Base from U.S. Geological Survey,
Shaded Relief Map, National Atlas Series,
Scale: 1:7,500,000

Compiled in 1976-1977

DESCRIPTION OF MAP UNITS

(The map units are defined primarily on the basis of genesis. Areas mapped as one specific unit locally contain areas of other deposits and areas in which the mapped unit is locally absent. A slash (/) separates one unit from an underlying unit; for example, gu/v indicates unit gu overlies unit v.)

QUATERNARY GLACIAL DEPOSITS--Primarily till, but include associated loess, alluvium, lake deposits, and peat. Where outer boundary is dashed, deposits are very thin and discontinuous

gw Deposits of the youngest, or Wisconsin, Glaciation--Especially useful in determining ages of events 10,000 to 70,000 years old

go Older, or pre-Wisconsin, deposits--Can be useful in determining ages of events as old as 700,000 years or more

gu Deposits undifferentiated as to age--In western mountains this unit contains extensive areas of bedrock and is mostly of Wisconsin age, but marginal areas commonly contain older deposits

m QUATERNARY MARINE DEPOSITS AND TERRACES--Locally include associated alluvial deposits and, along eastern seaboard, swamp deposits. In unglaciated areas, marine deposits are commonly associated with relatively high sea stands during interglacial times. Especially useful in determining ages of events as much as about 100,000 years old (the last group of high sea stands); locally useful for events as much as several hundred thousand years old

QUATERNARY LAKE DEPOSITS--Consist of lake-floor sediments and shore deposits and associated multiple strand lines; include associated and younger alluvium. Generally useful in determining ages of events 10,000 to 20,000 years old; locally useful for events 100,000 or more years old

lp Pluvial lake deposits

lg Major glacial lake deposits

a QUATERNARY ALLUVIAL DEPOSITS--Alluvium occurs along almost all streams, but only alluvium along major streams and areas where alluvial terraces provide stratigraphic control are shown. Along coasts some fluvial terraces are graded to marine deposits and provide similar age control. Glacial outwash occurs downstream from most glacial deposits, but commonly is not mappable at this scale. Generally useful in determining ages of events within the last 20,000 years; locally useful for events within the last several million years

v QUATERNARY VOLCANIC ROCKS--Useful in determining ages of events within the last two million years

+ Major eruptive center that served as a source for widespread air-fall ash; ashes are not shown on the map, but occur mostly west of the 95th meridian, where they may provide excellent age control

QUATERNARY EOLIAN DEPOSITS--Mostly silt (loess), but also include areas of windblown sand and locally redeposited eolian deposits. Where shown, eolian deposits are the uppermost (surface) Quaternary unit, and the underlying Quaternary deposit or pre-Quaternary bedrock is also shown. Deposits having little time-stratigraphic significance, such as active sand dunes, are not shown. Useful in determining ages of events 10,000 to 20,000 years old; locally useful for events as old as several hundred thousand years

UPPER TERTIARY ROCKS--Enclosed areas (highly generalized) contain volcanic and (or) sedimentary rocks less than about 10 million years old. Within the boundary, upper Tertiary rocks are discontinuous due to either discontinuous deposition (particularly in basin-and-range terrain) or to subsequent erosion. In many places these rocks are buried by Quaternary materials. Useful in determining ages of events younger than 10 million years

MOSTLY PRE-QUATERNARY BEDROCK--In these areas colluvium commonly overlies bedrock; other Quaternary deposits are only locally present. In addition to local alluvial, colluvial, or eolian deposits, these areas may contain such features as soils, erosion surfaces, and saprolite, which may provide some degree of Quaternary age control. Areas labelled Saprolite contain thick, extensive residuum derived from underlying crystalline rocks

Table 1.--*Summary of Quaternary dating methods*

	METHOD	APPROXIMATE AGE RANGE in years AND RESOLUTION[1/] in parentheses	MINIMUM EXPECTABLE UNCERTAINTY in percent for age given in parenthesis	USE IN DATING COMMON QUATERNARY DEPOSITS: --, Seldom, if ever, used; x, Occasionally used; xx, Often used; xxx, Very often used; ( ), Potential rather than actual use — GLACIAL	MARINE	PLUVIAL LAKE	ALLUVIAL	EOLIAN	VOLCANIC	BASIS OF METHOD AND REMARKS
Numerical methods	1. Historical Records	0 to 6,000 (±0%) (±2%)	0% (500 yr)	x	x	x	xx	x	x	Requires preservation of pertinent records; applicability depends on quality and detail of the records. Limited to about 400 years in Western Hemisphere.
Numerical methods	2. Carbon-14 (^{14}C)	100 to >40,000 (±100%) (±2%)	1% (15,000 yr)	xxx	xx	xxx	xxx	xx	x	Depends on availability of carbon. Based on the decay of ^{14}C, produced by cosmic radiation, to ^{14}N. Subject to errors due to contamination, particularly in older deposits and in carbonate material (such as mollusk shells, marl, caliche). Range can be extended from about 40,000 to 70,000 years by enrichment techniques, but 0.02 percent contamination will produce apparent age of 70,000 years from "dead" sample.
Numerical methods	3. Uranium-Series (U-Series)	5,000 to ≥300,000 (±50%) (±10%)	5% (100,000 yr)	--	xx	xx	x	--	--	Mostly used to date coral, mollusks, or bone. Potentially useful in dating travertine and soil caliche. A variety of schemes, involving members of the U-decay series are used, including $^{230}Th/^{234}U$ (most commonly used, and the method described in the table), $^{234}U/^{238}U$ (with a range back to 600,000 years), $^{231}Pa/^{235}U$, U-He (0-2 million years[2/]), and $^{226}Ra/^{230}Th$ (<10,000 years). Errors due to the lack of a closed chemical system are a common problem, especially in mollusks and bone.
Numerical methods	4. Potassium-Argon (K-Ar)	50,000 to [2/]2,000,000 (±20%) (±2%)	2% (1-2 m.y.)	x	x	(x)	x	--	xxx	Directly applicable only to igneous rocks and glauconite. Requires K-bearing phases such as feldspar, mica, glass and others. Based on the decay of ^{40}K to ^{40}Ar. Subject to errors due to excess argon, loss of argon, and contamination.
Numerical methods	5. Fission Track	50,000 to [2/]2,000,000 (±40%) (±5%)	5% (1-2 m.y.)	x	x	x	x	x	xxx	Directly applicable only to igneous rocks (including volcanic ash); requires uranium-bearing material (zircon, sphene, apatite, glass). Based on the continuous accumulation of tracks (strained zones) caused by recoiling U fission products. Subject to errors due to track misidentification and to track annealing.
Numerical methods	6. Dendrochronology[4/]	0 to 9,000 (±0%) (±2%)	0-1% (<5,000 yr)	x	--	--	xx	x	x	Requires either direct counting of annual rings back from the present, or construction of a chronology based on variation in annual ring growth. Restricted to areas where trees of the required age and (or) environmental sensitivity are preserved.
Numerical methods	7. Varve Chronology[4/]	0 to 12,000 (±0%) (±10%)	0-1% (<8,000 yr)	x	--	x	--	--	--	Requires either direct counting of varves back from the present or construction of a chronology based on overlapping successions of continuous varved lake sediments. Subject to errors in matching separate sequences, and to misidentification of annual layers.
Numerical methods / Relative-age methods	8. Lichenometry	50 to 8,000 (±10%) (±25%)	10% (<1,000 yr)	x	--	--	--	--	x	Useful only in environments with stable rock substrates suitable for lichen growth, most commonly in alpine or arctic regions, where lichen thallus diameter is proportional to age. The technique must be calibrated by other methods. Subject to error due to local lichen kill, moisture variation, and misidentification. The limit of the useful range varies considerably with climate and rock type, and commonly is less than 4,000 years.
Relative-age methods	9. Obsidian Hydration	100 to [2/]2,000,000 (±20%) (±30%)	10% (100,000 yr)	(x)	--	(x)	(x)	--	x	Requires primary or transported obsidian. Based on the thickness of the hydrated layer at an obsidian crack or surface; the thickness is proportional to the square root of time. Depends on experimental hydration rate determination, or on other techniques for calibration. Subject to errors due to temperature history, variation in chemical composition, and probably to variation in chemistry of hydrating waters.
Relative-age methods	10. Tephra-hydration	1,000 to [2/]2,000,000 (±100%) (±70%)	50% (100,000 yr)	(x)	(x)	(x)	(x)	(x)	(x)	Requires volcanic glass of the same age as the deposit being dated. Based on the progressive filling of bubble cavities in glass shards with water. Subject to same limits as obsidian hydration, plus others, including the geometry of glass shards and bubble cavities.
Relative-age methods	11. Thermoluminescence	<2,000 to 250,000 (±50%) (±10%)	5% (100,000 yr)	--	(x)	(x)	(x)	--	x	Applicable to feldspar, quartz, and possibly calcite, relative to calibration by other techniques. Based on the accumulation of energy due to radioactive decay, which is released as light when the sample is heated. Ages can be obtained for pottery and ceramics in the 400- to 10,000-year range.
Relative-age methods	12. Amino Acid Racemization[4/]	100 to 1,000,000 (±50%) (±50%)	20% (100,000 yr)	--	xx	(x)	(x)	--	--	Requires shell or skeletal material. Based on the release of amino acids from protein and subsequent inversion of their stereoisomers. Shell protein is much more reliable than bone protein. Is strongly dependent on other variables, especially temperature and leaching history. Presently used mostly as a relative-age (or correlation) technique, but may yield numerical ages when calibrated by other techniques.
Relative-age methods	13. Rate of Deposition	0 to [2/]2,000,000 [3/](5-50%)	[3/]5%	--	xxx	xx	x	x	x	Requires relatively constant rate of sedimentation over time intervals considered. Calculations based on sediment thickness between horizons dated by other methods are commonly used.
Relative-age methods	14. Soil Development	100 to 2,000,000 (±100%) (±90%)	25% (100,000 yr)	xxx	xx	xx	xxx	xx	x	Encompasses a number of soil properties which develop with time, all of which are dependent on other variables in addition to time (parent material, climate, vegetation, topography). Is most effective when these variables can be evaluated. Precision varies with the soil property measured; for example, soil carbonate locally yields age estimates within ±25 percent.
Relative-age methods	15. Rock and Mineral Weathering	100 to 2,000,000 (±50%) (±50%)	15% (100,000 yr)	xx	--	x	xx	x	x	Includes a number of rock- and mineral-weathering features which progress with time, such as development of weathering rinds, solution of limestone, etching of pyroxene, grussification of granite, and desert varnish. Has the same basic limitations as soil development. Precision varies with the weathering feature measured.
Relative-age methods	16. Progressive Landform Modification	100 to [2/]2,000,000 (±100%) (±100%)	50% (100,000 yr)	xxx	x	x	xx	x	xx	Depends on many factors in addition to time, including climate and resistance to erosion of material comprising the landform. Depends on recognition and evaluation of progressive landform modification. Includes rate of erosion.
Relative-age methods / Correlation methods	17. Geomorphic Position	0 to 2,000,000 (±100%) (±100%)	70% (100,000 yr)	xxx	xx	xx	xxx	xx	xx	Has similar limitations to those of landform modification, but is commonly useful in determining age sequence. Only useful for certain types of landforms, such as terrace or moraine sequences.
Correlation methods	18. Paleomagnetism	0 to [2/]2,000,000 [3/](5-20%)	[3/]5%	(x)	(xx)	(xx)	(xx)	(xx)	xxx	Requires material with remanant magnetism. Depends on correlation of magnetic properties (magnetic vector or polarity, or a sequence of vectors or polarity) with a known chronology of magnetic variation. Subject to errors due to chemical magnetic overprinting and physical disturbance.
Correlation methods	19. Volcanic Tephra Layers	0 to [2/]2,000,000 [3/](2-10%)	[3/]2%	xx	xx	x	x	x	xx	Requires volcanic ash (tephra) and unique chemical or petrographic identification and (or) dating of the ash. Very useful in correlation because an ash eruption represents a virtually instantaneous geologic event.
Correlation methods	20. Fossils and Artifacts	0 to [2/]2,000,000 [3/](10-50%)	[3/]10%	x	xx	xx	xx	xx	--	Depends on the availability of fossils, including pollen, and artifacts. Resolution depends on the rate of evolution or change of organisms or cultures and on calibration by other techniques. Subject to errors due to misidentification and interpretation.
Correlation methods	21. Stable Isotopes	0 to [2/]2,000,000 [3/](5-20%)	[3/]5%	--	xxx	(xx)	--	(x)	--	Depends on correlation of the sequence of isotopic changes with an age-controlled master chronology. Oxygen isotopic record is very useful in deep-sea and icecap cores.
Correlation methods	22. Stratigraphic Sequence and other Physical Properties	0 to [2/]2,000,000 [3/](5-50%)	[3/]5%	xxx	xxx	xxx	xxx	xxx	xxx	Based on superposition and physical properties of units; depends on the establishment of time equivalence of units. Gives only the sequence of units unless the age of at least one unit can be determined by other methods.

[1/] Limits are those between which a technique is normally applied. Approximate resolutions at each limit is given in parentheses.

[2/] These methods may be applicable to pre-Quaternary (>2 m.y. old) materials.

[3/] Where resolution is mostly dependent on factors other than age, a single range of resolution is given, and the minimum uncertainty does not apply to a specific age.

[4/] Also used as a correlation technique.

PRELIMINARY MAP SHOWING QUATERNARY DEPOSITS AND THEIR DATING POTENTIAL

Compiled by S. M. Colman and K. L. Pierce

Introduction and purpose

This map outlines Quaternary deposits in the conterminous United States which have been defined on the basis of their potential use in age dating. Recent geologic history is generally reconstricted from deposits or soils whose age can at least potentially be determined. Such history is important because a wide variety of man's activities are directly or potentially influenced by natural geologic processes; knowledge of the frequency and timing of geologic events is necessary to assess the potential impacts of geologic hazards. Many geologic hazards, especially faulting, flooding, and landsliding, leave persistent evidence in the geologic record. The past frequency of such hazards, deduced from reconstructed geologic history, is very useful in the prediction of their future occurrence.

Obtaining age control for a geologic history depends both on the presence of deposits, soils, landforms, or other features, and on the accuracy of the methods used to date them. The map units were designed to emphasize the distribution of deposits, although some deposits, such as colluvium and some eolian deposits, have been omitted where they have little time or stratigraphic significance. Table 1 summarizes the application of dating techniques to the different kinds of deposits or rocks shown on the map.

The map is intended to provide a general overview of areas in which time-significant deposits of Quaternary and late Tertiary age are found. Genetic units were used because their distribution is relatively well known, because they are easy to represent on a small-scale map, and because of the natural grouping of dating methods within genetic units. This map may be useful to planners, administrators, and researchers who need to know: 1) the general distribution of Quaternary deposits, 2) areas where Quaternary geologic history can at least potentially be deciphered, and (or) 3) what dating techniques may be applicable in a given area or to a given deposit.

Dating Techniques

Any process which is time-dependent has the potential for use as a dating method. The accuracy and precision of dating techniques vary greatly and depend primarily on the rate at which the process occurs and on the degree to which the process is affected by other variables. Dating techniques are based on processes that range from those that depend virtually on time alone, such as radiometric decay, to those that depend on a host of other variables, such as soil development. Different methods also vary widely in their useful time range; for example, lichenometry is useful in a time range of several tens of years to several thousand years, whereas the potassium-argon method is useful in a time range of a few tens of thousands to a few billion years.

In many cases, determining a chronology or geologic history of an area requires combinations of several dating techniques. Multiple methods of age determination are necessary because of the general paucity of materials whose ages can be determined by a specific method and because of the need to cross-check the accuracy of most methods. Very few sequences of deposits are complete and not all units of most sequences can be dated; therefore, the ages of some units commonly are inferred by correlation with units whose ages have been determined elsewhere. Thus, multiple dating methods and correlation methods are used in conjunction to construct as complete a chronology as possible for a given area.

Table 1 is a summary of Quaternary dating methods which have relatively wide application, and whose methodologies are either well developed or in advanced developmental stages (Colman and Pierce, 1977). Parts of the table are subjective and are based on our best estimates because there is disagreement on the interpretation of some age determinations, on the time ranges for which some techniques are useful, and on the applicability of some techniques to certain materials. In addition, different workers or laboratories commonly use different methods, assumptions, or physical constants in calculating ages. Because evaluation of each age determination normally depends on the specific method of analysis, the ranges and uncertainties given in table 1 are those applicable under favorable conditions. In many individual examples, such ranges or limits of resolution are not obtainable; conversely, under optimum conditions, ages beyond the stated limits or with less than the stated uncertainty are obtainable.

Table 1 is primarily concerned with the application of dating techniques to geologic materials. Some variations of these techniques have been applied to archeological materials such as pottery, tools, and hearths. These include fission-track methods, used to determine ages of manmade glasses as young as several hundred years; archeomagnetism, which uses calibrated fluctuations in magnetic intensity, declination, and inclination to determine ages of pottery, ovens, or bricks as old as several tens of thousands of years; obsidian hydration, used to determine ages of obsidian tools as young as a few hundred years; and thermoluminescence, used to determine ages of pottery as young as 400 years.

A number of potentially useful techniques have not been included in table 1 because they have limited time ranges and (or) very specialized applications. These include the following techniques: tritium, used to estimate ages of snow, ice, and ground water over the last 100 years; lead-210, used to estimate ages of water, recent sediments, and pigments over the last several hundred years; the counting of annual snow or ice layers, potentially useful over the last several thousand years; and fluoridation of bone and rock fragments, a relative-age technique useful for ages of as much as a million years or more.

Other techniques, including the aluminum-26, beryllium-10, and chlorine-36 methods, are not listed in the table because the processes or the factors that affect them are poorly understood, or because of severe analytical problems. With continued research, these techniques may become more useful in dating geologic materials.

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References

The summary table of dating methods is modified from Colman and Pierce (1977), who give general references for each of the techniques. The map has been compiled from a number of sources, the most important of which are listed below. These general sources have been supplemented by State geologic maps, detailed and local geologic maps, and other reports. In addition, we have modified these sources according to our own experience, and that of colleagues listed in the acknowledgements.

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