A simple approach to assessing the accuracy of age models from Holocene sediment cores

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Introduction

- A new database of proxy climate records from the Arctic has been assembled to investigate the spatial-temporal pattern of Holocene climate changes

- Most proxy records are from sedimentary sequences sampled in cores from lakes and oceans

- The database includes the original geochronological data so the accuracy of the underlying age models can be assessed uniformly

Motivation

- The geochronological accuracy of proxy-data time series must be assessed objectively to identify records appropriate to address a given level of temporal inquiry

- We have devised a scoring scheme to rate the accuracy of age models that focuses on the most important factors that determine the overall accuracy

- Only five input variables are required:

  - original ^{14}C ages
  - lab errors
  - sample depths
  - number of rejected ages
  - material type (one category for all ages)

- ChronRater is programmed in 'R' as part of the "Virtual Paleo-climate Laboratory in R" (vpIR)

ChronRater: A simple three-part scoring scheme

Three characteristics of dated materials and their downcore trends are used to assess the overall age accuracy

1. Delineation of downcore trend (D)

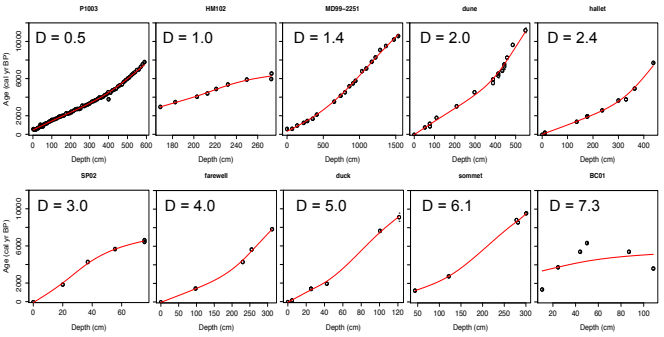
$D = w_f f + w_r r + w_u u$

f = frequency of accepted ages (yr)
age range / number of accepted ages (including the surface)

r = regularity of their spacing (yr)
SD of length of time between consecutive age

u = uniformity of the sedimentation rate (yr)
RMSE wrt cubic smoothing spline (df = 4, or incrementally lower to ensure no reversals in the spine fit)

w_f, w_r, w_u = weightings
set at 2, 0.5 and 3, respectively



Examples of age models with increasing D values (delineation of downcore trend)

Red curves are cubic smoothing splines

2. Quality of dated materials (Q)

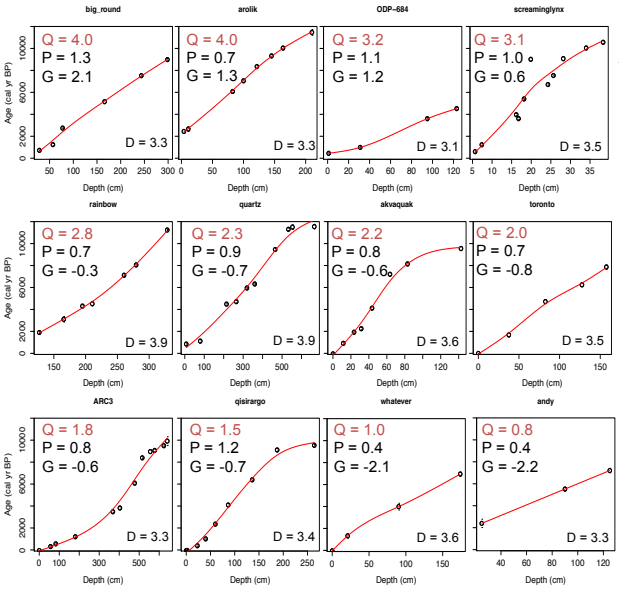
Q = pm

p = proportion of rejected ages plus downcore age reversals
(number of rejected + number of reversals > 100 yr among accept ages) / total number of ages

m = type of materials analyzed and extent to which their ages are verified by independent information, as judged using a five-point scale (below)

m values for lacustrine materials:
5 = at least one age can be confirmed by tephra or ^{14}C wiggle matches; no bulk-sediment ages
4 = mainly (> 90%) plant macrofossils
3 = 50-90% plant macrofossils; bulk-sediment ages can be reasonably adjusted
2 = < 50% plant macrofossils
1 = all bulk-sediment ages

m values for marine materials:
5 = >90% whole, monospecific forams with a constrained reservoir age (at least one well-dated tephra or wiggle match used to determine the reservoir correction)
4 = mainly (>90%) monospecific forams
3 = >50% monospecific forams & articulated mollusks
2 = mixture of sample types: fragmented and whole; monospecific and mixed species
1 = mainly (>90%) fragmented and unidentifiable tests & shells



Examples of age models with decreasing Q values (quality of dated materials) arranged for left to right

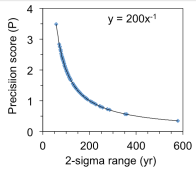
D values (delineation of downcore trends) are similar for all models shown

P values (precision of calibrated ages) and G values (geochronology accuracy score) are also shown

3. Precision of calibrated ages (P)

$P = s^{-1}$

s = average 2-sigma range of all calibrated ^{14}C ages (yr)
based on INTCAL04 calibration dataset

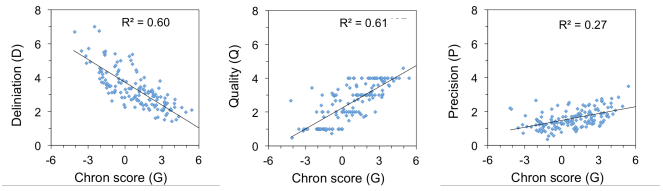


Relation between P value and the average 2-sigma calibrated age range

Geochronology Accuracy (ChronScore, G)

$G = -w_D D + w_Q Q + W_P P$

Where w_D, w_Q and w_P are weighting factors set = 0.001, 1 and 200, respectively, so that each component is of the same order of magnitude



ChronScores (G) from our database of Arctic Holocene proxy climate records, including 31 marine and 111 lake records. ChronScores range from about -6 to +6 and correlate equally with D values (delineation of downcore trends) and Q values (quality) and less strongly with P values (precision of calibrated ages)

Conclusions

- Judging the quality of material and weighting the various factors that influence geochronological accuracy can be subjective, but is necessary to systematically screen records for synthesis products

- Our scoring scheme can be used to assign reasonable numerical ratings to the reliability of downcore age models based on a simple, reproducible, and customizable procedure that focuses on the most important factors that determine the overall geochronological accuracy

Acknowledgement

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