ashfalls, and, in discussing other species, he includes variables such as overhunting and pollution in his explanations of population decline.

It appears that the western Alaska Peninsula was underutilized in ethnographic times. Further studies of this area might well focus on an evaluation of the real, as opposed to the apparent, wealth of the ecosystem. Endemic volcanism (including periodic "fallout" from active volcanoes on Unimak Island to the west) should be considered as a factor in this evaluation.

VOLCANISM IN A MARITIME ZONE: THE EASTERN ALEUTIANS

The Aleuts were a populous island folk who subsisted almost entirely on products of the sea. Marine mammals (including large whales), halibut and cod, a variety of birds, salmon, and intertidal invertebrates were mainstays in the traditional economy, which has recently been described in considerable detail by McCartney (1975). Facets of Aleut traditional culture have been described by the great naturalist Ivan Veniaminov from firsthand observation over a period of years (1840a, 1840b) and in secondary compilations by Hrdlička (1945) and Lantis (1970). In the Aleutian Islands a rich environment and a sophisticated extractive technology meshed to permit growth of large populations and a stable village life. Here we will consider primarily the eastern islands of the Aleutian Archipelago, with special reference to Umnak Island, for which a rich archaeological and geological record exists.

The Aleuts made fairly extensive use of volcanic products, including a variety of volcanic stones for flaked stone implements and pumice and scoria for abraders. Perhaps the most significant stone material, because it was rare and highly prized, was obsidian or volcanic glass. A major Aleutian obsidian source is found on the northwest slope of Okmok Caldera on northeastern Umnak (Denniston 1966:90; Laughlin 1972:2; Black 1976:11). Veniaminov indicates that Okmok Caldera was the only source in the Aleutians (1840b:94–95), but he indicates in his geographic observations (1840a:43, 193) that obsidian also occurs in huge chunks tumbled down a cliff near three springs on southeastern Akutan. Conflict over obsidian was a cause of war and discord in protohistoric times in the eastern Aleutians (Veniaminov 1840b:94–95).

The Aleuts used sulfur as a fire starter, apparently collecting it at or near the vents of active volcanoes (Veniaminov 1840a:135, 160–162, 193, 195, Jochelson 1933:7, 11). They also used hot springs, which occur near volcanoes, to cook fish, sea mammals, and edible roots in plaited bags. They thought the hot springs were healthful and many were fond of food cooked in them. According to Veniaminov, in aboriginal times they bathed only in cold water, but Jochelson quotes a 1750 account indicating that bathing as well as cooking was done in hot springs in the western Aleutians, indicating either regional variation (Veniaminov's data apply almost entirely to the eastern Aleutians) or early evidence for acculturation to Russian ways (Veniaminov 1840a:135–137, 149;

1840b:114; Jochelson 1933:7, 10). Aleut traditions pertaining to volcanoes are said to deal mainly with specific volcanoes (Veniaminov 1840a:29ff). Veniaminov characterized the traditions as "interesting but not very satisfactory." In another context he describes a tradition dealing with a war between the volcanoes of Unalaska and Umnak during which "they erupted fire, rock and ashes in such quantity that all animals living near them perished [1840b:276–277]." From this it appears that volcanoes were seen as sensate beings and that the Aleuts were familiar with their destructive power.

The eastern Aleutians have been volcanically active in historic times, with volcanoes on all the major and some of the smaller islands. The volcanoes of Unimak were most active in early historic times (Veniaminov 1840a:29ff), but, as we shall see, Umnak has had a colorful and eventful past. The area is also seismically active. Veniaminov records no less than three earthquakes a year on Unalaska during the decade he spent there (1840a:29). Because the Aleutians are volcanic islands with a large population and limited shoreline area suitable for villages, the ancient Aleuts had little choice but to live in sometimes uncomfortable proximity to active or dormant volcanoes. For this reason they were likely to suffer from a variety of eruptive phenomena (meltwater floods, glowing avalanches, lava flows, etc.) of limited geographic extent. Since they always lived near the sea, we must also consider the impact of tsunamis.

In his consideration of Aleut settlements, McCartney has noted (1974a:118) that "Sites are relatively rare on islands made up largely of volcanoes and evidencing extreme past volcanism." He suggests that volcanism limits human settlement in two ways: by the steep topography it creates and by the destructive impact of lava flows, ashfalls, etc. He estimates that only 5–10% (240–480 km) of the total coastline of the Aleutians was available for primary human settlement.

Because of the proximity of volcanoes, the Aleut upon occasion had early warning of forthcoming eruptions. Thus Veniaminov notes that earthquakes were more common and stronger before a volcanic eruption on Unimak in 1825 (1840a:29ff). That the Aleut heeded such warnings is indicated by the case of Shishaldin Village on Unimak (Veniaminov 1840a:219). Aboriginally located on a small cove, with the coming of the Russians it was moved 6–8 km east to a location on Shishaldin River. In Veniaminov's time it was moved back to its aboriginal location, which had a less convenient harbor and a poorer subsistence base, for fear of Shishaldin Volcano, which was smoking mightily at the time. On the Alaska Peninsula strong earthquakes were felt at Katmai Village 32 km from Katmai Volcano 5 days before its cataclysmic eruption in 1912. People became so frightened that they moved 32 km down the coast. Villagers at Savonski 32 km to the northeast also became frightened but did not act on their fears until after the eruption began (Wilcox 1959:417). It is difficult to evaluate the effectiveness of the Aleut early warning system.

The maritime Aleut would have been extremely vulnerable to tsunamis generated by volcanism, although as Macdonald notes (1972:414), energy of volcanically induced waves is not usually enough for them to travel great distances as tectonically induced waves do. Veniaminov notes a terrible "flood" that struck the island of Unga in July 1788 (1840a:29ff) and killed many Aleuts, although he appears justifiably skeptical of a reported wave height of about 106.5 m (50 *sazhen* or 300 ft). He reports without providing details another flood on Sanak Island in 1790 (1840a:25ff). Black notes that tsunamis have carried driftwood up to 30 m above sea level in places along the Pacific shore of Umnak Island (1974:136). In 1957 many low-lying sites on the Pacific shores of this island were inundated by tsunamis as well (Black 1975:167) A tsunami generated by the 1883 eruption of Mount Augustine struck the community of English Bay 80 km east on the Kenai Peninsula, causing great damage to houses and boats. This was a wave 8–10 m high, but fortunately it came at low tide and there was no loss of life (Miller 1976:18). Turner and his colleagues have described evidence suggesting that a tsunami could have accompanied deposition of a volcanic ash at the Chaluka site on Umnak Island about 3000 years ago, inundating the settlement (1974:139; see pages 363–364 of this chapter).

A further danger to those living in proximity to erupting volcanoes is catastrophic floods caused by the melting of mountain snow and ice cover and the drainage of caldera lakes. A 1795 eruption on southwest Unimak caused the perpetual ice cap to slide down both sides of the mountain with much water and lava. Revegetation of the affected area had just started in the 1820s. An eruption on northeastern Unimak in March 1825 created a "horrifying" river of meltwater from ice and snow 4.8–11.3 km (5–10 *versts* or 3–7 mi) wide. Although the eruption was in spring, the sea remained muddy until late fall (Veniaminov 1840a:29ff). The affected area would obviously undergo a change in its productivity from such an inundation, which would probably annihilate all intertidal life.

Turning to geological evidence, we note that a large lake formed in Okmok Caldera drained catastrophically sometime after caldera formation in the early Holocene and before the present glaciers formed. This catastrophic drainage cut a gorge 150 m deep in the side of the mountain (Black 1974:133; 1975:163) and presumably was accompanied by a huge flood. Rechesnoi Volcano on Umnak extruded lava about 3000 years ago, a time when neoglacial ice was in existence (Black 1976:13).

A further danger to people living in proximity to exploding volcanoes would have been glowing avalanches. Okmok Volcano deposited up to 30 m of pyroclastic debris at the coast about 9 km from the caldera rim in the early stages of its cataclysmic outburst in the early Holocene. Lithological studies indicate that this glowing avalanche was accompanied by melting snow and ice cover on the mountain. This event would have literally sterilized northern Unmak Island (Black 1975:163; see pp. 360–361 of this chapter). Fisher Caldera on Unimak erupted in similar fashion at about the same time (Miller and Smith 1977:74).

We must now consider the probable consequences of ashfalls that are well documented in the archaeological record from Umnak Island. At the blade site on Anangula Island near Nikolski Village on southwestern Umnak Island, a shallow pond, one of two freshwater sources on the island, was largely filled by volcanic ash (Ash III; see pp. 360–361), which overlies the occupation (Black 1976:23). Presumably this water source would have been unavailable to the occupants of the site during the eruption and for some time thereafter. It would seem that the acid rains that routinely accompany ashfalls might have been especially hard on the covers of skin boats on which the people depended for transportation, including flight. Construction of these boats represented a substantial investment of effort, and they could not easily be replaced, especially under crisis conditions. In the case of major eruptions, floating pumice might also be thick enough upon the sea to damage skin boats or impede their progress. Macdonald notes that after the eruption of Krakatoa, pumice piled in rafts up to 3 m thick so that modern ships with engines experienced great difficulties forcing their way through it (1972:239). Jaggar (1945:85) reports that pumice rafts thick enough to support a man formed in Shelikof Strait after the Katmai eruption of 1912. A year later patches of floating pumice persisted. Pumice windrows along the beaches reached 60–90 cm in depth (Ball 1914:61). These hindrances, coupled with the total darkness that accompanies many ashfalls, might sometimes have rendered flight impossible until the eruption was over.

Little information exists on specific effects of volcanic explosions on marine ecosystems, which is of course the fundamental question in considering the significance of past volcanism in the Aleutians (see Brongersma-Sanders 1957:974–977 for a brief catalog of volcanic and related impacts on marine environments). The Katmai eruption of 1912 provided an opportunity for such study, but Griggs and his co-workers seem to have concentrated almost exclusively on the terrestrial impact (1922). Several impacts on sea mammals can, however, be predicted with some confidence. Since sea mammals need to surface periodically to breathe and are subject to shocks transmitted through water, it is reasonable to suppose that they might withdraw for a time from the vicinity of active eruptions and ash- and pumice-laden seas. The seals and sea lions would be sensitive to the behavior of the fish on which they prey and would abandon those areas left by them. Sea otters, with their special dependency on sea urchins and kelp beds, would suffer greatly from factors adversely affecting these resources, and their preference for fairly shallow waters might render them especially vulnerable to tsunamis. Since most sea mammals haul up on land to breed and have their young, it seems reasonable to suppose that significant deposits of ash in their rookeries during the breeding season would be an annoyance to them and might cause abandonment of areas or of young. Their sensitivity in this regard should not be overrated, however, since a colony of sea lions was noted hauled up on Bogoslof just a year after the eruption of 1883 had enlarged the island. They apparently avoided the "new land," however (Alaska Geographic Society 1976:49).

Ashfalls appear to be very damaging to birds who attempt to find escape through flight in the ash-laden dark. Mariners enveloped in ash clouds during the Katmai eruption noted birds of all species falling helpless on deck, with many of their companions presumably perishing in the sea (Griggs 1922:11; Alaska Geographic Society 1976:40). Significant ashfalls during the nesting season might affect nesting behavior adversely (Ball 1914:61–62, 64). Sea birds are likely to frequent cliffy shores safe from human or other predators where they might be overwhelmed by floods, glowing avalanches, etc. emanating from nearby volcanoes. Myriad puffins were noted perching in rocks and clefts on Bogoslof a year after its eruption, although it is not specified that they were nesting there (Alaska Geographic Society 1976:49). Birds are highly mobile and could easily abandon an affected area, as they apparently did after Katmai. Migratory waterfowl may bypass an impacted area or terminate their stay abruptly (Ball 1914:61, 64).

Volcanism and associated submarine explosions appear to have an adverse impact on certain economically significant marine fishes. Veniaminov notes that no cod were taken in Unalaska in 1825 and 1826, although previously they had been available in large numbers. An Unimak volcano had erupted in the winter of 1825 and great quantities of cod and sculpins floated to the surface in stunned and half-dead condition, presumably victims of a submarine explosion. None were caught thereafter until 1827 (Veniaminov 1840a.69–70). Ball reports a similar situation near Afognak Island after the Katmai eruption (1914:62). As noted above, significant withdrawal of fish would have a multiple effect, since sea mammal predators would be obliged to move with them. We have also previously discussed the impact of ashfalls on salmon streams. Veniaminov suggested the reduction of salmon he witnessed in some places might be due in part to the change in the configuration of streams due to volcanic activity in addition to overfishing and pollution by man (1840a:69–70). Abortion of a major salmon run or destruction of eggs and fry would have unfortunate consequences for local human populations for years following the outburst that caused it.

Intertidal invertebrates were an important part of the Aleut diet. These are of course among the least mobile of creatures and would not be able to save themselves from altered conditions through flight On the other hand, they occur in economically useful quantities in reef and strand-flat communities that are often located at a considerable distance from volcanic mountains, so they may not often have been subject to the deleterious effects of glowing avalanches, landslides and mudflows of volcanic origin, and dilution of salt water by freshwater floods. Large numbers of sea urchins died near Afognak Island after the Katmai eruption, and clams and cockles also seemed to suffer (Ball 1914:62). Barnacles and mussels were killed down to low tide in Katmai Bay (Jaggar 1945:88).

Very limited study of the effect of ashfalls on water plants suggests it to be very temporary, with major damage caused by the grinding effect of floating pumice, poison gases, and actual burial in ash (Wilcox 1959:455). Kelp attached to rocks and reefs near Afognak blackened and withered after the Katmai eruption (Ball 1914:64) It has been suggested that submarine volcanism may add many nutrients (compounds of phosphorus, nitrogen, silicon, etc.) to the water in areas of recurring volcanism and may thus in the long run enhance the productivity of the area (Wilcox 1959:470), a minor consolation to hungry people in a devastated post-ash world.

In summary, though few detailed studies of the effect of volcanism on a rich marine ecosystem are available, it seems reasonable to suppose that these effects may have been drastic on a localized basis for a period and that certain consequences (i.e., disruption of salmon runs and harm to intertidal invertebrates) might have reduced carrying capacity of an area for a period of years. Psychological trauma attendant on being a close witness of some of nature's more appalling spectacles might have prompted a willingness to move as well. Since the Aleutians for at least the last few millennia have had a large population combined with a limited amount of usable shore area, major volcanic events were almost certain to affect some human settlements I suspect without quantified data that the process of population readjustment would have been easier in this rich area than it would have been in the boreal interior discussed above with its very limited carrying capacity. On the other hand, the marine Aleutian ecosystem was probably much more resilient than the boreal interior ecosystem previously discussed. The flushing action of the vast sea would cleanse all but the greatest damage from ejecta, etc., in a short period of time. No equivalent mechanism exists on land. In a complex paper, Hett and O'Neil (1974:36–37) have constructed an admittedly very crude model of the Aleutian ecosystem, and they find it to be quite resistant to minor environmental fluctuations, perhaps as much as 300 times more resistant than terrestrial ecosystems.

When considering the geographic extent of the Aleutian Islands and the vagaries of the wind, it becomes clear that volcanism is and was a localized phenomenon, unlikely to affect many areas at once. Relatively stable dense populations are probably harder to disrupt in a cultural–historically significant way than are sparsely scattered ones. We tentatively conclude that endemic volcanism in the eastern Aleutians may have had drastic effects on a relatively local scale but that its total cultural historical impact, at least in the last 4000 years, was probably less than the much rarer volcanism in the boreal interior.

We turn now to a brief discussion of the Holocene human and volcanic history of Umnak Island as elucidated over the last few years by the geologist Robert Black and by William Laughlin, Jean Aigner, and their colleagues with special attention to suggestions concerning the significance of volcanism in prehistoric Aleut life there. Umnak Island is divided into three topographic segments (Figure 11.3). The northeast end of the island is dominated by Okmok Caldera, 1000 m high and 12 km in width. The central portion of the island contains the beautifully symmetric Vsevidov Volcano, towering to 2100 m, and the dissected elongate ridge of Recheshnoi, 2000 m high. Southwestern Umnak, the focus of Aleut settlement and archaeological research, is a rolling plain of low relief. All three volcanoes have been active since man first came to Umnak at least 8500 years ago. Okmok is currently active, Vsevidov has been

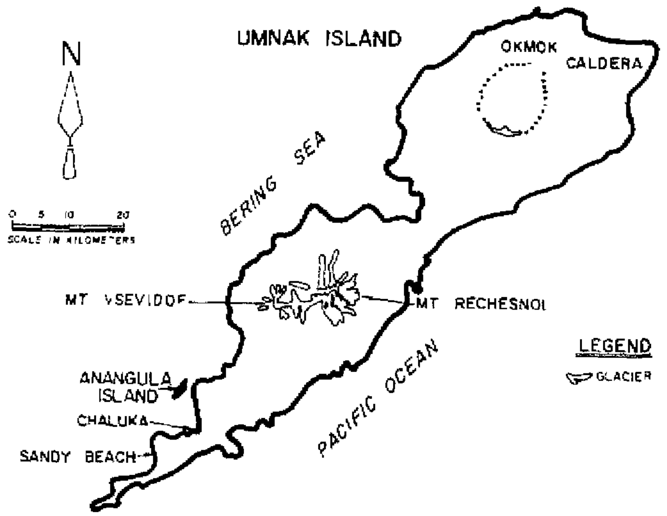

FIGURE 11.3. Volcanoes and archaeological sites on Umnak Island, Eastern Aleutians. (After Black 1975.)

active since 1750, and Recheshnoi generated a lava flow that reached the Pacific about 3000 years ago (Black 1976:9–10).

Black has developed the following basic chronology of Holocene events on Umnak (1976:9). The lowlands of southwestern Umnak were deglaciated by about 11,000 years ago, a major ash (Ash I) fell about 10,000 years ago, another major ash fell about 8500 years ago (Ash II), and Ash III was emplaced about 8250 years ago. There followed a long interval of Hypsithermal soil formation, with evidence for neoglacial activity in the mountains, a lava flow from Recheshnoi, and imposition of the last major ashfall (Ash IV) about 3000 years ago. Other minor Holocene eruptions are also reflected in minor ashfalls. Laughlin prefers a somewhat different chronology, with Ash II emplaced 9000 rather than 10,000 years ago and Ash III falling about 7000 rather than 8250 years ago (1975:509; see discussion of the Anangula site on pp. 361–362). Black notes that Ash I thickens to the west and thus presumably has its source west of Samalga Pass, probably in the Islands of the Four Mountains, whereas Ashes II and III presumably came from Okmok Volcano to the northeast (1976:16, 20). Ash IV also came from the northeast and it might be tempting to associate it with the documented activity of Recheshnoi about 3000 years ago, although Black does not attempt this correlation. No sources have been precisely determined lithologically as yet. Although it has not been proved, Black favors the interpretation that Ash III represents the cataclysmic eruption of Okmok that resulted in the formation of the caldera, whereas Ash II represents a lesser eruption from a similar source (1974:137).

Although noting cautiously that some of the geological correlations are not proven (1976:20–21), Black advances the following plausible suggestions about the cultural significance of volcanism on Umnak. Umnak was a peninsula forming the southern terminus of the Bering Land Bridge when late-Pleistocene lowered sea levels brought that land connection between Asia and

America into being. Down to at least 11,000 years ago heavy glaciaton of the mountains of the western Alaska Peninsula and on Umnak would have barred human access (1974:127). If boat-using people had filtered into the Umnak area, they would have come from the north and east following the shore of the land bridge. Virtually continual early Holocene eruptions of Okmok would have made it a significant barrier to pass and likely would have barred in-migration of any large terrestrial herbivores (1974:126). Fisher Caldera on Unimak Island was active at the same time (Miller and Smith 1977:174). Catastrophic volcanism resulting in the creation of Okmok Caldera about 8250 B.P. would have sterilized northeastern Umnak and probably would have severely impacted the settlement at Anangula Island about 70 km from the source (Denniston 1972:21; Black 1975:163; 1976:11; see also discussion of Anangula on pp. 361–362). Littoral obsidian sources on northeast Umnak may have been available to the inhabitants of Anangula Island. These would have been buried by up to 30 m of pyroclastic deposits during this cataclysm.

Mount Vsevidov on central Umnak is a very young volcano with evidence of a long Holocene eruptive history in the form of multiple lava flows, the youngest of which is certainly post-Hypsithermal and possibly post-1760. Black notes that, although none of Vsevidov's eruptions were as large or destructive as those of Okmok, ancient Aleuts living near it would have had to move often, and that ancient settlements might well be covered with lava flows (1975:163). Recheshnoi erupted about 3000 years ago, sending lava flows to the Pacific. It bore glaciers at the time, and Black wonders whether the eruption, in combination with other factors, might not have stimulated neoglacial ice advance here (1976:13). In closing he notes that volcanism and tectonic activity cannot be ignored in considering the extremely complex problem of Holocene sea levels in the Aleutians (Black 1974:16), a topic we need not pursue here.

The first occupation of the blade site on Anangula Island, located in Nikolski Bay about 70 km from Okmok Volcano, is dated to about 8500 years ago (Black 1974:133; S. Laughlin *et al.* 1975:39). The rich cultural level is sandwiched between Ashes II and III, with a number of lesser ashfalls, including the basal "key ash" noted as well (S. Laughlin *et al.* 1975:43; McCartney and Turner 1966:37; Black 1975.164; W. Laughlin 1975:510). The occupation layer is overlain by 10–20 cm of Ash III, which Black correlates with the explosion that created Okmok Caldera. Obsidian tools make up approximately 20% of the tool inventory (W. Laughlin 1972.2). This suggests either that the ancient inhabitants braved the dangers of Okmok Caldera or that they had access to a source since buried or lost. Three samples of this obsidian that have been analyzed resemble certain samples from northwest Alaska (Black 1974:137; 1976:11), but this source seems improbable on geographic grounds and I suspect that this interpretation is in error.

At present there is strong disagreement as to the duration of the Anangula occupation. Because of lack of evidence for soil development within the cultural layer, Black believes that Anangula was occupied for a very short time, between one Aleut generation and at most 100 years (1976:25). In 1966

McCartney and Turner suggested a short occupation, several centuries at most (p. 37). Aigner (1974:15; 1976a; 1976b:34) suggests an occupation of 500 years or less. W. Laughlin, on the other hand, interprets 33 radiocarbon dates as suggesting a span of occupation of 1500 years (1972:3; 1975:508). The difference of interpretation (which includes the dating of Ashes II and III) hinges on conflicts over the reliability of radiocarbon samples taken on soil humates and driftwood from the cultural level at Anangula and possibly contaminated by sea water, as opposed to a much smaller series taken from peat deposits undisturbed by man, and the weight to be attached to relative degree of soil development between the various ash levels (Black 1976:17). We need not attempt to resolve this issue here. Far more important for our purposes is the possible significance of the imposition of Ash III and related collapse of Okmok Caldera in the abandonment of the Anangula site.

W. Laughlin has suggested that the blade site was abandoned because of rising sea levels and that Ash III fell after the people left (1972:3). More than a decade ago McCartney and Turner suggested that absence of a sterile layer between the cultural horizon and Ash III at the site indicated that the ashfall may have led to abandonment of the site (1966:37). Black agrees, suggesting that the appalling spectacle of the collapse of Okmok Caldera and the deleterious impact of the associated ashfall and related events would have been sufficient reasons to abandon the site (1976:25; 1975:164). He cites as a personal communication from Aigner that the abandonment of the site appears to have been fairly precipitous, with a number of tools left behind that one might ordinarily expect to have been taken along (1974:139). Another possibility that has to be mentioned is that the occupants perished, either at the site or in the area. I find this intuitively unlikely, but possible. Evidence is lacking since the acid soils of the site preserve no bones. Could the well-known artifactual richness of the site reflect such abandonment? If so, there would perhaps be a greater concentration of tools at the top of the deposit.

Black thinks it likely that the Anangula people were driven either to seek refuge elsewhere on southwestern Umnak or perhaps to disperse to the west across dangerous Samalga Pass in their skin boats to the Islands of the Four Mountains and beyond (Black 1974:139; 1975:164). No archaeological evidence buttresses this view, with the problematical exception of a radiocarbon date of about 8000 B.P. of unspecified association from the Sandy Beach Bay site in the next bay west of Nikolski Bay (Black 1975:164). The prehistoric record on Umnak is blank for several thousand years after the Anangula occupation, but geological complexities (especially changing sea levels) preclude the drawing of conclusions about areal abandonment. Most scholars would probably concur with W. Laughlin (1975) and Aigner *et al.* (1976) that the Anangula technology is implicated, through one or several possible "transitional industries," in the technological ancestry of later Aleut culture. This indirect reasoning seems sufficient to indicate that it is unlikely that the Anangula people were a unique isolate that perished in the holocaust associated with the formation of Okmok Caldera, but no direct archaeological evidence bears on their post-Anangula history, and even the suggestion that they were driven from the area by