Hrdlička's Aleutian Population-Replacement Hypothesis

A Radiometric Evaluation

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In a 1945 monograph, Hrdlička argued that, at 1,000 BP, Paleo-Aleut people on Umnak Island were replaced by Neo-Aleut groups moving west along the island chain. His argument was based on cranial measurements of skeletal remains from Chaluka Midden and mummified remains from Kagamil and Ship Rock burial caves. By the 1980s, researchers had concluded that the transition demonstrated by Hrdlička, from a high oblong to a low-vaulted wide face, was merely one example of a global trend in cranial morphology and therefore population replacement had not occurred. Calibrated accelerator radiocarbon dates on purified bone collagen from 80 individuals indicate that Paleo-Aleuts were the oldest population in the Aleutians, with a time depth of ca. 4,000 years, that Paleo- and Neo-Aleuts were fully contemporary on Umnak Island after 1,000 BP, and that the former continued to bury their dead as inhumations long after the introduction of Neo-Aleut mummification practices. These results as well as features of the Aleut dietary, genetic, and material record suggest that the appearance of Neo-Aleut people represents an influx of closely related people characterized by greater social complexity and that social disparities that may have existed between Paleo- and Neo-Aleuts were largely subsumed in the social and demographic upheaval following Russian contact.

The view that occupation of the Aleutian Islands was best characterized as a relatively unbroken, uniform adaptation to a rich marine environment has given way to the recognition that Aleut prehistory was significantly shaped by contact with the Alaska Peninsula and a complex of environmental variables unique to the island chain (e.g., Corbett, West, and Lefevre 2001; Dumond 2001a, b; Knecht and Davis 2001; Mason 2001; McCartney and Veltre 1999; Veltre and McCartney 2001). Here we report AMS radiocarbon dates on purified bone collagen from skeletal assemblages recovered at three well-known burial sites in the eastern Aleutian Islands—Chaluka Midden and Kagamil and Ship Rock burial caves—

and discuss the implications of these data for long-standing arguments regarding late Holocene population movement on the island chain.

A Historical Perspective

In the eastern Aleutian Islands, the collection of human remains from burial caves began late in the nineteenth century with explorations by Alfonse Pinart (1872) and William Healey Dall (1878), the latter while conducting a geographic and hydrographic survey of the islands. Whereas Pinart's artifacts were taken to France, the bundled mummies secured by Dall were collected in 1874 from Kagamil Island's "warm cave" by Captain E. Hennig of the Alaska Commercial Company (Hrdlička 1945, 186), and the majority, 9 of 12, were donated to the Smithsonian Institution, becoming part of the collection subsequently analyzed by Hrdlička (see Frohlich and Laughlin 2002; Hunt 2002 for reviews). Three decades later, Waldemar Jochelson led the anthropological division of the Aleut-Kamchatka Expedition under the direction of the Imperial Russian Geographical Society. Assisted by his wife, Dina Brodsky, Jochelson conducted archaeological, ethnographic, and linguistic research in the Aleutian Islands. Publication of his findings was delayed by the outbreak of the Russian Revolution, allowing him time to add an English translation and a critical review of previous research. When finally available, Jochelson's monographs (1925, 1933) became the seminal work on Aleutian prehistory and ethnography, defining the direction of research for several decades (see Maschner and Reedy-Maschner 2002a, b). On the question of Aleut origins, he definitively concluded that the island chain could not have been peopled from the west (Jochelson 1925, 115)—a view first posited by Dall (1877)—and that no evidence was present for a succession of material cultures (in contrast to Dall's argument for three cultural phases), thus establishing cultural continuity as a long-standing perspective in Aleutian prehistory.

In the late 1930s, Aleš Hrdlička (1945) organized three expeditions to the eastern Aleutian and Commander Islands, conducting limited archaeological excavations and collecting human remains from various burial contexts with the intention of examining genetic affinities between prehistoric Aleuts, Asians, and other regional populations. Returning to the Smithsonian, he hoped to learn when the Aleutians were occupied and revisit the issue of Aleut origins, seeking to identify an ancestral population in support of a growing consensus that the Americas were peopled by land migration from Asia. The bulk of his study population consisted of inhumations from Chaluka Midden (Hrdlička 1945, 364–81) in Nikolski village on western Umnak Island and mummified remains from burial caves on Ship Rock and Kagamil Islands (Hrdlička 1945, 237–42, 325–26), the former uninhabited, little more than an imposing rock in the narrow pass between Umnak

and Unalaska, and the latter among the Islands of the Four Mountains immediately west of Umnak (fig. 1).

In the course of his work, Hrdlička (1945) identified two biological types based on cranial morphology: pre-Aleuts, since renamed Paleo-Aleuts, and Aleuts, now called Neo-Aleuts (Laughlin and Marsh 1951, 79). The former were a high-vaulted, more oblong, dolichocranic form, with a taller, less robust postcranial configuration found nearly exclusively in Chaluka Midden, while the latter exhibited a low-vaulted, wider, rounder brachycranic cranium and were recovered from the Kagamil and Ship Rock burial caves. "The essential differences are those in the vault of the skull. The pre-Aleuts had a decidedly higher and more oblong vault. They also had an appreciably higher face, giving higher facial indices, a longer base, and less prognathism" (Hrdlička 1945, 575). Although inferential statistics were in use at the time, Hrdlička compared the means of discrete measurements to distinguish pre-Aleut from Aleut crania (Scott 1991, 8). Given his extensive experience, he is thought to have produced a reliable data set, and to our knowledge these collections have not been reanalyzed.

Hrdlička further hypothesized that Neo-Aleuts replaced Paleo-Aleut populations at ca. 1,000 BP, given the apparent superposition of the former in Chaluka Midden profiles. He

argued (1944) that a similar temporal distinction was also evident in the Pre-Koniag and Koniag skeletal series from the Uyak site on Kodiak Island, although cranial differences were not accompanied by distinctive postcranial morphologies and have been attributed at least in part to cranial deformation (see Fitzhugh 2003, 53–54; Scott 1991 for reviews). Unfortunately, in both cases the provenience of individual burials was poorly recorded, and at Chaluka human remains were catalogued separately from more carefully provenienced items of material culture, making it impossible to reconstruct the temporal sequence of burials. Today indigenous residents of the eastern Aleutians are brachycephalic while those who lived on the central and western islands during the last century tended to be dolichocephalic. An east-west trend in dental traits (Turner 1961) is also present among living and historic Aleut populations.

Following World War II, William Laughlin excavated additional burials at Chaluka Midden, obtaining a single radiocarbon date of 3,000 BP on charred wood a meter above the "natural floor" of the site (Laughlin and Marsh 1951, 81). Two later dates from 60 and 75 cm above the floor dated the occupation to $3,750 \pm 180$ and $3,600 \pm 180$ radiocarbon years BP respectively (Laughlin 1963, 74). Addressing Hrdlička's argument for population replacement, Laughlin

Modified from Fitzhugh and Chaussonnet (1994), Keenleyside (1994), and McNally (1977)
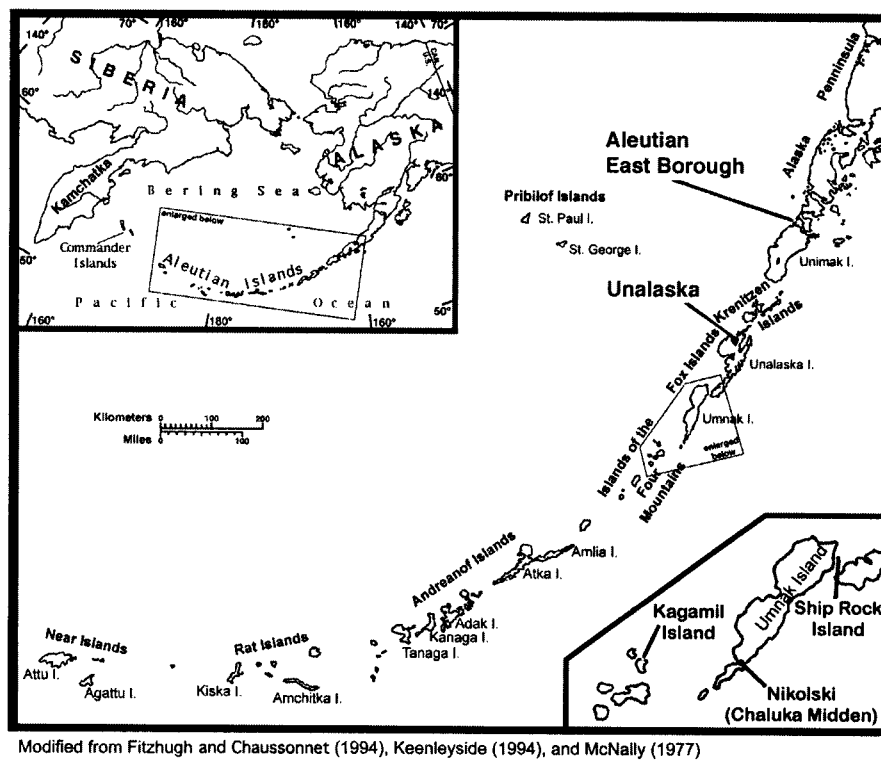
Figure 1. Map of study area and geographic location of Aleut skeletal samples (modified from Fitzhugh and Chaussonnet [1994], Keenleyside [1994], and McNally [1977]).

agreed that "rounded headed" individuals represented a recent influx of people of "Eskimo stock" who migrated only as far west as the Fox Islands in the eastern Aleutians, thus accounting for the presence of two geographically distinct "major breeding isolates" (Laughlin and Marsh 1951, 79). He also concluded that stylistic similarities in harpoon heads at Chaluka supported Jochelson's argument for cultural continuity. In sum, he argued for occupation of the Aleutians from the east at ca. 4,000 BP by people of Eskimo morphology possessing a typical Eskimo tool kit, followed at ca. 1,000 BP by the arrival "of a new Eskimo population having a somewhat different morphology" but similar material culture (Laughlin 1958, 1963; Laughlin and Marsh 1951, 82).

Laughlin and Marsh (1951, 82) also contended that grave goods accompanying some Kagamil mummies were of the same age as the "superficial layer" at Chaluka, indicating that they postdated Russian contact in 1741. In fact, people living at Nikolski knew by name some of those interred in Kagamil Island's warm cave (Laughlin 1958, 524). This was in keeping with Hrdlička's belief that his Kagamil mummies were no older than 100–200 years. More recently Hunt (2002) has argued that their remarkable state of preservation relative to the Dall/Hennig collection and the likelihood that Hennig would have removed all mummies present suggests that they were interred after his visit to the cave in 1873. A small set of unpublished radiocarbon readings on tissue and bone from Hrdlička's Kagamil collection, commissioned by the state of Alaska, dated the samples to 1,600–600 radiocarbon years BP (Hunt 2002). However, the significance of these dates was questioned when contamination issues were raised, and they remain uncorrected for marine-reservoir effect (p. 148).

During the same period in which Laughlin was working at Chaluka, he and Marsh performed test excavations at the Anangula Blade and Village sites on Anangula Island, along the northern rim of Nikolski Bay. Their interest in the sites derived from a 1938 visit to the Blade site, where Laughlin and Hrdlička had collected a handful of lithics. Named for its unifacial core and blade technology, the Anangula Blade site was considered contemporary with Chaluka's lowest occupational level (Laughlin and Marsh 1954, 36). Later, prompted by the recognition that the Blade site was overlain by the same 5,000-year-old ash fall upon which Chaluka Midden rested (Black 1966, 1976; Black and Laughlin 1964), Laughlin and Marsh obtained 33 radiocarbon readings. Dates ranged from 8,480 ± 350 to 6,992 ± 91 radiocarbon years BP (Laughlin 1975, table 1), leading Laughlin to present a revised argument for an unbroken occupation of Nikolski Bay spanning 8,700 years, ancestral populations having followed a coastal migration route along the southern margin of Beringia onto the Alaska Peninsula then west into the Aleutians. This revision called into question the argument for replacement of an earlier dolichocephalic people by an incoming brachycephalic population at ca. 1,000 BP. Laughlin (1975; Laughlin and Aigner 1975) resolved the seeming inconsistency by arguing that population densities increased over time in the

eastern Aleutians, becoming sufficiently large (∼10,000) to allow selection for cranial configuration to counter the effects of drift, selecting for Neo-Aleut brachycephaly, at ca. 1,000 BP, whereas population densities remained low in the central and western islands (∼5,000 and ∼1,000 respectively) and Paleo-Aleut dolichocephaly remained the dominant form. The argument was further amended in Turner, Aigner, and Richards (1974) with a reanalysis of excavations conducted by Laughlin during the 1962 field season. On the basis of two recent interments, Turner believed that the Neo-Aleuts recovered from Chaluka Midden postdated Russian contact and had indeed been brought to Chaluka by the Russians. Laughlin and Aigner (1975, 197) concurred, concluding that the "Neo-Aleut are clearly part of a postcontact relocation-migration at Chaluka. The only precontact Neo-Aleut skeletons known, as we predicted from density and size of effective breeding population, are in the east on Akun Island . . . according to Turner and Turner [1972]."

Although Aigner's (1976) critical review of radiocarbon dates from the Anangula Blade site effectively narrowed the duration of occupation from 1,500 to 500 years (see Dumond and Bland 1995 for an even shorter chronology and Mason 2001 for a review), her treatment of the Anangula culture was fully supportive of Laughlin's argument for continuous occupation of the eastern Aleutians by a single population until Russian contact (Aigner 1970, 60; see also Laughlin and Aigner 1975):

There are 4000 years of documented Aleut culture at Chaluka alone. Skeletons prove that the Chaluka people were racially Aleuts and geological, faunal and archaeological evidence documents continuity in exploitation activities over time. There is sound evidence that the area enjoyed a rich and stable ecosystem for longer than it was inhabited by humans; thus, the resource base available to the Anangula people was essentially the same as that associated with later Aleuts. All of the available geological, physical, linguistic and archaeological information indicate that the Aleutians have been occupied by a single population system—that of the Aleuts . . . a single human population, well isolated from other people.

The persistence of a suite of archaeological traits, prominent among them carved stone lamps, stone bowls, faceted red ochre grinders, and grinding pallets, testified to "deep-seated, complex, pervasive Aleut cultural patterns" (Laughlin and Aigner 1975, 190).

Reviews of Aleutian prehistory from the following decade concurred with regard to the east-to-west habitation of the island chain from a gateway on the Alaska Peninsula (e.g., Laughlin 1980; McCartney 1984) and supported a ca. 8,000-year-old occupational date for the Anangula Blade site. However, the belief that the Aleutians had been characterized by a stable, rich resource base since the early Anangula phase (Aigner 1970) was undermined by the appearance of shell middens at 4,500 BP, suggesting greater reliance on marine

Table 1. Aleutian Burials with Sex, Cranial Category, and Radiocarbon Measurements Sorted by Site and Within Site by Cal Age BP

Curation No.	Site	Sex	Cranial Category[a]	AA Number	Radiocarbon Age BP	Cal Age BP	Cal 2σ Range BP	Cal Intercept Date AD	Cal 2σ Range AD
17485	Kagamil	F	NA	43237	952 ± 41	386	283–487	1564	1463–1667
377810	Kagamil	F	NA	43242	1,026 ± 50	449	308–538	1501	1412–1642
377815	Kagamil	F	NA	57420	1,056 ± 40	476	330–556	1474	1394–1620
377919	Kagamil	M	NA	57431	1,059 ± 40	479	330–560	1471	1390–1620
377920	Kagamil	F	NA	57432	1,070 ± 40	487	365–603	1463	1347–1585
377918	Kagamil	F(?)	NA	57430	1,088 ± 41	500	403–620	1450	1330–1547
377911	Kagamil	F	NA	57426	1,104 ± 41	512	425–622	1438	1328–1525
377817	Kagamil	M	NA	57421	1,106 ± 41	514	427–623	1436	1327–1523
377811	Kagamil	F	NA	46433	1,111 ± 42	518	431–625	1432	1325–1519
377914	Kagamil	F	NA	57427	1,116 ± 41	521	437–626	1429	1324–1513
377916	Kagamil	M	NA	57429	1,162 ± 41	557	476–645	1393	1305–1474
377818	Kagamil	F	NA	57422	1,170 ± 43	562	479–649	1388	1301–1471
377813	Kagamil	M	NA	57419	1,182 ± 41	571	489–653	1379	1297–1461
377917	Kagamil	M	NA	46432	1,182 ± 45	571	485–655	1379	1295–1465
377812	Kagamil	M	NA	46426	1,185 ± 42	572	490–655	1378	1295–1460
377906	Kagamil	M	NA	57424	1,193 ± 41	577	495–658	1373	1292–1455
377915	Kagamil	F	NA	57428	1,200 ± 41	581	498–661	1369	1289–1452
377901	Kagamil	M	NA	43243	1,206 ± 51	585	491–675	1365	1275–1459
377902	Kagamil	M	NA	43235	1,214 ± 58	589	488–692	1361	1258–1462
377808	Kagamil	F	NA	43240	1,216 ± 32	590	511–662	1360	1288–1439
377814	Kagamil	F	NA	46427	1,227 ± 45	596	507–684	1354	1266–1443
377816	Kagamil	M	NA	46428	1,228 ± 43	596	508–682	1354	1268–1442
377903	Kagamil	M	NA	43236	1,234 ± 54	601	503–704	1349	1246–1447
377910	Kagamil	M	NA	57425	1,247 ± 41	609	518–697	1341	1253–1341
17479	Kagamil	M	NA	43238	1,255 ± 62	616	505–736	1334	1214–1445
377821	Kagamil	F	NA (?)	46430	1,257 ± 43	616	521–710	1334	1240–1429
377904	Kagamil	F	NA	43245	1,266 ± 52	624	518–730	1326	1220–1432
377809	Kagamil	F	NA	43241	1,292 ± 34	645	543–734	1305	1216–1407
377807	Kagamil	M	NA	43239	1,331 ± 45	679	550–796	1271	1154–1400
377900	Kagamil	M	NA	57423	1,353 ± 43	699	573–832	1251	1118–1377
377819	Kagamil	F	NA	46429	1,401 ± 42	741	645–881	1209	1069–1305
377913	Kagamil	M	NA	46431	1,580 ± 52	916	752–1,060	1034	890–1198
378462	Ship Rock	M	NA	43250	1,071 ± 39	488	370–604	1462	1346–1580
378472	Ship Rock	M	NA (?)	43256	1,237 ± 41	602	513–687	1348	1263–1437
378543	Ship Rock	M	NA	57437	1,263 ± 44	621	524–717	1329	1233–1426
378542	Ship Rock	F	NA	57436	1,335 ± 44	683	553–801	1267	1149–1397
378461	Ship Rock	M	NA	43249	1,336 ± 59	686	545–836	1264	1114–1405
378474	Ship Rock	M	NA	43247	1,361 ± 45	706	604–868	1244	1082–1346
378464	Ship Rock	M	NA	43251	1,372 ± 39	714	623–859	1236	1091–1327
378467	Ship Rock	F	PA	57434	1,400 ± 44	740	644–883	1210	1067–1306
378469	Ship Rock	M	NA	43253	1,410 ± 39	749	652–882	1201	1068–1298
378544	Ship Rock	M	NA	57438	1,410 ± 41	749	651–884	1201	1066–1299
378468	Ship Rock	F	PA	43252	1,420 ± 37	758	658–887	1192	1063–1292
378463	Ship Rock	M	PA	57433	1,434 ± 42	773	663–899	1177	1051–1287
378471	Ship Rock	M	NA (?)	43255	1,446 ± 44	785	669–907	1165	1043–1281
378541	Ship Rock	F	NA (?)	57435	1,457 ± 41	795	676–911	1155	1039–1274
378470	Ship Rock	F	NA	43254	1,506 ± 56	838	685–967	1112	983–1265
378473	Ship Rock	F	NA	43257	1,506 ± 42	839	705–953	1111	997–1245
378606	Chaluka	F	PA	43226	962 ± 48	393	284–498	1557	1452–1666
378613	Chaluka	F	PA	43231	977 ± 38	407	298–499	1543	1451–1652
378619	Chaluka	F	PA	46415	1,268 ± 82	629	487–795	1321	1155–1463
378610	Chaluka	M	PA	43244	1,306 ± 53	658	535–780	1292	1170–1415
378663	Chaluka	F	PA (?)	40425	1,335 ± 43	683	554–799	1267	1151–1396
378607	Chaluka	M	PA	43227	1,343 ± 59	692	551–846	1258	1104–1399
378615	Chaluka	M	PA	43233	1,351 ± 48	698	564–835	1252	1115–1386
378620	Chaluka	M	PA	46416	1,348 ± 82	702	544–886	1248	1064–1406
378612	Chaluka	M	PA	43230	1,363 ± 95	718	542–909	1232	1041–1408
378609	Chaluka	M	PA	43248	1,392 ± 39	732	641–872	1218	1078–1309
378608	Chaluka	F	PA	43228	1,404 ± 62	749	631–907	1201	1043–1319
378603	Chaluka	M	PA	43223	1,441 ± 65	783	650–924	1167	1026–1300

378611	Chaluka	M	NA	43229	1,479 ± 42	816	687–927	1134	1023–1263
378605	Chaluka	M	PA	43225	1,485 ± 44	821	688–933	1129	1017–1262
378629	Chaluka	M	PA	46422	1,536 ± 32	868	737–972	1082	978–1213
378601	Chaluka	F	PA	43246	1,566 ± 52	900	744–1,047	1050	903–1206
378604	Chaluka	F	PA	43224	1,573 ± 44	908	763–1,046	1042	904–1187
378622	Chaluka	M	PA	46418	1,830 ± 84	1,170	962–1,340	780	610–988
378623	Chaluka	F	PA	57414	1,918 ± 43	1,261	1,134–1,387	689	563–816
378602	Chaluka	M	PA	43222	1,944 ± 37	1,285	1,170–1,399	665	551–780
378633	Chaluka	M	PA	57417	2,025 ± 44	1,362	1,257–1,504	588	446–693
378627	Chaluka	M	PA	57416	2,042 ± 44	1,378	1,268–1,513	572	437–682
378639	Chaluka	F	PA	57418	2,044 ± 44	1,380	1,270–1,514	570	436–680
378621	Chaluka	F	PA	46417	2,044 ± 84	1,388	1,202–1,597	562	353–748
378616	Chaluka	F	PA	43234	2,124 ± 67	1,462	1,292–1,643	488	307–658
378646	Chaluka	F	PA	46424	2,179 ± 44	1,524	1,377–1,686	426	264–573
378614	Chaluka	M	PA	43232	2,805 ± 54	2,258	2,082–2,449	BC 309	BC 500–133
378628	Chaluka	F	PA	46421	2,838 ± 48	2,305	2,120–2,486	BC 356	BC 537–171
378624	Chaluka	M	PA	57415	3,708 ± 57	3,380	3,206–3,557	BC 1431	BC 1608–1257
378625	Chaluka	M	PA	46419	3,722 ± 88	3,396	3,150–3,635	BC 1447	BC 1686–1201
378626	Chaluka	M	PA	46420	3,754 ± 54	3,431	3,267–3,604	BC 1482	BC 1655–1318
378630	Chaluka	F	PA	46423	3,758 ± 42	3,434	3,301–3,594	BC 1485	BC 1645–1352

[a] NA = Neo-Aleut; PA = Paleo-Aleut.

invertebrates (McCartney and Veltre 1999). Evidence for the development of strand flats and thus access to littoral resources indicated not only the presence of a "starvation larder" but also that children and the elderly were able to participate more effectively in food acquisition (Laughlin 1980), perhaps supporting increased population densities and underwriting the deep time depth of Chaluka Midden.

In his monograph, Laughlin (1980, 89) referred briefly to the Paleo-/Neo-Aleut transition at Chaluka, indicating that while the issue had not been fully dismissed, it was also not diagnostic of an event unique to Aleutian prehistory. "Passage from the earlier, more narrow-headed form to the broad-headed form . . . appears to represent an evolutionary change within the Aleut population system that is comparable to the same direction of change in all other parts of the world." In contrast, McCartney (1984, 122) noted, without, however, contextualizing his comments, that "in spite of Hrdlička's (1945) questionable field procedures used in dividing early longheaded peoples from later broadheaded ones, physical anthropologists still support this two-population model. In fact, Hrdlička's contention that Aleuts were late prehistoric or early historic people is supported by study of midden stratigraphy during the 1960s and 1970s (Turner et al. 1974)." The Paleo/Neo-Aleut population-replacement argument received virtually no attention in a recent edited volume highlighting current research in the Aleutians (Dumond 2001*a*), suggesting that Laughlin's (1980) treatment of the issue had been widely accepted despite McCartney's views.

Current Research

We have obtained 80 accelerator radiocarbon dates on purified bone collagen from individuals recovered in three burial contexts in the eastern Aleutians. This research represents one component of a larger project focusing on the genetic and dietary history of Aleutian foraging populations, the results of which are dealt with briefly here and in detail elsewhere (see Hayes et al. 2005). Because bone collagen preservation was carefully monitored and the stable carbon isotope chemistry of each individual was analyzed, we are able to eliminate concerns regarding contamination or diagenesis of dated proteins and employ a calibrated correction for marine-reservoir effect, thus producing a data set useful for addressing Hrdlička's population-replacement hypothesis and the time depth of these collections.[1] A brief discussion follows regarding the methodology upon which our calibration of marine-reservoir effect was based.

Stable carbon isotope analysis. Stable carbon isotope analysis

1. One gram of cortical bone was cleaned of surface contaminants and then soaked for 24 hours in 2 : 1 toluene : methanol, followed by 24 hours of soxhlet extraction in the same solvent mixture to treat for sea mammal oil contamination. Samples were demineralized whole in 0.6N HCl at 4°C, rinsed to neutrality, and treated with 5% KOH to remove organic contaminants. The acid- and base-extracted collagen pseudomorph was again rinsed to neutrality and lyophilized and a fraction curated. Approximately 100 mg of lyophilized collagen was gelatinized in 5 ml of acidified water (pH 3) for 24 hours at 120°C. Water-soluble and -insoluble phases were separated by filtration and the water-soluble phase lyophilized for isotope analysis. Collagen δ^{13}C and δ^{15}N values were determined by flash combustion to produce CO_2 and N_2 and then measured against the appropriate reference gas on a Finnigan Delta Plus mass spectrometer coupled with a Carlo Erba EA118 CHN elemental analyzer at the Stable Isotope Ratio Facility for Environmental Research at the University of Utah. Stable isotope measurements and sample weight percent carbon and nitrogen were obtained from a single sample combustion. Analytic precision is 0.1‰ for stable carbon isotope measurements and 0.2‰ for nitrogen. Atomic-carbon-to-nitrogen ratios were calculated from weight percent C and N and provided a widely used measure of protein preservation (Ambrose 1990). Aleutian skeletal samples exhibited high collagen yields and near-modern protein preservation. Approximately 10 mg of purified collagen were forwarded to the NSF-Arizona AMS Facility, Tucson, for dating, and dates were forwarded to the NSF-Arizona AMS Facility, Tucson, for dating, and dates were normalized using measured δ^{13}C values.

is frequently used to estimate reliance on marine resources in forager diets lacking a C_4 component. Introduced by Tauber (1981) to demonstrate a reduction in dependency on marine foods at the Mesolithic to Neolithic transition in coastal Denmark (see also Chisholm, Nelson, and Schwarcz 1982), stable carbon isotope analysis has been widely used to reconstruct mixed marine/terrestrial diets (e.g., Coltrain, Hayes, and O'Rourke 2004; Lovell, Nelson, and Schwarcz 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). Stable carbon isotope reconstructions of past diets derive from the following principles:

When atmospheric CO_2, dissolved CO_2, or marine bicarbonates (HCO_3-) are incorporated into plant tissues during photosynthesis, physical and metabolic processes alter or fractionate the ratio of ^{13}C to ^{12}C, depleting it relative to the substrate from which it was taken. This ratio ($^{13}C/^{12}C$) is expressed in delta ($\delta^{13}C$) notation as parts per mil (‰) difference from an internationally recognized standard (Craig 1957). The degree of discrimination against $^{13}CO_2$ during photosynthesis covaries with photosynthetic pathway type (Farquhar, Ehleringer, and Hubick 1989). Submerged marine plants, terrestrial cool-season grasses, trees, and most bushy plants employ C_3 photosynthetic mechanisms that discriminate heavily against ^{13}C. Thus, modern terrestrial C_3 plants express a mean $\delta^{13}C$ value of -26.7 ± 2.7‰ ($n = 370$) (Cerling, Ehleringer, and Harris 1998), approximately 19‰ more depleted than atmosphere. Alternatively, kinetic processes governing bicarbonate (HCO_3-) formation in seawater fractionate marine bicarbonates approximately 7‰ relative to atmosphere, placing seawater $\delta^{13}C$ values near 0‰ (Tauber 1981; Chisholm, Nelson, and Schwarcz 1982). Because submerged marine plants employ a C_3 photosynthetic pathway and derive carbon primarily from seawater bicarbonates, they express mean $\delta^{13}C$ values of -16 to -18‰, approximately 7‰ more positive than terrestrial C_3 plants, giving them a distinctive marine label. This label is passed from producer to consumer, leaving a diagnostic signature in both hard and soft consumer tissues.

Fractionation between primary producers and consumer bone collagen approximates 5‰, and enrichment at higher trophic levels approaches 1‰ (Katzenberg 1993). Adult bone collagen $\delta^{13}C$ values represent a weighted average of long-term dietary intake, since the carbon in bone collagen turns over slowly, requiring ca. 30 years to replace existing carbon with an equivalent amount of carbon (Harkness and Walton 1972; Libby et al 1964; Stenhouse and Baxter 1977, 1979).

Stable nitrogen isotope analysis. Because $^{15}N/^{14}N$ increases by approximately 2–4‰ with each increase in trophic level, nitrogen isotope ratios ($\delta^{15}N$) monitor the trophic level of sampled diets. Enrichment is primarily associated with discrimination against isotopically heavy urea at renal membrane boundaries, enriching the isotope signature of nitrogen available for protein synthesis (Schoeller 1999). Atmospheric nitrogen is the analytical standard, with a $\delta^{15}N$ value of 0‰. Phytoplankton are primary producers in marine ecosystems and exhibit nitrogen isotope ratios in the 4–8‰ range with a mean of approximately 6‰ (Peterson 1999). High-latitude foragers subsisting at the top of marine food webs commonly exhibit $\delta^{15}N$ values in the 18–20% range (Coltrain, Hayes, and O'Rourke 2004).

Results. Dates in radiocarbon years before present (normalized using measured $\delta^{13}C$ values), calibrated intercept dates, and two-sigma ranges are shown in table 1. All burials date to well before Russian contact. The oldest Chaluka burial has a two-sigma range of cal 3,301–3,594 BP, predating a 3,000-BP occupational boundary suggested by Dumond (2001b). Also, and perhaps of greatest interest, all individuals dating older than ca. cal 1,000 BP are Paleo-Aleuts ($n = 10$) from Chaluka Midden. Shortly after cal 1,000 BP, Neo-Aleut populations appear in the eastern Aleutian record at Chaluka and elsewhere and are fully contemporary with Paleo-Aleuts (figs. 2 and 3).

Mean stable carbon and nitrogen isotope values (tables 2 and 3) reflect similar diets high in high-trophic-level marine resources. All samples produced high collagen yields and met established preservation criteria (Ambrose 1990). Site mean $\delta^{13}C$ values were very similar, within 0.2‰ of the overall mean value (-12.5 ± 0.5‰). Thus, we estimate that Aleutian diets averaged 95% marine intake and use this statistic to calibrate
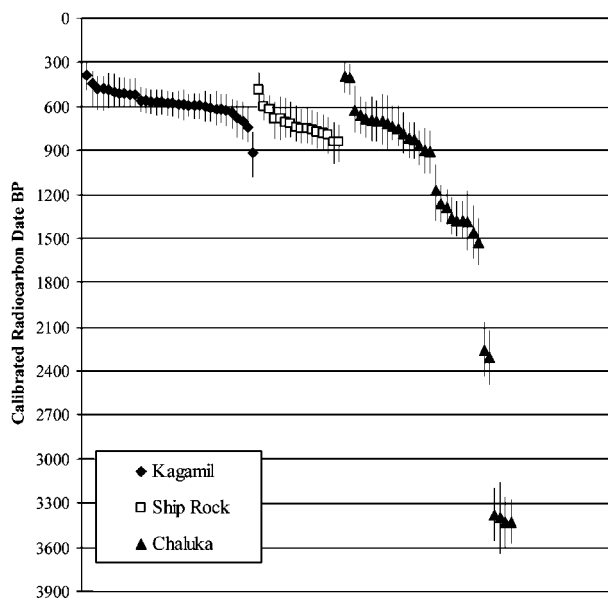

Figure 2. Calibrated Aleut radiocarbon dates at two sigma graphed by archaeological site of origin. Because the relationship between radiocarbon and solar years varies over time, the effects of calibration can appear to offset marine-reservoir effect corrections; for example, our oldest sample dates to $3,758 \pm 42$ radiocarbon years BP but calibrates to 3,434 BP, while the youngest dates to 952 ± 41 and calibrates to 386 BP (table 1).
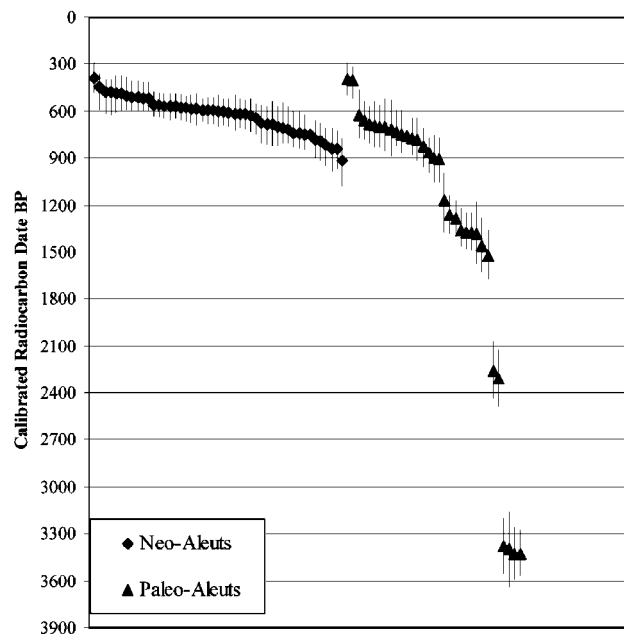
Figure 3. Calibrated Aleut radiocarbon dates at two sigma graphed by Hrdlička's cranial categories.

marine-reservoir effect. While percent marine intake could be calculated on each individual, using the most positive individual value in the data set as the benchmark for a 100% marine diet (−11.3‰), there is little reason to expect this method to be more accurate. Values reflect both percent marine intake and trophic level of intake, and therefore calculating individual percentages is likely to introduce a false level of confidence in the absence of isotope values on commonly exploited foods. An individual with a slightly enriched $\delta^{13}C$ value relative to the mean may merely have consumed a slightly higher-trophic-level diet. Mean $\delta^{13}C$ values accurately reflect diets extremely high in marine foods, and ethnographic data (e.g., Laughlin 1980) indicate that a 95% estimate is reasonable (see also Arneborg et al. 1999; Coltrain, Hayes, and O'Rourke 2004 for additional discussion of percent marine intake based on $\delta^{13}C$ values).

Dates were calibrated using Calib 4.4 (Stuiver and Reimer 1993), which weights global (+ 400 radiocarbon years) and regional marine reservoir effects (ΔR; Stuiver and Braziunas 1993) relative to reliance on marine foods. In addition to the global correction, a regional correction of $+237 \pm 50$ radiocarbon years was used and is an estimate of ΔR calculated on the bivalve *Protothaca staminea* collected in Pavlov Harbor (162° W) near Port Moller on the Alaska Peninsula (Robinson and Thompson 1981). This ΔR value is the best regional estimate available for the effects of upwelling on radiocarbon readings in the study area but may not precisely capture that effect because the intensity of upwelling and therefore the intraregional contribution of carbon depleted in ^{14}C to marine food webs can vary both temporally (Deo, Stone, and Stein

2004) and spatially. For example, Dumond and Griffin (2002) dated marine-mammal/wood-charcoal and marine-shell/wood-charcoal pairs from the eastern Bering Sea, demonstrating that in sea-mammal/charcoal pairs ΔR was larger and more varied than in the marine-shell/charcoal pairs sampled. They provisionally attributed this finding to the wide-ranging foraging strategies characteristic of some marine mammals versus the relatively stationary feeding ecology of bivalves (see also Fitzhugh et al. 2002). We make two brief comments regarding the uncertainty associated with ΔR corrections illustrated by Dumond and Griffin (2002) and similar studies. First, ΔR is difficult to measure accurately with paired samples of assumed age. While undoubtedly every effort was made to ensure that marine samples were matched with contemporary wood charcoal, it cannot be demonstrated that matched pairs were of relatively the same age in solar years. Contemporaneity is an underlying assumption, and previous research, as well as data reported here, has shown that it is not always correct (i.e., Coltrain, Hayes, and O'Rourke 2004). Ensuring contemporaneity may be particularly problematic in high-latitude settings, where driftwood is the primary source of wood charcoal. The only study we are aware of in which the contemporaneity of paired samples for calibration of ΔR was ensured entailed the paired dating of Greenland Viking burials and fibers from the clothing in which dated individuals were wrapped for burial (Arneborg et al. 1999).

Nonetheless, it is clear that upwelling varies temporally and spatially both within and between regions, and wide-ranging or migratory taxa, those consumed by human foragers as well as by their prey, complicate the calculation of ΔR values. In this regard, Yesner (1977, 1981) analyzed the Chaluka Midden faunal assemblage and those of three additional sites in the eastern Aleutians and argued that four sea mammals, sea otter (*Enhydra lutris*), northern sea lion (*Eumetopias jubatus*), fur seal (*Callorhinus ursinus*), and hair or harbor seal (*Phoca vitulina*), provided approximately 99% of marine caloric intake, with birds, fish, and invertebrates supplying the reminder (Yesner 1977: table 33; see also Davis 2001). Although Yesner may have somewhat overestimated the importance of sea mammals, their feeding ecology is likely to have had the greatest effect on ΔR among the burials under study. Because of their size, northern or Steller sea lions, which are not migratory, may have made the greatest contribution to eastern

Table 2. Mean Isotope Values for Burials from the Eastern Aleutians by Cranial Category, Age, and Site

	n	$\delta^{13}C$	$\delta^{15}N$
Paleo-Aleut	34	−12.3 ± 0.5	19.3 ± 0.7
Neo-Aleut	46	−12.6 ± 0.4	20.3 ± 0.8
Post-1,000 BP	19	−12.1 ± 0.4	19.5 ± 0.7
Pre-1,000 BP	15	−12.5 ± 0.6	19.1 ± 0.6
Chaluka	32	−12.3 ± 0.5	19.2 ± 0.6
Kagamil	32	−12.7 ± 0.3	20.3 ± 0.6
Ship Rock	16	−12.4 ± 0.5	20.4 ± 1.0

Table 3. Significance of Differences in Mean Isotope Values for Burials from the Eastern Aleutians by Cranial Category, Site, and Age for Paleo-Aleut Samples

	p	
	$\delta^{13}C$‰	$\delta^{15}N$‰
Paleo-Aleut/Neo-Aleut	0.002	<0.001
Kagamil/Chaluka	0.001	<0.001
Ship Rock/Kagamil	0.01	n.s.
Ship Rock/Chaluka	n.s.	<0.001
Paleo-Aleut Pre-/Post-1,000 BP	0.02	n.s.

Aleutian forager diets. They breed throughout the Aleutians and can be encountered year-round in the region, although males in the northernmost areas of the Bering Sea can be displaced southward by the formation of winter sea ice (Sease and York 2003). Likewise, neither the sea otter nor Arctic phocid species are migratory. However, while northern fur seal males currently remain in the region year-round, juveniles and females may migrate as far south as central California (Crockford, Frederick, and Wigen 2002; Trites and Bigg 1996). The average ΔR for northern California is +271 ± 19 years (Robinson and Thompson 1981; Ingram and Southon 1996), not widely disparate from the Port Moller value used here, while that of the San Francisco Bay is +327 ± 52 (Ingram and Southon 1996). Clearly, the ΔR value of female fur seal, as well as that of sea birds and perhaps other prey types, may differ somewhat from the Port Moller value. However, our inability to estimate ΔR precisely with respect to the specific migratory component of each individual's diet does not invalidate our results, since it is unlikely to have a marked effect on the strongly patterned, relative temporal distribution of Paleo- to Neo-Aleut burials and has no effect on their spatial distribution or mortuary context.

Discussion

The youngest individual in this data set (17485) was likely interred in Kagamil Island's "warm cave" during the mid-sixteenth century, with an intercept date of cal. AD 1564 and a two-sigma range of AD 1463–1667 (table 1). This individual was one of two in our sample recovered by Dall; the other, dated to cal. AD 1255 (17479), fell well within the age-range of Hrdlička's collection, indicating no detectable temporal bias in Dall's assemblage. Kagamil burial intercept dates range from AD 1034 to 1564, the majority falling in the fourteenth century, whereas Ship Rock burials cluster in the twelfth and thirteenth centuries, with a two-sigma range of AD 1346–1580. The most recent individual interred in Chaluka Midden dates to AD 1557 with a two-sigma range of AD 1452–1666, virtually identical to the most recent interment at Kagamil's warm cave and clearly predating Russian contact.

If uncalibrated, our earliest Kagamil date, 1,580 BP, is very similar to the earliest date cited by Hunt (2002, 148), but our Kagamil data set does not include individuals younger than 952 radiocarbon years BP, whereas the range of dates Hunt cited terminates at 600 BP and would include modern or near-modern individuals if corrected for marine-reservoir effect. Although our random sampling strategy may have included the oldest interments at Kagamil and perhaps Ship Rock, we may not have captured the full temporal range of these sites. In the absence of a publication that includes identification of the individuals and chemical fraction dated as well as pretreatment procedures, etc., it is not possible to comment further on the dates cited by Hunt relative to our results.

Four Chaluka burials are older than cal. 3,000 BP, the oldest with a two-sigma range that terminates at ca. cal. 3,600 BP (table 1, fig. 2). Thus, a 4,000-BP occupational date for Chaluka is reasonable. With one exception (378611), our entire Chaluka data set is Paleo-Aleut and dates from cal. 3,635–535 BP, with what could be construed as evidence for an occupation hiatus between ca. cal. 3,000–2,500 BP and cal. 2,000–1,500 BP. The single Neo-Aleut sampled from Chaluka dates to cal. 816 BP. All burials from Kagamil and all but two Ship Rock burials are Neo-Aleut and fully contemporary with the youngest Paleo-Aleut individuals interred at Chaluka (fig. 3).

As noted, all individuals older than ca. cal. 1,000 BP are Paleo-Aleut (fig. 3), and most were inhumations recovered from Chaluka Midden. An interesting set of implications derives from this patterning. First, it appears that Paleo-Aleuts may represent the oldest population in the eastern Aleutians and that they buried their dead as inhumations. Hrdlička (1945, 364–81) consistently referred to remains recovered at Chaluka Midden as "skeletons" in contrast to "mummies," the term he used to describe those from Kagamil and Ship Rock Islands (Hrdlička 1945, 237–42, 325–26). Second, Paleo- and Neo-Aleut people were fully contemporary on Umnak Island after cal. 1,000 BP, falsifying Hrdlička's population-replacement hypothesis. Also, it appears that Paleo-Aleuts continued burying their dead as inhumations for nearly a millennium after the initiation of Neo-Aleut mummification rituals (Frohlich and Laughlin 2002; Hrdlička 1945; Hunt 2002; Jonsdottir 2002; Laughlin 1980; Lynnerup and Sørensen 2002). Hrdlička (1945, 399) recorded one curious exception to the common Paleo-Aleut burial practice:

> In the warm cave [Kagamil], below all the mummies removed in '36, under a great slab . . . found a cremation burial of a woman and child, doubtless sacrificed slaves. But the layer of burnt bones was found to extend farther . . . showing the burnt remains of possibly as many as 10 individuals, seemingly all females and young. . . . One largely burnt skull in pieces taken for reconstruction has shown the pre-Aleut type.

Frohlich and Laughlin (2002, 92) indicate that "the Unangan [or Neo-Aleuts] preserved all deceased members of their community from new-born to elderly and of both sexes."

In some cases, remains were clothed and then wrapped in animal skins or woven matting. In other cases, mummification was accomplished by removing internal organs and filling the body cavity with dried grasses before wrapping. After a suitable passage of time, such remains, commonly accompanied by grave goods, kayaks, hunting implements, etc., were placed on the floor or suspended from the wall or ceiling of a dry cave or rock shelter. Mummified remains were also interred in *umqan*, suspended in above-ground "huts," and sealed in burial compartments within households (see Veniaminov and others cited in Hrdlička 1945, 179–82; see also Laughlin 1980). Infant remains were bundled and might be kept within household living quarters for many weeks (Frohlich and Laughlin 2002; Hrdlička 1945; Hunt 2002). Minimally, these practices served to inhibit decay by keeping the bodies of the deceased dry.

The post–cal-1,000-BP appearance of a Neo-Aleut form on Umnak Island in correlation with the appearance of an ideologically complex mandate to preserve the deceased appears to indicate that Neo-Aleuts represent an influx of people from the east characterized by a level of social complexity exceeding that of the Paleo-Aleuts. Fitzhugh (2003) makes a compelling argument for increased social competition and alliance formation on Kodiak Island at the termination of the Late Kachemak phase (ca. AD 1000–1200), evidenced by technological intensification and the addition of defensive sites, as well as distinctive mortuary practices that included cremation, curation of human bone, disarticulation, and possible mummification (Simon and Steffian 1994). He also notes that mortuary practices which distinguish high- from low-ranking members of society and slaves from nonslaves are among the archaeological indicators of social inequality (Fitzhugh 2003, 129). Increased competition for positions of status, leading to higher levels of violence on the Alaska Peninsula or Kodiak Island, may have motivated the migration of Neo-Aleut people into the eastern Aleutians. Once in place, their distinctive mortuary practices would have been among the cultural markers that served to maintained class distinctions. Increased social complexity coincident with the arrival of Neo-Aleut people is also supported by the post-1,000-BP appearance of fortified refuge rocks and longhouses, the latter not found west of the Islands of the Four Mountains but reminiscent of large, multiroomed, semisubterranean residential structures on Kodiak Island and the Alaska Peninsula (Fitzhugh 2003; Johnson and Wilmerding 2001; McCartney and Veltre 2002).

The results of a recent mtDNA study are also consistent with an influx of people from the Alaska Peninsula (Hayes et al. 2005). Hayes (2002, 109) initially haplotyped 30 individuals from the collection under study and reported that "the two cranial types are members of a single continuous population," exhibiting a nearly identical distribution of A and D mitochondrial haplogroup frequencies. However, when the mtDNA study was expanded to include all 80 radiocarbon-dated individuals, a statistically significant difference in haplogroup frequencies between Paleo- and Neo-Aleut people was evident (Hayes et al. 2005). Paleo-Aleut haplogroup frequencies were also significantly different from those of modern Aleuts (see Zlojutro et al. 2005), and high frequencies of haplogroups A and D suggest that the Aleutian Islands were colonized from the east (Hayes 2002; Torroni et al. 1993).

It is also worth noting that significant differences exist in the mean isotope chemistry of Paleo- and Neo-Aleuts, as well as in the mean $\delta^{13}C$ values of post- and pre-1,000-BP Paleo-Aleuts and between sites in both isotopes. Although mean differences that are significant are small, they exceed analytical precision for these methodologies (0.1‰ for carbon isotope measurements and 0.2‰ for nitrogen), and in the case of Paleo- vs. Neo-Aleut $\delta^{15}N$ values the mean difference is several times greater. Thus, these differences are not likely to be the product of random variation or analytical error but represent measurable differences in diet. The following general patterns are evident: (1) Neo-Aleuts have significantly enriched mean $\delta^{13}C$ and $\delta^{15}N$ values, indicating that they were more reliant on higher-trophic-level marine foods than both pre- and post-1,000-BP Paleo-Aleuts, who may have relied more heavily on littoral resources. (2) Post-1,000-BP Paleo-Aleut diets are not significantly higher in trophic level than pre-1,000-BP diets, but their mean $\delta^{13}C$ value is significantly more positive. This indicates that, while the trophic levels of these diets remained relatively constant over time, a higher percentage of nearshore (versus offshore) foraging pinnipeds may have been taken (Burton and Koch 1999), suggesting a change in foraging strategies with the arrival of Neo-Aleut people. (3) Between-site differences are largely due to the intersite distribution of Paleo- versus Neo-Aleuts. While it is not possible to fully reconstruct eastern Aleutian diets, given the absence of isotope data on prey taxa, it is clear that persistent differences existed in the economic practices of Paleo- versus Neo-Aleut foragers. Until specific diets are identified, it is difficult to explain these differences fully, but they suggest that Neo-Aleuts represent a distinct, socially and economically complex foraging population.

In sum, all remains in the study older than ca. cal. 1,000 BP are Paleo-Aleut. Neo-Aleut burials date after cal. 1,000 BP and coexist with Paleo-Aleuts until shortly before Russian contact. As far as we are able to determine, Neo-Aleuts from cave contexts were mummified interments, while Paleo-Aleut midden burials were inhumations. This pattern, along with other evidence for increased social stratification and significant differences in mtDNA haplogroup frequencies, indicates that Neo-Aleuts represent an influx of relatively closely related people migrating westward along the island chain and characterized by elaborate mortuary practices and heightened social and economic complexity. Significant social disparities between Paleo- and Neo-Aleut people may have existed but were largely subsumed in the social and demographic upheaval following Russian contact. Ongoing research with faunal collections and skeletal populations originating farther east in the island chain will further clarify these issues.

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