## How Long Did Clovis Last?

A Re-assessment of the Clovis and

Other Paleoindian Occupations Using Bayseian Statistics and IntCall3

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

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 Bayseian 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 several assumptions about the imprecision in 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

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 unitary 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 (Bronk 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 sequences 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

David Thulman and Michael Faught Archaeological Research Cooperative

## HOW TO INTERPRET THE TIMELINES

These timelines were developed from the results of the OxCal 4.3 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.

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

Trapezium Model of Liberal Clovis Set

Trapezium Model of Plains Clovis to Folsom

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

Frapezium Model of South American Fishtail

Trapezium Model of Western Stemmed

Western Stemmed

13038 Span of Start

12668 Span of End

W&S Boundary end 12701 to 12666 Span of W&S Boundary 153-25

W&S Trapezium Start of End

W&S Boundary start 12941 to 12852

W&S Trapezium End of End

Liberal Clovis Start of End

Plains CL/Folsom End of Transition 12577

East CL/Debert Start of Transition

East CL/Debert End of Transition

Debert/Bull Brook Start of Transition

Bull Brook/Michaud Start of Transition 12

Michaud/Cormier Start of Transition

Cormier Start of End

Cormier End of End

Fishtail Start of End

Fishtail End of End

Western Stemmed End of End

Debert/Bull Brook End of Transition 12599 Span of Bull Brook: 111-327

Bull Brook/Michaud End of Transition 12256 *Span of Michaud: 48-270* 

Michaud/Cormier End of Transition 11991 Span of Cormier: 0-100

Western Stemmed End of Start 13219 Span of W. Stem 1348-1654

Western Stemmed Start of End 12134 Span of End 0-1285

Liberal Clovis End of End

12915 Span of W&S Trap 163-332

Span of Liberal CL 464-608

Span of Plains CL 578-748

12914 Span of East CL: 107-237

Span of Transition: 0-84

Span of Debert: 20-146

Span of Transition: 0-139

12903 **Span of Fishtails** 248-444

Span of End

Span of Transition: 0-170

Span of End 0-76

Number of Sites & Dates

W&S sites= W&S ages =

Liberal Clovis sites = 19

Liberal Clovis ages = 61

Plains Clovis sites=

Plains Clovis ages =

Number of Sites & Ages

Debert/Vail sites =

Debert/Vail ages =

Bull Brook sites =

Cormier sites =

Cormier ages =

Fishtail sites =

Fishtail ages =

Western Stemmed sites = 1

Western Stemmed ages= 42

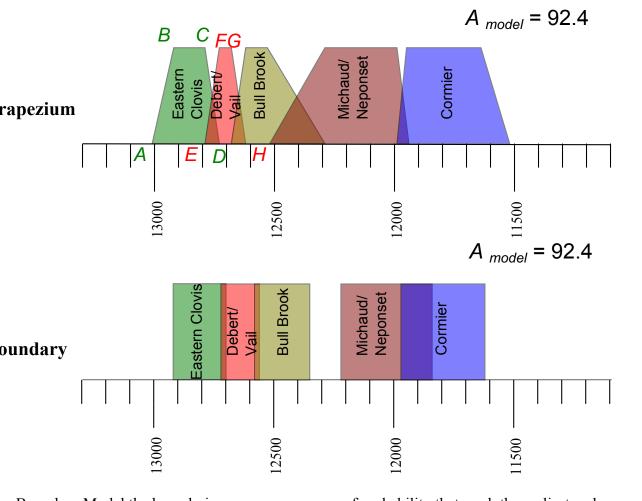
Bull Brook ages = 4

Michaud/Neponset sites = 4

Michaud/Neponset ages = 4

Eastern Clovis ages = 12

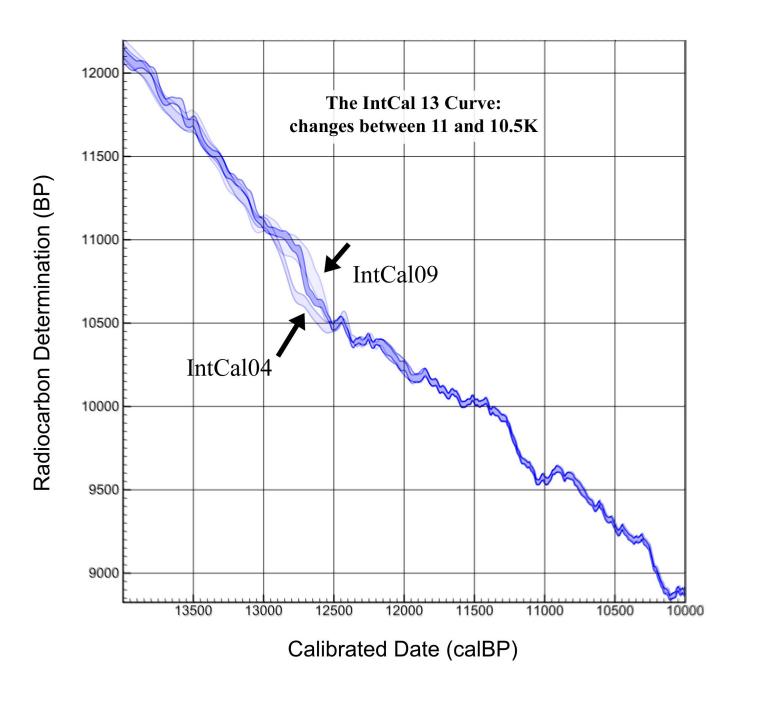
In the Trapezium sequence model the nodes represent the start of the end of Eastern Clovis (C) and they are coincident with the start of the start of the rise of the Debert/Vail Phase (E). Likewise, the end of the end of the Eastern Clovis Phase (D) is coincident with the end of the start of the Debert/Vail 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.



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.





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 constraints and the data. 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 Superimposition 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

For the analyses here, we ran 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. The 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 automatically 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 outlier.

### 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 sites 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, Sheriden).

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 ShCall3 showing close contemporaneity with the people who made Clovis points in North

**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.

# Trapezium Model Trapeziums Model

### Waters & Stafford Sites and Ages

Sequence WS2007

Boundary Start 1

Start Start of Start 1 R\_Date Lange-Ferguson AA-905 R\_Date Lange-Ferguson UCIAMS 11345 R\_Date Lange-Ferguson UCIAMS 11344 R\_Date Sloth-Hole SL-2850 R\_Date Anzick Beta-163832 R\_Date Anzick Beta-168967 R\_Date Dent UCIAMS-11340 R\_Date Dent UCIAMS-11339 R\_Date PaleoCrossing AA-8250-0 \_\_\_\_ \_\_\_ R\_Date PaleoCrossing AA-8250-E R\_Date PaleoCrossing AA-8250-D R\_Date Domebo UCIAMS-11341 R\_Date Lehner Site SMU-264 R\_Date Lehner Site SMU-181 -R\_Date Lehner Site SMU-196 R\_Date Lehner Site SMU-194 \_\_\_ \_ R\_Date Lehner Site SMU-290 \_\_\_ R\_Date Lehner Site A-378 R\_Date Lehner Site SMU-164 R\_Date Lehner Site SMU-168 \_\_\_ R\_Date Lehner Site SMU-340 R\_Date Lehner Site SMU-297 \_ R\_Date Lehner Site SMU-347 R\_Date Lehner Site SMU-308 R\_Date Shawnee-Minisink Beta 10193 R\_Date Shawnee-Minisink Beta 12716 \_\_\_\_\_ R\_Date Shawnee-Minisink Beta-20386 \_\_\_ R\_Date Shawnee-Minisink UCIAM\$-24865 R\_Date Shawnee-Minisink UCIAM\$-24866 R\_Date Murray Springs SMU-18 R\_Date Murray Springs Tx-1413 R\_Date Murray Springs Tx-1462 R\_Date Murray Springs SMU-27 \_\_\_\_ R\_Date Murray Springs SMU-41 R\_Date Murray Springs SMU-42 \_ R\_Date Murray Springs Tx-1459 R\_Date Colby UCIAMS-11342 R\_Date Colby UCIAMS-11343

R\_Date Jake Bluff CAMS-79940

R\_Date Jake Bluff CAMS-90968

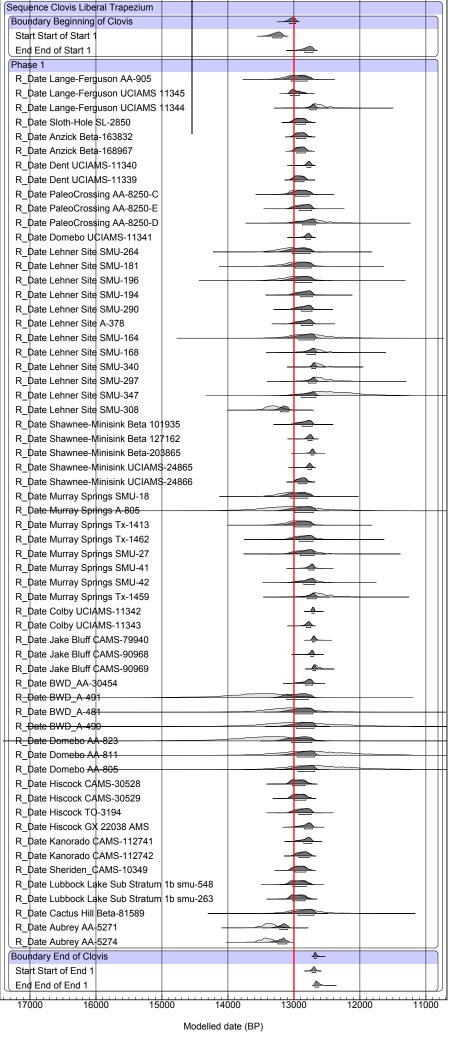
R\_Date Jake Bluff CAMS-90969

Start Start of End 1

End End of End 1

### **Liberal Clovis**

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

## Plains Clovis to Folsom

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Sequence Plains Clovis to Folsom Trapezium

Boundary Start Plains Clovis

Start Start of Start Plains Clovis

End End of Start Plains Clovis

R\_Date Lange-Ferguson AA-905

R\_Date Anzick Beta-163832

R\_Date Anzick Beta-168967

R Date Dent UCIAMS-11340

R\_Date Dent UCIAMS-11339

R\_Date Domebo UCIAMS-11341

R\_Date Lehner Site SMU-264

R\_Date Lehner Site SMU-181

R\_Date Lehner Site SMU-196

R\_Date Lehner Site SMU-194

R\_Date Lehner Site SMU-290

Date Lehner Site A-378

R\_Date Lehner Site SMU-164

R\_Date Lehner Site SMU-168

R\_Date Lehner Site SMU-340

R\_Date Lehner Site SMU-297

R\_Date Lehner Site SMU-347

R\_Date Lehner Site SMU-308

R\_Date Murray Springs SMU-18

\_Date Murray Springs A-805

R\_Date Murray Springs Tx-1413

R\_Date Murray Springs Tx-1462

\_Date Murray Springs SMU-27

R\_Date Murray Springs SMU-41

R\_Date Murray Springs SMU-42

R\_Date Murray Springs Tx-1459

R\_Date Colby UCIAMS-11342

R\_Date Colby UCIAMS-11343

R Date Jake Bluff CAMS-79940

R\_Date Jake Bluff CAMS-90968

R\_Date Jake Bluff CAMS-90969

R\_Date BWD\_AA-30454

R Date BWD A-491

R\_Date BWD\_A-481

R <del>Date BWD A-49</del>0

R\_Date Domebo AA-825

R\_Date Domebo <del>AA-805</del>

R\_Date Aubrey AA-5271

Date Aubrey AA-5274

R\_Date Agate Basin SI-373

R\_Date Agate Basin I-472

R\_Date Agate Basin SI-3732

R Date MacHaffie Beta-159167

Date Bobtail Wolf WSU-4444

R\_Date Bobtail Wolf WSU-4447

R\_Date Mountaineer CAMS 105764

R\_Date Mountaineer UCIAMS 11240

R\_Date Mountaineer UCIAMS 11241

R Date Indian Creek 1

R\_Date Indian Creek 2

R Date Waugh NZA-3602

R\_Date Waugh NZA-3603

R\_Date Hanson RL-374

R Date Hanson RL-558

R\_Date Hanson Beta-22514

R Date Hanson Beta-31072

R\_Date Hell Gap A-503

R Date Hell Gap A 504

R\_Date Lindenmeier I-141

R\_Date Lindenmeier TO-337

R\_Date Lindenmeier TO-342

R Date Blackwater Draw A-488

R\_Date Blackwater Draw A-492

R Date Bonfire Shelter TX-153

R\_Date Bonfire Shelter TX-658

R Date Bonfire Shelter TX-657

R\_Date Bonfire Shelter AA-346

R\_Date Folsom-CAMS-74655

R\_Date Folsom-CAMS-74656

R Date Folsom-CAMS-74657

R\_Date Folsom-CAMS-74658

R Date Folsom-CAMS-74659

Start Start of End Folsom

R\_Date Blackwater Draw A-386

\_Date Mountaineer CAMS 105765

R\_Date Black Mountain

Boundary Transition Plains Clovis/Folsom

Start Start of Transition Plains Clovis/Folsom

nd End of Transition Plains Clovis/Folsom

R Date Domebo AA-811

R\_Date Kanorado CAMS-112741

R\_Date Kanorado CAMS-112742

R\_Date Lubbock Lake Sub Stratum 1b smu-548

R\_Date Lubbock Lake Sub Stratum 1b smu-263

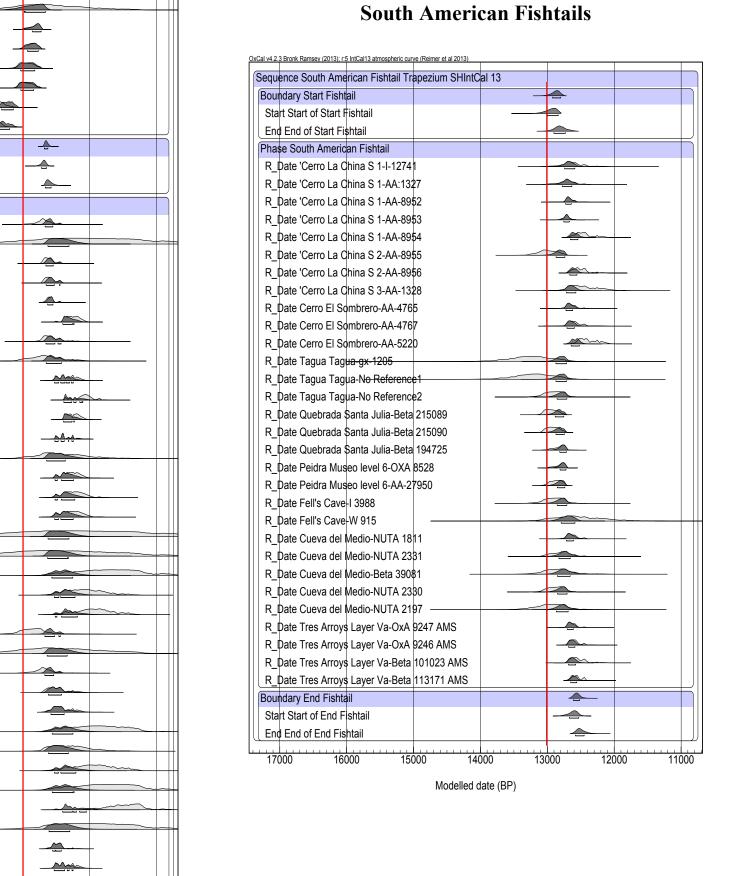
R\_Date Lange-Ferguson UCIAMS 11345

R\_Date Lange-Ferguson UCIAMS 11344

Phase Plains Clovis

Sequence Eastern Clovis - Debert and beyond sequential phases Boundary Start Eastern Clovis R\_Date Cactus Hill Beta-81589 R\_Date Sheriden\_CAMS-10349 \_\_\_\_\_ R Date Hiscock CAMS-30528 \_\_\_\_\_ R\_Date Hiscock CAMS-30529 R\_Date Hiscock TO-3194 \_ R\_Date Hiscock GX 22038 AMS R\_Date Shawnee-Minisink Beta 10193 R\_Date Shawnee-Minisink Beta 127162 R\_Date Shawnee-Minisink Beta-203865 R\_Date Shawnee-Minisink UCIAM\$-24865 R\_Date Shawnee-Minisink UCIAM\$-24866 R\_Date Sloth-Hole SL-2850 Boundary End Eastern Clovis Boundary Start Debert R Date F04-P743 R\_Date Vail Beta-207579 \_\_\_\_\_ Boundary End Debert Boundary Start Bull Brook R\_Date Hedden Beta-70668 R\_Date Hedden Beta-68806 Boundary End Bull Brook Boundary Start Michaud R\_Date Templeton W-3391 R\_pate Michaud Beta-15660 R\_Date Neponset Beta-7552 R\_Date Colebrook Beta-10742 \_\_\_\_ Boundary End Michaud Boundary Start Cormier R\_Date Cormier Beta-126645 \_\_\_\_ R\_Date Esker Beta-103284 Modelled date (BP)

**Eastern Clovis to Debert and Beyond** 



### Western Stemmed

Start Start of Start 1 End End of Start 1 R\_Date BERck-AA-58592 \_\_\_ \_\_\_\_ R\_Date BERck-AA-58593 R Date BERckAA-58594 \_\_\_\_ R\_Date BERck-Beta 195047 -----R\_Date BERck-Beta-207009 \_\_\_\_ R\_Date Buhl Beta-43055 R\_Date Coopers Beta-114949 R\_Date Coopers TO-7349 R\_Date Coopers TO-7351 \_\_\_\_ R\_Date Coopers TO-7352 R\_Date Fishbone 'no lab according to l R\_Date Fishbone-'FC:L-245 R\_Date Handprint 'Beta-21885 R\_Date Hatwai Tx-3159 R Date Hatwai Tx-3160 R\_Date Hell Gap 'A-500 R\_Date Hell Gap 'AA-16600 R\_Date Hell Gap 'I-167 R\_Date Marmes 'WSU 211 \_\_\_\_ R\_Date Marmes 'WSU 363 R\_Date Marmes 'WSU 366 R\_Date Paisley - Beta 213423 R\_Date Paisley - OxA 16376 R\_Date Paisley-Beta 171938 \_\_\_\_\_ R\_Date Paisley-Beta 182920 R\_Date Paisley-Beta 195908 \_\_\_\_ R\_Date Paisley-Beta 213425 \_\_\_\_ R\_Date SmthCrk-'birm-702 R\_Date SmthCrk-'birm-917 R\_Date SmthCrk-'gak-5442 R\_Date SmthCrk-'gak-5443 R\_Date SmthCrk-'gak-5444b R\_Date SmthCrk-'gak-5445 R Date SmthCrk-'tx-1638 

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 also compiled a more liberal set of ages and analyzed that set using both Boundary and Trapezium Models. We also investigated two transition models with data from Western Clovis and Plains Folsom 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 W&S age average 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**.

**RESULTS** 

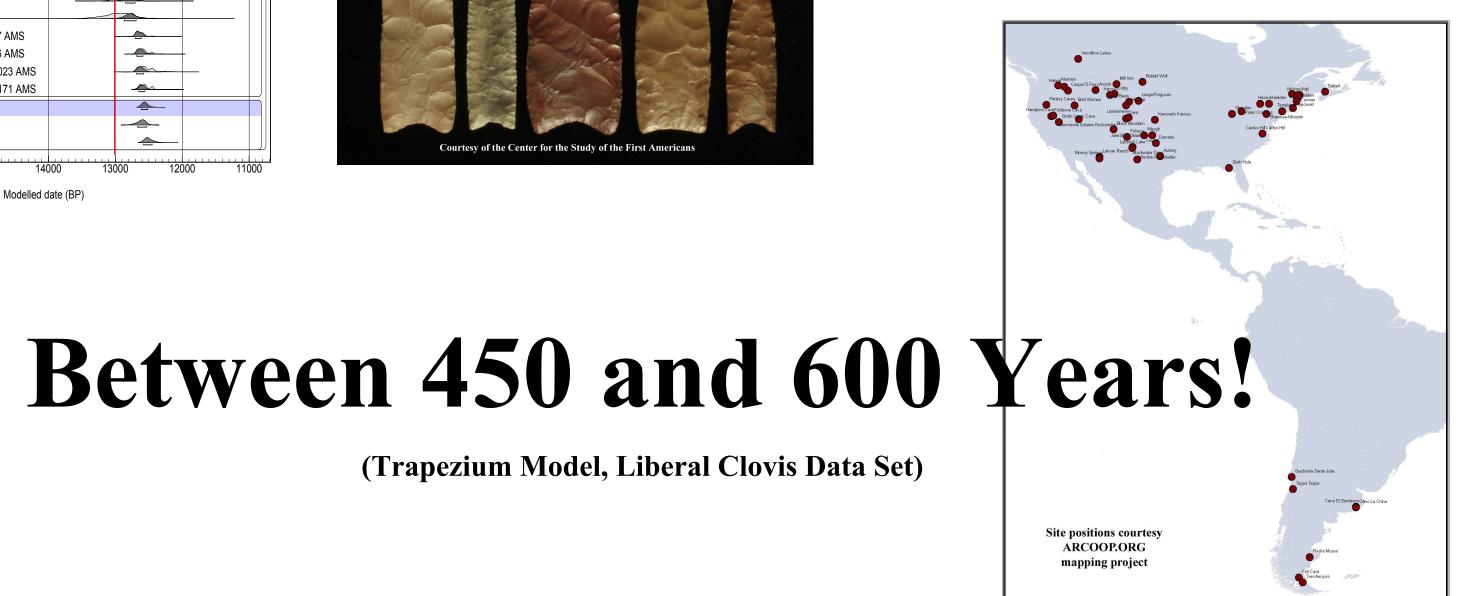
The Bayesian analysis in OxCal 4.2 was used to evaluate the span and strength of different

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 the 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 beginning of the 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 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 Frapezium 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 the end between 12,684-12,622 calBP. 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 <sub>model</sub> index	Start in Calendar Years	End in Calendar Years	Span in Calendar Yea
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 yea
Trapezium	W&S individual ages	96.2%	13044-12864 BP	12690-12629 BP	163 to 352 yea
Boundary	Liberal Clovis	85.2%	13222-13140 BP	12644-12587 BP	499 to 603 yea

Frapezium Liberal 121.6% 13322-13181 BP 12684-12622 BP 464-608 years



Map of Sites