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THE ANIAKCHAK TEPHRA DEPOSIT, A LATE HOLOCENE MARKER HORIZON IN WESTERN ALASKA

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We describe here a Holocene tephra (volcanic ash) deposit that, because of its widespread occurrence, ready identification, and approximately known absolute age, should prove to be a useful stratigraphic marker throughout western Alaska from the Alaska Peninsula north to at least the Seward Peninsula. Moreover, the deposit is of interest because we have identified its source in the caldera-forming eruption of Aniakchak Crater, in the Aleutian volcanic arc on the Alaska Peninsula (fig. 1).

Our analyzed tephra samples are from four distal sites--three around Norton Sound and one in southwestern Alaska --and three proximal sites on the Alaska Peninsula near the source at Aniakchak Crater (fig. 1). The distal samples are uniformly fine-grained and, where not contaminated, consist almost entirely of glass (table 1). Megascopically, the glass fragments are clear to pale gray to solid or streaked brown. Particles composing the distal samples have variable shapes that include bubble-wall platelets, fibrous pumice, and equant blocks (fig. 2). In most tephra deposits, the ratio of glass (nonporous density 2.3-2.5 g cm^{-3}) to minerals (density >2.56 g cm^{-3}) normally increases with increasing distance of transport, as for example in the May 18, 1980 eruption of Mount St. Helens (Sarna-Wojcicki and others, 1981). Thus, the ratios of glass to the phenocryst phases are not a quantitative basis for correlation among samples. However, all of our proximal and distal samples are remarkably similar to one another, and are distinguishable from other tephra samples from the Alaska Peninsula (J.R. Riehle, unpub. data) except for the rhyolitic ash of the 1912 Katmai eruption (Hildreth, 1983), on the basis of their large proportion of glass. The mineral content of the samples (plagioclase > orthopyroxene > clinopyroxene = amphibole > opaques = apatite = zircon [?]) is not unique among tephra deposits of the Alaska Peninsula.

Glass separates have been analyzed by microprobe for nine major elements (table 2). To compare the degree of similarity of different pairs of samples we use a similarity coefficient, s.c. (Borchardt and others, 1972), which is the averaged ratio of all pairs of oxides (normalized to 100 percent) where the lesser oxide is the numerator. Because analytical uncertainty is inversely proportional to concentration, we exclude from calculation of the s.c. any oxide occurring in concentrations less than an arbitrary 0.40 percent (MnO, occasionally MgO and TiO_2). A perfect match of 1.00 is not expected even where comparing duplicate analyses of the same sample because the average standard deviation of the oxides is about 5 percent. Riehle (1985) concluded that tephra samples from elsewhere in the Aleutian arc are provisionally the same deposit, that is, the same fall of tephra, if their similarity coefficient exceeds 0.95. He interpreted an s.c. of 0.94 or 0.95 to indicate that sample pairs are either of different falls of coincidentally similar tephra, or may be the same tephra fall where analysis of one or more oxides was less reliable than usual. Similarity coefficients less than 0.94 were interpreted to preclude correlation as the same tephra fall. We adopt the same interpretations here.

Samples of the ash-flow tuff produced during formation of Aniakchak Crater, and of the antecedent proximal airfall deposits (fig. 3), are highly similar (each s.c. >0.95) to one another and to each of our distal samples except for the sample from site 4 (table 3). The lower similarity coefficients for sample 4 are mainly due to a single oxide, TiO_2 (table 2), which is only marginally significant due to its low abundance. Because the approximate age and petrographic character of sample 4 are similar to those of the other distal samples, we still consider it a

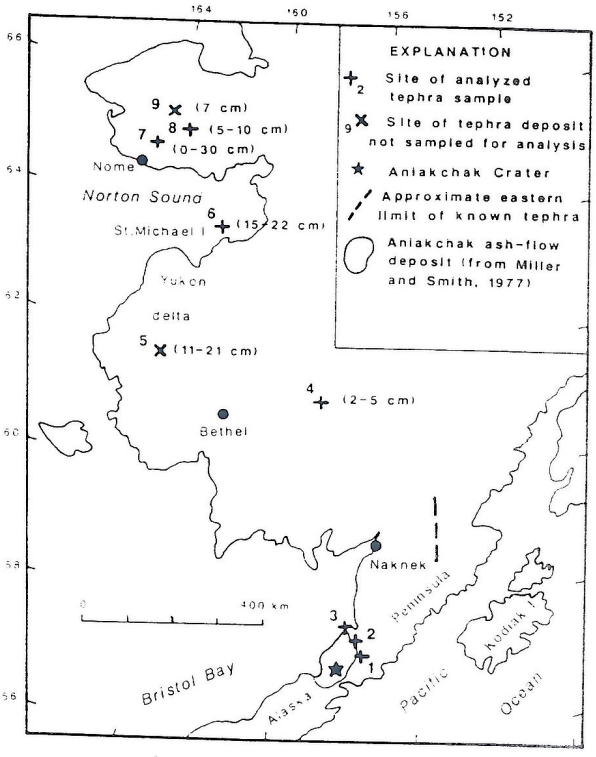
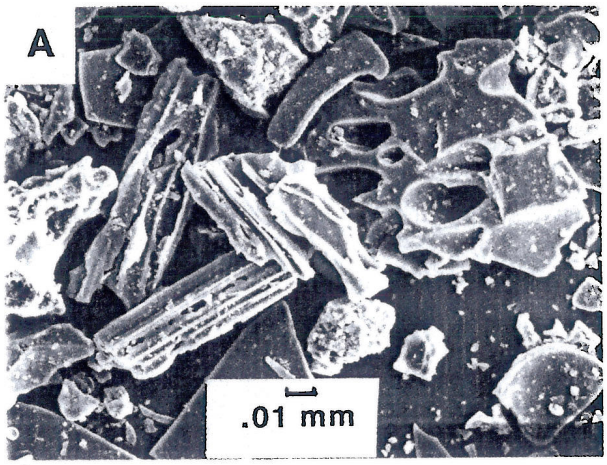
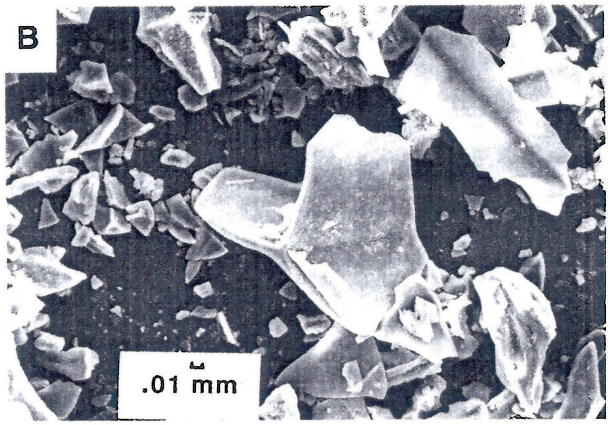


Figure 1.--Sites in western Alaska where late Holocene tephra deposit of Aniakchak Crater has been sampled. Thickness of deposit is given at distal sites in parentheses and is known to include some reworked tephra at sites 5 and 6.





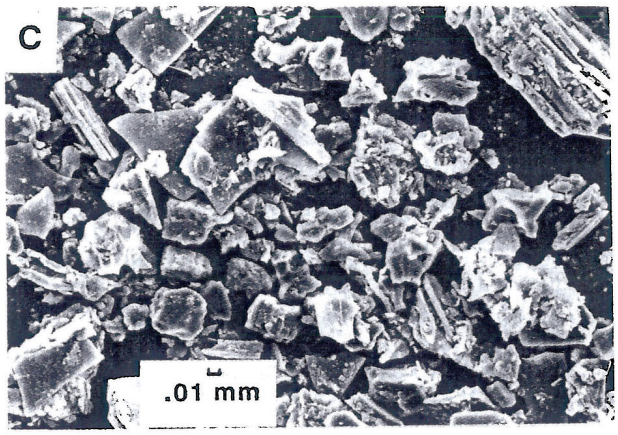


Figure 2.--Representative scanning electron micrograph of distal tephra samples of Aniakchak Crater. A, Blocky equant clast with a few coarse vesicles (upper right), curving platelets (lower right and upper left), and fibrous pumice (center); site 6. B, Bubble-wall junction (center) from which curving platelets in all samples are derived; site 7. C, Fibrous pumice (top right), equant blocks (center), and curving platelets (center of left margin); site 4. Occurrence of equant clasts with a few coarse vesicles and with adhering microparticles may indicate phreatic component of eruption (see Heiken and Wohletz, 1985). Photographs taken by Effie Shaw.

correlative. Of 130 samples of other tephra deposits from the Alaska Peninsula (J.R. Riehle and C.E. Meyer, unpub. data), none have a similarity coefficient that is greater than 0.94 with any of these distal samples. Because two to four tephra deposits (beds) can be recognized at the proximal sites (see fig. 3), the distal samples may be a composite of the deposits of two or more tephra falls.

Black glass shards handpicked from the sample at site 6 for microanalysis have a composition similar to lithic clasts of black vitrophyre in tephra deposits that immediately overlie and underlie Aniakchak deposits at site 1 (fig. 3; table 3, "vitrophyre"). The vitrophyre may be accessory to the Aniakchak eruptions or it may be contamination from nearly contemporaneous eruptions. Black glass in rare amounts was tentatively identified in the other distal samples and provides another criterion for recognition.

Radiocarbon ages indicate that the Aniakchak tephra deposit is of late Holocene age. The age of the Aniakchak ash-flow deposit that overlies the tephra deposits at proximal sites 2 and 3 (fig. 3) was originally estimated as 3,300-3,700 yr (Miller and Smith, 1977). Three samples of wood contained in the ash-flow deposit now yield a

Table 1.--Petrographic descriptions of proximal and distal tephra samples, Aniakchak caldera-forming eruption

Proximal deposits	
1C:	white to tan pumice and scoriaceous dark glass; mineral abundances not determined
1E:	fibrous, clear to tan pumice; trace of brown microvesicular glass and dense gray vitrophyre; 96% glass, 2% plagioclase, 2% mafics by weight
2M:	like sample 1E
3E:	like sample 1E; 97% glass, 1.5% plagioclase, 1.5% mafics by weight
3G:	like sample 1E
3I:	dominantly white pumice; rare scoriaceous glass and dense black vitrophyre; mineral abundances not determined
Distal deposits	
4:	clear to pale gray glass and fibrous white pumice; trace pale grey to medium brown scoriaceous glass; rare fine black fragments may be black glass shards; estimated 98% glass, remainder is plagioclase and pyroxene>amphibole>opaques=apatite=zircon(?)
6:	like sample 4
8:	like sample 4
7B:	dominantly clear to pale gray glass with some brown streaks; clast shapes range from fibrous pumice to curving platelets; estimated 99% glass, remainder is plagioclase and pyroxene>amphibole>opaque=apatite=zircon(?)

weighted mean age of 3,430 yr (T.P. Miller, USGS, written commun., 1986).

A maximum limiting age for our distal sample 8 is 4,000 ± 100 yr B.P. (I-13,990); an unanalyzed sample from site 9 petrographically resembles the other Aniakchak samples and is bounded by ages of 2,400 ± 80 yr B.P. (Beta 7760) and 3,340 ± 90 yr B.P. (Beta 7761) (Kaufman and Hopkins, 1985). Our analyzed sample 6 is from lake sediments cored on St. Michael Island; lacustrine sediments in the interval from 0 to 11 cm above the tephra deposit yielded a date of 4,830 ± 80 yr B.P. (W 4929) and the interval from 0 to 10 cm below yielded a date of 6,430 ± 90 yr B.P. (W 4625) (Ager, 1983). A similar tephra deposit at site 5 (Tungak Lake) has not been chemically analyzed but is correlated with the Aniakchak deposit on the basis of petrographic similarity; the 12-cm interval immediately overlying the tephra deposit yielded a date of 3,400 ± 750 yr B.P. (W 3776) and the interval from 13 to 44 cm below the tephra deposit yielded a date of 5,645 ± 250 yr B.P. (W 3934) (Ager, 1982). The sample from site 4 contains partially to completely charred wood, which may have been mixed by cryoturbation from an overlying horizon; it yielded a date of 3,684 ± 98 yr B.P. (WSU 2759).

If the available radiocarbon data are taken at face value, then the distal tephra deposits must span 3,000 years. The apparent lack of soils or erosional contacts between the proximal airfall deposits, however, weighs against such a hypothesis (see fig. 3). Moreover, tephra deposited on the Seward Peninsula must be a major component of the deposits on St. Michael Island because these sites are in line with Aniakchak Crater; thus, the ages of the Seward Peninsula and St. Michael deposits may differ from the age of the ash-flow deposit, but they should themselves be identical or at least overlap. Clearly the ages do not overlap, and consequently we cannot accept

Table 2.--Composition of glass separates
[Analyses by electron microprobe; analysts, C.E. Meyer and J.R. Riehle. FeO* is total iron reported as FeO. One standard deviation as percentage of reported abundance is given in parentheses. For brevity, compositions of proximal samples are not reported here but are available from the authors]

Oxide	7B		8		6 pumice		6 black glass		4	
SiO_2	69.9	(0.9)	69.9	(0.9)	70.1	(0.9)	57.1	(0.9)	69.7	(2.1)
Al_2O_3	14.92	(3.1)	15.03	(3.1)	14.58	(3.1)	15.97	(3.1)	14.81	(3.5)
FeO*	2.34	(3.5)	2.34	(3.5)	2.39	(3.4)	7.16	(2.4)	2.49	(4.8)
MgO	.49	(6.9)	.51	(6.7)	.50	(6.7)	2.92	(2.9)	.47	(5.0)
CaO	1.71	(2.0)	1.72	(2.0)	1.72	(2.0)	6.00	(1.3)	1.69	(6.4)
Na_2O	5.19	(3.4)	5.13	(3.4)	5.38	(3.0)	4.49	(3.1)	5.04	(3.2)
K_2O	2.91	(1.8)	2.95	(1.8)	2.91	(1.8)	1.50	(2.2)	2.97	(5.1)
TiO_2	.46	(12)	.45	(13)	.46	(13)	1.34	(6.6)	.58	(10)
MnO	.11	(20)	.15	(19)	.13	(22)	.20	(16)	.13	(25)
Total	98.1		98.1		98.2		96.7		98.2	

Table 3.--Similarity coefficients among distal and proximal samples, Aniakchak tephra deposits
[-- , no data]

Distal samples	Proximal samples 1C	1E	2M	3F	3G	3I	(vitrophyre) 1E	1J
7B	0.97	0.97	0.98	0.96	0.97	0.98	--	--
8	.96	.96	.98	.96	.97	.98	--	--
6, pumice	.96	.97	.97	.96	.97	.97	--	--
4	.95	.95	.95	.93	.96	.95	--	--
6, black glass	--	--	--	--	--	--	0.98	0.96

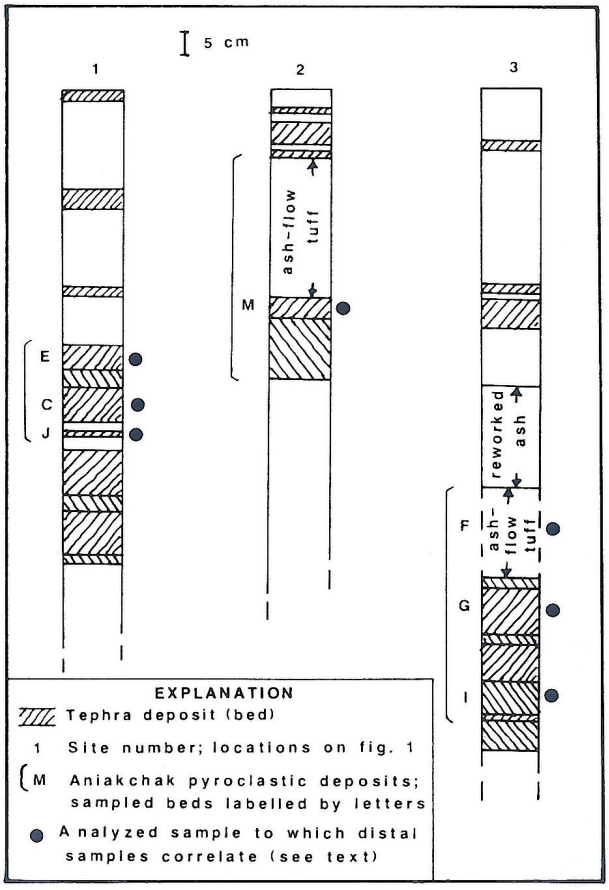


Figure 3.--Geologic sections at proximal sites where Aniakchak ash-flow deposit and underlying tephra deposits have been sampled. Non-pyroclastic deposits are loess or peat.

the radiocarbon ages from the distal sites at face value. One of several possible sources of error is that the lacustrine sediments at site 6 contain older reworked organic material. If the ages from site 6 are deleted, then the remaining ages limit the tephra deposit to between 3,400 yr B.P. and about 4,000 yr B.P. In conclusion, the lack of evidence for any hiatus between the proximal airfall deposits suggests that the age range is no more than a few hundred years, from about 3,400 yr to perhaps 4,000 yr. We cannot rule out an age range of as much as 3,000 years for these tephra deposits, however, and additional dating of samples from western Alaska would help to confirm this provisional age assignment.

In summary, the Aniakchak tephra deposit is sufficiently thick to be readily identified where preserved in late Holocene deposits that extend from its source at Aniakchak Crater north to the Seward Peninsula. The deposit may be recognizable even north of the Seward Peninsula by a high ratio of glass to phenocrysts (>98:2) and by the presence in rare amounts of (accessory?) black glass shards, but beyond the Seward Peninsula its fine grain size will probably make chemical analysis intractable. North of the Alaska Peninsula, the deposit is probably a mixture of the compositionally similar deposits of two or more tephra falls. The inferred age of the distal deposits ranges from a minimum of 3,400 yr, the age of the ash-flow deposit, to probably no more than 4,000 yr.

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