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Bayesian Assessment of Northern Alaskan Chronological Issues: Implications for Future Research

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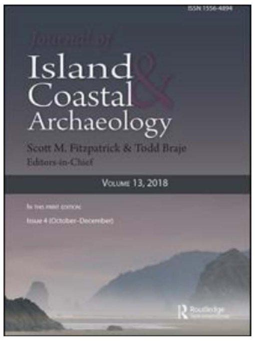

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Bayesian assessment of northern Alaskan chronological issues: Implications for future research

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ABSTRACT
Cultural interaction and exchange across the Bering Strait of northern Alaska played a central role in the emergence of Arctic maritime adaptations. Yet poor chronological control limits our ability to explore processes of cultural change over the last 5000 years. We address this problem by synthesizing the available radiocarbon record for the region, carrying out Bayesian analysis of a regional radiocarbon database, and analyzing the BAR-1 (Birnirk) site using new dates published in this paper. Our synthesis and our illustrative analysis of the BAR-1 site highlights several intriguing temporal and spatial trends with implications for interaction between cultural groups. Our analysis also underscores the uncertainty associated with dating cultural phases and identifies specific areas where additional research is needed to further our understanding of cultural interaction in this complex region.

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Bayesian analysis; chronology; cultural interaction; maritime foragers; Arctic

Introduction

Over the last 5000 years, northern hunting and gathering peoples along the Bering Strait (Figure 1) developed specialized tool technologies, marine-focused settlement patterns, and complex social organization (Ackerman 1998; Fitzhugh 2016); theoretically central to the emergence of these Arctic maritime lifeways is the region's intricate history of migration, cultural interaction, conflict, competition, and cooperation through extensive exchange networks (Dumond 2000; Mason 1998; Tremayne and Brown 2017; Tremayne and Winterhalder 2017). Yet poor chronological control (see Gerlach and Mason 1992) and confusion about evolutionary relationships among cultural groups (Mason 1998, 2000, 2009a, 2009b; Mason and Bowers 2009) limits our ability to further explore cultural change in the Arctic. The complex and overlapping cultural historical phases of northern Alaska are interpreted as evidence of intense interaction among groups; the underlying assumption is that these phases represent distinct ethnic groups that interacted and mixed over time (Mason 2009a). There have been several efforts over the years to clarify the timing of key transitions and to study the evolutionary relationships

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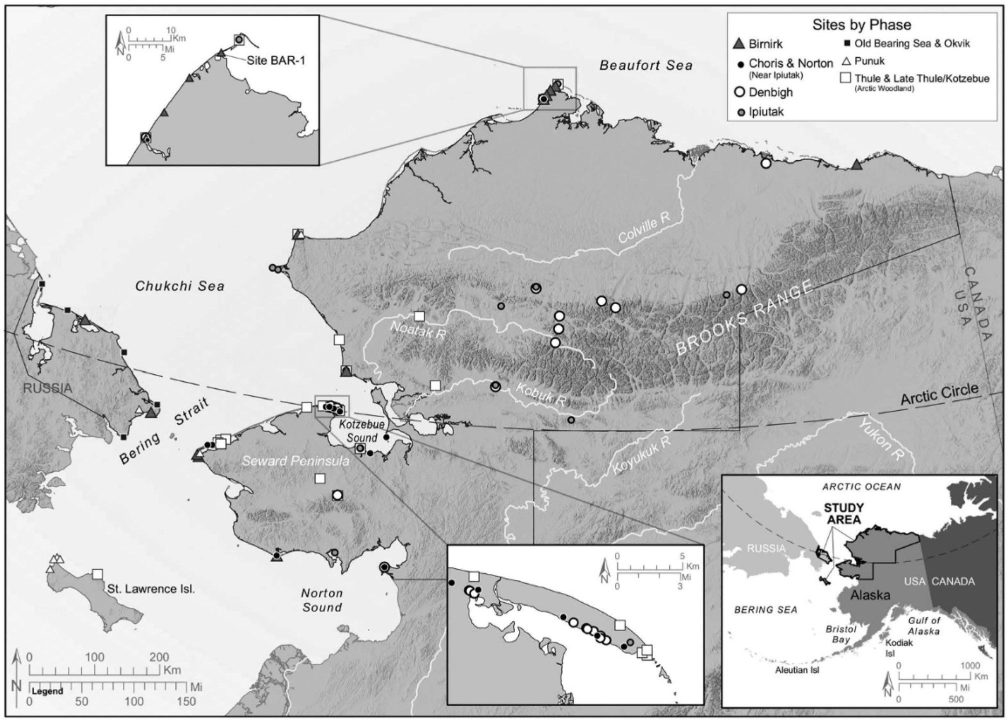

Figure 1. Map showing key locations mentioned in the text. Radiocarbon database area indicated by dark outline. (Figure by Johonna Shea).

between groups (e.g., Blumer 2002; Dumond 1998, 2008; Gerlach and Mason 1992), but we do not yet have a firm understanding of the temporal and geographic relationships between groups of people in this region. Overall, tighter chronological control and a better understanding of the tempo of cultural phases is needed to study interaction among groups during the mid-late Holocene and to examine the role of interaction in the development of Arctic maritime traditions. Moreover, because northwest Alaska was at the center of Holocene migrations into and across northern North America, understanding the chronology in this region has broader implications for understanding the timing and drivers of migration across the North American Arctic.

In this paper, we systematically examine and synthesize our current understanding of the chronology of major northern Alaskan cultural historical groups and their potential interaction over the last 5000 years, focusing on the transitions between major cultural traditions—Paleo and Neo Inuit cultures. Our focus is on northern Alaska (Figure 1) where multiple groups of people migrated across the Bering Strait and into the North American Arctic; available Russian Bering Strait dates are also included. Our goals are to empirically assess the strength of the mid-late Holocene chronology for the region and to examine the revised chronological evidence for interaction between cultural groups. To do so, we first apply Bayesian chronological models to a wide range of cultural phases in northern Alaskan to begin clarifying their timing, duration, and potential internal characteristics. We then provide a more focused analysis, with additional modeling, of the Birnirk site (BAR-1). The goal of this analysis is to illustrate how targeted use of Bayesian chronological models in combination with relatively few dates from specific time periods can be used to address some of the interpretive problems brought up in the first part of our analysis and thus strengthen the regional chronology/studying interaction and evolution. Our analysis lays the foundation for further study of the role of interaction in cultural change and demonstrates the potential of Bayesian analysis in unraveling long-standing problems in Arctic archaeology.

Prior research: Chronological and evolutionary confusion

Overall, there is general consensus among researchers in the region regarding the broad sequence in which significant technological, socio-political, and economic changes occurred (see Table 1). However, there remains considerable debate regarding the specific timing, cause, and meaning behind major cultural shifts in the region (Dumond and Collins 2000; Harritt 2004). This is especially true regarding the role of interaction. As the location of northwest Alaska at a cultural crossroads between Eurasia and North America means that unraveling the spatio-temporal dynamics of culture phases, linked to technological and/or ethnic migration, plays an uncommonly large role in understanding cultural evolution in the region. Because of this, considerable effort was undertaken, especially in the 1990s and early 2000s, to carefully examine and analyze the radiocarbon record of culture phases (Blumer 2002; Dumond and Griffin 2002; Gerlach and Mason 1992). However, numerous projects were undertaken following these excellent syntheses, dates from which have yet to be widely published and/or circulated, creating a need for a new synthesis. Moreover, as discussed above, methodological advances in analyses of radiocarbon data allow us to standardize and empirically evaluate our understanding of northwest Alaskan culture phases in ways not previously possible.

The goal of our analysis is to: (1) synthesize the current state of knowledge and empirically assess what we know and do not know about northern chronology, and timing of major migrations and periods of cultural interaction between groups; (2) explore how simple and preliminary Bayesian analysis of new dates from a key time period can contribute to questions about processes of cultural change; and (3) identify through empirical analysis time periods and places where strategic dating and additional analysis could help Arctic archaeology move forward toward new understandings of cultural change during the mid-late Holocene. We do this by compiling and analyzing a radiocarbon database of northern Alaskan sites and by analyzing five new dates from a significant archaeological site, the Birnirk Phase type site, BAR-1 (Figure 1).

Methods

Radiocarbon database construction

We compiled radiocarbon data from 6000 cal BP to the present from a variety of sources including the Alaska Heritage Resource Survey (AHRS), reports, theses, dissertations, agency archival records, and recent publications. We used cultural historical designations provided by the original researchers (i.e., phase names). In some cases, Old Bering Sea and Okvik sites and associated dates cannot be clearly attributed to one group or the other; this leads to the designation "Old Bering Sea-Okvik". Furthermore,

Table 1. Key periods in the development of Arctic maritime traditions.

Time period	Cultures	Previously established age (cal BP)	Key phase attributes	Geographic range	Subsistence base	References
I: Initial coastal occupation	Denbigh	(5000?) 4500–2750	i Arctic Small Tool Tradition (ASTt); (ii) migrants from Beringia; (iii) Highly mobile foraging strategies	Kotzebue Sound, Brooks Range	Caribou, marine mammal	Buonasera et al. (2015); Tremayne and Rasic (2016)
II: Increased coastal occupation and use of coastal resources	Choris	2750–2450	(i) Earliest pottery in Alaska, likely from Russia; (ii) earliest semi-subterranean houses in NW Alaska; (iii) Distinctive lithic production and projectile point/knife morphology (possibly derived from Denbigh) (iv) Semi-Sedentism.	Kotzebue Sound, Brooks Range, northern Yukon Territory	Seal, possibly small whale (beluga), caribou, possibly fish	Darwent and Darwent (2016:371-394)
	norton (Near Ipiutak in Northwest Alaska)	2500–2000a	(i) Checked and linear stamped pottery; (ii) pentagonal flaked points, split-base arrowheads, and slate technology; (iii) houses and villages; (iv) lithic production and tool morphology possibly derived from Denbigh/ASTT	Southern Alaska to western Canada.	Seal, possibly whale, caribou, fish	Dumond (2000); Mason (2016)
III: Increased marine focus	Old Bering Sea	2150–750	(i) Whaling technology; (ii) elaborate winged figures; (iii) small, dispersed settlements; (iv) formal cemeteries with elaborate grave goods; (v) distinctive end blades and harpoon styles; (vi) appearance of ranked social structures; vii earliest use of iron	Western shore of Chukchi Sea and Bering Strait Islands	Seal, walrus, whale	Mason (2016); Mason and Rasic (2019)
	Okvik	1750–1550b	Same as above but slight variation in art motifs used.	Western shore of Chukchi Sea and Bering Strait Islands	Seal, walrus, whale	Mason (2016)
	Ipiutak	1750–1150	(i) Disappearance of pottery, slate technologies, lamps and specialized whaling equipment; (ii) significant elaboration in burials with grave goods; (iii) earliest use of iron; (iv) specialized tool forms, possibly derived from Norton/	Norton Sound to Point Barrow, interior of northwest Alaska and Brooks Range	Seal, walrus, caribou, possibly small whale (beluga)	Mason (2016)

(*continued*)

Table 1. Continued.

Time period	Cultures	Previously established age (cal BP)	Key phase attributes	Geographic range	Subsistence base	References
			Choris (e.g., end blades, discoid scrapers, lunate biface knives and groundstone 'burin-like' instruments.			
	Birnirk	1350–750	(i) New whaling technology (e.g. multiple spurred harpoon heads); (ii) ground slate technologies; (iii) plain and curvilinear pottery; (iv) lithic flaking techniques somewhat similar to Ipuitak, very different than seen in OBS; (v) highly distinct decorative styles, emphasizing incising of ivory with straight lines paired with recurring patterns.	Eastern and western shores of Chukchi Sea, Bering Strait Islands	Seal, walrus, whale, caribou (north Alaska)	Alix, Mason, and Norman (2018)
IV: Emergence and spread of complex and highly marine focused groups	Punuk	1150–550	(i) Elaborate curvilinear design motifs; (ii) expanding use of iron and archery; (iii) evidence of increased inter-group conflict (e.g. slat armor)	Western shore of Chukchi Sea and Bering Strait Islands, limited distribution in mainland northwest Alaska	Seal, walrus, whale	Cooper and Bowen (2013); Harritt (2004); Mason (2009b)
	Thule	950 to 550	(i) Similar to Birnirk, but more whaling, larger population aggregations and social differentiation	Bering Strait to Greenland	Seal, walrus, whale, caribou, fishing	Mason (2009b)
V: Shift to fishing focus	Late Thule/Kotzebue/ Arctic Woodland (in interior)	550 to contact era	Smaller settlements (possible dispersion from larger settlements of earlier Thule period); occupation of new regions of coast/interior	Coastal areas of northwest Alaska	Seal, walrus, whale, caribou, fishing (possibly with greater intensity than before)	Giddings (1952); Schaaf (1988)

we only included dates on terrestrial bone or plant material. Dates on unknown sample materials, marine/mixed marine or potentially marine contaminated materials, dates missing information, and dates known to be incorrect due to lab error were excluded from our analysis (Supplemental Table 1). While there is the potential for old wood from wood re-use and use of driftwood (e.g. Arundale 1981; Friesen and Arnold 2008; Giddings 1952a), it was not possible to exclude old wood from our analysis because details on plant or tree material are not typically provided by the original investigator and doing so would leave us with an unusable sample (see discussions in Anderson et al. 2019 and for more details). It is important to emphasize again that because of these issues, the analyses presented here should be viewed as preliminary and descriptive, meant to highlight what can be said at this time and how best to target future research. After eliminating problematic samples and samples without phase designations, there are 410 dates and 90 sites in the post-6000 cal BP radiocarbon database for the project area (Supplemental Table 2)

New radiocarbon dates

The Birnirk site (BAR-1) was the first place the Birnirk culture was identified and determined to be the probable antecedent to more widespread Thule culture. The site was investigated by James A. Ford and by Wilbur Carter in the 1950s and 1960s (Carter 1966; Ford 1959). We selected two diagnostic harpoon points and three modified caribou antler fragments from the site for dating (Table 2). In addition, we also incorporated seven recently published (Anichtchenko 2016; Clark et al. 2019) Birnirk associated radiocarbon dates from Mounds L and H in our analysis. See Table 2 for more details.

Bayesian analysis

To better understand the temporal characteristics for the cultural phases we used a series of Bayesian calibration models to clarify the probable timings and durations of each archaeological phase. Twelve individual archaeological phases from northern Alaska were modeled using the *boundary, phase,* and *interval* commands using OxCal version 4.2.3 (Bronk Ramsey 2009b) IntCal13 atmospheric curve (Reimer et al. 2013) (see Supplemental Figure 1 for model schematic). This analysis uses a uniform prior and identifies the highest probability age ranges for the beginning and end of the established phases, the individual dates within each phase, and the duration or span of each phase (Bayliss 2009; Bronk Ramsey 2009a, 2009b) based upon the sample size, range of dates, and error of dates within the model. In effect, this means that phases with small sample sizes, which are not tightly clustered in time will have large ranges in their temporal estimates. This does not necessarily reflect the quality of individual dates, but rather the statistical uncertainty around trying to extrapolate from small and disparate sample sizes. Although this may lead to less precise modeled phase estimates than given by others, it is a more accurate and replicable statement of our certainty about the temporal extent of cultural phases.

Important assumptions of these models are that all the dates within the model form a coherently related event (i.e. an archaeological phase), that this event has a definite

Table 2. New and newly published Birnirk radiocarbon dates from BAR-1 (Anichtchenko 2016; Clark et al. 2019).

Beta ID #	CAT_NUM	Description	Feature	Unit	Depth	Conventional Error	δ13C (0/00)	δ15N (0/00)		Reference
Beta-519506	BK Q-0943	Harpoon, caribou antler	Mound Q	–	48–60"	1020+/-30	30	−20.3	1.9	This paper
Beta-519507	BK-Q-0640	Harpoon, caribou antler	Mound Q	–	36–48"	980+/-30	30	−18.8	2.1	This paper
Beta-517962	UA2012-051-5784	Modified caribou antler	Mound Q	18	24–36	880+/-30	30	−19.1	3.6	This paper
Beta-517963	UA2012-051-5604	Modified caribou antler	Mound Q	3	24"–36"	900+/-30	30	−19.3	2.4	This paper
Beta-517964	UA2012-051-6547	Modified caribou antler	Mound Q	S2E2 (north half), S1E2	5.70–6.20 (67–74")	1030+/-30	30	−20.5	2.0	This paper
UGAMS-25367	UA2012-51-2227, BK-H-2217 (ADMR04481)	Caribou bone	Mound H	S6E1	2–2.5′	1047+/-23				Clark et al. 2019
Beta-331678	UA2012-51-36, BK-H-2589 (ADMR05920)	Wood	Mound H	N1W1	2–2.5′	1040+/-30				Anichtchenko 2016
Beta-331679	UA2012-51-3563, BK-H-3551 (ADMR08714)	Wood	Mound H	N0W1	3–3.5′	990+/-30				Anichtchenko 2016
Beta-321203	UA2012-51-2873, BK-H-2862 (ADMR05920)	Wood	Mound H	N0W1	–	1070+/-30				Anichtchenko 2016
UGAMS-25364	UA2012-51-5182, BK-L-0605 (ADMR06775)	Caribou antler	Mound L	S1W2	1.5–2′	940+/-23				Clark et al. 2019
UGAMS-25368	UA2012-51-5364, ADMR12726	Caribou antler	Mound L	S3E0	2.5–3′	913+/-22				Clark et al. 2019

beginning and end, that we have samples at least somewhat representative for the span of its existence, and that there are no strong biases toward any single period within the phase. Additionally, OxCal provides us with "Agreement Indices" (AI) for the model and for individual dates. AI scores less than 60 for an individual date indicates that it is inconsistent with the rest of the dates in the model, while a score of less than 60 for the model means the data is altogether inconsistent with the assumptions of the model. Thus, we can identify dates or phases which are particularly problematic. It is important to note, however, that this is not the same as a formal "outlier" analysis (e.g. Bronk Ramsey 2009a), which provides more sensitive and nuanced assessments among the dates within the model.

Although some of the phases here do not meet all the requirements for these models, our goal is not to necessarily define cultural historical phases. Rather, we wish to use them to test the assumption that phases designated by other researchers form coherent temporal events and help to identify problematic phases and dates. It is likely that original phase designations are not always correct and even more likely that there have been some inconsistencies in the use of the terms. Indeed, it is likely that most working in this region would agree that available data in the region is too incomplete and/or problematic to "fix" or "define" the absolute temporal characteristics of phases. Thus, the focus on this broad analysis is more concerned with summarizing and analyzing data in a coherent framework to highlight how empirical and theoretical work can more efficiently address chronological connections among phases.

It is important to note that various authors have suggested that the uniform prior, which we use, may be inappropriate for cultural phase modeling and instead suggest the use of Trapezoidal or Sigma (roughly normal distribution) priors (see Lee and Bronk Ramsey (2012) and Manning et al. (2014)). However, these studies were based on phases defined mostly by single diagnostic artifact types, which can be expected to seriate neatly in relative frequency (thus approximate the Trapezoidal and/or Sigma priors). These studies were also focused on understanding the transition period among phases, while our goal is to simply derive estimates for the absolute beginning and ending for each phase, with subsequent research intended to more specifically address the nature of overlap and interaction Thus, for this study, we argue that the use of a uniform prior is more appropriate for northern Alaska phases as a preliminary analytic step because we have little understanding *a priori* of the distribution these phases should take and because these phases are not defined by a single artifact type, but by a combination of settlement/economic practices and a range of various stylistic and functional artifact types (e.g. ceramic types). However, we also wish to emphasize again that our use of basic uniform prior phase models reflects current state of understanding and is a preliminary assessment of northwest Alaskan phases. However, future research regarding more specific questions of tempo and degree of interactions among phases will benefit greatly from employing the Trapezoidal and Sigma priors mentioned above. Below, we present in our results in two ways: the first is by providing the 95% range estimates for the beginning, end and span of each phase as provided by the *Boundary* and *Interval* commands, respectively (Table 3). We then use the summed probability distributions (SPD) created using the SUM function in OxCal from each of the modeled phases to illustrate general patterning in the radiocarbon record within each phase.

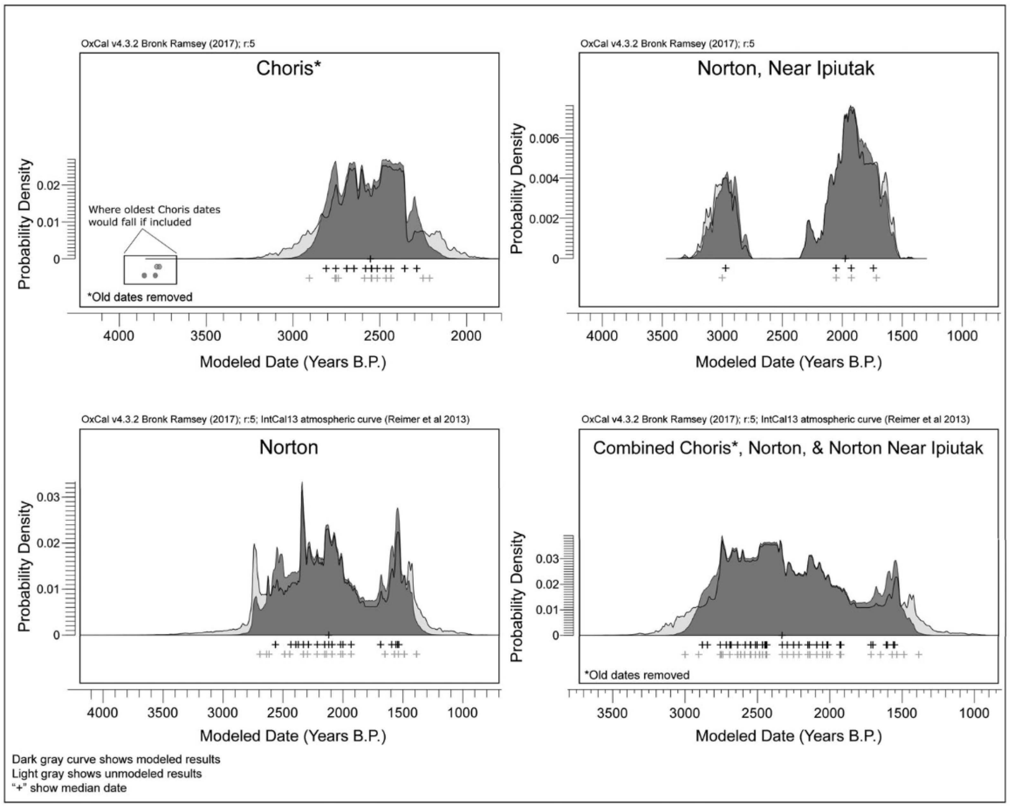

Figure 2. SPDs of dates associated with Choris, Norton, and Norton Near Ipiutak phases. Bottom right shows SPD combining data from all three phases. (Figure by Johonna Shea).

Peaks and valleys within SPDs indicate fluctuations in probability density of radiocarbon ages through time and thus, are generally illustrative of relative changes in sample size through time. It is important to clarify that the SPDs shown below are meant for illustrative purposes and to provide context for the distribution of dates within a phase. They have not been modified or manipulated in any way and are not intended to be used as proxies for other phenomena (e.g. demography). It is also important to clarify that our estimates for the beginning, end, and span for each phase were not derived from these SPDs.

As mentioned above, additional analyses of the Birnirk phase, using newly available data, were also employed to illustrate how modest efforts in obtaining new dates can elucidate our understanding of these culture phases. These efforts are discussed in more detail after the initial analyses. OxCal's CQL code and additional details regarding the results of these analyses are found within Supplemental Figures 2 and 3.

Results and discussion

Bayesian analysis tightens the chronological range of several cultural historical phases and highlights the lack of dates for some phases. This lack of dates yields uncertainty in modeled date ranges (Table 3). The Choris, Near Ipiutak, Okvik, and Arctic Woodland

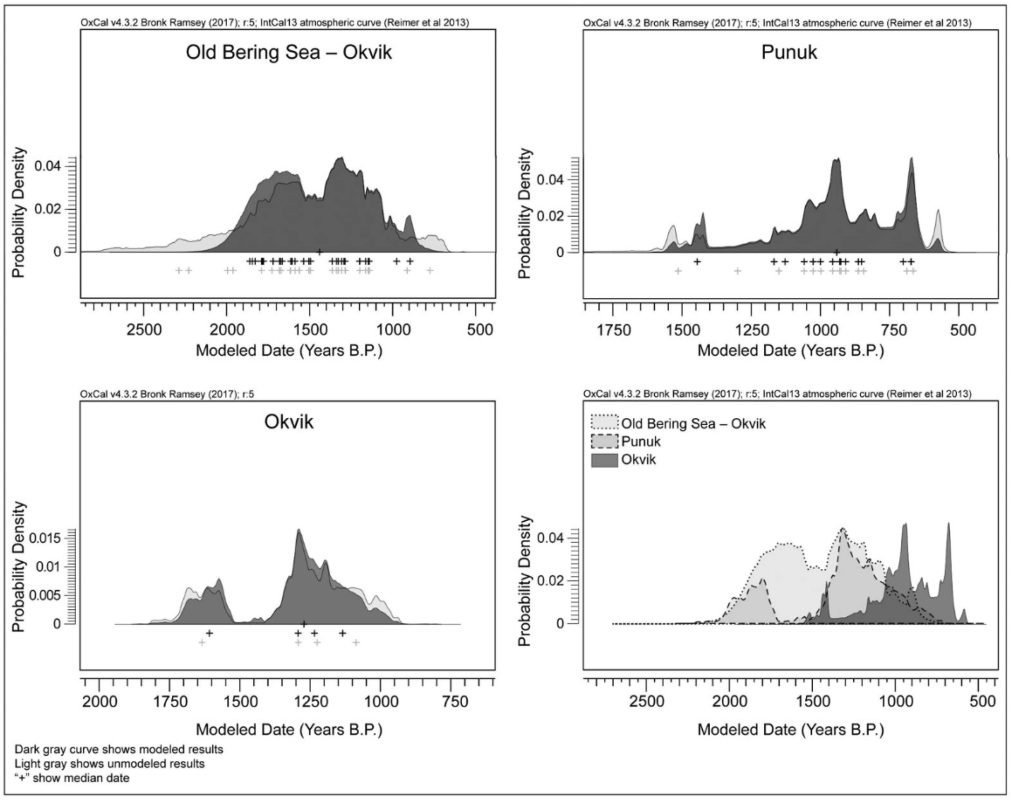

Figure 3. OBS Ovik punuk. Modeled Bering Strait (Old Bering Sea, Okvik, Punuk) phases. (Figure by Johonna Shea).

phases are particularly poorly dated. Several dates were rejected by the model; in many cases these dates were identified as suspect by the original investigator (Supplemental Table 2). Birnirk and Punuk dates are also limited.

In the following discussion, we unpack the chronological problems identified by this analysis. We consider the possible implications of revised phase ranges for our larger understanding of regional cultural interaction, migration, and change. We also discuss specific areas for future research to both address the chronological problems identified here and to pursue some of the patterns indicated by our analysis.

Timing of the Paleo Inuit (Denbigh) migration into Alaska

Initial modeling of the Denbigh phase yielded highly problematic results with OxCal rejecting the first model (Amodel = 29.7, Aoverall = 16.2), indicating inconsistency between data and model parameters. Inspection of the results showed that most of this discrepancy was caused by dates identified as too old for the model (Table 3; also see Supplemental Figure 2 and Table 3). To reach an acceptable agreement score, we minimally had to remove three of the oldest dates rejected by the model and re-run the analysis, which provided acceptable agreement indices (Amodel = 85.4, Aoverall = 84.7) and a date range of (~4500–3600). Our modified modeled Denbigh start date is

Table 3. Comparison of previous and revised date ranges for cultural historical phases.

Cultural phase	Previous phase range (cal BP)	Modeled phase range start 95%	Modeled phase range end 95%	Span (duration) 95%	N Dates	Outside range of modeled estimates[a]	Agreement index score (Amodel)
Denbigh	4500 to 2750	4684–4456	3554–3403	925–1240	74	End 700–800	29.7
Denbigh Modified[b]	n/a	4560–4442	3637–3509	823–1012	71	N/A	85.4
Choris	2750 to 2450	4215–3722	2326–1851	1464–2233	15	Start 1000–1500 yrs End −100–600 yrs	101.9
Choris oldest dates removed		3263–2852	2340–2102	533–1090		Start 100–500 yrs End −100–300 yrs	
Norton	2500 to 1000[c]	2931–2503	1584–1193	990–1636	19	End 580–193 yrs	95.7
Near Ipiutak	2500 to 1000	4784–2798	1882–modern	1064–4281	4	N/A	99.0
Combined Choris/Norton/Near Ipuitak	N/A	4028–3712	1584–1217	2193–2727	38	N/A	97.5
Old Bering Sea/Okvik	2250 to 1550	2179–1773	1032–686	858–1407	32	Start −80–480 yrs End −500–900 yrs	79.5
Okvik	1750 to 1550[d]	2491–1426	1262–221	236–2034	4		97.1
Ipiutak	1750 to 1150	2131–1918	736–600	1226–1493	74	Start 200–400 yrs End −400–500 yrs	72.4
Birnirk	1350 to 750	1507–1229	1034–723	298–729	15		110.6
Birnirk New Dates		1400–1186	869–722	349–500	27	End 0–100 yrs	
Punuk	1150 to 550	1682–1413	694–437	753–1168	15	Start 300–500	109.2
Thule	950 to contact era	1045–953	269–206	702–814	93	Ending 200 yrs[e]	89.2
Late Thule/Kotzebue/	550 to contact era	1178–693	188–Modern	570–1256	21	Start 140–600 yrs	72.0
Arctic Woodland	550 to contact era	1169–583	403–modern	315–1213	8	____	109.0

[a]Negative '−' sign denotes younger than previous estimate. No sign denotes older than previous estimate.
[b]See comments regarding problematic Denbigh model
[c]2400/2300–1000 cal BP in western and southwest Alaska
[d]2550–2350 cal BP in Chukotka
[e]Problems with the calibration curve during this period may be exaggerating difference between previous and modeled estimate.

like that identified through Bayesian analysis for the Chukchi Coast (*4605 ± 110 cal BP*) and northern Bering Coast (1) (*4750 ± 430*) regions (Tremayne and Winterhalder 2017). However, our results suggest an earlier end for Denbigh (*∼3600–3500 cal BP*) than Tremayne and Winterhalder (2017) identify in their analysis of Denbigh dates from across Alaska (*4950 ± 50 to 3200 ± 80 cal BP*) (Table 3). It should be noted though that after removing the first problematic dates, the model continued to identify even more problematic dates, which were still flagged as too old to be consistent with the rest of the Denbigh data. Tremayne and Winterhalder (2017) observed similar issues with the Denbigh phase, noting questionable archaeological association with some of their dates. While this is a possibility for explaining the problematic agreements seen here, there does not seem to be a strict correlation between ambiguous association and "early" Denbigh dates. Nor are we suggesting that the oldest dates cannot be related to Denbigh, only that they are statistically inconsistent with the rest of the Denbigh data. Regardless, the rejection of many of the earliest Denbigh dates during our modeling suggests that the beginning of Denbigh needs further inspection. The models' estimation of an earlier than expected ending for Denbigh is also in need of more robust inspection, as this further separates Denbigh from any of the region's subsequent phases, i.e. Choris (Figures 2 and 3), adding complications to the already ambiguous relations between the phases (see Choris discussion below). Better understanding of the timing of the Denbigh phase has significance for establishing why and how Inuit people first came into, and migrated across, the North American Arctic, bringing with them unique northern maritime adaptations.

Potential for Later Paleo Inuit cultural interaction

In northern Alaska, the Denbigh phase is followed by the Choris and Norton (or Near Ipiutak) phases. The transition between Denbigh and Choris cultures has not been examined in depth, although it seems that Choris culture could have emerged as new people/technology migrated into Alaska from western Beringia (Table 1) (Anderson et al. 2017; Darwent and Darwent 2016).

The number of known Choris (Darwent and Darwent 2016) and Near Ipiutak sites is extremely limited so there is little data on which to base these phase designations. Choris culture is considered by some an early northern phase of the Norton Tradition (e.g. Dumond 2000; Tremayne and Brown 2017). Alternatively, it is viewed as a distinct northwest Alaskan cultural phase, in lieu of information that would clarify the relationship between Choris, Denbigh, and Norton culture to the south (Darwent and Darwent 2016, 386). Because of affinities between Choris and Norton pottery (e.g. Griffen and Wilmeth 1964; Oswalt 1955), Choris is identified archaeologically by a combination of traits (Table 1) (i.e. presence of both lithic and ceramic Choris-type materials). However, in northwest Alaska, the presence of pottery is sometimes taken alone as an indication that a site can be attributed to Choris culture, which is potentially problematic (e.g. Gal 1982; see Darwent and Darwent 2016 for additional discussion).

Our modeled results reflect the lack of in-depth studies and ambiguity of associated traits for these phases. The relatively wide age ranges for Choris, Norton, and Near Ipiutak phases result from the small number and widely dispersed dates from each

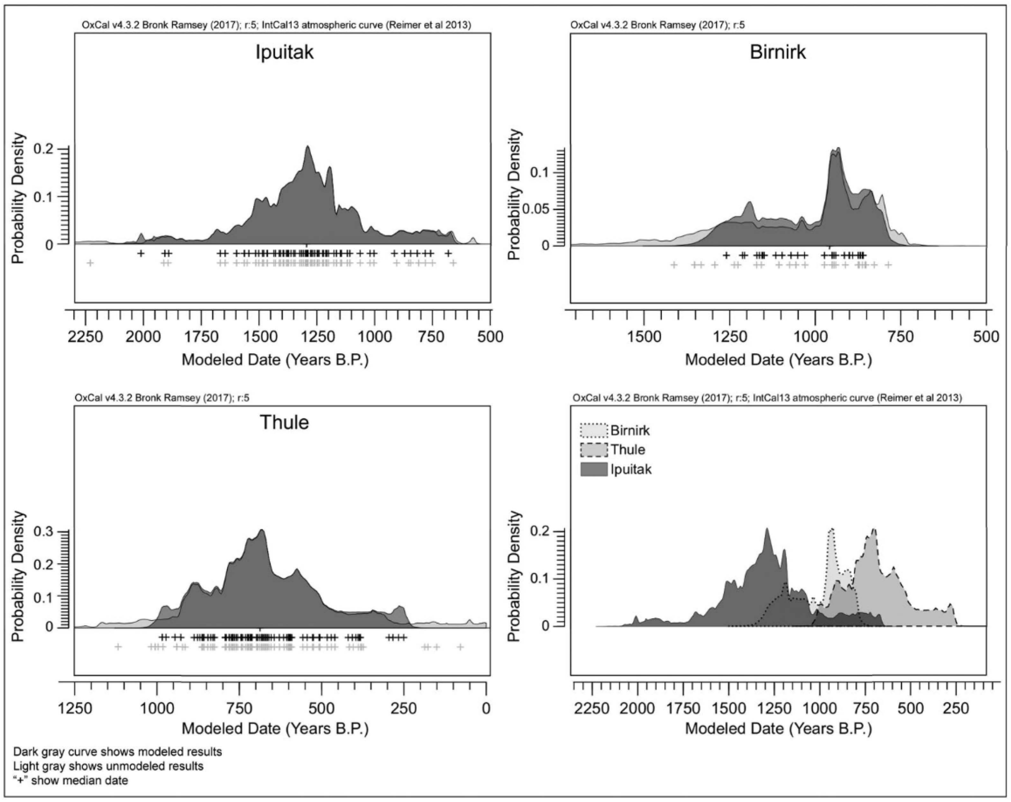

Figure 4. Ipuitak Birnirk thule composite. Modeled Ipiutak, Birnirk, and Thule cultural phases. (Figure by Johonna Shea).

phase (Table 2); additional dates from these phases would refine our modeled chronologies further and allow us to accurately assess their temporal relationships. For example, there is a conspicuous gap in dated material between the earliest few Choris dates and the subsequent bulk of dated material (Figure 2). However, a lack of detailed reporting makes it unclear why the original investigator at the Coffin site attributed these dates to the "Choris" component (Wilmeth 1964) and not the earlier Denbigh component. While tempting to write these early dates off as outliers, it is important to note that the entirety of the Choris sample comes from three sites (Darwent and Darwent 2016), making large gaps resulting from simple sampling error—not altogether unexpected. Regardless, given that Choris is associated with the introduction of pottery and sedentism (Table 1), the discrepancy in dates has profound implications for our understanding of culture change. Moreover, the historical reality of this gap should not be assumed to be an artifact of sampling or error in typological attribution *a priori,* as this gap may be showing a staggered migration of people and/or ideas from Russia.

As mentioned above, the overlap between these cultural phases could also result in part from inconsistent identification of sites as Choris, Norton, and Near Ipiutak in northwest Alaska (Figure 2); from literature review associated with our compilation of radiocarbon dates, and previous synthesis of early pottery sites in Alaska (Anderson et al. 2017). It is clear that archaeologists who find pottery in northwest Alaska often use it as a basis for designating a site as "Choris", or are unsure what to do given the affinities between Choris and Norton pottery, and end up labeling the sites Choris/Norton.

Despite these problems, our results do suggest interesting temporal patterns that can be further explored with additional dating and modeling efforts. As mentioned above, the modeled estimates for the Choris phase may be much earlier than anticipated, ranging from *4215–3722* to *2326–1851 cal BP* (Table 2). Even when these are excluded (Figure 2) our modeling estimates that Choris began 100–500 years prior to previous estimates, indicating an earlier transition to a semi-permanent coastal occupation than previously established. If the earliest Choris dates are valid, these modeled estimates also indicate an earlier evolution from Denbigh to Choris culture than typically understood. Moreover, this temporal overlap suggests the possibility of interaction between Denbigh and Choris groups; at the same time, there is a temporal separation between the Denbigh and Norton, as well as Denbigh and Near Ipiutak phases, suggesting limited interaction between these groups of people, and calling into question any derived relationships. Tremayne and Brown (2017) come to a similar conclusion regarding limited interaction between Denbigh and Norton groups in an analysis of a pan-Alaskan radiocarbon database. When we combine Choris, Norton, and Near Ipiutak dates and model them together, the resulting modeled phase is highly cohesive, with the exception of the early Choris dates from Coffin that form a separate cluster apart from the rest of the phase (Figure 2). This supports the hypothesis that these cultural phases are part of the same tradition or culture and that archaeologists may be inconsistently applying cultural phase names.

Cultural interaction during Late Paleo/Early Ancestral Inuit periods

After about 2000 years ago, there is an increase in the number and size of semi-permanent sites on the coast (Anderson and Freeburg 2014); this increase in coastal occupation is interpreted as growing reliance on marine resources. Evidence from across the Bering Strait and northern Alaska points to occupation of the coasts by multiple groups of people—Ipiutak, Okvik, and Old Bering Sea cultures, with somewhat different but related marine adaptations, technology, subsistence economies, and settlement patterns (Table 1). Modeled chronologies for Old Bering Sea (OBS)/Okvik, Okvik, and Punuk, differ from accepted age ranges (Figure 3; Table 2). The wide range for the Okvik phase is due to the small and dispersed date sample ascribed to the phase ($n = 4$). Our analysis tentatively supports the interpretation of these phases as concurrent and overlapping (Figure 3), while highlighting the need for additional dating before drawing any further conclusions about temporal span or interaction between groups.

The modeled Ipiutak phase is somewhat earlier and much longer than previously accepted with modeled dates from *2131–1918* to *736–600 cal BP* (Figure 4, Table 2), firmly overlapping with the Old Bering Sea, Okvik, and Punuk phase occupations of the Bering Strait Islands and Chukotka Peninsula (Figures 3 and 4). Figure 4 shows that dates from the earliest part of this phase form a disconnected tail from the main part of the phase. Although tempting to write these early dates off as outliers, possibly suffering from "Old-Wood" effects, it should be noted that these early dates are from three different sites, and have no better or worse contextual information than most other dates for

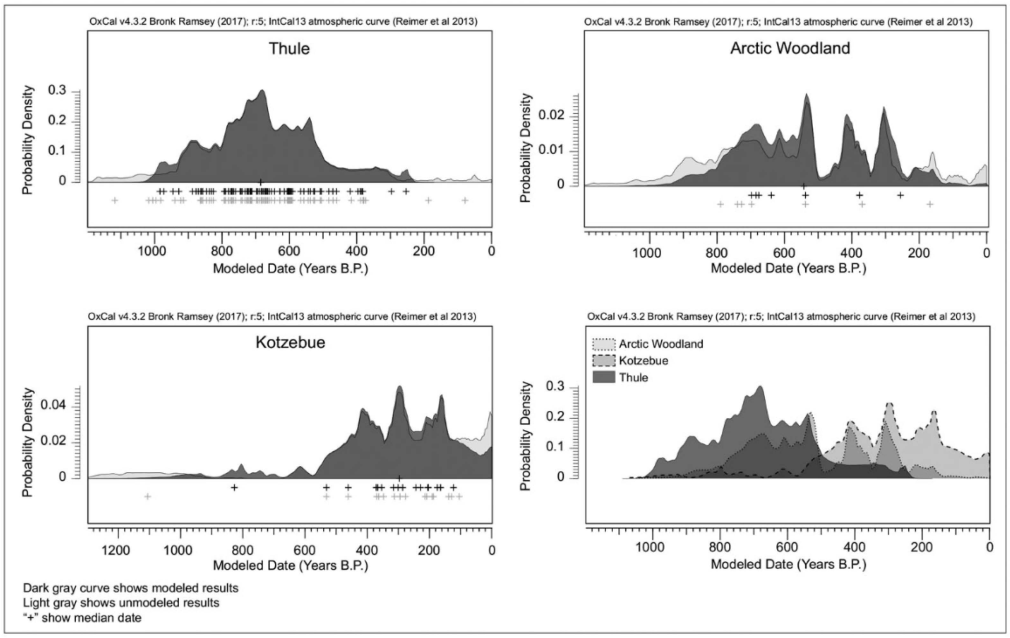

Figure 5. Kotzebue Actic Woodland Thule Composite2. SPDs showing modeled results for Kotzebue, Arctic Woodland, and Thule Phases. (Figure by Johonna Shea).

the Ipuitak phase. Moreover, "old-wood" alone cannot explain their discrepancy as the dataset for most of the entire phase also suffers from Old-Wood effects; it should be noted that our model yields this temporal distribution even with the exclusion of problematic dates from the Dicarb lab (see Mason 2000; Mason and Barber 2003; Gerlach 1989; Reuther and Gerlach 2005). The end of the Ipuitak phase is even more discordant with previous estimates, showing that the phase may have persisted centuries longer than previously thought (Table 3). The Ipiutak occupation is generally accepted to have ended around 1000 cal BP (Mason 2000; Mason 2006), but modeled end dates for the Ipiutak phase extend well into the Thule phase, to around *550 cal BP*. Interestingly, the later Ipiutak dates are from interior northwest Alaskan sites, providing some support for the hypothesis that Ipiutak groups were pushed by Birnirk colonizers to the interior after 1000 cal BP (see Mason 2000).

Following the rise of the Ipuitak phase, Birnirk and Punuk groups emerge in this same region beginning around 1350 cal BP (Tables 1 and 3). However, both Birnirk and Punuk sites are relatively rare and show strong spatial patterning, especially Punuk sites, which are largely restricted to St. Lawrence Island, while Birnirk sites are all located along the coasts of the Bering Strait, Chukchi Sea, and in the Barrow region (Figure 1; Mason 2000). Despite their rarity, both phases play critical roles in theories of culture change in the region (Table 1), e.g. Birnirk culture is widely viewed as the progenitor of later, widespread Ancestral Inuit or Thule culture (Mason 2000).

Though previous estimates of Birnirk fit within the 95% range modeled estimates, the modeled span of the phase is much shorter than anticipated. This short time span indicates a very rapid migration or colonization event by Birnirk people that overlaps with a decline in regional population or a substantial reorganization of occupied sites at the end of the Ipiutak phase around 1000 cal BP (see Figure 4) (Anderson et al. 2019; Mason 2000). This supports the hypothesis (Mason 2009b; Mason and Bowers 2009) that Birnirk peoples were, perhaps, taking advantage of a depopulated landscape and not necessarily competing with Ipiutak people for resources during what may have been a period of resource scarcity (Bockstoce 1973, 1979; Mason 1998, 2000; Mason and Bowers 2009). Below, we address the temporal dynamics of the Birnirk phase in more detail, illustrating how future research using chronological modeling may add clarity to larger debates regarding the emergence and spread of Ancestral Inuit culture.

The modeled span for the Punuk phase is between 750 and 1170 years, from *1682–1413* to *694–437 cal BP*; the modeled age range is approximately 500 years earlier and 250–500 years longer than the generally accepted age range for Punuk (Table 2). Our modeling highlights the uncertainty associated with the dating of the Punuk phase; while the modeled age ranges suggest the potential for sustained interaction between Punuk, Birnirk, and Thule groups, there are too few dates from too few sites (especially Punuk sites) to further assess this possibility. Moreover, Alaskan archaeologists have difficulty identifying Punuk sites, in part because the cultural phase is known best in Chukotka rather than Alaska, where Punuk materials are rare and may represent brief incursions.

Thule migration

The period beginning around 950 cal BP was one of dramatic change across the region. Thule culture developed and spread; new maritime hunting technology and an increased focus on marine resources expanded with the Thule people as they migrated across the North American Arctic from western Alaska to Greenland. Thule people are the direct ancestors of modern Inupiaq groups living across the North American Arctic. Many questions remain about where, exactly, Thule culture developed, and when, why, and how it spread (Friesen and Arnold 2009; McGhee 2009; Mason and Barber 2003; Morrison 2009).

Modeled date ranges for Thule are consistent with previously established dates for the phase. This is likely because of the large sample size ($n = 93$) (Figures 4 and 5). The majority of Kotzebue and Arctic Woodland phase dates are from the last 600 years (Table 3; Figure 5) (see Giddings (1952b) and Schaaf (1988)). The overlapping modeled age ranges suggest inconsistencies in how these phases are identified or differentiated from late Thule sites. These terms, perhaps, need to be better defined and applied, or abandoned for the more general concept of “late Thule phase sites”; the distribution of modeled Arctic Woodland and Kotzebue dates are nearly identical (Figure 5), further suggesting that combining or abandoning terms is reasonable. These are probably the same groups of people.

Summary/discussion

Overall, modeled age estimates greatly exceeded the error in beginning/end estimates typically associated with each phase (Table 3). Though suggesting that the chronology of northwest Alaska phases is problematic is neither novel nor insightful to many working in the

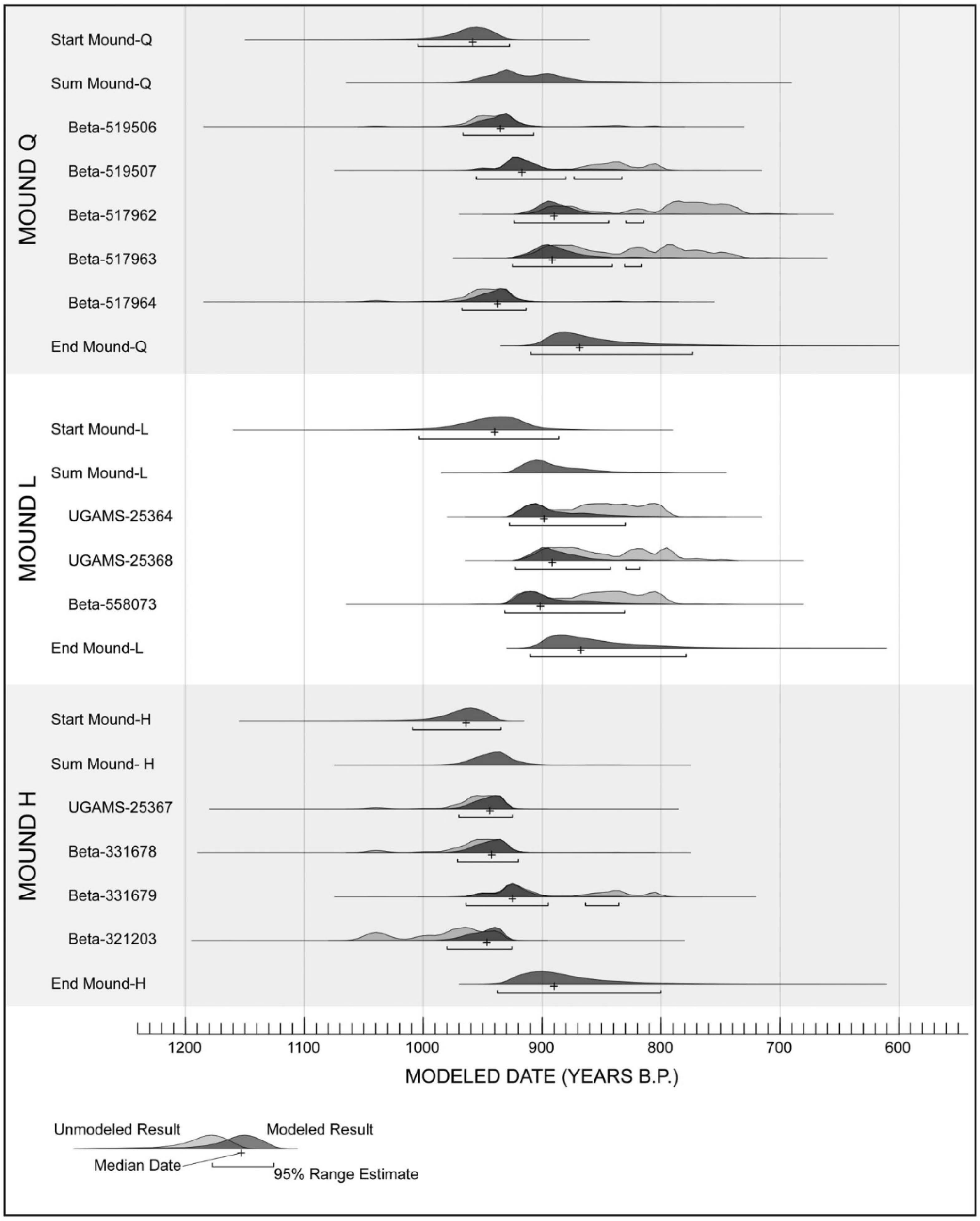

Figure 6. Birnirk Mound Model. Modeling of occupation of Birnirk associated dates from different mound features at BAR-1. (Figure by Johonna Shea).

region, we believe that the above analysis is critical for three key reasons: (1) while widely understood as problematic, this understanding is implicit and has never been systematically quantified or evaluated. Thus, despite widespread agreement of problems, the previous estimates cited above are still routinely used without regard for their associated error; (2) despite acknowledgement of error, our analysis shows that the magnitude of this error has been dramatically under-represented. Lastly, (3) this paper provides the first coherent synthesis of data for these phases in a single place, the previous lack of which has made it difficult to understand how/why phase chronologies were determined and how they compare. While this may be viewed as a pessimistic interpretation of our understanding, we view it as quite the opposite. The error in our understanding of all these phases was always present, just not explicitly represented. As shown below, acknowledging the error explicitly allows us to tactically address problematic aspects of phases using relatively few dates, permitting us to better understand more interesting questions about how groups interacted and the dynamics of migration and culture change.

Regarding critical avenues for future research, there are a couple of recurrent patterns in the distribution of dates associated with each phase that we would like to highlight. The first is that many of the phases lack coherence in their modal distribution of dates. For example, Denbigh, Choris, Near-Ipuitak, Punuk, and Okvik all have what could be called multiple, disconnected nodes of dates across their phase duration. While insufficient sample size can easily explain the cases of Okvik and Near-Ipuitak, this recurrent issue among phases suggests that criteria for phase attribution may need to be systematically addressed in future research. However, given the transcontinental connections and physiographic/environmental difficulties that characterize the region, it may be that these temporal incongruities are historically real, but only insofar as these phases are present within our study area. Thus, our "incongruities" may simply be illustrating incursions and retreats into the region.

Posing similar issues to these modal incongruities is that other key phases (i.e. Thule and Ipuitak) have very strong central tendencies in where the data is clustered but also very long tails at either end of these central clusters. These tails are significant features that need to be better understood in terms of both empirical modeling and theoretical interpretation of interaction because our understanding of cultural interaction would change substantively depending on whether interaction occurred during a phase's peak representation or at the tails of their beginning/ending. Moreover, we could better address questions of whether a rise in one cultural phase is the reason for the decrease in another. Like the modal incongruities mentioned above, these issues must be understood as both spatial and temporal questions.

Regardless of whether these issues are sampling artifacts or historically real trends, they demonstrate why questions of interaction in the region have been difficult to untangle. Indeed, until the tempo of these phases is better understood, it will remain impossible to accurately assess the nature, degree, and quality of cultural interaction and evolution in the region. Below, we focus on the Birnirk phase, using newly acquired radiocarbon dates (Table 2) to provide an example of how modeling efforts focused on multiple scales of interpretation can help resolve some of the issues discussed above.

Bayesian modelling of new Birnirk dates

As discussed in the beginning of this paper, even in places where provenience and association of dates with cultural activities are secure, the high measurement error and reliance on dating large chunks of unidentified wood-charcoal prone to "old-wood" puts substantial limitations on the precision of modeled estimates for the beginning, ending, and span of a phase. Moreover, because many sites are represented by three or fewer dates, it is difficult

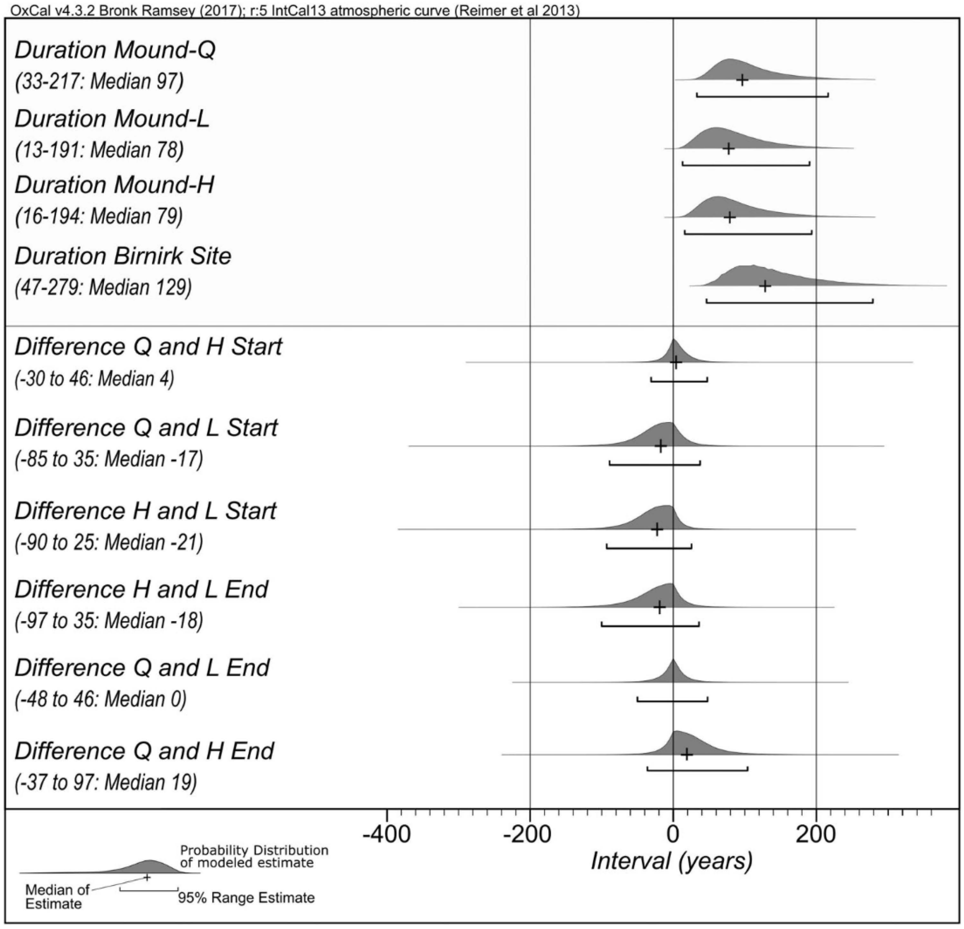

Figure 7. Duration and span. Duration and Difference Estimates for Birnirk Site. Numbers in parentheses are the numeric 95% range estimates and the median estimates depicted on the probability distributions on the right of the graphic. Negative values denote the number of years one event happened prior to another, while positive numbers indicate an event came after another.

to reconcile whether differences in timing among sites and/or features is due to old-wood, sampling error, or simply because a date is an outlier. This hinders attempts to analyze the tempo of movement and occupation across the landscape or within a phase. However, while these issues likely prohibit us for the time being from being able to effectively solve chronological problems for any given phase, modeling efforts can still provide considerable insight. For example, our modeling of recently assayed Birnirk dates from the Birnirk site, BAR-001, sheds some light on existing understanding of the timing and duration of this transitional phase (Supplemental Figure 4).

Note that almost all the youngest dates in the model are the dates assayed most recently, and that the majority of these come from a single site (BAR-1) (Figure 6 also see Supplemental Figure 4). This suggests several possibilities:

(1) These results may indicate that while acknowledged by researchers in the region, the old-wood effect has been underestimated, and in combination with high-

measurement error, has resulted in the duration of the Birnirk phase being substantially overestimated. This is also consistent with the modeled results (Supplemental Figure 4), estimating that Birnirk may have lasted for as little as 350 years, almost half the duration previously estimated (Table 3)

(2) Alternatively, the short duration and late dates from BAR-1 may represent one of the terminal occupations associated with the Birnirk phase.

(3) Lastly, these results show that there is potentially little overlap in occupation among the sites sampled. Thus, the Birnirk phase may be characterized by a series of non-coincident occupations across a landscape, perhaps more consistent with the migration of small, unified, or extended family groups, rather than a colonization attempt.

This last point is further attested to when we model the occupation at the Birnirk site using the newest dates, which are largely derived from house floors/mounds (Figure 6). In this model, we estimated the occupation of just the Birnirk site, as opposed to the whole phase. We then treated each house/mound occupation as sub-phase, allowing us to generate estimates for the beginning, end, and span for the site as a whole and for each house (Figure 6).

Results of the model show that occupation of the site began between *∼1000–940 cal BP* and ended between approximately *900 and 750 cal BP*. This suggests occupation at the site may have been quite short lived (Figures 6 and 7). The estimates for the duration of each house range from less than a generation to at most two centuries, with the median estimate for each house ranging from a 93–30-year occupation. To further clarify occupation dynamics at this site, we used the "difference" and "order" commands in OxCal. The difference command measures the difference in timing between two dates/estimates (i.e. end of occupation at two mounds/houses), while the order command returns the likelihood that one event preceded another. Using these two commands, we evaluated the temporal difference among each mound's estimated start and end to assess their relative contemporaneity.

Figure 7 shows the 95% range and median estimate for each. Negative values denote the number of years one event happened prior to another, while positive numbers indicate an event that came after another. Thus, "Difference Q and H Start" should be read as House/Mound-Q began sometime between 30 years prior and 46 years after the start of House/Mound H. As shown in Figure 7, the estimates between each of the houses have negative and positive values in the 95% range, meaning that the estimates for the start/end of each house overlap in time. Therefore, it is likely that each of the houses were being occupied simultaneously and were abandoned at roughly the same time. As alluded to above, this suggests an intense but short-lived occupation, which, as discussed above, may be indicative of Birnirk occupations in general; they were short lived, intense, and non-repeating. Results from the order command are also consistent with this depiction, though they suggest that Mound-H may have been occupied first and that Mound-Q was likely the last to be abandoned (see Supplemental Table 4 for more details).

The major caveat with this analysis is that it is being interpretively driven by new dates from a single site, which may not be representative of the phase in general since it may be one of the very terminal settlements of Birnirk. Therefore, even a small number of dates from other sites could dramatically change this interpretation. However, we hope that this analysis demonstrates the possibilities of what can be done to address specific questions regarding the spatio-temporal dynamics of phases and their constituent demographic, organizational and settlement patterns at scales unattainable to previous researchers in the region. Moreover, the CQL code for this analysis (see supplemental materials) can effectively be copied as is to repeat similar analysis for a variety of other questions. For example, the speed of migrations across the landscape could be modeled by replacing the Mound phases with sites from the same phase, from different parts of the landscape; or replacing the mound dates with data from late Ipuitak and early Thule sites, indicating the tempo at which Thule replaced Ipuitak across the landscape. Following our analysis here, Thule sites/dates could also be used to determine whether the Thule migration occurred as a single wave or as a series of leapfrogged colonizations.

Conclusions: The potential of Bayesian analysis to address questions of migration and interaction

As stated in the beginning of the paper, this analysis is not claiming to solve the problems associated with the timing of culture phases within northern Alaska. Our goal was to synthesize available data to better understand what we do know about the beginning, end, and span of each phase. As others have made clear (Denaire et al. 2017; Burley et al. 2015; Whittle et al. 2008), Bayesian chronological models provide us with the analytically sound and standardized framework necessary for the productive comparison of chronological estimates. Additionally, we used SPDs in combination with these models to aid visually comparing internal dynamics among phases and in identifying interesting and potentially problematic chronological patterns within each phase. However, we emphasize again that the preceding synthesis and analysis is a first step toward this goal. As mentioned above, this synthesis and analysis allows us to systematically compare and understand patterning in the actual empirical ^{14}C record for each phase. Thus, given the chronological problems and inconsistencies identified in this and previous studies, our modeled results should be viewed as descriptive more than a necessarily accurate account of history. The models help generate hypotheses and empirical patterns that require further investigation.

We argue that the combined use of SPDs and Bayesian chronological models, at multiple scales, is critical because questions of cultural interaction, transition, and evolution are not adequately addressed by simply comparing the beginning and ending of different culture phases. These questions require precise and nuanced understanding of a phase's internal chronological tempo, i.e. did the phase appear and spread quickly, slowly rise and fade as it was replaced by another phase? Did the phase follow a typical battleship curve, with a typical rise, florescence and decline in prevalence, or did it end abruptly, at the height of its prevalence following a catastrophe? These same questions must also be addressed for a phase's spatial distribution (e.g. was the time-span of a phase uniform across space, or did one region see a decline in prevalence as others saw an increase?). Doing so would also permit us to use more customized model parameters and priors (e.g. Sigma, Trapezoidal, or Ramped) to address questions of interaction and evolution in even more nuanced and accurate ways. Until these questions are more explicitly explored using a rigorous and standardized analytical framework, progress in understanding northern Alaskan mid-late Holocene culture change and interaction will be difficult to attain. Although it is beyond the scope of this paper to fully address these questions for a particular phase, we provide a more focused analysis of the "Birnirk" phase. Although preliminary, this analysis allows us to illustrate how exploration of a phase's internal dynamics and use of additional modeling in future research can be used to add substantive clarity and complex understanding of history and are of paramount importance in northwest Alaskan and Arctic archaeology, given its unique history as a crossroads between continents and cultural influences.

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