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## **VOLCANISM AS A FACTOR IN HUMAN ECOLOGY: THE ALEUTIAN CASE<sup>1</sup>**

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### **ABSTRACT**

It is proposed that for human populations the ecosystem of the Aleutian Islands should be considered in terms of microhabitats, because local resource availability is periodically unstable. The single food resource, marine fauna, fluctuates due to a multiplicity of biological and environmental factors, including tectonic and volcanic activity.

Mass mortality of marine fauna due to tectonic and volcanic activity is documented. It is concluded that Aleutian subsistence resources were highly variable, causing frequent periods of extreme hardship, that an adaptation strategy of human groups was frequent movement resulting in intergroup conflicts, fluctuations in group size and overexploitation of local niches. It is postulated that such hardship periods affected the vital rates of human populations.

This paper is an outgrowth of intensive research on the population of the Aleutian Islands prior to and at the time of the European intrusion, i.e., the second half of the 18th century. I am concerned with the questions of the origin, ethnic composition, distribution, and development of the Aleut population, and with specific problems of population dynamics.

The Aleutians are a unique human habitat in the sense that throughout the archaeological and early historic period, human population survival has depended on a single resource: marine fauna. Terrestrial fauna were non-existent, avi-fauna only subsidiary, and vegetation had a lesser role than avi-fauna. The archeological record indicates that 4,000 and possibly as long as 18,000 years ago, people inhabiting the Aleutians developed an excellent technology that permitted them to exploit the single available resource base, the sea.

Current interpretations of Aleut population history rest on inferences from archaeology and physical anthropology. Population projections range from 16,000 to 35-40,000. These are primarily derived from enumeration of settlement sites and the underlying assumption of steady resources.<sup>2</sup> The number of sites, estimated on the basis of various surveys, of which the most recent are by McCartney (1974) and Frølich and Kopjanski (1976), is much larger than the number of inhabited villages and inconsistent with population data reported by observers at the earliest contact between Aleuts and Russians.

Extrapolation is made to a flourishing, dense population in prehistoric times, and is often taken as a paleodemographic given (Laughlin 1972; Laughlin and Aigner 1975), though in a recent publication McCartney warned that "there is a danger in assuming that site density on an island is a direct indicator of ecologic richness and diversity" (1977:68). The figure 16,000 is an accepted base line, appearing first in Mooney (1928). Examination of Mooney's methodology (Ubeliquer 1976) indicates that for Alaska his notes were sketchy and the 16,000 figure represents an educated guess. Kroeber (1939) considered this "probably too high." In recent years scholars working in the Aleutians expressed opinions suggesting that the accepted estimates are inflated. Lantis (1970) suggested 12,000 and McCartney (1975) 5,000-12,000. The assumption of a steady resource base also has been challenged. McCartney (1975, 1977) and Yesner (1977) discuss resource and population fluctuation, and Simenstadt, Estes and Kenyon (1978) propose that local overexploitation of resources by Aleuts occurred.<sup>3</sup>

The discrepancy between this extrapolation and population data available in primary sources pertaining to the second half of the 18th and the first half of the 19th centuries is serious. Available historical data indicate that at the time of contact, Aleut settlements *which were inhabited* were widely scattered, that many islands were either uninhabited or inhabited only seasonally or by hunting parties, and that settlements tended to be small with a west to east gradient from smallest to largest. Early reports consistently state that Aleuts were subject to seasonal food shortages and periodic famines. Themes of hunger and hardship are dominant in Aleut folklore. There seem to have been no built-in cultural controls on population growth. The only extant analysis of the Aleut social system (Veniaminov 1840, part 2) indicates that Aleuts practiced neither infanticide nor senilicide; abortion, while known, was discouraged. If a girl abandoned or killed an illegitimate child, or terminated pregnancy, she was subjected to punishment and purification ritual. Veniaminov noted that fertility of Aleut women was low in comparison to women married to Russians who adopted Russian dietary and other cultural rules, and in comparison to Russian women resident in the islands. He noted differential infant mortality and survival in childbirth for these groups. He attributed the low fertility of Aleut women to stress occasioned by food shortages during pregnancy and lactation and to sexual freedom permitted women in precontact times. Differential mortality and childbirth survival rates he attributed to Aleut medical practices, which he thought very efficient in some respects but not in infant and maternal post-natal care.

War was endemic in precontact times, but warfare alone cannot be considered a "necessary and sufficient condition" limiting population. Rather, highly structured Aleut warfare activities are best viewed as a result and reflection of societal stress. It is well documented that Aleuts fought over territory and resources. Capture of humans and loot were the main objectives of long distance raids. Psychological stress (or rather social recognition of psychological stress) is documented. Veniaminov reports that Aleuts had self-validating beliefs that insanity was inescapable punishment for a variety of delicts.

The question then arises, what factors ultimately would have constituted checks on population growth? In answer, I considered the physical environment as a possible causal and determining factor.

As stated earlier, the cardinal assumption of many technical and popular descriptions of the Aleutian environment is the notion that the sea offers an unlimited, unflinching food supply: *cornucopia* has been used in this context more than once. If one species fails,

another presents itself to be utilized. This impression may be valid in the long term, since archeologists, and geologists deal with temporal dimensions in units of thousands, or at best hundreds, of years.<sup>4</sup>

For ordinary human beings, however, the blink of an archeologist's eye — a century — represents three generations. A year, in terms of survival, is a *very long time*. A brief interruption in local availability of a major food source can cause both immediate distress and long-term consequences (Malde 1964; Colton 1960). It is my thesis that in the Aleutians, short term local disruptions in the availability of marine food resources were frequent, that the adaptive strategies of humans were movement to other locations or, alternatively, hunting and fishing in different localities. I propose that one of the major causes of local disruptions in availability of marine fauna and thus of food shortages was tectonic/seismic<sup>5</sup> and volcanic activity.<sup>6</sup>

Malde, discussing land-based groups, suggested that, where pertinent, volcanic activity must be considered a major factor in reconstruction of past environments and that a short-term perspective be employed: "Large ashfalls have been catastrophic for the early Indians. It was doubtless unimportant to them that vegetation eventually could recolonize an area devastated by ashfall. What mattered was their inability to find food during the interim" (1964:10).<sup>7</sup> I know of no discussion of the possible effects of tectonic activity and volcanism on marine environments in the anthropological literature.

Marine fauna is subject to mass mortality<sup>8</sup> which biologists ascribe to a multitude of causes ranging from changes in sea water salinity, to temperature changes of less than 2°C, to overproduction of plankton. Brongersma-Sanders (1957)<sup>9</sup> provides a useful summary, listing earthquakes and volcanism as a major cause of such mortality.

It is necessary to emphasize that the most characteristic feature of Aleutian ecology is tectonic activity and volcanism (Miller and Barnes 1976; Coats 1950). The islands themselves are a product of such activity: the geologically older formations, those on the Pacific side, and the roughly parallel Aleutian Trench, are products of uplift and subsidence associated with the interaction of two tectonic plates. Other formations are products of episodes of intensive and extensive volcanism (Hays 1970). Though incomplete and in some instances outdated, U.S. Geological Survey Bulletin 1028<sup>10</sup> is the basic source on the geology of the islands. More recent data and interpretations are widely scattered in specialist literature. Robert F. Black stated in a letter February 10, 1978: "Many major differences from one island to the next may be explained on the basis of their youth vs. age and their glacial history. Many of the symmetrical cones without major drainage systems have only been produced in the last few thousand years whereas others are hundreds of million years old. . . ."

Episodes of tectonic and volcanic activity on a massive scale occurred in the Late Pleistocene and continued into the Holocene; major episodes occurred within the last 10,000 years, when at least the Eastern Aleutians were occupied. Eastern Aleut folklore supports the hypothesis that major volcanic episodes occurred during the period of human occupation. The Aleutians are one of the world's tectonically most active areas. Earthquakes are frequent. Surface and especially submarine volcanism, though less frequent than earthquakes, is perhaps more frequent than supposed.<sup>11</sup> The initial stages in submarine volcanism are, apparently, very rapid. Then the process slows down and becomes sporadic, continuing for centuries, with rapid erosion from the sea and volcanic "rebuilding." In the Aleutians, the best known island created by submarine volcanism is

Bogoslof. The eruption began reportedly in 1796 and the volcanic activity and topographic changes continue (Jagger 1908; Munger 1909; Byers 1959; U.S.G.S. 1028-L; Bullard 1962; Davydov 1977:96-97; Khlebnikov 1979). Some of the volcanic cones (islands) on the Bering Sea side are products, at least in part, of similar processes. As "island building" has occurred in the Aleutians during the Holocene, accompanied by strong seismic activity,<sup>12</sup> human populations must have been affected by earthquakes and eruptions directly and, more frequently, indirectly.

However, local tectonic and volcanic events are not the sole causes of associated effects in the Aleutians. The Aleutians, a volcanic arc, are systemically related to several volcanic arcs fringing the Pacific.<sup>13</sup> Apparently episodes of intensified activity in one arc coincide with intensified activity in other arcs (Hein, Schell and Miller 1978). In case of seaquakes, associated phenomena such as *tsunami*<sup>14</sup> affect areas remote from the point of origin. It is known that *tsunamis* generated near Kamchatka, Kuriles, Japan, and even Chile affect the Aleutians. Fraser and Snyder (1959:404-405:U.S.Geological Survey Bulletin 1028-M) report that on November 4, 1952 water rose eight feet above normal at the Navy base on Adak, which was in the lee, due to a *tsunami* generated by an earthquake centered on Kamchatka. They also attribute the destruction of an Aleut settlement on Adak, ca. 3,000 BP to *tsunami* action. Nikolai Galaktionoff, Henry Swanson and John Eckhardt, all of Unalaska, insisted that earthquakes in the Pacific, especially Japan, invariably cause "water" — unusual rip tides and currents in passes linking the Pacific and the Bering Sea. W. Dyakonoff, Unalaska, described abnormal tides in Unalaska harbor following earthquakes in Japan and elsewhere in the Pacific. Stanley Holmes, Unalaska, stated that the tidal wave from a Chilean earthquake destroyed two campsites on the Pacific side of the Chernofski ranch at elevations of twenty-five and forty feet respectively, while waves observed in 1961-1962 deposited logs fifty feet above the tide line. Aleuts and American fishermen, long time residents of Unalaska, take it for granted that the Pacific side is exposed to tidal wave danger. Nikolai Galaktionoff, discussing one tidal wave that hit the eastern Aleutians, described logs thrown by waves onto Pacific cliffs to a height of 350-400 feet.

More than a century earlier, the Russian American Company maintained the position of a "water watchman" on Atka. On October 26, 1849 following an earthquake in the Andreanoff Islands, residents of Atka and Amlia, fearing a tidal wave, evacuated to the high ground, camping in the open and in tents for several days (Salamatov Ms.). Unga Island (Shumagins), Sannakh, and the southern shore of the Alaska Peninsula suffered a major flood in 1788, apparently caused by a *tsunami*. A series of earthquakes preceded the flood (Veniaminov 1840:I:47; Litke 1835:279). On April 1, 1946 at Scotch Gap, Unimak, a *tsunami* caused water to rise 115 feet (Fraser and Snyder 1959:U.S. Geological Survey Bulletin 1028-M).

To summarize, tidal wave danger exists throughout the Aleutians, is clearly recognized by the inhabitants, and is associated in their minds with earthquakes, which may originate anywhere in the Pacific.

Available data on tectonic and volcanic disturbances in the Aleutians are presented in Tables 1-4. These include only major recorded episodes and are not complete, especially with respect to eruptions, lava flows, and ashfalls. Data on submarine volcanism are lacking. Table 1 summarizes Veniaminov's statistics for the decade 1825-1834 for Unalaska. Table 2 presents data on earthquakes above 6.5 on the Richter

Table 1  
Earthquakes, Recorded at Unalaska Village, 1825-1834  
(after Veniaminov, 1840)

Year	Month:												Total
	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	
1825	2	—	1	2*	—	1	2	—	1	—	—	—	7
1826	—	1	2	—*	—	—	1	—	—	3	1*	—	5
1827	Not recorded (excluded by Veniaminov as the annual record was not complete).												
1828													
1829	"	"	incl. July		—	—	—	—	—	3	—	—	3
1830	2	—	—	—	—	—	—	—	—	—	—	—	2
1831	1	1	—	—	—*	—	—	—	—*	2**	—	—	4
1832	—	—	—	2	—	—	—*	4**	1*	—**	—	—	7
1833	—	—	—**	—	1	—	—	—	1*	2*	—	—	4
1834	—	—	—	—	—	—	—	End observation period					
Total	5	2	3	4	1	1	1	4	3	7	1	—	32
Asterisks * indicate occurrence of "weather." Total = 17; associated with earthquakes = 9.													

scale (courtesy L. D. Morris, NOAA). Table 3 lists known volcanic eruptions 1760-1796, based on Coats (1950) and Macdonald (1972). Table 4 notes known lava flows, from Coats (1950).

The destructive effects of such activity need not be dramatic annihilations of settlements, though at least one such instance is known to have occurred on northern Umnak, and Aleut tradition records another instance on Atka. Indirect effects on humans are great. Macdonald (1972) provides an impressive catalogue of woes befalling humans "with volcanic addresses."<sup>15</sup> Ecological effects of subaerial volcanism are well understood while submarine volcanism, to my knowledge, has not been considered. Until recently tectonic activity was either ignored or its effects considered in a limited way, but since the 1964 Alaska Earthquake multidisciplinary studies published by the U.S. Geological Survey and the National Academy of Sciences, environmental impacts and ecological effects of earthquakes are now better understood. Damage to physical environment and biota is thoroughly documented. Thus, we have a solid basis for the argument that earthquakes have a significant effect on human ecology. Although I am discussing tangible effects of earthquakes, I should also like to point out that any major tectonic or volcanic episode affects humans psychologically. Fear, often bordering on panic, is generated, so that even anticipation of such events can cause a population to flee the area. Veniaminov (1840) and Litke (1835) report abandonment of villages by the Aleuts both in fear of and in the wake of earthquakes and volcanic eruptions.<sup>16</sup>

Earthquakes (forthwith subsuming seaquakes) cause damage on land and at sea. It is convenient to list the effects for land and sea separately, though many are comparable, others overlap, particularly in shore areas. Topography is damaged extensively and in a variety of ways. Subsidence/uplift can cause drastic and devastating effects: shore configurations can be altered, which, in turn will cause alterations of local currents, tide levels or sea levels can be changed, causing inundation. Major earthquakes produce

**Table 2**  
**Recorded Earthquakes in Aleutian Area 1901-1975. Source: Earthquake Data File,**  
**courtesy Leslie D. Morris, NOAA, National Geophys. Solar — Terrestrial Ctr.**  
**Area: 48-60 N; 150 W - 170 E; Magnitudes: 6.5+**

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1901												1	1
1902	1												1
1903						1							1
1904	No record												
1905		1											1
1906								1					1
1907								1	1				2
1908	No record												
1909									1				1
1910					1				1				2
1911	No record												
1912	1					1					1	1	4
1913			1										1
1914-1915	No record												
1916				1									1
1917 through 1922	No record												
1923					1								1
1924-1925	No record												
1926										1			1
1927-1928	No record												
1929			1				2					1	4
1930												1	1
1931	No record												
1932								1		2			3
1933					1		1		1		1		4
1934					1		1				1		3
1935	1	1											2
1936	No record												
1937									1				1
1938											2		2
1939	No record												
1940		2		2			1	1					6
1941				1				2	1				4
1942									1			1	2
1943	No record												
1944							1					1	2
1945											1		1
1946		1		1			1			1	1	1	6
1947	No record												
1948	1				1							1	3

Year	Jan.	Feb.	March	April	May	June	July	Aug.	Sept.	Oct.	Nov.	Dec.	Total
1949		1						1					2
1950			1						1		1		3
1951		1											1
1952	2										1		3
1953	1					1							3
1954				1		1						1	3
1955	2		1	1		2	2				1		9
1956				1				1		1		2	5
1957	6	1	14	4	1	1							27
1958	2	1	1			2		1					7
1959							1					1	2
1960							1			2	1		4
1961	1											1	2
1962								1	2			1	4
1963	1					1							2
1964	1	3	2										6
1965		6	1				2		1	1		1	12
1966							1	1					2
1967-1968													
1969					1				1	1			3
1970			2										2
1971		1			1	1					1		4
1972-1973													
1974		1											1
1975		2									1		3
Total	19	21	25	14	8	11	14	11	12	9	13	15	177

subsidence/uplift in a wide area. The 1964 earthquake affected 34,000 square miles (Grantz, Plafker and Kachadoorian 1964:5). Locally, wells may run dry due to alterations in the ground water level. Seismic shocks, seismic shaking, ground motion and associated compaction, lateral displacement, cracking (fissuring) all can play havoc with local topography. Erosion processes can be altered (Kachadoorian and Plafker 1967 F 1 report a case on Kodiak). All of the above may affect drainage and fresh water systems in a variety of ways (Griggs 1922; Ferrians, Jr. 1966:E8-E10). Frequently salt water intrudes into the water supply and/or fresh water bodies (Kachadoorian and Plafker 1967; Marriott and Spetz 1971). Topographic damage is caused by *tsunamis* and seiching (Kachadoorian and Plafker 1967; Grantz, Plafker and Kachadoorian 1964).

Avalanches, rockfalls, slides (land, mud, ice and snow) occur (Grantz, Plafker and Kachadoorian 1964:6; Ferrians, Jr. 1966:E25; Griggs 1922; Veniaminov 1840). These, too, destroy natural features, settlements (an avalanche buried a village site on Umnak), fishing and hunting camps, landing sites, channels, passes which can be blocked, made otherwise impassable or so altered as to render them unusable and dangerous due to lack of familiarity. They can block rivers, creating flood hazards, damage lakes, and alter



**Table 3**  
**Known Volcanic Activity, 1760-1976 (after Coates 1950, Macdonald 1972, and**  
**with additional data courtesy Bruce Grant, NOAA)**

Island/Volcano	Year of eruption	Total known eruptions
Kiska	1907, 1927	2
Little Sitkin	1776, 1828	2
Cerberus	1772, 1790, 1792, 1828, 1873, 1922, 1929, 1930	8
Goreloi	1760, 1790, 1791, 1792, 1828, 1873, 1922, 1929, 1930	9
Tanaga	1763-70, 1791, 1829, 1914	4
Kanaga	1790, 1791, 1827, 1829, 1904, 1933	6
Great Sitkin	1792, 1829, 1904, 1933, 1945	5
Konjuji	1760, 1827, 1828	3
Korovinskiy	1829, 1830, 1844	3
Sarychef	1812	1
Seguam	1827, 1891, 1892, 1902, 1927	5
Amukhta	1786-91, 1876, 1963	3
Yunaska	1817, 1824, 1825, 1830, 1920s, 1937	6
Carlisle	1774, 1828, 1838	3
Cleveland	1893, 1929, 1932, 1938, 1944, 1944	6
Kagamil	1929	1
Vsevidov	1784, 1790, 1830, 1878, 1880 (and 1960?)	5
Okmok-Tulik	1817, 1824-29, 1830, 1899, 1931, 1936, 1938, 1945, 1945, 1960	11
Kotelnoy	1825	1 Veniaminov
Bogoslof	1796, 1806, 1814, 1820, 1884, 1890, 1891, 1906, 1907, 1907, 1909, 1910, 1913, 1926, 1927, 1931	18
Makushin	1768-69, 1790, 1802, 1818, 1826, 1826-38, 1845, 1865, 1867, 1883, 1907, 1912, 1926, 1938, 1960s, 1970s	16
Akutan	1790, 1828, 1834, 1838, 1845, 1848, 1852, 1865, 1867, 1883, 1887, 1892, 1896, 1907, 1908, 1911, 1912, 1928, 1929, 1931, 1946, 1947, 1948, 1971-73, 1974	25
Akun	ca. 1834	1 Veniaminov
Pogromnaya	1795, 1796, 1820, 1827-30	4
Fisher	1826, 1830, 1825	3
Westdahl	1964	1

Island/Volcano	Year of eruption	Total known eruptions
Shishaldin	1775-78, 1819, 1824, 1825, 1826, 1830-31, 1838, 1842, 1865, 1880-81, 1883, 1897, 1898, 1899, 1901, 1912, 1922, 1925, 1928, 1929, 1929-32, 1932, 1946, 1946, 1947, 1948, 1963, 1976	28
Isanotski (Issanakh)	1795, 1825, 1830, 1845	4
Pavlof	1786, 1790, 1838, 1844-46, 1852, 1866, 1880, 1892, 1906-09, 1910-11, 1911, 1914, 1917, 1922, 1923, 1924, 1929, 1931, 1931, 1936, 1939, 1945, 1942, 1947, 1948, 1965, 1973, 1973, 1976, 1976	31
Pavlof Sister	1762-86	1
Veniaminof	1830-38, 1838, 1852, 1874, 1892, 1930, 1939, 1939, 1939, 1944	10
Aniakchak	1931	1
Chiginagak	1852, 1929	2
Peulik (Bocharova)	1814, 1852	2
Mageik	1929, 1927, 1936, 1946	4
Trident	1950, 1950, 1953, 1954, 1956, 1960, 1962, 1963, 1964, 1965, 1968	11
Novarupta	1912, 1949	2
Katmai	1912, 1914, 1920, 1921, 1929, 1931, 1931, 1962, 1953, 1951	10
St. Augustine (Chernoburaya)	1812, 1883, 1902, 1935, 1935, 1935, 1963, 1976	8
Iliamna	1768, 1786, 1867, 1876, 1933, 1947	6
Redoubt	1778, 1819, 1902, 1933, 1966	5
Spurr	1953	1
Total known eruptions:		278

stream beds. They can strip the soil to bedrock, temporarily dewater streams and lakes, and damage estuaries, freshwater systems and soil cover (Martin 1913; Griggs 1917, 1918, 1922). Concomitant is damage to biota which can be affected by all of the above factors in many ways. For Aleuts, the effect on littoral and intertidal fauna and on salmon runs would have been critical.<sup>17</sup> Both can be destroyed in a locality overnight. Iokhel'son (1925:107) reported one such instance but failed to appreciate the significance of his observation: "On January 8, 1910, while on Umnak Island we experienced a serious volcanic shock. The following morning the shore was covered with a layer of stunned fish, sea urchins and shellfish, about 2 feet high and 2 feet wide. . . ." Uplift/subsidence

**Table 4**  
**Known Lava Flows, 1760-1948**  
**(after Coats 1950 and Macdonald 1972)**

Island/volcano	1760-1799	1800-1899	1900-1948	Total no.
St. Augustine			1935, 1935	2
Kiska				?
Goreloi	1792		1930	2
Tanaga			1914	1
Kanaga			1904	1
Great Sitkin			1945	1
Koniujii				?
Amukta				?
Cleveland			1944	1
Bogoslof	1796	1806, 1884	1906, 1909, 1907, 1910, 1927, 1931	13 (?)
Aniakchak			1931	1
Okmok-Tulik			1945 and 1960s (St. Holmes)	1
Akutan		1887	1908, 1929?, 1946, 1947	5
Pogromnaya	1796			1
Shishaldin		1824, 1830, 1842, 1898	1922, 1929, 1932	7
Pavlof		1846	1911, 1948?	3

destroys the "vertical habitat" niches of various species. Razor clam beds in many areas of Alaska were destroyed by the 1964 earthquake (Grantz, Plafker and Kachadoorian 1964; Baxter 1971; Eyerdam 1971; Haven 1971; Hanna 1971; Harry Jr. 1971; Johansen 1971; Hubbard 1971). Changes in tide levels have the same effect, regardless of cause. Damage to estuaries, however caused, adversely affects estuarine fauna (Odum 1970). Sediments deposited on the sea bottom, in stream beds, on spawning grounds and mollusk beds will smother all life.<sup>18</sup> Alteration of stream beds can affect salmon runs, as salmon are "bottom sensitive fish" (informants' statements, Unalaska). Some informants claim that defense-associated construction work caused long term interruption in salmon runs by relocation of stream beds and interference with estuaries. (See Roys 1971 on the decline in salmon due to tectonic deformation of stream beds in 1964.)

At sea, topography is affected by earthquakes in a comparable way: channels between islands may be blocked or opened; coast lines altered; bottom configurations and off-shore depth changed, creating hazards to navigation (compare post-1964 and pre-1964 navigational charts for earthquake created hazards off Unimak). Henry Swanson, Unalaska (March 23, 1978), specifically noted this problem. In addition, earthquakes alter currents. Of special importance to biota are alterations of vertical currents. Here, too, biota are affected by uplift/subsidence through "vertical displacement of habitat" (Baxter 1971). Local silting may occur in association with current alterations or changes in bottom and shore line configurations, producing smothering of biota. Nikolai Lekhanoff, Unalaska, attributes the disappearance of razor back clams from Illiuliuk Bay to the 1964 earthquake

associated phenomena. However, W. Dyakonoff explained that disappearance of clams by presuming water pollution due to increased traffic (interviews March 23, 1978).

It has been established that sea and earthquake caused *tsunamis* and locally generated seismic waves occur relatively frequently in the Aleutians. *Tsunamis* affect biota, specifically shore and littoral fauna, and possibly benthic fauna, in a multifaceted fashion, sweeping away and redepositing sediment in new areas, smothering underlying life especially in shallow waters (Noerenberg 1971:170-193; Hanna 1971:2); they carry contaminating salt water into fresh water basins (Marriot and Spetz 1971); cause silting and wash-outs which often close off outlets, affecting water circulation and making fresh water bodies unsuitable as faunal habitats or for use by humans. *Tsunamis* can be postulated to have especially devastating effects on estuarine habitats (Odum 1970). At sea, shockwaves, pressure alterations and vertical current changes can kill fish and possibly marine mammals. Mass fish kills have been reported in the wake of earthquakes and are extensively documented for 1964. After an earthquake the disappearance of sea otters in the northern Kuriles was reported by Russian fur hunters in 1780, causing them to shift operations to the "Distant" (eastern) Aleutians: Sannakh, Unimak and points east (Oglobin 18972:I:745-762). Khlebnikov (1979) noted the diminution of sea otters off Yunaska as late as 1827, following eruption and earthquakes in 1824, but it is not clear if such diminution was the result of earthquakes or volcanic phenomena and of drastically altered topography of the island. Kenyon (1975:181) notes that sea otters are susceptible to earthquake damage, possibly directly, and most certainly indirectly, quoting a letter from Dr. Hanna who observed damage to sea otters in Prince William Sound after the 1964 earthquake, and citing work by Voronov, who "observed starvation and changes in distribution of sea otters in 1963 and 1964 following the massive destruction of bottom fauna by a *tsunami* in the Kurile Islands." Sea otters reportedly were killed following the subterranean atomic bomb test at Amchitka, though the data are contradictory.<sup>19</sup> Robert D. Jones, Jr., Fish and Wildlife Service, Anchorage (personal communication Nov. 23, 1977) wrote: "Sea otters are locally but temporarily affected by catastrophic natural events. . . . In the same way volcanic activity would quite temporarily destroy a local population, probably by destroying food resources. . . ."

I am not aware of data about possible detrimental effects on other sea mammals, but the effect on fish, as stated above, is thoroughly documented. Veniaminov (1840:I:69) describes masses of "stunned and dead fish" mostly cod and sculpin floating on the surface following earthquakes in 1825 and 1826, and says that the local catch of these fish was practically nil for several years. The species gradually became more numerous, and the catch increased.<sup>20</sup> At the same time there was a decrease in salmon, especially noticeable at Makushin village, Unalaska, famed for its rich fish stream. Following an earthquake on July 2, 1965 Mrs. Beverly Holmes, formerly of Unalaska, observed dead fish (Dolly Vardens and humpback salmon) in Chernofski Creek and noted the water appeared discolored for several days. She attributed the fish kill to chemical pollution due to disturbance of the river bottom. Stanley Holmes also observed fish kills in various streams near Chernofski after the 1965 earthquake. Litke (1835:310) reported stunned and dead fish *en masse* near Pogromnoye village on Unimak, from 1826 to 1831, when the Pogromnaya volcano was very active and several earthquakes recorded.

In 1964 fish kills in Alaskan waters were massive. Observers report that deep water fish, primarily sebastoides, were affected (Reimnitz, Plafker, personal communication).

Grantz, Plafker and Kachadoorian (1964) report a mass kill of red snappers in Prince William Sound. The fish were bloated, with bladder damage. Pressure alteration, the sudden uplift of deep water fish to shallow depth, local slumping, seiching, *tsunamis*, and vertical eddies have been cited as possible causes. Plafker (personal communication 1977) remarked that, "Most of the kills occurred in deep fjords or bays where large-scale submarine slope-failures are known to have occurred." Thomas P. Miller (personal communication 1977) suggests submarine landslides as the cause. Damage to commercial Alaskan fishery is described by Noerenberg (1971) and Harry, Jr. (1971). Earthquakes, thus, cause local and temporary disruption in availability of fish. Sea mammals other than sea otters, are locally diminished indirectly; as an Aleut friend put it simply: "No fish — no seal."

In the Aleutians, as in other volcanic islands — Hawaii, the Galapagos, and Iceland — both surface (subaerial) and submarine volcanism must be considered. The immediate and catastrophic effects of surface volcanism are well documented. For Alaska, such documentation is found in descriptions of the eruption of St. Augustine volcano by Davidson (1884) and Katmai in 1912 (Ball 1914; Martin 1913; Griggs 1917, 1918, 1922; Perry 1912). Additional data may be found in various reports by Coast Guard skippers available in the "General Correspondence of the Territorial Governors of Alaska," National Archives, Seattle, Washington. Useful discussion of surface volcanism effects elsewhere is found in Gorshkov (1958), Suslov (1961), Thorarinsson and Sigvaldson (1972), and Macdonald (1972). The latter's discussion includes secondary effects of volcanic activity on living organisms, including humans. Here, the focus is on immediate hazards to life, which are: a) lava flows on land; b) lava flows into bodies of water and concomitant thermal and chemical pollution; c) lava flows at sea; d) ash falls; e) ash dust canopy; f) ash flows; g) ashfall-associated chemical pollution carried by atmospheric precipitation or "acid rain"; h) mudflows; i) associated floods, which can be caused by mudflows, blockage of streams, local *tsunamis*, snow and ice slides, or melting of ice caps and snow cover; j) ice slides; k) gaseous emissions and associated chemical pollution (Macdonald 1972:414); and l) "weather" associated with surface and submarine volcanism. Atmospheric electricity is generated and thunder, lightning and torrential rain add to the picture of impending chaos and destruction. The psychological stress due to "weather," especially daytime darkness caused by ash canopies is well described in various sources (Steller 1774; Beaglehole 1967; Pallas 1784; Oglobin 1892; Griggs 1922; Fridriksson 1975).

Effects on land vegetation are described extensively in many sources, and will not be enumerated here. Land and avifauna are redistributed following significant ashfalls which affect vegetation (summarized in Macdonald 1972; for Alaska, see Wilcox 1959, 1965; Workman 1974, ms.).<sup>21</sup>

The effects of submarine volcanic activity on life forms are less obvious and to my knowledge little studied. Macdonald, in addition to local *tsunamis* generated by surface volcanism, mentions only that: "... steam cloud from shallow submarine eruptions may contain large amounts of salt, which, if the cloud drifts over agricultural areas on adjacent land, may be carried down with rain and so do considerable damage to crops. Similar salt-laden steam clouds may result where lava enters from land into the ocean" (1972:415).

Extensive submarine lava flows also affect the distribution of marine fauna due to water temperature changes. Lindberg (1956) proposed that extensive Quaternary sub-

marine lava flows caused the disjunctive distribution of North Pacific marine fauna. He specifically cited as a cause for the postulated south-north movement during the period of the Bering Sea formation a "thermal barrier" due to water temperature increase caused by massive ejection of magma affecting the moderately cold water fauna. No supportive literature has been found so far, nor were any recent studies of the effect of lava flows on ocean water temperatures and their indirect effect on marine fauna located. I present here fragmentary data.

In February 1825 Cpt. Benjamin Morrell (1832:193-194) observed a volcanic eruption in the Galapagos:<sup>22</sup>

. . . At about half-past four o'clock A.M., the boiling contents of the tremendous caldron had swollen to the brim, and poured over the edge of the crater in the cataract of liquid fire. A river of melted lava was now seen rushing down the side of the mountain, pursuing a serpentine course to the sea, a distance of about three miles from the blazing orifice of the volcano. . . . The demon of fire seemed rushing to the embraces of Neptune; and dreadful indeed was the uproar occasioned by their meeting. The ocean boiled, and roared, and bellowed, as if a civil war had broken out in the Tartarean gulf. . . . At three A.M., I ascertained the temperature of the water, by Fahrenheit's thermometer, to be 61°, while that of air was 71°. At eleven A.M., The air was 113°, and the water 100°, the eruption still continuing with unabated fury. The *Tartar's* anchorage was about ten miles to the northward of the mountain, and the heat was so great that the melted pitch was running from the vessel's seams, and the tar dropping from the rigging. . . .

. . . All that day the fires continued to rage with unabated activity, while the mountain still continued to belch forth its melted entrails in an unceasing cataract.

The mercury continued to rise until four P.M. when the temperature of the air had increased to 123°, and that of the water to 105°. Our respiration now became difficult, and several of the crew complained of extreme faintness. . . .

Morrell moved his ship out of danger, but in doing so sailed through a channel separating Narborough Island from Albermarle Island:

. . . Heaven continued to favor us with a fine breeze, and the *Tartar* slid along through the almost boiling ocean at the rate of about seven miles an hour. On passing the currents of melted lava, I became apprehensive that I should lose some of my men, as the influence of the heat was so great that several of them were incapable of standing. At that time the mercury in the thermometer was at 147°, but on immersing it into water it instantly rose to 150° . . .

. . . while the flaming Narborough lay fifteen miles to the leeward. . . . Here the temperature of the air was 110°, and that of the water 102° . . .

. . . the heat had increased to such an alarming degree that we found it necessary again to get under way, and abandon the bay entirely. At twelve meridian we passed the south point of Albermarle Bay, called Christopher's Point, at which time I found the mercury at 122° in the air, and at 98° in water (1832:194-195).

Recently, Fridriksson (1975:25-37) examined the thermal areas associated with the Surtsey submarine eruption off Iceland from 1963 to 1967. Fridriksson's data pertain to the period after the eruption ended. By 1973 while the lava flow had stopped, thermal activity continued with magma temperatures variable between 800°C, 1100°C and 1300°C. When lava entered the sea, steam vapor was produced. In the forty-three months of eruption, the energy generated was enough to raise by 2°C the temperature of one

cubic kilometer of sea water, but Fridriksson states that only a fraction of that energy went into heating water, “due to insulation effect of tephra.”

Descriptive accounts exist for Bogoslof in the Aleutians; but with the exception of observations of some recent subaerial eruptions they are not first hand reports but descriptions based on data obtained from eyewitnesses (by Langsdorff in 1806, Khlebnikov and Litke in 1820s, Veniaminov in 1825-1834). According to these accounts, the eruption of Bogoslof lasted several years and the lava flow affected the sea.

In the year 1795 the islanders noticed a fog bank shrouding the vicinity of a rock [where they used to hunt sea lions]. The fog did not lift even in most clement weather and caused the inhabitants of Unalaska and the neighboring Umnak a lot of headaches, as it prevented them from obtaining one of their major food sources. In a couple of years, an Aleut, tired of waiting for the fog to lift, decided to attempt to reach the [sea lion] rock. He returned shortly in a state of great agitation with the news that what was supposed to be fog was “smoke” (steam). As it was believed that the spot was [now] inhabited by spirits, nobody went there until 1800, when the horizon cleared and the Aleuts observed much to their surprise not the rock they knew so well but a new mountain peak that flamed and smoked like a torch (Langsdorff 1812:2:209, my translation).<sup>23</sup>

Litke (1835) and Veniaminov (1840) refer to “steaming,” “boiling” sea, and Veniaminov says that many years later the ground, when approached, was too hot for comfort. Khlebnikov (1979) writes that flaming sea or flames emerging from the sea were observed from the northwest Umnak and on the Bering side of Unalaska for several days. Davidson (1884) speaks of steaming and boiling sea in describing the eruption of St. Augustine.

Stanley Holmes, Unalaska, reports that when Tulik (Okmok) caldera erupted in 1960, lava ran across Crater Creek. The temperature of the water in the creek remained above normal for over a year, disrupting the salmon run (personal communication, March 22, 1978). In 1941, J. P. Harrington (ms) recorded a statement by the supervisor of the sealing operation on St. Paul that sea urchins died *en masse* due to sea water temperature changes caused by submarine volcanic activity. Despite such observations, very little scientific data were located on local redistribution of marine fauna caused by water temperature changes due to submarine lava flows. Some volcanologists have the opinion it is non-existent, minimal (Coats, personal communication) or short-lived (Miller, personal communication). Tangential information on pillow lava formation off Hawaii is found in J. G. Moore (1975) but none exists for the Aleutians. Opinions regarding lack or insignificance of thermal effects of submarine eruptions seem to rest on observations made a considerable time after eruptions or, in the case of Moore, in a tropical area, and seem to be contradicted by the previous witnesses' accounts. McClelland of the Smithsonian Institution (personal communication 1977), mentions fish and tortoises killed in an eruption of Mt. Fuji (Japan) in 864 A.D., a fish kill off Hawaii when Mauna Loa erupted (1950), fish kills near Karkar Island in Melanesia when the sea was “boiling” in 1951, and dead fish observed after the 1973 submarine volcano eruption (Fujukin Okano-ba, Volcano Islands, North Pacific). Brongersma-Sanders (1957:974) discussed the lethal effect on fish and benthic fauna of seawater temperature changes and reports instances of massive fish kills due to lava flows at Mauna Loa, Hawaii, in 1859, 1919, and 1950; and in the Gulf of Naples in 1794. Henry Swanson, recounting his late 1920s experience of two submarine eruptions off the coast of Atka in the Bering Sea,



mentioned that in one instance he observed fields of floating pumice and a mass kill of octopi.

Ashflows, characteristic of Aleutian volcanism, have been studied as surface volcanic phenomena (personal communication, Miller 1977). However, ashflows, probably also affect the surrounding sea. Miller and Smith (1975, 1977) state that large ashflows reached the Bering and Pacific from three volcanoes on the Alaska Peninsula and have originated from at least eight sources in the seventy kilometer stretch between Mt. Douglas and Frosty Peak. An ashflow is

... a mixture of ash and gases which moves as a heavy fluid at speeds of up to 100 m.p.h. with temperatures of up to 700 C., and covering areas of several hundred square miles. Ashflows have been found 30 miles away from their source after, in some cases, having climbed barriers of 1500 feet or more. I think that the major effect on Aleut ecosystem has come from ashflows and ashfalls and not from lava flows (personal communication, Miller 1977).

I do not know if ashflows occur in the submarine environment. However in shore waters, ashflows may constitute a source of thermal and chemical pollution, and affect marine life analogous to the adverse effects of nuclear thermal pollution.

Chemical pollution is probable in many types of volcanic eruptions: lava, ash flows, ash, and gas. All of these, entering the sea by various means, may have drastic effects on the local marine fauna (Brongersma-Sanders 1957:974). The effects of ashfall on surface vegetation and the secondary effects on cattle and humans (through consumption of contaminated vegetative matter), chemical and texture poisoning, are too well known to be discussed here (Macdonald 1972; Malde 1964; Wilcox 1959, 1965; Martin 1913; Griggs 1917, 1918, 1922; Workman 1974 and ms.). One investigator attributes pathological bone growth to ingestion of substances chemically polluted by volcanic contamination (Soriano 1970).

For the Aleutians, Veniaminov (1840:I:36-37, 259) documented destruction of vegetation and subsequent redistribution of large terrestrial fauna for Unimak Island, the Shumagin Islands, and Alaskan Peninsula following heavy ashfalls in the 1820s. Khlebnikov (1979) recorded a heavy ashfall on Unalaska Island, following a strong earthquake shock and "weather" from the southwest on the night of March 15-16, 1820. The stream and lake at the Illiuliuk settlement were so covered with ashes that water could not be used for drinking; the sea was muddy. The ash layer was more than a foot deep on land. Following this ashfall, caused by explosion on Umnak Island (presumably the Tulik volcano, Okmok caldera), there were no fish at Unalaska for the entire year and "even whales were not as numerous as usual." Khlebnikov adds considerable detail to Veniamonov's description of 1824 ashfalls on Unimak, following the explosion of Shishaldin volcano. This ashfall was preceded by strong earthquakes, felt at Unalaska. The late September 1826 ashfall reached Unalaska, continued for ten days and caused physical suffering to people. Even after taking shelter in houses (semi-subterranean *barabaras*), eyes were affected and all suffered unbearable headaches. Petrov (1878) reported a fish kill due to ashfall at Makushin village, Unalaska, following the eruption of Makushin volcano.

I suggest that ashfalls are harmful to marine fauna, especially to littoral, intertidal and benthic species, which are adversely affected by chemicals carried by ash sediment and by smothering by ash sediment in the water. The damage caused by smothering



would depend on the thickness of the sediment and on the distribution of such sediment by local currents.<sup>24</sup> The effect of ash sediment on biota apparently has not been researched. Arnold Bouma (personal communication through D. Scholl 1977) reported that concentrations of ash were found off Kodiak and to a much lesser extent, in Cook Inlet. He wrote: . . . "We do not know the influence on benthic organisms. In both areas such cannot be studied very well due to reworking and concentrating by currents." The ash sediment effect on salmon streams has been studied (Griggs 1922; Eicher and Rounsell 1957; Kurnekov 1966; Mathiesen and Poe, 1978), and an increase in the primary productivity of planktons has been documented. However, there is no evidence that any secondary productivity increase follows. Overproduction of planktons is not necessarily beneficial and, can cause marine fauna mortality (Brongersma-Sanders 1957) or paralytic poisoning among humans who consume shellfish in areas of certain types of plankton overproduction.

To sum up, the potential for disruption of food supply derived from the marine environment in an area of high tectonic and volcanic activity is very high. The phenomena described do not, of course, occur simultaneously in one locality nor do they all simultaneously affect the entire Aleutian Island chain.<sup>25</sup> However, it seems reasonable to postulate that at one time or another in the last 10,000 years all settlement areas in the Aleutians have experienced major catastrophes and that a great deal more frequently tectonic/volcanic activity caused local interruptions in the food supply. In the absence of modern communication systems human suffering must have been considerable. It is to be expected that adaptive strategies such as temporary or permanent resettlement were developed.<sup>26</sup>

Human beings respond to immediate danger and to *anticipated* danger. As noted, the likely response in prehistoric times was removal to another microhabitat. If a promising microhabitat was already occupied, inter-group conflict was probable, though not absolutely necessary. An alternative strategy may have been the joining of forces: it is known that through affinal ties Aleut chiefs maintained links outside their own polities. Affinal kin were under obligations of mutual assistance. Resettlement, either friendly or hostile, in an already populated area would result in population fluctuation. In the first case, population increase in the new locality may have resulted in possible overexploitation of local resources (Yessner 1977; Simenstadt, Estes and Kenyon 1978). Resettlement in an area previously unoccupied would create an additional habitation site for future archeologists to discover.

Any reconstruction of the prehistoric Aleut ecosystem and human population must take tectonic, seismic and volcanic activity into account. I suggest that therefore we cannot speak of a single "Aleut ecosystem" but should speak of local ecosystems in terms of microhabitats. I suggest that *in the short run in a given locality* geological processes may account for frequent abandonment, shifting of, and returning to previously abandoned, habitation sites. Such short term relocations would rarely appear in the archeological record of any given site or locality, but it may help explain the number of suspected settlement sites and help interpret the number of traces of habitations per site.

To conclude, I again wish to quote Robert D. Jones, Jr.:

I view the pre-contact ecosystem very much in the context of major natural events, of which volcanism is one. Animal populations, including man, move in and out of an area in response to these pressures. Thus, in the Aleutian ecosystem volcanism can render a

given area inhospitable for quite a while, and when the volcanism diminishes the animals return. But remember, the ecosystem that develops upon the return of its inhabitants may not look the same at first. Witness the rise of Chaluka instead of re-establishing Anangula. Conditions may be altered or the order of returning inhabitants may be different and these affect the evolution of the ecosystem (personal communication 1977).<sup>27</sup>

## NOTES

*Acknowledgements.* It would have been impossible to assemble materials pertinent to this paper without the assistance by many individuals and organizations. Especially helpful was Mr. Stetson Tinkham, National Marine Fisheries Service, Washington, D.C. Many colleagues, from other disciplines shared their knowledge. I shall always remain indebted to all.

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1. A preliminary draft of this paper was read at the Annual Meeting of the Alaska Anthropological Association, Anchorage, March 17-19, 1978.
2. For example, Hett and O'Neill (1974) built a constancy factor into the model developed for system analysis of the Aleut ecosystem. Even so, they obtained a very large sensitivity factor to marine environments and concluded that "Our analysis clearly indicates more intensive research on the marine subsystem and its interactions with the human population . . . if one wishes a more precise picture of the Aleut environment." The built-in constancy factor, however, led the authors to conclude that the environment was capable of sustaining a subsistence-based population far larger than 16,000. Black (1966) recognized the importance of seismic and volcanic activity, but interpreted possible effects as direct ones, acting immediately on humans. He explicitly denies effects on animal populations and hence the food source for the Aleuts. (See also note 6 re. Black's position that climatic phenomena do not disrupt Aleut food resources and my disagreement with this position.) Resource constancy is also implicit (and sometimes explicit) in various contributions to "Studies in Aleut-Kodiak Prehistory, Ecology and Anthropology," Laughlin and Reeder, Eds. (1966). Recently, McCartney explicitly recognized that "Volcanic eruptions can, at the least, destroy food resources for several months and cause dire psychological trauma to local inhabitants" (1977:68).
3. The widely accepted notion of genocide by Russians is also being challenged. See, for example, Turner (1976).
4. This assumption contradicts Liebig's "law of the minimum" which states that populations adjust to minimal conditions under which survival is possible, not to the mean ones.
5. Technically, *tectonic* and *seismic* refer to phenomena of a different order. However, for brevity sake, *tectonic* will be used forthwith and it is to be understood as subsuming seismic activity.
6. This paper is purposely limited to a single causal factor and its short term effects. That resource fluctuation can be due to factors other than tectonic and volcanic activity is explicitly recognized. Problems of ecological theory, such as succession (E. P. Odum 1969; Drury and Nisbet 1973), steady state communities (Simenstadt, Estes and Kenyon 1978), population collapses and replacements are not discussed. Long term resource fluctuation is also excluded, though a link exists between long and short term fluctuations. Long term effects may be due to climatic changes, fluctuations in local glaciations, and in sea level changes. See R. F. Black (references cited) on glaciation and sea level changes in the Aleutians. A well developed hypothesis links climatic fluctuations, specifically local cooling, to volcanic activity (Abbott 1913) some recent data confirm such a hypothesis (Mendonca, Hanson and DeLuisi 1978). Global cooling and major glacials are believed to be also linked to volcanic activity, but in a less direct and very complex fashion (Lichkov 1956; Lamb 1970; Mauk and Kienle 1973; Hein, Scholl and Miller 1978). It is assumed that these fluctuations are cyclical (Reinhart

1972; Hein, Scholl and Miller 1978). Black's discussion of neoglaciation in the Aleutians is very important in any discussion of resource fluctuation, though I emphatically disagree with his assumption that the human population remained unaffected. At least for one economically important species, sea otter, presence or absence of open sea is crucial. Recently, herds of sea otters were annihilated by a relatively brief period of freezing of the water near Unimak (Jones, personal communication). Kenyon (1975:133-135) states that in areas where the sea freezes occasionally, sea otters will survive only if they are able to move to ice-free locations. Where such movement is impossible, sea otters will die of starvation. Presence of off-shore ice for any extended period would doom local herds.

7. Enrichment of agricultural soil through volcanism and hence productivity is well known, as a long term effect. However, such enrichment may not be permanent (Colton 1960) and in some areas not relevant (Malde 1964; Workman 1974 and ms.). It is immaterial in the Aleutian context.
8. Dr. V. B. Scheffer directed my attention to the vivid description of mass mortality of fur seals by Captain Benjamin Morrell, Jr. observed September 20 and 24, 1828 on three islands off South African Coast:

On the surface of this island I saw the effects of a pestilence or plague, which had visited the amphibious inhabitants of the ocean with as much malignancy as the Asiatic cholera has the bipeds of the land. The whole island is literally covered with the carcasses of fur seal with their skin still on them. They appeared to have been dead about five years, and it was evident they had all met their fate about the same period. I should judge, from the immense magnitude of bones and carcasses, that not less than half a million had perished here at once, and that they had fallen victims to some mysterious disease or plague (1832:290).

9. I am indebted to Dr. William B. Workman for bringing this publication to my attention.
10. Contributions to this bulletin consist of a number of brochures (by many authors) published at various dates under number 1028 plus a letter of the alphabet. The bulletin appears in "References cited" as U.S. Geological Survey Bulletin 1028, and then in a separate appendix, individual contributions are listed alphabetically by author. In the texts, citations appear by author, date of publication and the brochure number, for example, 1028-M. Other pertinent U.S.G.S. publications are bulletin 857-D (Capps 1934) 974-B and 989-A (Coats 1950, 1951).
11. I have recently obtained additional data on episodes of earthquake and surface volcanism in the Aleutians in the period 1750-1768, too late to incorporate into the body of this paper. This applies to some episodes of submarine volcanism also. Though Dr. Miller wrote me "I have very little information on submarine lava flows, because they are relatively rare in the recent (i.e., last 10,000 years) volcanic record," it is not clear to me if he meant "globally rare" or "rare in the Aleutians." Certainly, instances of submarine volcanism have been recorded recently in various areas and several have occurred within the decade. Surtsey, off Iceland, is but a major instance (Fridriksson 1975). Volcanic island building goes on off Hawaii (Dr. C. B. Wood, Providence College, verbal communication); submarine volcanism is frequent off the Kuriles (Suslov 1961:404-405). An island recently appeared — then vanished — off Baja California (courtesy Dr. F. C. Shipek). Bogoslof, in the Aleutians, described in many sources since the early 1800s is periodically active (Jagger 1908; Munger 1909; Byers 1959; U.S.G.S. 1028-L; Bullard 1962, *inter alia*). Davydov (1977:96-97) assumed that Bogoslof was not the only instance of submarine island building in the Aleutians. He mentions the appearance and later disappearance of several "islands" off Unimak. Khlebnikov (1979), though disputing Davydov's locations, does not question the assumption as a whole. Specifically, it appears that submarine eruptions are frequent off Atka. Kasatochi Island is supposed to be an instance of volcanic island building, though to my knowledge it is not described in literature. In addition, Henry Swanson told me in March 1978 that twice, in the early 1920s, he was caught at sea in a small craft north of Atka during submarine eruptions. In one instance a shallow was created "sounding 11 fathoms. All around it the depth soundings are 1400, 1500 fathoms." Indeed, on recent navigational charts a previously unmarked shallow is shown in the area pointed out by Swanson. In 1883, during the subaerial eruption of St. Augustine, a submarine vent apparently was erupting simultaneously (Davidson 1884:188).

- Submarine eruptions occur off Japan (Bullard 1962:319 ff; Kune 1962). Brongersma-Sanders mentions such an event for 1831 in the Southern Mediterranean (1957:974).
12. While tectonic phenomena and seismic activity occur without accompanying volcanic activity, the observe obtains: volcanic activity, especially a major one, is usually though not absolutely necessarily, associated with seismic activity. The more or less continued volcanic activity between 1795-1800 by Bogoslof was accompanied by major earthquakes, which continued to be felt with unusual frequency on Unalaska through 1802. At the Illiuliuk settlement, many native houses collapsed (Langsdorff 1812:209). Major earthquakes accompanied the Shishaldin eruption of 1825, Issanakh ridge eruption of 1826 on Unimak, the "explosion" in the north of Umnak (presumably Okmok Caldera) in 1820, and of Yunaska in 1825. Earthquakes preceded and accompanied the Katmai eruption of 1912 (Griggs 1917, 1918, 1922; Martin 1913). A reasonable postulate is that the Late Pleistocene-Early Holocene major volcanic episodes documented for the Aleutians by geologists, were accompanied by earthquakes. If so, major changes in land and marine topography may be postulated. There is an unconfirmed report of an Aleut tradition to this effect, communicated to me verbally, by Mr. J. Stewart of Newton, Massachusetts, recorded by his uncle in the 1930s when the latter served on a U.S. Geodetic Survey vessel. Reportedly, Aleuts claimed that the islands of Unalaska and Umnak at one time formed a single landmass and that Umnak Pass opened in a single incident. A village site, now under water, was located on an isthmus in the pass. The Aleuts reportedly said that Ship Rock is a remnant of the isthmus. In the Central Aleutians, the modern island of Kagalaska may have been part of the landmass of the island of Adak as late as the early 19th century or the end of the 18th. In early Russian sources the two modern islands are reported as a single landmass.
  13. They are directly related to the volcanic arcs of Kamchatka, the Kurile Islands, and Japan. See Catalogue of the Active Volcanoes of the World, parts 7 and 8 for Kamchatka and the Kuriles, Gorshkov (1958) and Vlodavets and Piip (1959). See also Suslov (1961:382 ff.). See Coleman (1973), Macdonald and Kune (1962), Knopoff, Drake and Hart (1968) re. systemic relationship of Pacific volcanic arcs.
  14. *Tsunami*: "a sea — or earthquake generated abnormal wave of unusual force, actually a series of waves, moving at speeds of about 800 km per hour" (Kerr 1978:521).
  15. I have borrowed this phrase from Dr. Wm. B. Workman who used it in a letter to me.
  16. For discussion of the psychological effect of volcanism see Malde (1964); Colton (1960); Ray (1954); Workman (1974 and ms.); Wilcox (1959); Souther (1970). Perry (1912) describes psychological stress generated by the 1912 Katmai eruption and Salamatov (ms.) the panic on Atka in 1848.
  17. For the importance of littoral and intertidal fauna to Aleut survival see, *inter alia*, Love (1976); Laughlin (1972); Laughlin and Aigner (1975); McCartney (1975); Aigner (1976).
  18. Brongersma-Sanders considers oxygen deprivation one of the leading causes of mass mortality of sea fauna. Consult her article (1957) for discussion of causes of oxygen deprivation. Note that ashfalls may cause oxygen deprivation also.
  19. Local residents (Unalaska and Anchorage) believe that a number of sea otters have been killed during the several tests conducted at Amchitka. R. D. Jones wrote me that "there was considerable mortality of sea otters (not widely mentioned in the press)." If so, it appears that sea otters may be damaged by shock waves. However, these unofficial reports are contradicted by official publications, as by Wright and altonin and Kirkwood, in *Symposium on Amchitka, Bioenvironmental Studies*, Duke, ed. (1971:673-677 and 1971:701-711) and in a personal communication by Coats and by Plafker, in response to my inquiry on the possible effect on marine fauna of earthquake generated shock waves. Plafker compared one of the tests, a one-megaton blast, to "a 7 magnitude earthquake" and pointed out that no damage to sea otters was observed. Dr. T. Shimkin, Smithsonian Institution, however, in a telephone conversation indicated that one megaton does not translate into earthquake magnitude scale that easily and stated that a sizeable earthquake would be equivalent to "megaton upon megaton." Coats thinks that during the "Longshot" test some sea otters were killed, while the official report by the U.S. Department of Energy (1967) states that there was no damage to biota.

20. Fr. Paul Morculief, a native of St. George Island and a resident of Nikolski, Umnak, pointed out that the Aleut term for codfish can be rendered into English "the fish that stops," meaning it disappears periodically (conversation in March 1978 at Unalaska).
21. Workman MS has been published in *Volcanic Activity and Human Ecology*, ed. by Payson D. Shields and Donald K. Grayson (1979, NY: Academic Press, pp. 339-372).
22. Portions of Morrell's account have been published by Sierra Club Publications, Kenneth Bowers, ed. (1964). There the date of observation is given incorrectly as 1812. The observations pertain to Morrell's second voyage, on the *Tartar*, 1824-1828.
23. Khlebnikov (1979) challenges the date of Bogoslof's emergence as reported by Langsdorff and in various contemporary publications in the early 1800s. He states that official reports on hand obtained from eyewitnesses date the first observation to 8 May 1796.
24. In a telephone conversation, December 1976, Dr. H. Sigurtsen, University of Rhode Island, told me that during a recent investigation off Iceland he observed ash sediment as much as ten centimeters thick on the sea bottom. He said that the marine life was totally extinct, but, unfortunately, he did not note the extent of the affected area.
25. For example, the Near Islands, geologically very old formations, do not stand any danger from local subaerial volcanism. Subaerial volcanoes do not extend west of Buldir Island. It follows, that Attu and Agattu would be affected only by earthquake associated phenomena, such as *tsunamis*, seismic shocks, seismic shaking (ground motion) and by long distance effect of subaerial volcanism elsewhere, possibly by ashfalls or acid rain. I do not know if submarine volcanic vents exist in the proximity of Attu-Agattu.
26. Aleut traditions of major catastrophes are extant for the Eastern Aleutians, Rat Islands, and Atka. A major catastrophe in the Rat Islands is supported by geological data. Nelson (1959:U.S.G.S. Bulletin 1028-J) speaks of a Krakatoa-like eruption which geologists have trouble dating. When such a catastrophe strikes, even when communication and transportation systems permit relief for the affected population, major dislocations occur. For example, in 1977 when Mt. Usu, Japan erupted and threatened the town of Toyako Onsen, 10,000 people were evacuated. Damage above ground was estimated at \$127,000,000: thousands of acres of fertile land were destroyed and "thousands of fish perished in one crystal lake, parts of which still turn ash after each rain." ("Town tries to be calm on edge of a volcano," San Diego Times, December 11, 1977, New York Times Service Dispatch. Courtesy of Dr. Florence C. Shipek.) For description of a recent catastrophic eruption in Kamchatka see Gorshkov (1959); see Thorarinsson and Sigvaldson (1972) for description of the 1970 Hekla eruption. Though I have no direct contemporary statements on the cause/effect of the Kamchatka famine of the 1760s, it is known that this famine was due to an unexplained absence of fish in Kamchatka waters (Levashev, cited in Sokolov 1852). It is interesting to note that the second half of the 18th century seems to have been a period of intensified seismic and volcanic activity in the area. Pallas reports a number of earthquakes and eruptions in Kamchatka in 1781, 1789, 1790 and 1791. Members of Cook's voyage to the North Pacific report a massive eruption of the Avachinskaya Sopka in June 1779 (Beaglehole 1967:677-678). Steller (1774) reports a number of earlier episodes. Bearing in mind the systemic relationship of the volcanic arcs in the Pacific, it is possible to hypothesize that such activity intensified in the Aleutians also.
27. It is unfortunate that a direct relationship between the Anangula and Chaluka sites is implied here. There is a significant temporal break between these two sites and direct succession, or that both sites were inhabited by the Aleuts or their direct ancestors, has been not established beyond a shadow of a doubt. Anangula is dated by the radio-carbon method at  $8425 \pm$  B.P., which "establishes Anangula as the earliest chronometrically dated site in the arctic and subarctic regions of North America" (McCartney and Turner 1966:31). Chaluka is dated at the earliest  $1724 \pm$  B.C. or roughly 4,500 B.P. (Denniston 1966:87), or to  $5165 \pm 391$  (see Aigner 1976 for the most recent in depth discussion of the dating of the SW Umnak sites). Thus, Mr. Jones' example is inappropriate and unsuitable for short-term population movement analysis.

# REFERENCES

- Abbot, G. C.
  - 1913 Do Volcanic Explosions Affect Our Climate? *National Geographic Magazine* 24(2): 181-198.
- Aigner, Jean S.
  - 1976 Dating the Early Holocene Maritime Village of Anangula. *Anthropological Papers of the University of Alaska* 18(1):51-62.
- Ball, E. M.
  - 1914 Investigation of the Effect of the Eruption of the Katmai Volcano Upon the Fisheries, Fur Animals and Plant Life of the Afognak Island Reservation. *In Alaska Fishery and Fur Seal Industries in 1913*. B. W. Evermann, Ed., pp. 59-64. Bureau of Fisheries Documents, 780 (1912), 797 (1913), 819 (1914).
- Baxter, Rae E.
  - 1971 Earthquake Effects on Class in Prince William Sound. *The Great Alaska Earthquake of 1964. Biology*, pp. 238-245. Washington, D.C.: The National Academy of Sciences.
- Beaglehole, A. C.
  - 1967 The Journals of Captain James Cook, III. *In The Voyage of the Resolution and Discovery 1776-1780*. A. C. Beaglehole, Ed. 1:677-678. Excerpts from the journal, with comments of Cpt. King.
- Black, Robert F.
  - 1966 Late Pleistocene to Recent History of Bering Sea-Alaska Coast and Man. *Arctic Anthropology* 3(2):7-21.
  - 1974a Geology and Ancient Aleuts, Amehitka and Umnak Islands, Aleutians. *Arctic Anthropology* 11(2):126-140.
  - 1974b Late Quaternary Sea Level Changes, Umnak Island, Aleutians: Their Effects on Ancient Aleuts and Their Causes. *Quaternary Research* 4:264-281.
  - 1975 Late Quaternary Geomorphic Processes: Effects on the Ancient Aleuts of Umnak Island in the Aleutians. *Arctic* 28(3):159-169.
  - 1976a Late Quaternary Glacial Events, Aleutian Islands, Alaska. *Quaternary Glaciation in the Northern Hemisphere IUCS. Report No. 3*, Project 73-1-24.
  - 1976b Influence of Holocene Climatic Changes on Aleut Expansion into the Aleutian Islands, Alaska. *Anthropological Papers of the University of Alaska* 18(1):31-42.
  - 1976c Geology of Umnak Island, Eastern Aleutian Islands as Related to the Aleuts. *In Arctic and Alpine Research* 8(1):7-35.
- Bowers, Kenneth, Ed.
  - 1964 Galapagoes. Sierra Club Publications.
- Brongersma-Sanders, Margaretha
  - 1957 Mass Mortality in the Sea. *Geological Society of America, Memoirs* 67(1):941-1010.
- Bullard, Fred M.
  - 1962 Volcanoes in History, in Theory, in Eruption. Austin: University of Texas Press.
- Byers, F. M., Jr.
  - 1959 Geology of Umnak and Bogoslof Islands, Aleutian Islands, Alaska. 1028-L.
- Capps, Stephen R.
  - 1934 Notes on the Geology of the Alaska Peninsula and Aleutian Islands. USGS Bulletin 857-D. Washington, D.C.: U.S. Government Printing Office.
- Coats, Robert R.
  - 1950 Volcanic Activity in the Aleutian Arc. U.S. Department of Interior, Geological Survey Bulletin 974-B. Washington, D.C.: U.S. Government Printing Office.
  - 1951 Geology of Buldir Island; Aleutian Islands, Alaska. USGS Bulletin 989-A. Washington, D.C.: U.S. Government Printing Office.
- Coleman, Patrick J., Ed.
  - 1973 The Western Pacific: Island Arcs. Marginal Seas. Geochemistry. University of Western Australia Press.



- Colton, Harold A.  
1960 *Black Sand — Prehistory of Northern Arizona*. Albuquerque: University of New Mexico Press.
- Davidson, George  
1884 Notes on the Volcanic Eruption of Mount St. Augustin, Alaska, October 6, 1883. *Science* 3(54): 186-189.
- Davydov, G. I.  
1977 *Two Voyages to Russian America, 1802-1807*. Richard A. Pierce, Ed. Kingston, Ohio: The Limestone Press. Originally published in Russian, 1810-1812. St. Petersburg.
- Denniston, Glenda  
1966 Cultural Change at Chaluka, Umnak Island. *Arctic Anthropology* 3(2):84-124.
- Drury, Wm. H. and Ian C. T. Nisbet  
1973 Succession. *In* *Journal of the Arnold Arboretum* 54(3):331-363.
- Duke, James H., Ed.  
1971 Symposium on Amchitak Island Bioenvironmental Studies. *BioScience* 21(12):599-711. American Institute of Biological Sciences.
- Eicher George J. Jr. and George A. Rounsell  
1957 Effects of Lake Fertilization by Volcanic Activity on Abundance of Salmon. *Limnology and Oceanography* 2:70-76.
- Eyderdam, Walter J.  
1971 Flowering Plants Found Growing Between Pre- and Postearthquake Hightide Lines During the Summer of 1965 in Prince William Sound. *The Great Alaska Earthquake of 1964, Biology*, pp. 69-81. Washington, D.C.: The National Academy of Sciences.
- Ferrians, Oscar J. Jr.  
1966 Effects of the Earthquake of March 27, 1964 in the Copper River Basin Area, Alaska. U.S. Geological Survey Professional Paper 543-E.
- Fraser, George D. and G. L. Snyder  
1959 Geology of southern Adak Island and Kagalaska Island. 1028-M.
- Fridriksson, Sturla  
1975 *Surtsey*. New/Toronto. John Wiley & Sons, Halsted Press.
- Frøhlich, Bruno and David Kopjanski  
1976 Aleut Site Survey, Adak Island and Attu Island. St. Louis, Society for American Archeology. Unpublished.
- Gorshkov, G. S.  
1958 Catalogue of the Active Volcanoes and Solfatra Fields of the Kurile Islands. Catalogue of the Active Volcanoes of the World. International Volcanological Association, 1957-1960, Eds.  
1959 Gigantic Eruption of the Volcano Bezymianny. *Bulletin Volcanologique* 20:77-112.
- Grantz, Arthur, George Plafker, and Reuben Kachadoorian  
1964 Alaska's Good Friday Earthquake, March 27, 1964. A Preliminary Geologic Evaluation. Washington, D.C.: Geological Survey Circular 491.
- Griggs, Robert F.  
1917 The Valley of Ten Thousand Smokes. *The National Geographic Magazine* 31(1):13-68.  
1918 The Valley of Ten Thousand Smokes. *The National Geographic Magazine* 33(2):115-169.  
1922 The Valley of Ten Thousand Smokes. Washington, D.C.: The National Geographic Society.
- Hanna, G. Dallas  
1971 Introduction: Biological Effects of the Earthquake as Observed in 1965. *The Great Alaska Earthquake of 1964, Biology*, pp. 15-34. Washington, D.C.: The National Academy of Sciences.
- Harrington, J. P.  
ms Unpublished. Anthropological Archives. Washington, D.C.: Smithsonian Institute.
- Harry, George Y. Jr.  
1971 Introduction, Part III, Effects on Fish and Shellfish. *The Great Alaska Earthquake of 1964, Biology*, pp. 169-174. Washington, D.C.: The National Academy of Sciences.

- Haven, Stoner B.
  - 1971 Effects of Land-Level Changes on Intertidal Invertebrates, with Discussion of Post-earthquake Ecological Succession. The Great Alaska Earthquake of 1964, Biology, pp. 82-126. Washington, D.C.: The National Academy of Sciences.
- Hays, James D., Ed.
  - 1970 Geological Investigations of the North Pacific. The Geological Society of America, Inc., Memoir 126.
- Hein, James R., David W. Schell and Jacqueline Miller
  - 1978 Episodes of Aleutian Ridge Explosive Volcanism. *Science* 199(4325):137-141.
- Hett, J. M. and R. V. O'Neill
  - 1974 Systems Analysis of the Aleut Ecosystem. *Arctic Anthropology* 11(1):31-40.
- Hubbard, Joel D.
  - 1971 Distribution and Abundance of Intertidal Invertebrates at Olsen Bay in Prince William Sound, Alaska, One Year After 1963 Earthquake. The Great Alaska Earthquake of 1964, Biology. Washington, D.C.: The National Academy of Sciences.
- Iokhel'son, Vladimir (Jochelson, W.)
  - 1925 Archeological Investigations in the Aleutian Islands. Washington, D.C.: Carnegie Institution.
- Jagger, T. A. Jr.
  - 1908 Journal of the Technology Expedition to the Aleutian Islands, 1907. Boston: Geo. H. Ellis Co., Printers.
- Johansen, H. William
  - 1971 Algae in Prince William Sound. The Great Alaska Earthquake of 1964, Biology, pp. 35-68. Washington, D.C.: National Academy of Sciences.
- Kachadoorian, Reuben and George Plafker
  - 1967 Effects of the Earthquake of March 27, 1964 on the Communities of Kodiak and Nearby Islands. Washington, D.C.: U.S. Government Printing Office. Geological Survey Professional Paper 542-F.
- Kenyon, Karl W.
  - 1975 The Sea Otter in the Eastern Pacific Ocean. New York, Dover Publications, Inc. Originally published by Bureau of Sport Fisheries and Wildlife. Washington, D.C.: U.S. Government Printing Office, 1969.
- Kerr, Richard A.
  - 1978 Tidal Waves: New Method Suggested to Improve Prediction. *Science* 200(4341):521-522.
- Khlebnikov, Kirill T.
  - 1979 Russkaya Amerika v neopublikovannykh zapiskakh K. T. Khlebnikova. Liapunova and Fedorova, Eds. Leningrad, Nauka.
- Knopoff, Leon, Charles L. Drake, and P. J. Hart, Eds.
  - 1968 The Crust and Upper Mantle of the Pacific Area. Washington, D.C.: American Geophysical Union.
- Kroeber, Alfred L.
  - 1939 Cultural and Natural Areas of Native North America. University of California Publications in Anthropology and Ethnology, Vol. 38. California: University of California Press.
- Kune, Hisashi
  - 1962 Catalogue of the Active Volcanoes and Solfatra Fields of Japan, Taiwan and Marianas. Catalogue of the Active Volcanoes of the World. International Volcanological Association, Napoli, Italy, 1957-1960, Eds. 16 part 11.
- Kurenkov, I. I.
  - 1966 The Influence of Volcanic Ashfall on Biological Processes in a Lake. *Limnology and Oceanography* 11:436-429.
- Lamb, H. H.
  - 1970 Volcanic Dust in the Atmosphere; With a Chronology and Assessment of its Meteorological Significance. *Philosophical Transactions of the Royal Society* 266:425-533.



- Langsdorff, G. H.  
1812 *Bemerkungen auf einer Reise um die Welt in den Jahren 1803 bis 1807*. Vol. 2. Frankfurt am Main, Friedrich Wilmans.
- Lantis, Margaret  
1970 *The Aleut Social System, 1750-1810, From Early Historical Sources. Part II of Ethnohistory of Southwestern Alaska and the Southern Yukon. Method and Content*. M. Lantis, Ed. Lexington, Kentucky: The University Press of Kentucky.
- Laughlin, William S.  
1972 *Ecology and Population Structure in the Arctic. The Structure of Human Populations*. G. A. Harrison and A. J. Boyce, Eds. Oxford: Clarendon Press.
- Laughlin, William S. and Jean S. Aigner  
1975 *Aleut Adaptation and Evolution. Prehistoric Maritime Adaptations of the Circumpolar Zone*. William Fitzhugh, Ed. The Hague/Paris: Mouton Publishers.
- Laughlin, William S. and W. G. Reeder, Eds.  
1966 *Studies in Aleutian-Kodiak Prehistory, Ecology and Anthropology*. *Arctic Anthropology* 3(2).
- Lichkov, B. L.  
1956 *O svyazi mezhdu izmeneniyami struktury zemli i izmeneniyami klimata. Doklady na yezhegodnykh ohtepiyakh pamiaty L.S. Berga I-III, 1952-1954*, pp. 193-210. Moscow-Leningrad: Academia Nauk SSR.
- Lindberg, L.  
1956 *K voprosu oproiskhozheniya prevannykh arealov morskoi fauny. Doklady pa yezhegodnykh ohtepiyakh pamiaty L.S. Berga, I-III, 1952-1954*, pp. 5-32. Moscow-Leningrad: Academia Nauk SSR.
- Litke, Feder Petrovich (Luetke)  
1835 *Puteshestviye vokrug sveta, sovershennoye po povelenu Imperatora Nikolaya no vovennom shlipe Seniyavine v. 1826-1829 godakh Flota Kapitana Fedorom Litke*. St. Petersburg.
- Love, Gordon  
1976 *The Biota of the Nikolski Strandflat*. *Anthropological Papers of the University of Alaska* 18(1):43-49.
- Macdonald, Gordon A.  
1972 *Volcanoes*. Englewood Cliffs, New Jersey.
- Macdonald, Gordon A. and Hisashi Kune, Eds.  
1962 *The Crust of the Pacific Basin*. Publication No. 1035. American Geophysical Union.
- Malde, Harold E.  
1964 *The Ecologic Significance of Some Unfamiliar Geologic Processes. The Reconstruction of Past Environments*. Assembled by J. J. Hester and J. Schoenwetter. No. 3, Fort Burgwin Research Center.
- Marriott, Richard A. and Carl E. Spetz  
1971 *Effects of Seawater Intrusion into Lakes of Kodiak and Afognak Islands. The Great Alaska Earthquake of 1964, Biology*, pp. 246-254. Washington, D.C.: The National Academy of Sciences.
- Martin, George C.  
1913 *The Recent Eruption of Katmai Volcano in Alaska*. *The National Geographic Magazine* 24(2):131-181.
- Mathiesen, Ole A. and Patrick H. Poe  
1978 *Effects of Volcanic Ash Deposits on Sockeye Salmon Lakes*. Contribution No. 481, College of Fisheries, University of Washington. *Vernehmungen, Internationales Verein fuer Limnologie* 20:165-172.
- Mauk, F. J. and J. Kienle  
1973 *Microearthquakes at St. Augustine Volcano, Alaska, Triggered by Earth Tides*. *Science* 182:386-389.

- McCartney, A. P.
  - 1974 1972 Archeological Site Survey in the Aleutian Islands, Alaska. *International Conference on the Prehistory and Paleoecology of Western North American Arctic and Subarctic*. S. Raymond and P. Snelderman, Eds. The University of Calgary Archeological Association.
  - 1975 *Maritime Adaptations in Cold Archipelagoes: An Analysis of Environment and Culture in the Aleutian and Other Island Chains*. Prehistoric Adaptations of the Circumpolar Zone. William Fitzhugh, Ed., pp. 281-338. The Hague/Paris: Mouton Publishers.
  - 1977 *Prehistoric Human Occupation of the Rat Islands*. The Environment of Amohitka Island, Alaska. M. L. Maeitt and R. G. Fuller, Eds. Technical Information Center, Energy Research and Development Administration TID — 26712, 1977.
- McCartney, A. P. and C. G. Turner II
  - 1966 Stratigraphy of the Anangula Unifacial Core and Blade Site. *Arctic Anthropology* 3(2):28-40.
- Mendonca, Bernard G., K. H. Hanson and J. J. DeLuisi
  - 1978 Volcanically Related Secular Trends in Atmospheric Transmission at Manua Lea Observatory, Hawaii. *Science* 202(3):513-515.
- Miller, Thomas P. and Ivan Barnes
  - 1976 Potential for Geothermal Energy Development in Alaska. *Circum-Pacific Energy and Mineral Resources*. Memoir No. 25, pp. 149-153. American Association of Petroleum Geologists.
- Miller, Thomas P. and Robert L. Smith
  - 1975 Ashflowers on the Alaska Peninsula: A Preliminary Report on their distribution, composition and age. *Geological Society of America, Abs. With Programs*, v. 7, p. 1201.
  - 1977 Spectacular mobility of ash flows around Fisher calderas, Alaska. *Geology* 5:173-176.
- Mooney, James
  - 1928 *The Aboriginal Population of America North of Mexico*. John R. Swanton, Ed., 80(70). Washington, D.C.: Smithsonian Miscellaneous Collection. Publication 2955.
- Moore, James G.
  - 1975 Mechanism of Formation of Pillow Lava. *American Scientist* 63(3):269-277.
- Morrell, Benjamin Jr.
  - 1832 *A Narrative of Four Voyages to the South Sea, North and South Pacific Ocean, Ethiopic and Southern Atlantic Ocean, Indian and Antarctic Ocean, From the Year 1822 to 1831*. New York: J. & J. Harper.
- Munger, F. M.
  - 1909 A Jack in the Box. An Account of the Strange Performance of the Most Wonderful Island in the World. *National Geographic Magazine* February 1909:194-197.
- National Academy of Sciences
  - 1971 *The Great Alaska Earthquake of 1964, Biology, Oceanography and Coastal Engineering*. Committee on the Alaska Earthquake of the Division of Earth Sciences National Research Council. Washington, D.C.
- Nelson, W. H.
  - 1959 *Geology of Seguam, Davidof and Khvostof Islands, Alaska*. 1028-P.
- Noerenberg, Wallace H.
  - 1971 *Earthquake Damage to Alaskan Fisheries*. The Great Alaska Earthquake of 1964, Biology, pp. 170-193. Washington, D.C.: The National Academy of Sciences.
- Odum, Eugene P.
  - 1969 The Strategy of Ecosystem Development. *Science* 1964:262-270.
- Odum, William E.
  - 1970 Insidious Alteration of the Estuarine Environment. *American Fisheries Society, Transactions* 4:836-847.
- Oglobin, N. N.
  - 1892 Putevye zapiski morekhoda I. M. Solovieva, 1770-1775. *Russkaya Starina* 76:183-214.

- Pallas, Peter S.  
 1781 *Neue Nordische Beitræge* 1:167-168.  
 1783 *Neue Nordische Beitræge* 4:142-145.  
 1784 Von dem in Ochozk dem 26 Maerz 1781 bemerkton Erdbeben and darauf erfolgter Witterung. *In* *Neue Nordische Beitræge* 7:142-145.
- Perry, K. W.  
 1912 Volcanoes of Alaska. *National Geographic Magazine* 23(8):824-832.
- Petrov (Petroff), Ivan  
 1878 *Journal of a Trip to Alaska in Search of Information for the Bancroft Library*, San Francisco. Typescript of an unpublished manuscript, pp. 42 and 23. Berkeley: Bancroft Library, University of California.
- Ray, Verne F.  
 1954 *The Sanpoil and Nespelem, Salishan People of Northeastern Washington*. Originally published 1933, Seattle: University of Washington Press. Reprinted 1954, New Haven: Human Relations Area Files.
- Rinehart, John S.  
 1972 18.6 — Year Earth Tide Regulates Geyser Activity. *Science* 177:346-347, 28 July 1972.
- Roys, Robert S.  
 1971 Effect of Tectonic Deformation on Pink Salmon Runs in Prince William Sound. The Great Alaska Earthquake of 1964, Biology, pp. 220-237. Washington, D.C.: The National Academy of Sciences.
- Salamatov, Lavrentiy  
 ms. A manuscript fragment of the daily journal, entries for 1848, Bancroft Collection. Berkeley: University of California. Listed as Anonymous priest, fragment of a journal. Identification of authorship by L. Black, 1978.
- Simenstadt, Charles A., James A. Estes, and Karl W. Kenyon  
 1978 Aleuts, Sea Otters and Alternate Steady-State Communities. *Science* 200(4340):403-411.
- Sokolov, A.  
 1852 *Ekspeditsiya k Aleutskim Ostrovam kapitanov Krenitsyna i Levasheva, 1764-1769*. *Zapiski Gidrograficheskogo Departamenta* 10:70-103.
- Soriano, M.  
 1970 Fluoric Origin of the Bone Lesion in the *Pithecanthropus Erectus* Femur. *American Journal of Physical Anthropology* 32:49-57.
- Souther, J. G.  
 1970 Recent Volcanism and its Influence on Early Native Cultures of Northwestern British Columbia. *In* *Early Man and Environment in Northwest North America*. R. A. Smith and J. W. Smith, Eds., pp. 53-64. Canada: Calgary, Alberta.
- Steller, Wilhelm Georg  
 1774 *Beschreibung von dem Lande Kamtschatka*. Stuttgart, 1774. Facsimile edition, Stuttgart, 1974:44-45.
- Suslov, S. P.  
 1961 *Physical Geography of Asiatic Russia*. Translated from the Russian by N. A. Gershevsky. J. E. Williams, Ed. San Francisco/London: W. H. Freeman.
- Thorarinsson, S. and G. E. Sigvaldson  
 1972 The Hekla Eruption of 1970. *Bulletin Volcanologique* 36:269-288.
- Thornstein, Frederick, John H. Vihelle and Dona Birkholtz  
 1971 Salmon Survival in Intertidal Zones of Prince William Sound Stream in Uplifted and Subsided Areas. The Great Alaska Earthquake of 1964, Biology, pp. 194-219. Washington, D.C.: The National Academy of Sciences.
- Turner, Christy G. II  
 1976 The Aleuts of Akun Island. *The Alaska Journal* 6(1):25-31.
- Ubeliquer, Douglas H.  
 1976 The Sources and Methodology for Mooney's Estimates of North American Indian Populations. *In* *The Native Populations of the Americas in 1492*. William M. Donovan, Ed., pp. 243-288. Madison, Wisconsin: University of Wisconsin Press.

- United States Department of Energy  
 1967 Final Report, Longshot Bioenvironmental Safety Program. A. E. Seymour and R. E. Nakatani, Eds., October 27, 1967. Laboratory of Radiation Ecology, College of Fisheries, University of Washington, Seattle. A Facsimile Report, reproduced by U.S. Department of Energy, Oak Ridge, Tennessee: Technical Information Center.
- United States Geological Survey  
 1956-1971 Bulletin 1028. Investigation of Alaskan Volcanoes. See Appendix I for listing of individual contributions.
- Veniaminov, Ioann (Innokentii)  
 1840 Zapiski ob Ostrovakh Unalshkinskogo Otdela. Three parts in two volumes. St. Petersburg; Russian American Company.
- Vlodavetz, V. I. and B. I. Piip  
 1959 Catalogue of the Active Volcanoes and Solfatra Fields of Kamchatka and Continental Areas of Asia. *In* Catalogue of the Active Volcanoes of the World. International Volcanological Association, Napoli, Italy 1957-1960, Ed., 16(8).
- Wilcox, Ray E.  
 1959 Some Effects of Recent Volcanic Ash Falls with Special Reference to Alaska. United States Geological Survey Bulletin, 1028-N, Investigation of Alaskan Volcanoes. Washington, D.C.: U.S. Government Printing Office.  
 1965 Volcanic-Ash Chronology. *In* The Quaternary of the United States. H. E. Wright, Jr. and E. G. Fray, Eds. Miscellaneous studies, pp. 807-816.
- Workman, William B.  
 1974 The Cultural Significance of a Volcanic Ash which Fell in the Upper Yukon Basin about 1400 Years Ago. *In* International Conference on the Prehistoric and Paleoecology of Western North Pacific American Arctic and Subarctic. Scott Raymond and Peter Schledermann. Eds. Canada: Calgary, Alberta. Archeological Association, University of Calgary.
- Yesner, David R.  
 1977 Resource Diversity and Population Stability Among Hunter-Gatherers. *The Western Canadian Journal of Anthropology* 7(2):18-57.

### Appendix I

United States Geological Survey Bulletin 1028 — Investigation of Alaskan Volcanoes. Washington, D.C., U.S. Government Printing Office.

- Barth, Tom F. W.  
     Geology and Petrology of the Pribilof Islands, Alaska. 1028-F.
- Byers, F. M., Jr.  
     1959 Geology of Umnak and Bogoslof Islands, Aleutian Islands, Alaska. 1028-L.
- Coats, Robert R.  
     1956a Geology of Northern Adak Island, Alaska. 1028-C.  
     1956b Geology of Northern Kanaga Island, Alaska. 1028-D.  
     1956c Reconnaissance Geology of Some Western Aleutian Islands, Alaska. 1028-E.  
     1959 Geological Reconnaissance of Semisopochnoi Island, Western Aleutian Islands, Alaska. 1028-O.
- Coats, R. R., W. H. Nelson, R. Q. Lewis, and H. A. Powers  
     1961 Geological Reconnaissance of Kiska Island, Aleutian Islands, Alaska. 1028-R.
- Drews, H., G. D. Fraser, G. L. Snyder, and H. F. Barnett, Jr.  
     1961 Geology of Unalaska Island and Adjacent Insular Shelf, Aleutian Islands, Alaska. 1028-S.
- Fraser, George D. and H. F. Barnette  
     1959 Geology of the Delarof and the Westernmost Andreanof Islands, Aleutian Islands, Alaska. 1028-I.
- Fraser, George D. and G. L. Snyder  
     1959 Geology of Southern Adak Island and Kagalaska Island. 1028-M.
- Gates, Olcott, H. A. Powers, and Ray E. Wilcox  
     1971 Geology of Near Islands, Aleutian Islands, Alaska, with a section on Surficial Geology by John P. Schafer. 1028-U.
- Kennedy, George C. and H. H. Waldron  
     1955 Geology of Pavlov Volcano and Vicinity, Alaska. 1028-A.
- Lewis, R. G., W. H. Nelson, and H. A. Powers  
     1960 Geology of Rat Island, Aleutian Islands, Alaska. 1028-C.
- Nelson, W. H.  
     1959 Geology of Seguam, Davidof and Khvostof Islands, Aleutian Islands, Alaska. 1028-J.
- Powers, H. A., R. R. Coats, and W. H. Nelson  
     1960 Geology and Submarine Physiology of Amchitka Island, Alaska. 1028-P.
- Simmons, Frank S. and D. E. Mathewson  
     1955 Geology of Great Sitkin Island, Alaska. 1028-B.
- Snyder, G. L.  
     1959 Geology of Little Sitkin Island, Alaska. 1028-H.
- Waldron, Howard H.  
     1961 Geologic Reconnaissance of Frosty Peak Volcano and Vicinity, Alaska. 1028-T.
- Wilcox, R. E.  
     1959 Some Effects of Recent Volcanic Ash Falls with a Special Reference to Alaska. 1028-N.