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Stable isotope chemistry, population histories and Late Prehistoric subsistence change in the Aleutian Islands

David A. Byers [a,*], David R. Yesner [b], Jack M. Broughton [c], Joan Brenner Coltrain [c]

[a] Department of Sociology, Anthropology and Criminology, Missouri State University, Springfield, MO 65897, USA
[b] Department of Anthropology, University of Alaska Anchorage, 3211 Providence Drive, Anchorage, AK 99508, USA
[c] Department of Anthropology, University of Utah, Salt Lake City, UT 84112, USA

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ABSTRACT

Aleut population history has been a topic of debate since the earliest archaeological investigations in the region. In this paper, we use stable isotope chemistry to evaluate the hypothesis that two distinct groups of people, Paleo- and Neo-Aleut, occupied the eastern Aleutians after 1000 BP. This study focuses on 80 sets of directly dated eastern Aleutian burial assemblages from Chaluka midden, Shiprock Island and Kagamil Island. We use a linear mixing model informed by isotopic analysis of two large Aleut faunal assemblages to address temporal and spatial variation in human carbon and nitrogen stable isotope data from these sites. The patterning we report addresses both Aleut demographic and economic prehistory, illustrating a transition in both at ca. 1000 BP. Our results suggests that the Chaluka diet, dominated by Paleo-Aleut inhumations, differed in both trophic level and foraging location from the other two sites for much of the past 4000 years. Trends in our data also suggest that individuals from Shiprock and Kagamil burial caves, primarily Neo-Aleuts, had enough access to higher trophic level foods to differentiate their bone chemistries from those buried in Chaluka midden. These trends in diet, recently reported genetic differences, as well as the introduction of novel mortuary practices at ca. 1000 BP, suggest that Neo-Aleuts do represent a population new to the eastern Aleutians.

1. Introduction

The Aleutian Islands contain a rich prehistoric record reaching back at least 8000 years that includes not only evidence of ancient material culture and subsistence, but also a remarkable number of well-preserved sets of human remains. Moreover, these data have allowed for comprehensive reconstructions of the local culture history, as well as functional aspects of lifeways practiced by prehistoric Aleut foragers (e.g. Dumond, 2001; Dumond and Bland, 1995; Frohlich et al., 2002; Lefèvre et al., 1997; McCartney, 1984; McCartney and Veltre, 1999; Spaulding, 1953). While a maritime adaptation to plentiful local resources has always characterized the region, the local population history has been a topic of debate since the earliest archaeological investigations in the region (Aigner, 1976; Bank, 1953; Hrdlicka, 1945; Laughlin, 1975, 1980; Laughlin and Marsh, 1951). This discussion derives largely from the observation that while eastern Aleut material culture appears to represent long-term continuity in lifeways over at least the last 4000 years, skeletal morphologies suggest that two distinct groups of people occupied the region after 1000 BP. To further understand this aspect of Aleut prehistory, we use a linear mixing model informed by isotopic analysis of two large Aleut faunal assemblages to address temporal and spatial variation in carbon and nitrogen stable isotope data from three, directly dated eastern Aleutian burial assemblages (Coltrain, in press; Coltrain et al., 2006). The patterning we report addresses both Aleut demographic and economic prehistory, illustrating a transition in both at ca. 1000 BP.

Central to this study is a large and well-preserved collection of human remains obtained from the eastern Aleutians during the late 19th and early 20th centuries (Fig. 1). This sample of skeletal material was collected from burial caves on Shiprock and Kagamil Islands, as well as from subsurface archaeological contexts in nearby Chaluka midden, located on Umnak Island (Hrdlicka, 1945). These human remains would later form the collection analyzed by Hrdlicka (1945) and provide the data for his craniometric assessment of the local population history.

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* Corresponding author.
E-mail addresses: dbyers@missouristate.edu (D.A. Byers), afdry@uaa.alaska.edu (D.R. Yesner), jack.broughton@anthro.utah.edu (J.M. Broughton), joan.coltrain@anthro.utah.edu (J.B. Coltrain).

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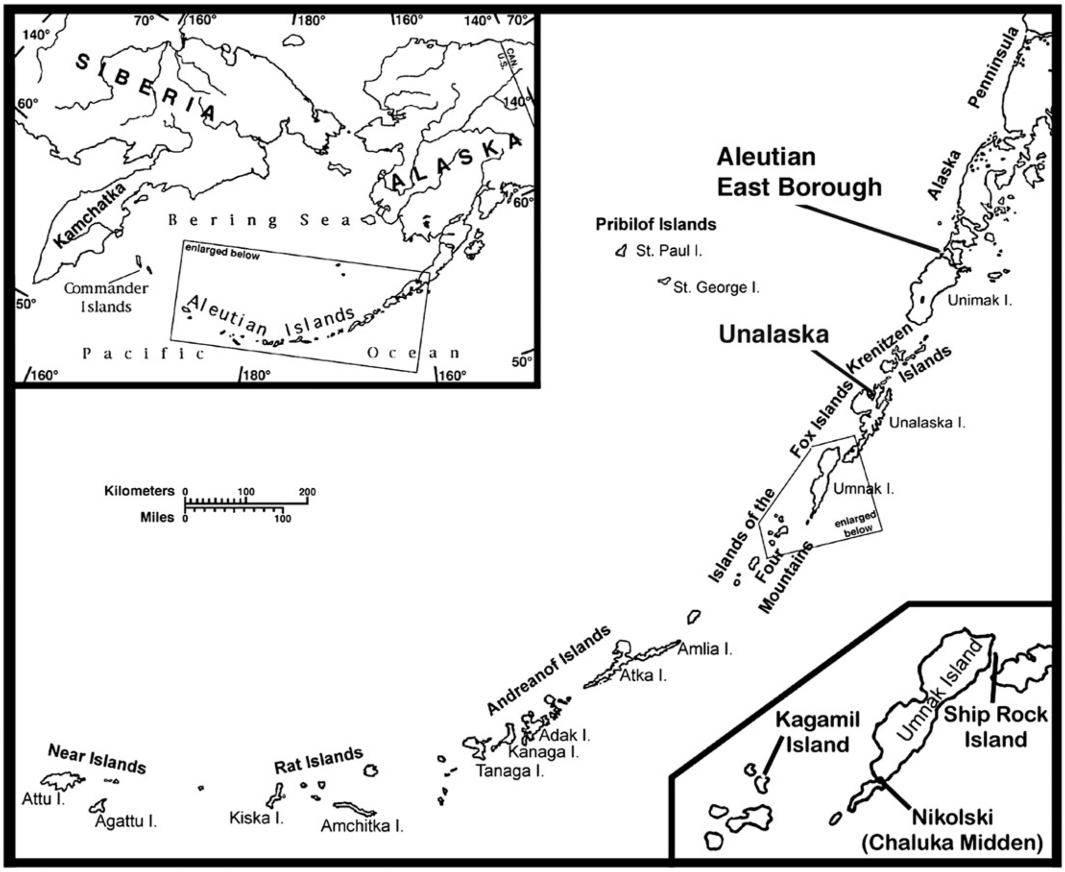

Fig. 1. Map of study area and geographic location of Aleut skeletal samples (modified from Fitzhugh and Chaussonnet (1994) and Keenleyside (1994)).

Hrdlicka based his analysis on biometric comparisons of skeletal remains and focused largely on understanding the origins of Aleut living on the islands at the time of European contact and their potential relationships with other human groups in both the Arctic and Asia. He identified two Aleut populations based primarily on cranial morphology: pre-Aleut and Aleut (Hrdlicka, 1945), more recently renamed Paleo-Aleut and Neo-Aleut (Laughlin and Marsh, 1951). We use this more recent terminology in the following discussion. Hrdlicka argued that high-vaulted, oblong, dolichocranic crania and relatively gracile postcranial skeletons characterized the Paleo-Aleut, whose remains were most common at Chaluka midden. In contrast, the Neo-Aleut possessed low-vaulted wider, rounder brachycranic crania, a configuration most common in remains from Kagamil and Shiprock burial caves as well as among some extant Aleut.

Based on the stratigraphic relationship between burials of the two groups at Chaluka midden, Hrdlicka (1945) suggested that Neo-Aleuts replaced Paleo-Aleuts approximately 1000 years ago, likely migrating into the area from the Alaskan Peninsula. Unfortunately, at Chaluka midden, human remains were not closely tied to the vertical provenance of items of material culture, making any attempts to connect craniomentric populations with observed changes in artifact or faunal assemblages difficult at best. Today indigenous peoples of the eastern Aleutians tend to exhibit more brachycranic traits while those in the central and western islands posses are more likely to be dolichocranic.

Where Hrdlicka argues for two different populations, others see only one (Coltrain et al., 2006). Based largely on early dates from the Anagula blade site in combination with apparent continuity in a range of artifacts types, Laughlin (1975) and others (Aigner, 1976) contended that a single population occupied the Aleutians until Russian contact. The apparent contradiction to Hrdlicka's craniometric study was resolved by arguing that Neo-Aleut brachycranic morphology was the product of genetic drift, not population replacement. The brachycranic form appeared at ca. 1000 BP in a growing, eastern Aleut population, whereas western Aleut groups remained small in number and dolichocranic in form (Laughlin, 1975).

Given the spatial trend in cranial configuration among extant Aleuts, our skeletal sample is well positioned to address these arguments. In Coltrain et al. (2006) and Coltrain (in press), Hrdlicka's population replacement hypothesis is clearly refuted. The authors demonstrate that Paleo-Aleut burials are present from ca. 4000 BP until Russian contact; whereas Neo-Aleuts appeared at ca. 1000 BP in the three eastern Aleutian sites under study and co-existed with, rather than replaced, Paleo-Aleuts until Russian contact. However, shifts in diet discussed below, recently reported genetic differences (Smith et al., 2009), as well as the introduction of new mortuary practices at ca. 1000 BP, suggest that Neo-Aleuts do represent a population new to the eastern Aleutians, calling the "genetic drift" argument into question as well.

Here we use stable isotope bone chemistry to explore these issues. First, if as the craniometric data suggest, there are genetically based, morphological differences between Paleo- and Neo-Aleut groups, are these reflected in dietary bone chemistry? This might be so, if the Neo-Aleut craniometric configuration represents an influx of people from areas such as Kodiak Island or other regions to the east known for complex hunting and gathering societies (Clark, 1984; Fitzhugh, 2003). Second, if differences in bone chemistry do exist, what do they reveal about temporal and socially mediated variation in subsistence?

2. Dataset

2.1. Human remains

To address the questions posed above, we generated two datasets from Aleut skeletal material. The human component of our study includes 80 adult remains from three sites studied by Hrdlicka (1945) (see also Coltrain, in press; Coltrain et al., 2006). We note that this sample represents only a portion of the 425 burials recovered collectively from these sites (Hunt, 2002) and includes 32 individuals from Chaluka midden, 32 individuals from Kagamil and 16 individuals from Shiprock burial caves (Table 1). Hrdlicka classified 39 of these individuals as Neo-Aleut and assigned the other 41 to the Paleo-Aleut group. Finally, the sample contains 36 females and 44 males.

Paleo-Aleut and Neo-Aleut remains were subject to strikingly different mortuary practices and display a pattern of differential distribution both in time and in space within the study area. The majority of Paleo-Aleut remains under study (30 of 41) were recovered from Chaluka midden as inhumations with few grave goods; nine Paleo-Aleuts were recovered from Shiprock and two are from the Kagamil burial cave assemblage, both burial cave sets included mummified remains with elaborate suites of grave goods. In contrast, thirty Neo-Aleut individuals were recovered from Kagamil and seven from Shiprock as mummified remains, whereas merely two were interred as inhumations in Chaluka midden.

Neo-Aleut burials range in age from cal. 816 to 386 BP, while Paleo-Aleuts range from cal. 3434 to 407 BP (Fig. 2; see also Coltrain et al., 2006). Viewed by site, only Chaluka Midden produced remains older than 1000 BP, with dates ranging from cal. 3434 to 393 BP. In contrast mummified remains from the burial caves all post-date 1000 BP regardless of whether they are Neo- or Paleo-Aleut, with the dates on human remains from Shiprock ranging from cal. 839 to 488 BP and those from Kagamil range from cal. 916 to 386 BP. In sum, while Paleo-Aleuts were found at all three locations and span the entire occupation of the study area, their remains dominated the human sample from Chaluka midden as inhumations. Conversely, Neo-Aleut remains date exclusively to post-1000 BP and with merely two exceptions recovered from Chaluka midden, originated as mummified remains from Kagamil and Shiprock burial caves.

2.2. Faunal material

To refine previous treatments of Aleut diet (Coltrain, in press; Coltrain et al., 2006), we report stable isotope data from two associated faunal assemblages, one from Amaknak Bridge and the other from Chaluka midden. Recent excavations at the Amaknak Bridge site (Knech and Davis, 2001; Knech et al., 2008), a large midden deposit located on the northern coast of Unalaska Island, produced an extensive faunal assemblage containing a broad range of food animals including cetacean, pinniped, and fishes, in addition to shell and urchin remains (Crockford et al., 2004). A series of 11 radiocarbon dates on wood charcoal placed occupation of the site between ~2570 and 3585 BP. We sampled 51 specimens from this assemblage (Table 2). Fishes sampled include Irish lord (*Hemilepidotus hemilepidotus*), greeling (*Hexagrammos* sp.), halibut (*Hippoglossus stenolepis*), Pacific cod (*Gadus macrocephalus*), and salmon (*Oncorhynchus* sp.). The mammalian fauna from Amaknak Bridge include porpoise (*Phocoena phocoena*), unidentified cetacean, sea otter (*Enhydra lutris*), bearded seal (*Erignathus barbatus*), harbor seal (*Phoca vitulina*), ringed seal (*Phoca hispida*), and fur seal (*Callorhinus ursinus*).

Chaluka midden contained a dense cultural deposit that also produced a similarly broad assemblage of food animals. Hrdlicka (1945) excavated the site in 1937 and 1938 and during the late 1940s Laughlin and Marsh (1951) conducted additional investigations. While the human remains documented in this paper derive from Hrdlicka's excavations, Chaluka fauna come instead from Laughlin's later collections. Dates on the Chaluka midden human material provide temporal control for the site and document an occupation lasting from ~3400 BP to ~400 BP (Coltrain et al., 2006). Unfortunately, the level of documentation associated with this faunal assemblage lacks sufficient information to link any portion of the sample directly to any dated human remains. Among the 75 specimens sampled from Chaluka midden (Table 2), fishes include Irish lord (*H. hemilepidotus*), halibut (*H. stenolepis*) and Pacific cod (*G. macrocephalus*). We also sampled a suite of mammalian taxa and these include unidentified canid (*Canis* sp.), fox (*Vulpes vulpes*), porpoise (*P. phocoena*), unidentified cetacean, sea otter (*E. lutris*), harbor seal (*P. vitulina*), fur seal (*C. ursinus*) and Stellar sea lion (*Eumetopias jubatus*).

3. Methods

3.1. Stable carbon isotopes

Stable carbon isotope ratios have been used in a number of ways to understand the terrestrial and marine diets of both human and non-human foragers. Within the context of marine environments, archeologists have used stable carbon isotope analysis to reconstruct the relative contributions of terrestrial versus marine resources to mixed human diets (e.g., Coltrain, 2009; Coltrain et al., 2004; Lovell et al., 1986; McGovern-Wilson and Quinn, 1996 [but see Ambrose et al., 1997]; Parkington, 1988, 1991; Richards and Hedges, 1999; Sealy, 1986; Sealy and van der Merwe, 1985, 1986, 1988; Walker and DeNiro, 1986). This method has also been used to track migration and foraging patterns of several Arctic species including bowhead whale, anadromous fish, migratory waterfowl and pinnipeds (e.g., Bunn et al., 1989; Burton and Koch, 1999; Caraveo-Patiño et al., 2007; Dehn et al., 2007; Hobson, 1987; Hobson and Welch, 1995; Kling et al., 1992; Tamelander et al., 2006; Wada et al., 1991). In the case of human foragers subsisting on marine resources, stable carbon isotope values can also covary with foraging environment. Spatial differences in ocean upwelling differentially condition the $\delta^{13}C$ signals of near-shore and open-water ecosystems, resulting in near-shore values enriched by as much as 2‰ relative to those of open-water resources (Burton and Koch, 1999). Our research makes use of the latter observation to monitor the contribution of marine resources from near-shore versus open-water environments to the diets of Aleut foragers.

3.2. Stable nitrogen isotopes

Our research also focuses on identifying trophic level differences in past Aleut diets. Among the study population, isotopic source values all derive from organisms living in marine ecosystems where phytoplankton are primary producers and exhibit nitrogen isotope ratios in the 4–8‰ range with a mean of approximately 6‰ (Dunton et al., 1989; Hobson, 1993; Hobson and Welch, 1992). Variation in stable nitrogen isotope chemistry at the base of the food web is passed up through successive trophic levels, with 3–4‰ enrichment at each trophic level. These data allow the comparison of $\delta^{15}N$ values derived from human samples to address the procurement of prey taxa differentially positioned in the local

Table 1
Human remains and associated isotopic and chronological data.

Site	Craniometric group	Sex	Curation number	δ^{13}C	δ^{15}N	Radiocarbon age BP	σ	Cal age BP	Cal 2σ range BP
Chaluka	*Neo-Aleut*	Female	378606	−11.9	20.2	962	48	393	284–498
Chaluka	*Paleo-Aleut*	Female	378613	−12.3	19.3	977	38	407	298–499
Chaluka	*Paleo-Aleut*	Female	378619	−12.1	19.4	1268	82	629	487–795
Chaluka	*Paleo-Aleut*	Male	378610	−12.3	19.9	1306	53	658	535–780
Chaluka	*Paleo-Aleut*	Female	378663	−12.0	19.0	1335	43	683	554–799
Chaluka	*Paleo-Aleut*	Male	378607	−11.4	19.8	1343	59	692	551–846
Chaluka	*Paleo-Aleut*	Male	378615	−11.9	18.3	1351	48	698	564–835
Chaluka	*Paleo-Aleut*	Male	378620	−12.5	19.1	1348	82	702	544–886
Chaluka	*Paleo-Aleut*	Male	378612	−11.3	20.0	1363	95	718	542–909
Chaluka	*Paleo-Aleut*	Male	378609	−11.6	20.1	1392	39	732	641–872
Chaluka	*Paleo-Aleut*	Female	378608	−12.0	19.4	1404	62	749	631–907
Chaluka	*Paleo-Aleut*	Male	378603	−12.1	19.6	1441	65	783	650–924
Chaluka	*Neo-Aleut*	Male	378611	−12.2	19.1	1479	42	816	687–927
Chaluka	*Paleo-Aleut*	Male	378605	−12.2	19.5	1485	44	821	688–933
Chaluka	*Paleo-Aleut*	Male	378629	−12.5	17.6	1536	32	868	737–972
Chaluka	*Paleo-Aleut*	Female	378601	−12.4	19.3	1566	52	900	744–1047
Chaluka	*Paleo-Aleut*	Female	378604	−11.9	19.3	1573	44	908	763–1046
Chaluka	*Paleo-Aleut*	Male	378622	−12.0	18.7	1830	84	1170	962–1340
Chaluka	*Paleo-Aleut*	Female	378623	−12.0	19.3	1918	43	1261	1134–1387
Chaluka	*Paleo-Aleut*	Male	378602	−11.9	19.2	1944	37	1285	1170–1399
Chaluka	*Paleo-Aleut*	Male	378633	−11.9	19.0	2025	44	1362	1257–1504
Chaluka	*Paleo-Aleut*	Male	378627	−12.0	19.8	2042	44	1378	1268–1513
Chaluka	*Paleo-Aleut*	Female	378639	−12.6	18.8	2044	44	1380	1270–1514
Chaluka	*Paleo-Aleut*	Female	378621	−12.9	18.5	2044	84	1388	1202–1597
Chaluka	*Paleo-Aleut*	Female	378616	−12.0	19.3	2124	67	1462	1292–1643
Chaluka	*Paleo-Aleut*	Female	378646	−12.9	18.0	2179	44	1524	1377–1686
Chaluka	*Paleo-Aleut*	Male	378614	−12.1	19.7	2805	54	2258	2082–2449
Chaluka	*Paleo-Aleut*	Female	378628	−12.4	18.3	2838	48	2305	2120–2486
Chaluka	*Paleo-Aleut*	Male	378624	−13.1	19.3	3708	57	3380	3206–3557
Chaluka	*Paleo-Aleut*	Male	378625	−13.1	20.1	3722	88	3396	3150–3635
Chaluka	*Paleo-Aleut*	Male	378626	−13.2	19.5	3754	54	3431	3267–3604
Chaluka	*Paleo-Aleut*	Female	378630	−13.6	19.4	3758	42	3434	3301–3594
Kagamil	*Neo-Aleut*	Female	17485	−12.9	19.0	952	41	386	283–487
Kagamil	*Neo-Aleut*	Female	377810	−12.8	20.5	1026	50	449	308–538
Kagamil	*Neo-Aleut*	Female	377815	−12.8	20.0	1056	40	476	330–556
Kagamil	*Neo-Aleut*	Male	377919	−11.9	20.4	1059	40	479	330–560
Kagamil	*Neo-Aleut*	Female	377920	−12.3	19.6	1070	40	487	365–603
Kagamil	*Neo-Aleut*	Female	377918	−12.4	20.1	1088	41	500	403–620
Kagamil	*Neo-Aleut*	Female	377911	−12.2	21.5	1104	41	512	425–622
Kagamil	*Neo-Aleut*	Male	377817	−12.5	21.2	1106	41	514	427–623
Kagamil	*Neo-Aleut*	Female	377811	−12.2	19.8	1111	42	518	431–625
Kagamil	*Neo-Aleut*	Female	377914	−12.5	21.2	1116	41	521	437–626
Kagamil	*Neo-Aleut*	Male	377916	−12.4	21.0	1162	41	557	476–645
Kagamil	*Neo-Aleut*	Female	377818	−12.5	20.8	1170	43	562	479–649
Kagamil	*Neo-Aleut*	Male	377813	−13.1	20.3	1182	41	571	489–653
Kagamil	*Neo-Aleut*	Male	377917	−12.9	19.5	1182	45	571	485–655
Kagamil	*Neo-Aleut*	Male	377812	−13.0	20.1	1185	42	572	490–655
Kagamil	*Neo-Aleut*	Male	377906	−13.0	21.0	1193	41	577	495–658
Kagamil	*Paleo-Aleut*	Female	377915	−13.2	20.5	1200	41	581	498–661
Kagamil	*Neo-Aleut*	Male	377901	−12.9	20.5	1206	51	585	491–675
Kagamil	*Neo-Aleut*	Male	377902	−12.8	20.1	1214	58	589	488–692
Kagamil	*Neo-Aleut*	Female	377808	−12.7	20.4	1216	32	590	511–662
Kagamil	*Neo-Aleut*	Female	377814	−13.0	20.3	1227	45	596	507–684
Kagamil	*Neo-Aleut*	Male	377816	−13.1	20.0	1228	43	596	508–682
Kagamil	*Neo-Aleut*	Male	377903	−12.6	20.4	1234	54	601	503–704
Kagamil	*Neo-Aleut*	Male	377910	−12.9	20.7	1247	41	609	518–697
Kagamil	*Neo-Aleut*	Female	377821	−12.9	20.7	1257	43	616	521–710
Kagamil	*Neo-Aleut*	Male	17459	−13.1	19.7	1255	62	616	505–736
Kagamil	*Neo-Aleut*	Female	377904	−12.9	20.0	1266	52	624	518–730
Kagamil	*Neo-Aleut*	Female	377809	−13.0	20.2	1292	34	645	543–734
Kagamil	*Neo-Aleut*	Male	377807	−12.9	20.4	1331	45	679	550–796
Kagamil	*Neo-Aleut*	Male	377900	−13.0	21.1	1353	43	699	573–832
Kagamil	*Neo-Aleut*	Female	377819	−13.0	20.0	1401	42	741	645–881
Kagamil	*Paleo-Aleut*	Male	377913	−12.6	19.5	1580	52	916	752–1060
Shiprock	*Neo-Aleut*	Male	378462	−12.1	21.2	1071	39	488	370–604
Shiprock	*Neo-Aleut*	Male	378472	−11.9	21.9	1237	41	602	513–687
Shiprock	*Paleo-Aleut*	Male	378543	−11.6	21.7	1263	44	621	524–717
Shiprock	*Paleo-Aleut*	Female	378542	−12.4	19.8	1335	44	683	553–801
Shiprock	*Neo-Aleut*	Male	378461	−12.6	20.2	1336	59	686	545–836
Shiprock	*Paleo-Aleut*	Male	378474	−11.8	21.5	1361	45	706	604–868
Shiprock	*Neo-Aleut*	Male	378464	−13.7	17.9	1372	39	714	623–859
Shiprock	*Paleo-Aleut*	Female	378467	−12.0	20.7	1400	44	740	644–883
Shiprock	*Paleo-Aleut*	Male	378544	−12.2	21.2	1410	41	749	651–884

Table 1 (*continued*)

Site	Craniometric group	Sex	Curation number	δ^{13}C	δ^{15}N	Radiocarbon age BP	σ	Cal age BP	Cal 2σ range BP
Shiprock	*Neo-Aleut*	Male	378469	−12.2	20.8	1410	39	749	652–882
Shiprock	*Paleo-Aleut*	Female	378468	−12.2	20.7	1420	37	758	658–887
Shiprock	*Paleo-Aleut*	Male	378463	−12.8	19.6	1434	42	773	663–899
Shiprock	*Neo-Aleut*	Male	378471	−12.4	20.0	1446	44	785	669–907
Shiprock	*Neo-Aleut*	Female	378541	−12.9	19.6	1457	41	795	676–911
Shiprock	*Paleo-Aleut*	Female	378470	−12.5	19.9	1506	56	838	685–967
Shiprock	*Paleo-Aleut*	Female	378473	−12.6	19.7	1506	42	839	705–953

food web and we use them here to understand both temporal and spatial trends in Aleut diets.

3.3. Laboratory protocol

Protocols for collagen extraction and purification of human remains are reported in Coltrain (in press). All wet chemistry was conducted at the University of Utah Department of Anthropology Archaeological Center Research Facility (ACRF) and spectrographic analysis was conducted in the University of Utah Stable Isotope Facility for Environmental Research (SIRFER). Faunal protocols are in keeping with the collagen extraction of the human remains and the lab procedure included the following. Approximately 1 g of cortical bone was demineralized whole. In cases where sample weight exceeded 1 g, a subsample of the desired weight was taken with a cut-off wheel chucked in a Dremel tool. Wheels were replaced and the tool was cleaned between each sample to avoid cross-sample contamination. Whole bone samples were demineralized in 0.6 N HCl and ddH_2O at 4 °C with the supernatant decanted and replaced daily until a density gradient was no longer visible. This protocol produces a collagen pseudomorph, which allows the close monitoring of preservation through visible changes in the structural integrity of the specimen and is complete when the supernatant is free of calcium phosphate. Archaeological samples typically require 4–10 days to demineralize. Collagen pseudomorphs were then rinsed to neutrality and treated with 5% KOH to remove organic contaminants. Much like the HCl treatment, the base extraction was decanted and replaced until the supernatant was clear, typically requiring 2–3 days for completion. The collagen pseudomorph was then lyophilized and weighed to obtain an initial yield. Samples were gelatinized in 5 ml of degassed water (pH 3) for 24 h at 120 °C. After gelatinization, water-soluble and -insoluble phases were separated by filtration and the water-soluble phase was lyophilized and weighed to obtain a final collagen yield.

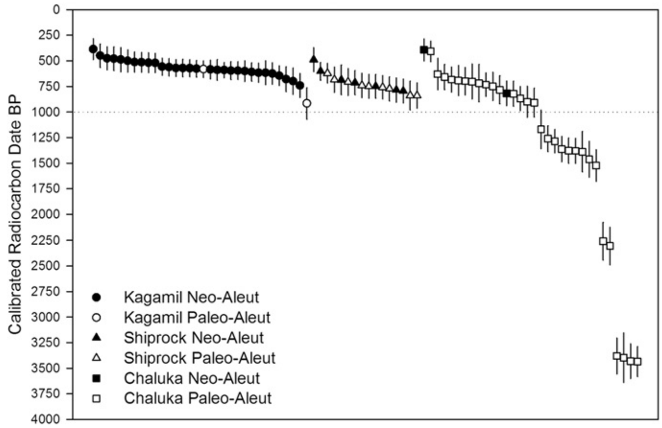

Fig. 2. Distribution of calibrated Aleut radiocarbon dates for at two sigma plotted by archaeological site and craniometric group.

δ^{13}C and δ^{15}N values were determined on acid and base extracted bone collagen by flash combustion to produce CO_2 and N_2. These gasses were then measured against the appropriate reference samples on a Finnigan Delta Plus mass spectrometer with Carlo Erba EA118 CHN interface. Stable isotope measurements and weight percent C and N values, used to assess preservation, were obtained from a single sample combustion. Analytical precision is ±0.1‰ for carbon and ±0.2‰ for nitrogen. All C:N Ratios for the analyzed materials fell between 3.1–3.4, fully within the range for well-preserved bone collagen (2.9–3.6) (Ambrose, 1990).

4. Results

4.1. Human isotope data

We first review and expand on results from analysis of human remains initially reported in Coltrain et al. (2006) and Coltrain (in press). Before continuing with our analysis, we speak to the scale of differences discussed in the paragraphs that follow. We recognize that in many cases small, but statistically significant differences separate our analytical groups. While such small differences might be attributed to variability inherent within individual levels of the food web supporting Aleut foragers, several points suggest otherwise. All of the human remains within our sample derive from individuals acting as apex predators subsisting largely on high-trophic level prey within a complex marine food web. Subsequently, any variation between individual prey of the same species or between different species at the same trophic level is averaged over a forager's lifetime and should result in similar values across a group of individuals, if all end consumers selected the same suite of prey in similar proportions. This last point allows us to leverage meaning from the data presented below. Since the isotopic values of a given Aleut represent an average of foods eaten over a lifetime, the differences between groups of individuals discussed here should document long-term differences in the proportional selection of prey types by those groups in the past.

We begin by evaluating our results within the context of Hrdlicka's two craniometric groups without regard to recovery site or age (Fig. 3, Table 3). The Neo-Aleut ($n = 39$) and Paleo-Aleut ($n = 41$) samples produced mean δ^{13}C values of -12.7 ± 0.4‰ and -12.3 ± 0.5‰ respectively, and differed significantly from one another ($t = -3.623$, $p = 0.001$), with Paleo-Aleut mean values enriched by 0.4‰. Neo-Aleut and Paleo-Aleut samples produced δ^{15}N values of 20.3 ± 0.7‰ and 19.5 ± 0.9‰ respectively. These datasets also differ significantly from one another ($t = 4.188$, $p < .001$), but in this case the Neo-Aleut mean was enriched by 0.8‰. These values suggest that near-shore resources were more important in Paleo-Aleut diets than Neo-Aleut and higher trophic level resources were more important to Neo-Aleuts.

While these results indicate clear differences in subsistence strategies between the two craniometric groups, within group

Table 2
Faunal material and associated isotope values.

Analytical group	Species	Name	$\delta^{13}C$	$\delta^{15}N$	Source
Canid	*Canid* sp.	Dog	−11.86300	14.18500	Chaluka
Canid	*Canid* sp.	Dog	−12.40800	16.87600	Chaluka
Canid	*Vulpes vulpes*	Fox	−13.47300	13.12400	Chaluka
Canid	*V. vulpes*	Fox	−13.57600	11.80100	Chaluka
Canid	*V. vulpes*	Fox	−12.14300	15.85700	Chaluka
Canid	*V. vulpes*	Fox	−11.39100	13.81700	Chaluka
Canid	*V. vulpes*	Fox	−14.30100	12.90400	Chaluka
Canid	*V. vulpes*	Fox	−13.84400	11.77600	Chaluka
Cetacean	*Cetacea* sp.	Whale	−13.28200	16.16900	Amaknak
Cetacean	*Cetacea* sp.	Whale	−13.76200	14.09700	Amaknak
Cetacean	*Cetacea* sp.	Whale	−12.86800	17.96600	Amaknak
Cetacean	*Cetacea* sp.	Whale	−13.53900	16.35600	Chaluka
Cetacean	*Cetacea* sp.	Whale	−12.88100	14.69600	Chaluka
Cetacean	*Cetacea* sp.	Whale	−14.10900	13.57900	Chaluka
Cetacean	*Cetacea* sp.	Whale	−13.22300	17.00100	Chaluka
Cetacean	*Cetacea* sp.	Whale	−12.98500	15.43200	Chaluka
Cetacean	*Cetacea* sp.	Whale	−14.60100	13.34900	Amaknak
Cetacean	*Phocoena phocoena*	Porpose	−13.40800	17.43900	Amaknak
Cetacean	*P. phocoena*	Porpose	−12.92400	16.37800	Amaknak
Cetacean	*P. phocoena*	Porpose	−13.27100	17.32300	Amaknak
Cetacean	*P. phocoena*	Porpose	−12.61800	15.51100	Amaknak
Cetacean	*P. phocoena*	Porpose	−13.21100	15.85700	Amaknak
Cetacean	*P. phocoena*	Porpose	−13.43100	14.04400	Chaluka
Cetacean	*P. phocoena*	Porpose	−13.15400	16.71000	Chaluka
Mustelid	*Enhydra lutris*	Sea otter	−13.00400	13.52200	Amaknak
Mustelid	*E. lutris*	Sea otter	−12.90100	10.06800	Chaluka
Mustelid	*E. lutris*	Sea otter	−10.65200	12.08200	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.40200	12.07100	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.12300	11.97100	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.69500	12.28600	Chaluka
Mustelid	*E. lutris*	Sea otter	−11.37600	12.67200	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.40700	12.69800	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.71000	11.75100	Chaluka
Mustelid	*E. lutris*	Sea otter	−11.99900	12.81100	Chaluka
Mustelid	*E. lutris*	Sea otter	−12.03100	12.07400	Chaluka
Near-Shore Fishes	*Hemilepidotus hemilepidotus*	Irish lord	−10.56300	14.27800	Amaknak
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−9.88100	16.10300	Amaknak
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−11.31300	14.52700	Chaluka
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−11.90800	14.10400	Chaluka
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−12.18600	14.11400	Chaluka
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−12.29000	14.52000	Chaluka
Near-Shore Fishes	*H. hemilepidotus*	Irish lord	−12.35400	14.09900	Chaluka
Near-Shore Fishes	*Hexagrammos* sp.	Greeling	−10.76900	13.76700	Amaknak
Near-Shore Fishes	*Hexagrammos* sp.	Greeling	−11.44700	12.30300	Amaknak
Near-Shore Fishes	*Hexagrammos* sp.	Greeling	−10.62600	13.13500	Amaknak
Near-Shore Fishes	*Hexagrammos* sp.	Greeling	−10.75400	13.55900	Amaknak
Near-Shore Fishes	*Hexagrammos* sp.	Greeling	−10.90000	13.84300	Amaknak
Near-Shore Fishes	*Hippoglossus stenolepis*	Halibut	−10.69300	17.72100	Amaknak
Near-Shore Fishes	*H. stenolepis*	Halibut	−11.10300	16.94800	Amaknak
Near-Shore Fishes	*H. stenolepis*	Halibut	−11.22200	15.11900	Amaknak
Near-Shore Fishes	*H. stenolepis*	Halibut	−11.28300	14.34100	Chaluka
Open-Water Fishes	*Gadus macrocephalus*	Pacific cod	−12.59500	16.44400	Amaknak
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−11.79200	18.08600	Amaknak
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−12.27300	15.58700	Amaknak
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−10.89300	15.98500	Amaknak
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−11.62000	18.40400	Amaknak
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−12.06700	16.85200	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−13.36400	15.57000	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−12.63200	16.87800	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−13.01400	15.89800	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−12.47000	15.86600	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−12.12300	17.19300	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−11.73800	18.17200	Chaluka
Open-Water Fishes	*G. macrocephalus*	Pacific cod	−11.58400	18.48800	Chaluka
Pinniped	*Callorhinus ursinus*	Fur seal	−13.10100	18.64700	Amaknak
Pinniped	*C. ursinus*	Fur seal	−13.82100	16.96700	Amaknak
Pinniped	*C. ursinus*	Fur seal	−13.76200	16.30800	Amaknak
Pinniped	*C. ursinus*	Fur seal	−14.07500	14.51200	Amaknak
Pinniped	*C. ursinus*	Fur seal	−10.12900	18.90500	Amaknak
Pinniped	*C. ursinus*	Fur seal	−13.79400	15.85400	Chaluka
Pinniped	*C. ursinus*	Fur seal	−12.64900	17.50700	Chaluka
Pinniped	*C. ursinus*	Fur seal	−14.76400	18.62200	Chaluka
Pinniped	*C. ursinus*	Fur seal	−14.38500	19.63900	Chaluka
Pinniped	*C. ursinus*	Fur seal	−16.03700	15.19800	Chaluka

Table 2 (*continued*)

Analytical group	Species	Name	δ^{13}C	δ^{15}N	Source
Pinniped	*C. ursinus*	Fur seal	−13.94000	18.50100	Chaluka
Pinniped	*Erignathus barbatus*	Bearded seal	−12.03400	17.42900	Amaknak
Pinniped	*E. barbatus*	Bearded seal	−11.77100	18.05400	Amaknak
Pinniped	*E. barbatus*	Bearded seal	−11.40000	15.88500	Amaknak
Pinniped	*E. barbatus*	Bearded seal	−11.30400	18.72300	Amaknak
Pinniped	*E. barbatus*	Bearded seal	−13.75000	16.85200	Amaknak
Pinniped	*Eumetopias jubatus*	Stellar sea l;ion	−13.90100	16.39400	Chaluka
Pinniped	*E. jubatus*	Stellar Sea lion	−13.04300	16.50200	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−14.05300	16.82300	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−12.38900	19.06400	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−14.03200	16.08800	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−15.06300	16.22100	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−14.08300	17.49900	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−13.77800	17.03800	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−13.78500	17.06800	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−14.07500	15.11900	Chaluka
Pinniped	*E. jubatus*	Stellar sea lion	−13.92400	14.80200	Chaluka
Pinniped	*Phoca hispida*	Ringed seal	−12.90600	19.09600	Amaknak
Pinniped	*P. hispida*	Ringed seal	−11.76500	17.07300	Amaknak
Pinniped	*P. hispida*	Ringed seal	−12.87000	17.15800	Amaknak
Pinniped	*P. hispida*	Ringed seal	−12.33400	18.07600	Amaknak
Pinniped	*P. hispida*	Ringed seal	−12.30200	17.11700	Amaknak
Pinniped	*Phoca largha/vitulina*	Spotted/harbor seal	−12.45500	16.32500	Amaknak
Pinniped	*P. largha/vitulina*	Spotted/harbor seal	−12.23400	17.34500	Amaknak
Pinniped	*P. largha/vitulina*	Spotted/harbor seal	−12.83500	20.25100	Amaknak
Pinniped	*P. largha/vitulina*	Spotted/harbor seal	−13.94300	17.62600	Amaknak
Pinniped	*P. largha/vitulina*	Spotted/harbor seal	−11.61700	19.69200	Amaknak
Pinniped	*P. vitulina*	Harbor seal	−13.57700	16.45700	Amaknak
Pinniped	*P. vitulina*	Harbor seal	−12.21300	15.52300	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−12.04900	16.63500	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−12.93400	15.56200	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−12.90200	15.34000	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−12.93400	15.53100	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−13.19800	16.41800	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−12.01500	20.42400	Chaluka
Pinniped	*P. vitulina*	Harbor seal	−13.58900	14.79600	Chaluka
Salmon	*Oncorhynchus* sp.	Salmon	−15.10100	10.34300	Amaknak
Salmon	*Oncorhynchus* sp.	Salmon	−14.63900	13.04400	Amaknak
Salmon	*Oncorhynchus* sp.	Salmon	−14.91500	12.58300	Amaknak
Salmon	*Oncorhynchus* sp.	Salmon	−14.95300	10.52100	Amaknak
Salmon	*Oncorhynchus* sp.	Salmon	−15.25400	11.68100	Amaknak
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.90100	7.06800	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−11.65200	9.08200	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.40200	9.07100	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.12300	8.97100	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.69500	9.28600	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−12.37600	9.67200	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.40700	9.69800	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.71000	8.75100	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−12.99900	9.81100	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−13.03100	9.07400	Derived
Urchin	*Strongylocentrotus* sp.	Sea urchin	−14.00400	10.52200	Derived

differences also become apparent when the data are aggregated by location (Fig. 3). Moreover, these differences suggest that the dietary inputs of the Chaluka Aleut may have differed from those interred in the Kagamil and Shiprock burial caves without regard to craniometric group or age, keeping in mind that all but two Chaluka midden burials are Paleo-Aleut (Coltrain, in press). To illustrate these differences, we compare mean δ^{13}C and δ^{15}N values for each location specific sample. The by-location datasets for Chaluka ($n = 32$), Kagamil ($n = 32$) and Shiprock ($n = 16$) produced δ^{13}C values of -12.3 ± 0.5‰, -12.8 ± 0.3‰ and -12.4 ± 0.5‰ respectively and δ^{15}N values of 19.2 ± 0.6‰, 20.3 ± 0.6‰ and 20.4 ± 1.0‰ respectively. A statistical comparison indicates that mean Chaluka δ^{13}C values differ from those of the Kagamil sample ($t = 4.549$, $p < .001$), with Chaluka values enriched 0.5‰. The δ^{15}N values for these two sites also differ ($t = -7.324$, $p < .001$) and in this case, Chaluka values are depleted by 1.1‰ relative to those from Kagamil. While Chaluka δ^{13}C values are statistically similar to those of the Shiprock sample, their δ^{15}N values differ from one another ($t = -4.170$, $p < .001$), with the Shiprock sample displaying a relative enrichment of 1.2‰. Shiprock δ^{13}C values differ from those of the Kagamil sample ($t = -3.212$, $p = .002$), displaying a mean difference of 0.4‰. In contrast, Shiprock and Kagamil data display statistically similar δ^{15}N values. In sum, these data suggest that the individuals interred at Kagamil and Shiprock had access to higher trophic level, higher ranked prey than Aleuts recovered from Chaluka Midden, regardless of craniometric affiliation. At the same time, Chaluka Aleuts spent more time collecting food in near-shore environments than individuals interred in the burial caves, although again, the Chaluka midden assemblage was vastly dominated by Paleo-Aleut inhumations and the burial caves dominated by Neo-Aleut mummified remains.

Since Neo-Aleut human remains date only to the most recent 1000 years of the archaeological record, we next compare pre-1000 BP Paleo-Aleut ($n = 15$) with post-1000 BP Paleo-Aleut ($n = 26$) samples to determine if differences between Paleo- and Neo-Aleuts simply reflect a time dependant phenomenon (Fig. 5).

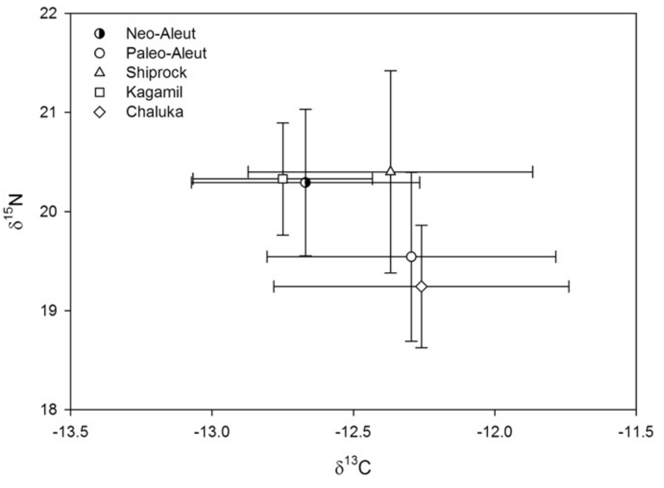

Fig. 3. Variation in δ^{13}C arrayed against variation in δ^{15}N for site specific and craniometric group specific subsamples of the Aleut human dataset.

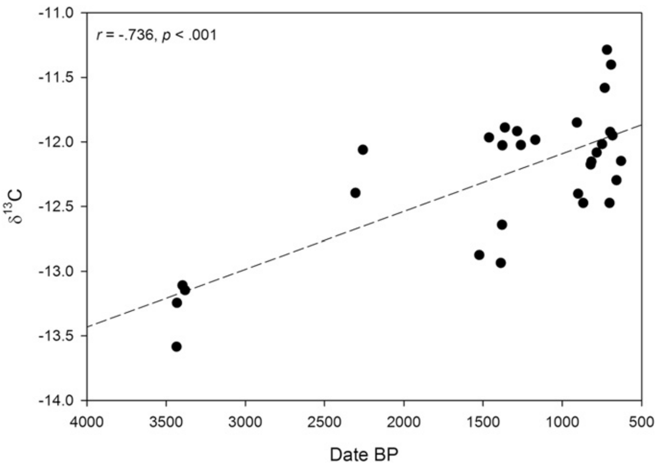

Fig. 4. Time trend in Chaluka Aleut δ^{13}C values.

The pre-1000 BP sample displays mean δ^{13}C values of -12.5 ± 0.6‰ and δ^{15}N of 19.1 ± 0.6‰ and the post-1000 BP sample δ^{13}C values of -12.2 ± 0.4‰ and δ^{15}N of 19.8 ± 0.9‰. This comparison found significant differences between both δ^{13}C ($t = 2.011$, $p = .056$) and δ^{15}N values ($t = 2.536$, $p = .015$). As a group, pre-1000 BP Paleo-Aleut δ^{13}C values are depleted by 0.3‰ and δ^{15}N values by 0.7‰ relative to Paleo-Aleuts from the most recent 1000 years. When viewed as a whole, these data appear to document a shift in Paleo-Aleut dietary preference to higher trophic level prey and/or prey living in near-shore environments after 1000 BP.

While the remains from Shiprock and Kagamil date to just at or younger than 1000 BP, the Chaluka sample spans ~3000 years. Recognizing this, the Chaluka sample was divided into pre-1000 ($n = 15$) and post-1000 BP ($n = 17$) groups and mean δ^{13}C and δ^{15}N values tested for differences (Fig. 5). The pre-1000 BP Chaluka sample displays mean δ^{13}C values of -12.5 ± 0.6‰ and δ^{15}N of 19.1 ± 0.6‰ and the post-1000 BP Chaluka sample δ^{13}C values of -12.0 ± 0.3‰ and δ^{15}N of 19.3 ± 0.6‰. The mean difference in δ^{13}C values is significant ($t = -2.793$, $p = 0.010$), while that for δ^{15}N is not. In fact when arrayed against their calibrated radiocarbon dates, individual δ^{13}C values for the Chaluka sample display a strong linear relationship ($r = -0.736$, $p < 0.001$; Fig. 4). These data suggest that foragers occupying Chaluka midden targeted prey from the same trophic level, while placing an increasing emphasis on near-shore resources during more recent occupations of the site.

Table 3
Tests for difference results.

Comparison	δ^{13}C		δ^{15}N	
	$t=$	$p=$	$t=$	$p=$
Neo-Aleut/Paleo-Aleut	−3.623	0.001	4.188	<0.001
Chaluka/Kagamil	4.549	<0.001	−7.324	<0.001
Chaluka/Shiprock	0.693	0.495	−4.170	<0.001
Kagamil/Shiprock	−3.212	0.002	−0.262	0.796
Pre/post-1000 BP Paleo-Aleut	2.011	0.056	2.536	0.015
Chaluka Pre/post-1000 BP	−2.793	0.010	−1.009	0.321
Chaluka Pre-1000 BP/Kagamil	1.490	0.153	−6.733	<0.001
Chaluka Pre-1000 BP/Shiprock	−0.746	0.462	−4.309	<0.001
Chaluka Post-1000 BP/Kagamil	7.244	<0.001	−5.489	<0.001
Chaluka Post-1000 BP/Shiprock	2.222	0.034	−3.515	0.002
Shiprock Paleo-/Neo-Aleut	−1.243	0.234	−0.580	0.571
Males/females	−0.773	0.442	−1.079	0.284
Chaluka males/females	−0.934	0.358	−1.109	0.276
Kagamil males/females	0.775	0.444	−0.400	0.692
Shiprock males/females	−0.386	0.705	−1.014	0.328
Amaknak/Chaluka fur seal	1.398	0.200	−0.776	0.460
Amaknak/Chaluka cod	1.504	0.161	0.056	0.956
Amaknak/Chaluka porpoise	0.833	0.443	1.177	0.292
Amaknak/Chaluka albatross	0.333	0.794	−0.651	0.536
Amaknak/Chaluka harbor seal	−0.124	0.903	1.793	0.098
Amaknak/Chaluka whale	−0.681	0.518	−0.015	0.988

We also compare the isotope values of pre- and post-1000 BP Chaluka samples with those from both Kagamil and Shiprock. The Chaluka pre-1000 and Kagamil samples display statistically similar δ^{13}C values, but different δ^{15}N values ($t = -6.733$, $p < 0.001$), with the mean Chaluka Midden value depleted by 1.2‰. The Chaluka pre-1000 and Shiprock samples also display similar δ^{13}C values, but different δ^{15}N values ($t = -4.309$, $p < 0.001$), with the mean Chaluka midden value depleted by 1.3‰. The Chaluka post-1000 and Kagamil samples display different δ^{13}C values ($t = 7.244$, $p < 0.001$) and mean values for Kagamil are depleted by 0.8‰. Their δ^{15}N values differ as well ($t = -5.489$, $p < 0.001$), with the mean Kagamil value enriched by 1.0‰. The Chaluka post-1000 and Shiprock data display different δ^{13}C values ($t = 2.222$, $p = 0.034$), with the Shiprock values depleted by 0.4‰. Their δ^{15}N values differ as well ($t = -3.515$, $p = 0.002$), with the Shiprock values enriched by 1.1‰. These comparisons suggest that regardless of temporal provenience, high-trophic level prey contributed less to Chaluka diet than to Kagamil and Shiprock Aleut diets. Comparisons of δ^{13}C values produce a less clear pattern, but where differences exist, they suggest that near-shore prey made a greater input to Chaluka diet relative to that of the Kagamil and Shiprock Aleut.

Since the Shiprock burial cave contained both Paleo-Aleut and Neo-Aleut remains in similar numbers all dating to after 1000 BP, this subsample provides an opportunity to test for differences between the craniometric groups while holding both time and location constant. In this instance, both δ^{13}C values and δ^{15}N values are statistically similar and, although two morphologically distinct groups are present in the Shiprock sample, these individuals demonstrate no observable dietary differences. Simply put, post-1000 BP Paleo-Aleuts buried as Neo-Aleut burials also subsisted as Neo-Aleuts.

Finally, to evaluate the potential for gender differentiated dietary preferences to confound these results, we divided the sample into male and female groups and compared their carbon and nitrogen isotope chemistries. This test failed to find any differences between the overall male and female samples for either carbon or nitrogen. Nor was any difference identified between the Paleo-Aleut and Neo-Aleut groups when evaluated relative to sex and this lack of difference between males and females also holds at the site level and within time sensitive comparisons.

When taken as a whole, patterning in Aleut bone chemistry suggests that time and burial location crosscut dietary differences mediated by craniometric group. However, burial location determined whether an individual was mummified or merely buried. All remains from Shiprock and Kagamil burial caves were mummified and 77% posses a Neo-Aleut cranial morphology. All remains from Chaluka midden were inhumations and 94% are Paleo-Aleut. While the between-group isotopic differences are small, the overall pattern suggests that the Chaluka diet, dominated by Paleo-Aleut inhumations, differed in both trophic level and foraging location from the other two sites for much of the past 4000 years (Figs. 5 and 6). The trends in our data also suggest that individuals interred in the Shiprock and Kagamil burial caves, primarily Neo-Aleuts, had enough access to higher trophic level foods to significantly differentiate their bone chemistries from those of the individuals buried in Chaluka midden. Further, these data also document a shift across the sequence at Chaluka in the location of food sources while the average trophic level of prey pursued by the Chaluka Aleut remains generally the same. Time also plays an obvious role in this discussion since the Neo-Aleut configuration appears only after 1000 BP.

4.2. Non-human isotope data

Six generic prey groups were constructed from the Amaknak Bridge and Chaluka midden faunal assemblages. These include cetaceans, pinnipeds, near-shore fishes, open-water fishes, salmon and sea urchins (Fig. 7). Statistical tests indicate that the distributions of prey specific δ^{13}C and δ^{15}N data differ from one another with three exceptions. Cetaceans, pinnipeds and urchins share statistically indistinguishable δ^{13}C values. However, not surprisingly, pinnipeds display the greatest enrichment in δ^{15}N and occupy the highest trophic level in our sample, followed closely by open-water fishes (cod) and the cetaceans. Urchins occupy the lowest trophic position in the food web and 7.9‰ separate them from the pinnipeds. Finally, the salmon and near-shore fishes occupy a place in between the high and low trophic level prey groups. Salmon display the most depleted δ^{13}C values, while the near-shore, bottom-dwelling fishes possess the most enriched values with a range of 3.8‰ defining the range of variation in δ^{13}C values for the faunal dataset.

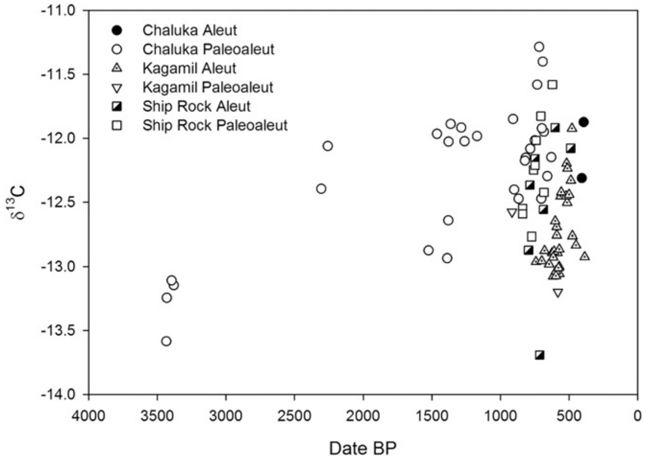

Fig. 5. Calibrated radiocarbon dates arrayed against δ^{13}C values for the site specific and craniometric group specific subsamples of the Aleut human dataset.

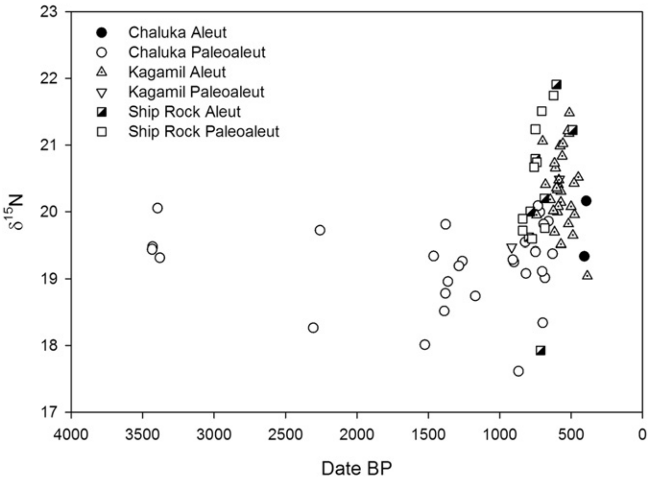

Fig. 6. Calibrated radiocarbon dates arrayed against δ^{15}N values for the site specific and craniometric group specific subsamples of the Aleut human dataset.

5. Discussion

5.1. A linear mixing model for the prehistoric Aleut diet

Our analysis identified several trends in Aleut isotope data. Most striking are consistent differences between the Chaluka data and those from the other two sites. As a group, these data also display differences when aggregated as pre- and post-1000 BP samples. However, we have focused only on differences in measured, end-member values for Aleut foragers. These isotopic signatures represent single point values that do not speak directly to the relative contribution of specific prey taxa. To identify shifts in reliance on specific prey types and further evaluate the trends reported above, we use the IsoSource 1.3.1 linear mixing model (Phillips and Gregg, 2003). This model examines combinations of source inputs from multiple prey types in an effort to identify possible proportional contributions from each source and determine a range of mass balance diets that would result in measured end-user isotopic signatures. Combinations that sum to these isotopic signatures constitute possible mass balance diets.

The faunal data used here derive from two assemblages and given the lack of temporal control over the Chaluka sample, a brief

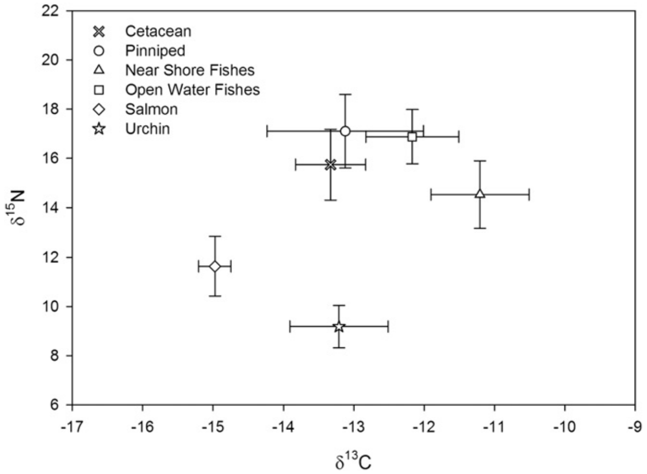

Fig. 7. Variation in δ^{13}C arrayed against variation in δ^{15}N for Aleut food taxa.

discussion of potential differences between the two datasets is important. To evaluate potential biases that may result from aggregating data from different locations with uncertain temporal control, we compare the δ^{13}C and δ^{15}N values derived from species recovered at both sites. These species include fur seal, cod, porpoise, harbor seal, and unidentified whale. In each case, the δ^{13}C and δ^{15}N values were statistically similar, suggesting that combining the data from both assemblages is unlikely to bias the following outcomes.

Reported isotope chemistry was measured directly for all taxa but sea urchin (*Strongylocentrotus* sp.), whose stable isotope chemistry was estimated by deducting trophic level enrichment from mean sea otter carbon and nitrogen values. Whereas sea otter feed heavily on sea urchin, Aleut foragers took them primarily for their hides, unlike sea urchin, which were collected in the littoral zone and contributed to Aleut diets. Finally, we do not use isotope data from the canids in the analyses that follow since ethnographic accounts suggest dogs had a range of non-subsistence uses (Hrdlicka, 1945; Lantis, 1984; Laughlin, 1980), but nonetheless report their data for reference purposes.

The mean isotopic value for each of the six prey groups was used as an IsoSource input value (Table 4) and prey species groupings were derived as follows. All values for cetacean bone formed a group that includes porpoise as well as the remains of several unidentified cetaceans. The pinniped group contains all data obtained from seals and sea lion. The value used for near-shore fishes includes data from Irish lord, Pacific halibut, and greeling. The isotopic value for open-water fishes derive solely from Pacific cod and those for salmon come from specimens indentified only to the genus level (*Oncorhynchus*). Regardless of group, all mean nitrogen food source values were adjusted +4‰ and mean carbon values adjusted +1‰ for trophic level enrichment (Table 3). IsoSource increments were set at 5% and the tolerance at 0.5‰.

5.2. Aleut mass balance diets

Using mean human δ^{13}C and δ^{15}N values for Paleo-Aleut, Neo-Aleut, pre-1000 BP Paleo-Aleut, post-1000 BP Paleo-Aleut, Chaluka Midden, Kagamil and Shiprock burials (Table 3), we calculated mass balance diets for each analytical group. We visually explore the direction of temporal and spatial trends within the context of shifting prey choice by plotting mean δ^{13}C and δ^{15}N values for human groups against the mean proportional contribution of generalized prey types calculated by IsoSource.

Fig. 8a displays directional differences between Neo- and Paleo-Aleuts in the proportional contributions of various prey taxa and Fig. 8b displays differences between pre- and post-1000 BP Paleo-Aleuts. Most notably, pinnipeds appear to make up nearly 35% of Neo-Aleut diets relative to less than 20% reliance on these taxa among Paleo-Aleuts. In keeping with this pattern, Neo-Aleuts take fewer near-shore fishes of all types and fewer sea urchins. Reliance on cetaceans is similar. The change in pre- and post-1000 BP Paleo-Aleuts diets is less marked, with the greatest shift seen in the increase in the use of open-water fishes. It is also important to note that Paleo-Aleuts at Shiprock and Kagamil exhibit Neo-Aleut subsistence patterns, undoubtedly influencing post-1000 BP Paleo-Aleut isotopic patterning. When plotted by site (Fig. 8c and e), proportional differences in diet between Chaluka midden and both burial caves are very similar to the differences between Paleo- and Neo-Aleut diets. This is not surprising, since Neo-Aleut burials dominated both of the cave sites. In keeping with this pattern, burials from Kagamil versus Shiprock show only minor differences in diet with slightly more reliance on open-water fish such as cod and a slightly reduced intake of pinnipeds and salmon (Fig. 8d). When viewed in concert with reconstructed Neo-Aleut diets, these data suggest that across the entire occupational sequence Paleo-Aleuts consumed fewer pinnipeds, but shifted their subsistence efforts to include greater numbers of open-water fishes during the most recent period of their occupational sequence. In sum, both Kagamil and Shiprock diets are characterized by higher relative contributions of high-trophic level marine mammals including pinnipeds and cetaceans.

Table 4
Isosource input values.

Group	δ^{13}C	σ	δ^{15}N	σ	n
Neo-Aleut	−12.7	0.4	20.3	0.7	39
Paleo-Aleut	−12.3	0.5	19.5	0.9	41
Kagamil	−12.8	0.3	20.3	0.6	32
Shiprock	−12.4	0.5	20.4	1.0	16
Chaluka	−12.3	0.5	19.2	0.6	32
Paleo-Aleut >1000 BP	−12.5	0.6	19.1	0.6	15
Paleo-Aleut < 1000 BP	−12.2	0.4	19.8	0.9	26
Cetaceans	−13.3	0.5	15.7	1.4	15
Pinnipeds	−13.1	1.1	17.1	1.5	46
Near-Shore Fishes	−11.2	0.7	14.5	1.4	16
Open-Water Fishes	−12.2	0.7	16.9	1.1	13
Salmon	−15.0	0.2	11.6	1.2	5
Urchin	−13.2	0.7	9.2	0.9	11

To further explore dietary differences between Neo- and Paleo-Aleuts, we next grouped all of the post-1000 BP Aleut data regardless of craniometric affiliation into 100-year interval groups beginning with a period from 300 to 399 BP and ending with one spanning from 900 to 999 BP. The IsoSource software was used to calculate a mass balance diet for each period and these were plotted in chronological order. This treatment of the data allows for the identification of temporal patterns within the IsoSource output that can also be linked to trends in the proportional craniometric and spatially defined make-up of the human remains within each period. Plotting the data this way revealed a striking pattern (Fig. 9). Across the 700-year period, the modeled proportional dietary contribution of pinnipeds to the overall Aleut diet increases steadily, peaking during the 500–599 interval and then decreases once again. To identify a potential cause for this trend, the interval specific proportions of Neo-Aleut remains, as well as those from each of the three burial sites were arrayed against the trend in the pinniped data. Strong, significant and positive correlations were found between the modeled dietary contribution of pinnipeds and the proportion of Neo-Aleut ($r = 0.909$, $p = 0.005$) and Kagamil burials ($r = 0.820$, $p = 0.024$) within each 100-year period (Fig. 10). Conversely a strong negative correlation exists between the proportional contribution of pinnipeds and Chaluka burials ($r = -0.965$, $p < 0.001$) within each 100-year period (Fig. 11). These trends are fully consistent with the spatio–temporal relationships between craniometric group, location and isotopic values discussed above, and serve to further underscore the differences in the contributions of high-trophic level prey between Neo- and Paleo-Aleut groups, as well as those observed between remains recovered from Chaluka and non-Chaluka contexts. In general, the Neo-Aleut from the Kagamil and Shiprock burial caves appeared to have enjoyed a greater intake of high-trophic level prey such as pinnipeds relative to Paleo-Aleuts from Chaluka midden.

6. Craniometrics, migrations and isotope chemistry

Our results from both the analyses of raw isotope data and the linear mixing models, present an interesting, but far from straightforward picture of the relationship between craniometric group and diet. Within our sample, isotopic signature differs not only by craniometric group, but also by time and location. In fact, it appears that

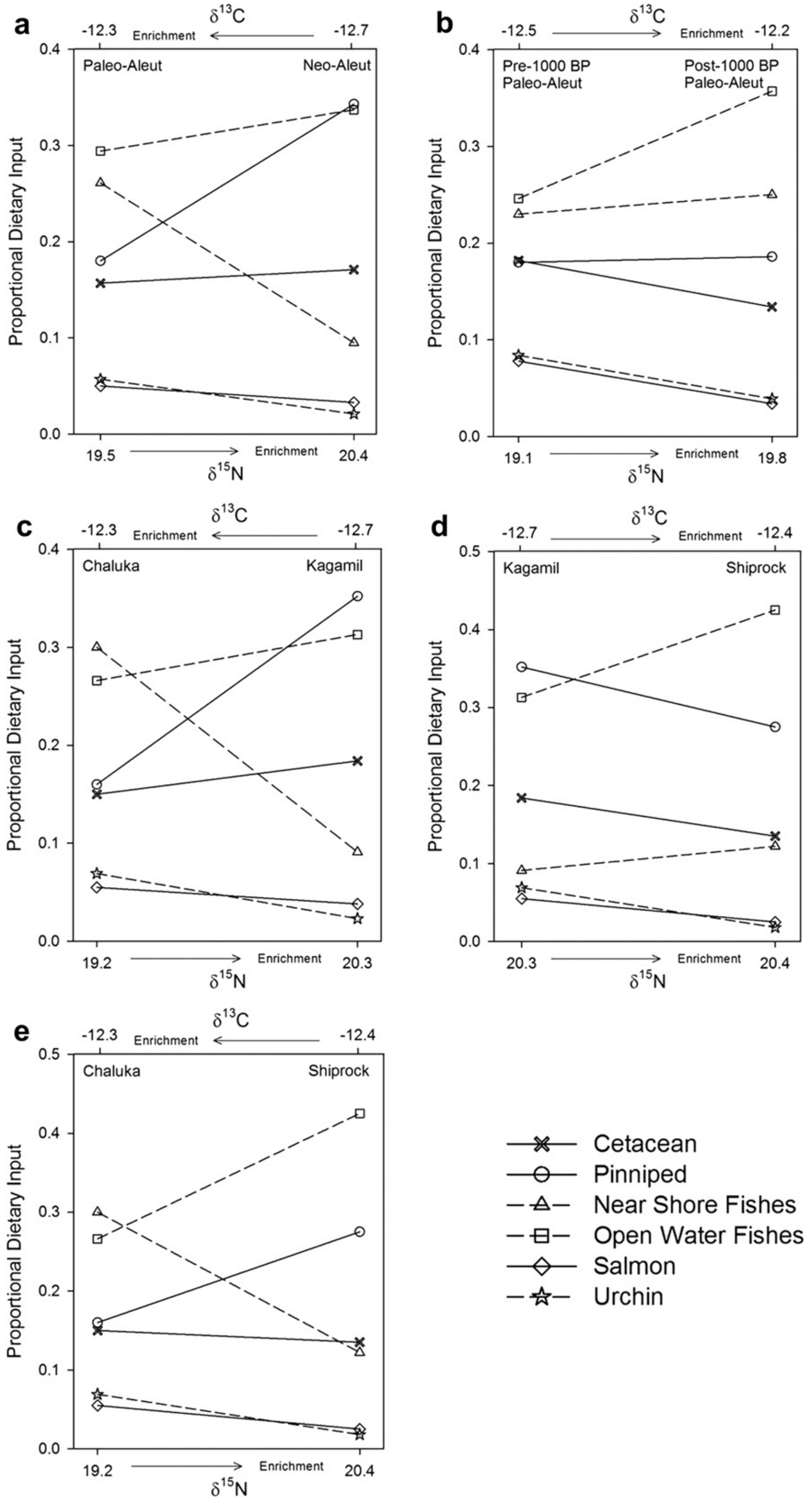

Fig. 8. $\delta^{13}C$ and $\delta^{15}N$ values for site specific and craniometric group specific subsamples of the Aleut human dataset plotted against the mean proportional contribution of generalized prey types calculated by IsoSource.

after 1000 BP everyone in the populations interring their dead in the Shiprock and Kagamil burial caves enjoyed similar diets high in pinnipeds regardless of whether they were Paleo- or Neo-Aleut. This was the case even though the vast majority in our sample were Neo-Aleut. In contrast, those living at Chaluka midden during this period, the vast majority of which were Paleo-Aleut, made only slight changes in their subsistence practices. If true, isotopic data may well signal a migration of maritime foragers into the area.

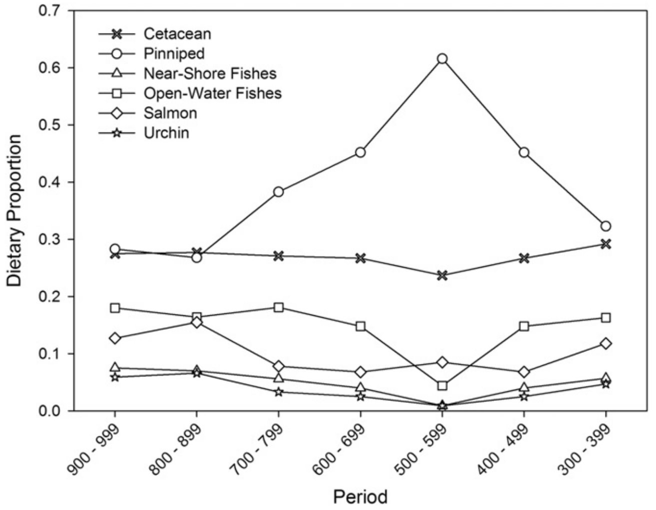

Fig. 9. Mass balance diets calculated for Aleut humans aggregated in 100-year intervals and arrayed across time for the most recent 1000 years of the Aleutian record.

Several complementary lines of evidence also suggest a new population of maritime foragers with a different lifeway appeared within and shared the study area after 1000 BP. The results of one genetic study mirror the temporal pattern seen in isotope data. Smith et al. (2009) preformed an aDNA analysis on a sample of 86 sets of Aleut human remains, including all 80 of those discussed here. Much like the temporal differences we identified between pre- and post-1000 BP samples, the genetic study identified a statistically significant difference in haplogroup frequencies when the dataset was compared as two temporal groups defined in the same manner. In fact, Smith et al. (2009) found that the pre-1000 BP Aleut were genetically different from the post-1000 BP Aleut, regardless of craniometric affiliation. While the earlier group consists entirely of remains identified as Paleo-Aleut, the younger sample includes both Paleo- and Neo-Aleut remains and within this younger sample, no between-group differences in haplogroup frequencies were identified.

Strikingly different mortuary practices documented at the three recovery sites also point to a spatially and temporally restricted phenomenon that emerged after ca. 1000 BP in conjunction with the Neo-Aleut cranial morphology. Chaluka midden Paleo-Aleut burials were flexed, inhumations accompanied by relatively well-made but impoverished collections of grave goods, often limited to stone lamps, bone and shell items (Hunt, 2002). Chaluka midden Neo-Aleuts, also inhumations, had few if any associated grave goods. In contrast, Kagamil and Shiprock burial cave adult remains were mummified "…eviscerated, stuffed with grass, wrapped in furs and grass matting, and then secured in a waterproof covering of seal skin" (Dall, 1875:399–400). In addition to the complex preparation of the deceased, these remains were often accompanied by rich, elaborate assemblages of grave goods that included canoes, mats, weapons and wooden body armor as well as numerous stone, bone, shell and wood artifacts. Dall (1875) (435–6, quoted in Hrdlicka, 1945:185–6) also notes that when dried, bodies were wrapped in a shirt made of skins of aquatic birds with feathers on and variously trimmed…." Taken in sum, the appearance if a novel craniometric configuration in combination with dietary shifts recorded in the isotope record, temporal differences in haplogroup frequencies, and temporal variation in mortuary practices, all point towards a notable shift in eastern Aleut lifeways, after 1000 BP.

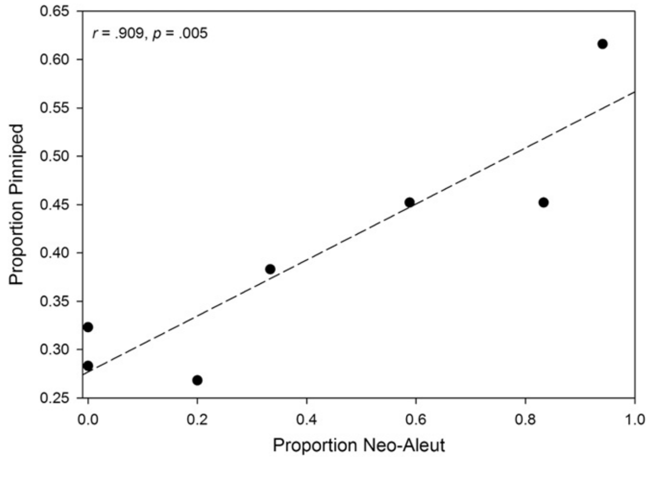

Fig. 10. Relationship between the proportion of Neo-Aleut and modeled dietary contribution of pinnipeds within in each 100-year aggregate.

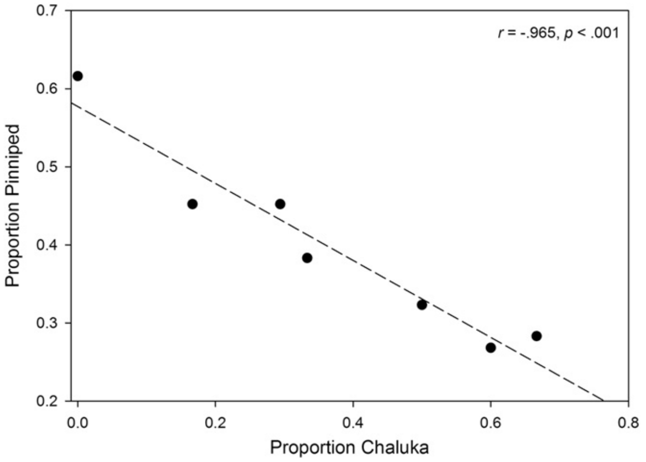

Fig. 11. Relationship between the proportion of Chaluka Aleut and modeled dietary contribution of pinnipeds within in each 100-year aggregate.

7. Conclusions

While we do document a relationship between craniometric configuration and isotopic signature, this pattern is also crosscut by both location and time. Our study suggests that the Chaluka diet differed in both trophic level and foraging location from those of Aleut interred in Shiprock and Kagamil burial caves. Individuals recovered from the burial caves, regardless of craniometric configuration appear to represent a subsistence pattern with greater emphasis on higher trophic level, open-water resources than the one practiced by Chaluka burials.

The Neo-Aleut cranial configuration appears only after 1000 BP and appears linked with shifts in diet, genetics, and aspects of material culture also occurring at this time. Within our sample, Neo-Aleuts are also limited largely to the two burial caves. Paleo-Aleuts recovered from Shiprock and Kagamil display similar isotope values to Neo-Aleuts, are genetically indistinguishable from Neo-Aleuts and received similar burial treatments; it appears that after 1000 BP, everyone within the populations interring their dead at these two sites practiced a similar lifeway regardless of whether they were Paleo- or Neo-Aleut. This observation may well document a migration of distinct, socially complex maritime foragers into the Aleutians at this time. Whether individuals recovered from Chaluka midden came to represent a social underclass and why they appear to retain similar bone isotope chemistries and burial practices in the face of the social changes occurring is unclear.

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