How Long Did Clovis Last?

A Re-assessment of the Clovis
and
Other Paleoindian Occupations
Using Bayseian Statistics and IntCal13

"All models are wrong, but some are useful."
George E. P., Norman R. Draper (1987)

Purpose

How long did clovis last as a phase? It is a question that has important implications for understanding Clovis expansion, demographics, and relationships to other contemporaneous, pre- and post-Clovis cultural phenomena. Previous analyses of the question have focused on increasing the accuracy and precision of the large pool of available RC ages (e.g., Waters and Stafford [W&S] 2007; Faught 2008) and have inferred the structure and length of the Clovis Phase from the RC ages. In contrast, we propose that the *first* step in the analysis is to *model the archaeological phenomenon* and then evaluate the RC ages in the context of the model. The model of the archaeological phenomenon should direct how the RC ages are treated, not the other way around. Here, we show ways to evaluate the ages in more disciplined ways using *Oxcal's* online Bayesian statistical package for calibrating and modeling data sets into phases and sequences of phases.

What's Wrong with Previous Models?

Models (explicit or implicit) are always used to evaluate a set of related RC ages, regardless of whether RC ages are evaluated as a set of independent data points or as a group of related ages. For example, W&S bracketed the Clovis Phase by using the latest end of the earliest age (the Lange-Ferguson average) and the earliest end of the latest age (the Jake Bluff average) making precision the accuracy in these RC ages and the growth and demise of the Clovis phenomenon. In contrast, Faught proposed that two or more ages from a single stratum would make more accurate ages and that averaging would increase precision.

Both W&S and Faught (2008) assume that the RC ages that define the Clovis Phase can be made more precise by eliminating ages with large sigmas, averaging ages in strata, and "bracketing" the phase with the earliest and latest averaged ages. Both W&S and Faught adopt models that bracket Clovis as a tertiary phenomenon with abrupt beginning and end points, analogous to an Oxcal "**Boundary Model**".

An alternative, and one that we think is likely, posits an initial, small population that grows through time and eventually transitions into subsequent cultures in different regions of North America (e.g., Folsom on the Plains and Debert/Vail in the Northeast). This model would describe the Clovis phenomenon whether it was the spread of an initial population or a new idea through an existing population. Under either scenario, the number of people or number of converts in an existing population was initially small, gradually increased through time, and then declined in popularity. This alternative is known as a "Trapezium model."

Bayesian Analysis: A Better Way to Model

Here, we use Bayesian analysis to evaluate different models of the Clovis and other Paleoindian phenomena. All the Bayesian analyses used here were run in *OxCal 4.2* using the most recent IntCal13 curve data (Brook Ramsey 2009). This curve is more precise than the previous two calibration curves (IntCal04 and IntCal09). We analyzed six different data sets including W&S's samples, a more liberal sample set of potential Clovis sites, examples of progeny culture groups in the Plains and the Northeast, a data set of Fishtail fluted point sites from Southern South America, and a sample of Stemmed point sites from the Western United States to show that there are other culture groups on the landscape at the same time.

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Waters and Stafford Estimate of the Clovis Phase (Gray) and Trapezium Model of Same Ages (Green)

A model = 96.2

Trapezium Model of Liberal Clovis Set

A model = 114.5

Trapezium Model of Plains Clovis to Folsom

A model = 94.6

Trapezium Model of Eastern Clovis to Debert, Bull Brook, Michaud, and Cormier

A model = 113.1

Trapezium Model of South American Fishtails

A model = 114

Trapezium Model of Western Stemmed

A model = 110.2

HOW TO INTERPRET THE TIMELINES

These timelines were developed from the results of the *OxCal 4.2* analyses producing Trapezium and Boundary models as indicated for each line. The results are probabilities so that each corner on the trapezoid or rectangle is actually a wide spread of ages. For example, the start of the start of the Eastern Clovis Phase Trapezoid Model falls somewhere between 13008 (A) and 121916 calBP, and the end of the start falls between 12785 (B) and 12661 calBP. The **span** of the start that is represented by the slanted line to the left is somewhere between 0 and 121 years in length.
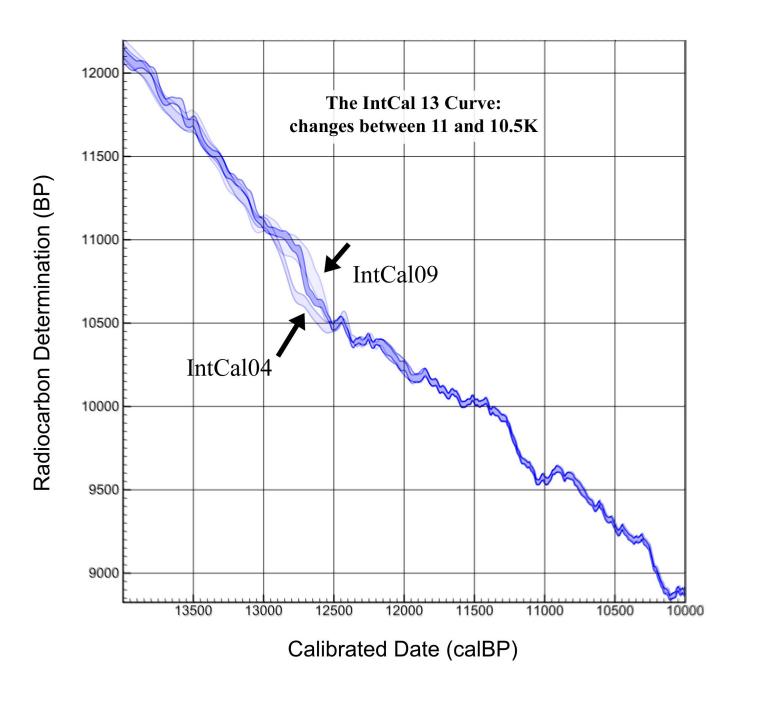
In the Trapezium sequence model the nodes represent the start of the end of Eastern Clovis (C) and they are coincident with the start of the start of the rise of the Debert/Vail Phase (E). Likewise, the end of the end of the Eastern Clovis Phase (D) is coincident with the end of the start of the Debert/Vail Phase (F). The start of the decline and end of the decline of the Debert/Vail Phase (G and H) coincides with the start of the start and end of the start of the Bull Brook Phase, and so on.

A model = 92.4

A model = 92.4

In a Boundary Model the boundaries are areas or spans of probability that mark the earliest and latest ages of the phase(s).

The program also produces the probable span of a phase and its beginning and ending, and this information is included in the timelines.

The IntCal 13 Curve:
changes between 11 and 10.5K

IntCal09

IntCal04

Comparison of the IntCal 04, 09, and 13 Calibration Curves

WHAT IS BAYESIAN ANALYSIS?

Bayesian analysis is a method for calculating the chance of an occurrence of an event based on prior information that informs the likelihood of that event. A Bayesian analysis repeatedly calculates the chances of an event occurring and, after a sufficient number of calculations, arrives at the most likely result given the prior information. The idea was originally formulated in the 1700's by Reverend Bayes, but it was not until the advent of computers that the method could be widely applied.

In the Bayesian analysis of radiocarbon ages, our prior knowledge constrains the possible RC and calibrated ages. For instance, the Law of Superposition requires that lower stratum A was laid down earlier than stratum B above. Thus, even though the sigmas of RC ages from strata A & B overlap, the Law of Superposition requires that the calibrated age of stratum A must precede the calibrated age of stratum B. A Bayesian analysis runs through all the possibilities that meet these constraints and converges on the most likely result. The number of iterations in a Bayesian analysis can run into the millions depending on the number of samples being compared

For the analyses here, we use two basic models of several offered by *Oxcal 4.2: Phase* and *Sequence*. A *Phase* model presupposes that we know the RC ages are related in time but we don't know their temporal order. We used variations of the *Phase* model to define the cultural phenomena Clovis, Folsom, Debert, etc. A *Sequence* model presupposes that we know the order of the RC ages. Here we don't know the order of the ages within a Phase, but we know the order of the Phases. Thus, we can instruct *OxCal 4.2* to consider the RC ages for each cultural phenomenon as a *Phase* and to order the Phases in a *Sequence* with Clovis at the early end followed by Folsom in one case and Debert/Vail, Bull Brook, etc. in another.

OxCal 4.2 provides several Indices that allow one to evaluate the extent and quality of the model. For our purposes, the most important is the A_model index, which is a measure of the overall quality of the model. If A_model drops below 60, the model is suspect. T he relative quality of models can be assessed by comparing the A_model indices; a higher index indicates a better model.

Some Important Considerations

Averaging is not needed (or usually appropriate) to increase precision.
Results from the one sigma error range are adequate. Simulations run in *OxCal 4.2* demonstrate that we can have high confidence in using the results from RC ages with one sigma error (Bayliss et al 2007).

It is not necessary to statistically exclude outliers. There should be additional reasons for excluding an age as an outlier, because we would expect about 1 in 20 RC ages to be outliers.

Which Age Sets Are Included?

1. W&S 2007:1124, Table 1 data set used to estimate of the range of the Clovis phase

2. A "Liberal" set of Clovis ages that includes ages excluded by W&S (Aubrey, Blackwater Draw, Cactus Hill, Hiscock, Kanorado, Lubbock Lake, and Sheridan Cave), as well as recently published ages not available then (Blackwater Draw, Sheridan).

3. A cull of ages from the Liberal set west of the Mississippi to run a sequence trapezoid model with ages from Folsom sites listed in Collard et al (2010).

4. A cull of ages from the Liberal set east of the Mississippi to run a sequence trapezoid model of Clovis-to-Debert-through-Cormier based on phases proposed by Bradley et al. (2008).

5. a compilation of South American Fishtail ages culled from Faught (2008) and processed using ShCal13 showing close contemporaneity with the people who made Clovis points in North America

6. a compilation of ages from Stemmed Point sites west of the Rocky Mountains from Davis and Schwegger (2004), Faught (2008), Goebel (2007), Jenkins (2007); and Pitblado (200) showing contemporaneous culture groups in North America with the people who made Clovis points.

Boundary Model

Trapezium Model

Sequencial Trapeziums Model

Waters & Stafford Sites and Ages

Plains Clovis to Folsom

Eastern Clovis to Debert and Beyond

Western Stemmed

Liberal Clovis

South American Fishtails

Multiplots of Single Calibrated Ages (gray) and Bayesian Calibrated Ages (Black) for Each of the Data Sets

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RESULTS

The Bayesian analysis in *OxCal 4.2* was used to evaluate the span and strength of different models, not all shown here. We tested two versions of the Boundary and Trapezium model proposed by W&S using the average age for each site as well as the individual ages from the sites with no averaging. We assume a more liberal set of ages and analyzed their set using both Boundary and Trapezium Models.

We also investigated two transition models with data from Western Clovis and Plains Clovis sites and Eastern Clovis-to-Debert-through-Cormier sites to show how Bayesian analysis can be used to picture a series of archaeological phases. Finally, we ran data sets of South American Fishtail and Western Stemmed point sites to evaluate and confirm their contemporaneity with Clovis (Faught 2008).

Re-Analysis of the W&S data

The Boundary Model using site averages for each site produced a marginally adequate A_model index of 66. However, averaging the ages from these sites is inappropriate under criteria developed by Ward and Wilson (1978). Using the suite of individual ages from the set of sites compiled by W&S to run a Boundary Model resulted in an even poorer A_model index of 55.9.

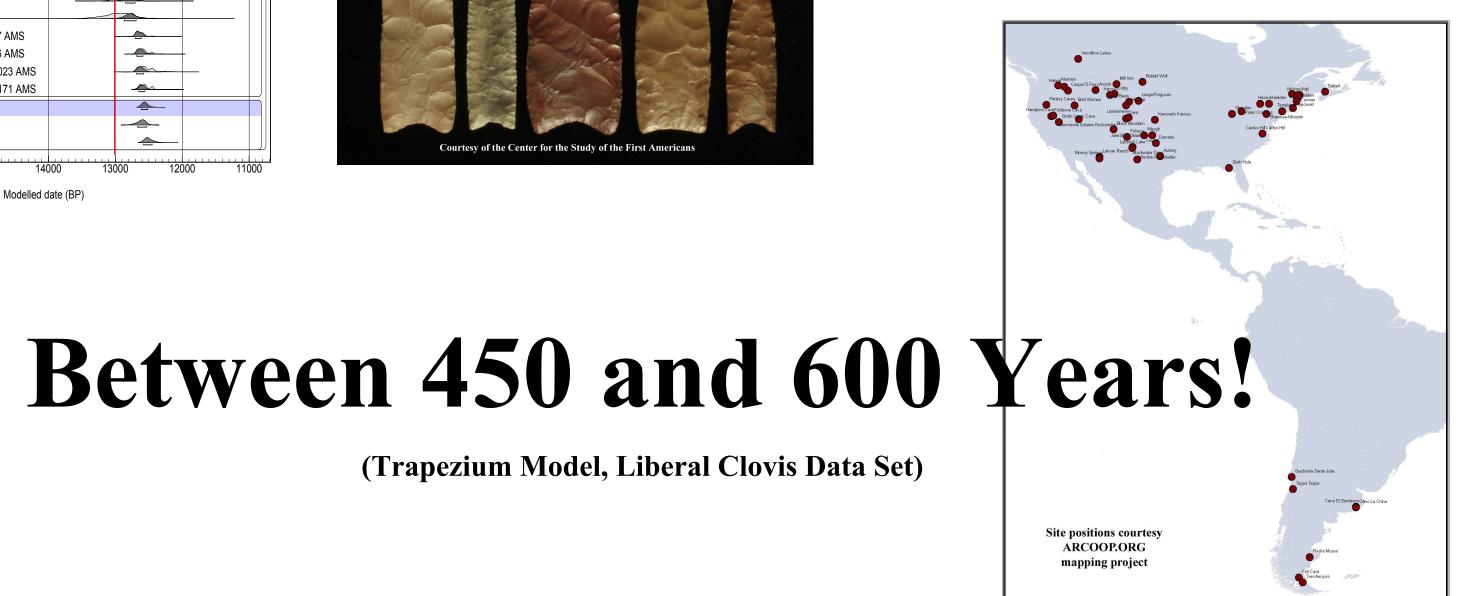The Boundary Model run with W&S individual ages resulted in the Clovis Phase starting between **12,941 calBP and 12,852 cal BP** and ending between **12,701 calBP and 12,666 calBP**. At 1-sigma, the span of W&S Clovis Phase was between **153 and 258** years, which is less than the 200 to 400 year estimate by W&S. On the other hand, the Bayesian analysis indicates the Trapezium Clovis Phase 300 years later than the W&S estimate of **13,250 calBP** and the ending 100 years or more later than their estimate of **12,800 calBP**.

Both Boundary and Trapezium Models were run with the more liberal set of ages from Clovis sites. The Boundary Model resulted in a beginning between **13,165 calBP and 13,059 calBP** and an end between **12,690 calBP and 12650 calBP** with an A_model index of **85.2**. The Trapezium Model had a more robust A_model index of **121.6** than the A_model index of **96.2** for the Trapezium model using W&S data. The beginning of the trapezium is between **13,322 calBP and 13,181 calBP** and between **12,684-12,622 BP**. The span of the Clovis Phase in this model is from **464 to 608** years at 1-sigma, approximating W&S at the early end, but extending the Clovis Phase later in time as with the Boundary Model.

Model	Dataset	A_model index	Start in Calendar Years	End in Calendar Years	Span in Calendar years
Boundary	W&S averages	66.2%	12941-12786 BP	12775-12644 BP	0 to 190 years
Boundary	W&S individual ages	55.9%	12941-12852 BP	12701-12632 BP	153 to 258 years
Trapezium	W&S individual ages	96.2%	13044-12864 BP	12690-12629 BP	163 to 352 years
Boundary	Liberal Clovis	85.2%	13222-13140 BP	12684-12587 BP	499 to 603 years
Trapezium	Liberal Clovis	121.6%	13322-13181 BP	12684-12622 BP	464-608 years

Between 450 and 600 Years!

(Trapezium Model, Liberal Clovis Data Set)

Map of Sites