SUMMARY TABLE OF QUATERNARY DATING METHODS

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1977

Introduction

This table is a summary of Quaternary dating methods which have relatively wide application, and whose methodologies are either well developed or in an advanced developmental stage. The table is designed for use by a scientific audience who needs to know: 1) what kinds of dating techniques are available, 2) to what general time ranges they are applicable, and 3) on what types of rocks or deposits they can be used. The table is a general summary, and is not intended to be a user's manual; for details on principles, methodology, and sample preparation, the reader should consult the literature or experts on specific techniques. A few references have been included for general background, however, they contain more detailed references.

Experts disagree on the interpretation of some dates, the time ranges of some techniques, and the applicability of some techniques to certain materials. In addition, different workers or laboratories often use different methods, assumptions, or physical constants. In view of these difficulties, parts of the table are necessarily subjective and are based on our best estimates. Because evaluation of each age determination normally depends on the specific method of analysis, the ranges and uncertainties given here 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.

The entries in the table primarily reflect applications to geologic materials. Some variations of listed techniques have specialized applications to archeological materials such as pottery, tools, and hearths. These include fission track methods, used to date man-made glasses as young as several hundred years old; archeomagnetism, using calibrated fluctuations in magnetic intensity, declination, and inclination to date pottery, ovens, bricks, etc., back through several tens of thousands of years; obsidian hydration, used to date obsidian tools as young as a few hundred years; and thermoluminescence, used to date pottery as young as 400 years.

A number of potentially useful techniques are not listed in the table because they have limited time ranges and (or) very specialized applications. Among these are: tritium, used to date snow, ice, and ground water over the last 100 years; lead-210, used to date 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.

Other techniques are not listed in the table because of severe limitations or analytical problems. These include aluminum-26, beryllium-10, chlorine-36. With continued research, these techniques may become more useful.

The techniques and applications discussed in the preceding paragraphs are treated in more detail in some of the selected references.

Acknowledgments

We would like to thank the following people for their contributions and reviews of the table: D. S. Fullerton, W. E. Scott, P. W. Birkeland, J. T. Andrews, C. S. Hunt, J. P. Bradbury, C. W. Naeser, V. Steen-McIntyre, E. E. Larson, Meyer Rubin, R. J. May, M. H. Hait, R. F. Madole, R. C. Buchnam, D. P. Russ, D. G. Herd, D. E. Marchand, D. L. Schmidt, M. A. Kuntz, H. E. Malde, T. H. Walsh, and G. I. Smith.

	METHOD	GUIDE TO SELECTED REFERENCES	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	REMARKS
	1. Historical Records	12	0 to 6,000 (±0%) (±2%)	0% (500 yr)	x	x	x	xx	x	x	Requires preservation of pertinent records, and applicability depends on quality and detail of the records. Limited to about 400 years in Western Hemisphere.
	2. Carbon-14 (^{14}C)	6, 8, 14, 15, 22	100 to >40,000 (±100%) (±2%)	1% (15,000 yr)	xxx	xx	xxx	xxx	xx	x	Depends on availability of carbon. 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.
	3. Uranium-Series (U-Series)	3, 6, 8, 15, 19, 22	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 various members of the U-decay series are used, including Th-230/U-234 (most common), U-234/U-238 (with a range back to 600,000 years), Pa-231/U-235, U-He (0-2 million years[2/]), and Ra-226/Th-230 (<10,000 years). Errors due to the lack of a closed system are a common problem, especially in mollusks and bone.
NUMERICAL METHODS	4. Potassium-Argon (K-Ar)	4, 6, 8, 14, 15, 22	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. Subject to errors due to excess argon, loss of argon, and contamination.
	5. Fission Track	8, 14, 16	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 ashes); requires uranium-bearing material (zircon, sphene, apatite, glass). Subject to errors due to track misidentification and to track annealing.
	6. Dendrochronology[4/]	5, 6, 14, 22	0 to 9,000 (±0%) (±2%)	0-1% (<5,000 yr)	x	--	--	xx	x	x	Requires either direct counting 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.
	7. Varve Chronology[4/]	6	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.
	8. Lichenometry	21	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 alpine or arctic regions. The technique must be calibrated by other methods. Subject to error due to local lichen kill, moisture variation, and misidentification. The age limit of the useful range varies considerably with climate and rock type, and is often less than 4,000 years.
	9. Obsidian Hydration	7, 14	100 to [2/]2,000,000 (±20%) (±30%)	10% (100,000 yr)	(x)	--	(x)	(x)	--	x	Requires primary or transported obsidian. Depends 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.
	10. Tephra-hydration	18	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. Subject to same limits as obsidian hydration, plus others, including the geometry of glass shards and bubble cavities.
	11. Thermoluminescence	13, 14	<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. Absolute dates can be obtained for pottery and ceramics in the 400 to 10,000 year range.
	12. Amino Acid Racemization[4/]	9, 11	100 to 1,000,000 (±50%) (±50%)	20% (100,000 yr)	--	xx	(x)	(x)	--	--	Requires shell or skeletal material. 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.
RELATIVE-AGE METHODS	13. Rate of Deposition	3, 15, 22	[3/]0 to [2/]2,000,000 [3/](5-50%)	[3/]5%	--	xxx	xx	x	x	x	Requires relatively constant rate of sedimentation over intervals considered. Calculations based on sediment thickness between horizons dated by other methods are commonly used.
	14. Soil Development	1, 6, 17, 22	100 to 2,000,000 (±100%) (±90%)	25% (100,000 yr)	xxx	xx	xx	xxx	xx	x	Encompasses a number of soil properties, 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 estimates within ±25 percent.
	15. Rock and Mineral Weathering	1, 6, 17, 20, 22	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 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.
	16. Progressive Landform Modification	1, 2, 22	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 of material comprising the landform to erosion. Depends on recognition and evaluation of progressive landform modification. Includes rate of erosion.
	17. Geomorphic Position	1, 2, 22	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 often useful in determining age sequence. Only useful for certain types of landforms, such as terrace or moraine sequences.
	18. Paleomagnetism	10, 14, 15, 22	[3/]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.
	19. Volcanic Tephra Layers	14, 15	[3/]0 to [2/]2,000,000 [3/](2-10%)	[3/]2%	xx	xx	x	x	x	xx	Requires volcanic ash (tephra) and unique 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	10, 15, 22	[3/]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 and on calibration by other techniques. Subject to errors due to misidentification and interpretation.
	21. Stable Isotopes	3, 22	[3/]0 to [2/]2,000,000 [3/](5-20%)	[3/]5%	--	xxx	(xx)	--	(x)	--	Depends on correlation of the sequence of isotopic changes with a dated master chronology. Oxygen isotopic record very useful in deep sea and icecap cores.
	22. Stratigraphic Sequence and other Physical Properties	6, 15, 22	[3/]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, and depends on the establishment of equivalence of units. Gives only the sequence of units unless at least one unit can be dated 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.

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[These references are intended as an entry into the literature and are by no means complete or exhaustive. Several are volumes containing a number of papers on various dating methods.]

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INTERIOR—GEOLOGICAL SURVEY, RESTON, VIRGINIA—1977

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