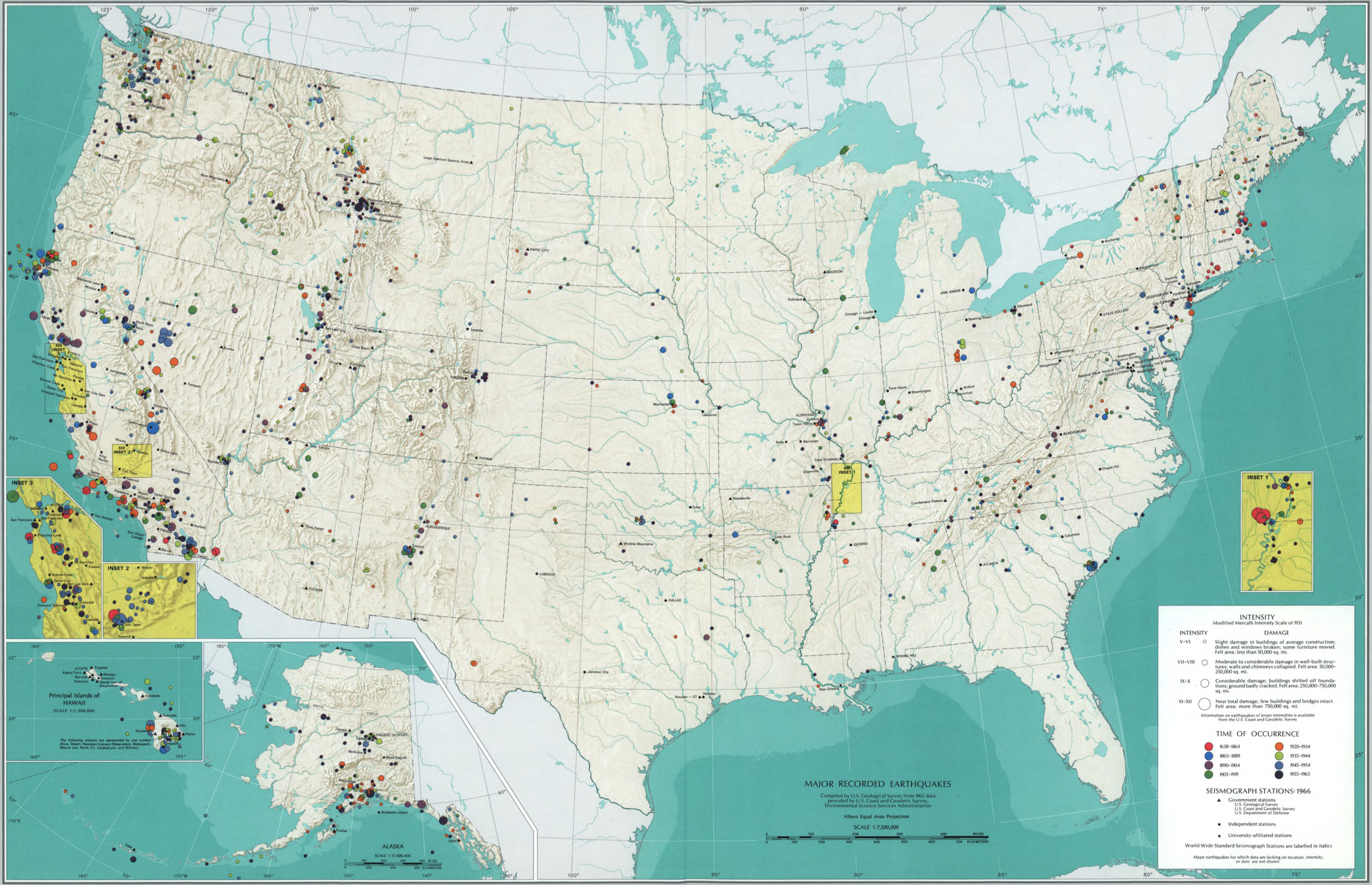
— *Vertical intensity chart of the United States,* 3077z, Washington, USC&GS, 1965, map 1:5,000,000.



BOUGUER GRAVITY ANOMALIES
20 MILLIGAL INTERVAL

See source reference 1 above

Albers Equal Area Projection



MAJOR RECORDED EARTHQUAKES

Compiled by U.S. Geological Survey from 1965 data
provided by U.S. Coast and Geodetic Survey,
Environmental Science Services Administration

Albers Equal Area Projection

SCALE 1:7,500,000

INTENSITY

Modified Mercalli Intensity Scale of 1931

INTENSITY		DAMAGE
V–VI	○	Slight damage in buildings of average construction; dishes and windows broken; some furniture moved. Felt area: less than 50,000 sq. mi.
VII–VIII	○	Moderate to considerable damage in well-built structures; walls and chimneys collapsed. Felt area: 50,000–250,000 sq. mi.
IX–X	○	Considerable damage; buildings shifted off foundations; ground badly cracked. Felt area: 250,000–750,000 sq. mi.
XI–XII	○	Near total damage; few buildings and bridges intact. Felt area: more than 750,000 sq. mi.

Information on earthquakes of lesser intensities is available
from the U.S. Coast and Geodetic Survey

TIME OF OCCURRENCE

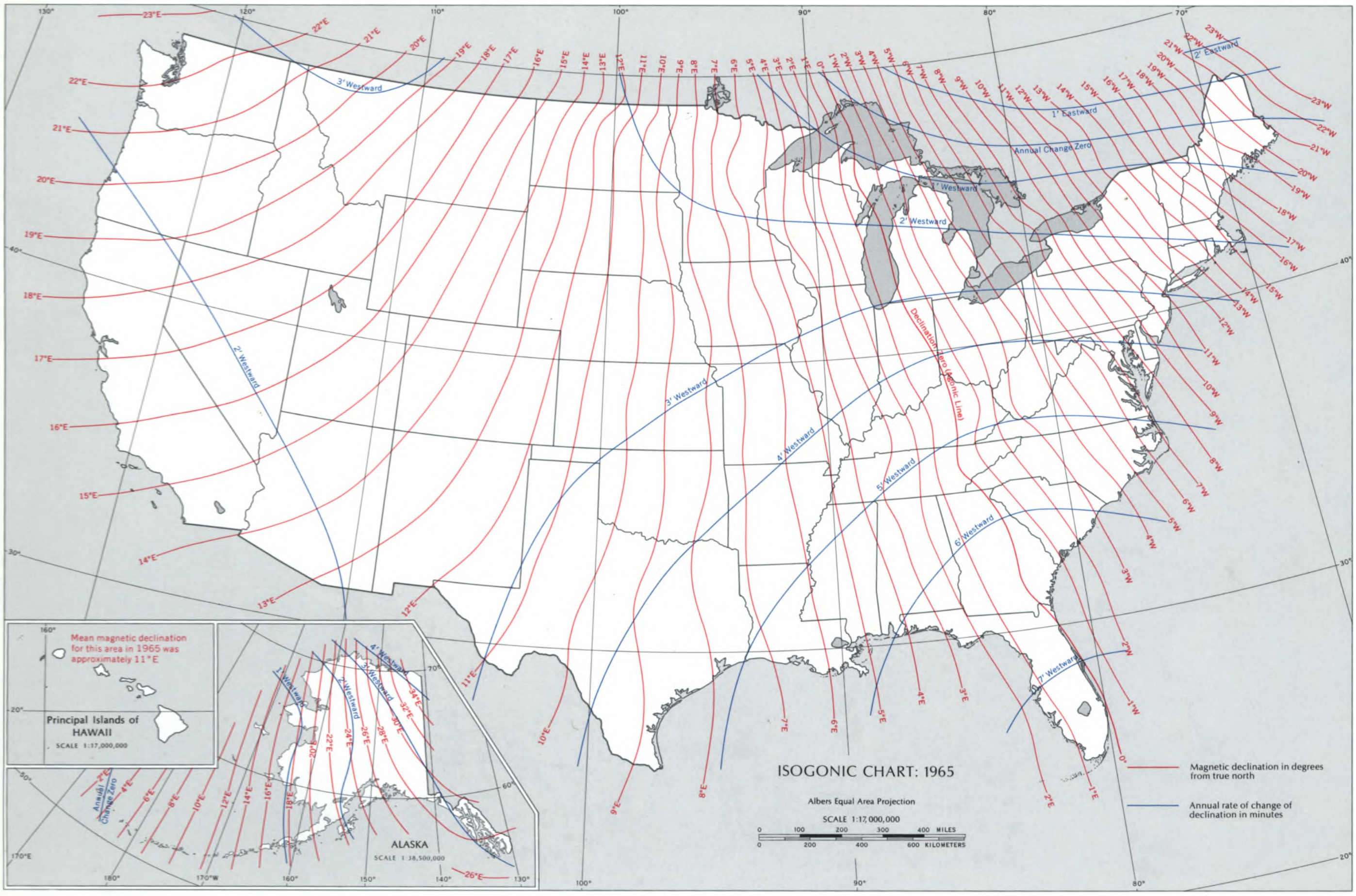
●	1638–1864	●	1920–1934
●	1865–1889	●	1935–1944
●	1890–1904	●	1945–1954
●	1905–1919	●	1955–1965

SEISMOGRAPH STATIONS: 1966

- ▲ Government stations
  - U.S. Geological Survey
  - U.S. Coast and Geodetic Survey
  - U.S. Department of Defense
- ● Independent stations
- ✖ University-affiliated stations

World Wide Standard Seismograph Stations are labelled in italics

Major earthquakes for which data are lacking on location, intensity,
or date are not shown

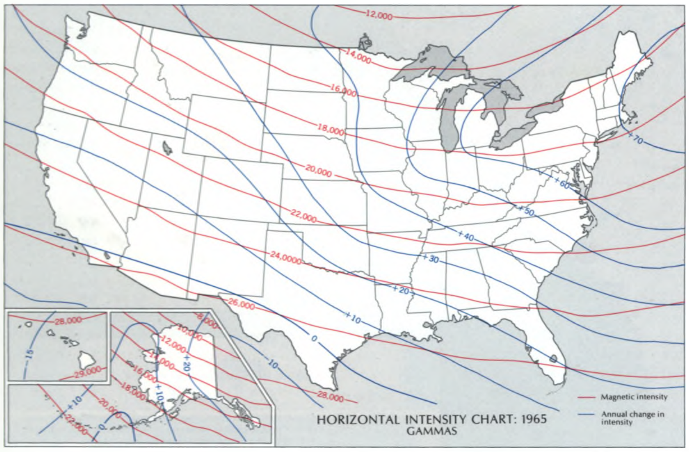


ISOGONIC CHART: 1965

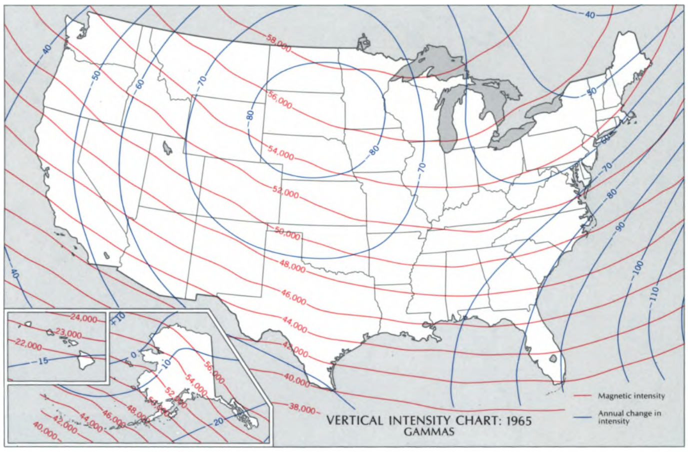
Albers Equal Area Projection

SCALE 1:17,000,000

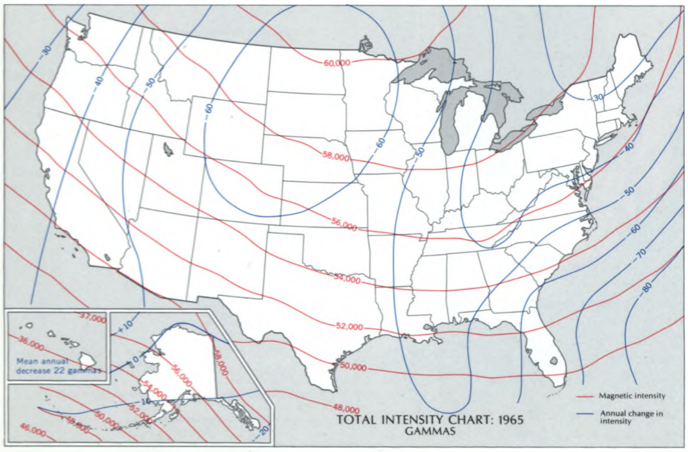
See text and source reference 3 on page 65



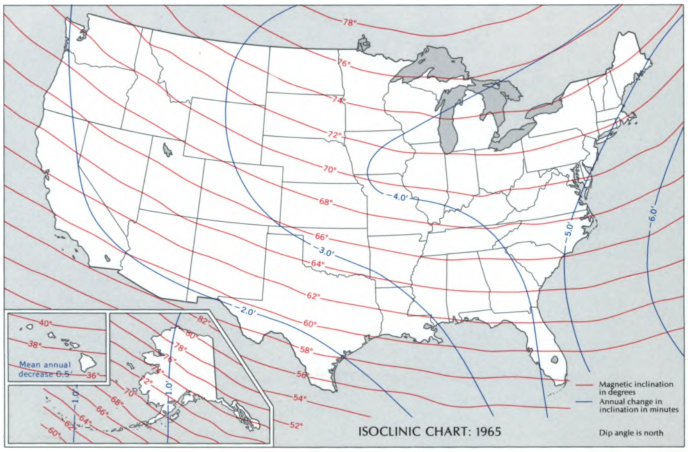
HORIZONTAL INTENSITY CHART: 1965
GAMMAS



VERTICAL INTENSITY CHART: 1965
GAMMAS



TOTAL INTENSITY CHART: 1965
GAMMAS



ISOCLINIC CHART: 1965

Dip angle is north

TECTONIC MAPS OF THE UNITED STATES

The maps on pages 70–71 and 72 summarize tectonic data compiled from many sources by the staff of the U.S. Geological Survey during preparation of a "Tectonic Map of the United States, exclusive of Alaska and Hawaii," scale 1:2,500,000 (Cohee, 1962); a "Tectonic Map of North America," scale 1:5,000,000 (King, in press); and an unpublished compilation of the tectonics of Alaska, made under the direction of George Gryc in 1958. In addition, tectonic data for Hawaii have been supplied by James G. Moore, based on original observations. For the two maps in the National Atlas, these tectonic data were generalized by Philip B. King, and the results were made into tectonic maps by Gertrude Edmonston.

TECTONIC MAPS DEFINED

To comprehend the tectonic maps, the user should compare them with the geologic map of the United States which appears on pages 74–75. The user will observe both resemblances and differences. By means of contrasting colors, both represent various classes of rocks which form the surface, and on both maps the fundamental classification of the rocks is according to their geologic ages. On the geologic map, however, the subdivision according to age is more detailed than that on the tectonic maps and only incidental attention is given to the nature of the rocks themselves. On the tectonic maps the rocks are subdivided according to their place in the evolution of the region of which they form a part. On the tectonic maps, moreover, structural symbols are used to represent the manner in which the rocks have been warped into domes and basins, folded into anticlines and synclines, and broken by faults. The combination of different colors and various structural symbols which appear on the maps thus portray the tectonics, or architecture of the rocks of the upper part of the earth's crust.

On the tectonic map of the 48 conterminous States, the arrangement of colors and symbols brings out two contrasting kinds of regions which are explained in more detail below—the platform areas and the foldbelts. The tectonic map of Alaska, covers only an area within a single foldbelt.

PLATFORM AREAS

Platform areas are generally constituted of plains and plateaus. They are underlain by flat lying, or gently dipping strata, largely of sedimentary origin, which are mostly a few hundred or a few thousand feet thick, but which in places attain thicknesses of 10,000 to 25,000 feet, or 3,000 to 8,000 meters. The sedimentary strata of the platform areas lie on a basement of much more deformed rocks which were at one time parts of foldbelts like those described below. After the foldbelts were created, their surfaces were eroded to lowlands which were subsequently buried by the strata of the platforms; since then, only very slight deformation has affected either these ancient foldbelts or their platform covers.

The map of the 48 conterminous States shows two platform areas: (A) the Interior Plains and Plateaus consisting of deposits of Paleozoic, Mesozoic, and Cenozoic ages that overlie the eroded surface of foldbelts of various Precambrian ages; (B) the Atlantic and Gulf Coastal Plains, consisting of deposits of Mesozoic and Cenozoic ages that overlie the eroded surface of foldbelts of Paleozoic age.

On the map, the two platform areas, A and B, are shown in subdued tints of flesh and gray, respectively. The configuration of the surfaces of the basement rocks beneath the platform deposits is shown by contour lines—red for Precambrian basement, purple for Paleozoic basement—drawn on an interval of 1,000 meters (3,280 feet). These contours express all the deformation to which the rocks of the platform areas have been subjected after the time when their ancient foldbelts were covered by deposits.

FOLDBELTS

Foldbelts commonly form a mountainous terrain. They are formed by orogenies which are, in effect, storms within the crust of the earth; but whereas atmospheric storms come and go within a few hours or days, the crustal storms endure for many millions of years because of the much greater rigidity of the materials involved. To be more exact, each foldbelt was created during stormy periods of geologic time—a succession of orogenic storms following on and reinforcing each other, the whole constituting an orogenic cycle. Like atmospheric storms, the orogenic tempests had small beginnings, built up to a climax, and then slowly wasted away. Like atmospheric storms, also, the orogenic storms occurred from time to time and from place to place in the earth. One foldbelt might be in the grip of an orogenic tempest, while others were becalmed. Thus, each of the orogenic cycles during which the foldbelts were created has its own age and duration.

The causes of these orogenic storms are poorly understood. Nevertheless their manifestations are plain—the folding and faulting of the near-surface strata; the flowage, recrystallization, and metamorphism of the parts beneath, and the emplacement of bodies of granite and other plutonic rocks into the deepest layers.

On the two tectonic maps, the various foldbelts are distinguished by brighter colors than those used for the platform areas, by the juxtaposition of areas of contrasting color, and by the close crowding of structural symbols.

FOLDBELTS OF PRECAMBRIAN AGE

The oldest foldbelts known on earth are of Precambrian age. In the 48 conterminous States these emerge at the surface only in small areas, the areas in the north being extensions of much larger areas in Canada; elsewhere, they compose the cores of uplifts in the younger foldbelts.

The small surface extent of the Precambrian foldbelts makes it impossible to indicate them in detail. The only subdivision of Precambrian rocks that is made is into differently colored units that represent three general ages of folding.

Ages of folding in the Precambrian rocks have been determined by isotopic dates which range from more than 3,000 million years to 600 million years ago, or to the time of the beginning of the Cambrian. The tectonic map of the 48 conterminous States shows that the ages of the Precambrian metamorphic and plutonic rocks tend to cluster about distinct spans of time; therefore, these rocks are divided into earlier Precambrian (rocks yielding dominant isotopic dates of about 2,500 million years; C1), middle Precambrian (rocks yielding dominant isotopic dates of about 1,700 million years; C2), and later Precambrian (rocks yielding dominant isotopic dates of about 1,000 million years; C3). These clusters of dates, believed to represent climaxes of orogeny, have been termed the Kenoran, Hudsonian, and Grenville orogenies in Canada (Stockwell, 1965). During these times, the rocks of each successive foldbelt were deformed and metamorphosed and were invaded by plutonic rocks.

Besides the Precambrian metamorphic and plutonic rocks, there are sedimentary and volcanic strata of middle and later Precambrian age (C4) which were little deformed during Precambrian time. These strata were laid down on the eroded surfaces of foldbelts formed earlier and were outside regions affected by orogeny later in Precambrian time.

FOLDBELTS OF PALEOZOIC AND LATER AGES

The tectonic maps show that the surface extent of foldbelts of Paleozoic and later ages is much greater than that of the foldbelts of Precambrian age. The Appalachian foldbelt extends across most of the Eastern States, from Maine to Alabama, and the related Ouachita foldbelt emerges in smaller areas farther west. The Cordilleran foldbelt covers all the western conterminous States and almost all of Alaska. Because of the wide surface extent of these younger foldbelts, it is possible, by means of different colors, to show separately the various kinds of rocks that compose them.

During the initial phases of an orogenic cycle, the areas that later evolved into foldbelts were geosynclines, or broad troughs in which great thicknesses of strata accumulated, mostly in a marine environment. Parts of the geosynclines were differently affected by crustal forces, and contrasting rocks and structures were produced; the rocks of these different parts are shown separately.

The miogeosynclines, or parts nearer the continental interior, were only mildly affected by crustal activity until late in their history and received mainly carbonate and quartzose sediments (limestone, dolomite, shale, sandstone, and quartzite; D3, F8, 5). The eugeosynclines, or parts farther from the continental interior and nearer the ocean basins, were much more affected by crustal activity throughout their history and were the first to feel the effects of orogeny. The eugeosynclines received large volumes of volcanics and volcanic-derived sediments, as well as poorly sorted clastic sediments (argillites and graywackes); carbonate rocks are minor, but beds of siliceous sediment (chert) are common (D2, F6, 3).

Before and during the climaxes of orogenies, the rocks of the eugeosynclinal areas were deeply depressed in the earth where they were subjected to heat and pressure, so that they are commonly much metamorphosed. Also during these same times, plutonic rocks were emplaced in these areas—partly by injection from below and partly by transformation of the eugeosynclinal rocks themselves. The most extensive of the plutonic rocks are silicic or granitic (D1, F2, E). Plutonic rocks of mafic or ultramafic composition are of smaller extent. In the Appalachian foldbelt such rocks form bodies too small to represent on the present map, but in the Cordilleran foldbelt they are differentiated in both the western conterminous States and in Alaska (F1, C). In the Cordilleran foldbelt in both the Western States and Alaska, smaller bodies of plutonic rocks continued to be emplaced in Cenozoic time, after the climax of the orogenies (F3, F).

The present gross features of the Cordilleran foldbelt are mainly the product of orogenic and postorogenic events during Mesozoic and Cenozoic time, but this region did not lie undisturbed throughout earlier geologic time; there are indications of earlier orogenies, both in early Mesozoic time and during various parts of Paleozoic time. The extent and nature of these earlier orogenies are as yet incompletely known, because their effects have been obscured by the later orogenies.

The rocks affected by these earlier orogenies cannot be indicated on the present map in the Western States, but some differentiation can be made in Alaska. Here, older Paleozoic geosynclinal deposits (2) are in many places much more deformed than the younger strata, and they have, in part, been much metamorphosed (B); there are also some bodies of granitic rocks of Paleozoic age (D), which are probably related to these early orogenies. Central Alaska includes extensive areas of a metamorphic complex (A), whose rocks may have originated during some part of the Precambrian; but in the complexes, metamorphic and plutonic processes are known to have continued much later, in places even into Mesozoic time.

After the climax of the orogenic cycles, various postorogenic deposits were laid down which form small mappable units in the Appalachian foldbelt and extensive mappable units in the Cordilleran foldbelt of both the conterminous States and Alaska.

The climax of the orogenic cycle in the northern part of the Appalachian foldbelt was during mid-Paleozoic time. Here, younger Paleozoic deposits (D4) are preserved in small areas; they lie on eroded surfaces of much more deformed and metamorphosed earlier Paleozoic rocks, but they are themselves deformed by orogenies late in Paleozoic time. Throughout the length of the Appalachian foldbelt there are also remnants of land-laid Triassic deposits (D5); these have been merely tilted and broken into fault blocks. Aside from these, the only postorogenic products in the Appalachian foldbelt are the late Mesozoic and younger platform deposits which cover the southeastern extension of the foldbelt beneath the Atlantic and Gulf Coastal Plains.

By contrast, the later orogenic history of the Cordilleran foldbelt was much more eventful; crustal instability continued long after the main orogenies, and areas near the Pacific coast are still unstable. The Cordilleran foldbelt thus contains tectonically significant post-orogenic units that formed between later Mesozoic time and the present.

In the eugeosynclinal part of the Cordilleran foldbelt in both the Western States and Alaska, climax of the orogenic cycle occurred during the mid-Mesozoic, at which time the rocks that had formed in the eugeosynclinal area were deformed, partly metamorphosed, and invaded by plutonic rocks. In this region, in later Mesozoic time, basins were formed, which received large volumes of sedimentary and volcanic deposits. These basins and their deposits occupy extensive areas in central and southern Alaska (6). In the interior of the Western States, such basins are less extensive and are shown in only a few places on the map; but toward the Pacific coast, especially in California, comparable deposits were laid down nearly continuously along the western margin of the earlier foldbelt (F9).

In addition, in both the Western States and Alaska, along the edge of the Pacific Ocean basin, a younger eugeosyncline developed which received large volumes of later Mesozoic deposits (F7, 4).

During Cenozoic time, marine and land-laid deposits accumulated in smaller basins in the Cordilleran foldbelt and were variously deformed by the later orogenies of the cycle. These are differentiated near the Pacific coast (F10). Such deposits are shown throughout Alaska (7), where they underlie small areas in the interior and more extensive areas along the Pacific coast.

Separately shown in the Cordilleran foldbelt on both maps are the thick youngest deposits, largely land-laid and of late Tertiary and Quaternary age (F11, 8). The thick youngest deposits are the products of the last movements of the orogenic cycle in the Cordilleran foldbelt—such as broad downwarps (as in Alaska), and the subsidence of fault troughs (as in the Basin and Range province of the Western States).

Igneous as well as sedimentary processes continued in the Cordilleran foldbelt after the climax of the orogenic cycle. Lavas and volcanic products were spread throughout Cenozoic time over extensive areas. The volcanics effectively conceal the earlier rocks over large parts of the Northwestern States and occur in smaller areas elsewhere. On the maps, they are divided into the earlier volcanics of Tertiary age (F4, G), and the younger volcanics, mainly of Quaternary age (F5, H). The younger volcanics occupy more restricted areas than the older and their distribution reflects the volcanic-tectonic patterns of latest geologic time. Especially significant, both in Alaska and the Northwestern States, are the belts of latest volcanics that lie near and parallel to the Pacific coast. These belts, marked by lines of volcanoes whose cones are represented on the maps, are small segments of the "circle of fire" that rings much of the Pacific Ocean basin.

TECTONICS OF HAWAII

The tectonic features of the State of Hawaii are shown on an inset on page 70. The islands which constitute this State lie in the central part of the Pacific Ocean; they are all volcanic. Landforms, the history of the volcanic activity, and isotopic dating all indicate that the islands have grown progressively southeastward with time, those to the northwest being the oldest, the "Big Island" of Hawaii to the southeast being the youngest. The process of volcanic island building began to the northwest in late Tertiary time, and continued through Quaternary time to the southeast. Based on isotopic dating, the volcanic rocks on Oahu and the islands northwest of it are mapped as Tertiary (F4), and those southeast of Oahu as Quaternary (F5).

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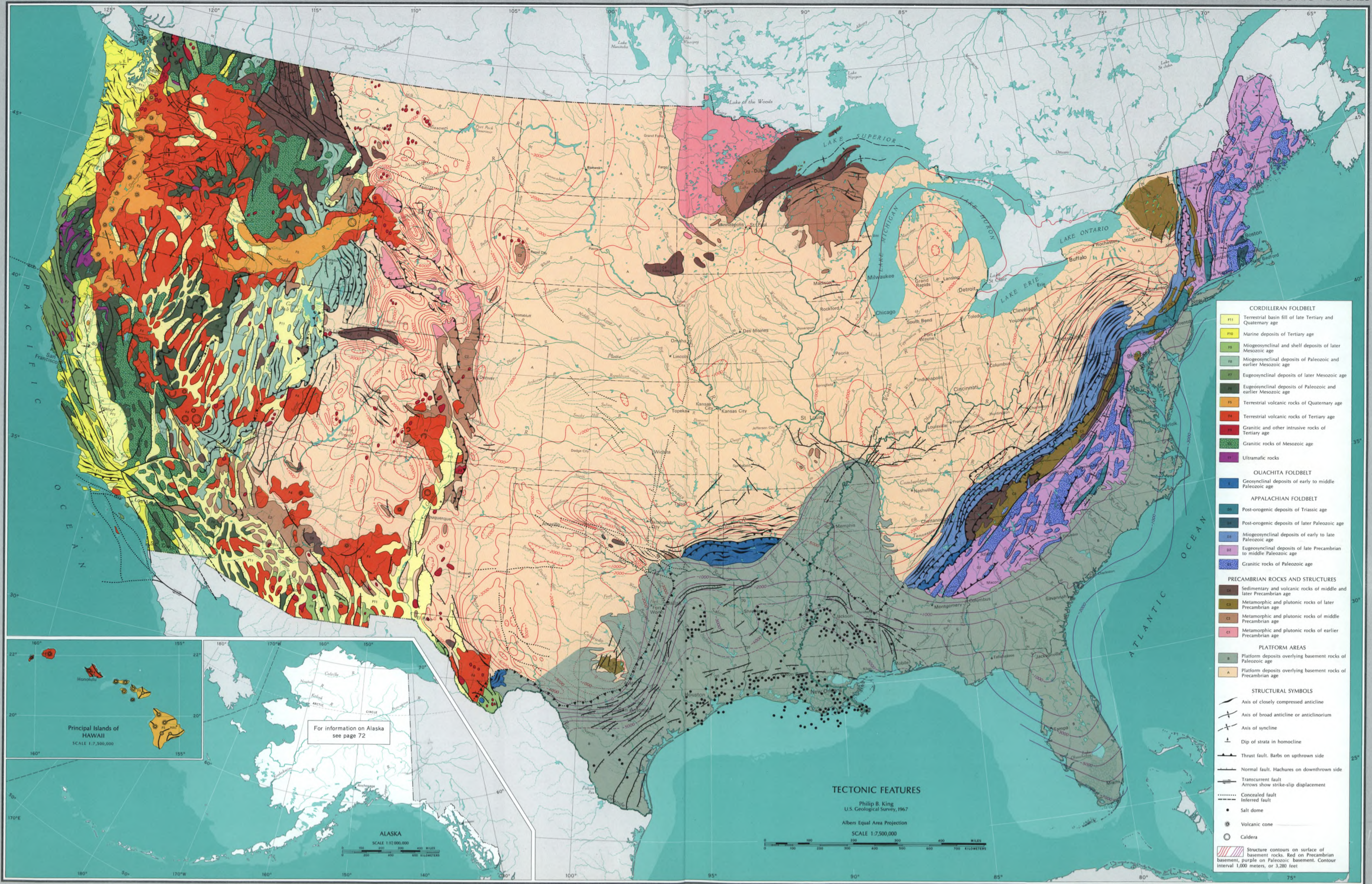


TECTONIC FEATURES

Philip B. King
U.S. Geological Survey, 1967

Albers Equal Area Projection

SCALE 1:7,500,000

TECTONIC FEATURES

Philip B. King
U.S. Geological Survey, 1968

Albers Equal Area Projection

SCALE 1:7,500,000

STRATIFIED ROCKS

8	Terrestrial basin fill of late Tertiary and Quaternary age
7	Marine and continental deposits of Tertiary age
6	Basin deposits of later Mesozoic age
5	Miogeosynclinal deposits of Paleozoic and earlier Mesozoic age
4	Eugeosynclinal deposits of later Mesozoic age
3	Eugeosynclinal deposits of later Paleozoic and earlier Mesozoic age
2	Geosynclinal deposits of earlier Paleozoic age
1	Deposits of later Precambrian age

IGNEOUS AND METAMORPHIC ROCKS

H	Terrestrial volcanic rocks of Quaternary age
G	Terrestrial volcanic rocks of Tertiary age
F	Granitic and other intrusive rocks of Tertiary age
E	Granitic rocks of Mesozoic age
D	Granitic rocks of Paleozoic age
C	Mafic and ultramafic rocks
B	Metamorphosed geosynclinal deposits of earlier Paleozoic age
A	Metamorphic complex of Precambrian and later age

STRUCTURAL SYMBOLS

- Axis of closely compressed anticline
- Axis of broad anticline or anticlinorium
- Axis of syncline
- Thrust fault. Barbs on upthrown side
- Normal fault. Hachures on downthrown side
- Transcurrent fault
  Arrows show strike-slip displacement
- Concealed fault
  Inferred fault
- Volcanic cone
- Caldera

GEOLOGIC HISTORY

PRECAMBRIAN ERA

Knowledge of Precambrian history is fragmentary. The most ancient rocks known in the United States are more than 2.5 billion years old and include sedimentary rocks highly altered by heat and pressure that must have been derived by weathering and erosion of preexisting and as yet unidentified older rocks. Studies in the Lake Superior region and adjacent parts of Canada indicate a history that involves four episodes of mountain building (orogeny) accompanied by intrusion and metamorphism. Radiometric ages determined for the intrusive and metamorphic rocks cluster at 2.5, 1.7, 1.4, and 0.9 billion years.

In the Grand Canyon of Arizona, and other places in southwestern United States, Precambrian rocks are divided into two series: an older series of folded, highly altered sedimentary and igneous rocks, and unconformably overlying them a younger series of tilted, slightly altered sedimentary rocks. Granitic intrusions at several places in the older series have been dated radiometrically at 1.6 to 1.8 billion years old.

Precambrian rocks of the Belt Series are widely exposed in mountains of western Montana and northern Idaho; these rocks are as much as 40,000 feet thick and consist of slightly altered mudstone, sandstone, carbonate rocks, and locally some lava flows. The upper part of the Belt Series has been dated radiometrically as 1.1 billion years old.

Ancient Precambrian sedimentary rocks are dominantly composed of fragments of preexisting rocks and are drab in color. Heterogeneous mineralogy of these early sediments suggests they were deposited with little mineral sorting. Local red beds and carbonate rocks in younger Precambrian rocks suggest an oxygen-rich atmosphere.

Life probably originated on this planet almost 3 billion years ago and distinct algal-like structures have been identified in rocks almost 2 billion years old, well back in Precambrian time.

MAJOR GEOLOGIC TIME DIVISIONS

ERA	PERIOD	AGE OF BOUNDARIES IN MILLIONS OF YEARS*
Cenozoic	Quaternary	
		2-3
	Tertiary	
		70
Mesozoic	Cretaceous	
		135
	Jurassic	
		180
	Triassic	
		225
Paleozoic	Permian	
		270
	Pennsylvanian	
	Mississippian	
		350
	Devonian	
		400
	Silurian	
		440
	Ordovician	
		500
	Cambrian	
		600
Precambrian		3,000+

*Holmes, Arthur, 1965, *Principles of Physical Geology*, 2d ed.: Ronald Press, p. 360-361, 373, 375

PALEOZOIC ERA

In contrast to the Precambrian, the later geologic history of the conterminous United States is well-known. Clearly defined structural elements were established at the beginning of the Paleozoic consisting of a broad, relatively stable central interior region bordered by generally north-trending, subsiding troughs (geosynclines) along the eastern edge and in the western part of the present continent. These geosynclines consisted of an inner belt – a miogeosyncline – in which thick sequences of carbonate and fine-grained quartzose fragmental sediment accumulated, and an outer belt–a eugeosyncline–in which thick sequences of impure fragmental sediment and many volcanic rocks accumulated. Sediments in the miogeosynclines and on the continental interior resembled each other except that deposits in the miogeosynclines attained considerably greater thicknesses due to greater subsidence and more rapid accumulation.

The seas have supported an abundance and variety of plants and invertebrate animals since the beginning of the Paleozoic. The first air-breathing land animals, a scorpion and a milliped, and the first land plants are found in rocks of the Silurian Period. The first vertebrates, primitive fishes, appear in the Ordovician Period but the first land-living vertebrate, an amphibian, does not appear until Late Devonian. By middle Paleozoic time, plants and animals occupied all major environments and all major divisions of animals had appeared.

During Cambrian time, gradual subsidence allowed marine waters that initially were confined to the marginal geosynclines to spread onto the central stable region, and eventually seas flooded much of the continent. A basal sandstone was deposited along the shoreward margins of the sea as it transgressed the land. At most places, finer grained marine fragmental rocks succeed the basal sandstone, followed by a sequence of carbonate rocks. By Early Ordovician time, limestone and dolomite were being formed nearly everywhere in the interior region. These carbonate rocks attained thicknesses of several thousand feet within the miogeosynclines and a few hundred feet at most places on the central interior. The widespread distribution and uniformity of the carbonate rocks reflect a long period of continental stability during which little detritus was derived from the continental platform.

In the eugeosynclines on the outer margins of the continent, the record of Cambrian deposition is not well defined. Detrital rocks, chert, and lavas accumulated to thicknesses of perhaps 10,000 feet locally in the western eugeosyncline. The impure detrital rocks of the eugeosynclines were formed from sediment derived from land areas at or seaward from the present coastlines of the United States.

Thick sequences of rocks also accumulated beginning in Late Cambrian or Early Ordovician time in the Ouachita geosyncline, which extended from northern Mississippi to northeast Texas and in a broad arc southwestward to southwest Texas.

Near the end of Early Ordovician time, broad uplift caused rather rapid retreat of the sea from the interior to the marginal areas of the continent. Beginning in Middle Ordovician time and continuing into the Silurian, however, shallow seas reinvaded and eventually covered most of the central interior. The initial deposit of this marine transgression at most places was quartzose sandstone, followed by carbonate rocks as submergence continued and interior land areas were inundated. Beginning in Middle Ordovician time, fragmental materials derived from the east were spread into the subsiding eastern miogeosyncline, and accumulation of detritus continued in this region through the Silurian Period. Wedges of detrital sediment several thousand feet thick were built up in Georgia and the Carolinas in Middle Ordovician time, and in the New England States in Late Ordovician time. These wedges include stream and shallow-water marine deposits and are thought to represent compound deltas of sediment derived from rising land masses farther east.

In the northeastern States, uplift culminated near the end of the Ordovician in folding and thrust faulting. This disturbance, the Taconic orogeny, was an early spasm in a history of repeated mountain building which continued along the eastern side of the United States for the remainder of the Paleozoic.

Elsewhere at the continental margins, deposition continued in the geosynclines through Ordovician and Silurian time; great thicknesses of impure detrital and volcanic rocks formed in the eugeosynclines, carbonate rocks and pure sandstone in the miogeosynclines.

At the end of Silurian time and beginning of Devonian, seas withdrew from most of the interior in response to broad uplift and local folding; widespread erosion resulted. One area extending from Michigan through western New York and Pennsylvania remained submerged longer than most, and thick salt deposits were precipitated as a result of long-continued evaporation in this remnant sea.

In Middle Devonian time, seas began to spread from the Appalachian miogeosyncline westward into the Mississippi Valley region, and from western Canada southward into the Rocky Mountain region. A temporary restriction of this sea in eastern Montana and western North Dakota at this time resulted in deposition of as much as 500 feet of potash and other salts. Meanwhile the continental interior was partly emergent and was eroded along a series of broad, irregular uplifts. The largest of these, the Transcontinental Arch, extended from Minnesota southwestward into New Mexico; arms extended eastward from Nebraska to Ohio, and southeastward from northern New Mexico into central Texas. During Late Devonian time the seas transgressed onto and locally across these uplifts. Sediments laid down in this interior sea were largely shallow-water marine carbonate followed at the end of the Devonian by thin but widespread deposits of black mud.

Beginning in about Middle Devonian time, the Acadian orogeny produced fold mountains along the Atlantic margin of the continent from Newfoundland to Alabama, including the area previously involved in the Taconic orogeny. Lower Devonian and older sedimentary rocks on the eastern side of the Appalachian miogeosyncline were strongly deformed and intruded by igneous rocks in New England and adjacent Canada. Deformation extended as far south as North Carolina, but south of New England the deformed area lay east of the miogeosyncline. Folding, uplift, and deep-seated igneous activity continued intermittently in this region during Mississippian and possibly Pennsylvanian time. This Late Devonian uplift and erosion east of the Appalachian miogeosynclinal trough produced sediment that formed a great wedge of detrital rocks as much as 13,000 feet thick extending from New York southward for about 500 miles into southern Virginia, and across the miogeosyncline as far as eastern Ohio.

While shallow-water marine shales and limestones were accumulating in the interior region, lavas and associated eugeosynclinal sediments of known or probable Devonian age were deposited in a marine basin or basins extending northward through the far western States.

In latest Devonian or Early Mississippian time a disturbance called the Antler orogeny produced eastward thrusting and folding in a northeast-trending band across central Nevada, and probably across western Idaho and eastern Washington. A general withdrawal of the sea from much of the mid-continent took place about the same time. Eugeosynclinal deposits of the western Nevada region were displaced by faulting at least 55 miles and perhaps as much as 90 miles eastward over miogeosynclinal deposits and a mountain belt possibly 500 miles long was produced. From these highlands detritus was shed eastward into shallow marine seas that persisted in eastern Nevada and adjacent regions farther east during much of the remainder of the Paleozoic.

In Early Mississippian time and continuing through most of the Mississippian a large part of the interior was submerged again. As subsidence continued, the Rocky Mountain and central States were covered by a shallow but open sea in which a widespread sheet of carbonate sediment accumulated to form limestone. In the northern Appalachian and eastern interior regions, mud and sand derived from highlands to the east and north were deposited on flood plains of streams and in deltas bordering the inland sea.

The Ouachita geosyncline along the southern margin of the continental interior sank rapidly in Late Mississippian time to form a trough which in its eastern part was filled with as much as 20,000 feet of shale and sandstone.

A major change in the tectonic framework of the western continental interior is evident in the Pennsylvanian Period. The vast, stable interior region was broken by several uplifts and adjacent basins in a band from southeastern Oklahoma northwestward into central Idaho. Basins and shelf areas between uplifts were flooded by the sea; the uplifts stood above sea level and detrital material collected on their flanks in fans and deltas or was dispersed in the marine basins. Among these uplifts was a mountain chain that rose at the beginning of the Pennsylvanian along the trend of the former Arbuckle basin in Oklahoma and the panhandle of Texas, and a subparallel range that rose along the Texas-Oklahoma border to the south. Disconnected uplifted blocks that probably stood at low to moderate elevations comprised the Ancestral Rocky Mountains in New Mexico, Utah, Colorado, and southern Wyoming. Uplifts that probably stood at low elevations during Early Pennsylvanian time, but were covered by later Pennsylvanian sediments, extended northwestward and northward across Kansas, Nebraska, into southwestern South Dakota.

Detrital sediment spread westward across the Appalachian region and southward from areas in Canada, to be deposited on lowlands and in the adjoining shallow sea. The strand line of this sea oscillated across the central, eastern interior, and Appalachian regions; Pennsylvanian rocks in these regions consist of alternating thin marine, brackish- and fresh-water deposits and include extensive beds of coal.

Compression and uplift began in the region of the Ouachita geosyncline early in Pennsylvanian time and in places continued until Early Permian time. Sediment poured northward from rising mountains within the former geosyncline and accumulated to considerable thickness in rapidly sinking basins formed between the orogenic belt and the stable continental interior. Lower Pennsylvanian rocks in one of these basins in Arkansas and Oklahoma reached a thickness of 20,000 feet.

In Permian time the eastern United States was uplifted in a mountain-building episode, the Appalachian Revolution, marking the end of the Paleozoic Era. Paleozoic rocks were folded, and thrust westward in a belt extending from southern Pennsylvania across Virginia and eastern Tennessee into Georgia and Alabama. This orogenic disturbance produced a telescoping of eugeosynclinal and miogeosynclinal rocks of the Appalachian region by an amount estimated to be more than 100 miles.

In Early Permian time a shallow sea occupied much of the mid-continent region from North Dakota to southern Texas and as far east as Iowa and Missouri. Mountains in east Texas and southeast Oklahoma marked a part of the former Ouachita geosyncline, and disconnected, moderately elevated land areas in New Mexico, Colorado, and Utah stood as remnants of the Ancestral Rocky Mountains. A peninsula extended from Canada southward through Montana and western Wyoming. This land area separated a shallow-water marine basin on the east from a deeper-water subsiding miogeosyncline on the west. Remnants of the mountain chain raised earlier during the Antler orogeny formed a chain of islands stretching from southern California through central Nevada into Idaho. During the Permian, this area was uplifted and the rocks folded, and finally thrust eastward during the Sonoma orogeny.

By mid-Permian time, the mid-continent sea was partly cut off from the open sea to the west by emergence of a large land area in the southern Rocky Mountain region. The inland sea consisted of a southern arm that terminated in the rapidly sinking Delaware basin in west Texas and eastern New Mexico, and a northern arm that terminated in the less actively subsiding Williston basin in North Dakota. Salts were deposited, locally to great thicknesses in both these basins, and thinner deposits of salts formed in some intermediate areas in western Kansas, Nebraska, and western Wyoming.

A shallow-water strait in Wyoming and parts of adjacent States to the north and south connected the shrinking mid-continent sea to areas of deeper water in Utah, eastern Nevada, and southern Idaho. The phosphatic shale of western Wyoming and adjacent areas, was deposited at the west entrance to the strait where the sea floor sloped westward into deep water. Windblown sand accumulated locally in dunes to thicknesses of several hundred feet on emergent areas of parts of Arizona, New Mexico, and Utah.

On the west coast the record of Pennsylvanian and Permian events is incomplete; however, volcanic ash and flows that are partly of Permian age and were deposited in deep, eugeosynclinal troughs are found in eastern Oregon, western Idaho, western Nevada, and northern California.

MESOZOIC ERA

The Appalachian Revolution at the end of the Paleozoic Era produced widespread uplift; most of the eastern part of the country was emergent throughout the early and middle parts of the Mesozoic Era. Continental deposits contain fossils of a wide variety of land animals. Reptiles first appeared in the Pennsylvanian, expanded rapidly in the Permian, and dominate the fossil record in the Mesozoic Era both in size (the dinosaurs) and number. Deciduous trees appeared late in the Mesozoic Era and by the end of the era were highly diversified and the dominant land plant.

Late in the Triassic Period northeast-trending fault valleys developed discontinuously in a band from eastern Canada southward for about 1,000 miles to South Carolina. These were filled with as much as 15,000 feet of detrital stream and lake deposits derived by erosion of adjacent highlands. Contemporaneous volcanism produced local interbedded lava flows.

In the Rocky Mountain region and adjacent Great Plains, Triassic rocks contain red beds which were deposited in shallow marine waters, in fresh-water ponds, and on flood plains of streams. Early in the Triassic a sea occupied a miogeosyncline that extended northeastward from southern California through southeastern Idaho. Marginal shelf deposits extended as far east as eastern Colorado and western South Dakota. Deposition was restricted in Middle Triassic time and definite Middle Triassic rocks are confined to a eugeosyncline in western Nevada. In Late Triassic time deposits were again widespread in the west. The shelf areas of Utah, Colorado, New Mexico, Arizona, and Wyoming were broken into a number of basins and platforms. Red beds were deposited which contained much volcanic material derived from volcanoes to the west. In Utah, western Colorado, and parts of Arizona extensive sand dunes were formed late in Triassic time. Marine shale, limestone, sandstone, chert, and interbedded lavas as much as 20,000 feet thick in western Nevada, Oregon, and parts of California indicate that rapid subsidence and locally intense volcanism took place in the eugeosyncline in the west coast region.

In Early Jurassic time much of the United States remained emergent. The Appalachian region was probably hilly; the mid-continent was mostly low plains. In a broad area in Utah, southern Wyoming, northern Arizona, and some parts of adjacent States deposits of windblown sand were formed.

During the Jurassic, a deep rapidly subsiding eugeosyncline persisted in northwestern Nevada, Oregon, and Washington and early in the period may have been separated from the open sea to the west by a peninsula extending from central California northward along the present northern California and southern Oregon coast. Volcanic activity continued periodically from Triassic into Jurassic time in California and Washington. The thickness of eugeosynclinal Jurassic rocks deposited in the coastal region may have been as much as 48,000 feet.

In Middle and Late Jurassic time the Rocky Mountain region was invaded by a shallow sea that advanced from Canada southward as far as northern New Mexico and spread westward to Nevada and eastward into South Dakota and Nebraska. Concurrently the Gulf Coast was downwarped and a shallow sea moved northward into Texas, Louisiana, Mississippi, Georgia, and eastern Florida. Gypsum or anhydrite formed with the initial deposits across large areas in both seas, but was soon buried by shallow-water detrital deposits. In latest Jurassic time, the western sea retreated northward into Canada and most of the area was covered by a blanket of stream and lake sediments containing large quantities of volcanic ash.

In the west coast region, the end of the Jurassic and beginning of the Cretaceous was marked by the Nevadan orogeny, during which eugeosynclinal rocks were folded, faulted, and extensively intruded by igneous rocks. A mountain chain was produced that extended from southern California northward along the Nevada-California border across eastern Oregon and Washington. West of this mountainous belt a rapidly subsiding geosyncline occupied the western parts of California, Oregon, and Washington. Detrital and volcanic rocks accumulated in this geosyncline to great thickness during the Cretaceous.

The Cretaceous Period was a time of renewed submergence in the western interior. Shallow seas advancing from Canada southward across the Rocky Mountain and northern Great Plains States connected about mid-Cretaceous time with seas advancing from the Gulf Coast northward across Mexico into Arizona, New Mexico, Utah, and Colorado. Detritus deposited in this seaway was mainly derived from the highlands on the west. Volcanoes in land areas in western Montana and nearby regions supplied ash that was carried eastward by the wind and deposited in extensive sheets a few inches to 30 feet or more thick. Coal deposits formed along the western shore of the sea, particularly in New Mexico and Colorado.

The Gulf and Atlantic Coastal States were submerged during Cretaceous time; the sea reached to central Oklahoma, northern Arkansas, and eastern Tennessee, and sluggish streams flowing across the low, eastern interior region contributed detrital material.

Orogenic disturbances that began with the Nevadan orogeny continued in the region west of the Rocky Mountain seaway, culminating in Late Cretaceous and early Tertiary time in the Laramide orogeny during which eastward thrusting occurred in a broad belt in Nevada, northwestern Utah, western Wyoming, eastern Idaho, and western Montana; anticlinal folding and vertical faulting–mostly of early Tertiary age–occurred east of the thrust belt in Colorado, Arizona, New Mexico, and central Wyoming. About 40 miles' displacement has been estimated for blocks thrust eastward in northern Utah during this disturbance. Large masses of igneous rocks were intruded in California, Idaho, and western Montana in mid-Cretaceous time.

CENOZOIC ERA

The sea began to retreat from the interior of the United States late in Cretaceous time. Soon after the beginning of the Cenozoic Era the only parts of the United States that remained submerged were the Atlantic and Gulf coastal plains, the Mississippi embayment, and embayments in parts of California, Oregon, and Washington. This emergent condition prevailed throughout the Cenozoic Era.

Mammals, which first appeared in the Triassic Period, rose to dominance in the Cenozoic; the large reptiles, so conspicuous in the Mesozoic, became extinct at the end of the Cretaceous Period. Man, of course, is a very recent arrival geologically although his primate ancestors may be traced back to about the beginning of the Cenozoic Era.

At the beginning of the Cenozoic, the Appalachian region was a level plain, probably close to sea level. This region was arched during several episodes of uplift in Cenozoic time, and the present Appalachian Mountains were carved by stream erosion along the preexisting folded belt.

Along much of the Gulf of Mexico coast, subsidence that began in the Mesozoic continued through the Cenozoic. Downwarping was balanced by deposition of sediment so that Cenozoic sediments accumulated mostly in shallow water and formed a southward-thickening wedge, at least 30,000 feet thick at the present coastal margin of Louisiana. During most of the Cenozoic, Florida was a subsiding shallow-water submarine bank on which limestone accumulated to a thickness of nearly 5,000 feet.

In early Cenozoic time, the far western states were occupied by plains and low hills and mountain ranges. Coal swamps occupied lowlands in a belt from Montana and North Dakota southward into New Mexico. Some low rank coal beds formed in lowlands in Oregon and Washington, also in swampy lowlands extending from southern Illinois southward across part of Arkansas, Louisiana, Mississippi, and east Texas. During part of early Cenozoic time large lakes occupied southwestern Wyoming, western Colorado, and northeastern Utah and widespread beds of oil shale were formed in them.

Erosion gradually reduced hills and mountains raised in the western States during Late Cretaceous and early Tertiary orogenies and sediment filled the intermontane basins. By mid-Cenozoic time the region was a rolling plain.

In late Cenozoic time, regional uplift and arching in the Rocky Mountain region rejuvenated the streams. Much nonresistant rock was stripped away; old mountains were exhumed; and at places through-going streams cut down across mountain ranges to form deep canyons. The present elevation and topography of the Rocky Mountains resulted mainly from this late regional uplift.

Volcanic activity was prevalent in large parts of the far west during the Cenozoic Era. During early Cenozoic time, lava flooded much of western Washington and Oregon, and submarine flows were extruded in rapidly sinking basins along the present coast of these States. Lava of early Cenozoic age in the Olympic Mountains of Washington accumulated to a thickness of 15,000 feet. Lava and local eruptions of volcanic ash covered most of central Idaho to depths locally greater than 5,000 feet. Volcanic rocks were extruded in the Yellowstone National Park area.

During mid-Cenozoic time lavas accumulated in the Columbia Plateau region of northern Oregon and eastern Washington to a thickness of more than 5,000 feet. Partly equivalent and partly younger lavas and ejected volcanic detritus make up much of the Cascade Mountains in Oregon and Washington and are several thousand feet thick. During the middle and late Cenozoic, volcanic ash and lavas were deposited over large areas of Nevada, parts of Colorado, New Mexico, Arizona, and southwestern Texas. Igneous rocks were intruded extensively in the western States in mid-Cenozoic time.

Late Cenozoic volcanism produced lavas of the Snake River Plains in southern Idaho, and thick lavas of the nearby Yellowstone region. Volcanic cones of late Cenozoic age are prominent features of the Cascade Mountains in northern California, Oregon, and Washington.

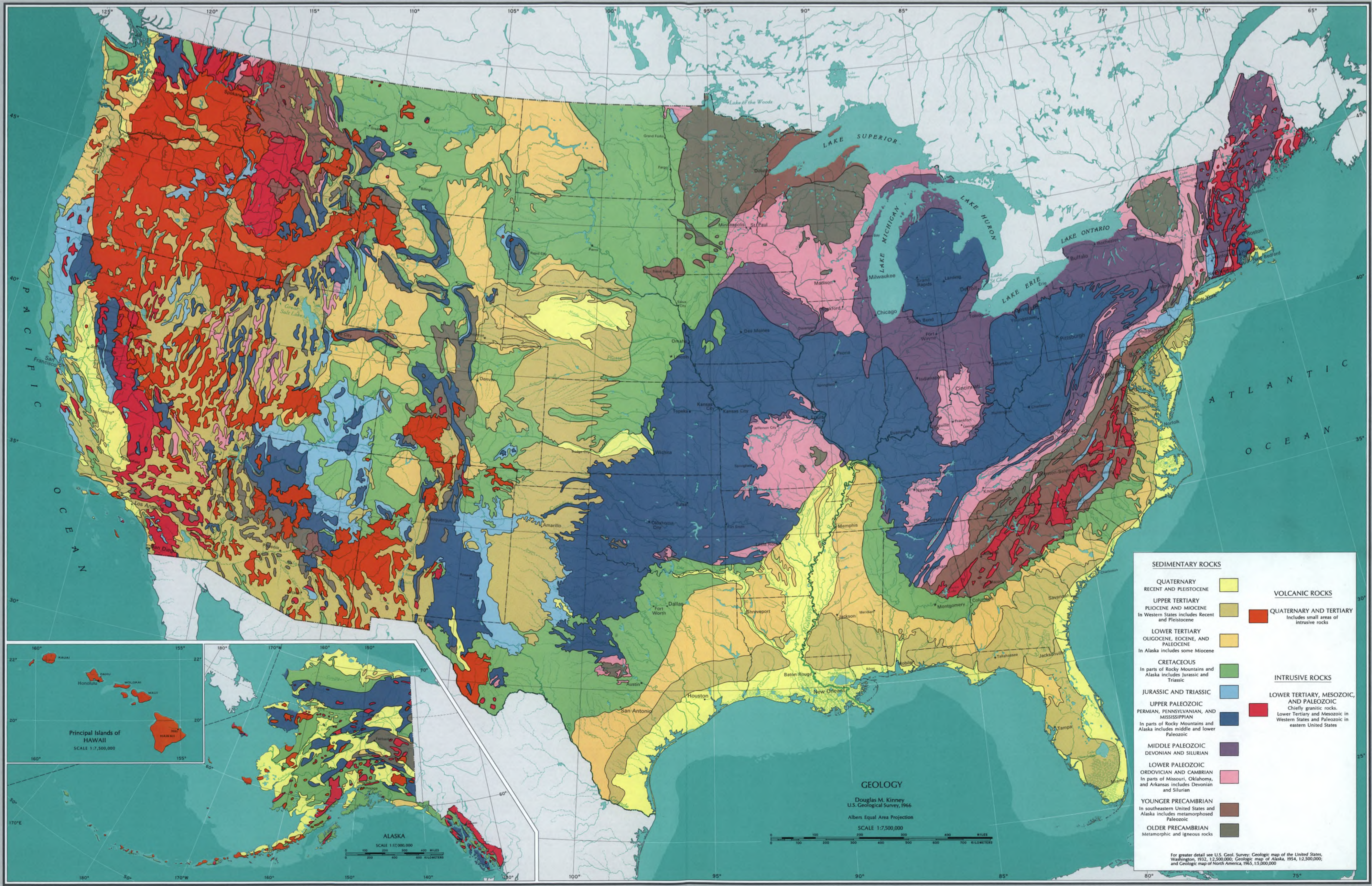
Extensive lake deposits are interbedded with the lavas and pyroclastic rocks of Idaho, Nevada, Arizona, and adjacent States and indicate that large lakes were a feature of the mid- and late Cenozoic landscape of the western States.

By mid-Cenozoic time, normal faults had begun to outline linear ranges and bordering basins that characterize the Basin and Range province. Faulting has continued intermittently in this region until the present. The Sierra Nevada, in California, one of the westernmost fault-block mountains, has been uplifted about 13,000 feet along a fault on its east side.

In the Pacific coast region local marine basins were sites of rapid sedimentation, whereas adjacent areas were uplifted, folded, and faulted. Deformation was virtually continuous throughout Cenozoic time and is continuing today.

Worldwide climatic fluctuations produced extensive glaciation late in the Cenozoic Era. A continental ice sheet spread outward from centers in the Hudson Bay and Rocky Mountain regions of Canada into the northern part of the United States in four episodes, separated by stages when much of the ice melted and ice sheets retreated to the north. At its maximum extent, continental ice advanced as far south as southern Illinois and into northern Pennsylvania; ice reached an irregular line across central Montana, northern Idaho, and central Washington. Glaciers occupied valleys in higher parts of the Rocky Mountains as far south as New Mexico; the Cascade Mountains and Sierra Nevada were also partly ice covered.

Melting of ice sheets produced large lakes in basins and at the margins of the ice. After final retreat of the ice the supply of water to these lakes was reduced and the lakes dwindled in size. The Great Lakes and Great Salt Lake are remnants of much larger lakes that existed in late Pleistocene time. With the last retreat of the ice, drainage was reestablished in the northern part of the country and the physical geography of the United States became essentially as we know it today.



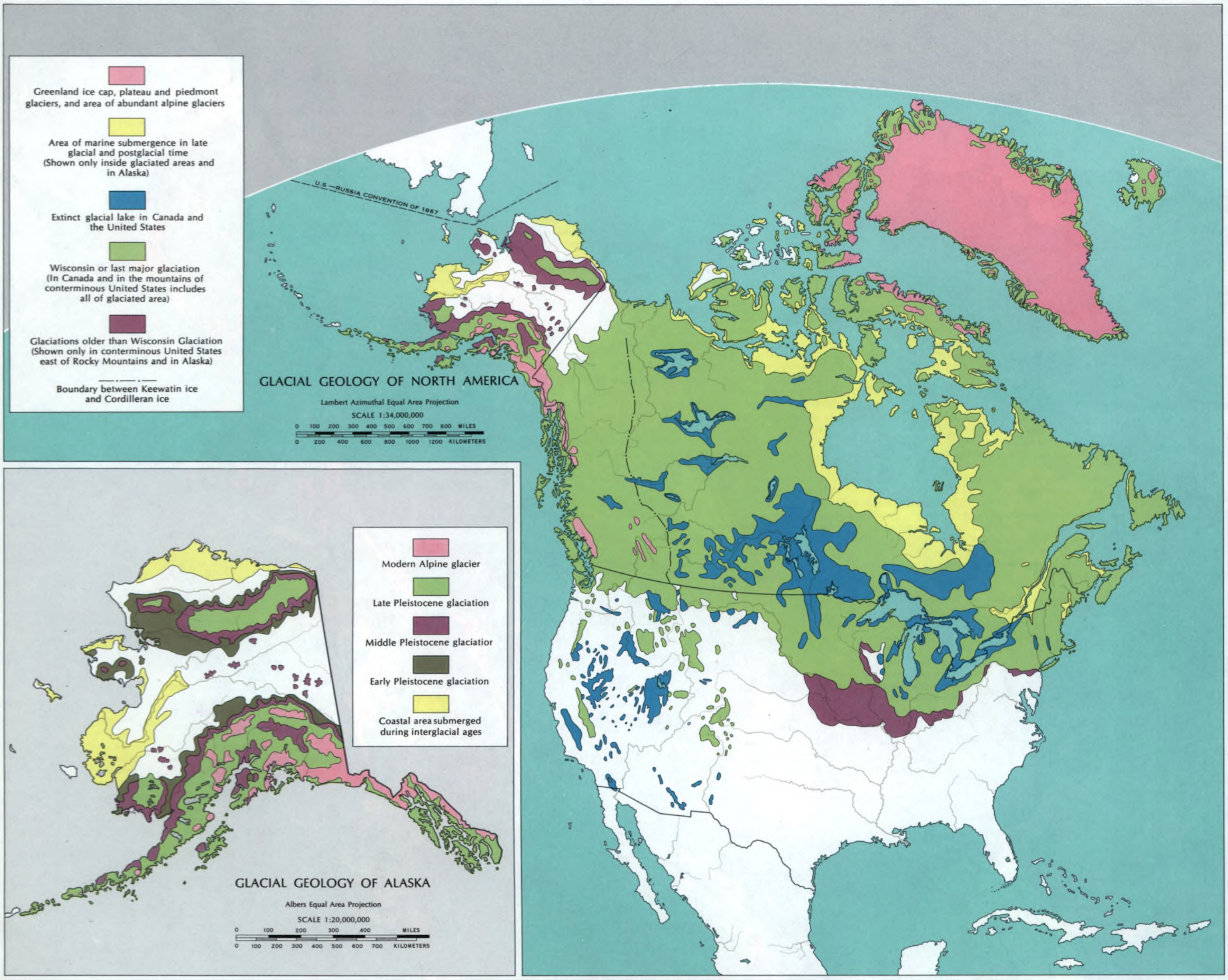
GEOLOGY

Douglas M. Kinney
U.S. Geological Survey, 1966

Albers Equal Area Projection

SCALE 1:7,500,000

For greater detail see U.S. Geol. Survey: *Geologic map of the United States*, Washington, 1932, 1:2,500,000; *Geologic map of Alaska*, 1954, 1:2,500,000; and *Geologic map of North America*, 1965, 1:5,000,000



GLACIAL GEOLOGY OF NORTH AMERICA

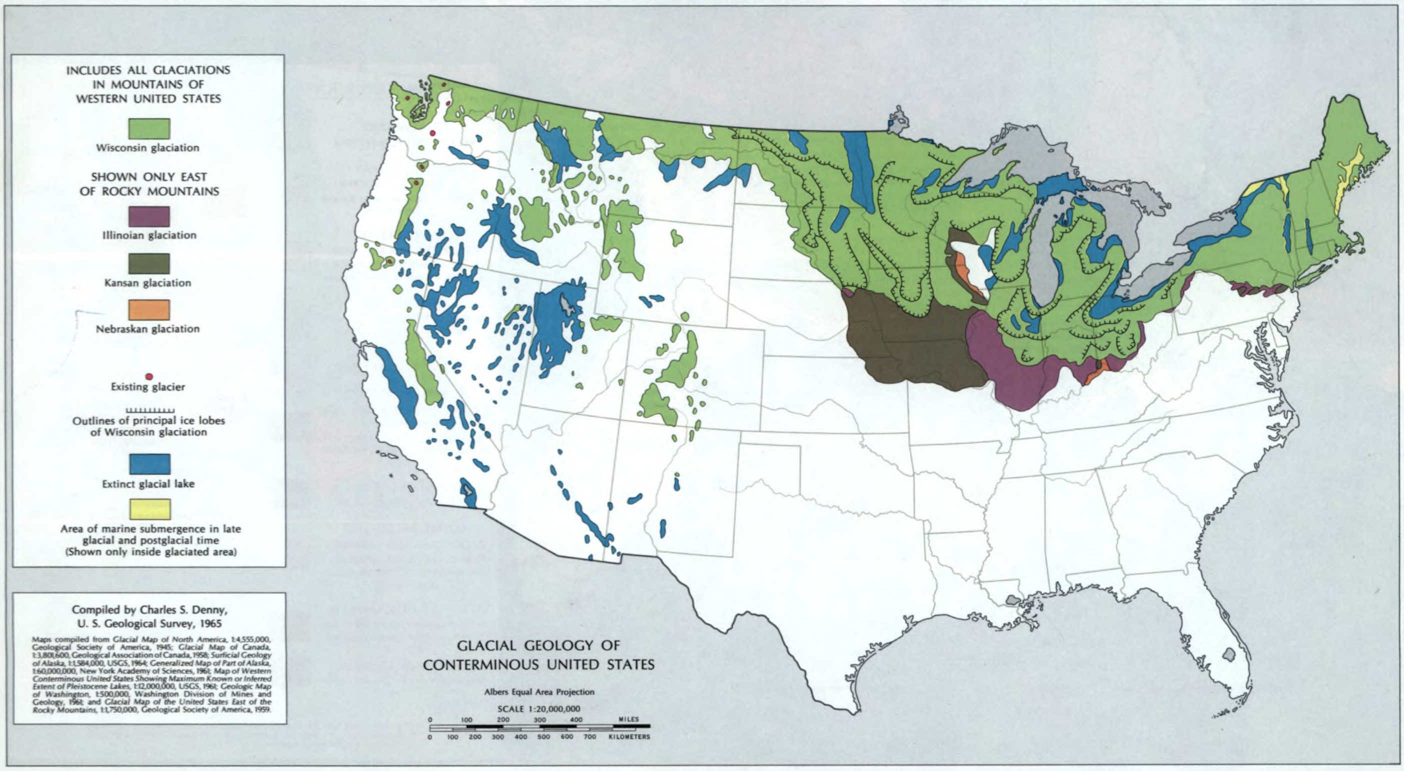
Lambert Azimuthal Equal Area Projection

SCALE 1:34,000,000

GLACIAL GEOLOGY OF ALASKA

Albers Equal Area Projection

SCALE 1:20,000,000



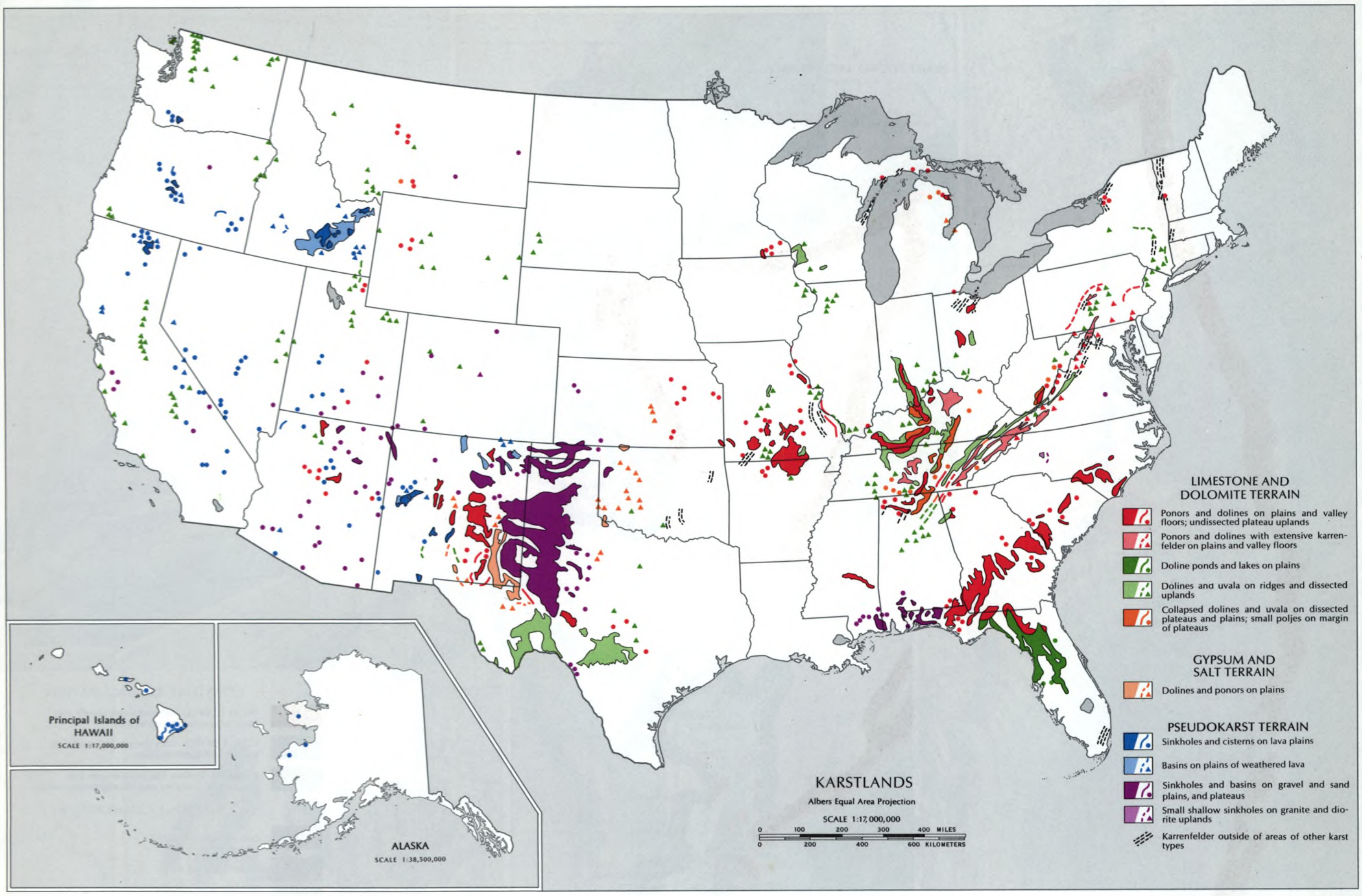
GLACIAL GEOLOGY OF CONTERMINOUS UNITED STATES

Albers Equal Area Projection

SCALE 1:20,000,000

Compiled by Charles S. Denny,
U. S. Geological Survey, 1965

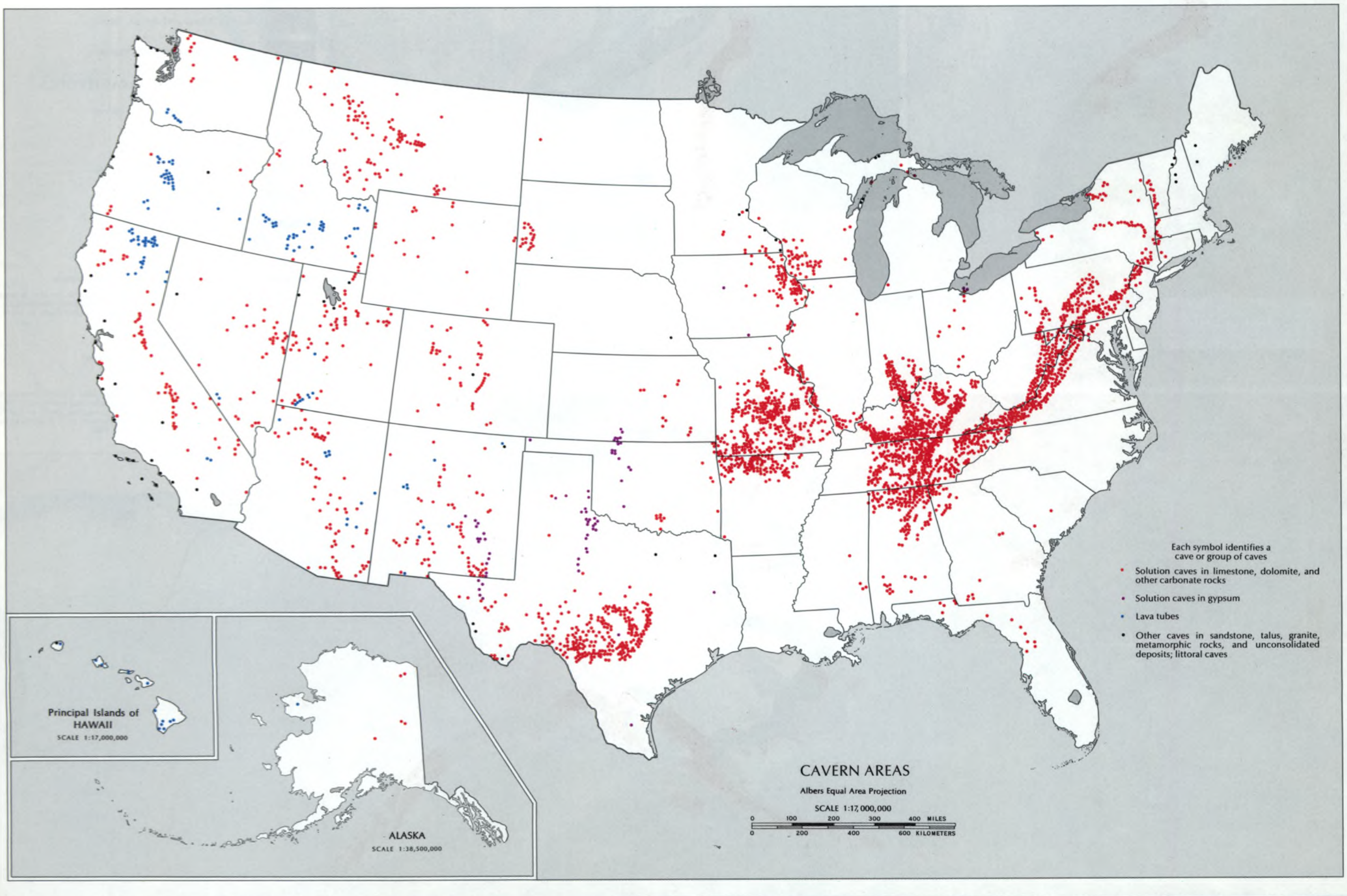
Maps compiled from *Glacial Map of North America*, 1:4,555,000, Geological Society of America, 1945; *Glacial Map of Canada*, 1:3,801,600, Geological Association of Canada, 1958; *Surficial Geology of Alaska*, 1:1,584,000, USGS, 1964; *Generalized Map of Part of Alaska*, 1:60,000,000, New York Academy of Sciences, 1961; *Map of Western Conterminous United States Showing Maximum Known or Inferred Extent of Pleistocene Lakes*, 1:12,000,000, USGS, 1961; *Geologic Map of Washington*, 1:500,000, Washington Division of Mines and Geology, 1961; and *Glacial Map of the United States East of the Rocky Mountains*, 1:1,750,000, Geological Society of America, 1959.



KARSTLANDS

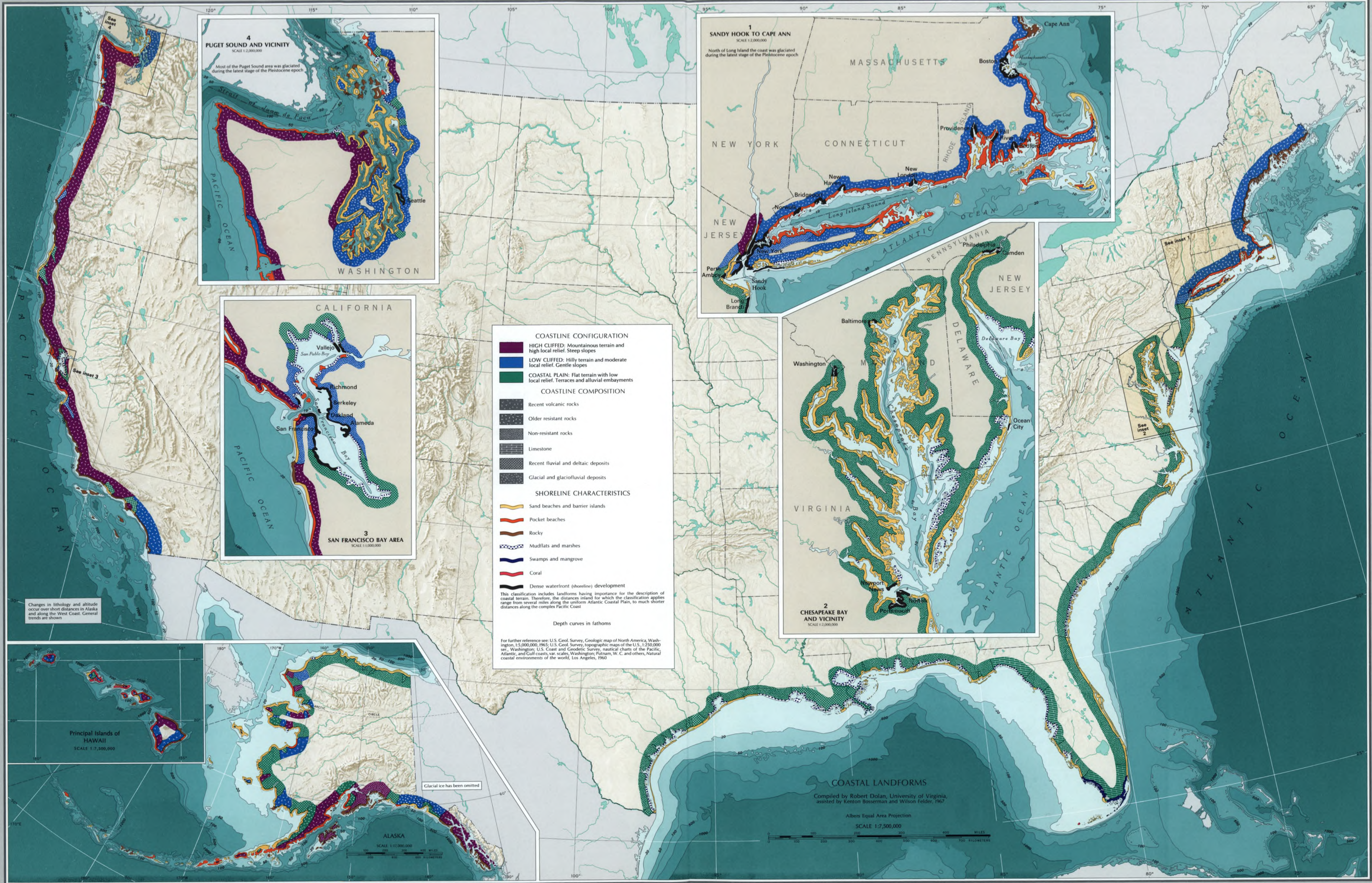
Albers Equal Area Projection

Compiled by William E. Davies with contributions
from William R. Halliday, U.S. Geological Survey, 1968



CAVERN AREAS

Albers Equal Area Projection



Changes in lithology and altitude occur over short distances in Alaska and along the West Coast. General trends are shown

COASTLINE CONFIGURATION

- HIGH CLIFFED: Mountainous terrain and high local relief. Steep slopes
- LOW CLIFFED: Hilly terrain and moderate local relief. Gentle slopes
- COASTAL PLAIN: Flat terrain with low local relief. Terraces and alluvial embayments

COASTLINE COMPOSITION

- Recent volcanic rocks
- Older resistant rocks
- Non-resistant rocks
- Limestone
- Recent fluvial and deltaic deposits
- Glacial and glaciofluvial deposits

SHORELINE CHARACTERISTICS

- Sand beaches and barrier islands
- Pocket beaches
- Rocky
- Mudflats and marshes
- Swamps and mangrove
- Coral
- Dense waterfront (shoreline) development

This classification includes landforms having importance for the description of coastal terrain. Therefore, the distances inland for which the classification applies range from several miles along the uniform Atlantic Coastal Plain, to much shorter distances along the complex Pacific Coast

Depth curves in fathoms

For further reference see: U.S. Geol. Survey, *Geologic map of North America*, Washington, 1:5,000,000, 1965; U.S. Geol. Survey, topographic maps of the U.S., 1:250,000 ser., Washington; U.S. Coast and Geodetic Survey, nautical charts of the Pacific, Atlantic, and Gulf coasts, var. scales, Washington; Putnam, W. C. and others, *Natural coastal environments of the world*, Los Angeles, 1960

COASTAL LANDFORMS

Compiled by Robert Dolan, University of Virginia,
assisted by Kenton Bosserman and Wilson Felder, 1967

Albers Equal Area Projection

SCALE 1:7,500,000

OCEANOGRAPHIC SURVEYS AND RESEARCH

The sea blankets more than 71 percent of the earth's surface, but less than 5 percent of this vast domain has been adequately charted for modern needs. About 9 percent of the ocean floor (mostly on the continental shelves) has been partially explored, but beyond the continental shelves, the bottom topography has been reconnoitered only briefly, and only a smattering of knowledge is available concerning the composition of the ocean floor.

Surveys are conducted to prepare precise charts of shorelines, shoals, and the configuration of the ocean bottom; the major current, temperature, and salinity patterns; as well as the composition and structure of the ocean floor. These charts often provide basic information that leads to new research. Oceanographic surveying and research have been given new impetus by the Marine Resources and Engineering Development Act of 1966, which provides for improved planning and coordination and significant expansion of the Nation's oceanographic program.

The presentations on these pages were compiled or adapted from charts, maps, and other data furnished by the U.S. Naval Oceanographic Office during 1967–68. Selected bathymetric curves are shown on the "Coastal Landforms" map, pages 78–79. The ice limits in some of these maps represent areas in which the average ice concentration equals or exceeds 5/10 (50% coverage by ice). The data are based on observations recorded over many decades; however, these boundaries may vary widely from day to day and year to year under the influence of changing climatic and oceanographic conditions. Most of the maps show no information in the Arctic Basin where, except for a few special expeditions, extensive ice coverage prevents gathering of data. Persons who desire more detailed knowledge of these subjects should contact the National Oceanographic Data Center, the U.S. Naval Oceanographic Office, or the U.S. Coast and Geodetic Survey.

BOTTOM SEDIMENTS

Seismic refraction and reflection methods have enabled geophysicists to make reliable estimates of the average thickness of unconsolidated sediments on the ocean floor. Sediments in the Atlantic Ocean are about 750 meters thick, while sediments in the Pacific average about 300 meters in thickness. Most sediments (sand, silt, and clay) come from the land; therefore, the thickest deposits are near land.

The average sediment deposition rate in the Atlantic Ocean is greater than that in the Pacific because the Pacific Ocean is larger, has fewer major rivers that contribute sediments, and contains large regions that are farther from the land. Red clay accumulates on deep ocean bottoms at a rate of half a centimeter or less every 1,000 years. Calcareous oozes may accumulate much faster. Deposits near land are so variable that no meaningful figures can be given. Very long cores (about 60 feet) from the ocean floor contain sediments deposited over a span of nearly 2 million years.

The primary interest in sediments is usually confined to the upper 5 or 6 inches. The character of marine sediments and their relationship to the topography of the ocean floor have long been of particular significance to commercial fishermen because of the close interrelationship between the characteristics of the sediments and the living resources on and above the ocean floor.

CURRENTS

Surface current speeds are frequently influenced by the augmenting or opposing effect of winds. Considerable variation from the directions and speeds of the prevailing currents shown on these maps can be expected, especially in areas where the currents are weak. Near the coasts, tidal currents and discharge from rivers may cause daily or variable fluctuations in current speeds and directions. Summer current speeds are for the months of July, August, and September. Winter current speeds are for the months of January, February, and March.

TIDES

Tides are caused by gravitational forces exerted by the moon, sun, and various other celestial bodies. The moon is nearest and has the greatest effect. The sun, despite its greater mass, exerts only a secondary effect, which is less than half that of the moon.

Because tides are not considered to be of practical importance in open ocean areas, little work on their measurement has been done; on the map the lines in the open ocean are only interpretations by analysts and are primarily of academic interest. The only places where corange lines in the open ocean have practical significance are near islands, banks, and other shallow areas.

On the map arrows are used to indicate the direction of tide progression. Cotidal lines, lines connecting points where high water occurs simultaneously, are omitted for the purpose of simplifying the map. However, that information and information on the various stages of tides are available from the tide tables published by the U.S. Coast and Geodetic Survey.

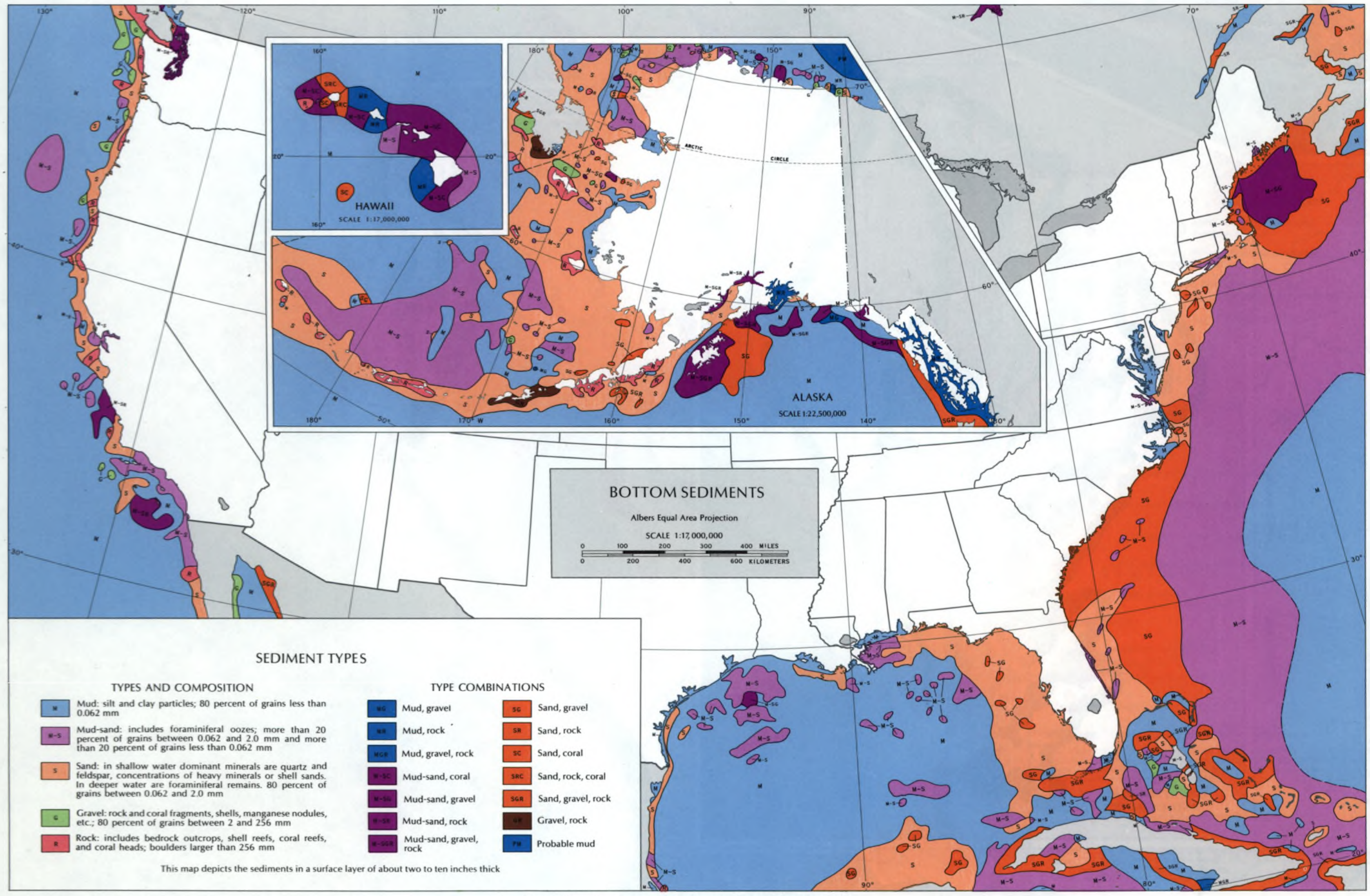
The type of tide refers to the characteristic form of the rise and fall of the tide in one tidal day, which is a lunar day of 24 hours 50 minutes. Diurnal tides consist of one high water and one low water each tidal day during most of each month. In regions of semidiurnal tides two nearly equal high waters and two nearly equal low waters occur each tidal day. Where the tide is mixed, two markedly unequal high waters and/or two markedly unequal low waters occur each tidal day during most of each month.

The different types of tides are produced by variations in the magnitude and period of attracting forces that arise primarily from the changing phase, parallax, and declination of the moon and, to a lesser extent, of the sun. Bottom topography, meteorological effects, and wave interference also influence the form of the tides.

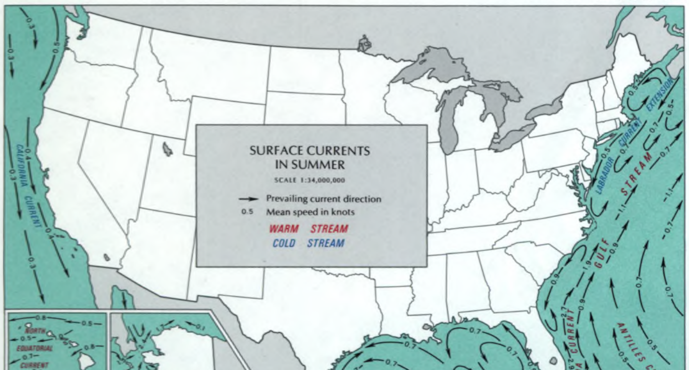
SALINITY

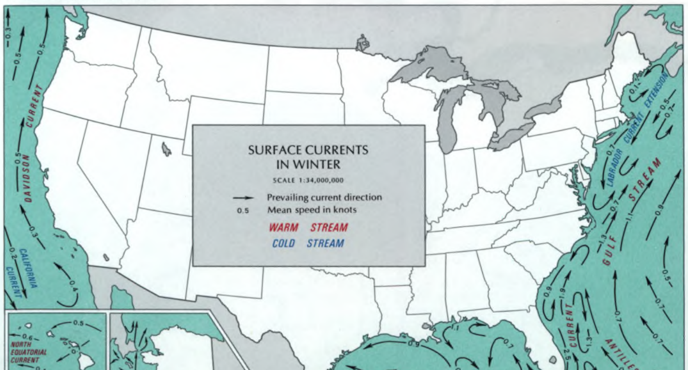
The saltiness of the oceans is undoubtedly increasing, but the process, which has been going on for hundreds of millions of years, is slow. For many years it was generally assumed that the ocean began as fresh water and that the age of the earth could be determined by comparing the annual increase of salt from rivers with the total salt in the ocean. However, radioactive dating of rocks indicates that the earth is much older than the age derived by such methods. It is now generally believed that the primeval seas were initially salty; their salts were dissolved from the rocks underlying the ocean basins. The wearing away of continental rocks by frost and erosion has added to the salts of the sea, but the dissolved materials in rivers still contain higher percentages of carbonate salts than does sea water, where chlorides predominate.

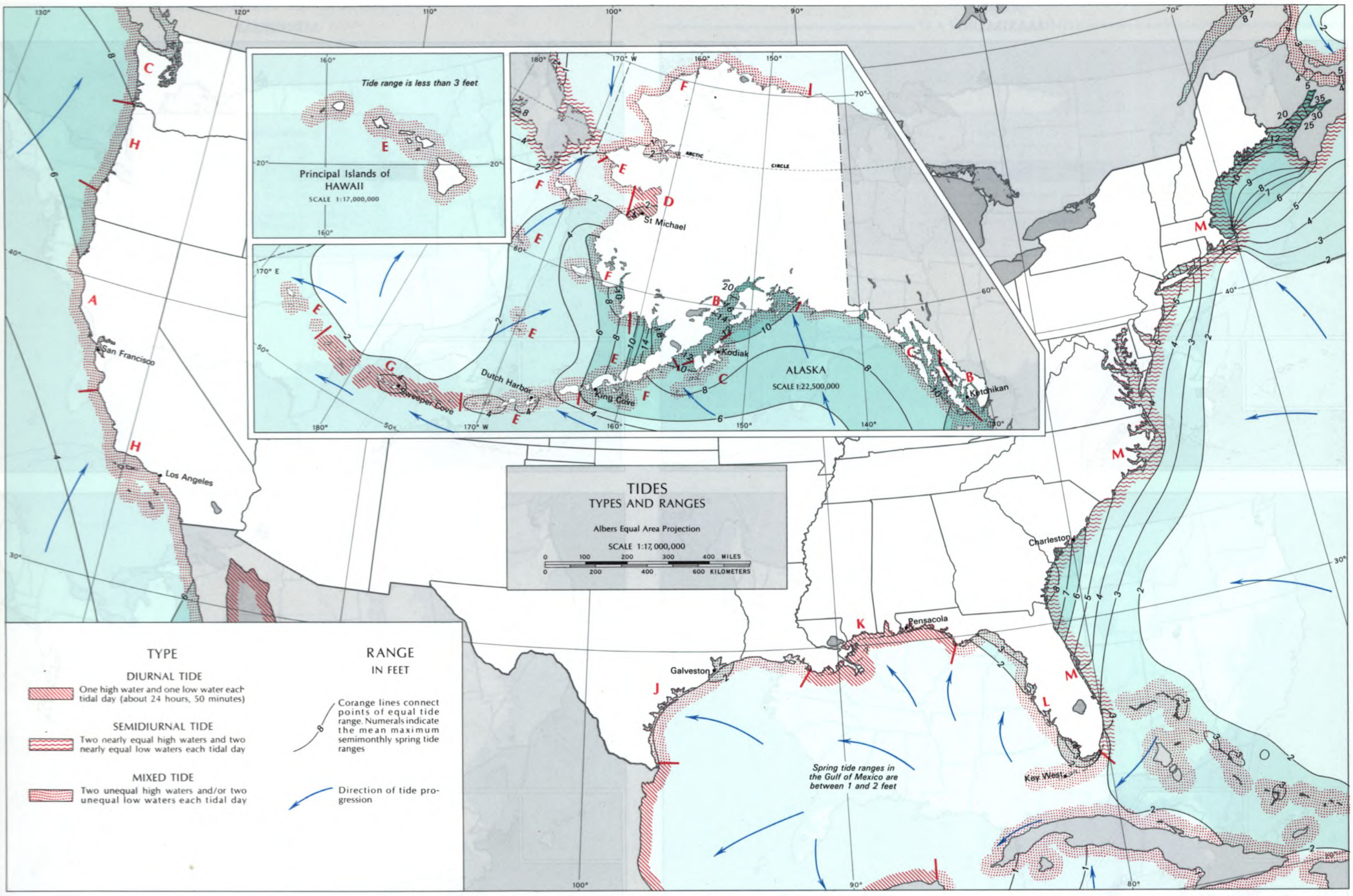
Salinity in the open ocean normally ranges from 34 to 36 parts per thousand. The saltiest ocean is the Atlantic, which contains 37 parts per thousand in the northern subtropical region. The highest salinities are found in the Red Sea and Persian Gulf, where values often exceed 40 parts per thousand because of the excess of evaporation over precipitation in these regions. Very low salinities occur where large quantities of fresh water are supplied by rivers or melting ice; thus, arctic and antarctic waters are of low salinity.



Compiled from information provided by U.S. Naval Oceanographic Office, 1968

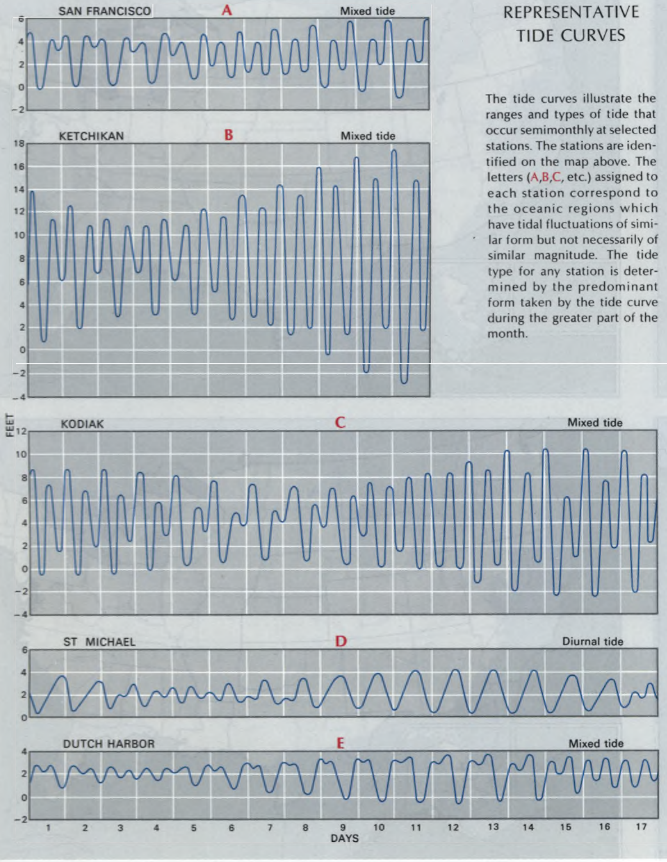




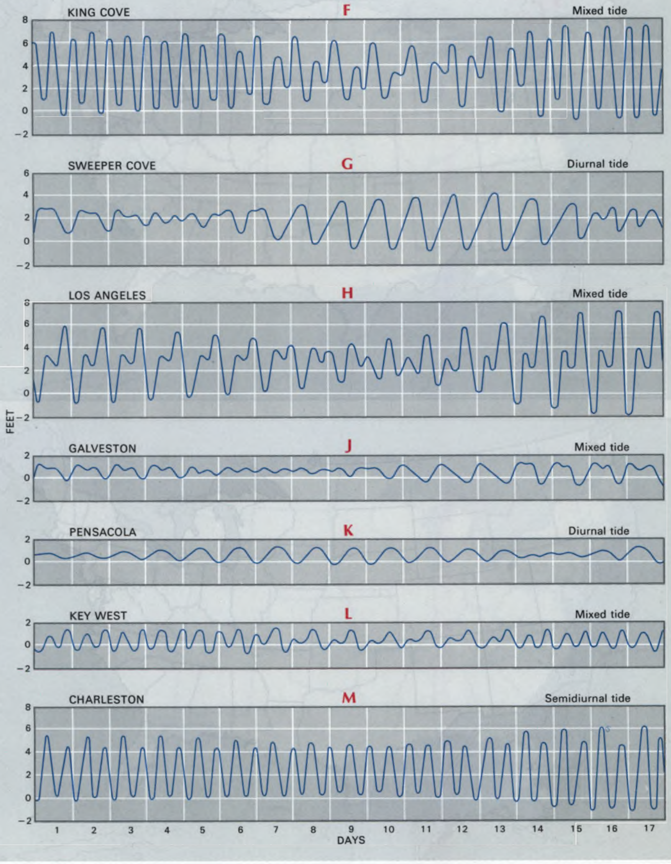


Compiled from information provided by
U.S. Naval Oceanographic Office, 1968

REPRESENTATIVE TIDE CURVES

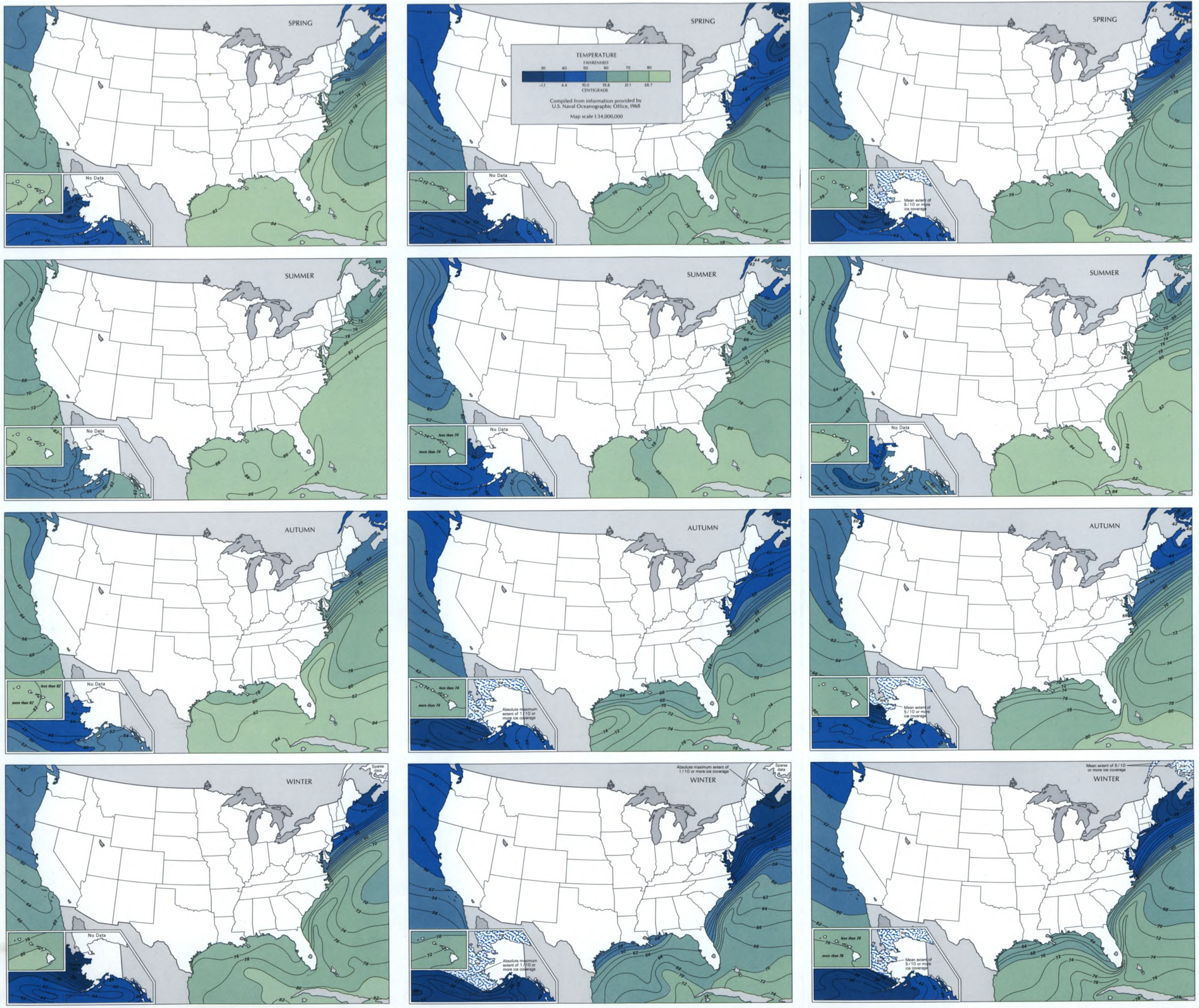


The tide curves illustrate the ranges and types of tide that occur semimonthly at selected stations. The stations are identified on the map above. The letters (A,B,C, etc.) assigned to each station correspond to the oceanic regions which have tidal fluctuations of similar form but not necessarily of similar magnitude. The tide type for any station is determined by the predominant form taken by the tide curve during the greater part of the month.



SEA SURFACE TEMPERATURE

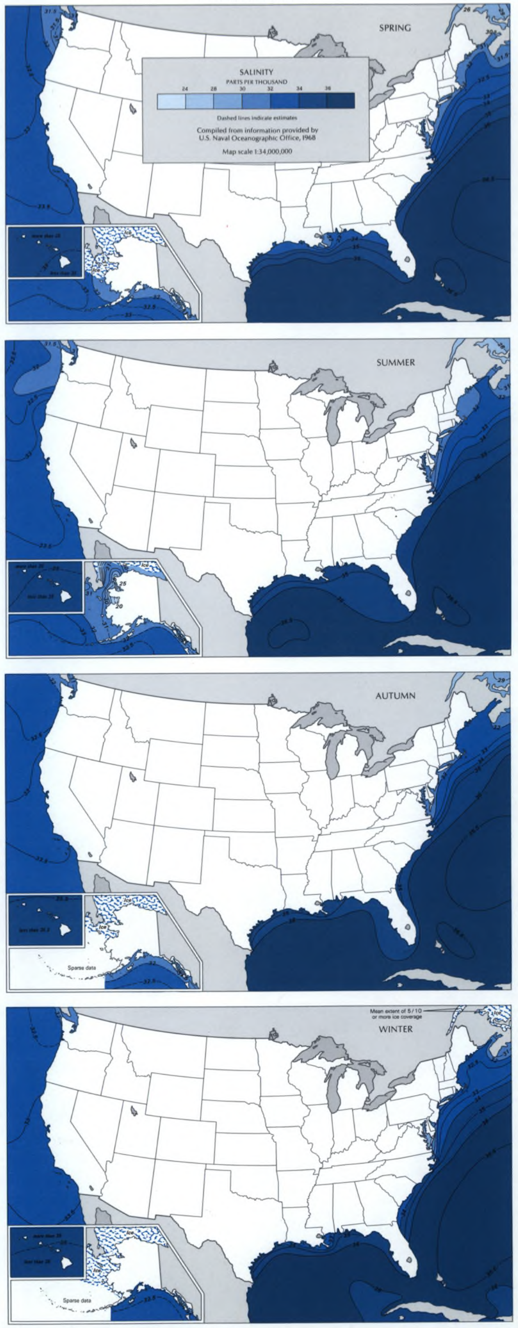
MAXIMUM MINIMUM MEAN



Compiled from information provided by U.S. Naval Oceanographic Office, 1968

Map scale 1:34,000,000

MEAN SEA SURFACE SALINITY



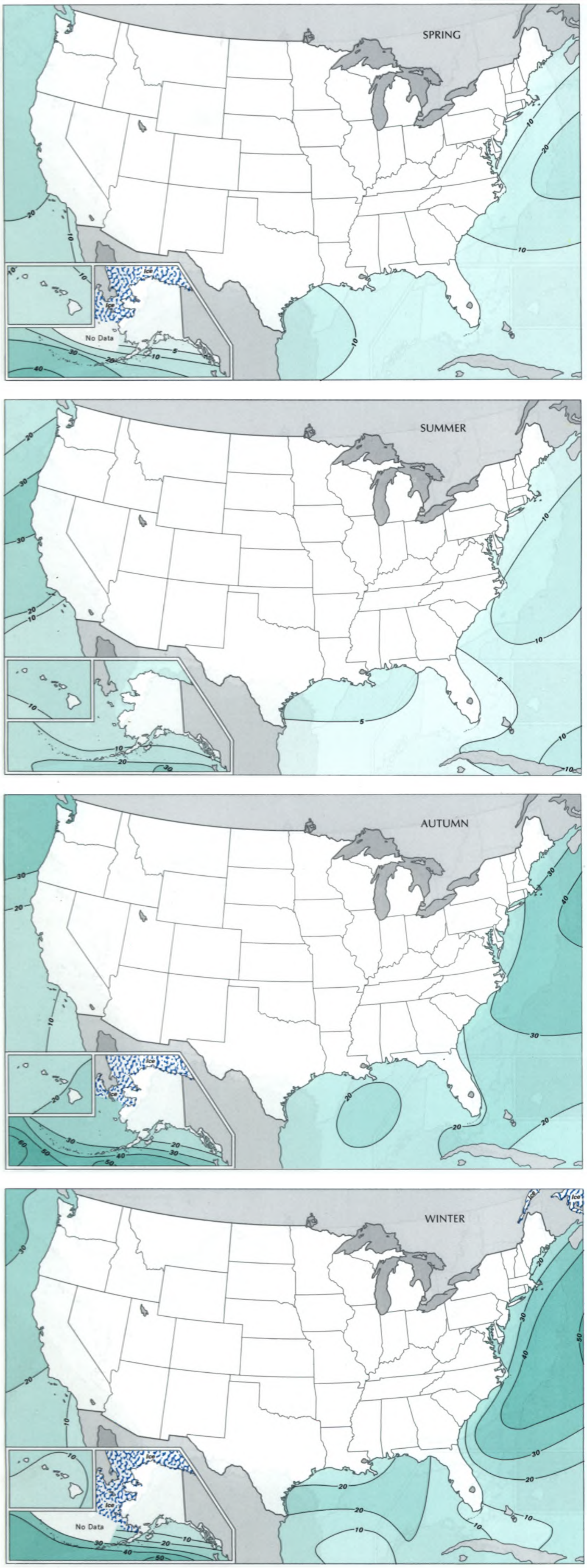
Compiled from information provided by U.S. Naval Oceanographic Office, 1968

Map scale 1:34,000,000

Map scale 1:34,000,000

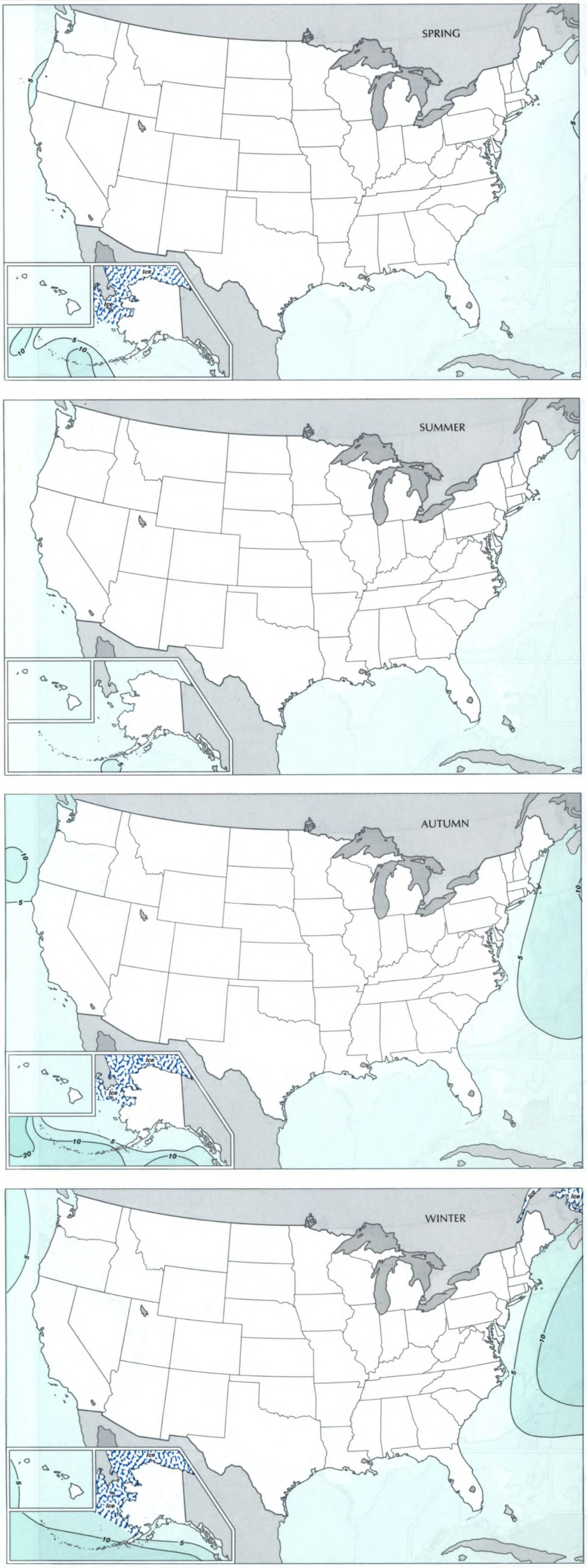
PERCENT
5 10 20 30 40 50

PERCENT FREQUENCY WAVES 5 FEET AND OVER



PERCENT FREQUENCY WAVES 12 FEET AND OVER

Compiled from information provided by
U.S. Naval Oceanographic Office, 1968



SOILS IN THE UNITED STATES

The following arrangement is alphabetical by order and by taxa in a category. General soil definitions are given for the three categories used—namely, order, suborder, and great group. Present dominant land use is given for the suborder. Names of orders, the highest category, end in "sol," for example, "Alfisol." Names of suborders have two syllables, the final syllable being taken from the order name; for example "Aqualf" is a suborder of "Alfisol." Names of great groups have one or more syllables as a prefix to a suborder name; for example, "Albaqualf" is one of the great groups of the suborder "Aqualf." Names that correspond approximately to those used in the 1938 classification system and additional names commonly used since about 1950 are also given.

The map units are mostly associations of phases of great groups. Only the principal kinds of soil are named for each map unit. The most extensive is listed first and the least extensive, last. Other kinds of soil are present in each map unit but are not extensive enough to be listed as inclusions.

Classes used for the approximate slope of each map unit are:

Gently sloping-------Slope mainly less than 10 percent.

Moderately sloping----Slope mainly between 10 and 25 percent.

Steep-----------Slope mainly steeper than 25 percent.

For complete definitions of the taxa see:

Soil Survey Staff, 1960, Soil classification, a comprehensive system, 7th approximation: U.S. Dept. Agriculture Soil Conserv. Service, 265 p.

------1967, Supplement to soil classification system (7th approximation): U.S. Dept. Agriculture Soil Conserv. Service, 207 p.

For explanation of the 1938 system and revisions see:

Thorp, James, and Smith, Guy D., 1949, Higher categories of soil classification—Order, suborder, and great soil groups: Soil Sci., v. 67, no. 2, p. 117–126.

U.S. Dept. of Agriculture, 1938, Soils and Men, yearbook of agriculture 1938: U.S. Dept. Agriculture, 1232 p.

Grumusols are defined in:

Oakes, Harvey, and Thorp, James, 1951, Dark-clay soils of warm regions variously called Rendzina, black cotton soils, regur, and tirs: Soil Sci. Soc. America Proc., v. 15, p. 347–354.

Sols Bruns Acides are defined in:

Tavernier, R., and Smith, Guy D., 1957, The concept of braunerde (Brown forest soil) in Europe and the United States, *in* Advances in agronomy, v. 9: New York, Academic Press Inc., p. 217–289.

Calcisols are defined in:

Harper, W. G., 1957, Morphology and genesis of calcisols: Soil Sci. Soc. America Proc., v. 21, no. 4, p. 420–424.

Hydrol Humic and Humic Ferruginous Latosols are defined in:

Cline, Marlin G., 1955, Relationships among soils of Hawaii: U.S. Dept. Agriculture Soil Conserv. Service Soil Survey, Territory of Hawaii, ser. 1939, no. 25, p. 67–88.

Calcium Carbonate Solonchaks are defined in:

McClelland, J. E., Mogen, C. A., Johnson, W. M., Schroer, F. W., and Allen, J. S., 1959, Chernozems and associated soils of eastern North Dakota—Some properties and topographic relationships: Soil Sci. Soc. America Proc., v. 23, no. 1, p. 51–56.

ALFISOLS

Soils that are medium to high in bases (base saturation at pH 8.2) and have gray to brown surface horizon and subsurface horizons of clay accumulation; usually moist but during the warm season of the year some are dry part of the time.

AQUALFS—Seasonally wet Alfisols that have mottles, iron-manganese concretions, or gray colors; used for general crops where drained and for pasture and woodland where undrained.

Albaqualfs (formerly Planosols).—Aqualfs that have a bleached (white) upper horizon and changes abruptly in texture into an underlying horizon of clay accumulation.

A1–1—Albaqualfs plus Argialbolls and Argiudolls, gently sloping.

A1–2—Albaqualfs plus Hapludalfs, gently sloping.

A1–3—Albaqualfs plus Natraqualfs and Fragiudalfs, gently sloping.

A1–4—Albaqualfs plus Ochraqualfs, gently sloping.

Fragiaqualfs (formerly Low-Humic Gley soils with fragipan).—Aqualfs that have a dense brittle but not indurated horizon (fragipan).[1]

Glossaqualfs (formerly Planosols).—Aqualfs that have tongues of an upper bleached (white) horizon in an underlying horizon of clay accumulation.[1]

Natraqualfs (formerly Solonetz soils).—Aqualfs that have a subsurface horizon of clay accumulation with alkali (sodium).[1]

Ochraqualfs (formerly Low-Humic Gley soils).—Aqualfs that change gradually in texture into the underlying horizon.

A2–1—Ochraqualfs plus Haplaquepts and Hapludalfs, gently sloping.

A2–2—Ochraqualfs plus Hapludalfs, gently sloping.

A2–3—Ochraqualfs plus Psammaquents, gently sloping.

BORALFS.—Alfisols of cool to cold regions; used for woodland, pasture, and some small grain.

Cryoboralfs (formerly Gray Wooded).—Boralfs of cold regions.

A3–1—Cryoboralfs plus Cryorthods, steep.

A3–2—Cryoboralfs plus Cryorthods, Cryoborolls, Cryaquolls, and Rock land, steep.

Eutroboralfs (formerly Gray Wooded soils).—Boralfs that have a subsurface horizon high in bases and a horizon that is dry for short periods in most years.

A4–1—Eutroboralfs, gently or moderately sloping.

A4–2—Eutroboralfs plus Fragiboralfs, gently or moderately sloping.

A4–3—Eutroboralfs plus Haplaquepts, gently or moderately sloping.

A4–4—Eutroboralfs plus Haplustolls, Ustorthents, and Rock land, gently sloping to steep.

A4–5—Eutroboralfs plus Histosols (plant residues not decomposed), gently sloping.

Fragiboralfs (formerly Gray Wooded soils with fragipan).—Boralfs that have a horizon of clay accumulation within 2 feet of the soil surface and a dense brittle but not indurated horizon (fragipan).[1]

Glossoboralfs (formerly Gray Wooded soils).—Boralfs that are always moist or are low in bases. They usually have tongues of an upper bleached (white) horizon in an underlying subsurface horizon of clay accumulation.

A5–1—Glossoboralfs plus Eutroboralfs, gently sloping.

UDALFS.—Alfisols that are in temperate to tropical regions. Soils usually moist but during the warm season of the year may be intermittently dry in some horizons for short periods; used for row crops, small grain, and pasture.

Fragiudalfs (formerly Gray-Brown Podzolic soils with fragipan).—Udalfs that have a dense brittle but not indurated horizon (fragipan) usually below a horizon in which clay has accumulated.

A6–1—Fragiudalfs, gently sloping.

A6–2—Fragiudalfs plus Fragiaqualfs and Haplaquepts, gently sloping.

A6–3—Fragiudalfs plus Fragiaqualfs and Hapludolls, gently sloping to steep.

A6–4—Fragiudalfs plus Fragiochrepts, gently sloping.

A6–5—Fragiudalfs plus Glossaqualfs, gently sloping.

A6–6—Fragiudalfs plus Hapludalfs, gently sloping.

A6–7—Fragiudalfs plus Hapludalfs, both moderately sloping, and Rock land, steep.

A6–8—Fragiudalfs plus Natraqualfs, gently sloping.

A6–9—Fragiudalfs plus Ochraqualfs and Fragiaqualfs, gently sloping.

Hapludalfs (formerly Gray-Brown Podzolic soils without fragipan).—Udalfs that have a subsurface horizon of clay accumulation that is relatively thin or is brownish.

A7–1—Hapludalfs, gently sloping.

A7–2—Hapludalfs, moderately sloping.

A7–3—Hapludalfs plus Albaqualfs, Humaquepts, and Ochraqualfs, gently sloping.

A7–4—Hapludalfs plus Argiaquolls, gently sloping.

A7–5—Hapludalfs plus Argiudolls, gently sloping.

A7–6—Hapludalfs plus Argiudolls, gently or moderately sloping.

A7–7—Hapludalfs plus Cryandepts, moderately sloping or steep.

A7–8—Hapludalfs plus Fragiudalfs, gently sloping.

A7–9—Hapludalfs plus Fragiudalfs, moderately sloping.

A7–10—Hapludalfs plus Haplaquolls, gently sloping.

A7–11—Hapludalfs plus Haplaquolls and Argiudolls, gently sloping.

A7–12—Hapludalfs plus Haplaquolls and Glossoboralfs, gently sloping.

A7–13—Hapludalfs plus Haplaquolls and Udipsamments, all gently sloping.

A7–14—Hapludalfs plus Hapludults, moderately sloping.

A7–15—Hapludalfs plus Ochraqualfs, gently sloping.

A7–16—Hapludalfs plus Paleudalfs, Hapludults, and Hapludolls, moderately sloping.

A7–17—Hapludalfs, moderately sloping, plus Rock land, steep.

Paleudalfs (formerly Red-Yellow Podzolic and Gray-Brown Podzolic soils).—Udalfs that have a thick reddish horizon of clay accumulation.

A8–1—Paleudalfs plus Hapludalfs and Dystrochrepts, gently sloping to steep.

A8–2—Paleudalfs plus Hapludults and Rock land, gently or moderately sloping.

USTALFS.—Alfisols that are in temperate to tropical regions. Soils mostly reddish brown; during the warm season of the year, they are intermittently dry for long periods; used for range, small grain and irrigated crops.

Haplustalfs (formerly Reddish Chestnut and Reddish Brown soils).—Ustalfs that have a subsurface horizon of clay accumulation that is relatively thin or is brownish.

A9–1—Haplustalfs plus Argiustolls, gently or moderately sloping.

A9–2—Haplustalfs plus Calciustolls and Argiustolls, gently sloping.

A9–3—Haplustalfs plus Haplustolls and Calciustolls (shallow), gently sloping.

A9–4—Haplustalfs plus Paleustalfs, gently sloping.

A9–5—Haplustalfs plus Ustipsamments, gently sloping.

Paleustalfs (formerly Reddish Chestnut and Reddish Brown soils).—Ustalfs that have an indurated (petrocalcic) horizon cemented by carbonates or a horizon having one or both of the following: A thick reddish clay accumulation or a distribution that is clayey in the upper part and abruptly changes in texture into an overlying horizon.

A10–1—Paleustalfs plus Argiustolls, gently sloping.

A10–2—Paleustalfs plus Haplustalfs, gently sloping.

A10–3—Paleustalfs plus Ustorthents (shallow), gently sloping.

Rhodustalfs (formerly Reddish Prairie soils).—Ustalfs that have a red subsurface horizon of clay accumulation that is relatively thin.[1]

XERALFS.—Alfisols that are in climates with rainy winters but dry summers; during the warm season of the year these soils are continually dry for a long period; used for range, small grain and irrigated crops.

Durixeralfs (formerly Noncalcic Brown soils with a hardpan).—Xeralfs that have a hardpan (duripan) that is cemented with silica.

A11–1—Durixeralfs plus Palexeralfs, gently sloping.

Haploxeralfs (formerly Noncalcic Brown soils).—Xeralfs that have a subsurface horizon of clay accumulation that is relatively thin or is brownish in color.

A12–1—Haploxeralfs plus Haplaquolls, Palexeralfs, and Xerorthents, gently sloping.

A12–2—Haploxeralfs plus Palexeralfs and Xerorthents (shallow), moderately sloping to steep.

A12–3—Haploxeralfs plus Xerorthents (shallow) and Chromoxererts, moderately sloping or steep.

Palexeralfs (formerly Noncalcic Brown soils).—Xeralfs that have an indurated (petrocalcic) horizon cemented by carbonates or a horizon having one or both of the following: A thick reddish clay accumulation or a distribution that is clayey in the upper part and abruptly changes in texture into an overlying horizon.

A13–1—Palexeralfs plus Durixeralfs, gently sloping.

A13–2—Palexeralfs plus Xerorthents and Haplaquolls, gently sloping.

ARIDISOLS

Soils that have pedogenic horizons and are low in organic matter and are never moist as long as 3 consecutive months.

ARGIDS.—Aridisols that have a horizon in which clay has accumulated with or without alkali (sodium); used for mostly range and some irrigated crops.

Durargids (formerly Desert, Red Desert, Sierozem and some Brown soils, all with hardpan).—Argids that have a hardpan (duripan) that is cemented with silica.

D1–1—Durargids plus Durorthids and Calciorthids, all gently sloping; also Haploxerolls and Argixerolls, steep.

Haplargids (formerly Sierozem, Desert, Red Desert and some Brown soils).—Argids that have a loamy horizon of clay accumulation with or without alkali (sodium).

D2–1—Haplargids plus Argiustolls, Ustorthents, and Calciustolls, gently sloping.

D2–2—Haplargids plus Argixerolls, Durargids, and Haploxerolls, gently sloping to steep.

D2–3—Haplargids plus Calciorthids, gently sloping.

D2–4—Haplargids plus Calciorthids, Natrargids, and Camborthids, gently sloping.

D2–5—Haplargids plus Calciorthids, and Natrargids, all gently sloping; also Torriorthents (shallow) and Camborthids, both steep.

D2–6—Haplargids plus Durargids and Torriorthents, gently sloping.

D2–7—Haplargids plus Paleorthids, Torriorthents, and Rock land, gently or moderately sloping.

D2–8—Haplargids plus Paleorthids, Torripsamments, Paleargids, and Calciorthids, gently sloping to steep.

D2–9—Haplargids plus Torrifluvents, Calciorthids, and Paleorthids, gently sloping to steep.

D2–10—Haplargids plus Torriorthents and Argiustolls, gently or moderately sloping.

D2–11—Haplargids plus Torriorthents, Argiustolls, and Torripsamments, gently sloping.

D2–12—Haplargids plus Torriorthents (shallow) and Calciorthids, gently sloping to steep.

D2–13—Haplargids plus Torriorthents, Calciorthids, and Camborthids, gently sloping to steep.

D2–14—Haplargids plus Torriorthents, Calciorthids, and Paleorthids, gently sloping to steep.

D2–15—Haplargids plus Torriorthents (shallow) and Calciustolls, gently sloping to steep.

D2–16—Haplargids plus Torriorthents (shallow) and Paleorthids, moderately sloping.

D2–17—Haplargids and other Aridisols plus Torriorthents and Rock land, gently or moderately sloping.

D2–18—Haplargids plus Torriorthents and Salorthids, all gently sloping; also Torriorthents (shallow), steep.

D2–19—Haplargids plus Torriorthents, Torriorthents (shallow) and Paleargids, gently or moderately sloping.

D2–20—Haplargids plus Torripsamments, Natrargids, and Salorthids, gently sloping.

Nadurargids (formerly Solonetz soils with hardpan).—Argids that have a subsurface horizon of clay accumulation with alkali (sodium) overlying a hardpan (duripan) that is cemented with silica.[1]

Natrargids (formerly Solonetz soils).—Argids that have a horizon of clay and alkali (sodium) accumulation.

D3–1—Natrargids, gently sloping.

D3–2—Natrargids plus Haplargids and Haplaquolls, gently sloping.

D3–3—Natrargids plus Nadurargids, Haplaquolls, and Torriorthents, gently sloping.

D3–4—Natrargids plus Salorthids and Torriorthents, gently sloping.

Paleargids (formerly Sierozems, Desert, and Red Desert soils).—Argids that have an indurated (petrocalcic) horizon cemented by carbonates or have a clayey subsurface horizon with or without alkali (sodium) that abruptly changes in texture into an overlying horizon.

D4–1—Paleargids plus Argiustolls, gently or moderately sloping.

ORTHIDS.—Aridisols that have accumulations of calcium carbonate, gypsum, or other salts more soluble than gypsum but have no horizon of accumulation of clay. They may have horizons from which some materials have been removed or altered; used for mostly range and some irrigated crops.

Calciorthids (formerly Calcisols).—Orthids that have a horizon in which large amounts of calcium carbonate or gypsum have accumulated.

D5–1—Calciorthids plus Calciorthids (shallow), Torriorthents, Paleorthids, and Torrifluvents, gently sloping.

D5–2—Calciorthids plus Durorthids, Torriorthents (shallow), and Rock land, gently or moderately sloping.

D5–3—Calciorthids plus Haplargids and Torriorthents, gently sloping.

D5–4—Calciorthids plus Torriorthents (shallow), gently sloping.

D5–5—Calciorthids plus Torriorthents (shallow), Camborthids, and Rock land, gently or moderately sloping.

D5–6—Calciorthids plus Torriorthents, Torripsamments, and Gypsum dune land, gently sloping.

Calciorthids (shallow; formerly Lithosols).—Calciorthids that are shallower than 20 inches to bedrock.[1]

Camborthids (formerly Sierozems, Desert, and Red Desert soils).—Orthids that have horizons from which some materials have been removed or altered but have no accumulation of large amounts of calcium carbonate or gypsum.

D6–1—Camborthids plus Calciorthids, Torriorthents, and Rock land, gently to moderately sloping.

D6–2—Camborthids plus Duraquolls, Durorthids, and Torripsamments, gently sloping.

D6–3—Camborthids (shallow) plus Haploxerolls, both steep; also Durorthids and Haplargids, gently sloping.

D6–4—Camborthids plus Torriorthents and Calciorthids, gently sloping.

D6–5—Camborthids plus Torriorthents and Torripsamments, gently sloping.

D6–6—Camborthids plus Torriorthents, Torripsamments, Calciorthids, and Badlands, gently or moderately sloping.

D6–7—Camborthids plus Xerolls, moderately sloping.

Durorthids (formerly Regosols, Calcisols, or Alluvial soils, all with hardpan).—Orthids that have a hardpan (duripan) that is cemented with silica.[1]

Paleorthids (formerly Calcisols).—Orthids that have a hardpan (petrocalcic horizon) cemented with carbonates.[1]

Salorthids (formerly Solonchaks).—Orthids that have a horizon in which large amounts of salts have accumulated.[1]

ENTISOLS

Soils that have no pedogenic horizons.

AQUENTS.—Entisols that are either permanently wet or are seasonally wet and that have mottles or gray colors; limited use for pasture.

Haplaquents (formerly Low-Humic Gley soils).—Aquents that have textures of loamy very fine sand or finer.[1]

Hydraquents.—Aquents that are permanently wet, have textures of loamy very fine sand or finer, and offer little resistance to applied weight, including grazing livestock.[1]

Psammaquents (formerly Low-Humic Gley soils and some poorly drained Regosols).—Aquents that have textures of loamy fine sand or coarser.

E1–1—Psammaquents plus Haplaquods, gently sloping (includes swamps).

E1–2—Psammaquents plus Sideraquods and Histosols (plant residues not decomposed), gently sloping.

FLUVENTS (formerly Alluvial soils).—Entisols that have organic-matter content that decreases irregularly with depth; formed in loamy or clayey alluvial deposits; used for range or irrigated crops in dry regions and for general farming in humid regions.

Torrifluvents (formerly Alluvial soils).—Fluvents that are never moist as long as 3 consecutive months.

E2–1—Torrifluvents plus Natrargids, Salorthids, and Haplargids, gently or moderately sloping.

E2–2—Torrifluvents plus Torriorthents, Calciorthids, Haplargids, and Salorthids, gently or moderately sloping.

Udifluvents (formerly Alluvial soils).—Fluvents that are usually moist.[1]

Xerofluvents (formerly Alluvial soils).—Fluvents that are in climates with rainy winters and dry summers; during the warm season of the year, these soils are continually dry for a long period.[1]

ORTHENTS.—Loamy or clayey Entisols that have a regular decrease in organic-matter content with depth; used for range or irrigated crops in dry regions and for general farming in humid regions.

Cryorthents (formerly Alluvial soils, Regosols, and Lithosols).—Orthents of cold regions.[1]

Torriorthents (formerly Regosols).—Orthents that are never moist as long as 3 consecutive months.

E3–1—Torriorthents plus Haplargids and Torrifluvents, gently or moderately sloping.

E3–2—Torriorthents plus Torrifluvents and Salorthids, gently sloping.

E3–3—Torriorthents plus Torriorthents (shallow), Camborthids, and Badlands, gently or moderately sloping.

E3–4—Torriorthents plus Torriorthents (shallow), Haplargids, and Rough stony land, moderately sloping or steep.

Torriorthents (shallow; formerly Lithosols).—Torriorthents that are shallower than 20 inches to bedrock.

E4–1—Torriorthents (shallow) plus Haplargids and Badlands, moderately sloping or steep.

E4–2—Torriorthents (shallow to soft bedrock) plus Haplargids, Camborthids, and Rock land, moderately sloping or steep.

E4–3—Torriorthents (shallow to soft bedrock) plus Haplargids, Torrifluvents, and Natrargids, gently sloping to steep.

E4–4—Torriorthents (shallow) plus Rough stony land, gently or moderately sloping.

E4–5—Torriorthents (shallow) plus Rough stony land and Calciorthids, steep.

Udorthents (formerly Regosols).—Orthents that are usually moist.[1]

Ustorthents (formerly Regosols).—Orthents that during the warm season of the year are intermittently dry for long periods.

E5–1—Ustorthents plus Argiustolls and Argiudolls, moderately sloping.

E5–2—Ustorthents plus Argiborolls and Natriborolls, moderately sloping.

E5–3—Ustorthents plus Haploborolls, moderately sloping or steep.

E5–4—Ustorthents plus Torriorthents, Camborthids, Argiustolls, and Haplargids, moderately sloping.

Ustorthents (shallow; formerly Lithosols).—Ustorthents that are shallower than 20 inches to bedrock.

E6–1—Ustorthents (shallow to soft bedrock) plus Badlands, steep.

E6–2—Ustorthents (shallow) plus Haploborolls and Argiborolls, steep.

E6–3—Ustorthents (shallow) plus Ustorthents, moderately sloping.

Xerorthents (formerly Regosols, Brown, or Alluvial soils).—Orthents that are in climates with rainy winters but dry summers; during the warm season of the year, they are continually dry for a long period.

E7–1—Xerorthents plus Calciorthids, Haploxerolls, Argixerolls, and Palexerolls, gently sloping to steep.

E7–2—Xerorthents plus Durixeralfs, Haploxeralfs, Xerofluvents, and Palexeralfs, gently sloping.

E7–3—Xerorthents plus Haploxeralfs, Xerofluvents, and Haplaquolls, gently sloping.

Xerorthents (shallow; formerly Lithosols).—Xerorthents that are shallower than 20 inches to bedrock.

E8–1—Xerorthents (shallow) plus Haploxeralfs, both steep.

PSAMMENTS.—Entisols that have textures of loamy fine sand or coarser; used for range, wild hay, and some hardy vegetables in Alaska, woodland and small grains where warm and moist, pasture and citrus in Florida, and range and irrigated crops where warm and dry.

Cryopsamments (formerly Regosols).—Psamments of cold regions.

E9–1—Cryopsamments plus Cryaquepts, Cryorthents, and Cryandepts, gently or moderately sloping.

Quartzipsamments (formerly Regosols).—Psamments that consist almost entirely of minerals highly resistant to weathering, mainly quartz.

E10–1—Quartzipsamments plus Paleudults, gently sloping.

E10–2—Quartzipsamments plus Paleudults, gently or moderately sloping.

E10–3—Quartzipsamments plus Ochraquults, gently sloping.

E10–4—Quartzipsamments plus Umbraquults, gently or moderately sloping.

Torripsamments (formerly Regosols).—Psamments that contain easily weatherable minerals; they are never moist as long as 3 consecutive months.

E11–1—Torripsamments plus Camborthids, gently or moderately sloping.

E11–2—Torripsamments plus Paleargids and Haplargids, gently sloping.

Udipsamments (formerly Regosols).—Psamments that contain easily weatherable minerals; they are usually moist in all parts of the soil in most years.

E12–1—Udipsamments plus Eutroboralfs and Haploborolls, gently or moderately sloping.

E12–2—Udipsamments plus Hapludalfs and Haplaquolls, gently or moderately sloping.

E12–3—Udipsamments plus Histosols (undifferentiated), gently sloping.

Ustipsamments (formerly Regosols).—Psamments that contain easily weatherable minerals; during the warm season of the year, they are intermittently dry for long periods.

Ustipsamments.—Psamments that contain easily weatherable minerals; during the warm season of the year, they are intermittently dry for long periods.

E13–1—Ustipsamments, moderately sloping.

E13–2—Ustipsamments plus Paleustalfs (sandy), gently or moderately sloping.

Xeropsamments—Psamments that are in climates with rainy winters but dry summers; during the warm season of the year, they are continually dry for a long period.

E14–1—Xeropsamments plus Camborthids, gently sloping.

HISTOSOLS

Wet organic (peat and muck) soils; includes soils in which the decomposition of plant residues ranges from highly decomposed to not decomposed; formed in swamps and marshes; used for mostly woodland or lie idle, but some drained areas have truck crops. Histosols are classified here only according to stage of plant-residue decomposition.

Plant residues not decomposed; formerly called peat. Histosols of cool regions.

H1–1—Histosols plus Psammaquents and Haplorthods, gently sloping.

Plant residues moderately decomposed or highly decomposed; formerly called peat or muck. Histosols of warm regions.

H2–1—Histosols (plant residues moderately decomposed), gently sloping.

H2–2—Histosols (plant residues highly decomposed), gently sloping.

H2–3—Histosols (plant residues moderately decomposed or highly decomposed), gently sloping.

INCEPTISOLS

Soils that have weakly differentiated horizons; materials in the soil have been altered or removed but have not accumulated. These soils are usually moist, but during the warm season of the year some are dry part of the time.

ANDEPTS.—Inceptisols that either have formed in ashy (vitric pyroclastic) materials, have low bulk density and large amounts of amorphous materials, or both; used for woodland and range or pasture.

Cryandepts (formerly Brown Podzolic or Gray-Brown Podzolic soils).—Andepts of cold regions.

I1–1—Cryandepts plus Cryochrepts and Cryorthods, steep.

I1–2—Cryandepts plus Cryorthods, Eutrandepts, Xerochrepts, and Haploxerolls, steep.

I1–3—Cryandepts plus Cryumbrepts, Cryorthods, and Haplumbrepts, steep.

I1–4—Cryandepts plus Rock land, Cryaquepts, and Histosols (plant residues not decomposed), gently or moderately sloping.

Dystrandepts (formerly Ando soils).—Andepts that have a thick dark-colored surface horizon that is low in bases or that have a light-colored surface horizon.

I2–1—Dystrandepts plus Andaquepts, gently sloping to steep.

I2–2—Dystrandepts plus Eutrandepts, moderately sloping to steep.

I2–3—Dystrandepts plus Hydrandepts and Rubble land, moderately sloping or steep.

Eutrandepts (formerly Brown or Reddish Brown soils).—Andepts that have a thick dark-colored surface horizon that is high in bases.

I3–1—Eutrandepts plus Vitrandepts and Rubble land, moderately sloping or steep.

Hydrandepts (formerly Hydrol Humic Latosols).—Andepts that harden permanently if dried.[1]

Vitrandepts (formerly Regosols).—Andepts mostly formed in pumice or slightly weathered volcanic ash.[1]

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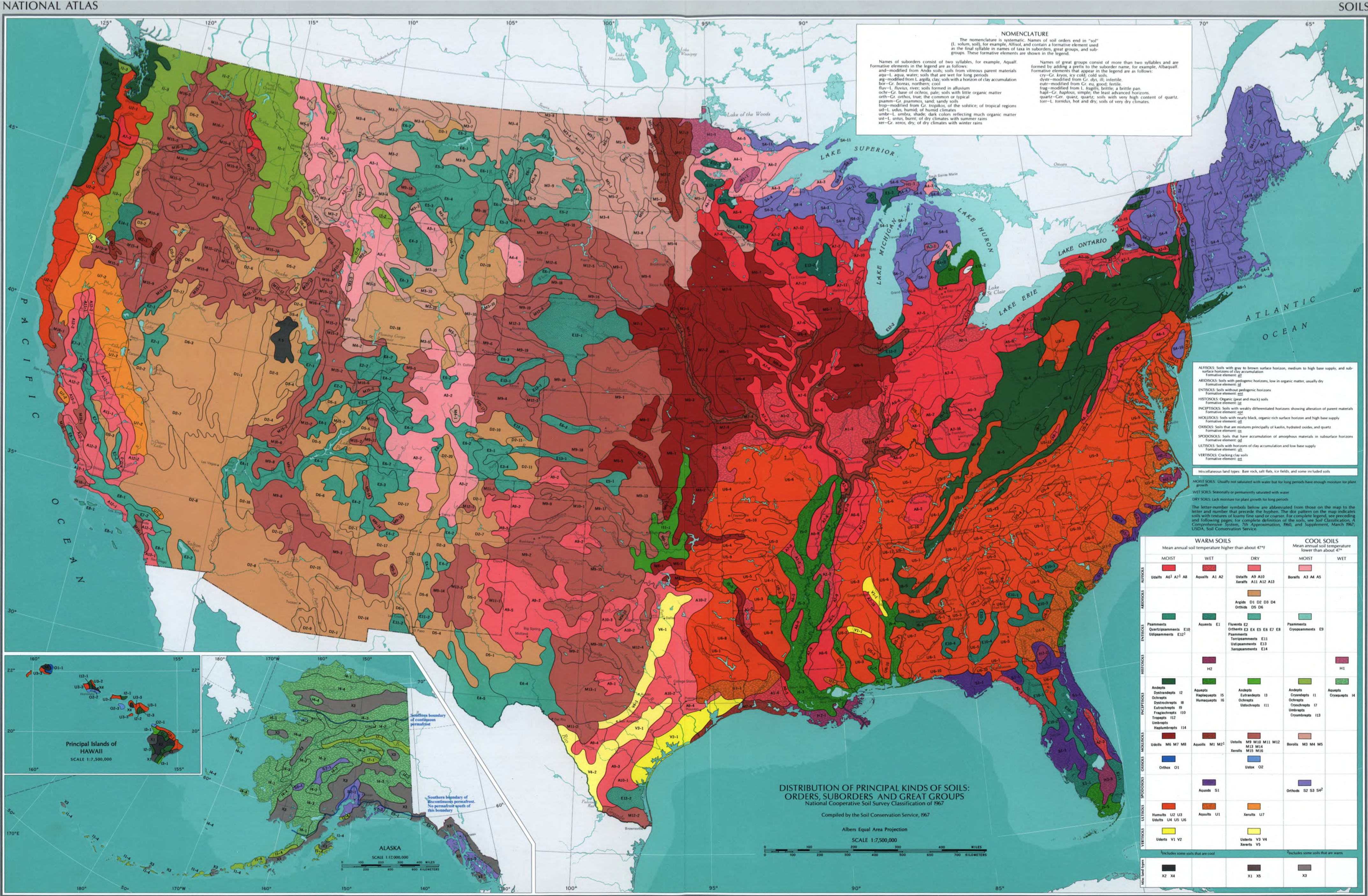
[1] No map units are listed under this great group (or phase) because it is not the most extensive soil in any map unit.

(Continued on page 88)



NOMENCLATURE

The nomenclature is systematic. Names of soil orders end in "sol" (L. solum, soil), for example, Alfisol, and contain a formative element used as the final syllable in names of taxa in suborders, great groups, and subgroups. These formative elements are shown in the legend.

Names of suborders consist of two syllables, for example, Aqualf. Formative elements in the legend are as follows:

and–modified from Ando soils; soils from vitreous parent materials
aqu–L. *aqua*, water; soils that are wet for long periods
arg–modified from L. *argilla*, clay; soils with a horizon of clay accumulation
bor–Gr. *boreas*, northern; cool
fluv–L. *fluvius*, river; soils formed in alluvium
ochr–Gr. base of *ochros*, pale; soils with little organic matter
orth–Gr. *orthos*, true; the common or typical
psamm–Gr. *psammos*, sand; sandy soils
trop–modified from Gr. *tropikos*, of the solstice; of tropical regions
ud–L. *udus*, humid; of humid climates
umbr–L. *umbra*, shade; dark colors reflecting much organic matter
ust–L. *ustus*, burnt; of dry climates with summer rains
xer–Gr. *xeros*, dry; of dry climates with winter rains

Names of great groups consist of more than two syllables and are formed by adding a prefix to the suborder name, for example, Albaqualf. Formative elements that appear in the legend are as follows:

cry–Gr. *kryos*, icy cold; cold soils.
dystr–modified from Gr. *dys*, ill; infertile.
eutr–modified from Gr. *eu*, good; fertile.
frag–modified from L. *fragilis*, brittle; a brittle pan.
hapl–Gr. *haplous*, simple; the least advanced horizons.
quartz–Ger. *quarz*, quartz; soils with very high content of quartz.
torr–L. *torridus*, hot and dry; soils of very dry climates.

DISTRIBUTION OF PRINCIPAL KINDS OF SOILS: ORDERS, SUBORDERS AND GREAT GROUPS

National Cooperative Soil Survey Classification of 1967

Compiled by the Soil Conservation Service, 1967

Albers Equal Area Projection

SCALE 1:7,500,000

ALFISOLS: Soils with gray to brown surface horizon, medium to high base supply, and subsurface horizons of clay accumulation
Formative element: alf

ARIDISOLS: Soils with pedogenic horizons, low in organic matter, usually dry
Formative element: id

ENTISOLS: Soils without pedogenic horizons
Formative element: ent

HISTOSOLS: Organic (peat and muck) soils
Formative element: ist

INCEPTISOLS: Soils with weakly differentiated horizons showing alteration of parent materials
Formative element: ept

MOLLISOLS: Soils with nearly black, organic-rich surface horizon and high base supply
Formative element: oll

OXISOLS: Soils that are mixtures principally of kaolin, hydrated oxides, and quartz
Formative element: ox

SPODOSOLS: Soils that have accumulation of amorphous materials in subsurface horizons
Formative element: od

ULTISOLS: Soils with horizons of clay accumulation and low base supply
Formative element: ult

VERTISOLS: Cracking clay soils
Formative element: ert

Miscellaneous land types: Bare rock, salt flats, ice fields, and some included soils

MOIST SOILS: Usually not saturated with water but for long periods have enough moisture for plant growth

WET SOILS: Seasonally or permanently saturated with water

DRY SOILS: Lack moisture for plant growth for long periods

The letter-number symbols below are abbreviated from those on the map to the letter and number that precede the hyphen. The dot pattern on the map indicates soils with textures of loamy fine sand or coarser. For complete legend, see preceding and following pages; for complete definition of the soils, see *Soil Classification, A Comprehensive System, 7th Approximation,* 1960, and *Supplement,* March 1967; USDA, Soil Conservation Service.

	WARM SOILS Mean annual soil temperature higher than about 47°F			COOL SOILS Mean annual soil temperature lower than about 47°	
	MOIST	WET	DRY	MOIST	WET
ALFISOLS	🟥 Udalfs A6[1] A7[1] A8	🟥 Aqualfs A1 A2	🟥 Ustalfs A9 A10 Xeralfs A11 A12 A13	🟥 Boralfs A3 A4 A5	
ARIDISOLS			🟫 Argids D1 D2 D3 D4 Orthids D5 D6		
ENTISOLS	🟩 Psamments Quartzipsamments E10 Udipsamments E12[1]	🟩 Aquents E1	🟩 Fluvents E2 Orthents E3 E4 E5 E6 E7 E8 Psamments Torripsamments E11 Ustipsamments E13 Xeropsamments E14	🟩 Psamments Cryopsamments E9	
HISTOSOLS		🟪 H2			🟪 H1
INCEPTISOLS	🟩 Andepts Dystrandepts I2 Ochrepts Dystrochrepts I8 Eutrochrepts I9 Fragiochrepts I10 Tropepts I12 Umbrepts Haplumbrepts I14	🟩 Aquepts Haplaquepts I5 Humaquepts I6	🟩 Andepts Eutrandepts I3 Ochrepts Ustochrepts I11	🟩 Andepts Cryandepts I1 Ochrepts Cryochrepts I7 Umbrepts Cryumbrepts I13	🟩 Aquepts Cryaquepts I4
MOLLISOLS	🟥 Udolls M6 M7 M8	🟫 Aquolls M1 M2[1]	🟫 Ustolls M9 M10 M11 M12 M13 M14 Xerolls M15 M16	🟫 Borolls M3 M4 M5	
OXISOLS	🟦 Orthox O1		🟦 Ustox O2		
SPODOSOLS		🟪 Aquods S1		🟪 Orthods S2 S3 S4[2]	
ULTISOLS	🟥 Humults U2 U3 Udults U4 U5 U6	🟧 Aquults U1	🟧 Xerults U7		
VERTISOLS	🟨 Uderts V1 V2		🟨 Usterts V3 V4 Xererts V5		

[1] Includes some soils that are cool

[2] Includes some soils that are warm

Misc land types	⬛ X2 X4		⬛ X1 X5	⬛ X3	

GENERAL SOIL CLASSIFICATION

(Continued from page 85)

AQUEPTS.—Seasonally wet Inceptisols that have an organic surface horizon, sodium saturation, mottles, or gray colors; used for pasture, hay, and where drained, hardy vegetables in Alaska, woodland pasture, and where drained, row crops in Southeastern United States.

Andaquepts (formerly Humic-Gley and Alluvial soils).—Aquepts that either have formed in ashy (vitric pyroclastic) materials, have low bulk density and large amounts of amorphous materials, or both.[1]

Cryaquepts (formerly Tundra).—Aquepts of cold regions.

I4-1—Cryaquepts plus Cryorthents, Cryopsamments, and Cryumbrepts, gently or moderately sloping.

I4-2—Cryaquepts plus Cryorthents, Histosols (plant residues not decomposed), and Cryorthods, gently or moderately sloping.

I4-3—Cryaquepts plus Cryumbrepts, Histosols (plant residues not decomposed), and Rock land, moderately sloping or steep.

I4-4—Cryaquepts plus Cryumbrepts, Histosols (plant residues not decomposed), and Rock land, gently or moderately sloping.

Fragiaquepts (formerly Low-Humic Gley soils with fragipan).—Aquepts that have a dense brittle but not indurated horizon (fragipan).[1]

Haplaquepts (formerly Low-Humic Gley soils).—Aquepts that have either a light-colored or a thin black surface horizon.

I5-1—Haplaquepts plus Haplaquods, gently sloping.

I5-2—Haplaquepts plus Haplaquolls, Udifluvents, and Hapludalfs, gently sloping.

I5-3—Haplaquepts plus Ochraqualfs, Haplaquolls, and Natraqualfs, gently sloping.

I5-4—Haplaquepts plus Ochraquults, Paleudults, and Hapludults, gently sloping.

I5-5—Haplaquepts plus Psammaquents, Haplaquents, and Haplaquods, gently sloping.

Humaquepts (formerly Humic-Gley soils).—Aquepts that have an acid dark surface horizon.

I6-1—Humaquepts plus Hydraquents and Psammaquents, gently sloping (Tidal marsh).

OCHREPTS.—Inceptisols that have formed in materials with crystalline clay minerals, have light-colored surface horizons, and have altered subsurface horizons that have lost mineral materials; used for woodland and range in Alaska and Northwestern United States, pasture, wheat, sorghum and hay in Oklahoma and Kansas, and pasture, silage corn, small grain, and hay in Northeastern United States.

Cryochrepts (formerly Subarctic Brown Forest soils).—Ochrepts of cold regions.

I7-1—Cryochrepts plus Cryaquepts, Histosols (plant residues not decomposed), Cryorthents, and Cryorthods, gently or moderately sloping.

I7-2—Cryochrepts plus Rock land, Cryumbrepts, and Cryandepts, steep.

Dystrochrepts (formerly Sols Bruns Acides and some Brown Podzolic and Gray-Brown Podzolic soils).—Ochrepts that are usually moist and low in bases and have no free carbonates in the subsurface horizons.

I8-1—Dystrochrepts, gently sloping.

I8-2—Dystrochrepts, gently sloping to steep (dissected plateaus).

I8-3—Dystrochrepts plus Fragiochrepts and Hapludalfs, moderately sloping.

I8-4—Dystrochrepts, steep, plus Hapludalfs and Hapludults, both moderately sloping.

I8-5—Dystrochrepts, steep, plus Paleudalfs and Hapludults, both moderately sloping.

I8-6—Dystrochrepts plus Rock land and Hapludults, steep.

Eutrochrepts (formerly Brown Forest soils).—Ochrepts that are usually moist and are either high in bases, have free carbonates in the subsurface horizons, or both.

I9-1—Eutrochrepts, steep.

I9-2—Eutrochrepts plus Dystrochrepts, gently sloping.

I9-3—Eutrochrepts plus Chromuderts, gently sloping.

Fragiochrepts (formerly Sols Bruns Acides and some Brown Podzolic and Gray-Brown Podzolic soils, all with fragipans).—Ochrepts that have a dense brittle but not indurated horizon (fragipan).

I10-1—Fragiochrepts plus Dystrochrepts (both stony), steep.

I10-2—Fragiochrepts plus Fragiaquepts and Dystrochrepts, gently sloping.

I10-3—Fragiochrepts plus Fragiaquepts and Dystrochrepts, moderately sloping.

I10-4—Fragiochrepts plus Fragiaquepts and Dystrochrepts, gently sloping to steep.

Ustochrepts (formerly Reddish Chestnut soils).—Ochrepts that during the warm season of the year are intermittently dry for long periods.[1]

Ustochrepts (shallow; formerly Lithosols).—Ustochrepts that are shallower than 20 inches to bedrock.

I11-1—Ustochrepts (shallow) plus Haplustalfs, both moderately sloping.

Xerochrepts (formerly Regosols).—Ochrepts that are in climates with rainy winters but dry summers; during the warm season of the year, the soils are continually dry for a long period.[1]

TROPEPTS (formerly Latosols).—Inceptisols of tropical climates; used for pineapple and irrigated sugarcane in Hawaii.

I12-1—Tropepts plus Ustox and Rock land, gently sloping to steep.

UMBREPTS.—Inceptisols with crystalline clay minerals, thick dark-colored surface horizons, and altered subsurface horizons that have lost mineral materials and that are low in bases; used for woodland and range.

Cryumbrepts (formerly Tundra soils).—Umbrepts of cold regions.

I13-1—Cryumbrepts plus Cryorthods, Haplorthods, and Rock land, steep.

Haplumbrepts (formerly Brown Forest soils).—Umbrepts of temperate to warm regions.

I14-1—Haplumbrepts plus Haplorthods, Humaquepts, Haplaquepts, and Histosols (undifferentiated), gently or moderately sloping.

I14-2—Haplumbrepts, steep, plus Haploxerolls, Dystrandepts, and Vitrandepts, gently sloping.

Xerumbrepts (formerly Regosols).—Umbrepts that are formed in climates with rainy winters but dry summers; during the warm season of the year, the soils are continually dry for a long period.[1]

MOLLISOLS

Soils that have nearly black friable organic-rich surface horizons high in bases; formed mostly in subhumid and semiarid warm to cold climates.

ALBOLLS.—Mollisols of flat places and high closed depressions. They have a seasonal perched water table and a nearly black surface horizon underlain by a bleached (white) mottled horizon over a horizon of clay accumulation that has mottles or gray colors; used for small grain, peas, hay, pasture, and range.

Argialbolls (formerly Planosols and Solodths).—Albolls that have a horizon of clay accumulation without alkali (sodium).[1]

AQUOLLS.—Seasonally wet Mollisols that have a thick nearly black surface horizon and gray subsurface horizons; used for pasture, and where drained, small grains, corn, and potatoes in the North-Central States, and rice and sugarcane in Texas.

Argiaquolls (formerly Humic-Gley soils).—Aquolls that have a subsurface horizon in which clay has accumulated.[1]

Calciaquolls (formerly Calcium Carbonate Solonchaks).—Aquolls that have a horizon near the surface in which large amounts of calcium carbonate have accumulated.

M1-1—Calciaquolls, gently sloping.

M1-2—Calciaquolls plus Haploborolls, gently sloping.

Cryaquolls (formerly Alpine Meadow soils).—Aquolls of cold regions.[1]

Duraquolls (formerly Humic-Gley soils with hardpan).—Aquolls that have a hardpan (duripan) that is cemented with silica.[1]

Haplaquolls (formerly Humic-Gley soils).—Aquolls that have horizons in which materials have been altered or removed but no clay or calcium carbonate has accumulated.

M2-1—Haplaquolls, gently sloping.

M2-2—Haplaquolls (clayey) plus Calciaquolls, both gently sloping.

M2-3—Haplaquolls plus Histosols (plant residues highly decomposed) and Haplaquepts, gently sloping.

M2-4—Haplaquolls plus Udifluvents, Hapludolls, and Hapludalfs, gently sloping.

M2-5—Haplaquolls plus Udipsamments, both gently sloping.

M2-6—Haplaquolls plus Udipsamments and Humaquepts, all gently sloping.

BOROLLS.—Mollisols of cool and cold regions. Most Borolls have a black surface horizon; used for small grain, hay, and pasture in North-Central States and range, woodland, and some small grain in Western States.

Argiborolls (formerly Chernozems).—Borolls of cool regions. They have a subsurface horizon in which clay has accumulated.

M3-1—Argiborolls, moderately sloping.

M3-2—Argiborolls, gently sloping.

M3-3—Argiborolls plus Eutroboralfs, moderately sloping.

M3-4—Argiborolls plus Haploborolls, gently sloping.

M3-5—Argiborolls plus Haploborolls, gently sloping to steep.

M3-6—Argiborolls plus Haploborolls and Calciaquolls, gently or moderately sloping.

M3-7—Argiborolls plus Haploborolls, Natrargids, and Calciborolls, gently sloping.

M3-8—Argiborolls plus Natriborolls and Haploborolls, gently sloping.

M3-9—Argiborolls plus Ustorthents, gently sloping.

M3-10—Argiborolls plus Ustorthents (shallow) and Boralfs, steep.

Cryoborolls (formerly Chernozems).—Borolls of cold regions.

M4-1—Cryoborolls plus Cryorthents and Haplargids, moderately sloping.

M4-2—Cryoborolls plus Haplustalfs and Argiustolls, greatly sloping to steep.

Haploborolls (formerly Chernozems).—Borolls of cool regions. They have no horizon of clay accumulation.

M5-1—Haploborolls, gently sloping.

M5-2—Haploborolls, moderately sloping.

M5-3—Haploborolls plus Argiborolls, moderately sloping.

M5-4—Haploborolls plus Haplaquolls, and Calciaquolls, gently sloping.

M5-5—Haploborolls plus Natriborolls, gently sloping.

Natriborolls (formerly Solonetz soils).—Borolls that have a subsurface horizon of clay accumulation with alkali (sodium).[1]

RENDOLLS (formerly Rendzinas).—Mollisols with subsurface horizons that have large amounts of calcium carbonate but no accumulation of clay; used for cotton, corn, small grains, and pasture.

UDOLLS.—Mollisols of temperate climates. Udolls are usually moist and have no horizon in which either calcium carbonate or gypsum has accumulated; used for corn, small grains, and soybeans.

Argiudolls (formerly Brunizems and Reddish Prairie soils).—Udolls that have a subsurface horizon in which clay has accumulated.

M6-1—Argiudolls, gently or moderately sloping.

M6-2—Argiudolls plus Albaqualfs and Paleudolls, gently sloping.

M6-3—Argiudolls plus Argiaquolls, gently sloping.

M6-4—Argiudolls plus Argiaquolls and Argialbolls, gently or moderately sloping.

M6-5—Argiudolls plus Argiustolls, Argiaquolls, and Ustipsamments, gently sloping.

M6-6—Argiudolls plus Haplaquolls, gently sloping.

M6-7—Argiudolls plus Hapludalfs and Haplaquolls, gently or moderately sloping.

Hapludolls (formerly Brunizems and some Regosols, Brown Forest, and Alluvial soils).—Udolls that have horizons from which some materials have been removed or altered but have no subsurface horizon of clay accumulation.

M7-1—Hapludolls, gently sloping.

M7-2—Hapludolls, gently or moderately sloping.

M7-3—Hapludolls plus Argiudolls, gently sloping.

M7-4—Hapludolls plus Argiudolls, Udorthents, and Hapludalfs, gently or moderately sloping.

M7-5—Hapludolls plus Eutrochrepts and Udifluvents, gently sloping.

M7-6—Hapludolls plus Haplaquolls, gently sloping.

M7-7—Hapludolls plus Ustorthents, gently sloping.

Hapludolls (shallow; formerly Lithosols).—Hapludolls that are shallower than 20 inches to bedrock.

M8-1—Hapludolls (shallow) plus Argiustolls and Argiudolls, moderately sloping.

USTOLLS.—Mollisols that are mostly in semiarid regions. During the warm season of the year, these soils are intermittently dry for a long period or have subsurface horizons in which salts or carbonates have accumulated; used for wheat or small grains, and some irrigated crops.

Argiustolls (formerly Chernozem, Chestnut, and some Brown soils).—Ustolls that have a subsurface horizon of clay accumulation that is relatively thin or is brownish.

M9-1—Argiustolls, gently sloping.

M9-2—Argiustolls plus Calciustolls and Paleustolls, gently sloping.

M9-3—Argiustolls plus Chromusterts, Rhodustalfs, Argiborolls and Torriorthents (shallow), gently sloping to steep.

M9-4—Argiustolls plus Haplargids, Ustorthents, and Paleustolls, gently sloping.

M9-5—Argiustolls plus Haploborolls and Argiborolls, moderately sloping.

M9-6—Argiustolls plus Haplustolls, gently sloping.

M9-7—Argiustolls plus Haplustolls, gently sloping to steep.

M9-8—Argiustolls plus Haplustolls, Chromusterts, Ustorthents, and Ustipsamments, gently or moderately sloping.

M9-9—Argiustolls plus Haplustolls, Paleustolls and Calciustolls, gently sloping.

M9-10—Argiustolls plus Haplustolls (shallow), Paleustolls and Ustorthents, gently sloping.

M9-11—Argiustolls plus Haplustolls, Ustorthents (shallow) Argiborolls and Rock land, gently sloping to steep.

M9-12—Argiustolls plus Natrustolls, gently or moderately sloping.

M9-13—Argiustolls plus Paleustolls, gently sloping.

M9-14—Argiustolls plus Paleustolls and Haploborolls, gently sloping to steep.

M9-15—Argiustolls plus Paleustolls and Ustorthents, gently sloping.

M9-16—Argiustolls plus Ustipsamments, gently sloping.

M9-17—Argiustolls plus Ustipsamments and Ustochrepts, gently or moderately sloping.

M9-18—Argiustolls plus Ustorthents, gently sloping.

M9-19—Argiustolls plus Ustorthents (shallow), gently sloping.

Calciustolls (formerly Calcisols).—Ustolls that are calcareous throughout and have either an indurated (petrocalcic) horizon cemented by carbonates or a horizon in which calcium carbonate or gypsum has accumulated.

M10-1—Calciustolls plus Haplustolls, Argiustolls, and Ustochrepts (shallow), gently or moderately sloping.

Calciustolls (shallow; formerly Lithosols).—Calciustolls that are shallower than 20 inches to bedrock.

M11-1—Calciustolls (shallow) plus Argiustolls, both gently sloping.

M11-2—Calciustolls (shallow) plus Pellusterts and Torrerts, all gently sloping.

Haplustolls (formerly Chernozem, Chestnut, and some Brown soils).—Ustolls that have a subsurface horizon high in bases but without large accumulations of clay, calcium carbonate, or gypsum.

M12-1—Haplustolls plus Argiustolls and Calciustolls (shallow), gently sloping.

M12-2—Haplustolls plus Argiustolls and Haplustalfs, gently sloping.

M12-3—Haplustolls plus Argiustolls and Ustorthents, gently sloping.

M12-4—Haplustolls plus Pellusterts, gently sloping.

M12-5—Haplustolls plus Ustorthents, moderately sloping.

M12-6—Haplustolls plus Ustorthents and Camborthids, moderately sloping.

Haplustolls (shallow; formerly Lithosols).—Haplustolls that are shallower than 20 inches to bedrock.

M13-1—Haplustolls (shallow) plus Haplustolls, both gently or moderately sloping.

M13-2—Haplustolls (shallow) plus Torriorthents (shallow) and Calciorthids, all moderately sloping or steep.

Natrustolls (formerly Solonetz soils).—Ustolls that have a horizon of clay and alkali (sodium) accumulation.

M14-1—Natrustolls plus Argiborolls, gently sloping.

XEROLLS.—Mollisols that are in climates with rainy winters but dry summers; during the warm season of the year, these soils are continually dry for a long period; used for wheat, range, and irrigated crops.

Argixerolls (formerly Brunizems).—Xerolls that have a subsurface horizon of clay accumulation that is relatively thin or is brownish.

M15-1—Argixerolls plus Argialbolls and Haploxerolls, gently or moderately sloping.

M15-2—Argixerolls plus Argiborolls and Haploxerolls, steep.

M15-3—Argixerolls plus Argiborolls and Cryaquolls, moderately sloping.

M15-4—Argixerolls plus Cryandepts and Haploxerolls, moderately sloping or steep.

M15-5—Argixerolls plus Haploxerolls, moderately sloping.

M15-6—Argixerolls plus Haploxerolls, gently or moderately sloping.

M15-7—Argixerolls plus Haploxerolls and Haplaquolls, gently sloping.

M15-8—Argixerolls plus Haploxerolls, Haplargids, and Camborthids, gently or moderately sloping.

M15-9—Argixerolls plus Haploxerolls, Xererts, and Palexerolls, moderately sloping or steep.

M15-10—Argixerolls plus Haploxerolls, Xerorthents (shallow), and Rock land, gently or moderately sloping.

M15-11—Argixerolls plus Xerorthents (shallow), Haploxerolls, and Rock land, steep.

M15-12—Argixerolls plus Xerorthents (shallow), Xeralfs, and Rock land, steep.

Calcixerolls (formerly Calcisols).—Xerolls that have a calcareous surface horizon and subsurface horizons in which large amounts of calcium carbonate, with or without cementation, or gypsum have accumulated.[1]

Durixerolls (formerly Brunizems with hardpan).—Xerolls that have a hardpan (duripan) that is cemented with silica.[1]

Haploxerolls (formerly Chestnut and Brown soils).—Xerolls that have a subsurface horizon high in bases but without large accumulations of clay, calcium carbonate, or gypsum.

M16-1—Haploxerolls plus Argixerolls, Chromoxererts, and Xerothents (shallow), steep.

M16-2—Haploxerolls plus Argixerolls and Haploxerolls (shallow), moderately sloping.

M16-3—Haploxerolls plus Argixerolls and Xerorthents, gently sloping to steep.

M16-4—Haploxerolls plus Calciaquolls and Argixerolls, gently or moderately sloping.

M16-5—Haploxerolls plus Calcixerolls and Xerofluvents, gently sloping.

M16-6—Haploxerolls plus Camborthids and Calciorthids (shallow), moderately sloping or steep.

M16-7—Haploxerolls plus Haplaquolls, Durixerolls, and Rock land, moderately sloping.

Palexerolls (formerly Brunizems).—Xerolls that have a hardpan (petrocalcic horizon) cemented with carbonates or a horizon of clay accumulation that is thick and reddish or is clayey in the upper part and changes abruptly in texture into an overlying horizon.[1]

OXISOLS

Soils that are mixtures principally of kaolin, hydrated oxides, and quartz and that are low in weatherable minerals; formed on gentle or moderate slopes at low or moderate elevations in tropical or subtropical climates.

HUMOX.—Oxisols that are moist all or most of the time. They have a high content of organic matter but are low in bases; used for sugarcane, pineapple, and pasture in Hawaii.

Gibbsihumox (formerly Humic Ferruginous Latosols).—Humox that have nodules or sheets cemented with hydrated aluminum oxides.[1]

ORTHOX (formerly Latosols).—Oxisols that are moist all or most of the time. They have moderate to low content of organic matter and are relatively low in bases; used for sugarcane, pineapple, and pasture in Hawaii. (These soils are not classified here below the level of suborder.)

01-1—Orthox plus Gibbsihumox, gently or moderately sloping.

USTOX (formerly Latosols).—Oxisols that are continually dry in some part of the soil for a long period during the year; used for pineapple, irrigated sugarcane, and pasture in Hawaii. (These soils are not classified here below the level of suborder.)

02-1—Ustox plus Andepts and Aquepts, gently sloping to steep.

02-2—Ustox plus Chromusterts, Tropepts, and Andepts, gently or moderately sloping.

02-3—Ustox plus Tropepts, Andepts, and Rock land, gently sloping to steep.

SPODOSOLS

Soils with low base supply that have in subsurface horizons an accumulation of amorphous materials consisting of organic matter plus compounds of aluminum and usually iron; formed in acid mainly coarse-textured materials in humid and mostly cool or temperate climates.

AQUODS.—Seasonally wet Spodosols; formed in humid climates of arctic to tropical regions; used for mostly pasture, range, or woodland and some citrus and truck crops in Florida.

Haplaquods (formerly Ground-Water Podzols).—Aquods that have a subsurface horizon that contains dispersed aluminum and organic matter but only small amounts of free iron oxides; used for woodland, pasture, and where drained, some truck crops and citrus.

S1-1—Haplaquods plus Quartzipsamments, gently sloping.

Sideraquods (formerly Ground-Water Podzols).—Aquods that have appreciable amounts of free iron in subsurface horizons.[1]

ORTHODS.—Spodosols that have a horizon in which organic matter plus compounds of iron and aluminum have accumulated; used for woodland, hay, pasture, fruit, and, on gently sloping areas, potatoes and truck crops.

Cryorthods (formerly Podzols).—Orthods of cold regions.

S2-1—Cryorthods plus Histosols (plant residues not decomposed) and Cryaquepts, gently or moderately sloping.

S2-2—Cryorthods plus Histosols (plant residues not decomposed) plus Cryandepts and Cryaquepts, moderately sloping or steep.

Cryorthods (shallow; formerly Podzols).—Cryorthods that are shallower than 20 inches to bedrock.[1]

Fragiorthods (formerly Podzols and Brown Podzolic soils, both with fragipans).—Orthods that have a dense brittle, but not indurated horizon (fragipan) below a horizon that has an accumulation of organic matter and compounds of iron and aluminum.

S3-1—Fragiorthods, moderately sloping.

Haplorthods (formerly Podzols and Brown Podzolic soils).—Orthods of cool regions. They have a horizon in which organic matter plus compounds of iron and aluminum have accumulated, but they have no dense, brittle, or indurated horizon (fragipan).

S4-1—Haplorthods (loamy), gently sloping.

S4-2—Haplorthods (sandy), gently or moderately sloping.

S4-3—Haplorthods plus Fragiorthods, gently sloping.

S4-4—Haplorthods plus Fragiorthods, moderately sloping.

S4-5—Haplorthods plus Fragiorthods and Rock land, steep.

S4-6—Haplorthods plus Glossoboralfs, gently sloping.

S4-7—Haplorthods plus Glossoboralfs and Udipsamments, moderately sloping.

S4-8—Haplorthods plus Haplaquepts and Fragiochrepts, gently or moderately sloping.

S4-9—Haplorthods plus Haplaquepts and Ochraqualfs, gently sloping.

S4-10—Haplorthods plus Quartzipsamments and Hapludults, gently sloping.

S4-11—Haplorthods plus Rock land, moderately sloping or steep.

ULTISOLS

Soils that are low in bases and have subsurface horizons of clay accumulation; usually moist, but during the warm season of the year, some are dry part of the time.

AQUULTS.—Seasonally wet Ultisols that have mottles, iron-manganese concretions, or gray colors. Used for limited pasture and woodland, and where drained, some hay, cotton, corn, and truck crops.

Fragiaquults (formerly Planosols with fragipan).—Aquults that have a dense brittle but not indurated horizon (fragipan).[1]

Ochraquults (formerly Low-Humic Gley soils).—Aquults that have either a light-colored or a thin black surface horizon.

U1-1—Ochraquults plus Glossaqualfs and Paleudults, gently sloping.

U1-2—Ochraquults plus Paleudults and Hapludults, gently sloping.

U1-3—Ochraquults plus Quartzipsamments, gently sloping.

U1-4—Ochraquults plus Umbraquults and Tidal marsh, gently sloping.

Umbraquults (formerly Humic-Gley soils).—Aquults that have a thick black surface horizon.[1]

HUMULTS.—Ultisols that have a high content of organic matter; formed in temperate or tropical climates that have high amounts of rainfall throughout the year; used for woodland and pasture where steep, small grain and truck and seed crops in Oregon and Washington, and pineapple and irrigated sugarcane in Hawaii where gently or moderately sloping.

Haplohumults (formerly Reddish-Brown Lateritic soils).—Humults that either have a subsurface horizon of clay accumulation that is relatively thin, a subsurface horizon having appreciable weatherable minerals, or both; formed in temperate climates.

U2-1—Haplohumults plus Haplumbrepts, moderately sloping or steep.

U2-2—Haplohumults plus Xerumbrepts and Haploxerolls, moderately sloping or steep.

Tropohumults (formerly Reddish-Brown Lateritic soils).—Humults that either have a horizon of clay accumulation that is relatively thin, a subsurface horizon having appreciable weatherable minerals, or both; formed in tropical climates.

U3-1—Tropohumults plus Dystrandepts and Rubble land, moderately sloping or steep.

U3-2—Tropohumults plus Tropepts, gently sloping to steep.

U3-3—Tropohumults plus Tropepts and Rock land, gently sloping to steep.

UDULTS.—Ultisols that are usually moist and that are relatively low in organic matter in the subsurface horizons; formed in humid climates that have short or no dry periods during the year; used for general farming, woodland and pasture, and cotton and tobacco in some parts.

Fragiudults (formerly Red-Yellow Podzolic soils with fragipan).—Udults that have a dense brittle but not indurated horizon (fragipan) in or below a horizon in which clay has accumulated.

U4-1—Fragiudults plus Paleudults, gently or moderately sloping.

Hapludults (formerly Red-Yellow Podzolic and some Gray-Brown Podzolic soils).—Udults that either have a subsurface horizon of clay accumulation that is relatively thin, a subsurface horizon having appreciable weatherable minerals, or both.

U5-1—Hapludults gently or moderately sloping.

U5-2—Hapludults, gently sloping to steep (mostly dissected plateaus).

U5-3—Hapludults, moderately sloping.

U5-4—Hapludults, steep.

U5-5—Hapludults plus Dystrochrepts, moderately sloping.

U5-6—Hapludults plus Dystrochrepts, steep.

U5-7—Hapludults plus Dystrochrepts, gently or moderately sloping, and Rock land, steep.

U5-8—Hapludults plus Fragiudults, gently sloping.

U5-9—Hapludults plus Hapludalfs and Dystrochrepts, steep.

U5-10—Hapludults plus Hapludalfs and Rock land, moderately sloping or steep.

U5-11—Hapludults plus Ochraquults, gently sloping.

U5-12—Hapludults plus Paleudults, moderately sloping.

U5-13—Hapludults plus Paleudults and Dystrochrepts, gently sloping to steep.

Paleudults (formerly Red-Yellow Podzolic soils).—Udults that have a thick horizon of clay accumulation without appreciable weatherable minerals.

U6-1—Paleudults, gently sloping.

U6-2—Paleudults plus Fragiudults, gently sloping.

U6-3—Paleudults, moderately sloping, plus Fragiudults, gently sloping.

U6-4—Paleudults plus Fragiudults, moderately sloping.

U6-5—Paleudults plus Hapludults, gently sloping.

U6-6—Paleudults plus Hapludults, both moderately sloping, and Fragiudults, gently sloping.

U6-7—Paleudults plus Ochraquults and Fragiaquults, gently or moderately sloping.

U6-8—Paleudults plus Paleudalfs, Hapludults, and Hapludalfs, gently or moderately sloping.

U6-9—Paleudults plus Quartzipsamments, gently sloping.

U6-10—Paleudults plus Quartzipsamments, moderately sloping.

U6-11—Paleudults plus Rhodudults, moderately sloping.

Rhodudults (formerly Reddish-Brown Lateritic soils).—Udults that have dark-red subsurface horizons of clay accumulation.[1]

XERULTS.—Ultisols that are relatively low in organic matter in the subsurface horizons. They are in climates with rainy winters but dry summers; during the warm season of the year, these soils are continually dry for a long period; used for range and woodland.

Haploxerults (formerly Reddish-Brown Lateritic and some Red-Yellow Podzolic soils).—Xerults that either have a subsurface horizon of clay accumulation that is relatively thin, a subsurface horizon having appreciable weatherable minerals, or both.

U7-1—Haploxerults plus Haploxerolls, Xerochrepts, and Xerumbrepts, moderately sloping to steep.

U7-2—Haploxerults plus Xerumbrepts and Xerorthents, steep.

VERTISOLS

Clayey soils that have wide, deep cracks when dry; most have distinct wet and dry periods throughout the year.

TORRERTS (formerly Grumusols).—Vertisols that are usually dry and have wide, deep cracks that remain open throughout the year in most years; used for range and some irrigated crops.

UDERTS.—Vertisols that are usually moist. They have wide, deep cracks that usually open and close one or more times during the year but do not remain open continuously for more than 2 months or intermittently for periods that total more than 3 months; used for cotton, corn, small grains, pasture and some rice.

Chromuderts (formerly Grumusols).—Uderts that have a brownish surface horizon.

V1-1—Chromuderts plus Eutrochrepts, gently sloping.

PELLUDERTS (formerly Grumusols).—Uderts that have a black or dark gray surface horizon.

V2-1—Pelluderts plus Pellusterts and Rendolls, gently sloping.

USTERTS.—Vertisols that have wide, deep cracks that usually open and close more than once during the year and remain open intermittently for periods that total more than 3 months but do not remain open continuously throughout the year; used for general crops and range plus some irrigated cotton, corn, citrus, and truck crops in the Rio Grande valley.

Chromusterts (formerly Grumusols).—Usterts that have a brownish surface horizon.

V3-1—Chromusterts plus Paleustalfs, gently sloping.

Pellusterts (formerly Grumusols).—Usterts that have a black or dark-gray surface horizon.

V4-1—Pellusterts plus Chromusterts, gently sloping.

V4-2—Pellusterts plus Camborthids and Torrerts, gently sloping.

XERERTS.—Vertisols that have wide, deep cracks that open and close once each year and remain open continuously for more than 2 months; used for irrigated small grains, hay, and pasture.

Chromoxererts (formerly Grumusols).—Xererts that have a brownish surface horizon.

V5-1—Chromoxererts plus Pelloxererts and Humaquepts, gently sloping.

Pelloxererts (formerly Grumusols).—Xererts that have a black or dark-gray surface horizon.[1]

MISCELLANEOUS LAND TYPES.—Barren or nearly barren areas that are mainly rock, ice, or salt and some included soils. Mostly not used for crops but some in warm, moist climates have vegetation.

X1—Rock land plus Andepts, steep.

X2—Rock land plus Andepts and Stony land, steep.

X3—Rock land plus Cryandepts, Cryumbrepts, Cryaquepts, and Cryorthods (shallow), all moderately sloping or steep (includes icefields and glaciers).

X4—Rock land plus Rough broken land, Andepts, and Tropepts, steep.

X5—Salt flats and Playas, gently sloping.

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[1] No map units are listed under this great group (or phase) because it is not the most extensive soil in any map unit.

POTENTIAL NATURAL VEGETATION

Vegetation may be defined as the mosaic of plant communities (phytocenoses) in the landscape. It consists of a given combination of life forms (trees, shrubs) and a given combination of taxa (genera, species) with relatively uniform ecological requirements. Potential natural vegetation is defined as the vegetation that would exist today if man were removed from the scene and if the plant succession after his removal were telescoped into a single moment. The time compression eliminates the effects of future climatic fluctuations, while the effects of man's earlier activities are permitted to stand. The potential natural vegetation is a particularly important object of research because it reveals the biological potential of all sites.

In contrast to the potential vegetation is the actual, or real vegetation, which occurs at the time of observation. It may be natural (not appreciably affected by man) or seminatural or cultural vegetation, depending on the degree of human influence. In many parts of the United States vegetation is now natural or is so well known that it is entirely feasible to determine the potential natural vegetation with a high degree of accuracy. In other parts, the potential natural vegetation of this country can be determined only approximately.

The identification of the potential natural vegetation rests on the degree of disturbance, the available amount and detail of information on the vegetation that was disturbed, and on remnants of the natural vegetation. The history of the United States is short, and the botanical exploration began early enough to permit a great deal of insight today into the nature of vegetation in most of the country. The two extremes are perhaps in Alaska and Hawaii.

In Alaska remoteness and a very sparse population have combined to preserve the vegetation. Even extensive fires cannot hide the potential natural vegetation, which is severely limited to relatively few types by extremely harsh environmental conditions. Introduced species are few, and disturbed vegetation types return to their original state when given an opportunity. One of the outstanding characteristics of the Alaskan vegetation is its uniformity over very large areas.

In Hawaii great complexity is the rule. More than two-thirds of all plant species on the Hawaiian Islands have been introduced. Some arrived long ago, others more recently; some spread fast, others more slowly. Some introduced species, such as the mesquite *(Prosopis pallida)* and the guava *(Psidium guayava),* have crowded out the native species and taken over their territory. Man has changed, removed, or replaced the vegetation. In addition, he introduced pigs and goats that soon spread without control into the hills and mountains where they became very destructive. Finally, the vegetation and its evolution are strongly affected by the age and the physical and chemical nature of individual lava flows that built up the islands. This volcanism occurred long ago in Kauai, in the west, but continues on the easternmost island of Hawaii.

THE UNITS OF VEGETATION

It is the presence and the particular proportion of life forms and of taxa that give a plant community its unique and unmistakable character. The life-form pattern gives a plant community its physiognomy and structure, whereas the species pattern accounts for the floristic composition. As these two features of life forms and taxa are basic and applicable without exception anywhere on earth, they have been selected here to serve exclusively as the criteria for establishing the units of vegetation. These criteria permit a uniform approach to the vegetation throughout the country and put the various parts of the country on a comparable basis. In addition, a vegetation map based exclusively on life forms and taxa remains open to continual revision, correction, and refinement. This is a valuable advantage.

The physiognomic types consist of easily recognizable categories. Usually, these categories occur over wide areas and are established without any difficulty. Only one, or very few, life forms are admitted in characterizing the physiognomy. If more than one life form is included, however, it may well be that different life forms will dominate in different areas covered by this type. For example, in the Southwest there are shrub savannas dominated in one area by shrubs with relatively little grass between densely growing bushes, whereas elsewhere this same type is dominated by grass with shrubs thinly scattered in the landscape. Variations may range from one extreme to the other. The extreme, however, should be an exception.

The floristic approach permits a choice among various levels, or ranks, of taxa. At the given map scale, the species level is too low. All vegetation units are here characterized by genera. Their maximum number of dominant genera was arbitrarily set at six.

As a result of using genera, units may seem to occur more than once. For example, there are oak forests in the East as well as in the West. The species are different, but this may not be evident on the map. The names of such types are elaborated in the legend to avoid confusion. Compare, for example, Appalachian oak forest *(Quercus;* legend item 95 on map) with Oregon oak woods *(Quercus;* legend item 22). This terminology alerts the reader that the two types of oak forests *(Quercus)* are unlike.

Several dominant genera in a given phytocenose may dominate in varying degrees. Thus, of genera A, B, and C in one phytocenose, it is understood that genus A may be more dominant in one part of an area, genus B may dominate in a second part, and genus C may dominate in a third part.

The types of vegetation are, therefore, not uniform throughout their area, and this lack of uniformity applies to both life forms and taxa. The small scale of the maps requires a degree of generalization that does not show local variation of a given vegetation type. In many areas a type occurs in its pure form, but commonly there are variations, inclusions, and complexes. These variations make a type more heterogeneous than appears on the maps. For example, numerous conifer bogs (legend item 85) are scattered as inclusions through much of the areas where types of legend items 98 and 99 predominate, although they are shown on the map only where their extent justifies it.

Inclusions and complexes within a vegetation type are the result of local conditions. As the conditions change, so will the vegetation. But another, broader aspect of the variations which is equally important is the fact that a vegetation type extends horizontally (in plains) and vertically (in mountains) from one set of environmental conditions to another. Thus, a type of vegetation may differ markedly at its opposite borders, be these northern and southern, upper and lower, drier and moister, or of some other kind. In view of the degree of generalization on these maps, a given vegetation type may, in fact, consist of several basic plant communities and represent clines of population. For example, the type in legend item 27 consists, at the highest altitudes, of open pine forests with *Pinus leiophylla* var. *chihuahuana* and *P. cembroides* as dominants. But the dominance of these species declines rapidly with decreasing altitudes, and they may disappear altogether near the lower altitudinal limits for this type. Such floristic gradients are common.

Finally, it happens that two types of vegetation occur together as transitions, or as mosaics. In a transition, the two types have mixed life forms and taxa. They share the available sites, as in legend item 28. The species of one plant community disappear gradually—that is, first one, then another—to be replaced little by little by the species of the other community. In contrast, the mosaics are so arranged that each of the two vegetation types involved retains its discrete character. The species of one type are not mixed with those of the other. Usually, islands of one type are embedded in a matrix of the other type; each type may be either matrix or island, depending on the relative extent of each. For example, the bluestem prairie (legend item 66) is treeless and dominated by tall grasses. Through this type, islands of oak-hickory forest (legend item 91) are scattered. Yet, in such a mosaic (legend item 73), each individual island consists of pure oak-hickory forest, and there is no blending or merging with the bluestem prairie. This is not a savanna with trees or shrubs scattered loosely over a grassland. Where two types of vegetation form a mosaic, each type retains its identity.

Transitions and mosaics have been kept to a minimum. Where they are shown, it is largely because not to do so would have seemed too gross a distortion. The fact that transitions and mosaics are shown does not imply a high degree of uniformity in the other types.

Lack of uniformity of the individual vegetation types is more pronounced in eastern United States than in the West. The mountainous terrain west of the 102d meridian causes the usual altitudinal zonation of vegetation, the contrasts between windward and leeward sides, and other features. The phytocenoses stand out more boldly, and vegetational boundaries can be very meaningful.

By comparison, the eastern part of this country is characterized by modest relief and few contrasts of any kind. Vegetation types there merge more gradually, and the establishment of types is often difficult.

Three overprinted symbols show the occurrence of junipers (J), Joshua-trees (Y), and groves of giant sequoias (S). The symbol for junipers refers to the genus *Juniperus* and implies different species in different regions. The symbol for Joshua-trees, on the other hand, represents an individual species, *Yucca brevifolia.* The symbols J and Y are distributed in their respective areas where convenient. Therefore, the location of a given symbol does not mean that the symbolized plants grow exactly there and not elsewhere. These plants are likely to grow anywhere throughout the area in which such symbols are shown.

The symbol S, representing *Sequoia wellingtonia,* is different. The small groves of these spectacular trees do not form a type of vegetation of sufficient extent to be shown here. They must, therefore, be indicated by symbols which are shown on the map exactly where the groves occur.

The dominant genera listed in the title of each legend item are joined by hyphens to indicate that they belong together and form a vegetation type of which each is an important part. The alpine meadows (legend item 45), however, are an exception. All alpine meadows of the high altitudes in the West are here combined into a single type. The genera enumerated in the title of this legend item do not form a single type and do not necessarily occur together; they do not all belong together. To maintain one vegetation type for this map and at the same time to indicate that the connection between the listed taxa is very loose, their names are separated by commas rather than joined by hyphens.

The vegetation types here presented are not units of some classification in an hierarchic sense, and therefore all legend items are placed on the same level. This classless approach is not affected by the grouping of vegetation types into physiognomic and floristic units such as needleleaf forests and creosote bush. These broad categories may serve as nuclei for a classification, but as used here they are only a device to assist the reader in establishing and locating a type more readily.

THE MAP LEGEND

The legend is concise and simple. The name of every item in the legend consists of two parts. The first part of the names is given in English. Names of vegetation types have evolved in various parts of the country. They are not scientific but rather a part of the folklore of their respective areas arising from popular usage as a kind of tradition. Names like chaparral, pocosin, shinnery, or cross timbers enrich our terminology and give their types a regional flavor. Many of these terms are historically interesting. In some areas it became desirable to introduce new names. Where this was not feasible and where no local names have evolved, the Latin names of the dominant genera have been translated into English. The second part of names in the legend items consists of the scientific botanical terms for the leading genus or genera. The consistent use of generic names ties the legend together and makes the legend items meaningful for readers everywhere. This, however, does not apply to the English part of the legend items where the use of species names is sometimes desirable and sometimes inevitable. For example, buffalo grass and creosote bush are the only species of their respective genera in this country, and the English names are the same for genus and species. Cenizo, sand pine, and others are a matter of convenience.

Terminology always presents problems, and some of these can be solved only arbitrarily. Many common terms have evolved. They may seem very clear, yet clarity often depends on the type of vegetation and the region where it is used. The term "forest" is clear and simple. It implies a type of vegetation dominated by trees to such an extent that they give the vegetation its basic character. Trees are life forms, and most readers will at once visualize sugar maples, tuliptrees, cottonwoods, and similar unequivocal examples. However, it may be impossible to distinguish between the tree and shrub forms of the paloverde *(Cerdidium)* in Arizona and the mesquite *(Prosopis)* in Texas and elsewhere. The selection of English terms as used here is based primarily on local usage.

Similar problems arise with regard to herbaceous vegetation. In central United States, some authors distinguish prairies from high plains. This is not acceptable because the terms are not comparable. One describes vegetation, the other a physiographic province. The term "prairie" was introduced by the early French explorers who applied it to the grassland vegetation between the forests of the east and those of the Rocky Mountains. Later, and in harmony with this, people spoke of the Prairie States and, in Canada, of the Prairie Provinces. On this map, the term "prairie" is therefore used through this area. Farther west, "prairie" was retained in only one area (legend item 48) where the vegetation is transitional between the western and the central types. Elsewhere, the term "steppe" has been used for the grassy vegetation types of the more arid regions, a usage not unlike that in southeastern Russia and southwestern Siberia where this term historically evolved. On this map the term "desert" has been applied only to areas where the vegetation is either absent or at least very sparse.

In general, the names of shrubs and forbs adopted herein are those used by scientists considered most authoritative on the vegetation of their respective regions. Taxonomic plant names, however, may change sometimes, and authors may disagree on which names should be used, but that problem can usually be solved by consulting the following source material:

Check List of Native and Naturalized Trees of the United States, Elbert L. Little, Jr.

Manual of the Grasses of the United States, A. S. Hitchcock and Agnes Chase.

These two authorities are nationwide in scope (excluding Hawaii) and have been followed throughout the continental United States.

The map of the conterminous (48) States in the National Atlas is a reduced and slightly modified version of the map of the "Potential Natural Vegetation of the Conterminous United States," published in 1964 by the American Geographical Society of New York, at a scale of 1:3,168,000. The larger map is accompanied by an illustrated manual in which the vegetation is described more elaborately.

THE COLORS

The best known method for using colors on vegetation maps is one developed by Henri Gaussen of Toulouse, France, but two arguments prompt against using this renowned method here. First, Gaussen uses colors to show vegetation and climate together. This approach is not applicable here because vegetation is shown exclusively. Second, Gaussen assumes that the boundaries of climate and vegetation coincide. In the United States there are numerous instances where this is not true. Nevertheless, the use of colors on the vegetation maps in this atlas illustrate certain Gaussenian influences.

Thus, the spruce-cedar-hemlock forest (legend item 1) along the rainy northwest coast is blue; the creosote bush-bur sage (36) of the southwestern desert is red; the more mesic eastern forests are green and the less mesic grasslands are yellow; and the hot and humid mangrove forest (96) is purple.

POTENTIAL NATURAL VEGETATION

A. W. Küchler
University of Kansas, 1966

Albers Equal Area Projection

SCALE 1:7,500,000

For information on Alaska and Hawaii see page 92

WESTERN FORESTS

NEEDLELEAF FORESTS

1	Spruce-cedar-hemlock forest	*(Picea-Thuja-Tsuga)*
2	Cedar-hemlock-Douglas fir forest	*(Thuja-Tsuga-Pseudotsuga)*
3	Silver fir-Douglas fir forest	*(Abies-Pseudotsuga)*
4	Fir-hemlock forest	*(Abies-Tsuga)*
5	Mixed conifer forest	*(Abies-Pinus-Pseudotsuga)*
6	Redwood forest	*(Sequoia-Pseudotsuga)*
7	Red fir forest	*(Abies)*
8	Lodgepole pine-subalpine forest	*(Pinus-Tsuga)*
9	Pine-cypress forest	*(Pinus-Cupressus)*
10	Western ponderosa forest	*(Pinus)*
11	Douglas fir forest	*(Pseudotsuga)*
12	Cedar-hemlock-pine forest	*(Thuja-Tsuga-Pinus)*
13	Grand fir-Douglas fir forest	*(Abies-Pseudotsuga)*
14	Western spruce-fir forest	*(Picea-Abies)*
15	Eastern ponderosa forest	*(Pinus)*
16	Black Hills pine forest	*(Pinus)*
17	Pine-Douglas fir forest	*(Pinus-Pseudotsuga)*
18	Arizona pine forest	*(Pinus)*
19	Spruce-fir-Douglas fir forest	*(Picea-Abies-Pseudotsuga)*
20	Southwestern spruce-fir forest	*(Picea-Abies)*
21	Juniper-pinyon woodland	*(Juniperus-Pinus)*

BROADLEAF FORESTS

22	Oregon oakwoods	*(Quercus)*
23	Mesquite bosques	*(Prosopis)*

BROADLEAF AND NEEDLELEAF FORESTS

24	Mosaic of numbers 2 and 22	
25	California mixed evergreen forest	*(Quercus-Arbutus-Pseudotsuga)*
26	California oakwoods	*(Quercus)*
27	Oak-juniper woodland	*(Quercus-Juniperus)*
28	Transition between 27 and 31	

	Juniperus spp. (juniper, red cedar)
s	*Sequoia wellingtonia* (giant sequoia)
	Yucca brevifolia (Joshua tree)

WESTERN SHRUB AND GRASSLAND

SHRUB

29	Chaparral	*(Adenostoma-Arctostaphylos-Ceanothus)*
30	Coastal sagebrush	*(Salvia-Eriogonum)*
31	Mountain mahogany-oak scrub	*(Cercocarpus-Quercus)*
32	Great Basin sagebrush	*(Artemisia)*
33	Blackbrush	*(Coleogyne)*
34	Saltbush-greasewood	*(Atriplex-Sarcobatus)*
35	Creosote bush	*(Larrea)*
36	Creosote bush-bur sage	*(Larrea-Franseria)*
37	Palo verde-cactus shrub	*(Cercidium-Opuntia)*
38	Ceniza shrub	*(Leucophyllum-Larrea-Prosopis)*

39	Desert: vegetation largely absent

GRASSLAND

40	Fescue-oatgrass	*(Festuca-Danthonia)*
41	California steppe	*(Stipa)*
42	Tule marshes	*(Scirpus-Typha)*
43	Fescue-wheatgrass	*(Festuca-Agropyron)*
44	Wheatgrass-bluegrass	*(Agropyron-Poa)*
45	Alpine meadows and barren	*(Agrostis, Carex, Festuca, Poa)*
46	Fescue-mountain muhly prairie	*(Festuca-Muhlenbergia)*
47	Grama-galleta steppe	*(Bouteloua-Hilaria)*
48	Grama-tobosa prairie	*(Bouteloua-Hilaria)*

SHRUB AND GRASSLAND COMBINATIONS

49	Sagebrush steppe	*(Artemisia-Agropyron)*
50	Wheatgrass-needlegrass shrubsteppe	*(Agropyron-Stipa-Artemisia)*
51	Galleta-three awn shrubsteppe	*(Hilaria-Aristida)*
52	Grama-tobosa shrubsteppe	*(Bouteloua-Hilaria-Larrea)*
53	Trans-Pecos shrub savanna	*(Flourensia-Larrea)*
54	Mesquite-acacia-savanna	*(Andropogon-Setaria-Prosopis-Acacia)*
55	Mesquite-live oak savanna	*(Andropogon-Prosopis-Quercus)*

CENTRAL AND EASTERN GRASSLANDS

GRASSLAND

56	Foothills prairie	*(Agropyron-Festuca-Stipa)*
57	Grama-needlegrass-wheatgrass	*(Bouteloua-Stipa-Agropyron)*
58	Grama-buffalo grass	*(Bouteloua-Buchloë)*
59	Wheatgrass-needlegrass	*(Agropyron-Stipa)*
60	Wheatgrass-bluestem-needlegrass	*(Agropyron-Andropogon-Stipa)*
61	Wheatgrass-grama-buffalo grass	*(Agropyron-Bouteloua-Buchloë)*
62	Bluestem-grama prairie	*(Andropogon-Bouteloua)*
63	Sandsage-bluestem prairie	*(Artemisia-Andropogon)*
64	Shinnery	*(Quercus-Andropogon)*
65	Northern cordgrass prairie	*(Distichlis-Spartina)*
66	Bluestem prairie	*(Andropogon-Panicum-Sorghastrum)*
67	Nebraska Sandhills prairie	*(Andropogon-Calamovilla)*
68	Blackland prairie	*(Andropogon-Stipa)*
69	Bluestem-sacahuista prairie	*(Andropogon-Spartina)*
70	Southern cordgrass prairie	*(Spartina)*
71	Palmetto prairie	*(Serenoa-Aristida)*

GRASSLAND AND FOREST COMBINATIONS

72	Oak savanna	*(Quercus-Andropogon)*
73	Mosaic of numbers 66 and 91	
74	Cedar glades	*(Quercus-Juniperus-Sporobolus)*
75	Cross timbers	*(Quercus-Andropogon)*
76	Mesquite-buffalo grass	*(Bouteloua-Buchloë-Prosopis)*
77	Juniper-oak savanna	*(Andropogon-Quercus-Juniperus)*
78	Mesquite-oak savanna	*(Andropogon-Prosopis-Quercus)*
79	Fayette prairie	*(Andropogon-Buchloë)*
80	Blackbelt	*(Liquidambar-Quercus-Juniperus)*
81	Live oak-sea oats	*(Quercus-Uniola)*
82	Cypress savanna	*(Taxodium-Mariscus)*
83	Everglades	*(Mariscus and Magnolia-Persea)*

EASTERN FORESTS

NEEDLELEAF FORESTS

84	Great Lakes spruce-fir forest	*(Picea-Abies)*
85	Conifer bog	*(Picea-Larix-Thuja)*
86	Great Lakes pine forest	*(Pinus)*
87	Northeastern spruce-fir forest	*(Picea-Abies)*
88	Southeastern spruce-fir forest	*(Picea-Abies)*

BROADLEAF FORESTS

89	Northern floodplain forest	*(Populus-Salix-Ulmus)*
90	Maple-basswood forest	*(Acer-Tilia)*
91	Oak-hickory forest	*(Quercus-Carya)*
92	Elm-ash forest	*(Ulmus-Fraxinus)*
93	Beech-maple forest	*(Fagus-Acer)*
94	Mixed mesophytic forest	*(Acer-Aesculus-Fagus-Liriodendron-Quercus-Tilia)*
95	Appalachian oak forest	*(Quercus)*
96	Mangrove	*(Avicennia-Rhizophora)*

BROADLEAF AND NEEDLELEAF FORESTS

97	Northern hardwoods	*(Acer-Betula-Fagus-Tsuga)*
98	Northern hardwoods-fir forest	*(Acer-Betula-Abies-Tsuga*
99	Northern hardwoods-spruce forest	*(Acer-Betula-Fagus-Picea-Tsuga)*
100	Northeastern oak-pine forest	*(Quercus-Pinus)*
101	Oak-hickory-pine forest	*(Quercus-Carya-Pinus)*
102	Southern mixed forest	*(Fagus-Liquidambar-Magnolia-Pinus-Quercus)*
103	Southern floodplain forest	*(Quercus-Nyassa-Taxodium)*
104	Pocosin	*(Pinus-Ilex)*
105	Sand pine scrub	*(Pinus-Quercus)*
106	Sub-tropical pine forest	*(Pinus)*

POTENTIAL NATURAL VEGETATION OF ALASKA

A. W. Küchler
University of Kansas, 1966

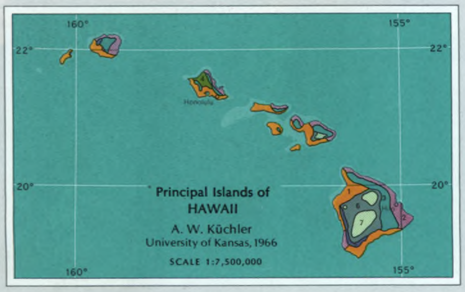
Albers Equal Area Projection

SCALE 1:7,500,000

0 100 200 300 MILES
0 100 200 300 400 KILOMETERS

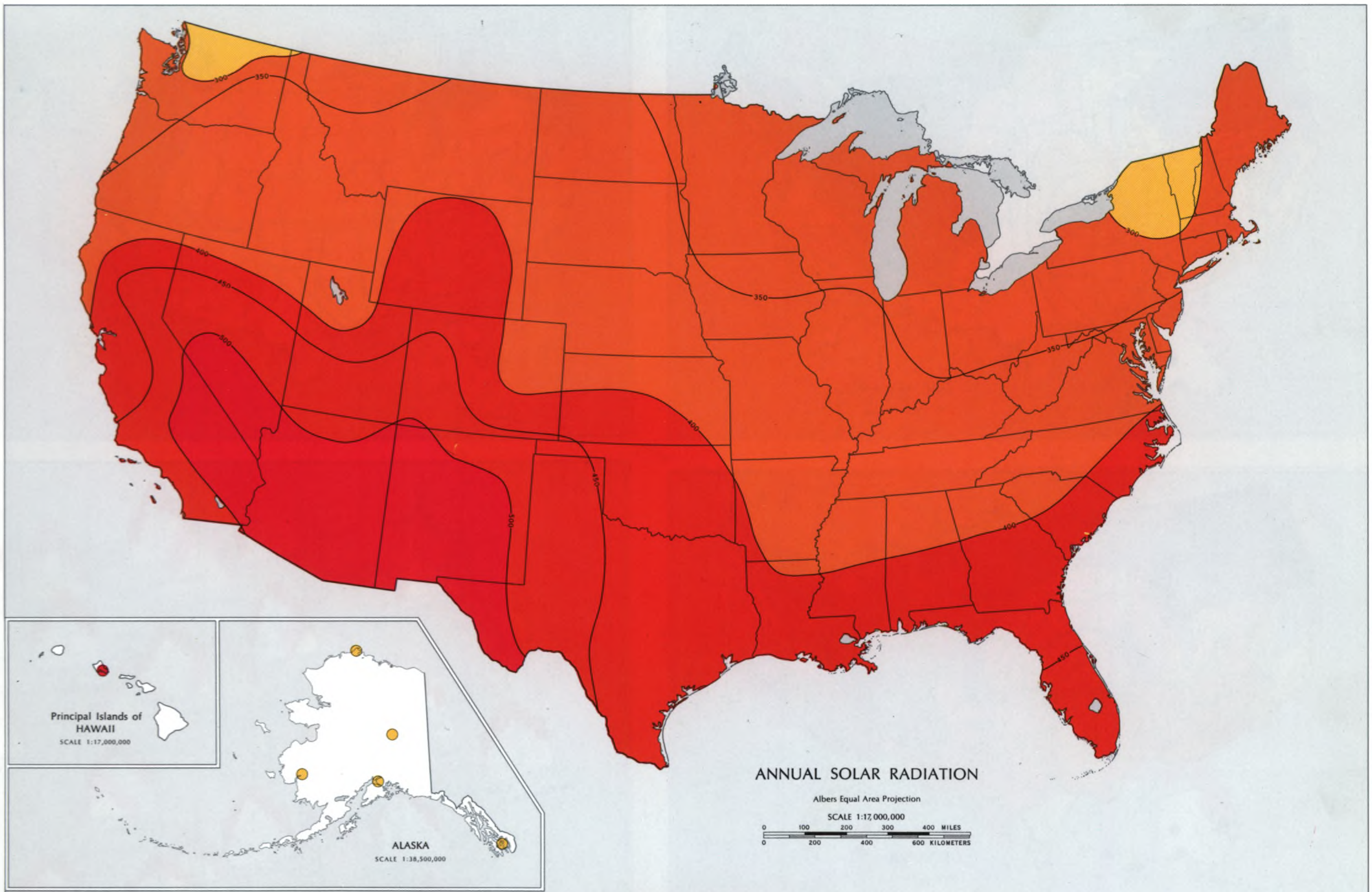
1	Hemlock-spruce forest (*Tsuga-Picea*)
2	Spruce-birch forest (*Picea-Betula*)
3	Black spruce forest (*Picea*)
4	Muskeg (*Eriophorum-Sphagnum-Betula*)
5	Alder thickets (*Alnus*)
6	Cottonsedge tundra (*Eriophorum*)
7	Watersedge tundra (*Carex*)
8	Dryas meadows and barren (*Dryas-Carex-Betula*)
9	Aleutian meadows (*Calamagrostis-Anemone*)
10	Aleutian heath and barren (*Empetrum-Vaccinium*)

POTENTIAL NATURAL VEGETATION OF HAWAII



Principal Islands of HAWAII
A. W. Küchler
University of Kansas, 1966
SCALE 1:7,500,000

1	Sclerophyllous forest, shrubland, and grassland (*Heteropogon-Opuntia-Prosopis*)
2	Guava mixed forest (*Aleurites-Hibiscus-Mangifera-Psidium-Schinus*)
3	Ohia lehua forest (*Metrosideros-Cibotium*)
4	Lama-manele forest (*Diospyros-Sapindus*)
5	Koa forest (*Acacia*)
6	Koa-mamani parkland (*Acacia-Deschampsia-Myoporum-Sophora*)
7	Grassland, microphyllous shrubland, and barren (*Deschampsia-Styphelia-Vaccinium*)



ANNUAL SOLAR RADIATION

Albers Equal Area Projection

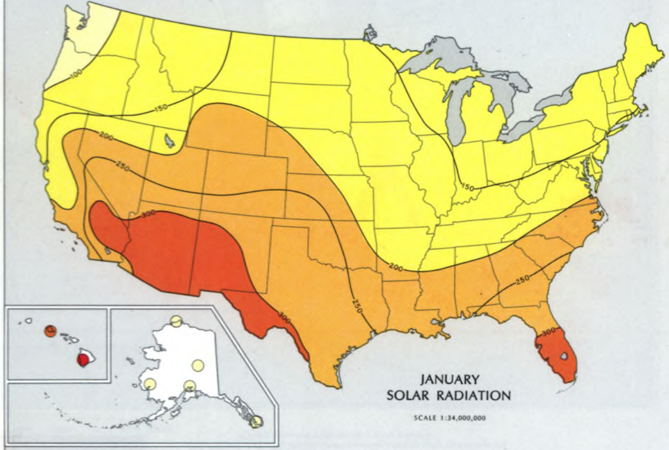
Adapted from 1:20,000,000 and 1:30,000,000-scale maps by Environmental Data Service, Environmental Science Services Administration based upon data for varying periods up to 46 years in length, ending in 1962

Incoming radiation in langleys; i.e., gram calories per square centimeter

100 200 300 400 500 600 700 LANGLEYS

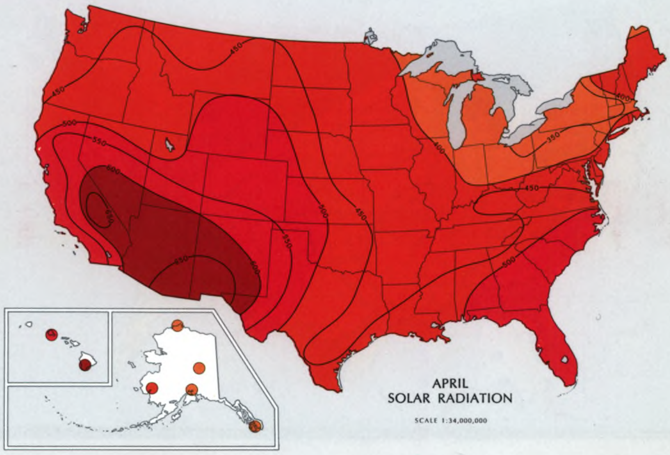
MEAN SOLAR RADIATION

Based on mean daily readings



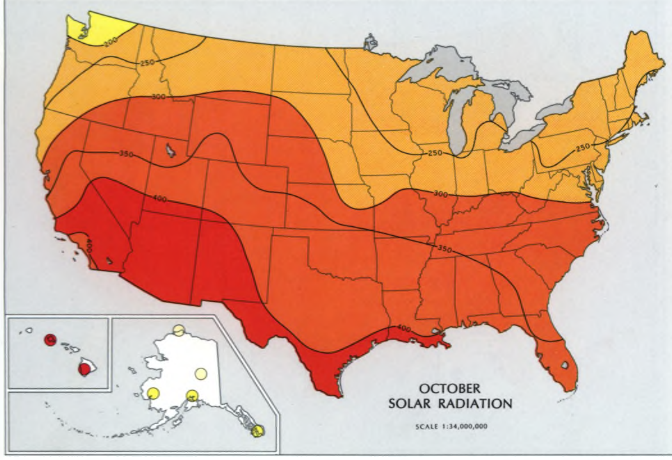
JANUARY SOLAR RADIATION

SCALE 1:34,000,000



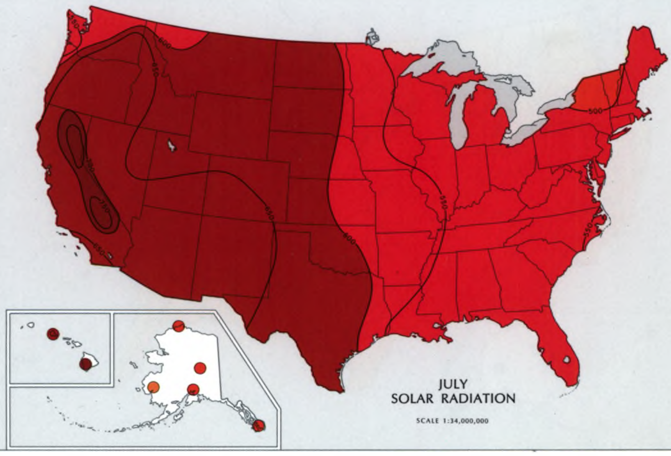
APRIL SOLAR RADIATION

SCALE 1:34,000,000



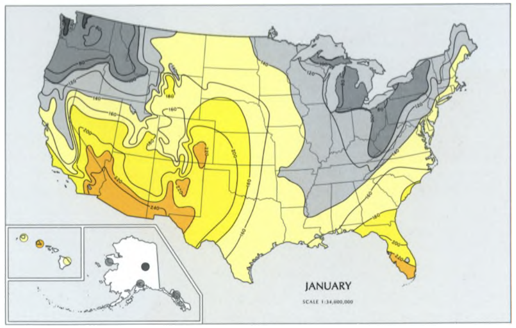
OCTOBER SOLAR RADIATION

SCALE 1:34,000,000



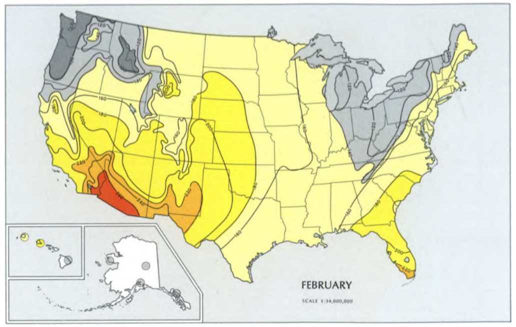
JULY SOLAR RADIATION

SCALE 1:34,000,000



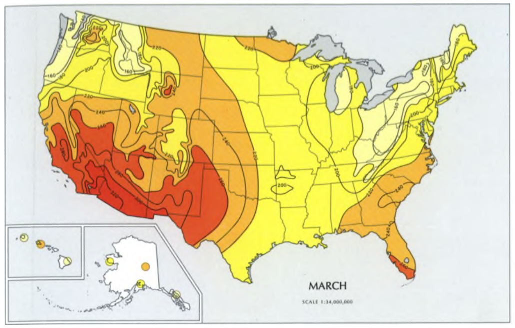
JANUARY

SCALE 1:34,000,000



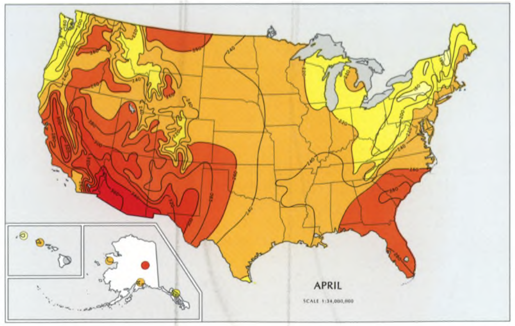
FEBRUARY

SCALE 1:34,000,000



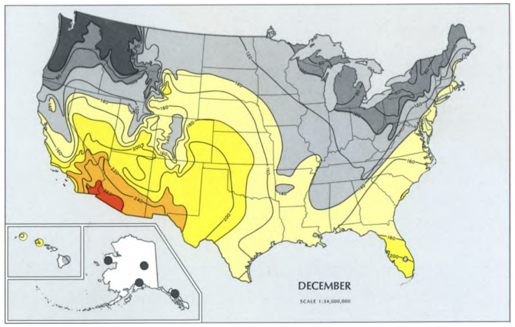
MARCH

SCALE 1:34,000,000



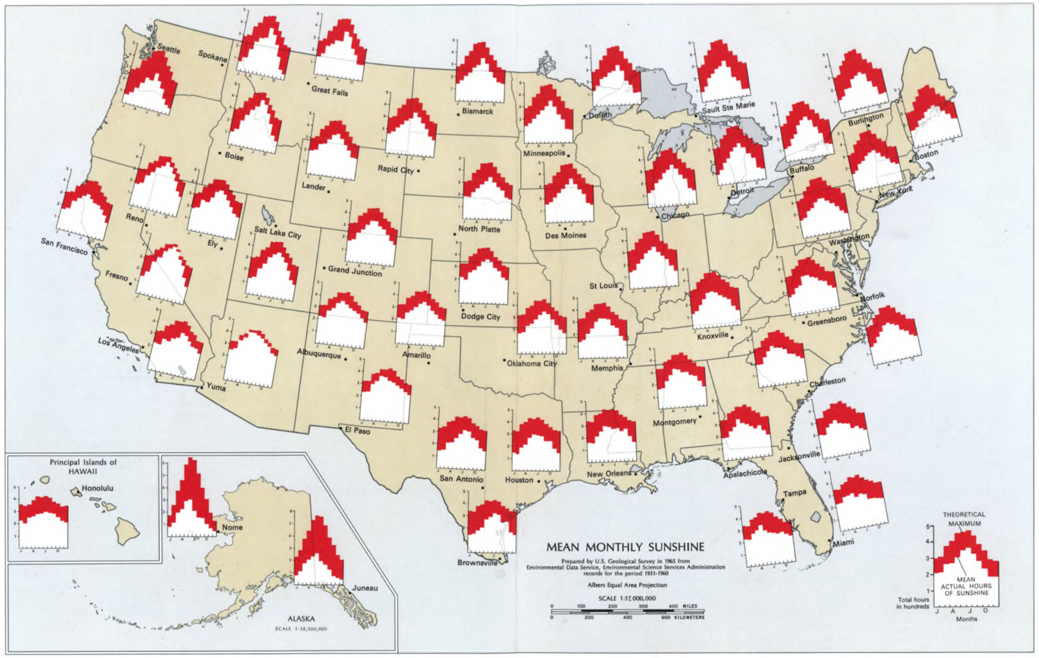
APRIL

SCALE 1:34,000,000



DECEMBER

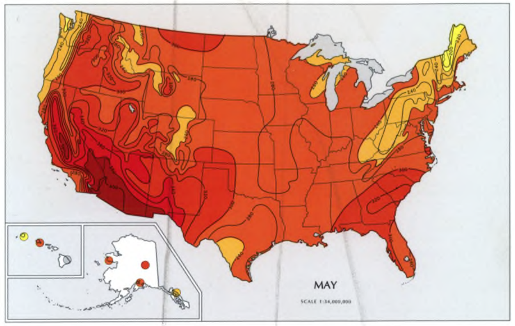
SCALE 1:34,000,000



MEAN MONTHLY SUNSHINE

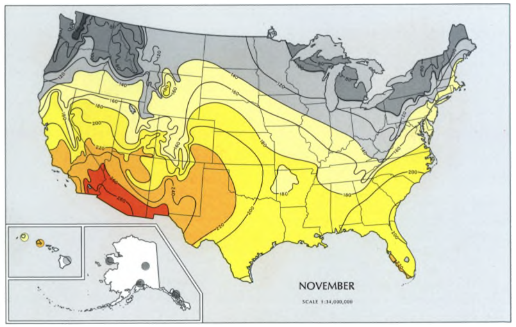
Prepared by U.S. Geological Survey in 1965 from
Environmental Data Service, Environmental Science Services Administration
records for the period 1931-1960

Albers Equal Area Projection



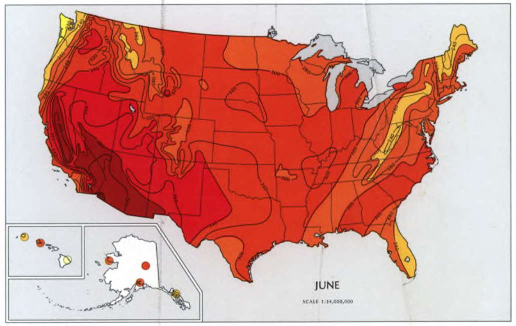
MAY

SCALE 1:34,000,000



NOVEMBER

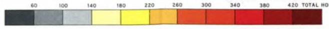
SCALE 1:34,000,000



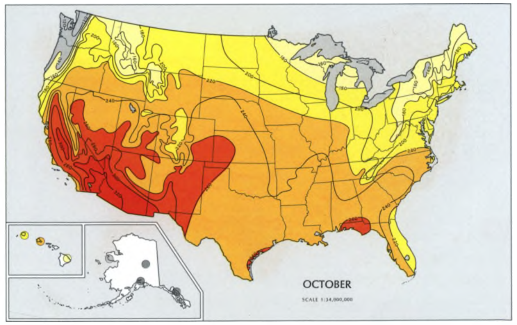
JUNE

SCALE 1:34,000,000

Adapted from 1:30,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

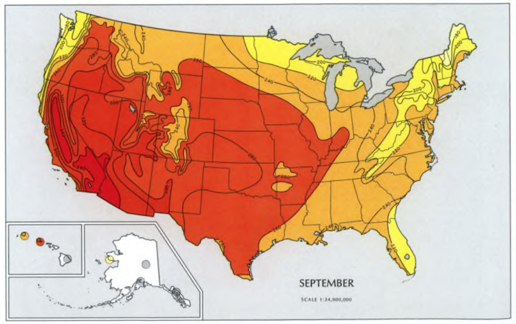


MEAN
MONTHLY SUNSHINE



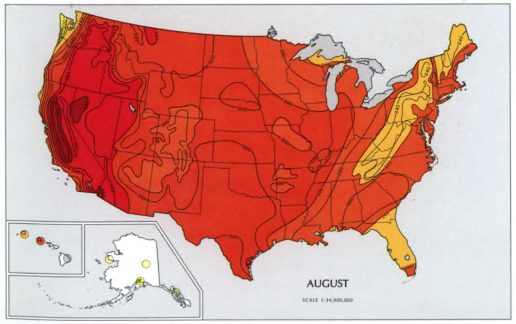
OCTOBER

SCALE 1:34,000,000



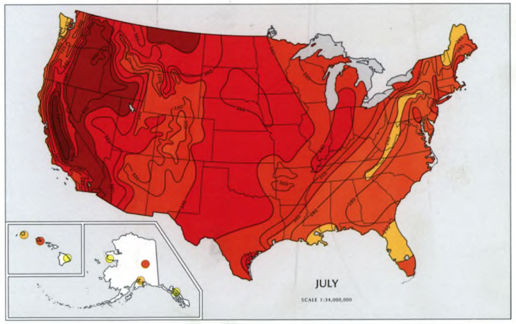
SEPTEMBER

SCALE 1:34,000,000



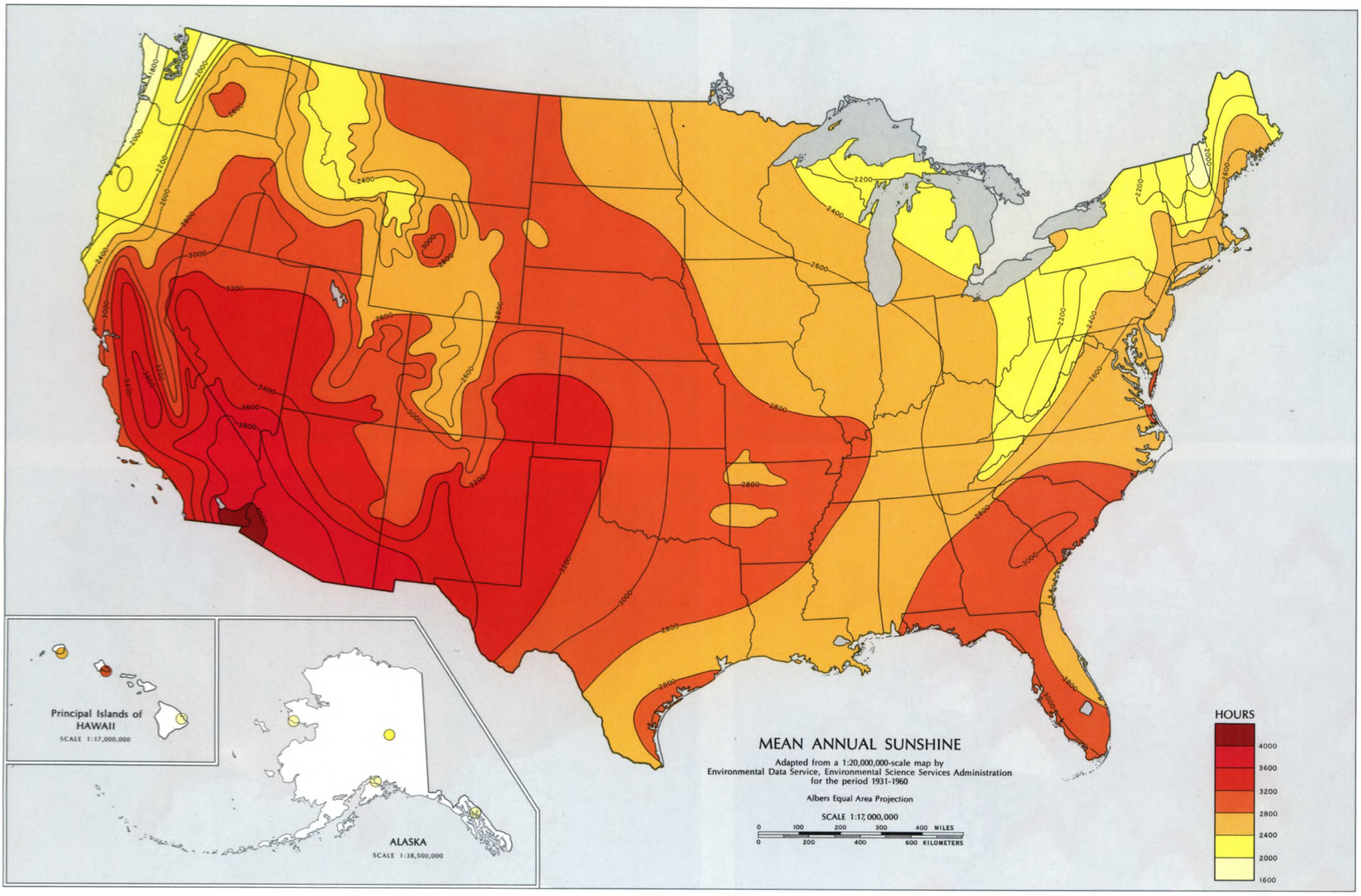
AUGUST

SCALE 1:34,000,000



JULY

SCALE 1:34,000,000



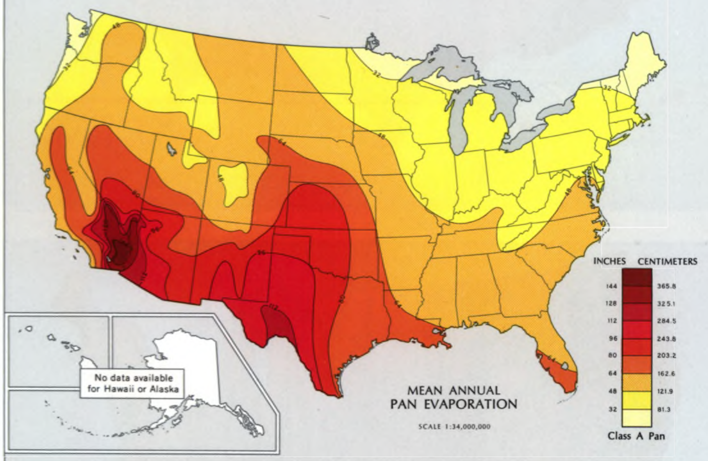
MEAN ANNUAL SUNSHINE

Adapted from a 1:20,000,000-scale map by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

Albers Equal Area Projection

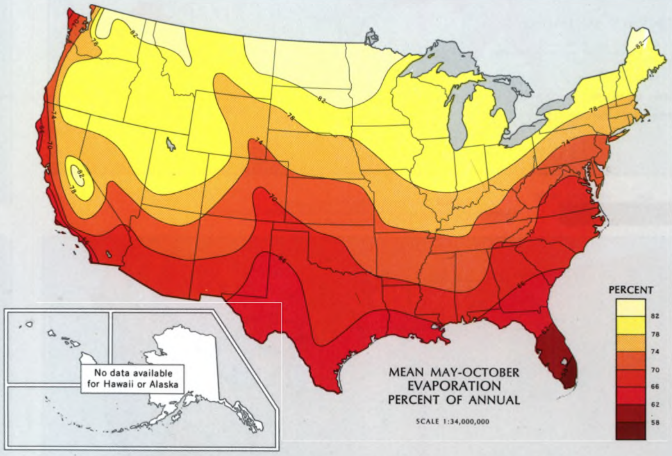
EVAPORATION

Adapted from a 1:20,000,000-scale map by Environmental Data Service,
Environmental Science Services Administration for the period 1931-1960



MEAN ANNUAL
PAN EVAPORATION

SCALE 1:34,000,000



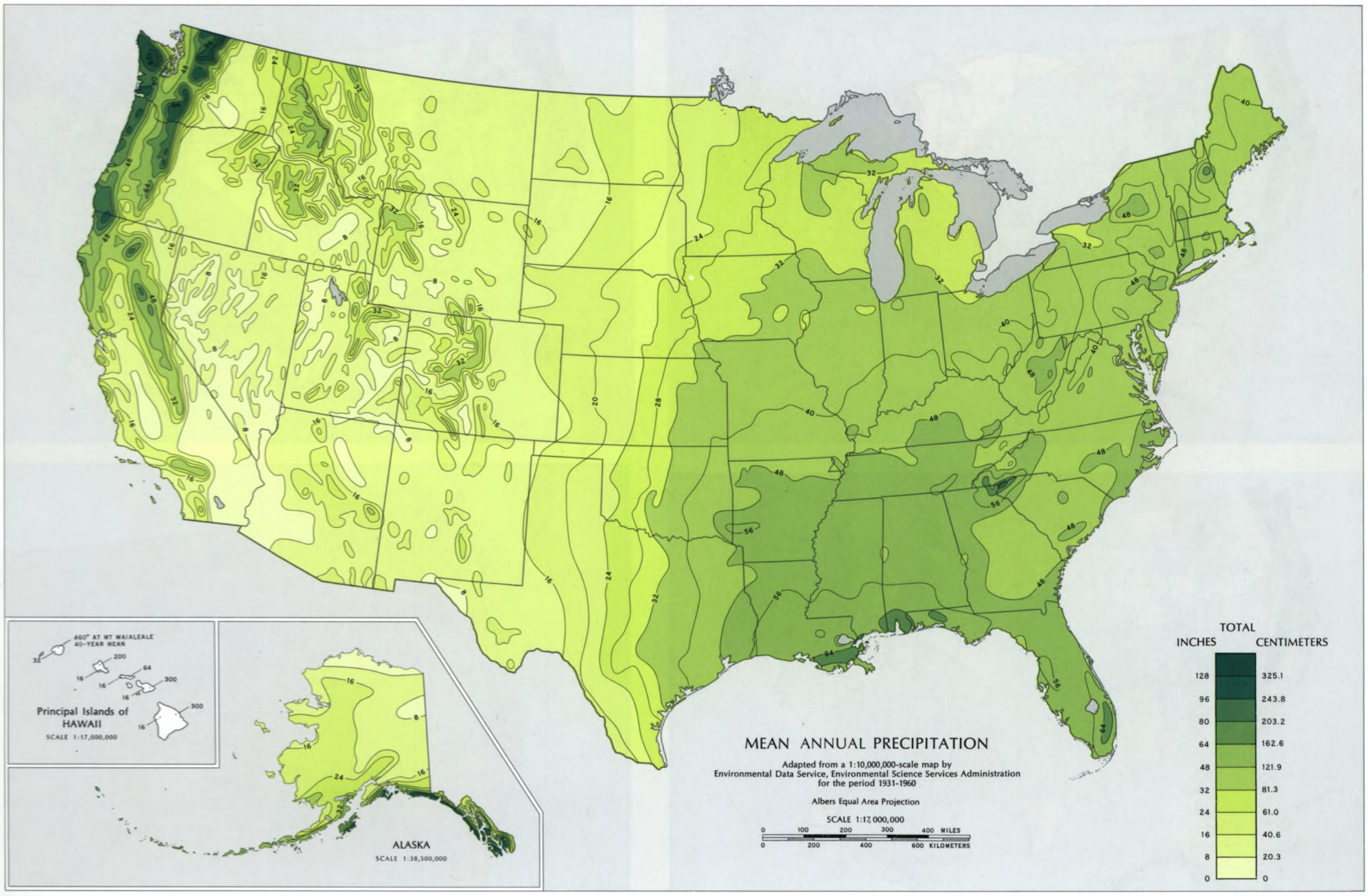
MEAN MAY-OCTOBER
EVAPORATION
PERCENT OF ANNUAL

SCALE 1:34,000,000

Class A pan evaporation is defined as the measured water loss from a metal pan four feet in diameter by ten inches deep and set very close to the ground.

The rate of evaporation, especially during the warmer months of April through October, has an important impact on water storage in reservoirs and on both irrigated and non-irrigated agriculture.

Evaporation can be considered as the opposite of precipitation. It is controlled by weather factors such as temperature, sunshine, and atmospheric humidity.



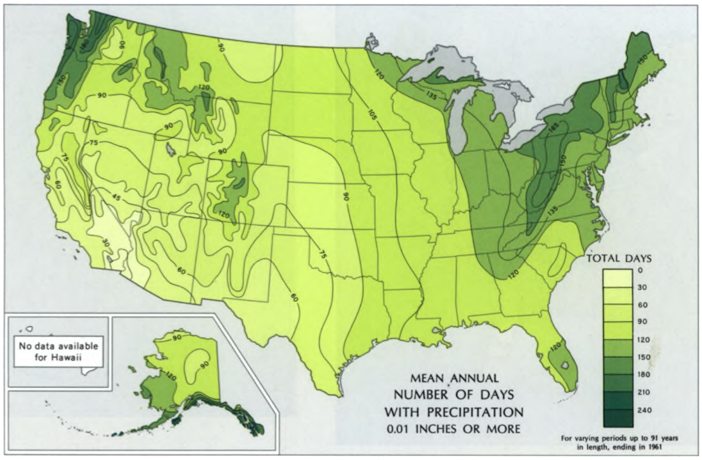
MEAN ANNUAL PRECIPITATION

Adapted from a 1:10,000,000-scale map by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

Albers Equal Area Projection

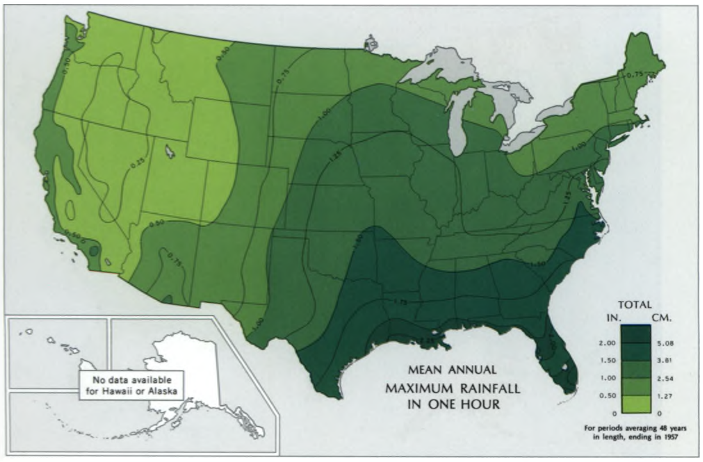
FREQUENCY AND INTENSITY

Adapted from 1:20,000,000 and 1:10,000,000-scale maps by Environmental Data Service,
Environmental Science Services Administration



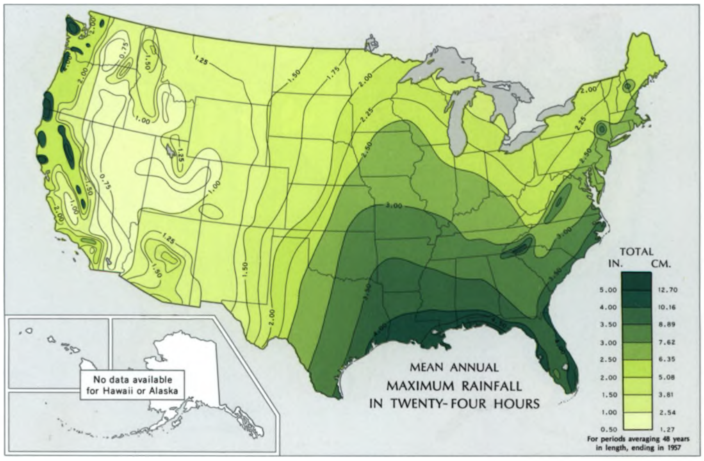
MEAN ANNUAL
NUMBER OF DAYS
WITH PRECIPITATION
0.01 INCHES OR MORE

For varying periods up to 91 years
in length, ending in 1961



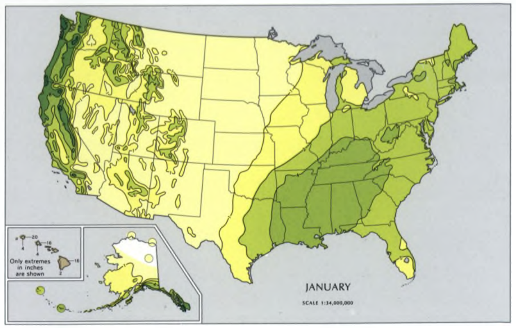
MEAN ANNUAL
MAXIMUM RAINFALL
IN ONE HOUR

For periods averaging 48 years
in length, ending in 1957



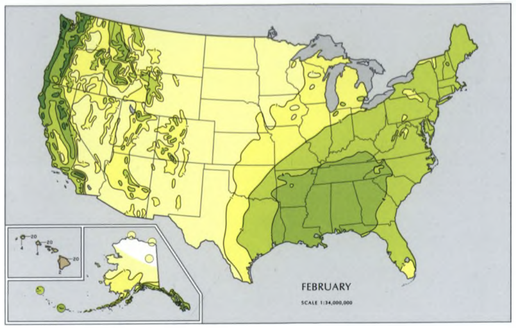
MEAN ANNUAL
MAXIMUM RAINFALL
IN TWENTY-FOUR HOURS

For periods averaging 48 years
in length, ending in 1957



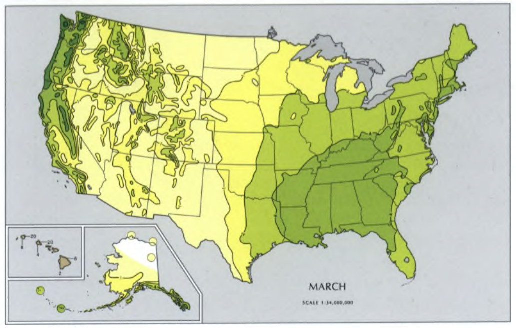
JANUARY

SCALE 1:34,000,000



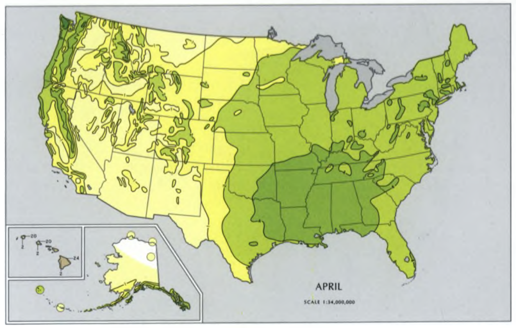
FEBRUARY

SCALE 1:34,000,000



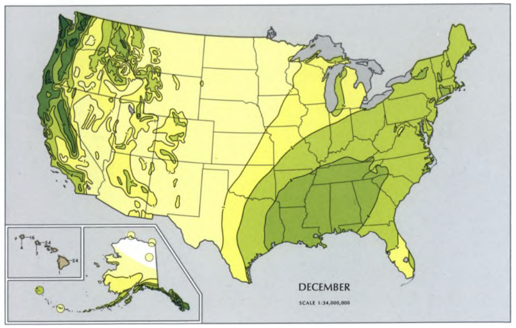
MARCH

SCALE 1:34,000,000



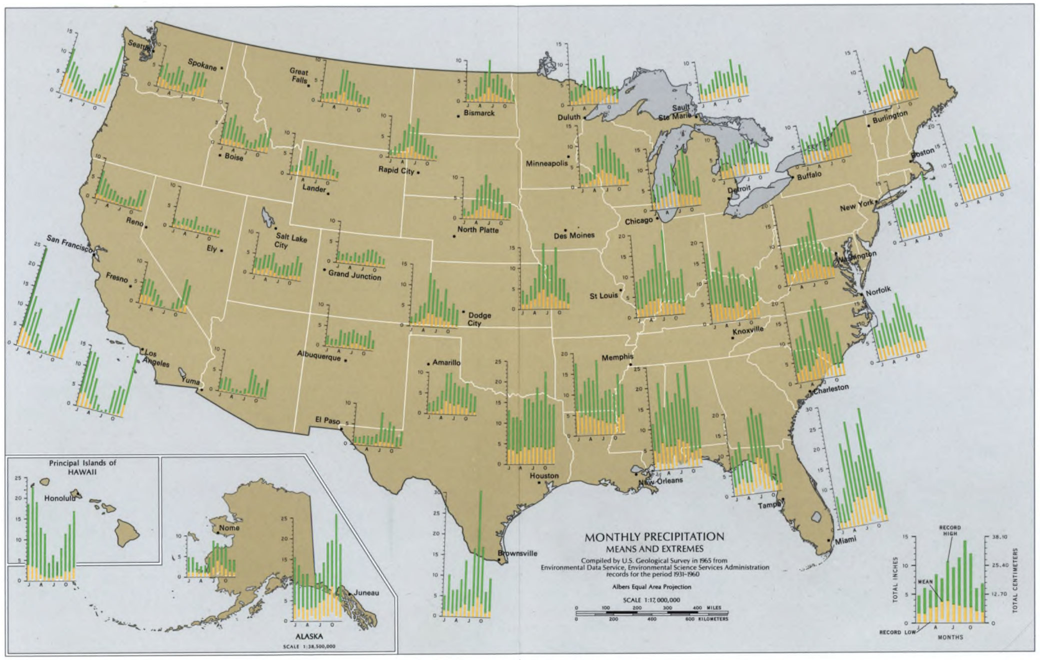
APRIL

SCALE 1:34,000,000



DECEMBER

SCALE 1:34,000,000

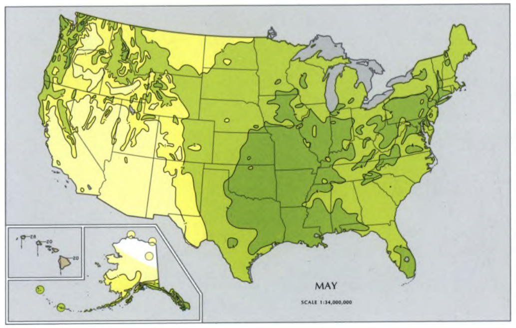


MONTHLY PRECIPITATION
MEANS AND EXTREMES

Compiled by U.S. Geological Survey in 1965 from
Environmental Data Service, Environmental Science Services Administration
records for the period 1931–1960

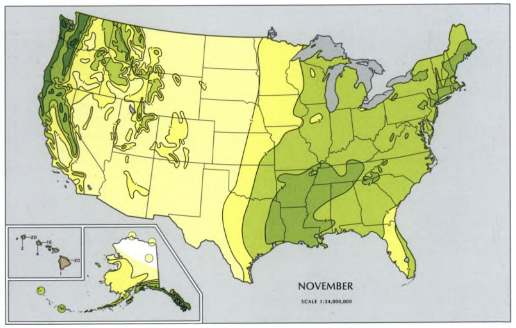
Albers Equal Area Projection

SCALE 1:17,000,000



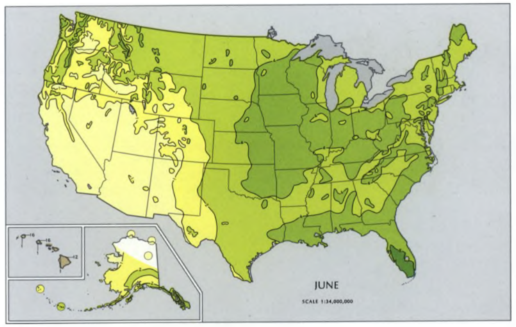
MAY

SCALE 1:34,000,000



NOVEMBER

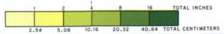
SCALE 1:34,000,000



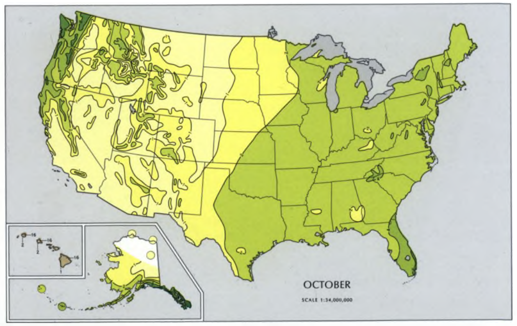
JUNE

SCALE 1:34,000,000

Adapted from 1:5,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1931–1960

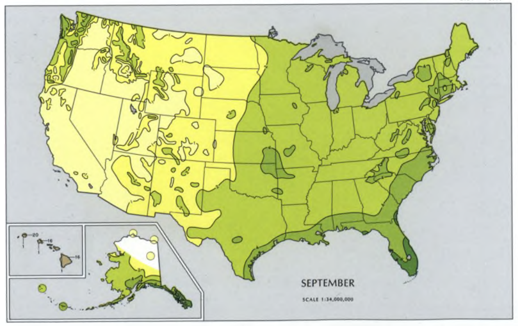


MEAN
MONTHLY PRECIPITATION



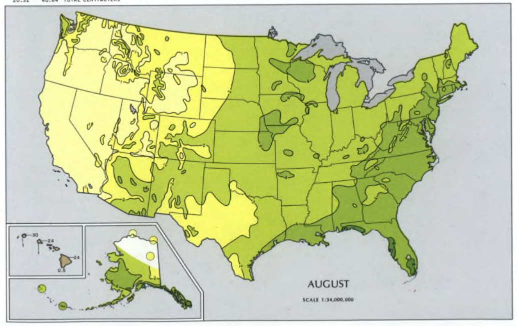
OCTOBER

SCALE 1:34,000,000



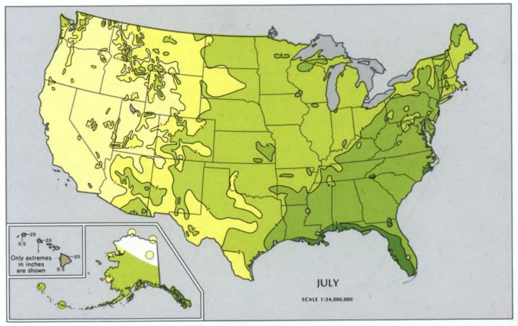
SEPTEMBER

SCALE 1:34,000,000



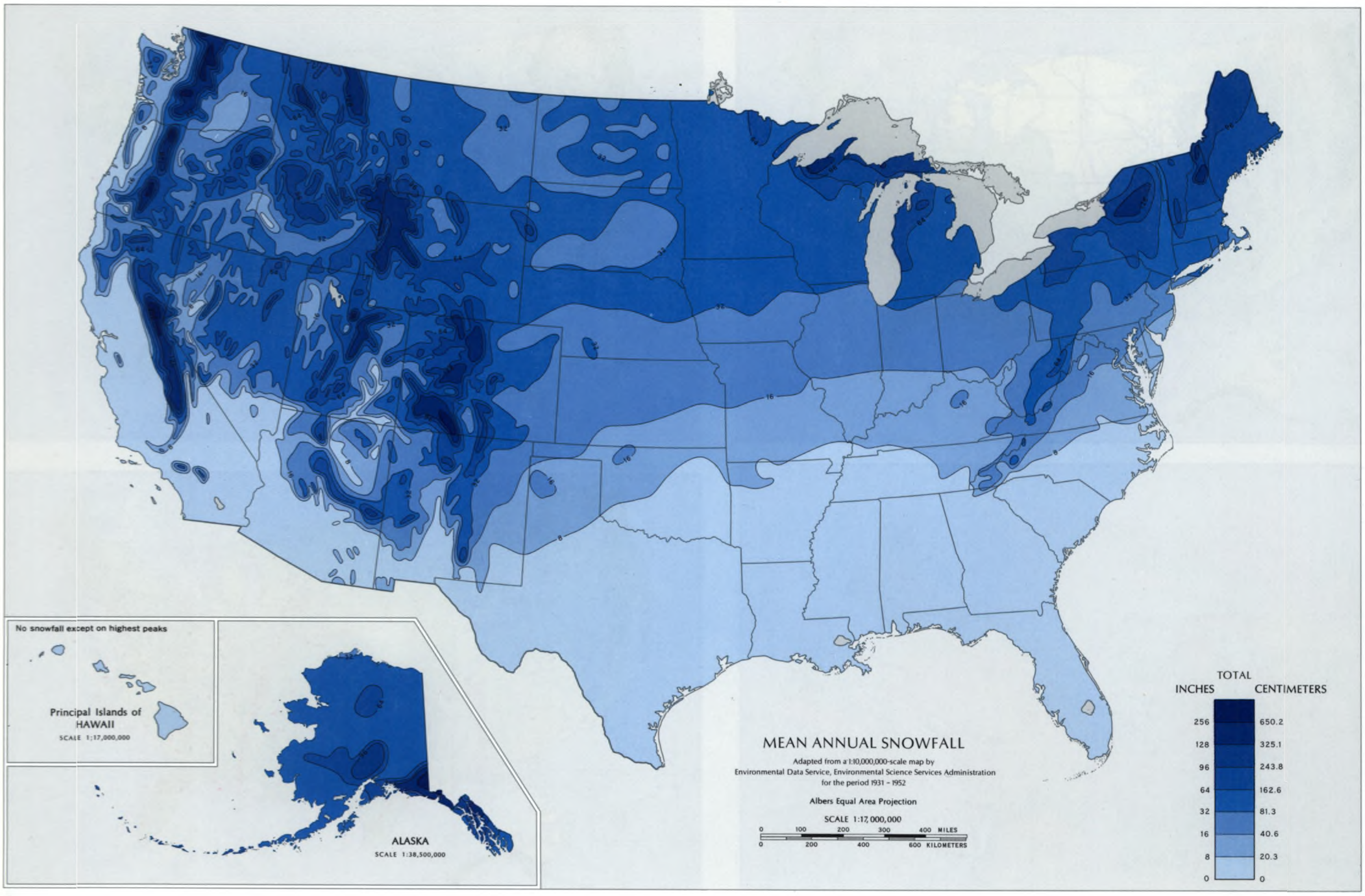
AUGUST

SCALE 1:34,000,000



JULY

SCALE 1:34,000,000

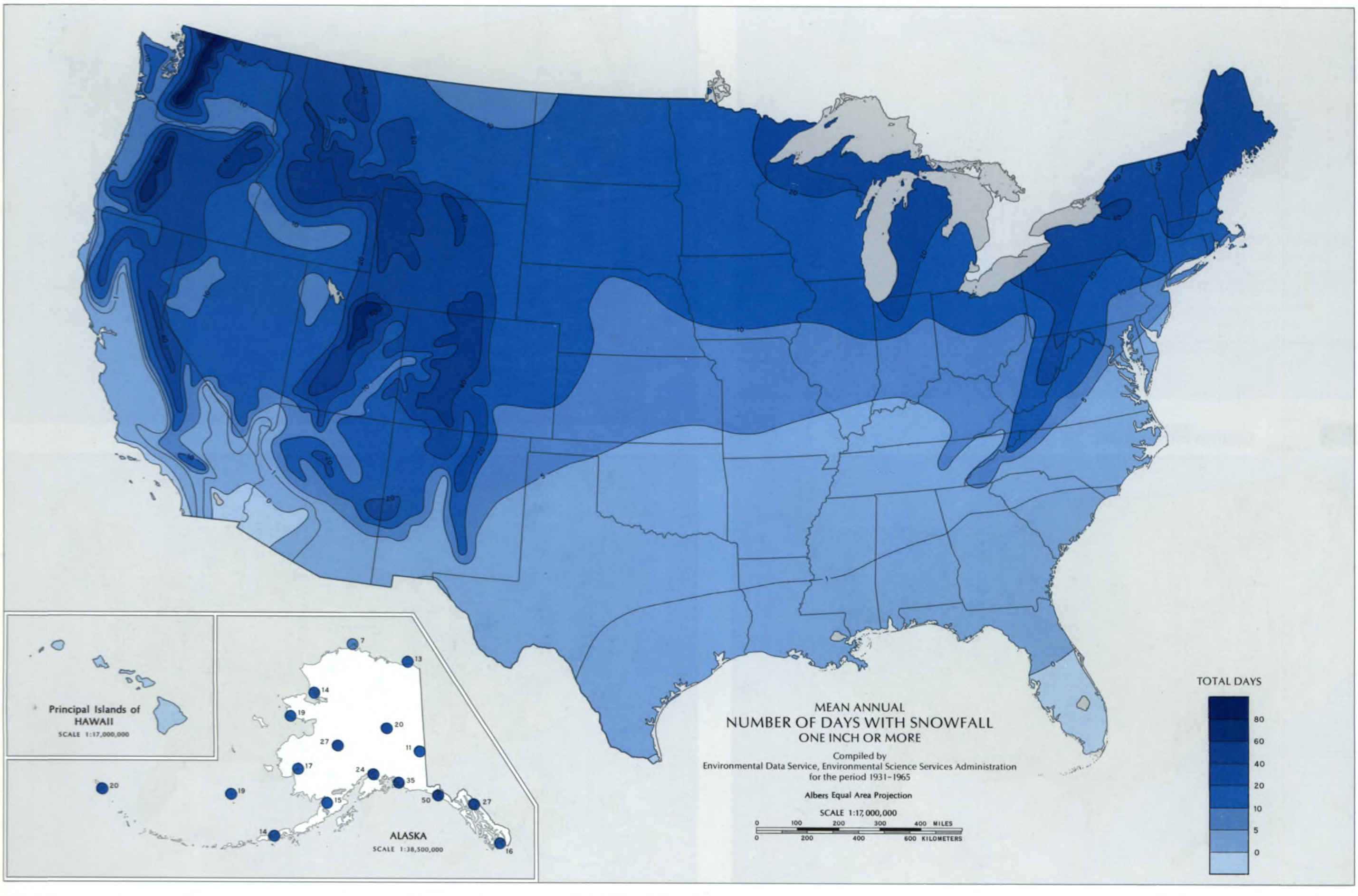


MEAN ANNUAL SNOWFALL

Adapted from a 1:10,000,000-scale map by
Environmental Data Service, Environmental Science Services Administration
for the period 1931 - 1952

Albers Equal Area Projection

SCALE 1:17,000,000



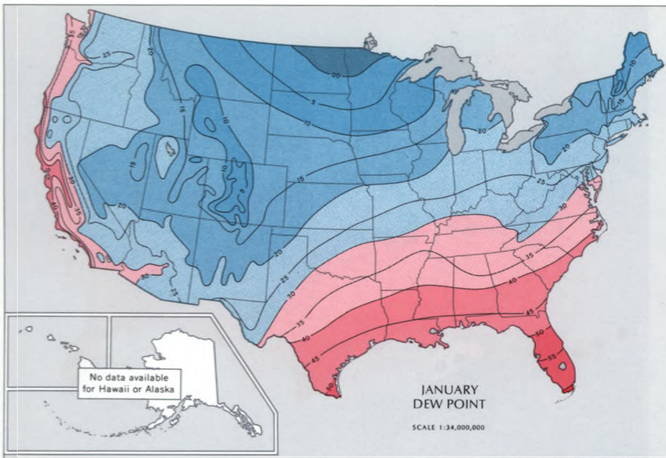
MEAN ANNUAL
NUMBER OF DAYS WITH SNOWFALL
ONE INCH OR MORE

Compiled by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1965

Albers Equal Area Projection

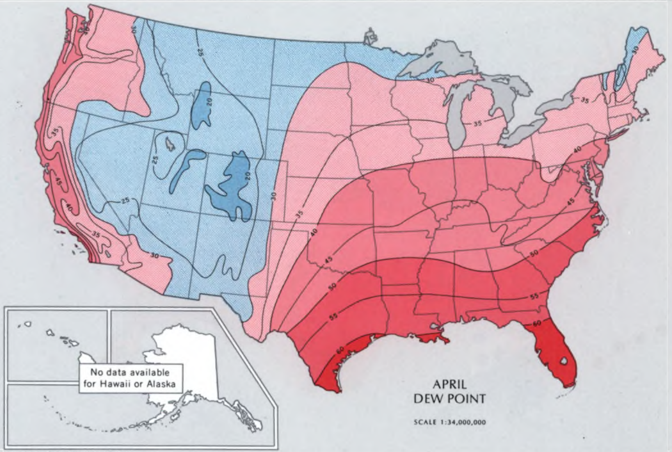
SCALE 1:17,000,000

MEAN MONTHLY DEW POINT TEMPERATURE



JANUARY
DEW POINT

SCALE 1:34,000,000



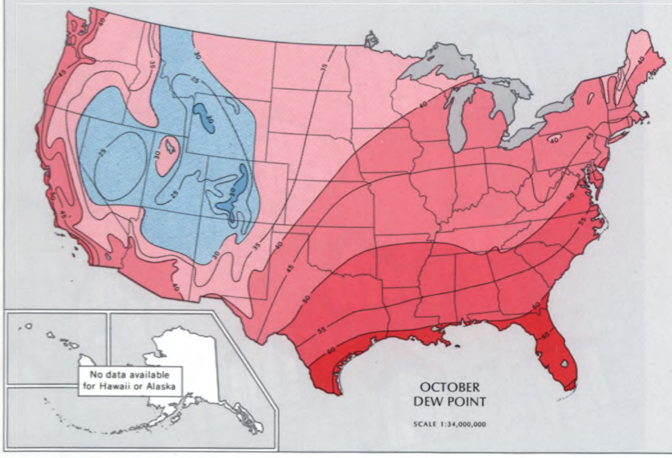
APRIL
DEW POINT

SCALE 1:34,000,000

Dew point is the temperature to which air must be cooled to reach saturation

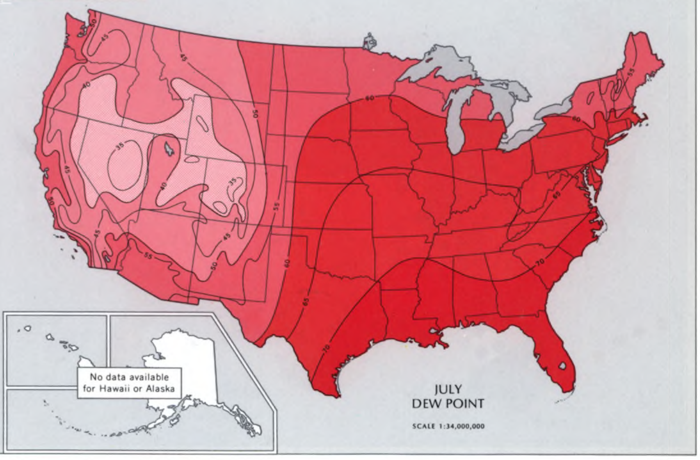
00	10	20	30	40	50	60	70	FAHRENHEIT
−17.8	−12.2	−6.7	−1.1	4.4	10.0	15.6	21.1	CENTIGRADE

Compiled by A. V. Dodd, U.S. Army
from official hourly weather records for
periods averaging 10 years in length prior to 1964



OCTOBER
DEW POINT

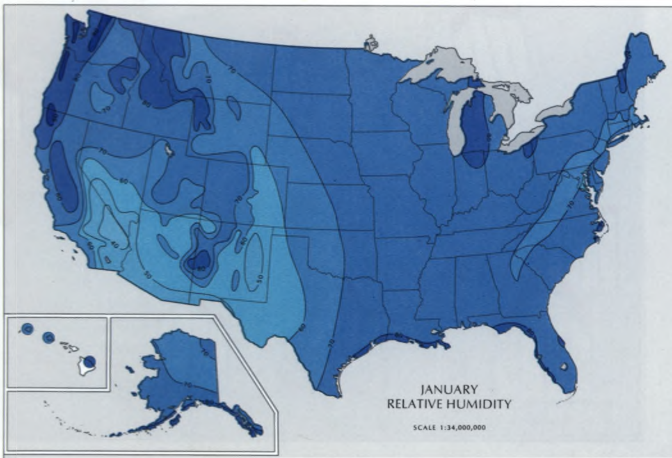
SCALE 1:34,000,000



JULY
DEW POINT

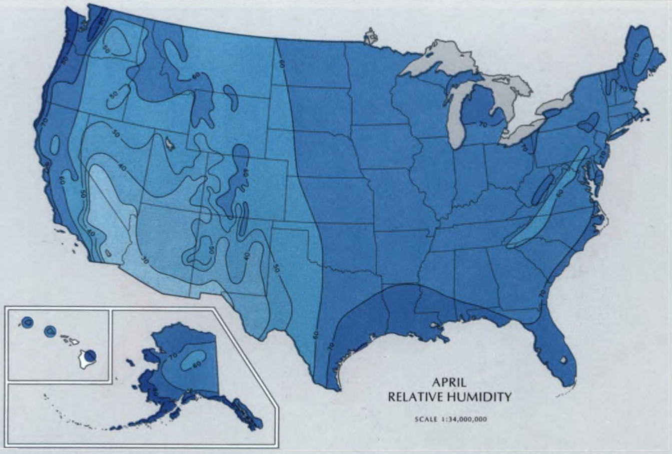
SCALE 1:34,000,000

MEAN MONTHLY RELATIVE HUMIDITY



JANUARY
RELATIVE HUMIDITY

SCALE 1:34,000,000



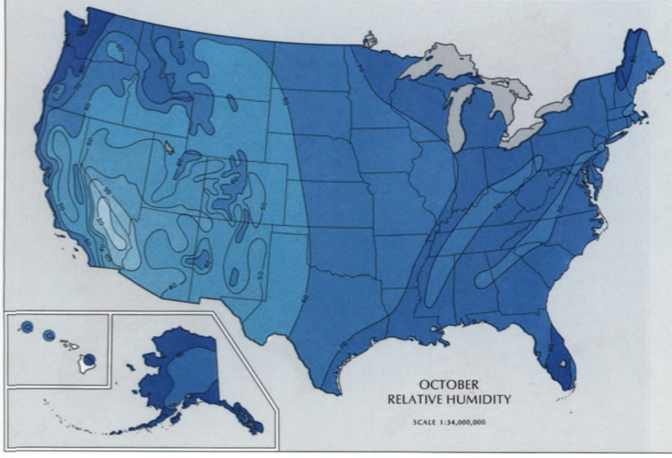
APRIL
RELATIVE HUMIDITY

SCALE 1:34,000,000

Relative humidity is the actual water vapor content of air compared with the water vapor at saturation

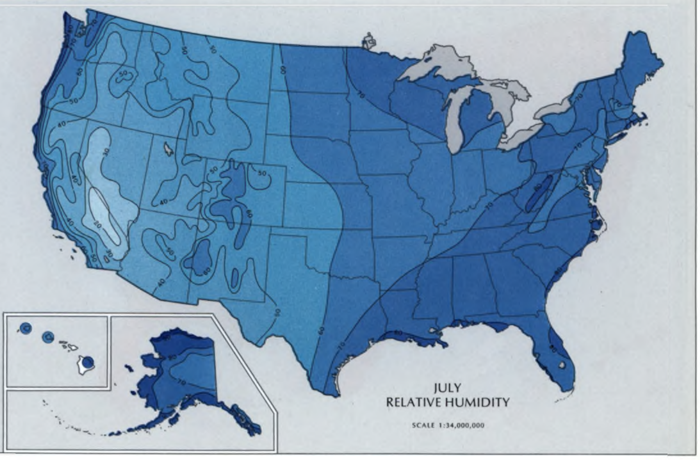
10 20 30 40 50 60 70 80 90 100 PERCENT

Adapted from 1:20,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for varying periods 20 years or more in length, prior to 1960



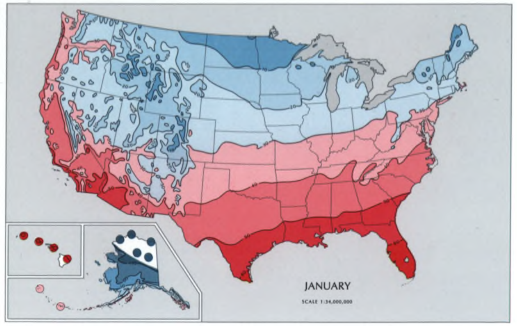
OCTOBER
RELATIVE HUMIDITY

SCALE 1:34,000,000



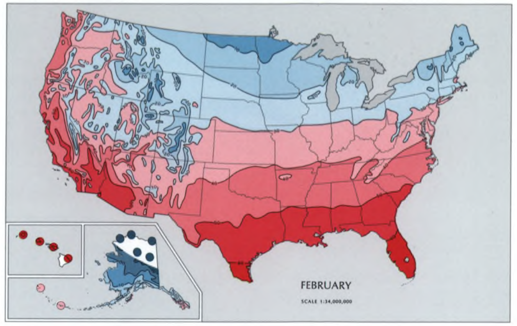
JULY
RELATIVE HUMIDITY

SCALE 1:34,000,000



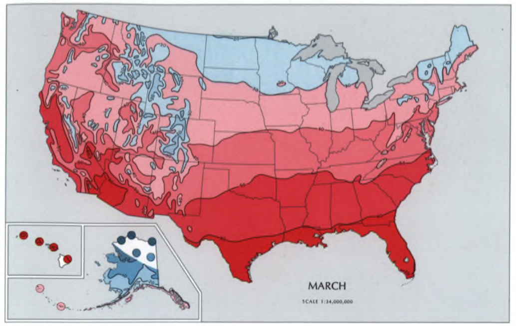
JANUARY

SCALE 1:34,000,000



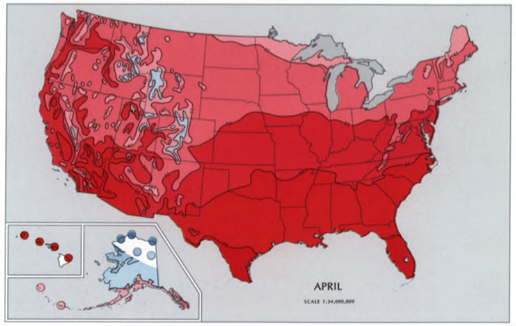
FEBRUARY

SCALE 1:34,000,000



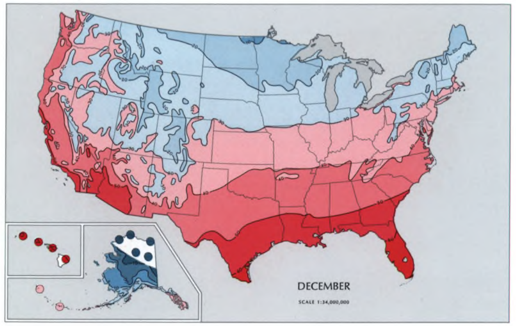
MARCH

SCALE 1:34,000,000



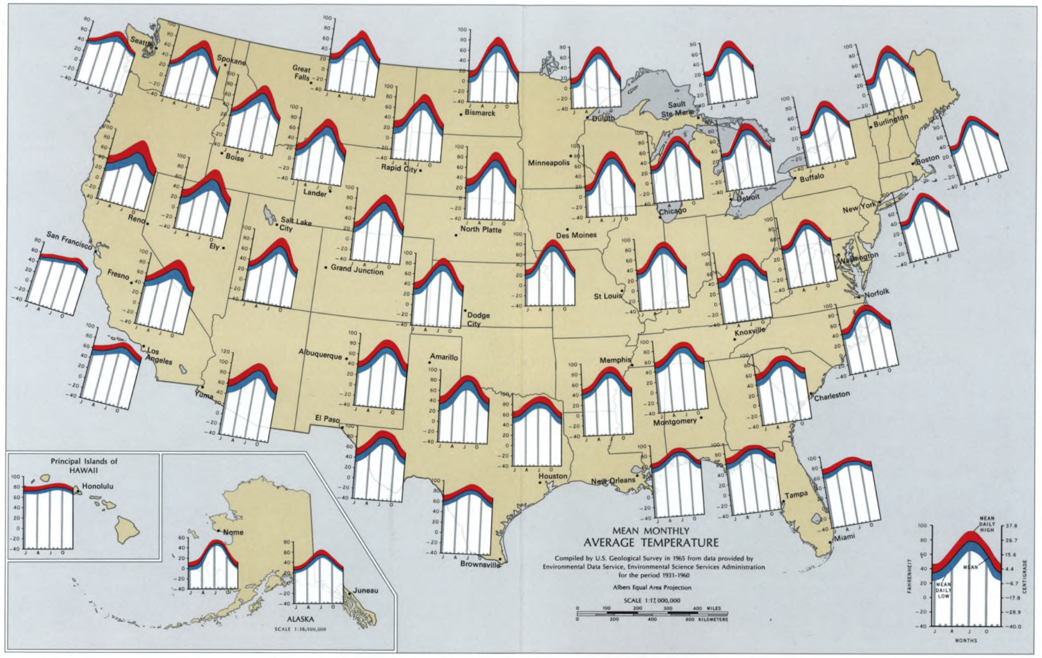
APRIL

SCALE 1:34,000,000



DECEMBER

SCALE 1:34,000,000

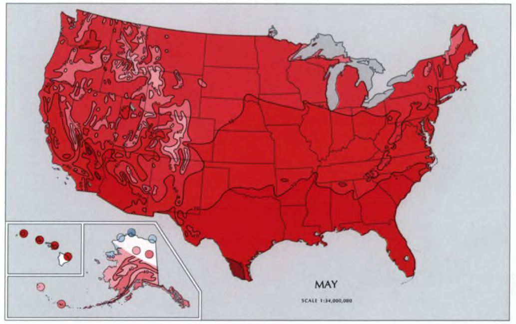


MEAN MONTHLY
AVERAGE TEMPERATURE

Compiled by U.S. Geological Survey in 1965 from data provided by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

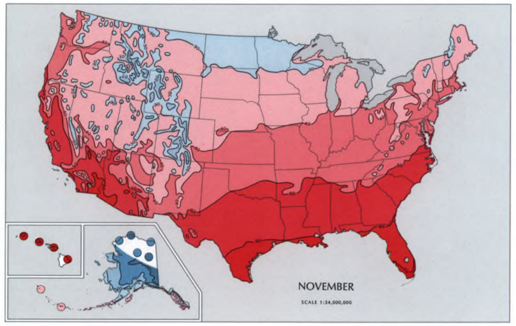
Albers Equal Area Projection

SCALE 1:17,000,000
0 100 200 300 400 MILES
0 200 400 600 KILOMETERS



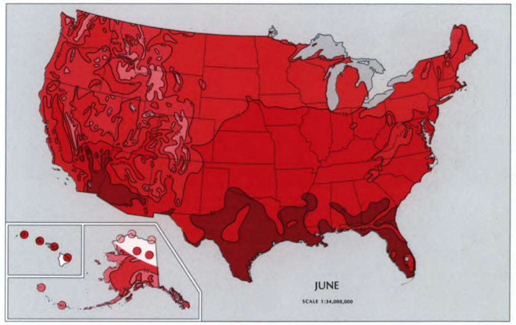
MAY

SCALE 1:34,000,000



NOVEMBER

SCALE 1:34,000,000



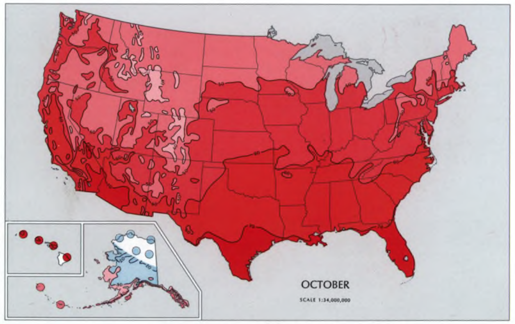
JUNE

SCALE 1:34,000,000

Adapted from 1:10,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

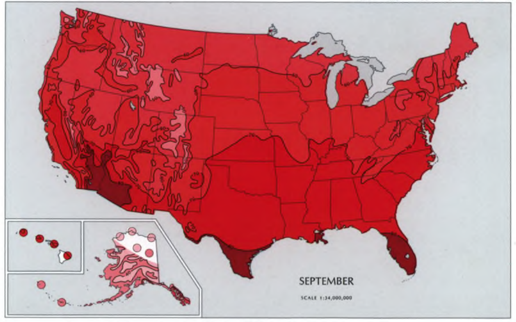
MEAN TEMPERATURE

FAHRENHEIT	−10	00	10	20	30	40	50	60	70	80	90	100
CENTIGRADE	−23.3	−17.8	−12.2	−6.7	−1.1	4.4	10.0	15.6	21.1	26.7	32.2	37.8



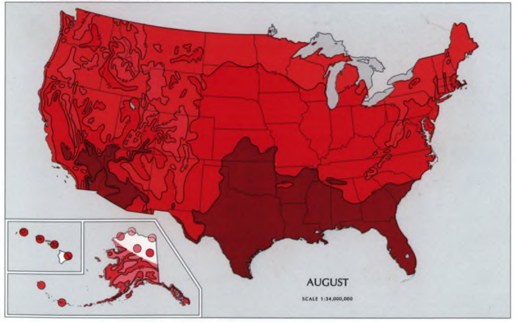
OCTOBER

SCALE 1:34,000,000



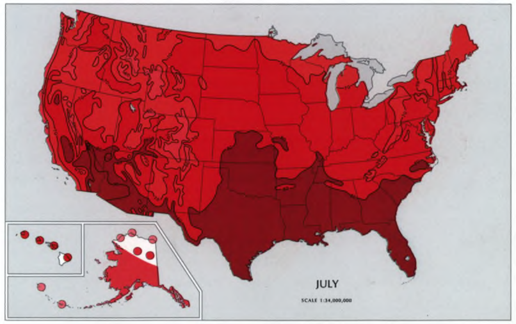
SEPTEMBER

SCALE 1:34,000,000



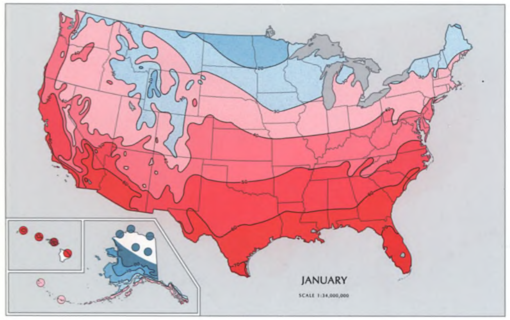
AUGUST

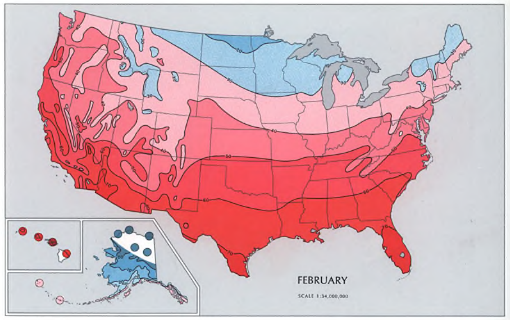
SCALE 1:34,000,000

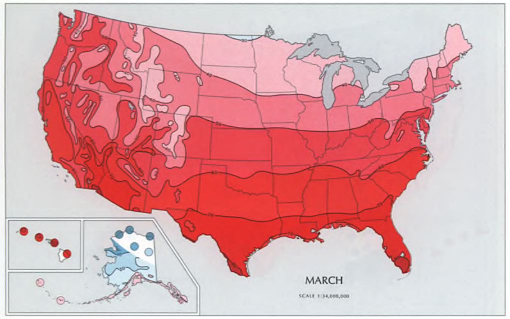


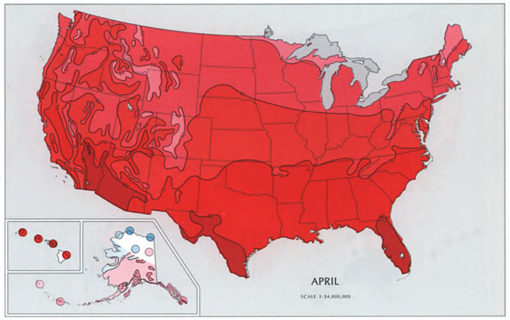
JULY

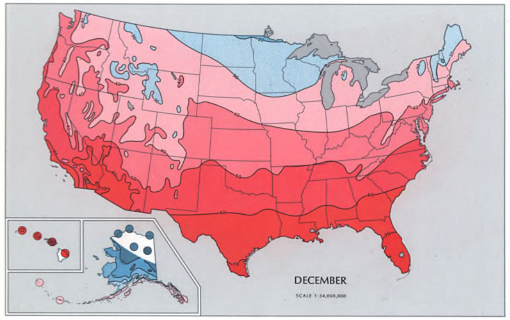
SCALE 1:34,000,000

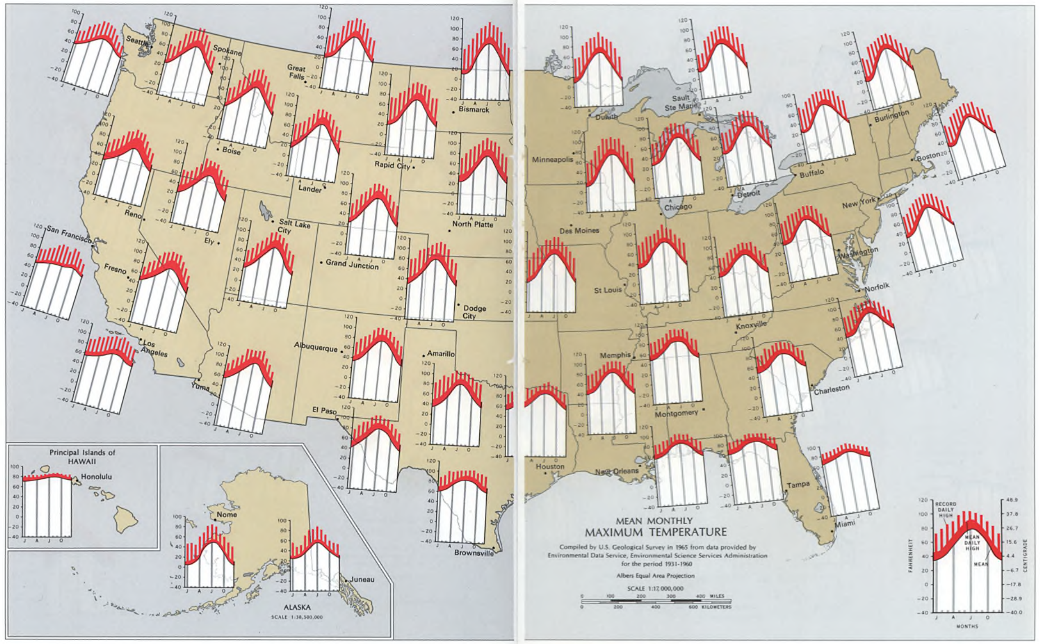

JANUARY
SCALE 1:34,000,000


FEBRUARY
SCALE 1:34,000,000


MARCH
SCALE 1:34,000,000


APRIL
SCALE 1:34,000,000


DECEMBER
SCALE 1:34,000,000



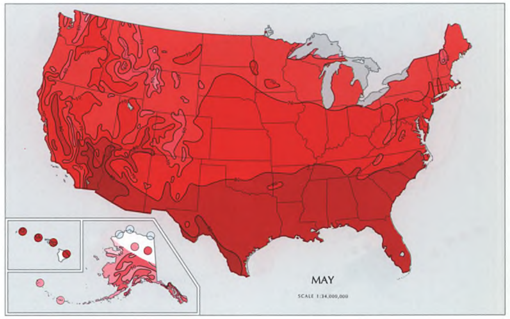
MEAN MONTHLY
MAXIMUM TEMPERATURE

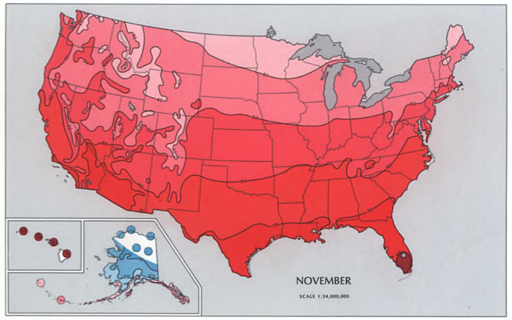
Compiled by U.S. Geological Survey in 1965 from data provided by Environmental Data Service, Environmental Science Services Administration for the period 1931-1960

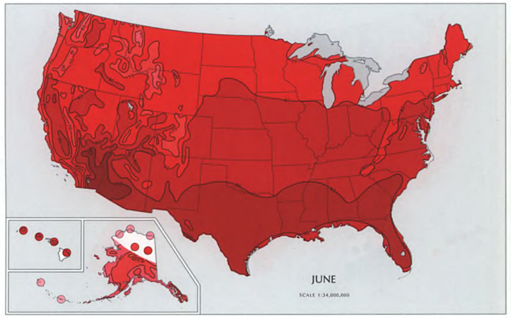
Albers Equal Area Projection

SCALE 1:17,000,000

0 100 200 300 400 MILES
0 200 400 600 KILOMETERS


MAY
SCALE 1:34,000,000

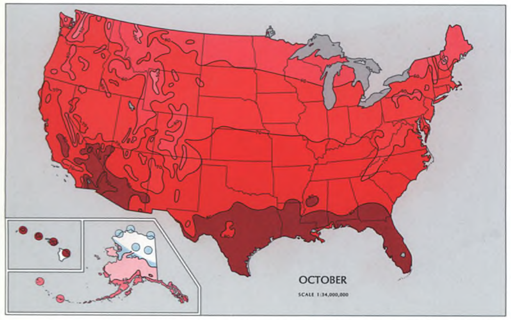

NOVEMBER
SCALE 1:34,000,000

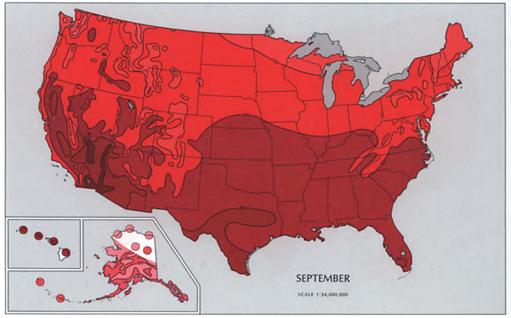

JUNE
SCALE 1:34,000,000

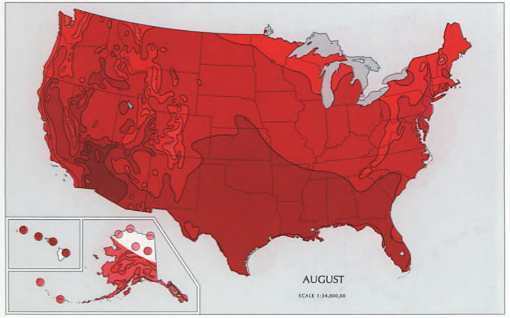
Adapted from 1:10,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

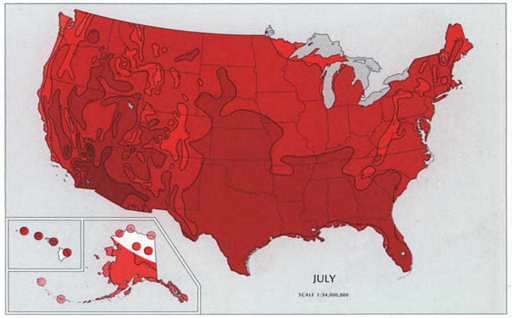
MEAN
MAXIMUM TEMPERATURE

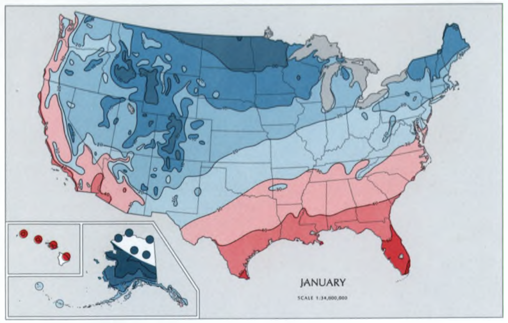
FAHRENHEIT	−10	00	10	20	30	40	50	60	70	80	90	100
CENTIGRADE	−23.3	−17.8	−12.2	−6.7	−1.1	4.4	10.0	15.6	21.1	26.7	32.2	37.8


OCTOBER
SCALE 1:34,000,000


SEPTEMBER
SCALE 1:34,000,000

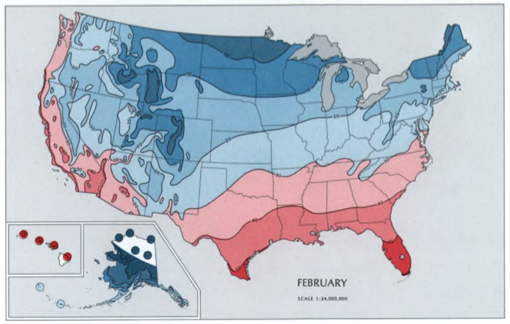

AUGUST
SCALE 1:34,000,000


JULY
SCALE 1:34,000,000



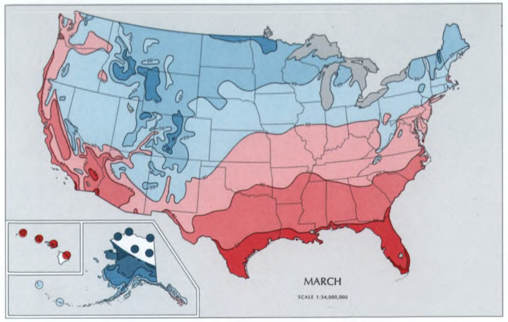
JANUARY

SCALE 1:34,000,000



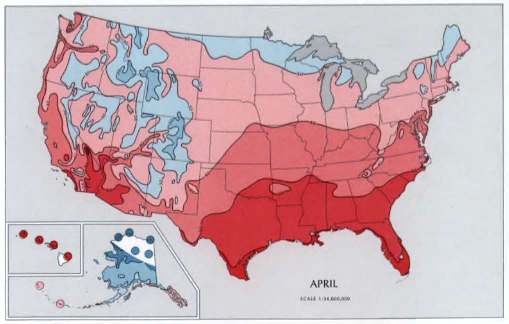
FEBRUARY

SCALE 1:34,000,000



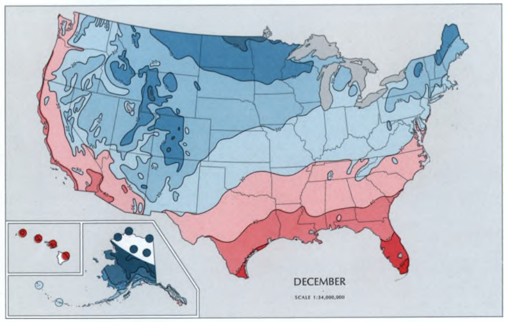
MARCH

SCALE 1:34,000,000



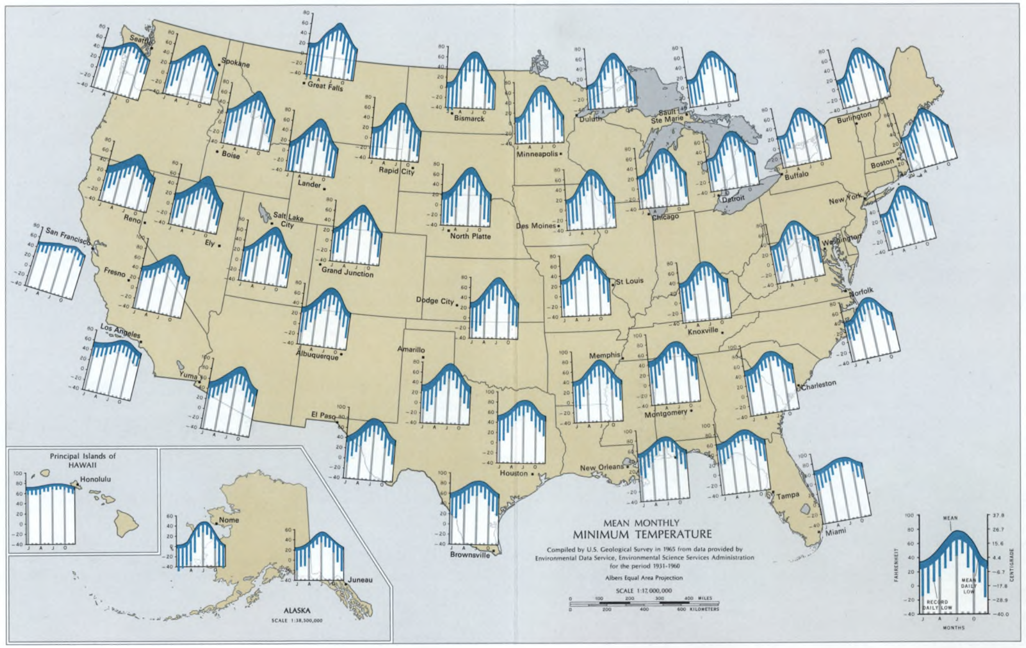
APRIL

SCALE 1:34,000,000



DECEMBER

SCALE 1:34,000,000



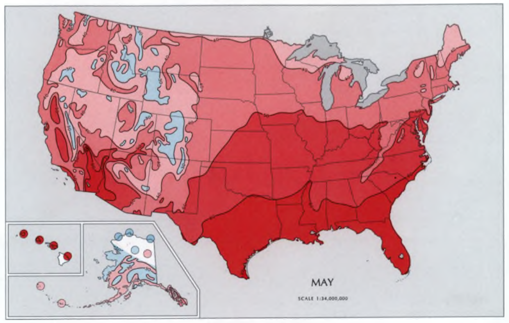
MEAN MONTHLY
MINIMUM TEMPERATURE

Compiled by U.S. Geological Survey in 1965 from data provided by Environmental Data Service, Environmental Science Services Administration for the period 1931-1960

Albers Equal Area Projection

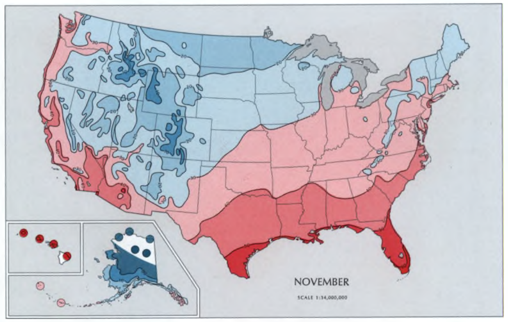
SCALE 1:17,000,000

0 100 200 300 400 MILES
0 200 400 600 KILOMETERS



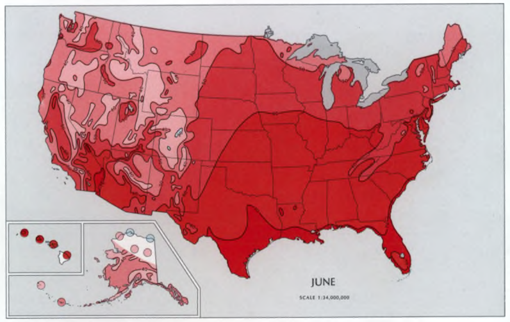
MAY

SCALE 1:34,000,000



NOVEMBER

SCALE 1:34,000,000



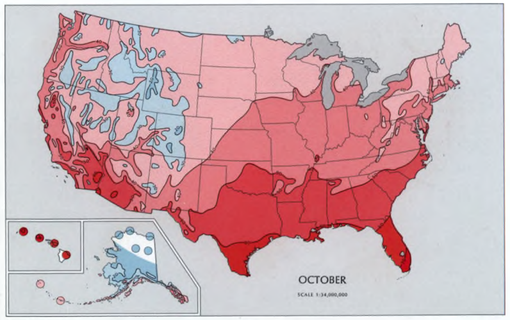
JUNE

SCALE 1:34,000,000

Adapted from 1:10,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

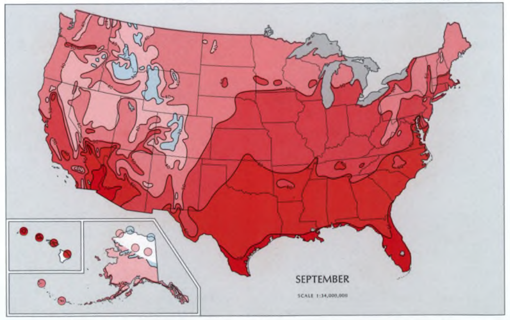
MEAN MINIMUM TEMPERATURE

FAHRENHEIT	−10	00	10	20	30	40	50	60	70	80
CENTIGRADE	−23.3	−17.8	−12.2	−6.7	−1.1	4.4	10.0	15.6	21.1	26.7



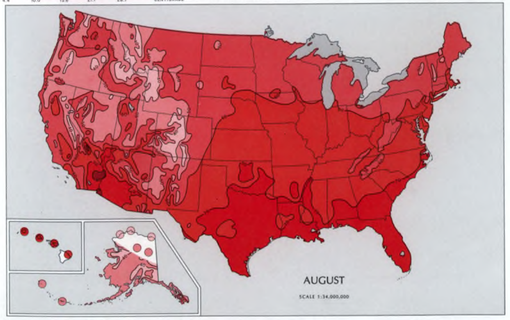
OCTOBER

SCALE 1:34,000,000



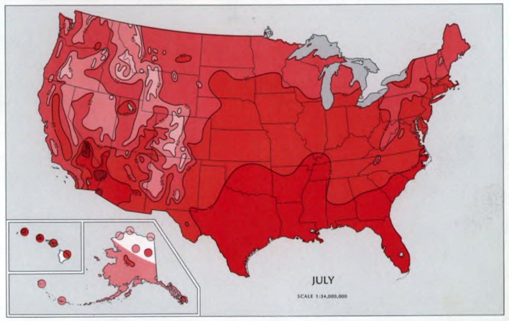
SEPTEMBER

SCALE 1:34,000,000



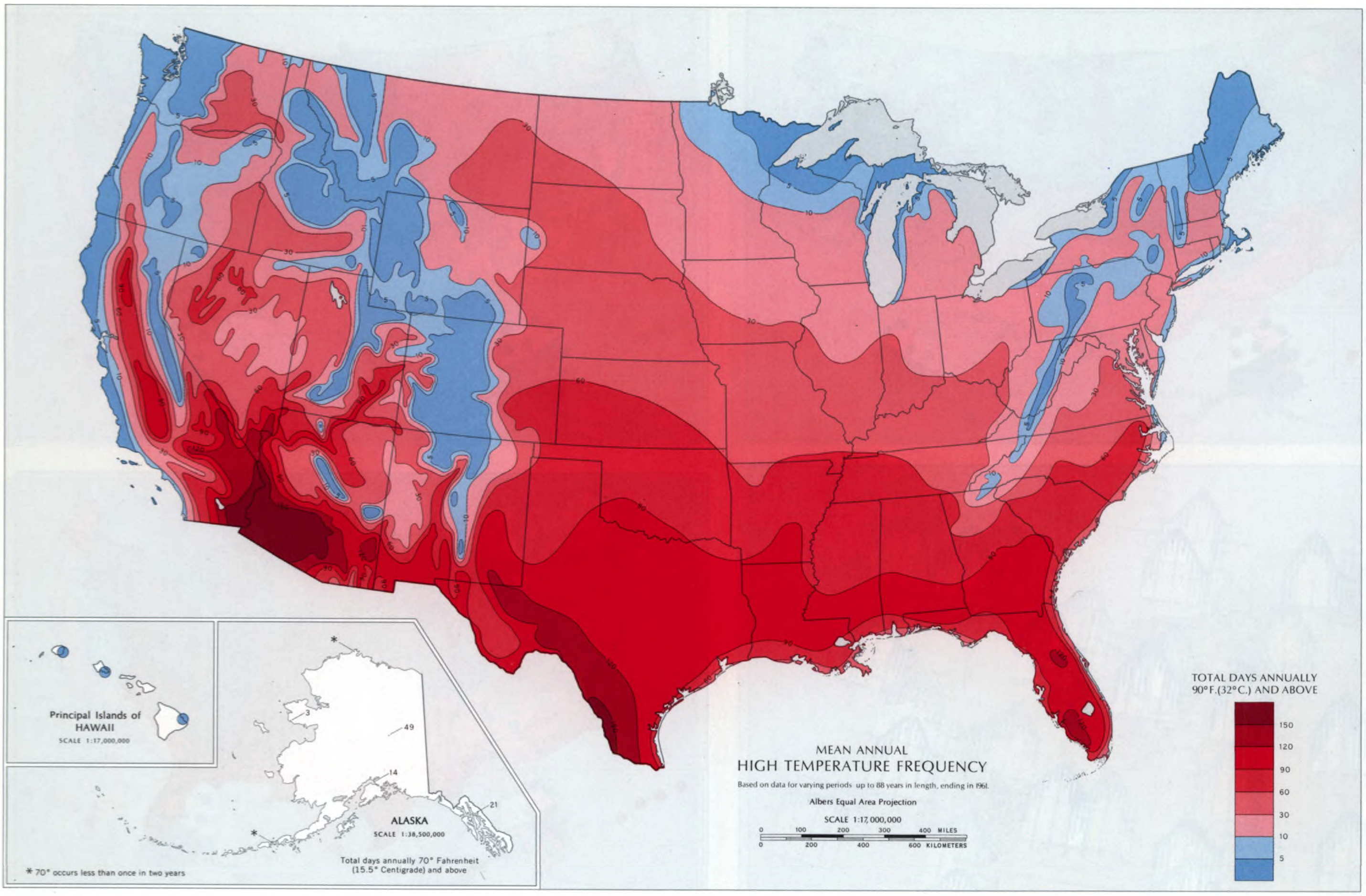
AUGUST

SCALE 1:34,000,000



JULY

SCALE 1:34,000,000

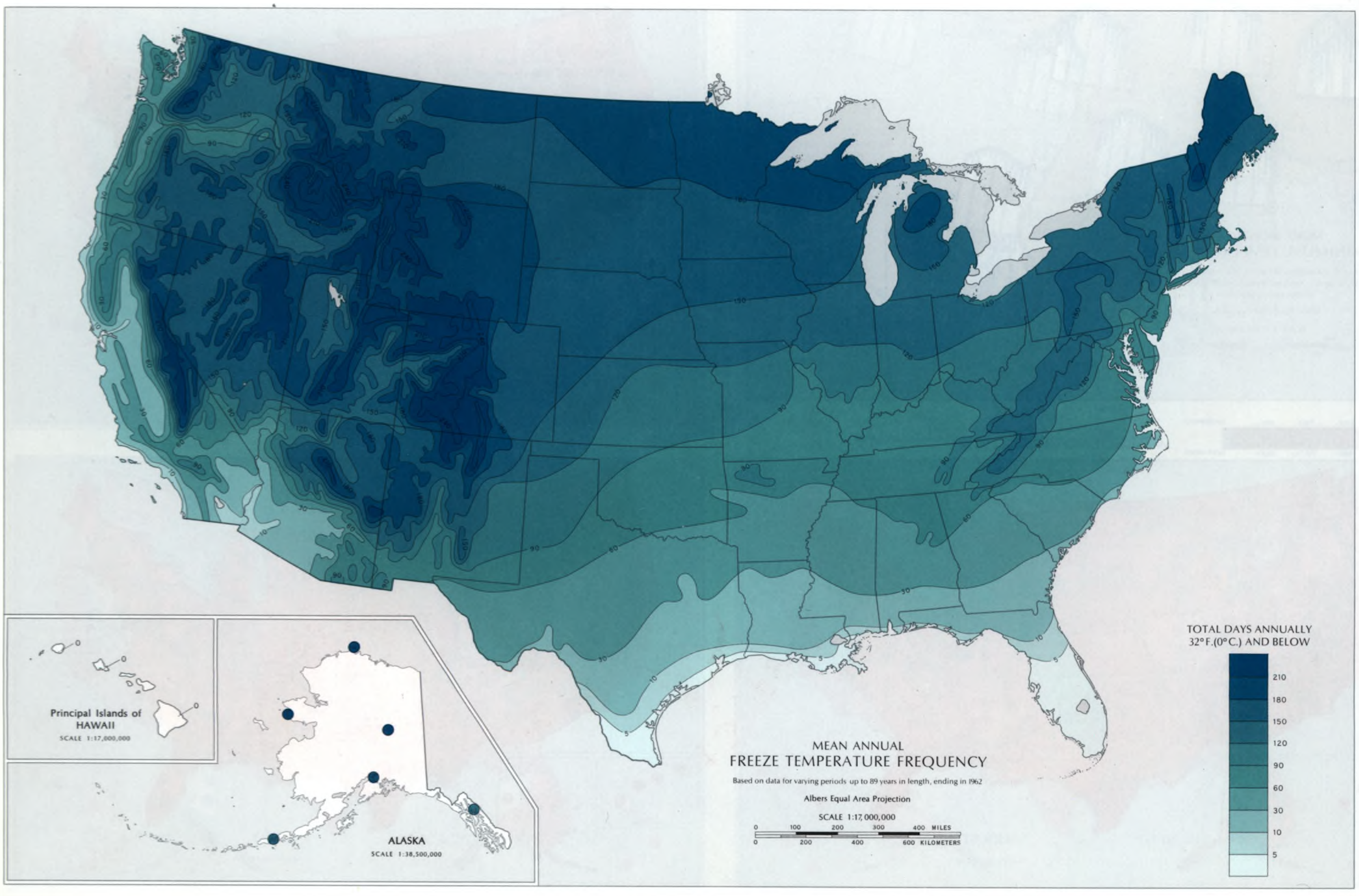


MEAN ANNUAL
HIGH TEMPERATURE FREQUENCY

Based on data for varying periods up to 88 years in length, ending in 1961.

Albers Equal Area Projection

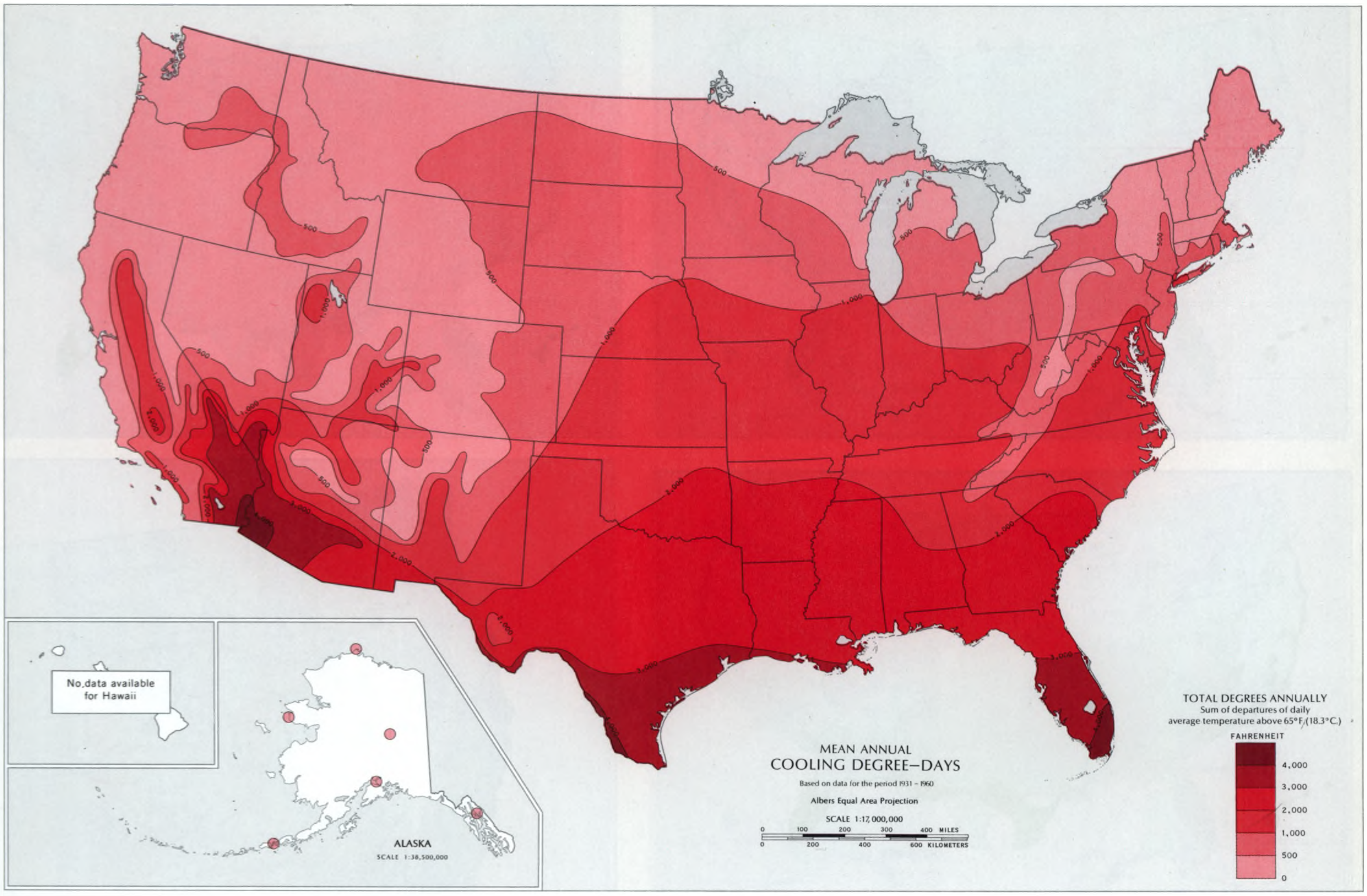
Adapted from 1:10,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration



MEAN ANNUAL
FREEZE TEMPERATURE FREQUENCY

Based on data for varying periods up to 89 years in length, ending in 1962

Albers Equal Area Projection



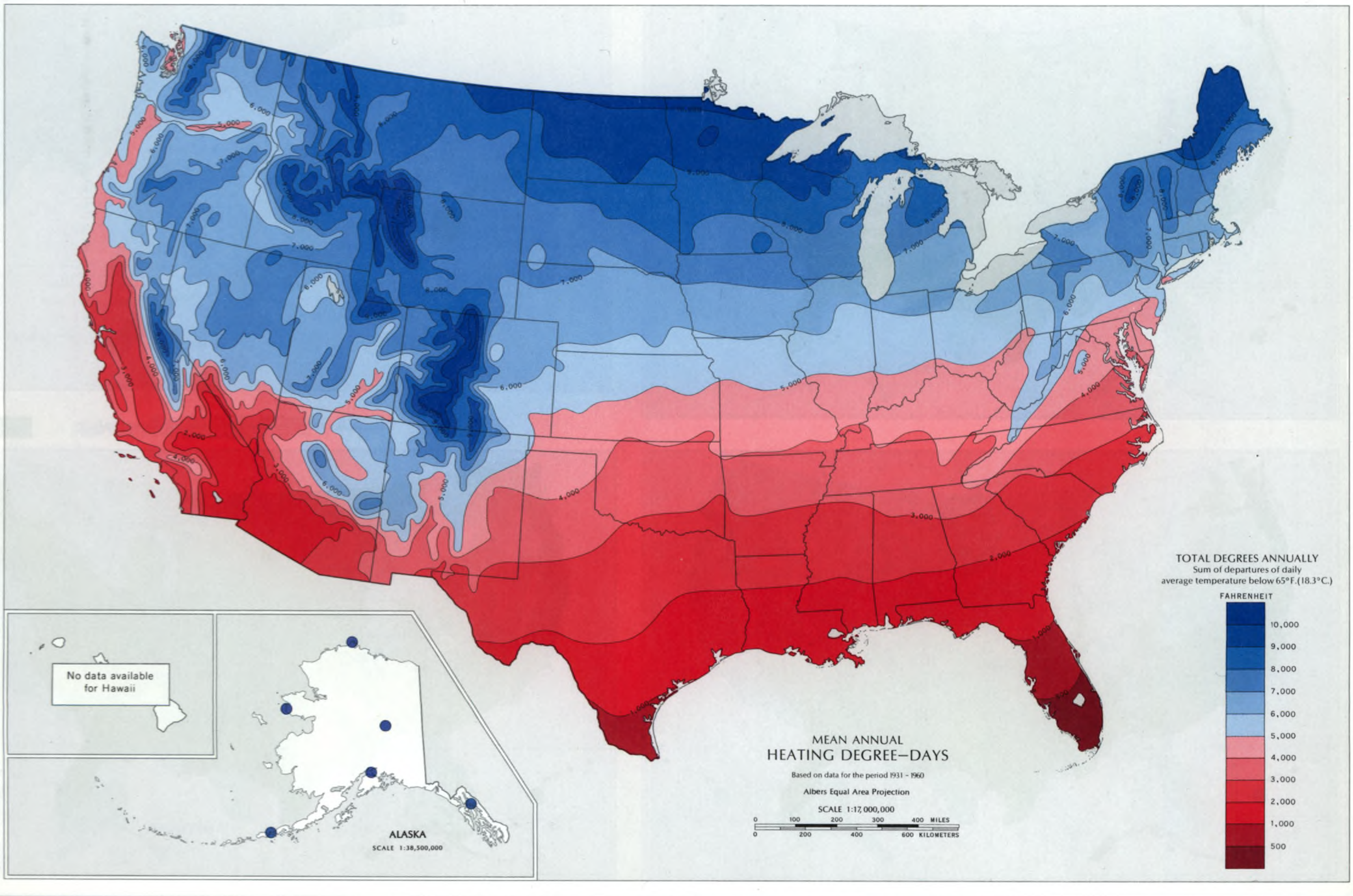
MEAN ANNUAL

COOLING DEGREE–DAYS

Based on data for the period 1931 - 1960

Albers Equal Area Projection

Adapted from 1:20,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration

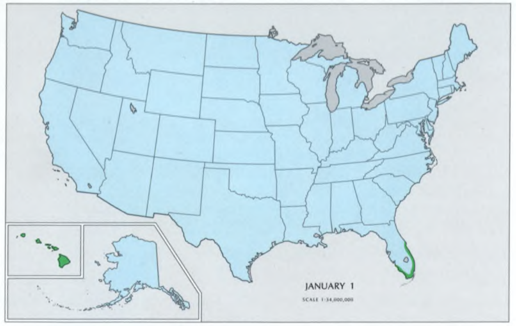


MEAN ANNUAL

HEATING DEGREE–DAYS

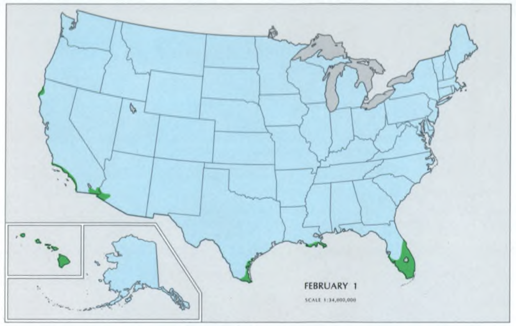
Based on data for the period 1931 - 1960

Albers Equal Area Projection



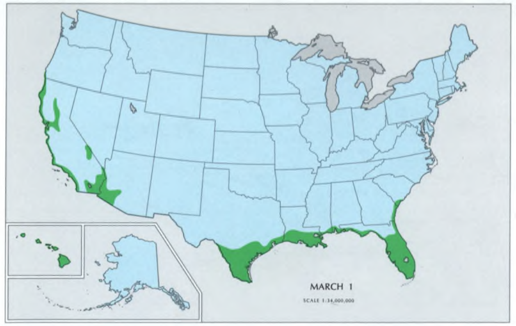
JANUARY 1

SCALE 1:34,000,000



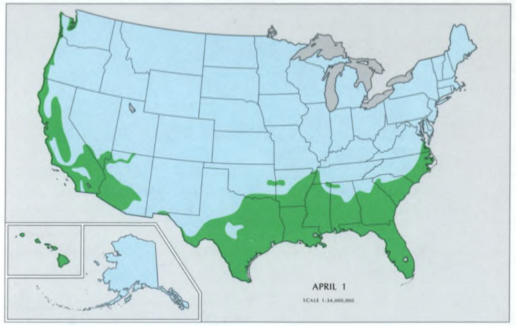
FEBRUARY 1

SCALE 1:34,000,000



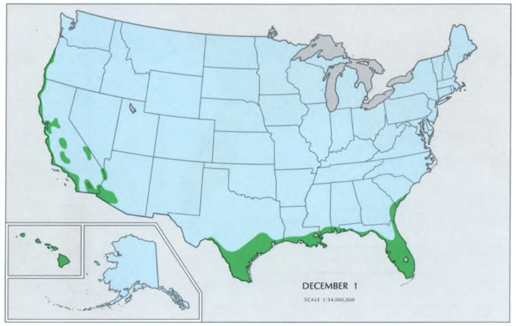
MARCH 1

SCALE 1:34,000,000



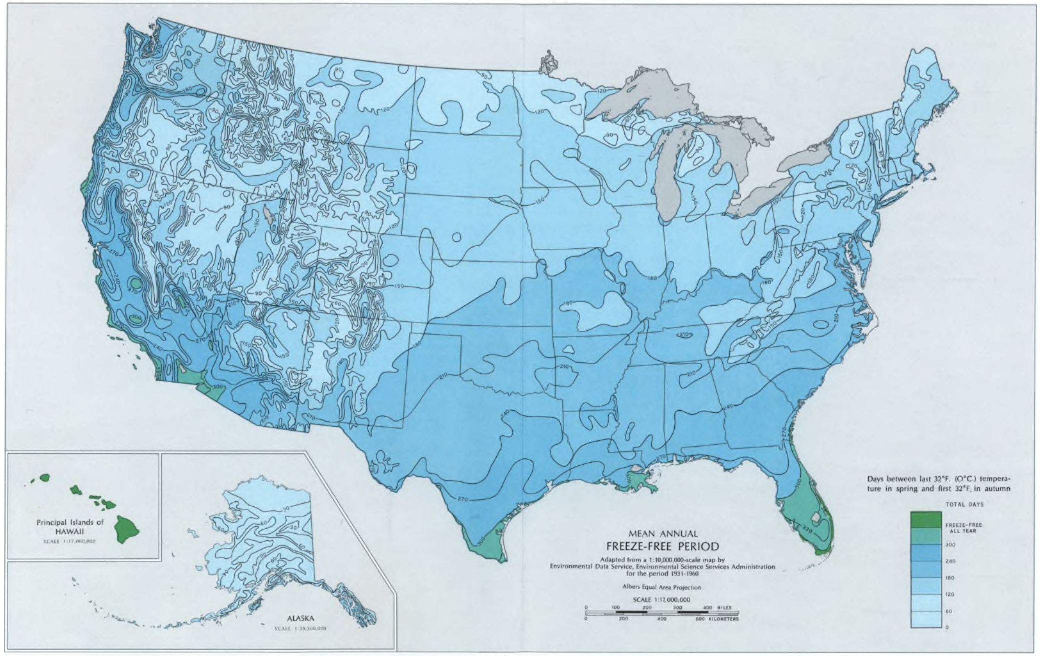
APRIL 1

SCALE 1:34,000,000



DECEMBER 1

SCALE 1:34,000,000



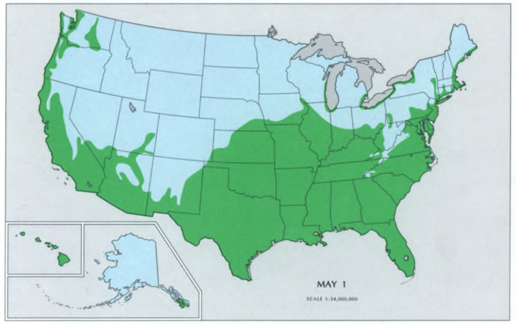
MEAN ANNUAL

FREEZE-FREE PERIOD

Adapted from a 1:10,000,000-scale map by
Environmental Data Service, Environmental Science Services Administration
for the period 1931-1960

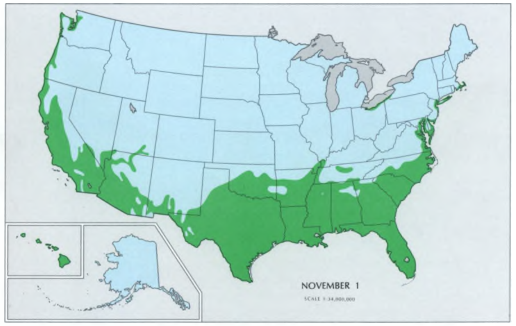
Albers Equal Area Projection

SCALE 1:17,000,000



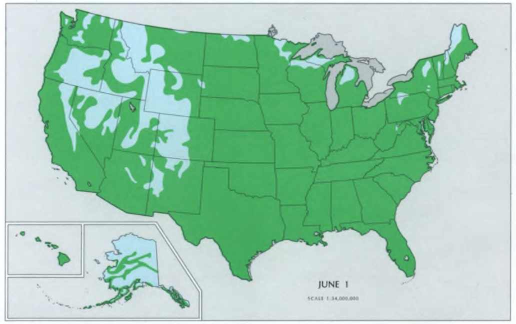
MAY 1

SCALE 1:34,000,000



NOVEMBER 1

SCALE 1:34,000,000



JUNE 1

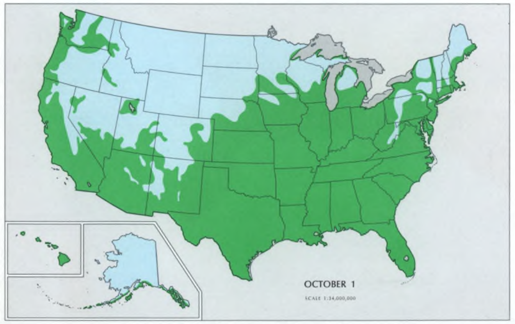
SCALE 1:34,000,000

Adapted from 1:20,000,000-scale maps by
Environmental Data Service, Environmental Science Services Administration
for the period 1921-1950

MONTHLY FREEZE-FREE AREAS

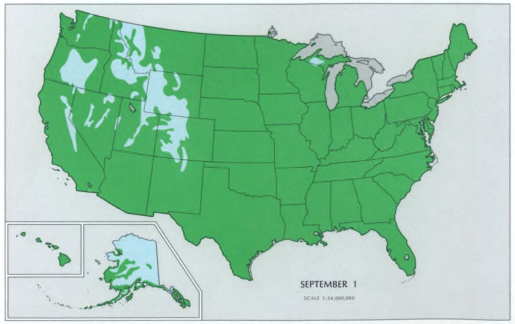
🟩 Freeze-free 🟦 Subject to freeze

(Spring freezes assumed to occur between Jan. 1 and June 30)
(Autumn freezes assumed to occur between July 1 and Dec. 31)



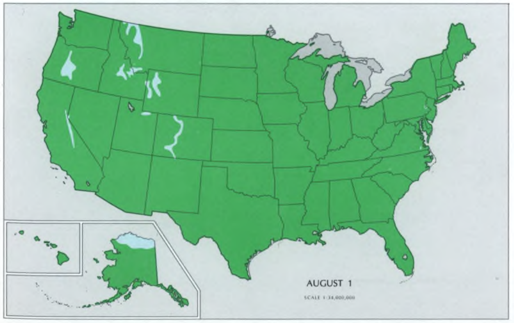
OCTOBER 1

SCALE 1:34,000,000



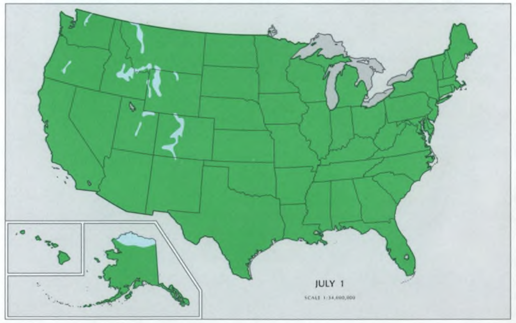
SEPTEMBER 1

SCALE 1:34,000,000



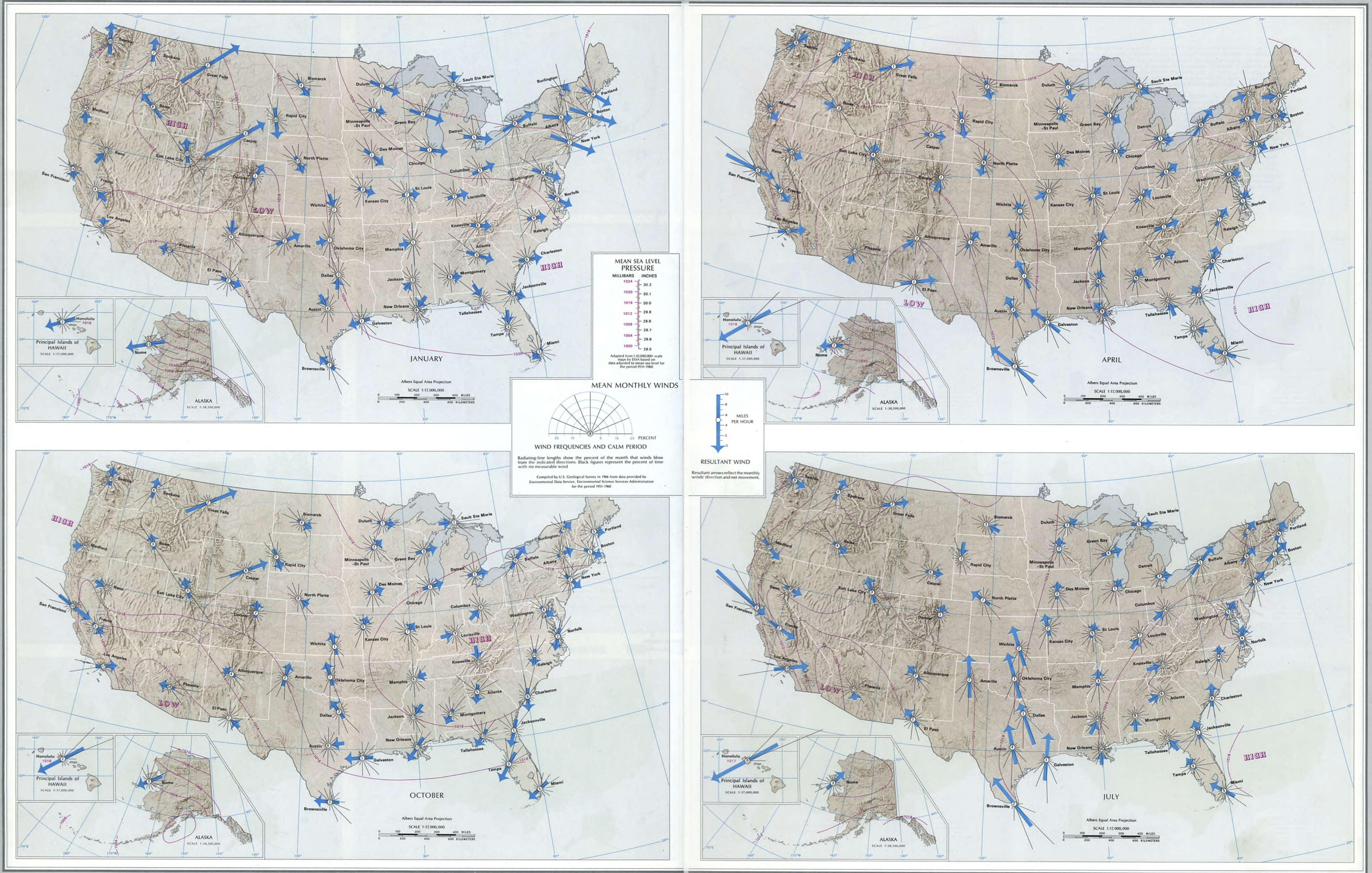
AUGUST 1

SCALE 1:34,000,000



JULY 1

SCALE 1:34,000,000



MEAN SEA LEVEL
PRESSURE

MILLIBARS	INCHES
1024	30.2
1020	30.1
1016	30.0
1012	29.9
1008	29.8
1004	29.7
1000	29.6
	29.5

Adapted from 1:10,000,000-scale maps by ESSA based on data adjusted to mean sea level for the period 1931-1960

MEAN MONTHLY WINDS

WIND FREQUENCIES AND CALM PERIOD

Radiating-line lengths show the percent of the month that winds blow from the indicated directions. Black figures represent the percent of time with no measurable wind

Compiled by U.S. Geological Survey in 1966 from data provided by Environmental Data Service, Environmental Science Services Administration for the period 1951-1960

RESULTANT WIND

Resultant arrows reflect the monthly winds' direction and net movement.

In 1957 the Public Health Service set up a National Air Sampling Network, now National Air Surveillance Networks (NASN), to measure solid pollutants in the air. In 1960 it began limited sampling for gaseous pollution, and in 1962 initiated the Continuous Air Monitoring Program (CAMP) to intensively measure concentrations of major gaseous pollutants in six representative urban areas. The 164 urban and 30 non-urban NASN stations and the six CAMP stations are being supplemented to an increasing extent by State and local sampling networks. Currently about 300 stations are being operated in State, city, or local networks.

Maps on these two pages illustrate some of the results of analyzing all accumulated air pollution data and related meteorological studies. Maps on this page are discussed below:

Map 1: Isolines represent the total number of days of high air pollution potential that were forecast since the national air pollution potential forecasting program began (Aug. 1, 1960 in the East and Oct. 1, 1963 in the West) through Dec. 31, 1966.

Maps 2–7 are based on data for calendar year 1964.

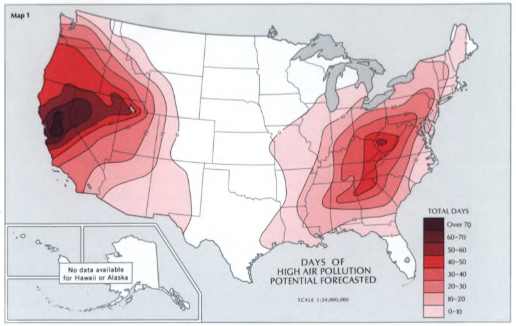
Map 2: The afternoon mixing depth represents the maximum height above the earth's surface to which active dispersion of pollutants take place during the daily cycle.

Map 3: The afternoon mixing layer wind speed is the average wind speed through the (afternoon) mixing layer based on surface speeds and speeds aloft at 1,000-foot intervals.

Maps 4–7: The afternoon ventilation is the product of the mixing depth and the average wind speed through the mixing depth. This value is proportional to the volume of air available to dilute pollutants emitted into the atmosphere.

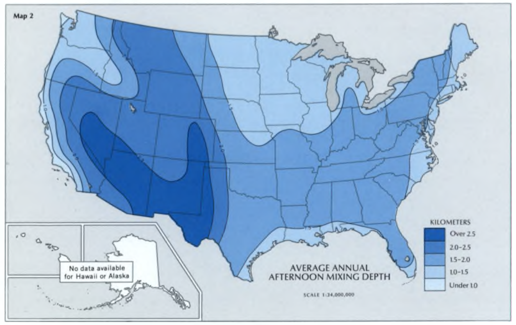
All maps on this page were compiled by the U. S. Geological Survey from data provided by the National Center for Air Pollution Control, now the National Air Pollution Control Administration, Public Health Service, Department of Health, Education, and Welfare.

Map 1


DAYS OF HIGH AIR POLLUTION POTENTIAL FORECASTED

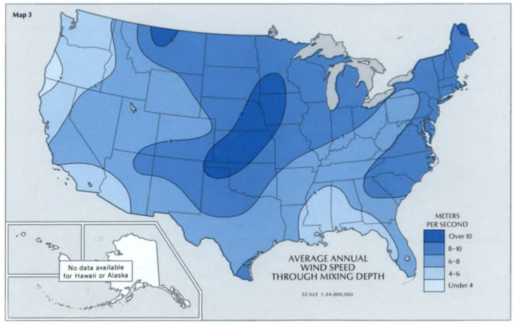
SCALE 1:34,000,000

Map 2


AVERAGE ANNUAL AFTERNOON MIXING DEPTH

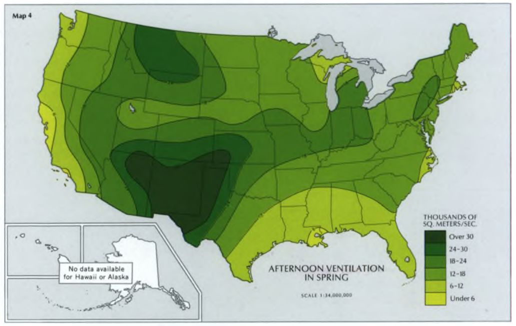
SCALE 1:34,000,000

Map 3


AVERAGE ANNUAL WIND SPEED THROUGH MIXING DEPTH

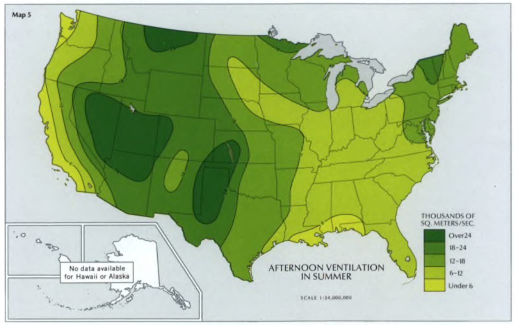
SCALE 1:34,000,000

Map 4


AFTERNOON VENTILATION IN SPRING

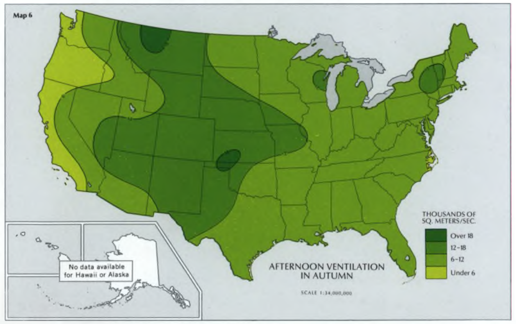
SCALE 1:34,000,000

Map 5


AFTERNOON VENTILATION IN SUMMER

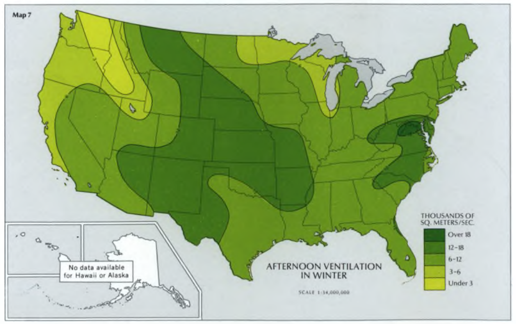
SCALE 1:34,000,000

Map 6

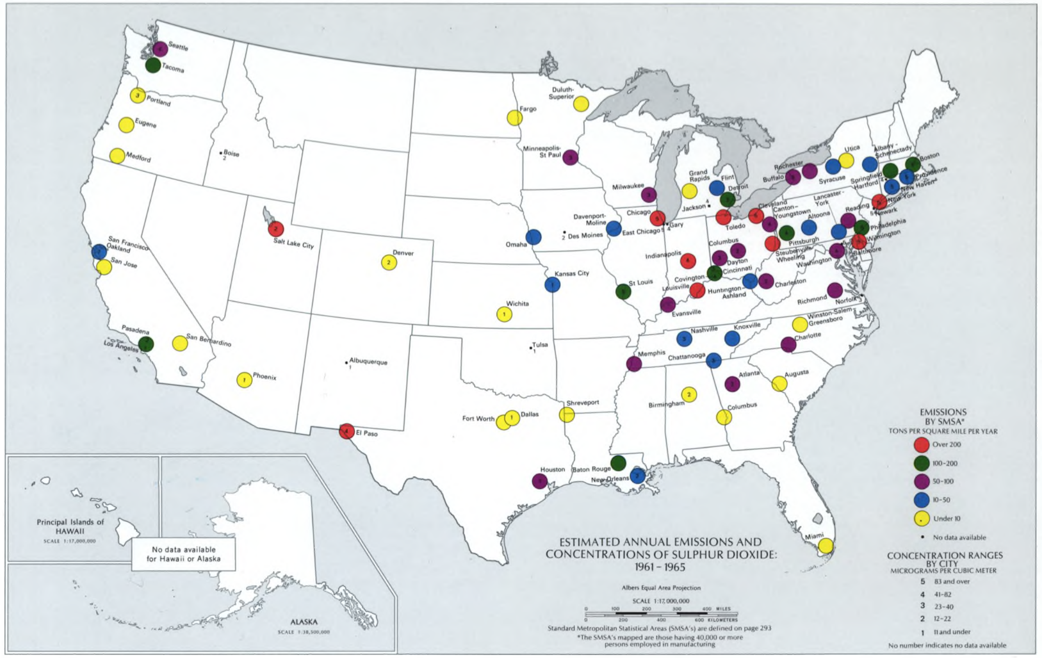

AFTERNOON VENTILATION IN AUTUMN

SCALE 1:34,000,000

Map 7


AFTERNOON VENTILATION IN WINTER

SCALE 1:34,000,000


ESTIMATED ANNUAL EMISSIONS AND CONCENTRATIONS OF SULPHUR DIOXIDE: 1961 – 1965

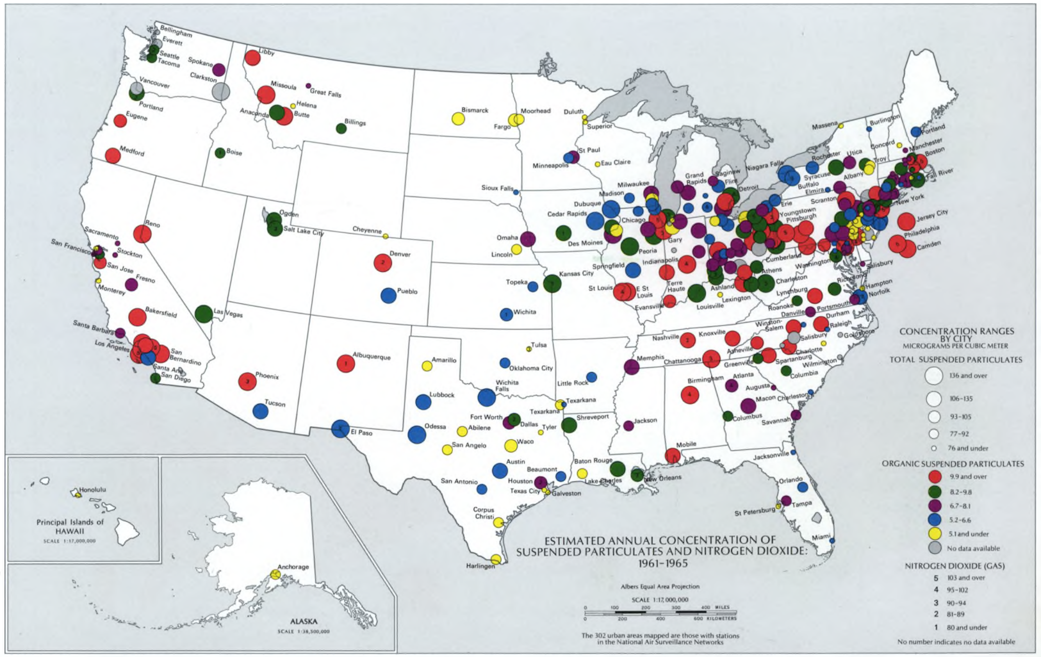
Albers Equal Area Projection

SCALE 1:17,000,000

Standard Metropolitan Statistical Areas (SMSA's) are defined on page 293

*The SMSA's mapped are those having 40,000 or more persons employed in manufacturing

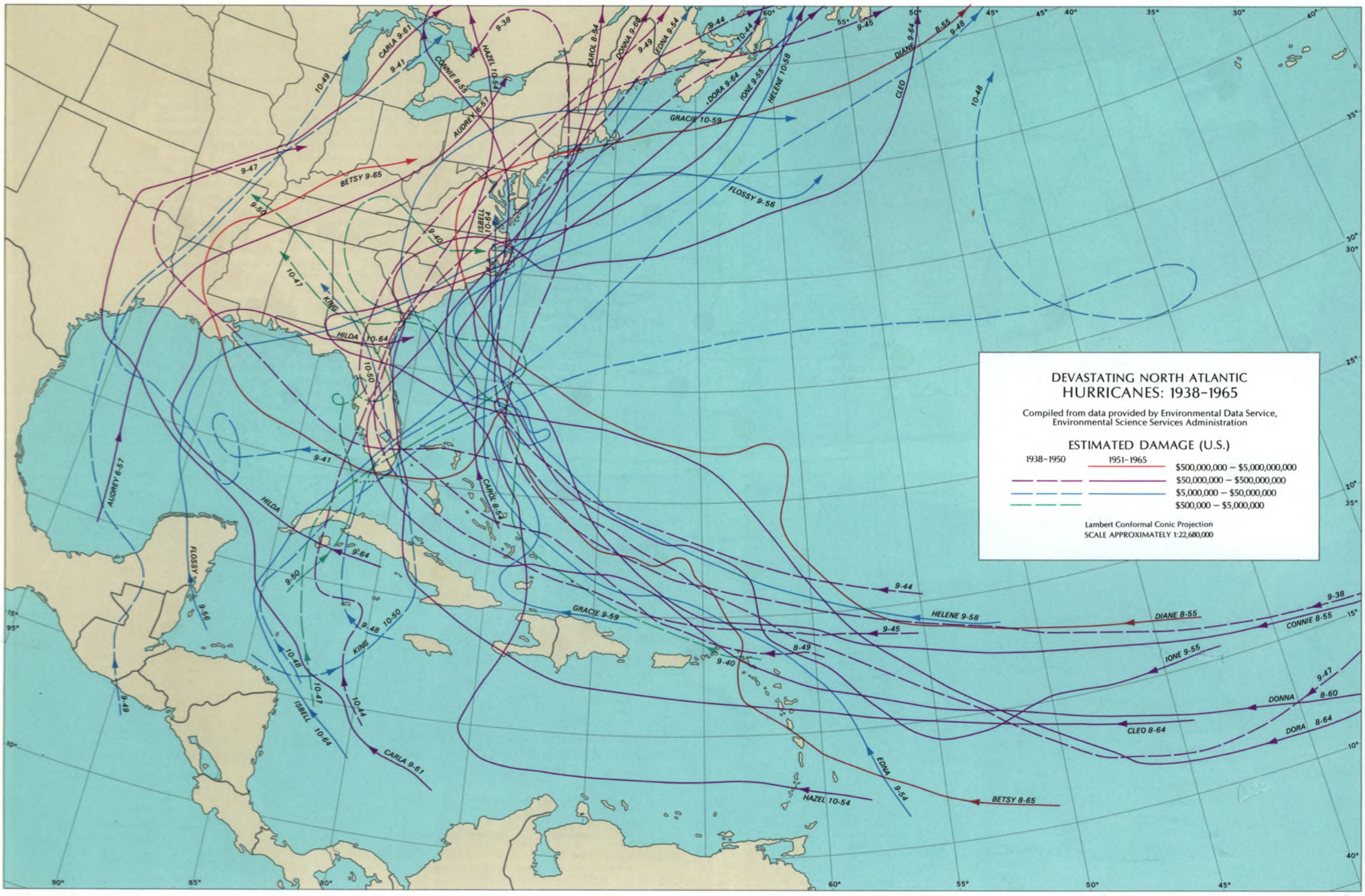
Compiled from information provided by U.S. Public Health Service


ESTIMATED ANNUAL CONCENTRATION OF SUSPENDED PARTICULATES AND NITROGEN DIOXIDE: 1961–1965

Albers Equal Area Projection

SCALE 1:17,000,000

The 302 urban areas mapped are those with stations in the National Air Surveillance Networks



DEVASTATING NORTH ATLANTIC
HURRICANES: 1938-1965

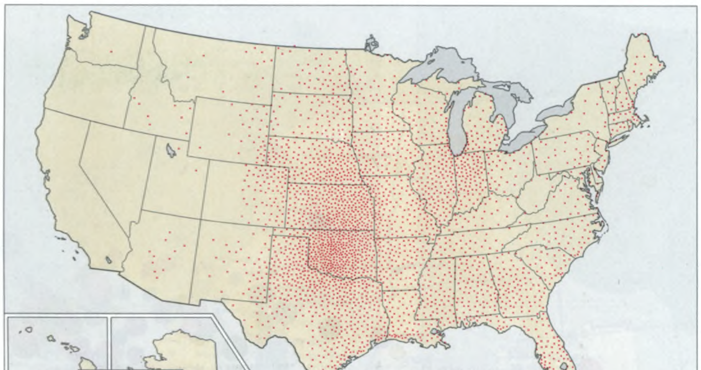
Compiled from data provided by Environmental Data Service,
Environmental Science Services Administration

ESTIMATED DAMAGE (U.S.)

1938-1950	1951-1965	
	━━━	$500,000,000 – $5,000,000,000
— — —	━━━	$50,000,000 – $500,000,000
— — —	━━━	$5,000,000 – $50,000,000
— — —		$500,000 – $5,000,000

Lambert Conformal Conic Projection
SCALE APPROXIMATELY 1:22,680,000

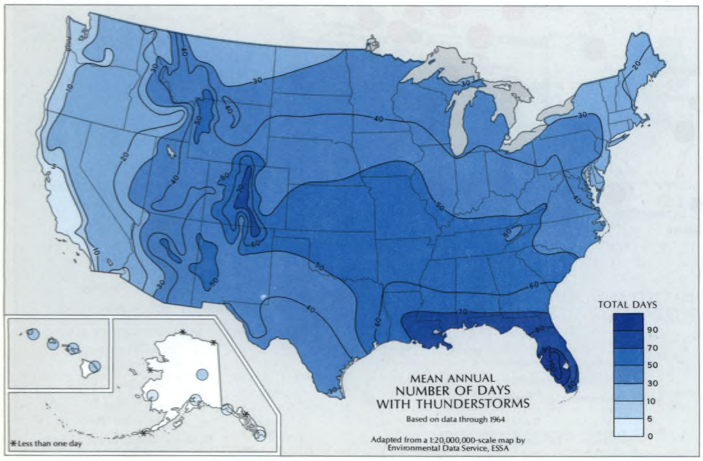
THUNDERSTORMS AND WINDS



FREQUENCY OF
TORNADOES: 1953-1962

Each dot represents the approximate location of two occurrences during the 10-year period.
An occurrence is defined as the first point of contact with the ground.

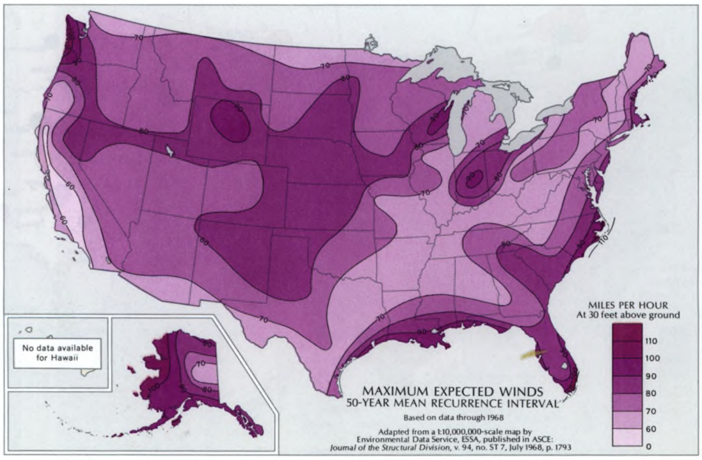
Compiled from data provided by
Environmental Data Service, ESSA



MEAN ANNUAL
NUMBER OF DAYS
WITH THUNDERSTORMS

Based on data through 1964

Adapted from a 1:20,000,000-scale map by
Environmental Data Service, ESSA



MAXIMUM EXPECTED WINDS
50-YEAR MEAN RECURRENCE INTERVAL

Based on data through 1968

Adapted from a 1:10,000,000-scale map by
Environmental Data Service, ESSA, published in ASCE:
Journal of the Structural Division, v. 94, no. ST 7, July 1968, p. 1793

WATER RESOURCES

> *"Every human enterprise is the mixture of*
> *a little bit of humanity, a little bit of soil,*
> *and a little bit of water."*
> *—Jean Brunhes*

The Water Resources section contains a summary of data compiled or adapted from various sources by the staff of the U.S. Geological Survey with text and coordination by Harold E. Thomas.

From other parts of the universe water, H_2O, appears to be the most abundant substance on Earth: about 71 percent of its surface is formed by oceans and another 3½ percent by polar ice caps; the remaining 25½ percent, constituting the land masses, is at various times and places obscured by clouds, covered by ice and snow, and draining or storing liquid water. But mankind has restrictive specifications for water—it must be suitable for his use, and it must be available where he wants to use it—which reduce drastically this apparent abundance. The oceans and polar ice caps, together containing more than 99 percent of the world's water, typify respectively the water unsuitable for use and inaccessible for use by man.

By modern technological processes we can remove the impurities from any natural or artificially-contaminated water and render it suitable for any intended use. Also, we can lift water from great depths and transport it long distances to make it available at any place of desired use. These technological processes for water purification and distribution involve costs in energy and equipment—costs which a man is willing to pay if he can and if he has no cheaper alternative, because suitable water is essential for life. In practically all times and places, however, there has been a cheaper alternative, provided by a natural system of purification and distribution of water, as a part of the hydrologic cycle.

Although the term "water resources" is variously defined or left undefined, it generally includes only the waters occurring naturally, and of a quality suitable for man's use—in common parlance, "fresh" water. The U. S. Public Health Service in its drinking water standards recommends that concentrations should not exceed 250 parts per million of chloride, 250 ppm of sulfate, and 500 ppm total dissolved solids, but considers that water containing as much as 1,000 ppm of solids is acceptable where purer water is not available. Some individuals have adapted themselves to drinking water containing as much as 1,500 ppm chloride, 2,000 ppm sulfate, and 5,000 ppm total dissolved solids, and several of the common domesticated animals and plants have similar limits of tolerance for dissolved salts in their water supply. The requirements as to quality of water range widely according to the use intended, but generally when people speak of "water resources" they are thinking of a product that is more than 99.9 percent pure, and frowning on any whose purity is less than 99.5 percent.

THE HYDROLOGIC CYCLE

The origin of practically all the fresh water on Earth is traceable to a natural distillation process powered by solar energy—that is, evaporation especially from the oceans and other water surfaces, transport as water vapor in the atmosphere, and precipitation upon the continents and islands. The rainwater is either absorbed in the soil or it accumulates on the surface and then starts to run off. Water has the same alternatives at every spot on earth during every storm: either infiltration, or accumulation on the surface (as snow, ponds, or lakes), or runoff downslope. This runoff may continue overland only until it finds a place where it can be absorbed in the soil, or it may enter a channel and eventually a river, as storm flow. The water absorbed by the soil may accumulate there as soil moisture; and it may continue downward through the openings within the rock materials, until it reaches a zone where all the pores are saturated. This ground-water zone is another place for accumulation, and for movement downslope similar to the overland runoff, but through small pores and thus far more slowly.

When it stops raining, the surface materials dry off—the water evaporates and returns as vapor to the atmosphere. Some of the water in the soil does likewise, and some is used in the life processes of vegetation, including transpiration which returns water as vapor to the atmosphere. The storm flow collects in the various channels of the drainage system, where it may create flood stages. The water in streams may be stored temporarily in lakes and reservoirs or along the streambanks; eventually it is debouched into the sea by the trunk river, except for that which is evaporated and returned to the atmosphere. The ground water moves slowly downgradient; in places it reappears at the land surface as springs; in other places it is shallow enough that it can be reached by vegetation, so that there is discharge to the atmosphere; and it may discharge into streams, contributing a base flow that sustains the stream in dry weather and makes it perennial.

Thus, wherever we look upon this earth, we can see parts of a "perpetual-motion" system, of which the portions upon and under the earth constitute an integrated flow system, replenished sporadically but persistently by precipitation. Man and living organisms generally have continuing requirements for water, even when it is *not* raining, and for these the aforementioned accumulations of water, stored as ground water or soil water or surface water, are essential.

The surface water, soil water, and ground water that originate in precipitation are obviously replenishable resources. The average annual precipitation is equivalent to a layer of water 760 millimeters (30 inches) thick over the area of the conterminous United States, of which 550 mm (21½ inches) is evaporated and returned to the atmosphere, and the rest is runoff to the seas or across the Nation's land boundaries. We say there is a natural equilibrium because of the long-range balance between inflow (precipitation) and outflow (evaporation and runoff) of fresh water, but because of climatic variations there are continuing fluctuations at any point in everything we measure—streamflow, ground water, soil water, evaporation, etc.

In addition to the replenishable resources, there are fresh-water accumulations underground from bygone years (or centuries) of precipitation, which in the aggregate have a far larger volume than could be replenished by the annual precipitation and infiltration. Throughout the country there are wide variations in climate, geology, and other elements that affect the geographic distribution of the fresh-water resources, both replenishable and nonreplenishable.

Man's uses of water are similar to its disposal in nature. In consumptive uses such as boiling and irrigating, the water goes as vapor to the atmosphere, as it does in natural evapotranspiration processes. In nonconsumptive uses such as washing, processing, or cooling, the water carries off waste and unwanted products. Through geologic ages rivers have been the natural waste-disposal systems for the continents, carrying soil and rock waste, organic debris, and dissolved mineral matter that make the oceans what they are. Man's achievements and purposes in water developments have always been to intercept water while it is still fresh and before it can return to the atmosphere or ocean, use it, and then let it go again—to atmosphere or ocean.

RUNOFF

The water that flows in rivers, creeks, and ephemeral streams represents water from precipitation that could not infiltrate into soil and rock materials, or that could not be retained in surface reservoirs (including lakes, ponds, snow and ice fields) or in underground reservoirs. Thus runoff constitutes a residual or surplus that cannot be accommodated in the storage facilities of the continental area. The annual runoff is determined on the basis of continuing measurements of stage and discharge of streams at 8,400 gaging stations distributed throughout the U. S. The average annual runoff in the period 1931–60 is represented on page 118–119 in inches of water over the land surface, and thus provides ready comparison with the pattern of precipitation, shown on page 97.

Seasonal variations in runoff are characteristic of most streams. The average proportion of the annual runoff that occurs each month is shown graphically on page 120 for 22 streams draining basins of less than 4,000 square kilometers (1,600 square miles), and also for the three largest rivers in the country. The maximum runoff in several of the streams occurs during a marked rainy season: winter along the Pacific Coast, summer in southern Arizona, autumn in Florida. In most streams the greatest runoff occurs during the spring, because of snowmelt (especially in mountain streams), spring rains, or both. The flow of a few streams is fairly uniform throughout the year. The large rivers carry the aggregate runoff from many such streams. The Columbia commonly reaches its peak in June, but the flow is well sustained throughout the rest of the year. The Mississippi varies far less from month to month than do most of the streams that contribute to it. The flow of the St. Lawrence River, regulated by storage in the Great Lakes, varies little from month to month throughout the year.

The flow of all streams varies also from year to year. Two maps on page 120 show respectively the maximum and minimum annual runoff in percentages of the average. The greatest deviations above and below the average occur in the same general areas, as indicated by a third map depicting the variability of streamflow. There may be large local variations from the general pattern depicted, even in areas where precipitation is relatively uniform, owing in part to the effects of the aggregate facilities for storage (soil water, ground water, and surface water) within the individual drainage basins.

The extreme events in variations of streamflow are designated *floods* and *droughts*. As generally defined, a flood is an overflow or inundation that comes from a river or other body of water and causes or threatens damage. The lands bordering rivers are among the most valuable in the country, whether for agriculture because of the fertile alluvial soils, or for communities and industries because of the facility with which communication and transportation can be developed. Human occupancy, however, raises the question as to the degree of security afforded against flooding. The answer to this question will vary from one property to the next, and will be modified by structures or techniques that have been developed for flood protection. The answer is also dependent in part upon the flood potential, including the frequency of recurrence of floods of various magnitudes. Two maps on page 121 show the geographic variations in potential of the mean annual flood and the 10-year flood in drainage basins of about 800 square kilometers (300 square miles). The potential of the 10-year flood is generally 1½ to 2½ times the volume of water of the mean annual flood.

Estimates of damage caused by floods are imprecise, because the losses are as diverse as the economic interests of modern society. Generally, the most spectacular damage occurs during one or two years of each decade, during a flood of exceptional magnitude in a specific river basin or region. A map on page 121 shows the principal areas affected by catastrophic floods in the 13 years of greatest flood damage in the 20th Century.

Drought occurs during a period when precipitation is significantly less than the long-term average, and is thus distinct from *aridity* which is the dryness of a region having a very low average precipitation. Periods of less than average precipitation may range from several days to several years, and even to several decades. During such periods the replenishment of soil mosture, surface water, and perhaps also ground water is reduced, and the accumulated storage of each may dwindle because of continuing use or outflow. Thus the deficiency in precipitation may be reflected in deficiencies in water available from a wide variety of sources on which man may depend to sustain him in his particular environment.

To constitute a drought as the term is generally used, the water deficiency must be great enough and continue long enough to hurt mankind. In regions of normally abundant rainfall, where crops are dependent entirely upon soil moisture replenished by rain, the lack of rain for only a few weeks is called a drought, even though there are untapped resources of ground and surface water. Such droughts have generally been encompassed within the growing season of a single year. In arid regions a rainless month or even an entire growing season without rain does not qualify as a drought, because these are usual occurrences, and agriculture and other human activity can succeed only where there is assurance of other water supply to supplement the inadequate rainfall. In such regions a drought is recognized when the *total* water supply is seriously reduced during several years of less than average precipitation over a broad region. A map on page 121 depicts the broad regions in which people have been vulnerable chiefly to short droughts, to long droughts, and to both. A chart on page 121 depicts annual variations in runoff of several streams with long records.

The variations in runoff that reach their extremes in floods and droughts have been reduced by storage in artificial reservoirs along the many rivers. Pages 118–119 show the locations of all reservoirs having a usable capacity greater than 100 million cubic meters (81,000 acre-feet). All these reservoirs can be used to modify the seasonal variations in runoff; those whose capacity exceeds the average annual inflow (that is, those with "holdover" storage) may also be effective in reducing the annual variations.

GROUND WATER

Ground water is the subterranean water that occurs where all pores in the rock materials are filled with water that is under greater than atmospheric pressure. These "pores" may be the spaces between boulders or pebbles, or between grains of sand or particles of clay, or the fractures or fissures or cavities in consolidated rocks. Ground water is discharged at the land surface in springs and seep areas in many places, and in other places it is discharged into streams, lakes, oceans, or inland seas. In many places it is tapped and used by various plants known as "phreatophytes", but most vegetation obtains its water from the soil and underlying zones which retain some moisture but habitually are not saturated.

Except where ground water comes to the surface or is close enough to be reached by shallow excavations, man's use of this resource is dependent upon wells. Wells penetrate rock materials until they reach an aquifer, or "waterbearer", which can yield water by gravity drainage to the well to replace the water withdrawn. Literally millions of wells in a wide variety of rocks and rock materials have yielded water enough for a family's needs for drinking, cooking, and washing. In extensive regions of the United States, ground water could be developed almost anywhere in quantities sufficient for such domestic use.

In ground-water development for public supply, for industry, or for irrigation, wells must yield far more than these miniscule quantities. On pages 122–123, all areas shown in color are underlain by at least one aquifer that is generally permeable enough to yield water to a well at rates exceeding 3½ liters per second (50 gallons per minute), which is the average water requirement of a community of 500 people. All the aquifers thus represented contain fresh water that is considered usable; in most of the country this means that the water contains less than 1,000 ppm of dissolved solids, but in numerous areas water containing as much as 2,000 ppm is used for irrigation and public supply. In the blank areas no productive aquifers of significant areal extent are yet known, although there are numerous productive wells.

In the search for permeable rocks, the general rule is that the loose rock materials—gravel, sand, silt, and clay—have greater porosity than do the consolidated rocks; but the pores in clay and silt are so small that a sizable proportion of clay and silt in any loose rock material makes it relatively impermeable. More than 80 percent of all the water pumped from wells in the United States comes from gravel or sand aquifers. The watercourses, shown in blue, are also sand-and-gravel aquifers, distinguished from those shown in yellow by the fact that they are in alluvial valleys in which ground and surface water are interrelated, and in which water withdrawn from wells is likely to be replenished eventually by infiltration from the river.

Sandstone has less pore space than sand because of the cement between the grains, but wells obtain large yields from sandstone that is poorly cemented or well jointed. Many limestones are sufficiently permeable to yield large volumes of water to wells, and some basalts are also excellent aquifers. In other consolidated rocks, whether igneous, sedimentary, or metamorphic, the permeability is generally limited to that provided by fractures; in a few States, such rocks yield water in the quantities needed for modest-scale irrigation or industry.

For all aquifers except the watercourses, the map gives no clue as to whether the withdrawals from wells can be sustained perennially. The rate at which water pours into a well from an aquifer gives no clue as to how long the well can continue to produce. The first water yielded by a new well comes from storage within the aquifer, and the well will continue to deplete the storage until recharge to the aquifer is increased, or until other discharge from it is decreased, in equivalent amounts. Many heavily-pumped aquifers, after an initial depletion of storage, appear to have approached a new equilibrium at present rates of pumping. The storage in some other aquifers is diminishing from year to year—in places because of progressively increasing aggregate withdrawals, in places because the present rates of withdrawal are far greater than the natural replenishment, and in places because of drought or artificial hindrance to natural replenishment.

The distribution of ground-water pumpage is indicated by dots, each representing an annual withdrawal from wells of about 100 million cubic meters (72 mgd or million gallons a day). In Alaska, Rhode Island, Vermont, New Hampshire, Maine, North Dakota, and Delaware the total withdrawal of ground water is less than 100 million cubic meters. In 10 other States no dots are shown, even though the statewide pumpage ranges from 100 to 300 million cubic meters, because that pumpage is widely dispersed. California, Texas, and Arizona account for about half the total pumpage of ground water in the entire Nation; this pumpage is chiefly for irrigation, and chiefly in the agricultural areas of California's Central Valley, Arizona's Gila River basin, and Texas' High Plains.

The statewide totals of pumpage reflect in some degree the geographic size of the respective States. Several Eastern States rate high in terms of pumpage per unit of area: on this basis, New Jersey's rate of withdrawal is as great as California's, and is exceeded only by that of Hawaii. The withdrawals of ground water per unit of area in Delaware, Massachusetts, and Rhode Island are less than in Hawaii, New Jersey, California, Texas, Idaho, and Arizona, but greater than in any other State.

IMPURITIES

In the hydrologic cycle water is most nearly devoid of impurities when it has just been condensed from atmospheric vapor. During precipitation the rain may absorb soluble solids and gases, and wash insoluble particles from the atmosphere. After reaching the earth anything in the path of water may contribute to its impurities: soluble minerals may be dissolved during overland flow and especially during sub-surface movement as soil water and ground water; surface water may also carry solid matter in flotation, in suspension, or as bedload. Consequently, practically all natural waters contain some impurities, and many of these persist in the water until it is evaporated and returned to the atmosphere—indeed, after such evaporation the impurities remain and accumulate on the land surface or in the soil or in the water left behind. In addition to the inorganic impurities, water contains impurities from the living world in great variety: fauna and flora ranging down to single-celled organisms, bacteria and viruses, plus all the products of their life processes and decay.

Many uses of water by mankind are for disposing of wastes, but organic wastes are putrescible, and therefore can be removed from the water by suitable processes of sewage treatment. Other byproducts of civilization include a variety of inorganic wastes that can be dissolved or suspended in water; some of these are lethal or toxic, others merely unpleasant or uneconomic, but most are persistent and not removable from the water by standard sewage treatment.

Only the natural inorganic impurities in waters are shown on pages 124 and 125. The maps are based upon determinations of the most common dissolved chemical constituents in water from streams or wells, and of the suspended sediment in streams. Thus the maps give no indication of the presence or absence of pollutants introduced by man, whether organic or inorganic. However, if human occupancy of a region has resulted in significant modification of sediment yield or of the common dissolved chemical constituents, the maps would show these modified characteristics rather than the "virgin" conditions.

The maps Prevalent Concentrations of Dissolved Minerals and Prevalent Chemical Types of Water in Rivers are based upon analyses of water in streams during periods of low flow, when the water comes chiefly from ground-water reservoirs. Analyses of water from wells and springs show that there are great variations in chemical quality of ground water in many parts of the country, both geographically and in depth—variations too intricate to be depicted on a map at this scale even if adequate data were available. The low flow of streams is therefore used as a composite sample of the ground-water outflow. Storm runoff usually is much more dilute than the low flow, because the contact with soil and rock is less and for a shorter period. The prevalent concentration of dissolved solids is generally least in the regions of greatest rainfall and runoff—in the East and Southeast and the mountains of the West—and greatest in the semiarid Southwest and Great Plains. Concentrations are low also in regions of dominantly crystalline rocks, and high in regions where the rocks include substantial proportions of evaporites such as rock salt and gypsum. Thus, both climatic and geologic controls are factors in the patterns shown by the map. In about half the country the prevalent concentration of dissolved solids is less than 230 ppm, and in 90 percent of the area it is less than 900 ppm.

In more than half the country the prevalent water is of the calcium bicarbonate type containing subordinate amounts of magnesium and carbonate. The areas where this type of water contains less than 120 ppm total dissolved solids are discriminated on the map, because such waters are generally the "soft" waters of best quality for most uses.

The sodium potassium chloride sulfate types of water are prevalent in about one-eighth of the country. Although such waters are generally soft, a sodium potassium water having total dissolved solids greater than 800 ppm may have concentrations of calcium and magnesium that would make it very hard.

Mineralized ground water in the past has not been considered a water resource because of its unsuitability for most uses, and it has been avoided in many places for fear of contamination of fresh-water resources. Development of economic processes of desalination will inevitably lead to recognition of mineralized ground water as a valuable resource wherever natural fresh-water resources are insufficient, particularly in interior regions where such water is far more readily accessible than sea water. The meager information presently available on saline water—chiefly from unsuccessful water wells, oil wells and other borings, mines and other subterranean exploration, and geologic studies—is presented in a map on page 124.

The map of sediment concentration (page 125) is based on the average annual discharge-weighted means of measured streams—that is, the quantity of suspended sediment that passes a section on a stream in a given time divided by the volume of water discharge for the period. Sediment concentrations of a river may range widely during a year, the maximum concentrations being 10 to more than 1,000 times the minimum. The average annual sediment concentrations shown represent suspended sediment carried by the major flowing part of the stream, and do not include the bedload. The discharge-weighted suspended-sediment concentration is less than 600 ppm in 50 percent of the country, and less than 8,000 ppm in 90 percent of the country.

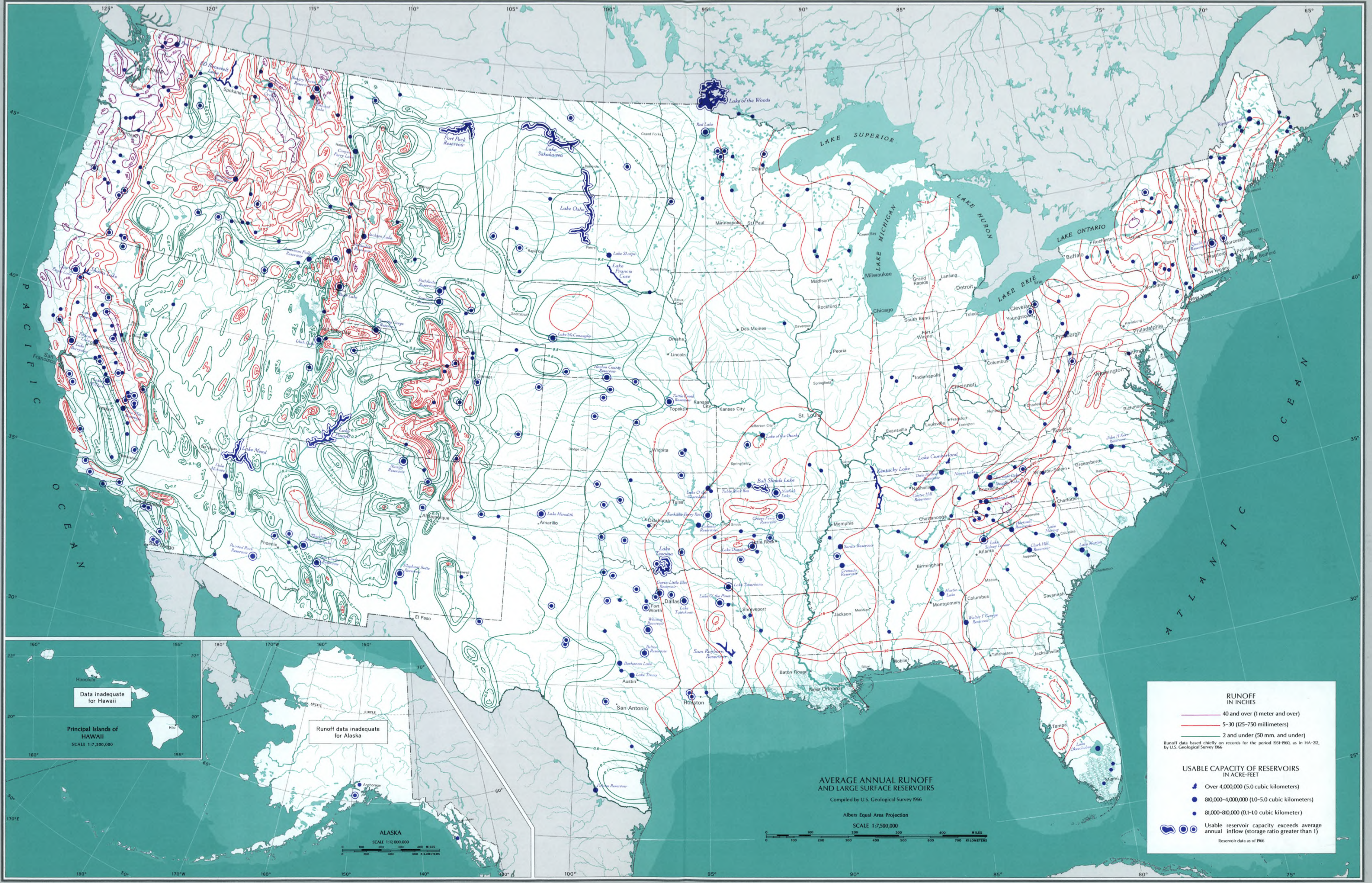
WATER USE

Of the diverse uses of water by mankind, several do not require the removal of water from its native environment: navigation; various forms of recreation including fishing, boating, and swimming; conservation of fish and wildlife; and disposal of sewage and other liquid and solid wastes. Certain minimum quantities of water may be essential for these uses, and the use may result in deterioration in the quality of some water, but the actual water use is not readily quantified. Hydroelectric power generation *does* require diversion through pipes, penstocks, and generators, but the water thereafter generally is returned to the stream undiminished in quantity. The total quantity of water used for hydropower in 1960 in the continental United States was of the order of 2,700 cubic kilometers, (2,000,000 mgd) which is 165 percent of the average annual runoff from the country.

The map on pages 126–127 shows withdrawal uses as of 1960 but does not include use for hydropower or any nonwithdrawal use. Four major types of withdrawal use are discriminated: irrigation, which accounted for 40 percent of the total withdrawal; fuel-electric power generation (chiefly for condenser cooling), 37 percent; other industrial use, 14 percent; and public supply, 8 percent of the total withdrawal. The total withdrawal use in the Nation in 1960 was about 375 cubic kilometers, or 270,000 mgd. Of this total, about 17 percent—65 cubic kilometers or 47,000 mgd—came from wells, and more than 99 percent of this was classified as fresh water. All other withdrawals came from surface water, which includes the water issuing from springs because that water is withdrawn after it reaches the surface. Of the total surface withdrawals of 310 cubic kilometers (220,000 mgd), about 45 km^3 or 32,000 mgd was saline water, pumped chiefly from tidal streams, estuaries, bays, or oceans and used for cooling.

ALASKA

Primarily because of Alaska's large areal extent, sparse population, and low temperature, the information concerning water resources in Alaska is distinctive from that in the other 49 states, both in amount and in type. Information concerning water-bearing rocks and rock materials, glaciation, and permafrost is assembled on page 128.



AVERAGE ANNUAL RUNOFF AND LARGE SURFACE RESERVOIRS

Compiled by U.S. Geological Survey 1966

Albers Equal Area Projection

SCALE 1:7,500,000

RUNOFF
IN INCHES

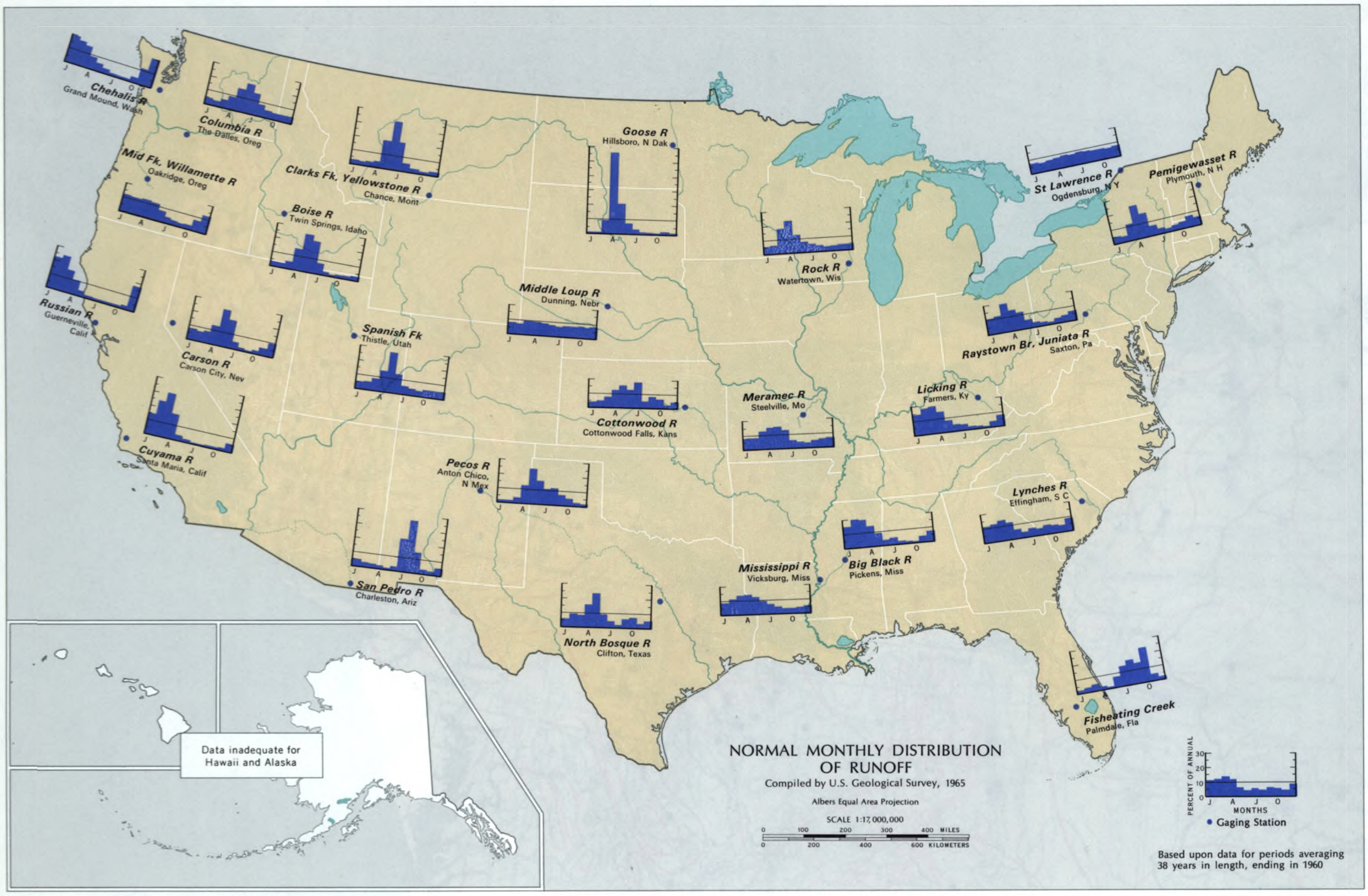
- 40 and over (1 meter and over)
- 5-30 (125-750 millimeters)
- 2 and under (50 mm. and under)

Runoff data based chiefly on records for the period 1931-1960, as in HA-212, by U.S. Geological Survey 1966

USABLE CAPACITY OF RESERVOIRS
IN ACRE-FEET

- Over 4,000,000 (5.0 cubic kilometers)
- ● 810,000-4,000,000 (1.0-5.0 cubic kilometers)
- • 81,000-810,000 (0.1-1.0 cubic kilometer)
- ◉ Usable reservoir capacity exceeds average annual inflow (storage ratio greater than 1)

Reservoir data as of 1966



NORMAL MONTHLY DISTRIBUTION
OF RUNOFF

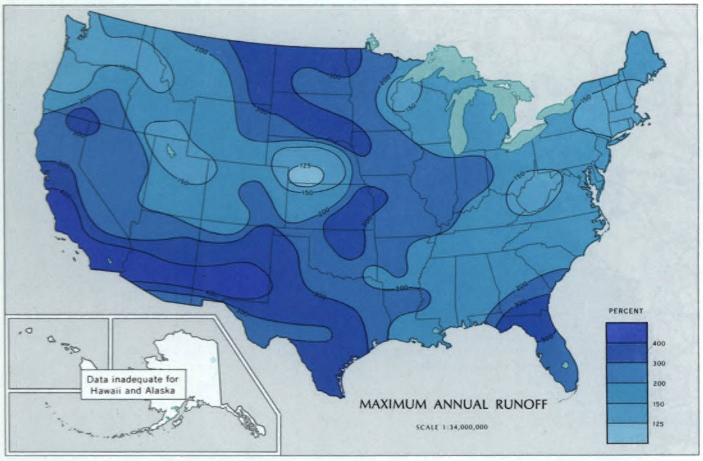
Compiled by U.S. Geological Survey, 1965

Albers Equal Area Projection

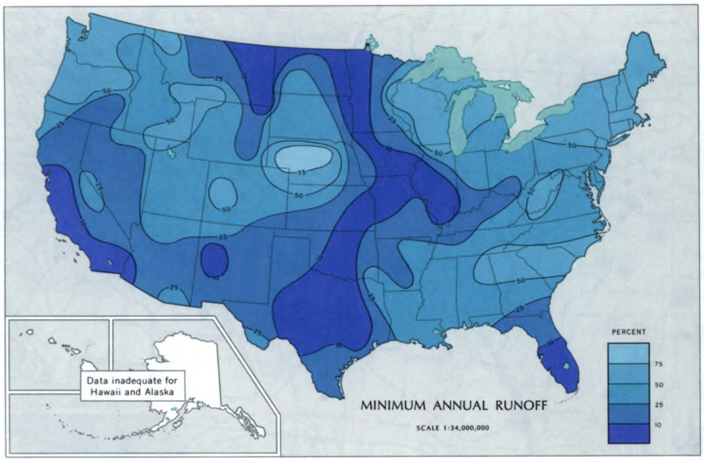
Based upon data for periods averaging 38 years in length, ending in 1960

VARIATIONS IN RUNOFF

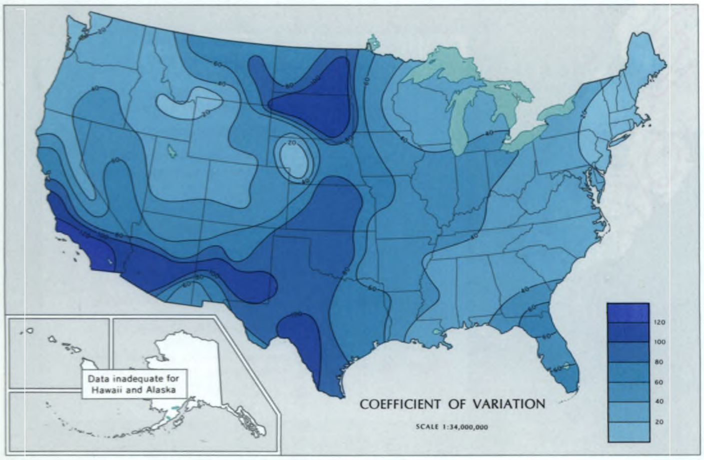
Compiled by U.S. Geological Survey, 1965



MAXIMUM ANNUAL RUNOFF



MINIMUM ANNUAL RUNOFF



COEFFICIENT OF VARIATION

MAXIMUM ANNUAL RUNOFF

Numbers show maximum annual runoff, in percent of the 1931–60 average, from representative drainage basins less than 4,000 km^2. The maximum runoff is necessarily greater than 100 percent of the average. The maximums for the individual streams occurred in various years.

MINIMUM ANNUAL RUNOFF

Numbers show minimum annual runoff from representative drainage basins, in percent of the 1931–60 average. The minimum runoff is necessarily less than 100 percent of the average. The minimums for the individual streams occurred in various years.

COEFFICIENT OF VARIATION

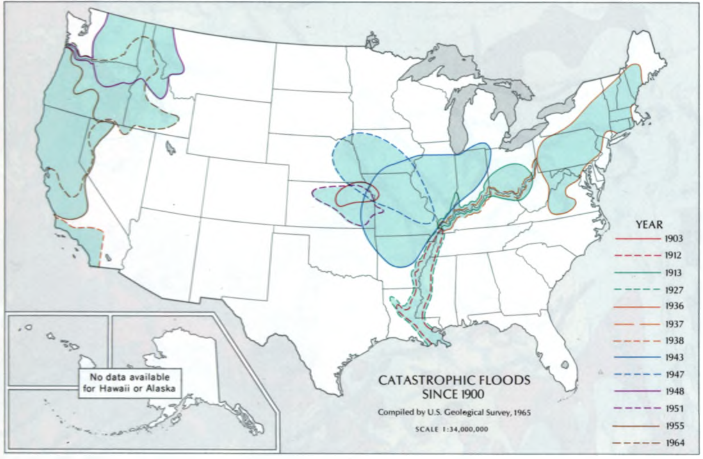
Contours are based on coefficients of variation as calculated for representative streams. (The coefficient of variation is the standard deviation of the annual runoffs divided by their arithmetic mean and multiplied by 100). Runoff is most stable in streams with low coefficient of variation. Annual runoff for the lightest color areas can be expected to be within 20 percent of the average in about 2/3 of future years.

The larger coefficients of variation are common in arid regions and in regions of continental climate. In these areas the annual runoff may deviate by more than 60 percent from the average in 1/3 of future years. Wherever the coefficient of variation exceeds 100, the runoff may be either negligible or more than twice the average in 1/3 of the years.

CATASTROPHIC FLOODS

Some of the historic catastrophic floods differ from 10-year floods chiefly in degree; the streams have greater volume of flow and thus rise to higher stage and inundate more area; but flows of this magnitude are far less frequent–100-year floods, or perhaps 200-year floods–so that the occupants of flood-hazard lands may achieve a false sense of security. As shown on the map below, the principal floods during the 13 years of greatest flood damage were generally in areas of relatively high potential for both mean annual and 10-year floods.

Most catastrophic floods have resulted from excessive rainfall over extensive areas. Damage from this runoff has occurred chiefly along the flood plains of large and middle-sized rivers, where cities and valuable properties have been inundated. In some localities the runoff from small drainage basins has inundated urbanized areas and caused extreme damage.



CATASTROPHIC FLOODS
SINCE 1900

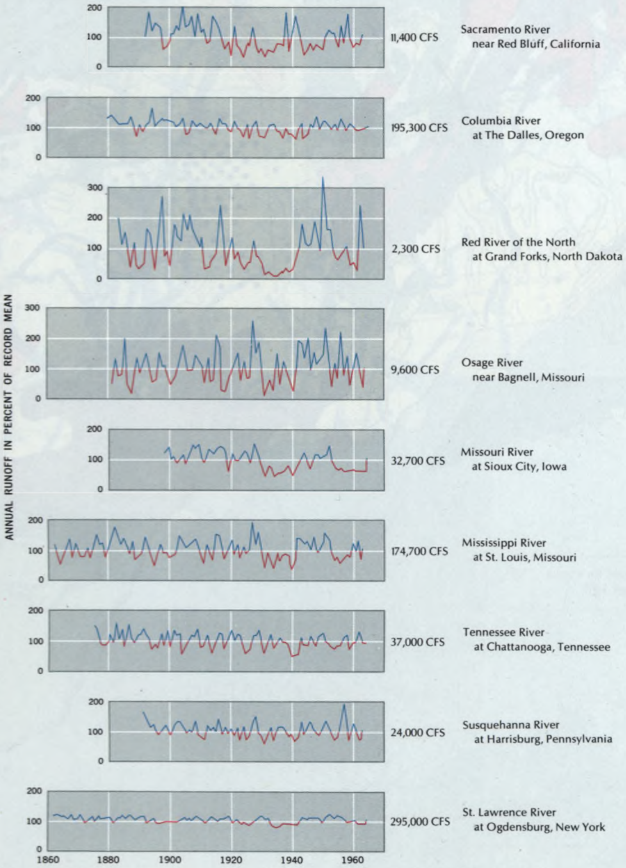
Compiled by U.S. Geological Survey, 1965

SCALE 1:34,000,000

LONG-TERM TRENDS IN RUNOFF

The graphs show the annual runoff, in percent of the mean, at several of the gaging stations with longest records. In general, the graphs fluctuate greatly, but there is similarity among the graphs for rivers within the respective regions (Sacramento and Columbia Rivers in the West; Tennessee, Susquehanna and St. Lawrence Rivers in the East; the others in the Middle West). In numerous rivers the years of minimum flow during the past century occurred in the decade 1930–40. All periods of water deficiency–runoff less than the mean–are shown in red.

In percent of the mean, the annual variations are generally greatest in the streams of least volume, less in the larger rivers, and least in the St. Lawrence (because of the natural regulating effect of the Great Lakes). Although most of the graphs are considered to represent the natural flow, the low flow of the Missouri River since 1953 is attributed in part to retention of water in reservoirs newly constructed upstream. Also, artificial regulation may be partly responsible for the smaller annual variations in flow observed in the Tennessee River since 1943 and the Columbia River since 1946.



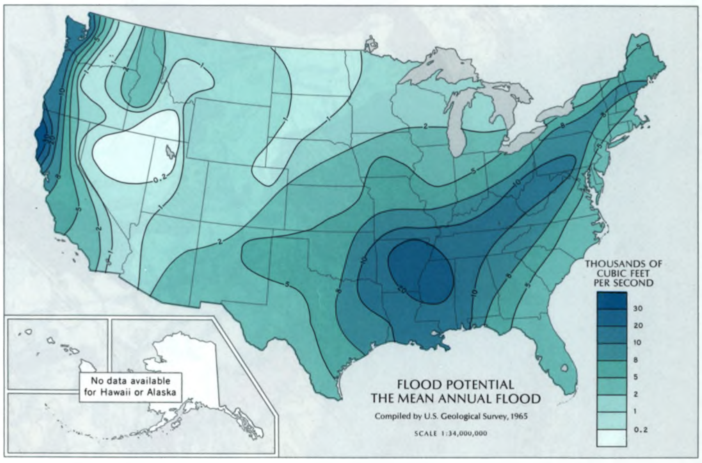
Compiled by U.S. Geological Survey, 1965

CFS=Cubic feet per second

FLOOD POTENTIAL

To be comparable, floods in different regions must be produced from drainage areas of the same size and must have the same frequency of occurrence. On the two maps below, the contours indicate the flood discharge, in thousands of cubic feet per second, that is to be expected from a 300-square-mile drainage basin during a mean annual flood and during a 10-year flood. (To obtain approximate cubic meters-per-second from an 800-square-kilometer drainage basin, multiply contour number by 30.) The mean annual flood is one which will be exceeded in about half the years; the 10-year flood will be exceeded at irregular intervals averaging 10 years in length.

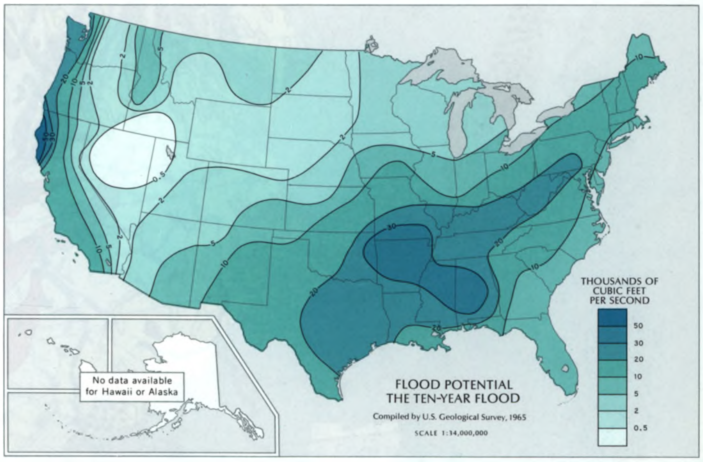
The lines of equal flood potential are necessarily generalized and are intended only to show wide-scope variability. Flood potential is intimately related to topography, precipitation, and antecedent storage conditions, all of which may change abruptly within a short distance, especially in western United States. Because the local variability cannot be shown, the maps should not be used to estimate the flood potential of a particular stream.



FLOOD POTENTIAL
THE MEAN ANNUAL FLOOD

Compiled by U.S. Geological Survey, 1965

SCALE 1:34,000,000



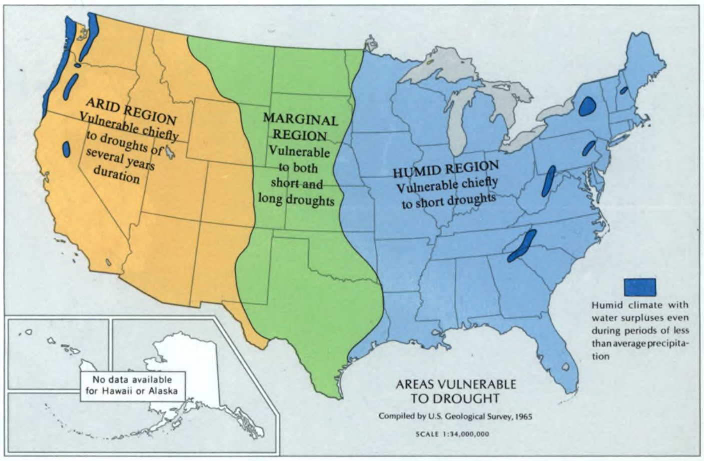
FLOOD POTENTIAL
THE TEN-YEAR FLOOD

Compiled by U.S. Geological Survey, 1965

SCALE 1:34,000,000

DROUGHT POTENTIAL

Drought occurs when precipitation is less than the long-term average, and when this deficiency is great enough to hurt mankind. In humid regions a drought of a few weeks is quickly reflected in soil-moisture deficiencies and other water resources. In arid regions the inhabitants protect themselves from short droughts by depending upon surpluses of ground or surface water, and a drought becomes critical when it is sufficiently prolonged to reduce these supplies. Prolonged droughts occur rarely in humid regions, but they reduce the normal ground or surface-water supplies. In semiarid regions, some people may be affected by every drought, whether of short or long duration.



AREAS VULNERABLE
TO DROUGHT

Compiled by U.S. Geological Survey, 1965

SCALE 1:34,000,000

PRODUCTIVE AQUIFERS AND WITHDRAWALS FROM WELLS

Compiled by U.S. Geological Survey, 1965

Albers Equal Area Projection

SCALE 1:7,500,000

0 100 200 300 400 MILES
0 100 200 300 400 500 600 700 KILOMETERS

Colored patterns indicate areas underlain by one or more aquifers generally capable of yielding to a well at least 50 gallons per minute (or 3½ liters per second) of fresh water (generally less than 1000 parts per million of dissolved solids, but up to 2000 or more in parts of the West)

UNCONSOLIDATED AQUIFERS

⥼	Watercourse: alluvial valley traversed by stream from which recharge can be induced
🟨	Sand and gravel: in intermontane valleys; abandoned or buried alluvial valleys; alluvial terraces; sand dunes; Coastal Plains and Great Plains; glacial outwash and ice-contact deposits of glaciated regions

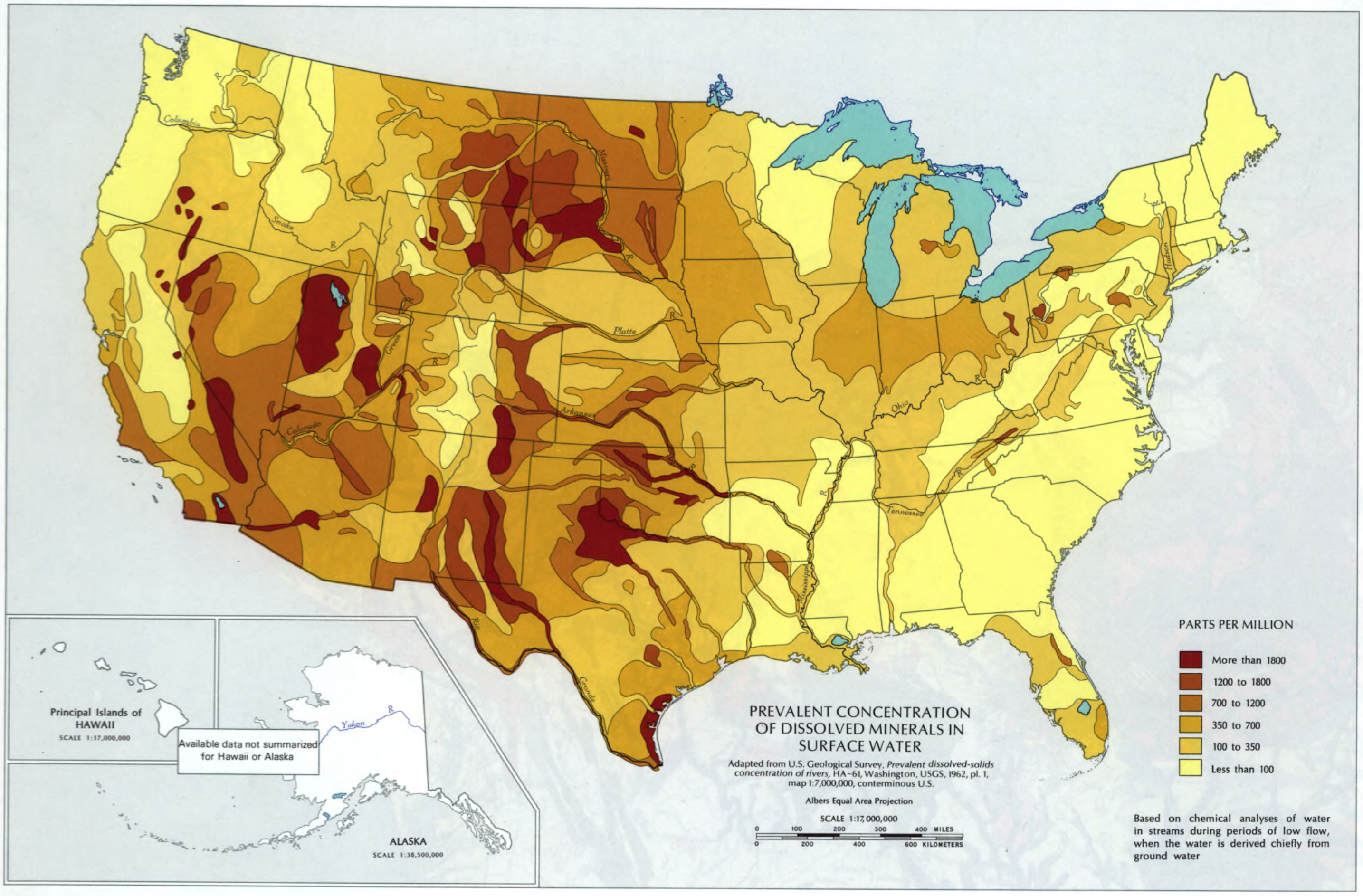
CONSOLIDATED ROCK AQUIFERS

🟥	Sandstone: includes some unconsolidated sand
🟩	Carbonate rock: limestone and dolomite; and in Texas and Oklahoma, some gypsum
🟫	Sandstone and carbonate rocks
🟪	Volcanic rocks, chiefly basalt
▨	Crystalline rocks, igneous and metamorphic

Ruled pattern of any of these colors indicates that the corresponding aquifer underlies a productive sand and gravel aquifer as explained above

WITHDRAWALS FROM WELLS

●	Represents withdrawal of 81,000 acre-feet or 100 million cubic meters annually, equivalent to 72 million gallons a day
•	Represents half of the quantity described for preceding symbol



PREVALENT CONCENTRATION OF DISSOLVED MINERALS IN SURFACE WATER

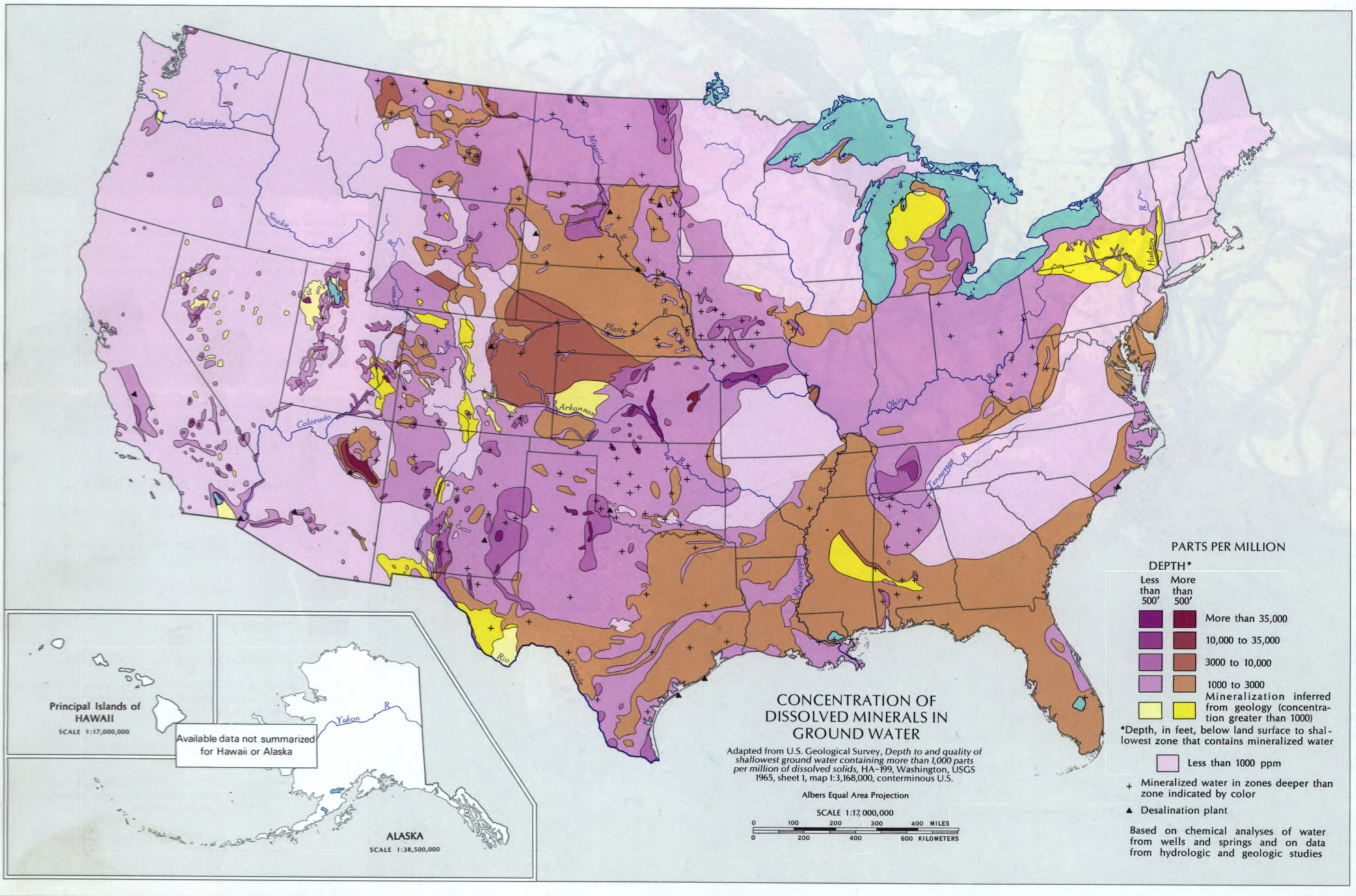
Adapted from U.S. Geological Survey, *Prevalent dissolved-solids concentration of rivers*, HA-61, Washington, USGS, 1962, pl. 1, map 1:7,000,000, conterminous U.S.

Albers Equal Area Projection

PARTS PER MILLION

■	More than 1800
■	1200 to 1800
■	700 to 1200
■	350 to 700
■	100 to 350
■	Less than 100

Based on chemical analyses of water in streams during periods of low flow, when the water is derived chiefly from ground water



CONCENTRATION OF DISSOLVED MINERALS IN GROUND WATER

Adapted from U.S. Geological Survey, *Depth to and quality of shallowest ground water containing more than 1,000 parts per million of dissolved solids*, HA-199, Washington, USGS 1965, sheet 1, map 1:3,168,000, conterminous U.S.

Albers Equal Area Projection

PARTS PER MILLION

DEPTH* Less than 500′	 More than 500′	
■	■	More than 35,000
■	■	10,000 to 35,000
■	■	3000 to 10,000
■	■	1000 to 3000
■	■	Mineralization inferred from geology (concentration greater than 1000)

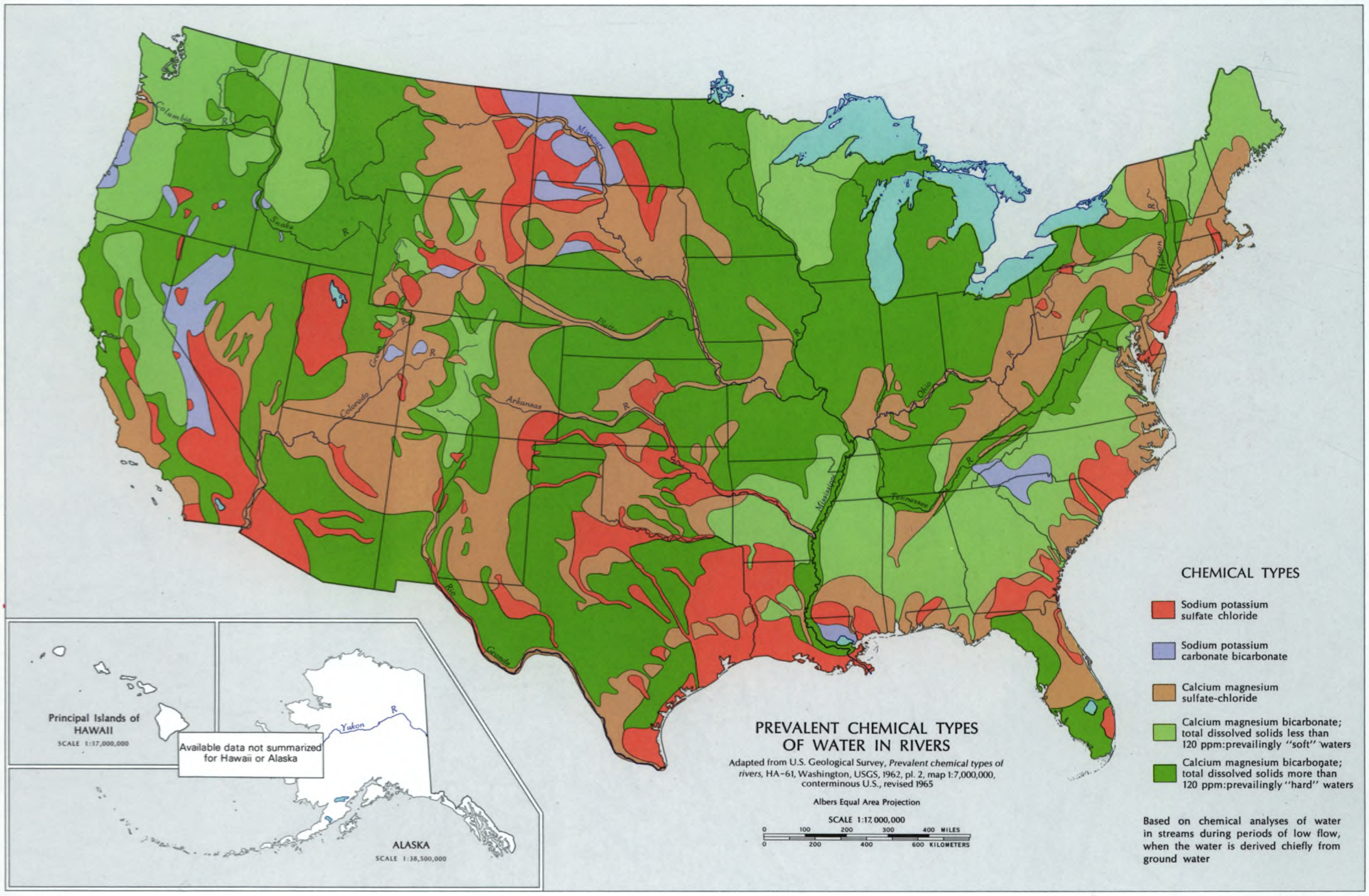
*Depth, in feet, below land surface to shallowest zone that contains mineralized water

■ Less than 1000 ppm

+ Mineralized water in zones deeper than zone indicated by color

▲ Desalination plant

Based on chemical analyses of water from wells and springs and on data from hydrologic and geologic studies

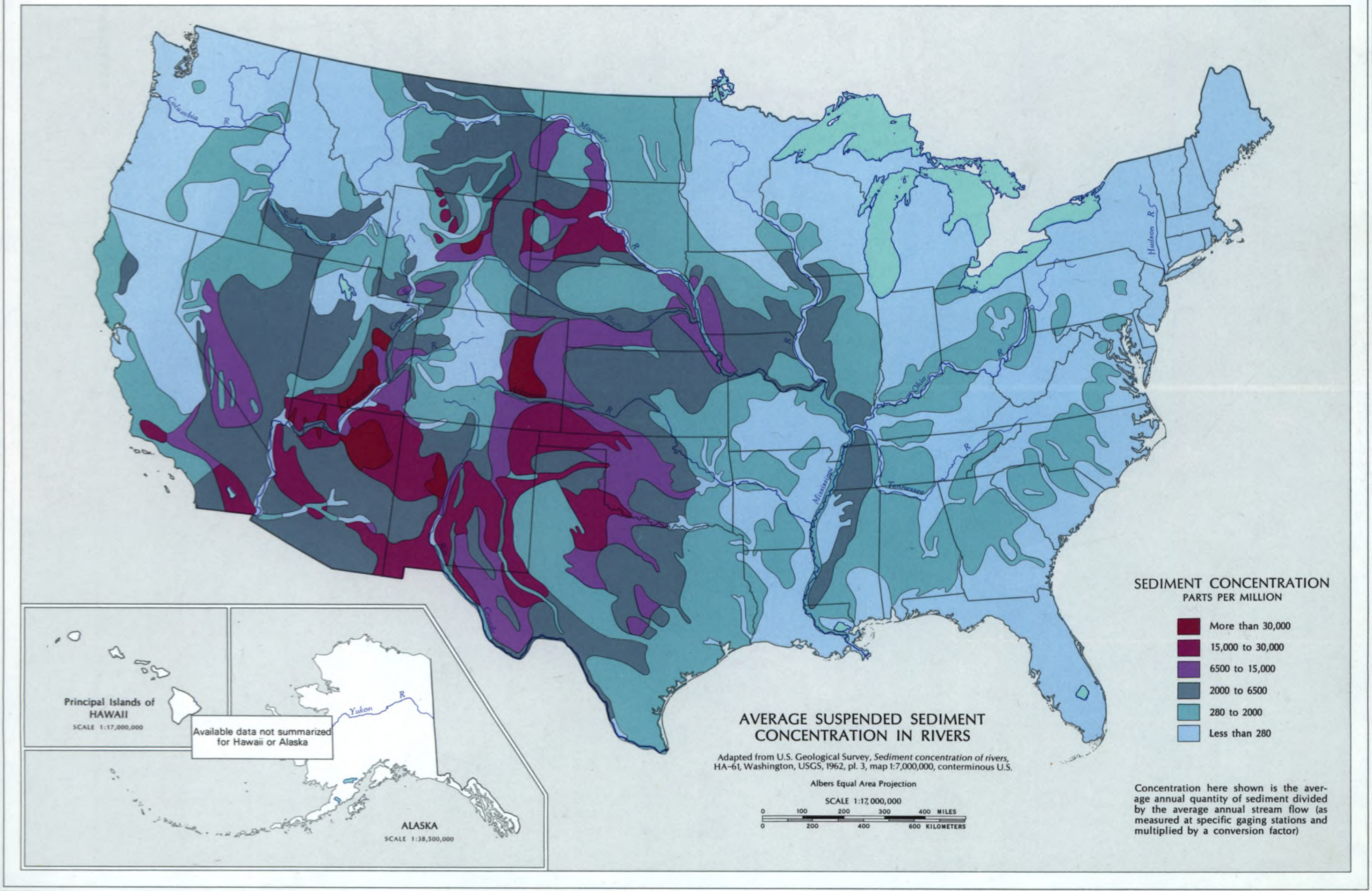


PREVALENT CHEMICAL TYPES OF WATER IN RIVERS

Adapted from U.S. Geological Survey, *Prevalent chemical types of rivers*, HA-61, Washington, USGS, 1962, pl. 2, map 1:7,000,000, conterminous U.S., revised 1965

Albers Equal Area Projection

Based on chemical analyses of water in streams during periods of low flow, when the water is derived chiefly from ground water



AVERAGE SUSPENDED SEDIMENT CONCENTRATION IN RIVERS

Adapted from U.S. Geological Survey, *Sediment concentration of rivers*, HA-61, Washington, USGS, 1962, pl. 3, map 1:7,000,000, conterminous U.S.

Albers Equal Area Projection

Concentration here shown is the average annual quantity of sediment divided by the average annual stream flow (as measured at specific gaging stations and multiplied by a conversion factor)

PRINCIPAL USES OF WATER

BASED ON DATA FOR 1960

Compiled by U.S. Geological Survey, 1968

Albers Equal Area Projection

SCALE 1:7,500,000

Each solid symbol represents annual use of approximately 1 cubic kilometer (1,000,000,000 cubic meters) of water, equivalent to 810,000 acre-feet, or to an average use of 720 million gallons per day. Open symbols represent half this rate of use

TYPE OF USE*	SOURCE FRESH SURFACE WATER	 FRESH GROUND WATER	 SALINE WATER
Public supply	♦ ◊	♦ ◊	
Irrigation	● ○	● ○	
Fuel-electric power generation	★ ☆	★ ☆	★ ☆
Other industrial	■ □	■ □	■ □

*Nonwithdrawal uses for hydropower, navigation, recreation, and dilution are not shown

Areas within blue boundaries are major water resource regions. Dashed blue lines within these basins outline interior (closed) sub-basins

WATER RESOURCES

Compiled by U.S. Geological Survey, 1966

Albers Equal Area Projection

SCALE 1:7,500,000

ALASKA WATER RESOURCES

Exceptional features result from the low average temperature. Glaciers now cover an aggregate area more than one-twelfth of the State's land area, and Pleistocene glaciers apparently covered nearly half of the present land area. Wherever the temperature of the lithosphere is continuously below 32°F., H_2O will be in the form of permafrost, although the surficial (soil) zone may melt in summer. The map discriminates (1) areas of continuous permafrost, where permafrost is generally thick and the ground water beneath it commonly is brackish or saline; and (2) areas of discontinuous permafrost, where ground water may occur above, within, or beneath the permafrost, although it may be mineralized below thick permafrost. Throughout the areas of permafrost, lakes and rivers may be underlain by unfrozen rocks which can yield ground water.

SURFACE WATER

Alaska has many fresh-water lakes, of which 94 have surface area exceeding 10 square miles (26 square kilometers), and 20 have depth exceeding 250 feet (75 meters). About 40 percent of Alaska is drained by the Yukon River, which in volume of runoff ranks just below the Columbia among the large rivers of North America. Headwaters of the Yukon are in Canada, but more than 60 percent of the flow of the Yukon is generated within Alaska. Many of the small streams in southeastern Alaska have exceptionally high runoff: in 27 years of record the average annual runoff of Mahoney Creek near Ketchikan was equivalent to 252 inches (6.4 meters). From the data that are available, lines of equal runoff cannot be drawn accurately.

GROUND WATER

Well exploration and hydrologic reconnaissance have proceeded far enough to permit discrimination of three major groups of unconsolidated deposits which, depending upon permafrost conditions, may yield water readily to wells: alluvium, coastal plain, and lacustrine deposits. Although the ground waters are generally usable, excessive amounts of dissolved iron are common. Very little is yet known concerning the water-bearing properties of the consolidated rocks in Alaska.

PLEISTOCENE GLACIATION

▨ Areas probably covered by Pleistocene glaciers

PERMAFROST

▤ Continuous permafrost

▤ Discontinuous permafrost

AQUIFERS

🟨 Alluvium: silt, sand, and gravel, of flood plains, low terraces and alluvial fans

🟥 Coastal plain deposits: silt, sand, and gravel, in bars, spits and deltas

🟧 Lacustrine deposits: clay, silt, sand, gravel, and stony silt, in glacial lakes