The Significance of Volcanism in the Prehistory of Subarctic Northwest North America

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INTRODUCTION

Frequently about the North Pacific coast of Alaska one encounters in archaeological sites and stratigraphic sections bands of volcanic ash, mute testimony to recurring episodes of Holocene volcanism. Similar evidence is encountered, albeit more rarely, in the vast forested interior of Alaska and northwest Canada. Consideration of available archaeological evidence probably leads us to underrate the frequency of past volcanic eruptions, since thin ash deposits may have been dispersed by past human activity on archaeological sites and may thus go unrecognized. Older ashes weather quickly to deposits superficially resembling clay in wet coastal sites (Wilcox 1959:461).

This chapter will evaluate the probable ecological and cultural–historical significance of past volcanism in several contrasting environmental zones. After considering the history of research on this topic we will proceed to a discussion of general characteristics of Alaskan volcanism, which may serve as an introduction to the regional studies that follow. In these regional sketches we will characterize the general nature of Holocene cultural adaptations, the uses made of volcanic products, and ethnohistoric traditions (if any) relating to past and contemporary volcanism in the forested interior of Northwest Canada, the western Alaska Peninsula, and the eastern Aleutians. We will then discuss the distribution of volcanoes and geological and historical evidence for their activity, combining this evidence with what archaeological and environmental evidence we have suggestive of the probable environmental impact of

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these past volcanic events (often drastic but almost invariably short-lived), and their impact on regional culture history. We will conclude by comparing and contrasting the impact of volcanism on these environmental zones and diverse indigenous food economies and will offer suggestions about profitable lines of future research. It should be noted here that studies of this nature are in their infancy in our area and that logic and historic precedent are often given more weight than hard field evidence in reaching our tentative conclusions. This chapter is, and is intended to be, suggestive rather than conclusive.

HISTORY OF RESEARCH

Much of the face of southern Alaska has been shaped over long ages by volcanic activity. Early travelers and sojourners were much impressed by the many active volcanoes in the Aleutian Islands and on the Alaska Peninsula (Veniaminov 1840a:29ff). There is a voluminous geological literature on Alaskan volcanism considered primarily from a stratigraphic and lithological point of view (Péwé 1975:11, 78–80), but relatively little attention has been paid to the impact of volcanism on the living world of which man is a part. Thus Nowak (1968) has treated volcanic ashfalls on the eastern Alaska Peninsula almost entirely from a stratigraphic point of view, whereas Lerbekmo and Campbell (1969) and Lerbekmo *et al.* (1975) have treated the prehistoric White River Ash of northwest Canada in useful detail but without consideration of its possible ecological significance. Souther (1970) has provided a summary of volcanism in interior British Columbia with some discussion of its probable impact on the aboriginal inhabitants. Further afield, stratigraphic considerations appear primary in reviews of volcanic ash studies in North America by Wilcox (1965) and Westgate *et al.* (1970), and in Japan by Kotani (1969).

Although studies of historic volcanic activity have focused on volcanoes in areas possessing agricultural economies, we do have a detailed pioneering study of the devastating Katmai eruption of 1912 by Griggs and his colleagues (Griggs 1922). To my knowledge, the literature of volcanism contains no study of the effects of volcanic eruptions in a subarctic terrestrial boreal environment.

Although the major emphasis to date has been on stratigraphic correlations of volcanic ashes and their chronological potential, the geologist Ray Wilcox published a paper in 1959 that contains much useful information about the impact of historic volcanic ashfalls, and the geologist Harold Malde included a brief but very useful discussion of the cultural impact of volcanism in a paper published in 1964. Robert Black, also a geologist, has dealt in a series of papers with the role of geological processes (including volcanism) in the population history of the Aleutian Islands (Black 1974, 1975, 1976).

With the partial exception of the Aleutian Islands, only passing attention has been paid by northern archaeologists to the possible significance of volcanism in the environmental or cultural history of their research areas. In

1974, I published a paper in which I considered the probable effect of the emplacement of the eastern lobe of the White River Ash on the lives of the prehistoric Indian inhabitants of northwest Canada and suggested the possibility that this event might be linked to the southern dispersion of ancestral speakers of Southern and Pacific Athapaskan languages (Workman 1974). Working independently, the late David Derry reached somewhat similar conclusions in a paper presented at the same 1972 symposium but not published until 1975. I undertook the present chapter in part because I was encouraged by results of similar, if more sophisticated and field-data-oriented work in other areas (e.g., Sheets 1976), in part to evaluate rather nebulous comparative conclusions drawn in the original paper (1974:246), and to determine if this particular line of inquiry is worth following further in the north. The activities of Black and others in the Aleutians provide modest encouragement for the view that an ecological consideration of past volcanism and the attempt to relate it to northern culture history is worthwhile, if fraught with difficulties.

GENERAL CHARACTERISTICS AND CONSEQUENCES OF ALASKAN VOLCANISM

Although our consideration of volcanism in the boreal interior takes into northwest Canada, all volcanoes considered in this report are located within the boundary of the modern state of Alaska. Most of Alaska's young volcanoes occur along a 2500-km arc between Mount Spurr, located about 150 km west of Anchorage, and Buldir Island in the western Aleutians. The majority are found on the Alaska Peninsula and in its island continuation, the Aleutian Archipelago. At least 60 volcanic mountains in this arc have been active in geologically recent times with at least 40 showing signs of activity in historic times (see Figure 11.1). About 10% of the world's identified volcanoes are located in Alaska (Alaska Geographic Society 1976:8). Geologically young volcanoes also occur in the Wrangell Mountains of south central Alaska; Mount Edgecombe, near Sitka in southeastern Alaska, though currently inactive, erupted with great violence in the early Holocene. Only Mount Wrangell appears to be active in the Wrangell Mountains (Miller 1976:28), but the source of the White River Ash was located nearby in the St. Elias Mountains. Certain lava flows on the Seward Peninsula are also geologically recent, but since they represent another type of volcanism than the Alaska norm and are geographically isolated, they will not be considered here.

Alaskan volcanoes characteristically erupt with great violence, distributing pumice, ash, and other pyroclastic debris over large areas (Wilcox 1959:415; Miller 1976:26). They appear to be of the type characterized by Tazieff (1971:59–60) as acid explosive, typified by relatively cool, highly viscous magma that virtually guarantees violent and spectacular explosions. Toon and Pollack (1977:14) note that Pacific volcanoes usually have viscous magmas resulting in explosive displays such as those exemplified by Krakatoa in Indonesia, which

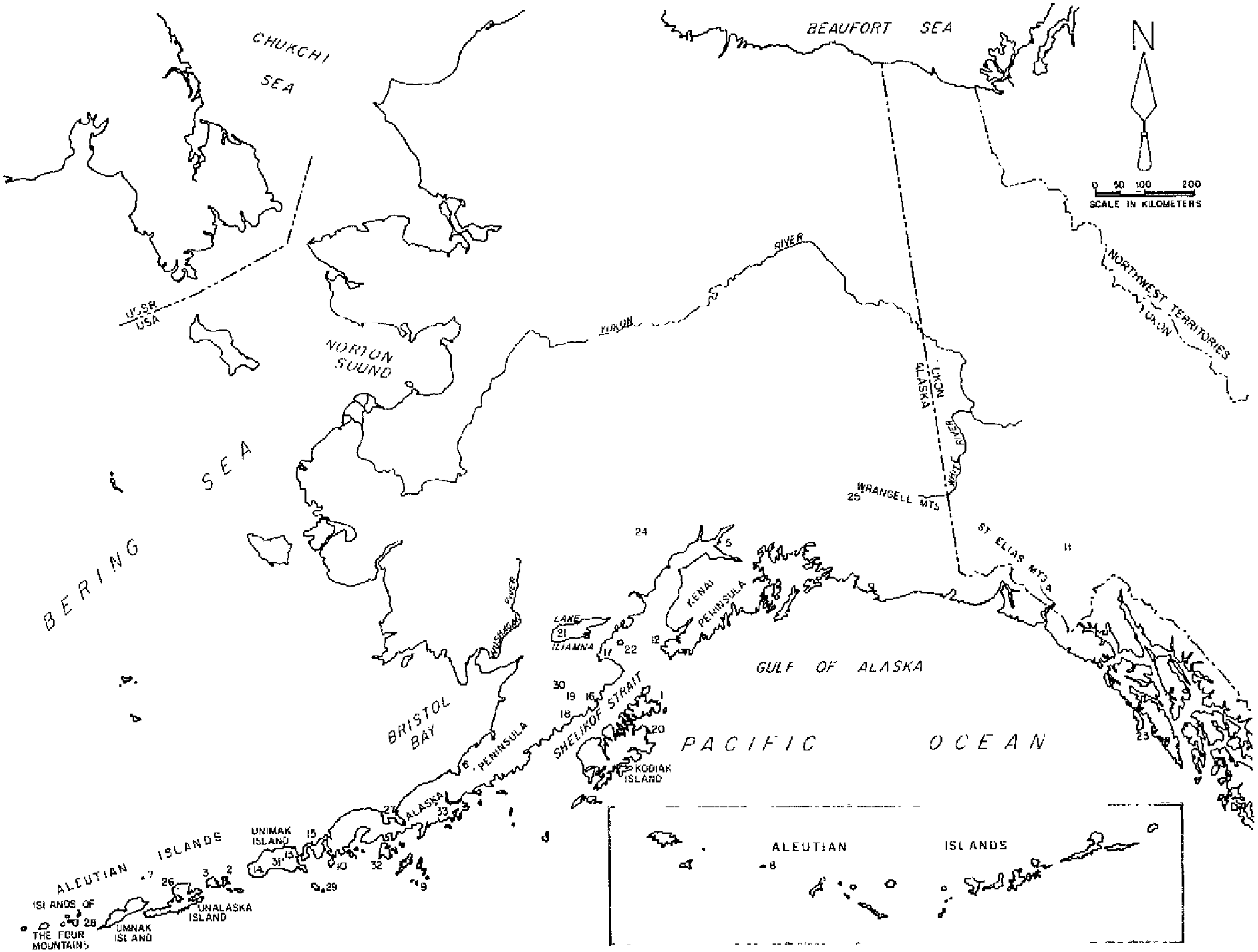

FIGURE 11.1. Index map of selected localities mentioned in this chapter.

1 Afognak Island, Kodiak Group
2 Akun Island, Eastern Aleutians
3. Akutan Island, Eastern Aleutians
4. Alsek River, southwestern Yukon Territory, southeastern Alaska
5. Anchorage, Upper Cook Inlet
6. Aniakchak Volcano, Alaska Peninsula
7 Bogoslof Island, Eastern Aleutians
8. Buldir Island, Western Aleutians
9. Chernabura Island, western Alaska Peninsula
10. Deer Island, western Alaska Peninsula
11. Dezadeash Valley, southwestern Yukon Territory
12. English Bay, Kenai Peninsula
13. False Pass, westernmost Alaska Peninsula
14 Fisher Caldera, Unimak Island, Eastern Aleutians
15. Izembek Lagoon, western Alaska Peninsula
16. Kaflia Bay, eastern Alaska Peninsula
17. Kamishak Bay, eastern Alaska Peninsula
18 Katmai Village, eastern Alaska Peninsula
19. Katmai Volcano, eastern Alaska Peninsula
20 Kodiak (town), Kodiak Island
21 Lake Iliamna, eastern Alaska Peninsula
22. Mount Augustine (opposite tip of Kenai Peninsula)
23. Mount Edgecombe, southeastern Alaska
24. Mount Spurr, Upper Cook Inlet
25. Mount Wrangell, Wrangell Mountains
26. Makushin Volcano, Unalaska Island, Eastern Aleutians
27. Port Moller, western Alaska Peninsula
28. Samalga Pass, west of Umnak Island, Eastern Aleutians
29. Sanak Island, southeast of Unimak Island, Eastern Aleutians
30. Savanoski village, eastern Alaska Peninsula
31. Shishaldin Volcano, Unimak Island, Eastern Aleutians
32. Unga Island, western Alaska Peninsula
33. Veniaminof Volcano, eastern Alaska Peninsula

threw ash 50 km into the air on its eruption in 1883. Major Alaskan eruptions often appear to be of the Plinian eruptive type (Macdonald 1972:236), characterized by the explosive emission of at least tens of cubic kilometers of magmas resulting in ash and pumice rains and eventual collapse into calderas. Glowing avalanches often occur as well, being associated with 17 of 49 major Quaternary eruptions on the Alaska Peninsula. Major glowing avalanches may radiate as far as 50 km from the source, annihilating all life even in seemingly protected areas far from the volcano (Miller and Smith 1977:174; Kienle and Forbes 1977:46). Lava flows may or may not accompany such explosive eruptions.

These violent pyroclastic eruptions have certain features and impacts in common, regardless of the specific environments in which they occur. Thus the relatively minor eruption of Mount Spurr in July of 1953 presented a truly appalling spectacle as viewed by military pilots. Convulsed by explosions, the mountain generated a mushroom cloud 18,000 to 21,000 m high and 50 km wide at its widest point in 40 min after initial observation. Lightning flashes occurred about every 30 sec on first observation, increasing to about every 3 sec as the enormous cloud of ash and gases began to disperse downwind (Wilcox 1959:421).

Volcanic ash, a hallmark of Alaskan volcanism, is really stone dust created in highly viscous magmas by the shattering of trapped gas bubbles, leaving glass splinters suspended in gas (Tazieff 1971:82). Clouds of ash disperse very quickly with the prevailing winds, with speeds between 24 and 97 km/hr on record (Macdonald 1972:137). Thunder, lightning, and rain commonly accompany the cloud on its dispersion downwind and torrential rains and sometimes hailstorms are to be expected (Wilcox 1959:427, 441, 451). It should be noted that thunder and lightning are almost never experienced under normal conditions along the Alaska coast and occur relatively rarely in the interior, adding a dimension of novelty to the terror of being immersed in an ash cloud. Total darkness, which may endure for days, also accompanies the ash cloud. The town of Kodiak experienced two days and three nights of almost unbroken darkness as the ash plume from Katmai Volcano deposited a foot of ash there in 1912 (Griggs 1922:10). The nature of this experience is indicated by Griggs in the following terms. "None of those who went through those days of terror fail to mention . . . the aweful darkness which is universally described as something so far beyond the darkness of the blackest night that it cannot be comprehended by those who have not experienced it [p. 10]." As an example it was indicated that it was almost impossible to see a lantern held at arm's length.

Various noxious substances fall out of ash clouds in the form of "acid rains" that may cause damage to plants and irritation to animals and men several hundred kilometers from the source. Analysis suggests that a major irritant is sulfuric acid, although different eruptions from the same vent vary significantly in acid content (Wilcox 1959:427, 467; Cadle and Mroz 1978:456; Hobbs *et al.* 1978). Griggs reports the experiences of a man who had difficulty in traveling on the Alaska Peninsula 6 months after the main Katmai eruption, suffering acid damage to skin and clothing from minor emissions of smoke and fumes. Dogs in the same area were reported to have been blinded by the acid rains (Griggs 1922:21). Ash-induced damage to the eyes, sometimes resulting in blindness for animals, is mentioned in other reports as well (Jaggar 1945:87–88; Freeman 1977:22). Once fallen to earth, the ash would be repeatedly redistributed by the winds or stirred up by animals and humans walking across ash-laden terrain. Although assuming that short-term exposure to volcanic dust would not be dangerous (presumably to the lungs), Wilcox suggests that long-term exposure might have a more harmful effect. There are informal reports of head, throat, and lung pains associated with the fumes and dust of the Katmai eruption (Jaggar 1945:88), and at least one consumptive died on Kodiak during the eruption (Freeman 1977:22). Surely constant exposure to glassy shards of ash in one's clothing, one's dwelling, and one's food would be a fact of life for several years following the deposition of any significant quantity of ash. It seems reasonable to suppose that lung problems, eye problems, and skin problems might well increase in an area for several years after a significant ashfall.

Significant ashfalls would contaminate water sources for a time, both through physical contamination with ash particles and through a temporary rise in acidity due to the adherence of noxious substances to the ash grains. Increase in acidity appears to be short-lived, although contamination can be reinforced by posteruptive runoff from ash-laden terrain (Whetstone 1955). Contamination of drinking water for even a few days would raise serious problems for man and beast alike (Wilcox 1959:445; Malde 1964:9; Macdonald 1972:426). Griggs quotes an eyewitness account from a temporary resident of Kaflia Bay about 50 km from the source of the Katmai eruption. "It is terrible, and we are expecting death at any moment, and we have no water. All the rivers are covered with ashes. Just ashes mixed with water [p. 19]."

One of the most significant short-term impacts of volcanic ashfalls is the intensification of erosion, landslides, and mudslides. In principle, intensified erosion is the consequence of any significant ashfall, with the danger persisting for some time after the event. Heavy rains are almost inevitable during or after the ashfall and are said almost to guarantee mudflows and floods. These dire consequences are rooted in the fact that ground covered with porous ash near the source can hold only a fraction of the runoff it could contain with its normal vegetational mat. Water saturates the interstices in coarse ash, providing lubrication on slopes and triggering landslides and mudflows. Finer deposits farther downwind are less porous and permeable, accelerating runoff and erosion. Floods following an ashfall carry a great suspended load, enhancing their ability to accelerate gully cutting and slope erosion, move boulders that unsaturated waters had left in place, etc. (Wilcox 1959:430, 449; Malde 1964:9–10; Workman 1974:249).

Ash falling on snow during the winter months may cause disastrous "early springs" with intensified flooding. Significant ashfalls on snow also interfere greatly with travel by sled or snowshoes (Suslov 1961:392–394). Under some conditions deep ashfalls retard rather than accelerate the melting of underlying snow, however, and sometimes, by insulating them, preserve snowbanks for several years at low elevations (Griggs 1922:149). When considering ashfalls on terrestrial environments in particular, it would be most useful to determine the season of the year during which the ash fell and whether or not there was snow cover.

It is recognized that in the long run volcanic ashfalls enhance the growth of plants in the affected area (see Veniaminov 1840a:216 for an early statement of this view; Griggs 1922:45ff for a detailed description of the process of recovery after Katmai). With equal fairness it can be stated that the short-term impact is disastrous.

Volcanic eruptions emit great quantities of noxious fumes such as sulfur dioxide, fluorine, and chlorine, which may do great damage to the vegetation as far downwind as 32 km from the source. This effect is greater in warmer climes, but evergreen trees apparently are more susceptible to damage from fumes than deciduous tress (Malde 1964:7). By adhering to the ash particles, these gases travel farther and can damage vegetation at great distances (Wilcox 1959:415), searing vegetation locally even farther downwind than where significant deposits of ash are formed (Griggs 1922:25). Wilcox (1959:451ff) has catalogued the various factors damaging to vegetation. These include mechanical overloading and breakage of broad-leaf plants and trees, smothering of vegetation by falls of ash 5 cm or greater in thickness, destruction by ash-induced hailstorms, mudslides, floods, etc., and weakening of overloaded trees, making them more susceptible to later attacks by insects and disease. The cutting effects of windblown ash are recognized as a strong deterrent to growth of young plants as well (Wilcox 1959:463). Suslov notes that changes in the drainage patterns of subarctic soils induced by ashfalls may change the local floral composition for some years (1961:395). Streams may be filled with ash, creating dangerous quicksand deposits (Ball 1914:62; Evermann 1914:65; Freeman 1977:23). Thus, in the short-term extensive volcanism is disastrous to terrestrial plants over vast areas, creating biological deserts or impoverished environments and causing significant difficulties for herbivorous mammals and the ultimate predator, man.

Ashfalls also appear to have significant if short-term impact upon freshwater ecosystems. Humans would feel this impact insofar as it affected the supply of lake, stream, and anadromous fish. Refined paleoenvironmental studies at Lost Trail Bog in Montana have detected a significant short-term reduction in two genera of lacustrine algae that is attributed to the emplacement of the Mazama ashfall (Mehringer *et al.* 1977:260). Although there were no base-line studies for comparison, streams and lakes on the western side of Afognak Island were found to be virtually devoid of invertebrate fish food in the summer following the Katmai eruption. Sticklebacks and salmon fingerlings were found to be starving in the lakes (Ball 1914:62–63).

In areas burdened by heavy ashfalls, streams, rivers and small ponds would be choked for years with ash, which might be hard on the delicate gill structures of fish (Ball 1914.62; Eicher and Rounsefell 1957:72; Malde 1964:11; Souther 1970:63). On Kodiak after the Katmai eruption lakes up to 150 cm deep disappeared entirely (Freeman 1977:22). One also wonders whether the increase in water acidity noted above might not be damaging in small ponds and streams, even if these abnormal conditions lasted only a few hours. Large lakes would probably feel less effect, but there was little aboriginal exploitation of deep-water lacustrine resources, and many economically significant fish spend at least part of their life cycle in streams (Workman 1974:250).

Red salmon were beginning their annual run when Katmai erupted in June 1912. Salmon already in the streams of Afognak Island stayed there until they suffocated with their gills filled with liquid mud. About 4000 perished in the Litnik Stream Hatchery. Rains kept the lakes and streams muddy, preventing or delaying salmon from reaching their spawning grounds. A heavy rain in mid-August put so much ash in the water that salmon suffocated as the June run had. In this later run salmon were observed ascending the polluted streams a short way, going back to sea, then trying to ascend again, repeating this erratic movement a number of times (Ball 1914:61, 62, 64).

Clearly the salmon run of 1912 was drastically affected by the Katmai eruption. By 1913 the streams were largely scoured clear of ash, and an unusually large number of young silver (cohoe) salmon were noted in all streams. However, drastic reduction of the previous year's red salmon run was confirmed by the very small number of year-old fingerlings taken in tests in the Litnik area (Evermann 1914:65). Eicher and Rounsefell have pointed out that red salmon, whose fry spend a year or more in freshwater lakes, would be particularly vulnerable to volcanic impact on their freshwater habitat. Their study indicated that the Katmai disaster of 1912 was clearly reflected in small runs (roughly half normal size) of sockeyes between 1916 and 1920 in three Afognak Island streams (1957:70, 73). Rapid full recovery thereafter led them to the conclusion that in the long term significant ashfalls enhance red salmon productivity by injecting new nutrients into the aquatic ecosystem, a finding closely paralleling the conclusions about the long-term impact of volcanism on terrestrial vegetation. Some confirmation for this suggestion comes from the study of an ash-impacted lake in Kamchatka (Kurenkov 1966).

Not all fish life would necessarily be eliminated even in heavily impacted areas. Griggs noted the somewhat anomalous occurrence of Dolly Varden char in 1917 in a stream near Katmai that had experienced a 46-cm ashfall. Further study indicated that these fish had been spawned in 1915, so Griggs surmises that their ancestors must have escaped destruction in deep pools. Neighboring brooks were devoid of fish, and one wonders what the survivors ate unless they retreated to sea. The same author noted an anomalous run of red salmon in a stream without a lake outlet in 1917, but in 1919 no salmon were observed there (Griggs 1922:61–63).

It has long been suspected that cataclysmic volcanism, by injecting vast amounts of volcanic dust and sulfuric acid into the stratosphere, might be implicated in at least short-term climatic cooling. Detailed consideration of this possibility lies beyond the scope of this chapter, but it should be noted that recent studies indicate that large volcanic eruptions may cool the surface of the earth by 1–2°F for several years, although such phenomena must be short-lived and cannot be held responsible in isolation for significant long-term climatic cooling (Macdonald 1972:136; Kennett and Thunell 1975:501; Bray 1977; Toon and Pollack 1977; Hein *et al.* 1978:140–141).

When considering the ecological impact of volcanic ashfalls one needs to determine if possible the minimum thickness of ash sufficient to impact the environment. Malde noted that after the Hekla eruption of 1947 in Iceland pastureland covered by as little as 1.9 cm of ash was noted to harm livestock (Malde 1964:9). Wilcox has indicated that grasses and low-lying plants may be smothered by as little as 5 cm of ash where falls of much greater thickness can weight down and smother low bushes (1959:451). After the Katmai eruption small birds, waterfowl, and small mammals died and caribou sickened in an area near Lake Iliamna that had received a fall of 2.5–10 cm of ash (Jagger 1945:88). In my earlier study I concluded that the "some effect" zone could be extended out as far as the 2.5-cm isopach (Workman 1974:248–249).

Studies of historic volcanism indicate that in many cases the major damage and suffering may well be more psychological than physical, caused by panic and fear of the unknown (Wilcox 1959:441–442; Workman 1974:248). The Katmai eruption of 1912, in which not a single life was lost, is a case in point (Griggs 1922:7ff). If this is the case among people fortified in part by a scientific understanding of the phenomena in question, one might well suppose that the effects would have been even more drastic in prehistoric times, especially where volcanic outbursts were relatively rare. With the exception of Griggs's thorough discussion of the fear and suffering accompanying the Katmai eruption, the only ethnographic reference I have seen pertains to a very minor fall of volcanic ash upon the territory of a plateau fishing and gathering people, the Sanpoil-Nespelem. An informant told Ray (1954):

> When my grandmother was a small girl a heavy rain of white ashes fell. The people called it snow. . . . The ashes fell several inches deep all along the Columbia and far along both sides. Everybody was so badly scared that the whole summer was spent in praying The people danced—something they never did except in winter. They didn't gather any food but what they had to live on That winter many people starved to death [p. 108]

While this isolated instance cannot be pressed too far, it is suggestive of a possible impact that is only indirectly related to environmental considerations.

A further issue regarding native traditions deserves some consideration. Though it has been demonstrated that the oral traditions of certain northern peoples can transmit accurate information for some centuries (Laguna 1958), one wonders how far into the past such accurate cultural memory might extend. Evidence reviewed below suggests that the emplacement of the East Lobe of the White River Ash some 12 centuries ago has been totally forgotten.

VOLCANISM IN THE BOREAL INTERIOR: THE WHITE RIVER ASH

The area affected by the emplacement of the East Lobe of the White River Ash (Figure 11.2) includes the historic territory of the Han (Osgood 1971), the poorly known Northern Tutchone, some Southern Tutchone (McClellan 1975), and some Upper Tanana Athapaskans (McKennan 1959). The basic ethnographic pattern, which can be extrapolated into the prehistoric past, is that of thinly scattered small groups of highly mobile hunters and fishermen lacking access to significant salmon runs. Big game animals such as moose, caribou, and mountain sheep supplemented by various smaller mammals, limited vegetal resources, birds, and freshwater fish provided the subsistence base. Various rough estimates of population density range between one individual per 250 km^2 (99 mi^2) and one individual per 100 km^2 (40 mi^2) (Workman 1974:260).

Volcanic activity is an unusual occurrence in this area, with two substantial pyroclastic eruptions in the first millennium A.D. providing the only record of Holocene volcanism. Use of volcanic products was confined to obsidian and other volcanic stones. Probably no Indians were close enough to the source area in the rugged and inaccessible eastern St. Elias Mountains to be affected directly by possible short-range effects (clouds of glowing ash, etc.) of these two catastrophic explosions; hence all discussion of ecological impact hinges on the

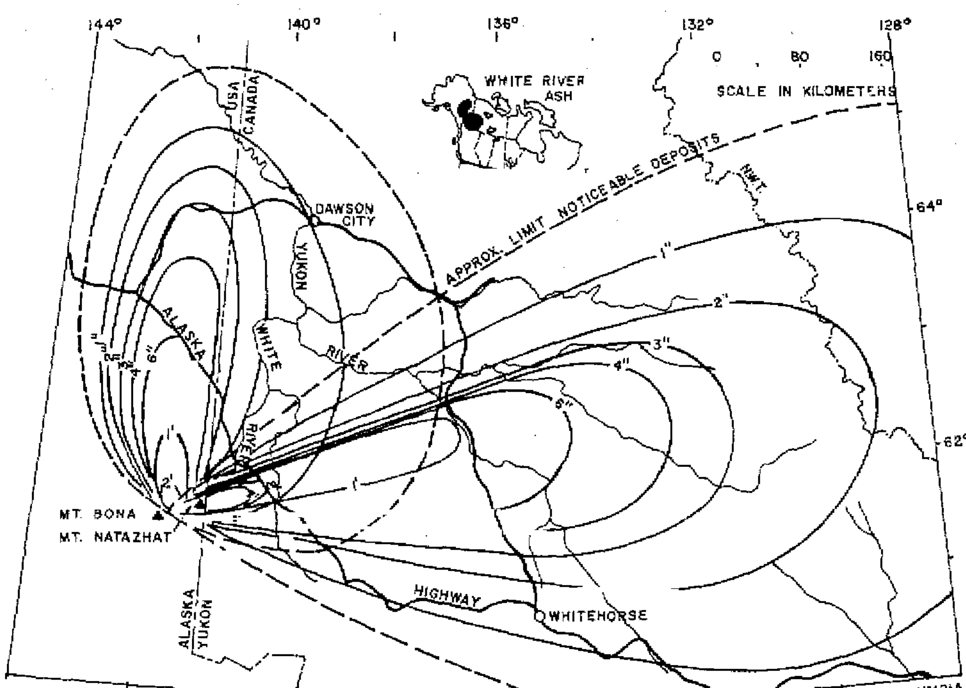

FIGURE 11.2. Isopach map of the distribution of the White River Ash. (After Lerbekmo *et al.* 1975.)

consequence of associated ashfalls. Discussion is limited here to the emplacement of the larger East Lobe of the White River Ash.

With one dubious exception, no local traditions seem to convey even a dim memory of this cataclysmic event of 12 centuries ago. Indeed, southwest Yukon Indians appear not to have speculated on the significance of the striking band of white volcanic ash that is encountered everywhere in roadcuts and natural exposures. A fragmentary tradition of the Han recorded by Osgood (1971:39) refers to a supernatural being called "fire man who lives in a house built of white clay and stone. In the house is a small table with a big hole behind it." Though the atypical architecture (white clay = white ash?) and the association with a fire being are suggestive, this fragment was recorded totally out of context. It is as likely to refer to experiences with the thick ash and pumice deposits of the upper White River country that lies in the territory Osgood attributes to the Han as it is to reflect some dim memory of 1200-year-old volcanism

Recent field and laboratory studies by Lerbekmo and his colleagues have refined our knowledge of the White River volcanic events first brought to the attention of the scientific world by Capps over 60 years ago (Capps 1915; Lerbekmo and Campbell 1969; Lerbekmo *et al.* 1975). The White River Ash is a bilobate formation covering well over 250,000 km^2, mainly in the Yukon Territory of Canada. The East Lobe has an axis of about 1000 km. A conservative estimate indicates that the volume of this ejecta is at least 25 km^3 (6 mi^3) (Lerbekmo and Campbell 1969:109–110, 115; Lerbekmo *et al.* 1975:204). Study of the properties of the ash confirms other evidence suggesting that the East Lobe eruption was a very violent short-lived event (Lerbekmo *et al.* 1975:208). The source has been localized to within a few kilometers of a pumice mound on the northeast slope of Mount Bona about 24 km west of the International Boundary in the St. Elias Mountains. About 90% of this area is under permanent ice fields today, and Lerbekmo and his colleagues feel that the vent of origin for the White River Ash is almost certainly buried beneath the ice (1975:204). Although I used a 1400 B.P. date for the emplacement of the East Lobe of the White River Ash in my 1974 paper, new radiocarbon evidence suggests a span between 1175 and 1390 B.P., with a mean of around 1250 years B.P. Nine new radiocarbon dates indicate that the North Lobe was placed around 1890 years ago (range 1750–2005 B P.), thus confirming a separation of several centuries between these events (Lerbekmo *et al.* 1975).

Review of the available paleoenvironmental evidence (Workman 1974: 243–245; 1978:26ff) indicates that the world on which the ash fell differed in some significant details from that of the present day. An ice dam across the Alsek River had impounded a large neoglacial lake that covered much of what is now the floor of Dezadeash Valley in southwest Yukon. The lake would have removed a significant area of pastureland, and the ice dam would have cut off access of salmon from the Pacific Ocean to the far interior. Other large lakes still in existence today may have been somewhat enlarged at the time the ash fell. The white spruce forest was spreading outward from the streams and water courses in southwest Yukon, but field evidence (Johnson and Raup 1964:111–116) indicates that spruce forest had not come to dominate as it does today and that extensive areas were still grassland. Revision of the dating of the White River Ash (see above) would place this event in the relatively mild Scandic climatic episode rather than, as previously suggested, at the end of the possibly more severe sub-Atlantic (Bryson and Wendland 1967:280, 294; Workman 1974:246).

Professor Lerbekmo has recently shared with me information based on work done by his former student Lawrence Hanson that suggests that the East Lobe eruption occurred in winter, perhaps in early winter (personal communication, April 1977). High-atmosphere winds generally blow eastward in January in this area today, swinging around to the north by July. Assuming that the same pattern prevailed in the past, one might suggest that the probabilities favored a winter emplacement of the East Lobe and a summer emplacement of the earlier North Lobe. In their 1969 publication Lerbekmo and Campbell noted the anomalous occurrence of thick deposits of ash on slopes up to 40° (p. 110). This observation coupled with a strongly bimodal distribution of ash particle size (Hanson 1965) led Lerbekmo and Hanson to the conclusion that the ash may have served as nucleation points for condensing water vapor. The observed stability of ash deposits on slopes leads to the interpretation that it may well have been snowing during the eruption, with the ash compacting under a snow load rather than being washed off steep slopes in a torrential rain. Preservation of ash on steep slopes might even raise the possibility that the ash accompanied an early winter snowfall, ensuring maximum preservation during the spring thaw.

Winter emplacement, strongly suggested by this new evidence, would have wrought maximum hardship upon the Indian hunters upon whom the ash fell, effectively immobilizing them in the ash-laden dark at a time of year when food was always scarce. Several days of immersion in the inky darkness of an ash cloud at a time of year when daylight was already at a premium might have added to the psychological impact of the event as well (Workman 1974:247, 249).

Little field evidence bears on the ecological impact of this ash. Stumps of trees killed by 60–150 cm of ash have been reported by Rampton near Klutlan Glacier (1971:976). The few pollen sections that incorporate the White River Ash reflect no significant vegetal changes. The area needs to be restudied using the refined techniques recently developed by Mehringer *et al.* to detect short-term vegetation changes (1977). The distribution of the ash clearly indicates that the prevailing wind at the time of the eruption blew steadily to the east away from the inhospitable ice-clad peaks of the St. Elias Mountains and across territory inhabited by prehistoric man. We can legitimately infer that the huge plume of ash was accompanied by torrential rains or snow, noxious fumes, etc. Hypothesized intensified erosion after the ash fell should be detectable by geological studies, but to my knowledge none have been made with this particular orientation. The lightning-riven unnatural darkness caused by the ash cloud would have been an appalling spectacle, especially in this area where volcanic outbursts were far from common.

Consideration of the impact of the ash on the living world, especially the fauna, is inferential, based largely on studies of the impact of historic volcanism on domestic livestock. It should be remembered that most domestic livestock are grazers (as is the caribou) while the moose, an important food resource in this area, is a browser. Ashfalls have a serious impact on domestic herbivores. Cattle grazing on ash-laden pastures often sicken, bloat, and die (Wilcox 1959:455), and fluorine adhering to ash damages the teeth and joints of sheep so that eventually they are unable to chew or walk. Fluorine-contaminated ash killed about 15,000 ewes and over 6000 lambs (of about 95,000 exposed sheep) after the 1970 eruption of Hekla Volcano in Iceland (Bauer 1971). Bad effects have been noted from an ash cover as thin as 1.9 cm (Malde 1964:9). Griggs suggests without totally satisfactory documentation that the teeth of both moose and caribou were so worn by ash adhering to their plant food after the Katmai eruption that many are said to have perished through inability to feed properly (1922:314). A similar statement was made by a witness to the May 1931 eruption of Aniakchak Volcano on the Alaska Peninsula with reference to the caribou of the Nushagak River area (Trowbridge 1976:73). Trowbridge also notes that this spring eruption caused the Nushagak herd to abandon their ash-laden calving grounds, leaving the newly born calves to die. The food supply itself is also adversely affected by ashfall. Reindeer moss is notoriously slow growing and probably would be affected by minimal ashfalls and regenerate only very slowly, although windswept upland pastures might be freed in a timely fashion by wind scouring. Berries, a seasonally significant food resource, appear to have been greatly affected by the Katmai eruption (Ball 1914:63; Freeman 1977:22). Moose, as browsers, would probably be less affected by light ashfalls than caribou but might be most vulnerable to the effects of ash contamination on the vegetation of small ponds, which appear to provide a significant portion of their summer diet.

Since waterfowl were a significant, if minor, resource in our area, we should note in closing Trowbridge's (1976:73) report that after the Aniakchak eruption the rivers of the Alaska Peninsula contained the bodies of geese, ducks, swans, and other birds that were said to have been killed by ingesting ash. This assertion, though plausible, is not documented. Ptarmigan, a year-round food resource that lives, nests, and feeds on the ground, appears to have been particularly hard hit by the Katmai eruption (Ball 1914:62–63; Freeman 1977:22)

Only the southern portion of the area affected by the East Lobe of the White River Ash has been studied in enough detail to permit the formulation of preliminary regional archaeological sequences (Johnson and Raup 1964; MacNeish 1964; Workman 1978, 1977). MacNeish postulated a cultural break and lack of cultural continuity between his final pre-ash Taye Lake phase of culture and the post-ash Aishihik phase (1964:322). Elsewhere he devoted a single sentence to the possible environmental significance of the volcanic ash

(1964:304), but he did not attempt to link these two observations. A restudy of some of MacNeish's material and additional information has led me to the interpretation of strong cultural continuity between the Taye Lake and Aishihik phases, despite the considerable ecological impact that I am prepared to attribute to the emplacement of the White River Ash (Workman 1974:250).

In this study I concluded that territory covered by as little as 2.5 cm of ash would have undergone considerable reduction in carrying capacity and that the affected area was large enough that a significant number of human beings (between 60 and 1000; see Workman 1974:260) would have been displaced for a time. Emigration would have been either in a northerly or southerly direction. It is doubtful that out-migration on this scale could have been accommodated peacefully by neighboring peoples, so I suggested the likelihood that there was strife and discord following the ashfall as various small groups jockeyed for position, with some groups peripheral to the area affected by the ashfall perhaps being displaced, to continue the process of disruption of equilibrium as they sought new homes elsewhere

I view the emplacement of the White River Ash as a likely triggering mechanism that may ultimately have detached certain small groups of ancestral Athapaskans to the south to become the ancestors of the Navajos and Apaches, and the Pacific Athapaskans (see Workman 1974:254–255 for details). I was encouraged in this view by tentative (and inherently controversial) glottochronological estimates suggesting that ancestral speakers of Southern Athapaskan left their northern homeland about 1200 years ago, whereas ancestral speakers of Pacific Athapaskan departed slightly later from a different staging area or areas (Krauss 1972:159 and personal communication, January 1973). Recent revision of the date for the East Lobe from about 1400 to about 1250 B.P. would seem to bring these events into even closer alignment.

I consider this a reasonable idea but one that cannot be regarded as confirmed on archaeological grounds (see Workman 1978:430), although data from the southern Brooks Range as interpreted by Derry (1975) and from the Chilcotin area in British Columbia as interpreted by Wilmeth (1977) are compatible with the general framework. I suggest that, if this idea is correct, further archaeological research on areas peripheral to the ashfall and perhaps far beyond should reveal considerable evidence for culture change and intensified cultural contacts in the second half of the first millennium A.D. as archaeological indicators of a time of flux and small-scale population movements. My interpretation of cultural continuity across the time of the great ashfall suggests that the area was not depopulated for any lengthy span of years and that we must search for subtler archaeological evidence, which I have had only limited success in finding in the sparse record from southwest Yukon. I persist both in my interpretation of the East Lobe of the White River Ash as an event of potential cultural historical significance and in my desire to see studies specifically designed to test the viability of this hypothesis as a significant problem in paleoenvironmental interpretation.

VOLCANISM IN A MIXED TERRESTRIAL AND MARINE ECONOMIC SETTING: THE WESTERN ALASKA PENINSULA

Ideally the western Alaska Peninsula, an active volcanic area, should afford an opportunity to study indigenous subsistence economies transitional between the purely terrestrial and the fully maritime under volcanic stress. Unfortunately there are only minimal data to work with, and I must confine myself to a few remarks based on a hitherto untranslated Russian report (Veniaminov 1840a).

The Alaska Peninsula east to Port Moller was occupied ethnographically by the Aleut (Dumond 1974), whose way of life has never been described in any detail. Veniaminov notes that even in later prehistoric times the western peninsula was sparsely populated by comparison with the Aleutian Islands, with at best only 10 villages, most on the southern or Pacific shore. In 1836 there were only three settlements harboring a total of 210 persons (Veniaminov 1840a:236) Ecologically Unimak Islanders should be included in this transitional category, since they had access to terrestrial resources such as caribou absent in the islands farther to the west, but we know little specific about either Unimak Aleut ethnography or archaeology.

The archaeology of the Alaska Peninsula west of Port Moller has been but little studied, the only substantial work being that of McCartney (1974b) at Izembek Lagoon located about 40 km east of False Pass on the Bering Sea shore of the peninsula. No large sites such as those of the Aleutians proper were found in the Izembek survey area Only one volcanic ash 7–10 cm thick was noted in the stratigraphic sections (1974b:63).

In Veniaminov's account of historic Aleutian volcanism he indicates that volcanoes on Unimak spread volcanic ash as far as the Alaska Peninsula. There also were sporadically active volcanoes on the peninsula itself (1840a:29ff). Interestingly, for our purposes, he attributes the rapid decline of caribou on the peninsula to ash originating in volcanic eruptions on Unimak in 1825 and 1826. In particular, he notes that the eruption of 1825 caused the caribou to withdraw into the interior of the peninsula followed by wolves and bears (1840a:70) and that caribou, formerly abundant on Deer Island, had by 1828 been virtually exterminated by volcanic eruptions and the crossing over on ice of wolves from the mainland (1840a:247–250). He also notes that in 1823 a pair of swine were introduced on Chernabura Island. By 1825 more than 20 swine were present as a result of natural increase, but over 100 swine (sic) perished in 1826 because of ashfalls and the cold, exterminating the population (1840a:74ff). These statements cannot be taken entirely at face value since other factors such as increased hunting pressures or (in the case of the swine) unsuitability to the environment may have played a role, but Veniaminov was very positive in correlating the timing of the events in question with various