

AMS RADIOCARBON DATES ON PEAT SECTION RELATED WITH TEPHRA AND ARCHAEOLOGICAL SITES IN CARLISLE ISLAND, THE ISLANDS OF FOUR MOUNTAINS, ALASKA

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ABSTRACT. We obtained radiocarbon (¹⁴C) dates with accelerator mass spectrometry (AMS) of vascular plant samples and a charcoal sample collected from peat deposits near the prehistoric village site informally designated CR-03 on Carlisle Island in the Islands of Four Mountains group, Alaska, to determine the eruption age of the CR-02 tephra. A fine vitric ash erupted from Okmok caldera, Umnak Island (ca. 2 ka BP) was also discovered in the bog. The ages of the CR-02 tephra and Okmok II ash are estimated to be 1050 and 2000 cal BP, respectively. Because both tephtras are distinctive and widespread, these are important chronostratigraphic markers for archaeological sites in this island group. The ¹⁴C dates obtained from this bog are 800 years younger than the dates of the charcoal fragments from cultural layers in the Unit 3 of prehistoric village site CR-02 (AMK-0003).

KEYWORDS: AMS radiocarbon dating, archaeological site, Carlisle Island, post-depositional disturbance, tephra and peat layers.

INTRODUCTION

The Aleutian Islands, Alaska, are located on the boundary of the Pacific Ocean and the Bering Sea (Figure 1). For nearly 9000 years, Aleutian peoples built villages and prospered in the eastern part of this archipelago. The climate of the Aleutians is cool to cold and supports grass and forb vegetation (tundra). During the Holocene period, soil and tephra complexes were deposited on the islands (Figure 2a; Coats 1956). The Islands of the Four Mountains (IFM) is a group of eight volcanic islands. Herbert and Carlisle represent single volcanoes; Chuginadak comprises two volcanic cones—Tana and Cleveland—that have coalesced, forming an isthmus (Figure 1). We conducted field surveys in 2014 and 2015 to determine geological hazards, climate change, and human/ecosystems resilience in the IFM (Hatfield et al. 2016).

We identified a distinctive and coarse-grained tephra (referred to as the CR-02 tephra) intercalated with cultural layers at the prehistoric village site CR-02 (AMK-0003) on Carlisle Island (Figure 3). The cultural deposits immediately above the CR-02 tephra suggest that prehistoric humans almost immediately returned to their village following this particular eruption (Okuno et al. 2015).

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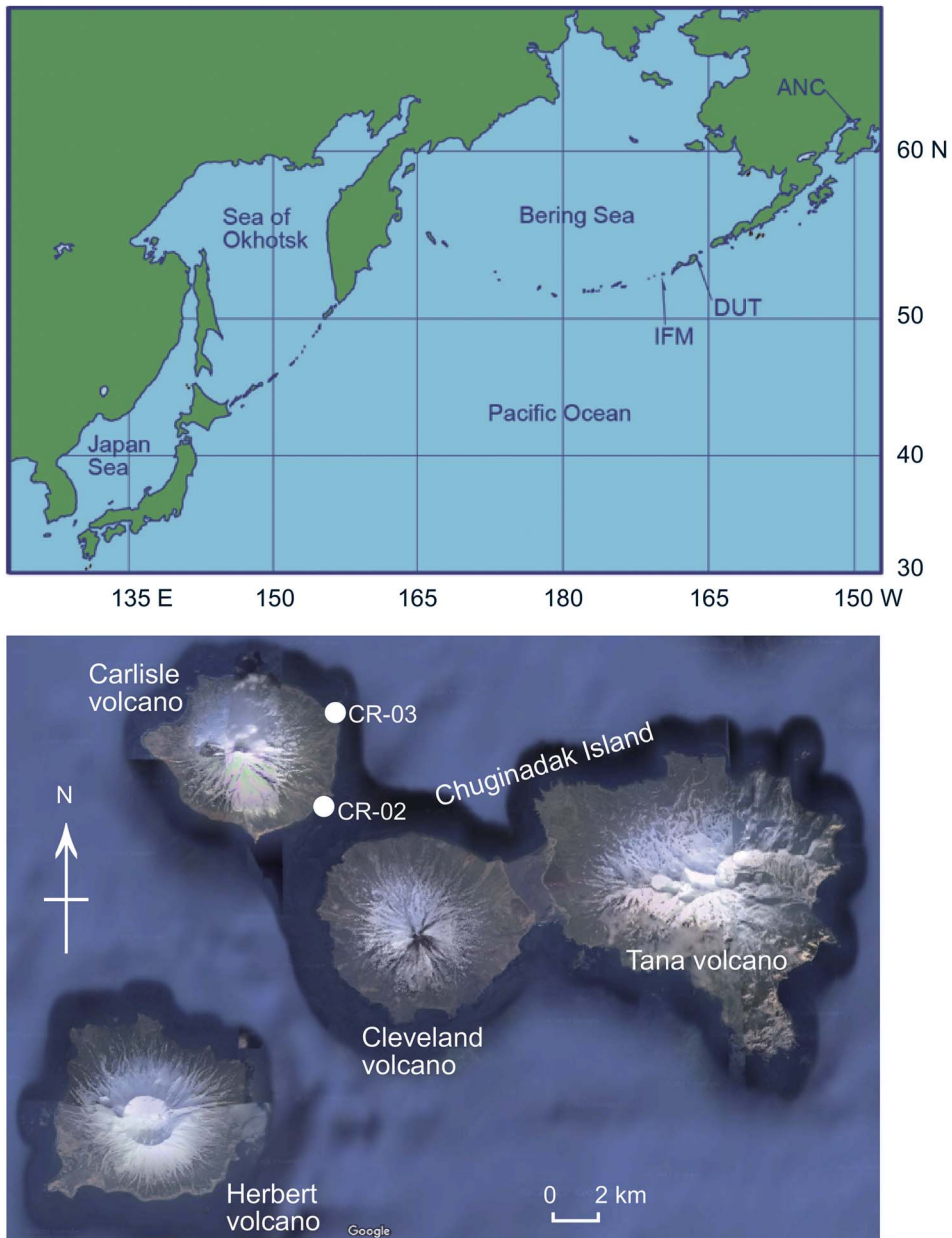


Figure 1 Location of the Islands of Four Mountains (IFM). DUT: Dutch Harbor, ANC: Anchorage. Satellite image was obtained from Google Maps.

The CR-02 tephra also occurs at a peat outcropping near the prehistoric village complex CR-03 (Figures 2c and 3). To determine the eruption age of the CR-02 tephra, we conducted accelerator mass spectrometry (AMS) radiocarbon (^{14}C) dating on charcoal and vascular plant fragment samples collected from the peat layers at this section. In this paper, we present these data and discuss the tephra and archaeological chronology in this area.



Figure 2 Photographs of the CR-02 and CR-03 sites on Carlisle Island: (a) soil and tephra complexes during Holocene Period near the prehistoric village site CR-02 (AMK-0003). A debris-flow deposit is intercalated with this complex. (b) CR-02 tephra intercalated with cultural layers in the prehistoric village site CR-02. Six ¹⁴C dates were obtained from charcoal fragments (Hatfield et al. 2016). Three dates shown in *italic* are obtained from charcoal of *Empetrum nigrum* (crowberries). (c) Peat section near the prehistoric village complex CR-03 (SAM-0017). (d) View of peat section. This cape was comprised by lava.

METHODS AND MATERIALS

Outline of Geology and Sampling Site

Carlisle (1620 m asl) is an andesitic stratovolcano with alluvial fans of debris-flow deposits on its flanks. Throughout the Holocene it has been periodically covered by a series of soil-tephras (Figure 2a) with a small glacier on its summit. The prehistoric village sites CR-02 and CR-03 are located on the coastal areas of the island (Figures 1 and 2).

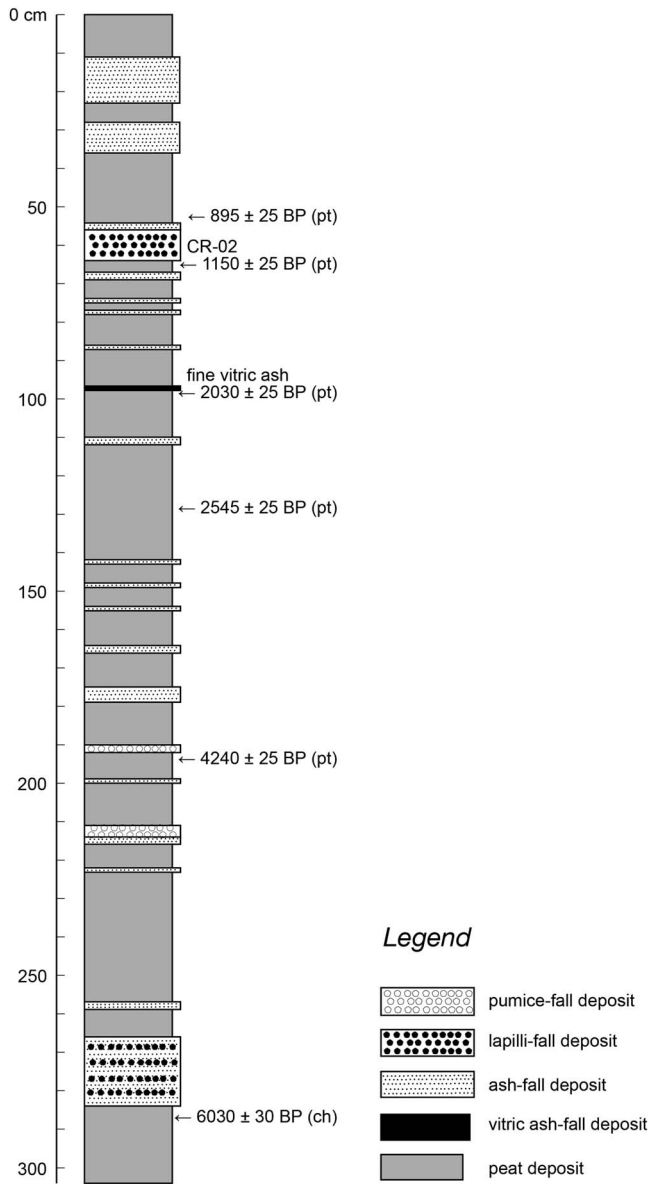


Figure 3 Columnar section of peat deposits near the CR-03 complex (Figure 2c). ch: charcoal, pt: plant from peat layer.

Lava flows comprise the basal part of the sea cliff section near the CR-03 site and it is covered by a debris-flow deposit (Figure 2d). Subsequently, this site was isolated from the volcanic slope and peat deposits accumulated in a wet environment without debris-flow deposits. In this section, at least 21 tephra layers including the CR-02 tephra and a fine vitric ash with a thickness of 1 cm are intercalated with peat deposit (Figures 2c and 3). The CR-02 tephra consists of a lapilli layer (thickness = 11 cm, median grain-size = 5.3 mm) and overlying volcanic ash layer (thickness = 1 cm). The depositional structure (micro-bedding) of the tephra implies that the lapilli layer was deposited during rainy conditions.

AMS ¹⁴C Dating

Five vascular plant samples and one charcoal sample were collected from a section of peat deposit near the CR-03 complex (Figure 3). Parts and species of plants could not be identified for all samples. Samples were cleaned by routine acid-alkali-acid (AAA) treatments using 1.2 N HCl and 1.2 N NaOH, respectively, to remove carbonates and secondary organic acids. After washing with distilled water and drying, each pretreated sample was sealed in a quartz tube together with CuO and then heated. The gas product was cryogenically separated and CO₂ gas was purified using a vacuum line and then reduced catalytically to graphite on Fe powder with H₂ gas. The three carbon isotopes in the samples and the NIST oxalic acid (HOxII) standard were measured by the NEC Peletron 9SDH-2 AMS system at the Institute of Accelerator Analysis Ltd (IAA). The ¹³C/¹²C ratios ($\delta^{13}\text{C}_{\text{PDB}}$) obtained by the AMS were used to correct carbon isotopic fractionation when calculating conventional ¹⁴C age. To estimate and remove the ¹⁴C background level, the ¹⁴C concentration of commercial graphite powder was also measured in the same analytic sequence of sample and standard measurements. Conventional ¹⁴C dates were calibrated to a calendar year timescale using the IntCal13 dataset (Reimer et al. 2013) and the computer program Calib 7.1 (Stuiver and Reimer 1993).

Tephra Analysis

The mineral and glass grains of the CR-02 tephra and a fine vitric ash were examined under the microscope. The chemical compositions of volcanic glass were also determined using the JXA-8900R (JEOL) electron-probe microanalyzer (EPMA) at Kobe University. Analytical conditions were 15 kV acceleration voltage, 12 nA of electron beam current, and a 15 s counting time for Na and 30 s for other elements. The spot size was 10 μm . The ZAF correction method was used. The original element data was normalized to 100 wt.%.

RESULTS AND DISCUSSION

The results of AMS ¹⁴C dating are shown in Table 1 and Figure 4. The obtained calibrated ages are consistent with the stratigraphy of this section (Figure 3). The CR-02 sequence was noted in several profiles investigated on Carlisle Island and is intercalated with cultural deposits at village sites CR-02. At the peat section this eruptive sequence is bracketed by ¹⁴C dates taken from plant

Table 1 Results of AMS ¹⁴C dating for the section near the CR-03 complex.

Depth (cm)	Material	¹⁴ C date (BP, 1 σ)	$\delta^{13}\text{C}$ (‰)	Calibrated age range (cal BP, probability % in 2 σ)	Lab nr (IAAA-)
33–34	Peat	895 \pm 25	–25.9	738–833 (58) 845–908 (42)	160136
34–35	Peat	1150 \pm 25	–26.4	979–1097 (76.8) 1101–1148 (15.6) 1158–1173 (7.6)	160137
62–63	Peat	2030 \pm 25	–27.8	1899–1914 (3.1) 1918–2056 (96.9)	160138
81–82	Peat	2540 \pm 25	–26.0	2499–2593 (35.1) 2614–2635 (11.1) 2692–2747 (53.8)	160139
143–144	Peat	4240 \pm 25	–25.6	4661–4666 (0.9) 4708–4755 (19.6) 4812–4858 (79.5)	160140
210–211	Charcoal	6030 \pm 30	–24.8	6787–6954 (100)	160141

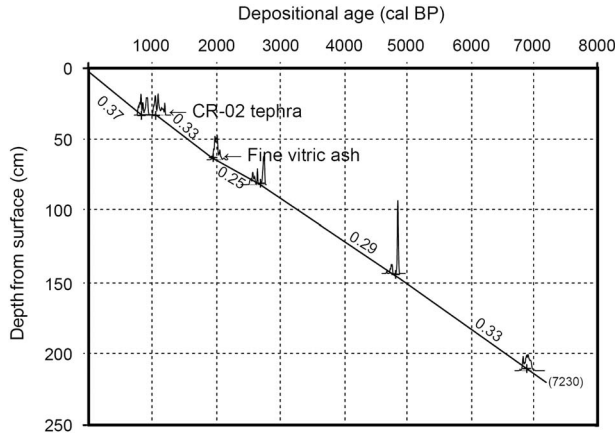


Figure 4 Probability distribution of calibrated years ranges using Calib 7.1 (Stuiver and Reimer 1993). + : median date of calibrated years ranges. Values indicate sedimentation rate in mm/yr. Note that “depth” does not include thickness of tephra layers.

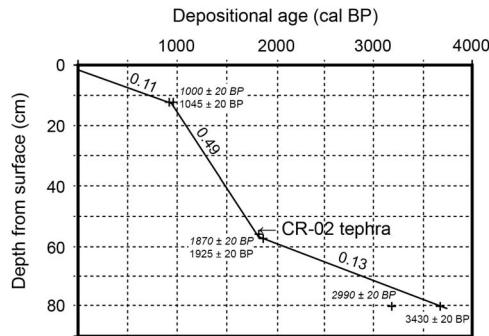


Figure 5 Sedimentation rate of cultural layers in Unit 3 at the prehistoric village CR-02. + : median date of calibrated years ranges using Calib 7.1 (Stuiver and Reimer 1993). A surface and three dates obtained from crowberry charcoals (Figure 2b) are used for estimating sedimentation rate (mm/yr). Note that “depth” does not include thickness of tephra layers.

and charcoal (Figure 3). Based on these results we conclude the age of the CR-02 tephra to be approximately 1050 cal BP (cal AD 900). The sedimentation rates of the peat deposit are estimated to be 0.25–0.40 mm/yr, based on median age of calibrated probability distributions (Figure 4). The grains of the CR-02 tephra consist of moderately fractured glass adhered to highly fractured microphenocrysts. They contain plagioclase, pyroxene, and titanomagnetite phenocrysts. The mean SiO₂ content of the glass shards is 58.1 ± 2.7 wt.% (n = 20).

The ¹⁴C date of 2030 ± 25 BP obtained from immediately below a fine vitric ash encountered 1 m below the surface (Figure 3) agrees with that of the Okmok II caldera-forming eruption (2050 ± 50 BP; Begét et al. 2005; Burgisser 2005; Larsen et al. 2007). The Okmok caldera is ~135 km northeast of the Carlisle peat bog. The agreement of our ¹⁴C date with those previously published may allow us to correlate proximal and distal tephtras associated with the

Okmok II eruption. It also provides strong support to our ¹⁴C chronology at this site. The tephra consists mostly of fresh pumice type (fibrous) glass shards with minor amounts of plagioclase, pyroxene, and magnetite phenocrysts. The mean SiO₂ content of the glass shards is 72.4 ± 1.4 wt.% (n = 48).

As mentioned above, the CR-02 tephra is intercalated with cultural layers around house pits at the CR-02 village and six ¹⁴C dates were obtained from charcoal fragments in cultural layers in Unit 3 (Hatfield et al. 2016; Figure 2b). The age of the CR-02 tephra inferred from Unit 3 profile (Figure 5) is approximately 800 years older than dates determined by the present study of the peat bog section. Because the Aleutian Islands are largely treeless, Aleut peoples obtained driftwood for house construction and tools. Thus, the wood or cultural charcoal found in any Aleutian site can date to many years older than the actual stratigraphic context from which it originated. However, three dates at CR-02 (shown in italics in Figure 2b) were obtained from charcoal fragments of local vegetation, *Empetrum nigrum* (crowberry). The old-wood effect may partially explain this difference, however, the possibility of post-depositional disturbance to the cultural layers may also contribute to the temporal discrepancy.

CONCLUSIONS

Based on the stratigraphic evidence in a peat section and ¹⁴C results, we have determined that the CR-02 tephra and Okmok II ash provide temporal indicators of 1050 and 2000 cal BP, respectively, because the ¹⁴C-dated Carlisle peat bog is not subject to marine reservoir contamination or old-wood issues. On Carlisle Island, IFM, the prehistoric village CR-02 was impacted by the volcanic eruption at about 1050 cal BP (cal AD 900). A peat deposit near the CR-03 complex had been accumulating almost constantly over the past 7200 years.

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