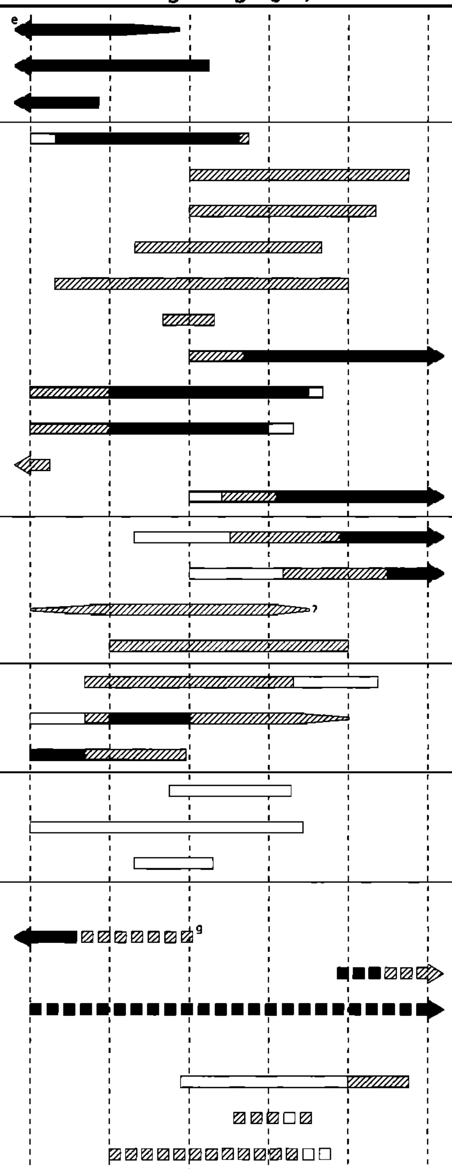
Methods for Dating Quaternary Surficial Materials

by Janet M. Sowers[1], Jay Stratton Noller[2], and William R. Lettis[1]

Resolution (±error)[a,b]: <10% | 10–50% | 50–200%

Age range (yrs): 10^2 | 10^3 | 10^4 | 10^5 | 10^6 | 10^7



Type of Result[c]	Type of Method[c]	Method	Status	Error and Reporting Standards	Comments	Basis of Method
NUMERICAL-AGE	Sidereal	1. Dendrochronology	I	(see ref)	Time range varies with availability of local ring-width data for cross dating	Aging of live trees, or correlating ring-width chronology to other trees
		2. Varve chronology	I	(see ref)		Counting seasonal sediment layers back from the present, or correlating a sequence with a continuous chronology
		3. Sclerochronology	II	(see ref)		Counting annual growth bands in coral and mollusks
	Isotopic	4. Radiocarbon	I	1σ	Total standard error combines 1σ analytical error and 1σ calibraton error (see ref)	Radioactive decay of atmospheric ^{14}C to ^{14}N in organic tissue or carbonates.
		5. ^{10}Be (Cosmogenic nuclides)	II	f	Range may be younger at high elevations or high latitudes, older at low elevations or low latitudes	Formation, accumulation, and decay of cosmogenic nuclides in rocks or soils exposed to cosmic radiation
		^{26}Al (Cosmogenic nuclides)	II	f		
		^{36}Cl (Cosmogenic nuclides)	II	f		
		^{3}He (Cosmogenic nuclides)	II	f	Range shown is for olivine samples	
		^{14}C (Cosmogenic nuclides)	II	f		
		6. K-Ar, Ar-Ar	I	2σ	Range assumes high-K materials For young materials (<1ma) the Ar-Ar method may be more accurate than K-Ar	Radioactive decay of ^{40}K trapped in K-bearing silicate minerals during crystallization, to ^{40}Ar
		7. U-series: ^{234}U–^{230}Th	I	1σ or 2σ	Resolution shown is for pure sedimentary carbonates and coral Error is often greater for impure carbonates Mass spectrographic analysis can improve precision	Radioactive decay of uranium and daughter nuclides in chemical and biogenic sedimentary minerals
		^{235}U–^{231}Pa	I	1σ or 2σ		
		8. ^{210}Pb	I	1σ	Resolution improved when used with ^{137}Cs	Radioactive decay of ^{210}Pb to ^{206}Pb
		9. U–Pb, Th–Pb	II		Age resolution is a function of the Δ $^{238}U/^{204}Pb$ of sample suite, range shown is calculated with Δ $^{238}U/^{204}Pb$=100.	Using normalized Pb isotopes to detect small enrichments of radiogenic lead from U and Th decay
CALIBRATED-AGE	Radiogenic	10. Fission-track: zircon & glass	I	2σ	Dating volcanics with zircon or volcanic glass	Accumulation of damage trails (fission tracks) from natural fission decay of trace ^{238}U in zircon, apatite, or glass
		apatite	I	2σ	Dating unroofing with apatite	
		11. Luminescence	I	1σ	Typical resolution is 5-20% Time range and resolution vary strongly with natural radiation level and mineralogy	Accumulation of electrons in crystal lattice defects of silicate minerals, due to natural radiation
		12. Electron-spin resonance	I	1σ	Assuming average level of radioactivity in the host rock	Accumulation of electrical charges in crystal lattice defects of silicate minerals, due to natural radiation
RELATIVE-AGE	Chemical & Biologic	13. Amino-acid racemization	I	(see ref.)	Range is for mollusks from midlatitudes, racemization rates increase with temperature	Racemization of L-amino acids to D-amino acids in fossil organic material
		14. Obsidian hydration	I	(see ref.)	Range depends on temperature and obsidian chemistry	Increase in thickness of hydration rind on obsidian surface
		15. Lichenometry	II	(see ref)	Time range varies with environmental conditions	Growth of lichen on freshly exposed rock surfaces
	Geomorphic	16. Soil-profile development	I	(see ref.)	Resolution and time range depend on the availability of a dated chronosequence for calibration	Systematic changes in soil properties due to weathering, additions, losses, and redistribution of material
		17. Rock and mineral weathering	I	(see ref.)	Time range varies with weathering parameter and climate Resolution may be improved with local calibration	Systematic alteration of rocks and minerals due to exposure to weathering processes
		18. Scarp morphology	II	(see ref)	Uncertainty may be <50% under favorable conditions For high scarps that change slowly, range may extend to 0 5 Ma	Progressive change in scarp profile due to surface processes, from steep and angular to gentle and rounded
CORRELATED-AGE	Correlation	19. Paleomagnetism:				
		Secular variation	I	(see ref.)	Resolution depends on the ability to correlate to master curves	Secular variation of the earth's magnetic field recorded in magnetic minerals
		Reversal stratigraphy	I	(see ref)	Assumes either independent age control or several magnetic polarity zones are available so that correlations to the Magnetic Polarity Time Scale can be made	Reversal of the earth's magnetic field recorded in magnetic minerals
		20. Tephrochronology	I	(see ref.)	Resolution depends on the resolution of dating methods used to establish reference stratigraphy (K-Ar, Ar-Ar, luminescence, ^{14}C, fission track)	Recognition of individual tephra by their unique properties, and correlation of these to a dated stratigraphy
		21. Paleontology:				
		Evolution of microtine rodents	I	(see ref)		Progressive evolution of microtine rodents
		Marine zoogeography	I	(see ref)	Time range may be extended if a chronology is available in that range Resolution is improved if used with another dating method such as amino-acid racemation	Climatically induced zoogeographic range shifts of marine invertebrates
		22. Climatic correlations	II	(see ref)	Resolution is highly dependent on the ability to correlate to a specific climate change Additional correlations may sometimes be made at extreme ends of range	Correlation of landforms and deposits to global climate changes of known age

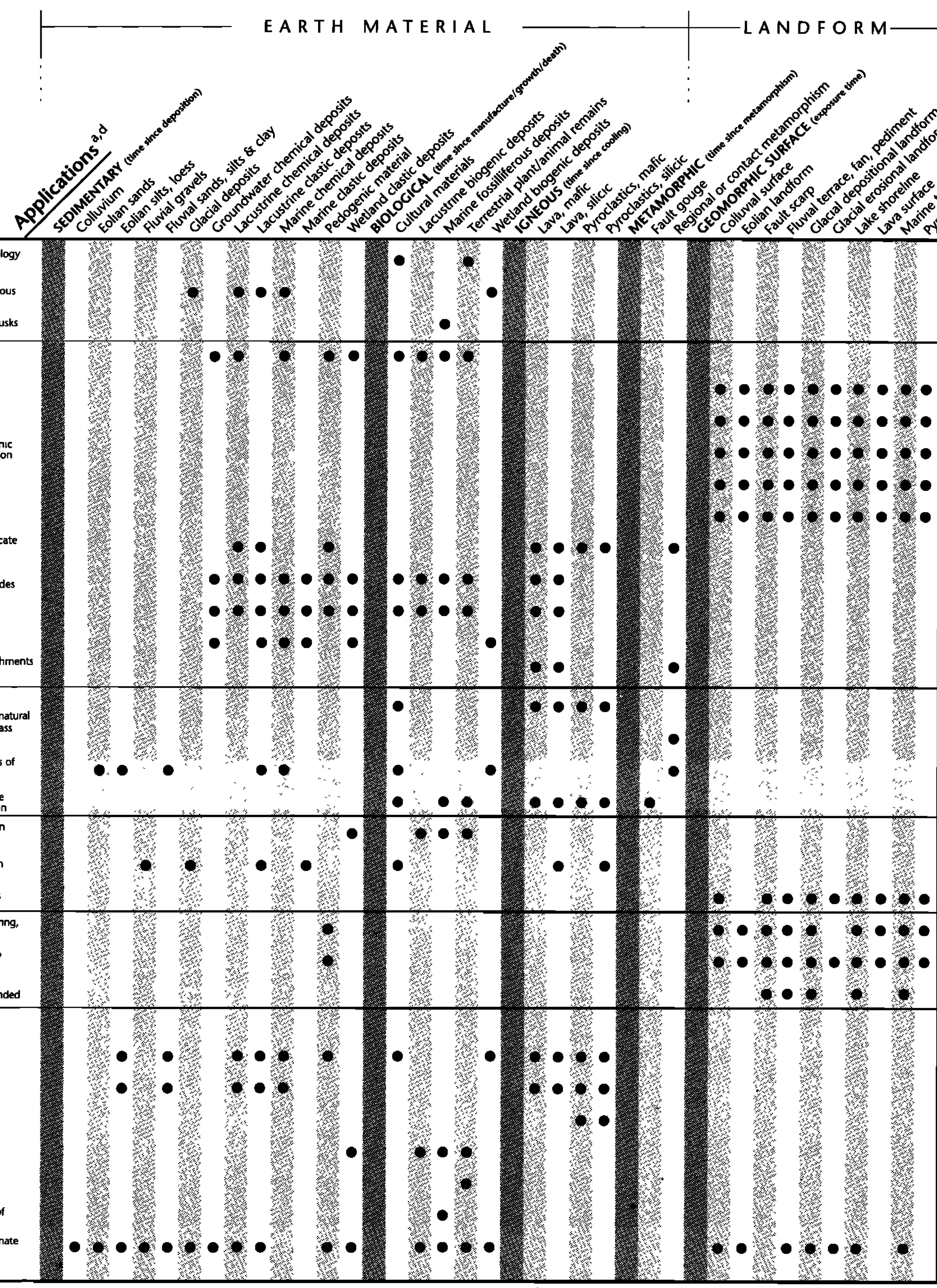


Plate 1. Methods for dating Quaternary surficial materials, in Noller, J.S., Sowers, J.M., and Lettis, W.R., 2000, Quaternary Geochronology: Methods and Applications.

Please note: This chart summarizes the more well known, widely used, or most promising new methods for dating Quaternary surficial materials as of 1999 It is not intended to be a complete list of these methods

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Status:
I. Well-Established
II Experimental, approaching established

Notes.
[a] Under optimum conditions where the assumptions of the method are met and the sample is of high quality. See references for further discussion.
[b] The resolution of correlated-age and calibrated-age methods (#11-24) is dependent on the resolution of the dating methods that establish the chronology used for calibration or correlation. The resolution of any of these methods can be improved if additional independent age constraints are available
[c] Classification of methods from Coleman, S , and Pierce, K , 1999, Classification of Quaternary Geochronologic Methods, in this volume
[d] Applications shown for each method are those considered typical. Under special conditions, or in certain geologic contexts, additional applications may be possible
e Range extends beyond time scales shown
f Resolution includes both 1σ analytical error of <5%, and geologic uncertainties
g Broken bar indicates that the method may not be continuously applicable through the time range shown, due to either lack of reference stratigraphies for that time range, or non-uniqueness of correlations.

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* in this volume

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t = table; *f* = figure

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Quaternary Geochronology
Methods and Applications

surveys the established and experimental means of dating Quaternary surficial materials. Experts review the basic theory, procedures, accuracy and applications for each method. A series of case studies illuminate the key role of geochronology in Quaternary geology and the emerging field of paleoseismology. This is an authoritative reference for Quaternary scientists, geochronologists, paleoseismologists and students.

ISBN 0-87590-950-7