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Report
on a Research Contract
between
The Department of Botany, The University of Tennessee
and
Battelle Memorial Institute, Columbus Laboratories
for the period 1 August 1967 through 30 June 1968
The Plant Ecology of Amchitka Island, Alaska

Submitted:

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ABSTRACT

The Department of Botany of The University of Tennessee is conducting a study of the plant ecology of Amchitka Island, Alaska, as a subcontractor for Battelle Memorial Institute of Columbus, Ohio. The primary purpose of the study is the gathering of basic information on the plant ecology of the island which will allow the prediction and assessment of the consequences of underground nuclear testing by the U. S. Atomic Energy Commission.

Field work during the fall (1967), winter and spring (1968) has progressed to the point where a vegetational continuum has been recognized across most of the maritime tundra ecosystem of the island. Within this continuum, which corresponds to a moisture gradient from standing water to relatively well drained substrate, the two topo-environmental units which have been recognized are poorly drained lowland tundra and better drained upland tundra. The two units are primarily divided by the aspect dominance of "mesophytic" grasses in the upland unit. Both of these vegetational units grow on a substrate of peat which diminishes in depth and extent as better drained conditions are encountered.

The third topo-environmental unit, the beach community, dominated by grasses, occurs on a mineral substrate, and is disjunct from the moisture gradient mentioned in the preceding paragraph.

The tundra continuum exists in a dynamic state as peat accumulation and movement on local topography causes drainage changes. Because of the dynamics of drainage rates and patterns, such plant succession as does occur is multi-directional. A flora poor in species and the acid peat substrate contribute to a rather slow recovery from natural and man-caused disturbances, as

evidenced by the incomplete recovery of areas disturbed by military occupation during World War II.

The amount of change in the vegetation which will result from underground nuclear test shock will depend on the magnitude of shock and the amount of moisture in the peat substrate at the time of the tests. The wetter the peat, the more likely it is to move under shock. A rapid movement will cause greater alterations in drainage patterns which will be reflected in plant community shifts toward more mesophytic or hydrophytic expressions. In the absence of catastrophic shock or the release of radioactivity, the long term effects of the current construction and nuclear testing will be similar to the effects of the military disturbance, although perhaps of longer duration.

Activities planned during F.Y. 1969 include the further definition of communities, a more complete collection of plants than was possible during fall, winter and spring seasons, and the preparation of a vegetation map using aerial photographs and controlled sampling. Portions of the landscape which are likely to be altered by severe ground shock will be delineated appropriately.

INTRODUCTION

Under contract with Battelle Memorial Institute - Columbus, Ohio, Laboratories, and The University of Tennessee, the Department of Botany has been conducting studies on the plant ecology of Amchitka Island, Alaska, a Supplementary Test Site of the U. S. Atomic Energy Commission.

The study of the plant ecology of Amchitka was undertaken for two principal reasons: (1) To provide baselevel information on the plant ecology of the island in keeping with the objectives of the Bioenvironmental Safety Program established for the Supplementary Test Site and to predict the impact of the activities associated with the development and use of the Supplementary Test Site, and (2) to take advantage of well developed logistical and multidisciplinary support to study an area little known from an ecological point of view.

The specific objectives of the plant ecology study include: (1) An inventory and collection of the vascular and cryptogamic flora, with specimens to be deposited in the herbarium of The University of Tennessee and duplicates to go to the U. S. National Herbarium, (2) Definition and mapping of consequential landscape units based on aerial photographs, (3) Investigations of the processes and dynamics of the vegetation, including studies on productivity and successional patterns, and (4) Investigations of the effects of man's past and projected activities on the terrestrial ecosystem and the probable consequences of underground nuclear testing, including any acceleration of processes leading to plant community shifts.

During the period September 1967 through the end of FY 1968, the Department of Botany of The University of Tennessee has conducted research on Amchitka Island under contract purchase order V393 for Battelle Memorial Institute of Columbus, Ohio. Investigators from The University of Tennessee have spent a total of 24 seven-day man weeks on Amchitka during this 43-week period. Qualitative and quantitative researches on the terrestrial plant ecology have been carried on under autumnal, hibernal, and vernal conditions.

The aestival period has not yet been covered, but extensive observations and restricted sampling in mostly dormant plant communities have been carried to the point where a general discussion of landscape units and dynamics is possible. An aerial photographic survey of the island is currently being conducted for the U. S. Geological Survey. The photographs from this survey, along with quantitative analyses of community structure and composition during the coming growing season, will provide data which will fit into the present framework of the Amchitka terrestrial ecosystems and allow the description and mapping of consequential landscape units along with more detailed discussions of patterns and processes which have been or are likely to be altered by continuing activity on the island.

The Terrestrial Landscape of Amchitka Island

Previous to the initiation of this current study, in the fall of 1967, little detailed information on or interpretation of the terrestrial ecology of Amchitka Island was available. The flora had been studied by Hultén, Shacklette, Sharp, and others, but the dynamics of the terrestrial ecosystem had received only brief consideration.

The Amchitka landscape can be considered an expression of a maritime tundra ecosystem,¹ characterized by cool, cloudy summers and relatively warm winters. In spite of certain seasonal similarities to better known subarctic landscapes, Amchitka is not subarctic, either geographically or environmentally. The use of the term tundra follows the definition of Hanson (1962)² and should include the qualification that, although there is no permafrost, often included as a characteristic of tundra (Tedrow and Cantlon 1958)³ there is a widely distributed, nearly impervious lithified breccia which retards or prevents the deep percolation of water over large areas of the island. A widely distributed and rather deep peat occurs over much of the island. This peat has been observed solidly frozen to a depth of some two feet in midwinter, but the peat was entirely frost free by the first of May 1968. The presence of both stein streifen and amorphous solifluction patches indicates the importance of frost action on poorly vegetated or unvegetated areas. Some of this frost action is diurnal, but

1. The term "oceanic" is occasionally used as a synonym for "maritime" to describe this type of landscape, but the problem in this case is semantic.
2. "The treeless land in arctic and alpine regions...consisting of grasses, sedges, forbs, dwarf shrubs, mosses and lichens." Hanson, H. C. 1962. Dictionary of ecology. Philosophical Library, New York.
3. Tedrow, J.C.F. and J.E. Cantlon, 1958. Concepts of soil formation and classification in Arctic regions. Arctic 11(3):166-179.

freeze-thaw cycles of several weeks duration have been observed.

The vegetation on the island reflects in large part the differential drainage occasioned by the combinations of the gleyed, lithified breccia and the peat accumulations on local topography. Except for the relatively "dry" beaches which are dominated by a graminaceous community on a mineral substrate above the high tide mark, the composition and structure of the vegetation are responsive to the degree of restriction of ombrogenous water drainage.

For purposes of classification, the vegetation of the island, disregarding the beach community mentioned above, is a structural and compositional continuum along a moisture gradient from sedentary full bog to wind desiccated grass--sub-shrub stripe communities at the drier and higher end of the gradient. For convenience, this clinal tundra ecosystem can be divided into two topo-environmental categories or units, (1) poorly drained lowland, and (2) relatively well drained upland. The beach communities represent a separate and distinct topo-environmental entity, although the dominants of the beach grass community (Elymus arenarius, Calamagrostis nutkaensis, Festuca spp.) are important in, and in fact dominate, certain expressions of the upland topo-environmental vegetation.

The separation of upland and lowland topo-environments is a division based on topography and the restriction of drainage rather than on empirical altitude. See Figure 1.

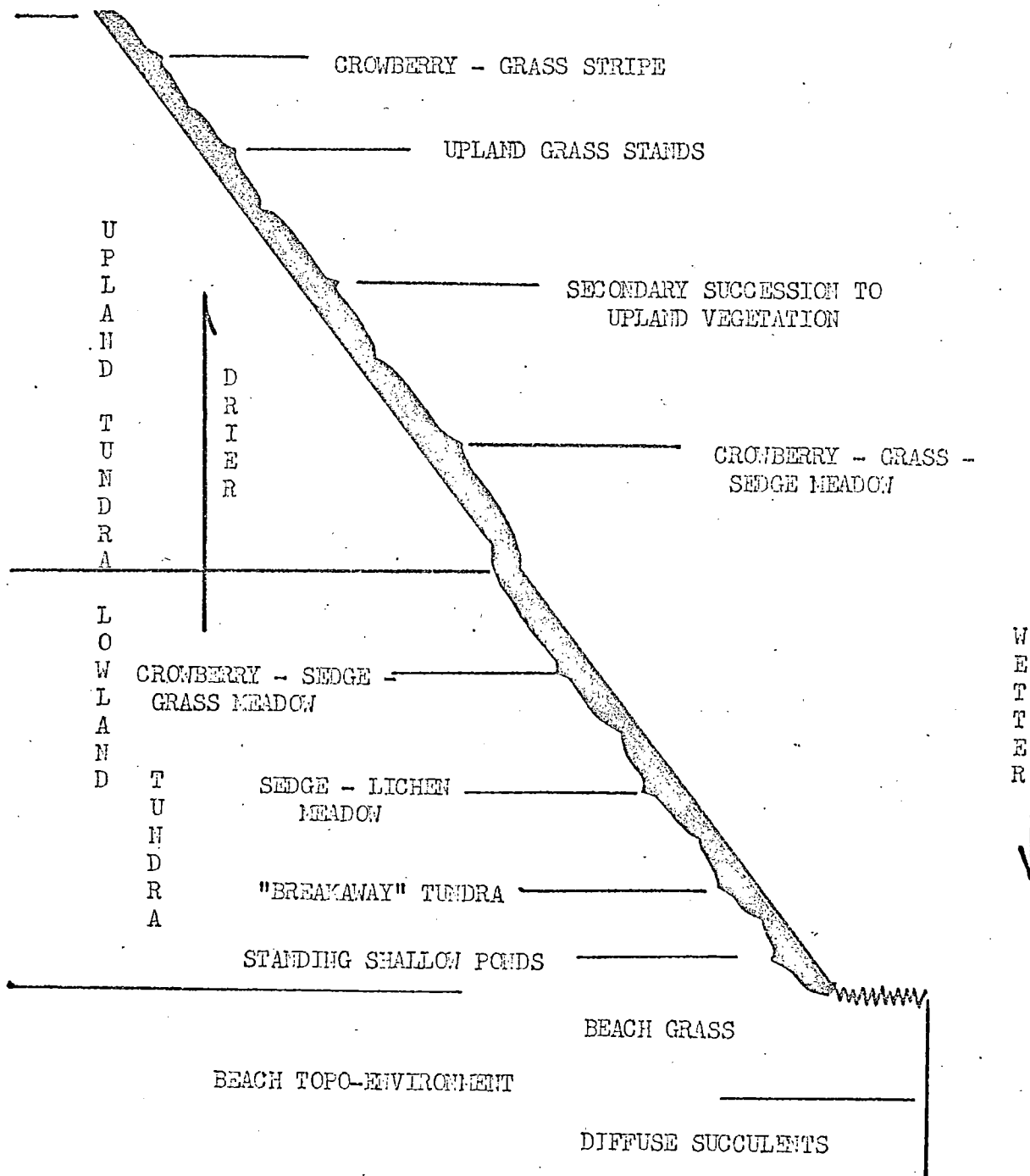


Figure 1. Community distribution along the moisture gradient on the maritime tundra landscape of Amchitka Island.

Methods and Investigations Under Way

Because there has been no opportunity as yet to study the vegetation during the active summer growing season, only a small amount of quantitative work has been completed. This work includes an altitudinal vegetation transect taken in mid-October 1967. This transect covered a rough line approximately three surface miles in length over elevations varying from 1100 to 50 feet msl on Chitka Ridge, west of Chitka Cove (see figure 2). This transect was taken using eight subjectively placed one square meter plots in conspicuous, well represented communities which were undisturbed by human activities. The vegetation was tabulated using the cover-abundance scale of Braun-Blanquet (1932)⁴. Details from field notes on this transect are included in the quarterly report submitted 8 March 1968. Although the results of study of this transect are not entirely comprehensive because of the late season, these data, along with extensive and repeated fall, winter and spring qualitative surveys, form the bases for the discussion of communities which follows in subsequent sections.

Four areas of more or less concentrated study have also been located and partially prepared. These areas, which will receive more intensive study during the coming summer, include: (see figure 2)

Triangle Park Station. This area south of the old Engineer Camp and east of the main camp was originally located in cooperation with an avian ecology study proposed by Dr. H. E. Childs. The area selected includes lowland "breakaway" tundra, lowland-upland tundra transition meadow and disturbed road berm vegetation. In each of these three types, a series

4. Braun-Blanquet, J. 1932. Plant Sociology: The study of plant communities (Trans., rev., and ed. by G. D. Fuller and H. S. Conard) McGraw Hill, New York.

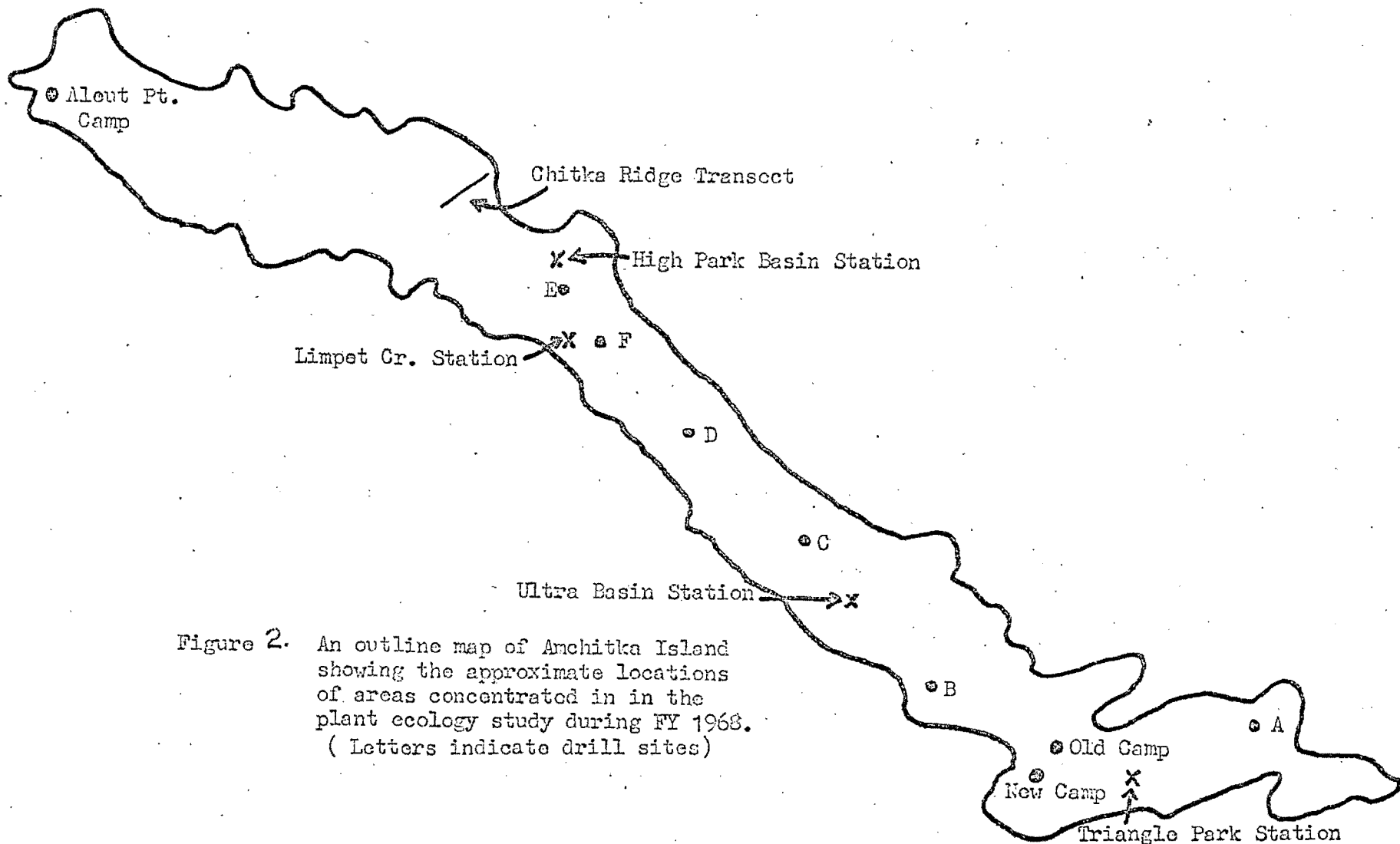


Figure 2. An outline map of Amchitka Island showing the approximate locations of areas concentrated in in the plant ecology study during FY 1968. (Letters indicate drill sites)

of three one-meter square plots was staked and located 3-4 October 1967. At the time of location, one plot in each series was excavated to a depth sufficient to remove most of the viable roots, and two other plots in each type were staked out. On 4 June 1968, one of the plots in each series was clipped to remove all standing dead higher vegetation. These clip plots will be harvested in the fall for species composition and productivity analyses. The third plot in each series has been left for comparative purposes. On 4 June 1968 nothing was growing in the excavated plots.

Ultra Basin Station. This area was selected during a February field trip for its relatively undisturbed character and its location between test sites B and C.

A temperature station was established, in a location selected to avoid excessive cold air drainage, on 20 March 1968. Two "U" tube maximum-minimum registering thermometers were installed in north facing shade shelters at 12 inches and 40 inches above the ground. These thermometers have been read and reset five times since installation, and the instruments have been switched at each reading. During the period 20 March - 1 June 1968, the 12" thermometer registered a low of +11⁰F. and a high of 53⁰F., while the 40" thermometer registered a low of +17⁰F. and a high of 48⁰F. The 11⁰F. reading is four degrees below the recorded 15⁰F. low at the airstrip on Amchitka 1943-1948⁵, while the 17⁰F. reading is only slightly higher. The current lack of a comprehensive meteorological station on the island is a handicap to the interpretation of climatic effects on the vegetation.

In cooperation with Holmes and Narver, Incorporated, a pair of surveyed, staked lines has been laid across a slope exhibiting peat movement in the basin. These lines consist of 58 and 77 stakes, 10 feet apart, which are

5. Per Bidding document for Amchitka road construction, U. S. Army Corps of Engineers, District Alaska, January 1968: SP10-SP14

tied in to the Ultra triangulation station. The lines will serve as a base for quantitative vegetational analysis as well as a measure of the rate and amount of peat slip before and as a result of nuclear test or earthquake shock, and any resultant vegetational change. Quantitative surveys should follow any test at either Sites B or C or any local seismic shock.

Six pairs of one meter square plots were established in the basin on 1 June 1968. One plot of each pair was clipped in preparation for composition and productivity analyses, while the second was left for comparison. The plots include representations of the following communities: lowland "breakaway" tundra, upland-lowland meadow transition, upland crowberry-grass-sedge meadow, upland grass, and a pond overflow which corresponds to a standing shallow pool. No plots were excavated here.

Limpet Creek Station. This drainage was selected as representative of the topography in the site F-site E area, but due to a reduction in the plant ecology effort, only minimum successional studies have been initiated. A series of small ponds has been altered so that one pond has been completely drained, a second partially drained, and third left alone. Another separate and larger, deeper pond has been partially drained. The exposed pond bottoms will be periodically examined for evidence of succession and compared with water covered bottoms. No plots have been established.

High Park Basin. This area of study near site E has the highest elevation (ca. 700') of the four areas prepared to this point. A sheltered thermometer was established at a 40 inch height on 25 March, 1968, but it was broken by a rock fall resulting from construction associated with road building during April. Another thermometer was installed 2 June 1968.

Three series of three plots each were established 26-27 September 1967 in the following communities: solifluction-blowout zone, crowberry-grass stripe, and crowberry-grass-sedge meadow. One plot in each series was excavated to remove viable roots, one of each was left for comparative

purposes, and one of each was clipped for fall composition-productivity analyses on 2 June 1968. The excavated plots showed no colonization as of 2 June 1968.

In keeping with the ecological studies currently under way, and those planned for the coming growing season, a plant collection is being prepared. Since the fall effort, discussed in the October 1967 report, plant collections suitable for inclusion in herbaria have been minimal, but it is expected that a representative collection will be possible during July and August. Specimens from these collections will be placed in the herbarium of The University of Tennessee and duplicates will be sent to the U. S. National Herbarium.

Field work has also produced 14 samples sent to Battelle Memorial Institute for chemical analyses. These samples include plant material and peat from selected areas. No acknowledgement of their receipt or any information on analyses performed has been received. In addition, four samples were taken from the vicinity of the mud sump at the Longshot site during early June 1968. These samples were frozen on the island and called to the attention of the Battelle personnel present.

THE MAJOR COMMUNITIES (Figure 1)

The Lowland Tundra

The lowland tundra has been extensively disturbed in many areas on the island, particularly on the eastern "half", by past military and past and present USAEC site development activities. The lowland tundra communities vary in composition and structure from the wettest expression, standing shallow pools which are usually dominated by Juncus balticus or Alopecurus aequalis⁶ to the driest of the lowland communities, Empetrum nigrum (crowberry)—Carex spp. (sedge)—Calamagrostis nutkaensis (reedgrass) meadow. The division of the tundra continuum into lowland and upland units occurs at the dry end of the latter community, with a reasonably distinct shift in annual productivity dominance from sedge to grass, and a more obvious presence of crowberry.

Between these two extremes two extensive communities occur, the first a "breakaway" tundra, dominated by sedges and lichens (particularly the lichen Cladonia pacifica, the local reindeer "moss"). The "breakaway" community is characterized by the lack of abundant well-rooted plants. This lack is reflected by the ease with which the living vegetation is disturbed or literally broken away by foot or vehicular traffic. The second of the two intermediate communities is a sedge-lichen meadow which, while containing many of the same species as the breakaway tundra, also contains enough grass (particularly reedgrass and Festuca spp.) and crowberry to resist easy displacement.

The semi-aquatic grass Alopecurus aequalis has not been found outside of shallow pools, many of which are of course ephemeral, but all the other

6. The study of the terrestrial plant ecology has not extended to the study of the ecology of well defined ponds and lakes except for occasional plant collections and such considerations as relate to terrestrial succession processes.

plants mentioned above in the lowland tundra grow in varying densities throughout the unit.

The primary factor controlling the cover and abundance of the various species of lichens, sedges, grasses, sub-shrubs and herbs is the drainage of substrate (peat) and surface. As the moisture gradient changes from an area of waterlogged peat to an area of wet peat which does have some drainage, even though it is severely retarded, the trend toward more mesomorphic plants follows. Extremely hydromorphic plants, such as Juncus balticus and Caltha palustris are found in abundance in the often extensive areas of nearly closed drainage, and occasionally in slowly moving shallow water, but at the drier end of the lowland tundra gradient, these plants are found only in special circumstances, where a small site, usually one that has been disturbed, holds standing water for some reason. Old vehicle tracks, especially "weasel" tracks, are a prominent example. The more mesomorphic plants, however, such as the crowberry and the reedgrass, are more abundant at the dry end of the lowland moisture gradient, but can be found under slightly improved drainage conditions in a generally very wet area. Low hummocks of peat, again often caused by past disturbances, support these species which are less tolerant of excess moisture.

Conspicuous moss mounds are found in lowland tundra and support vascular plants common to the upland tundra unit. Crowberry, Loiseluria procumbens, Vaccinium vitis-idaea, reedgrass and Deschampsia caespitosa are the most often encountered higher plants on the mounds. The moss mounds provide the better drainage conditions preferred by the upland plants, but the phenomena which bring about the preliminary development of these elevated organic mounds are not completely understood.

The lowland tundra topo-environmental vegetation can be summarized as a wet meadow vegetation with sedge and lichens more prominent in the wetter areas and grass and sub-shrubs becoming more prevalent as drainage

improves. The substrate for this vegetation is a sedge-lichen peat, generally varying from a depth of one to two feet on moderate slopes to depths in excess of 14 feet on lower slope transitions. The lowland tundra is dotted with ponds and shallow lakes which are supported by peat and may be crossed by a number of small streams. The terrain varies from flat to moderate slopes, and the absorbent peat over an impervious "bedrock" retains enough water (63 — 89% water by weight through fall-winter-spring, see Table 1) to restrict the plant species present to those that tolerate a great deal of moisture.

Table 1. Comparative water content of peat samples from fall, winter and spring samples on Amchitka Island. The samples are from the lowland-upland tundra meadow transition communities, except for #2, which is from a disturbed road berm which contained considerable mineral material and supported secondary succession to upland tundra grass. Samples were oven dried at 100^o-105^oC. until weight loss ceased. All figures are to the nearest whole number.

Sample #	1	2	3	4	5	6
Weight-g						
Wet	266	832	257	262	212	170
Dry	29	308	28	31	25	36
% Water	89	63	89	88	88	79
Date	7 Oct	14 Jan	25 Jan	1 Feb	23 Mar	10 May

The Upland Tundra

On well drained surfaces on Amchitka, the vegetation is generally dominated by grass or crowberry or a mixture of the two. The prominent grasses are reedgrass, Elymus arenarius (seagrass) and Festuca rubra (fescue)⁷. All three of these grasses are important members of the beach-grass community and are also found on certain drier microsites in the lowland tundra. The upland tundra also includes a good number of sedge species, and some Juncus and Luzula species are conspicuous in some situations. Salix spp. and Vaccinium spp. are also found on well drained sites. Loiseleuria procumbens (alpine azalea) is also an important member of the upland tundra sub-shrub communities.

The upland tundra grades from the crowberry-grass-sedge meadow at the drier end of the lowland tundra moisture gradient to the wind desiccated crowberry-grass stripe zone which is broken by solifluction zones at higher elevations on the island. The crowberry-grass-sedge community is the most stable vegetation on the island on moderate well drained topography.

Certain sites on the island support an almost pure grass community. These well drained sites are located at the edge of permanent lakes, along well established streams, just above steep sea cliffs and on steep slopes with a relatively well developed soil. Many of these grass stands (reed-grass, seagrass, fescue) cover considerable acreage and develop to heights of a meter or more. These grass communities are a part of the upland topo-environmental unit.

Another significant expression of the upland tundra vegetation occurs on the berms that resulted from road and building construction during

7. Festuca altaica intermingles with F. rubra in many situations. The two grasses are very similar in habit and in site preference.

the 1940's. These disturbed sites, well drained because they are elevated, support the same grasses mentioned in the preceding paragraph, as well as crowberry. This secondary succession to an expression of the upland tundra supports the most stable ranking of the crowberry-grass-sedge meadow community.

On mixed gravel-soil surfaces on the island, secondary succession to upland tundra vegetation is also occurring. The surfaces are generally of two origins—abandoned military roads and "desert pavements" or lag gravel surfaces in the wind—solifluction zones on exposed hills and ridges. Lupinus nootkatensis is the pioneer in most cases, and this robust hemi-cryptophyte provides both shelter and nitrogen enriched soil for the establishment of crowberry, grasses and herbs. Many small islets of vegetation have developed on the gravel surfaces in this fashion.

The origin of the gravel roads, and the subsequent secondary succession presents few problems of interpretation, but the desert pavement or lag gravel surfaces have more complex origins and processes of maintenance. A possible contributing factor is the apparent pathogenicity of a lichen of the genus Mycoblastis on the crowberry. Once the upland vegetation has been destroyed, whether by physical or organic agents, a bare gravel-soil surface subject to wind erosion and frost action results on exposed sites. The processes which control the establishment or reestablishment of vegetation on the very exposed sites are not completely clear at this point. Many of these surfaces have likely had an appearance similar to that extant since vegetation developed on the island under the present climatic regime. The pattern of the vegetated crowberry-grass stripes and intervening gravel surfaces is continually changing over the years with the migration of the vegetation and the movement of the gravel, but the overall aspect is unlikely to change much with the present floral composition of the island.

In summary, the upland tundra topo-environment unit vegetation grades from meadow to sub-shrub stands, reflecting the lesser accumulation of peat as drainage improves and soil forming processes are less inhibited. The lag gravel-soil surfaces are the "driest" well represented substrates on the island except for the beaches, but at certain times, when rainfall is copious, even these surfaces remain at field capacity.

The Beach Topo-environment

The dominant beach community above high tide line on those beaches which are wide enough and rise enough to prevent catastrophic storm flooding is a grass stand. The same sort of community appears on the small islets off the coast of Amchitka and on some of the larger sea stacks. The aspect dominant is Elymus arenarius (seagrass), but reedgrass and fescues are also common. Early in the growing season, geophytic herbs (especially Ranunculus spp., Geum macrophyllum, certain Umbelliferae) provide a welcome and conspicuous touch of green, but as the grasses develop fully, and the "canopy" closes, these vernal plants are less noticeable. The conspicuous but small Potentilla villosa is common in niches in rocks on the seacliffs and stacks.

There is also a rather diffuse community composed of succulent herbs which is generally found between the grass community and the mean high tide mark. These halophytes are often sea-washed, and nowhere provide a very dense cover. The principal species are Senecio pseudo-arnica, Honkenya peploide and Lathyrus maritimus.

The beach community is a separate topo-environmental expression because of the almost wholly mineral substrate. The largest beach grass stand yet found occurs at Bird Cape, which is apparently an old, stable sand spit. Although there has been military activity at Bird Cape, causing some secondary succession to upland tundra grass, the substrate appears to be mostly beach sand of considerable depth.

Very lush but localized expressions of the beach community vegetation occur on the seashell-calcium rich middens formerly occupied by Aleuts on or near many beaches on the island.

Community Comparisons and Dynamics

In the several plant communities which comprise the Amchitka terrestrial ecosystem, there are many species which are characteristic of two or more of these communities and complicate the exact delineation of community boundaries. Many of these are prominent species in terms of aspect dominance, but their annual productivity varies greatly, as does their gross biomass. Chief among these widely distributed species are the grasses Calamagrostis nutkaensis, Elymus arenarius, and Festuca spp., the sedges Carex circinata and C. macrochaeta, the sub-shrub Empetrum nigrum, mosses of the genus Rhacomitrium and several lichens of the genus Cladonia.

Although the crowberry and the lichen Cladonia pacifica are perhaps the most conspicuous elements of the vegetation of several of the communities, particularly in winter and spring, and although the gross biomass of the crowberry is probably the greatest of any of the island flora, the annual productivity of the lichen is negligible by comparison with other species. The highest total annual productivity by species on the island is contributed by Calamagrostis nutkaensis (reedgrass), with Elymus arenarius (seagrass) ranking second. The sedges are individually productive, but they seldom form dense stands as do the grasses.

The greatest annual productivity on a unit area basis is in the grass communities of the upland tundra unit and the beach topo-environment-unit. The most extensive community on the island is the crowberry-grass-sedge meadow at the wetter end of the upland tundra unit, and therefore the greatest gross biomass is found in this community. The annual productivity is not the greatest in this community, however, because neither the grass nor the sedge form extensive closed stands in the rather thick crowberry mat.

The second most extensive community in terms of area appears to be the crowberry-~~sedge~~-grass meadow at the dry end of the lowland tundra unit. This community is usually continuous with the crowberry-grass-sedge community discussed above.

Because of the similarity between the meadow communities, and because of their extensive distribution, a discussion of the dynamics of the Amchitka terrestrial ecosystem is best based on the processes which are operating in these communities.

As is common in bog communities, and even in spite of the relatively low annual biomass production of these tundra communities, productivity greatly exceeds decay and decomposition and the system is out of balance. The principal reason is the lack of consumers and reducing organisms. Primary consumers of viable plant material are limited to certain species of terrestrial birds, the Norway rat which is apparently on the island, and certain invertebrates which have been collected using Berlese funnel samples (centipedes, mites, springtails). These invertebrates also play a part in the decomposition of standing dead plant material and raw litter and humus. Although no detailed investigation of bacterial decomposers has been undertaken, such organisms are seldom abundant under the acid conditions which exist in peat systems. Many fungi are known to be important in the decomposition of organic material under acid conditions, but visual examination of the "F" layer of the substrate does not reveal conspicuous hyphae, and mushrooms or other fungal fruiting bodies have not been seen, indicating that soil fungi are not abundant.

A rough model of the terrestrial ecosystem of Amchitka is presented in Figure 3. Although this model indicates a balance, the facts that bacteria are probably not important here and such fungi as are certainly

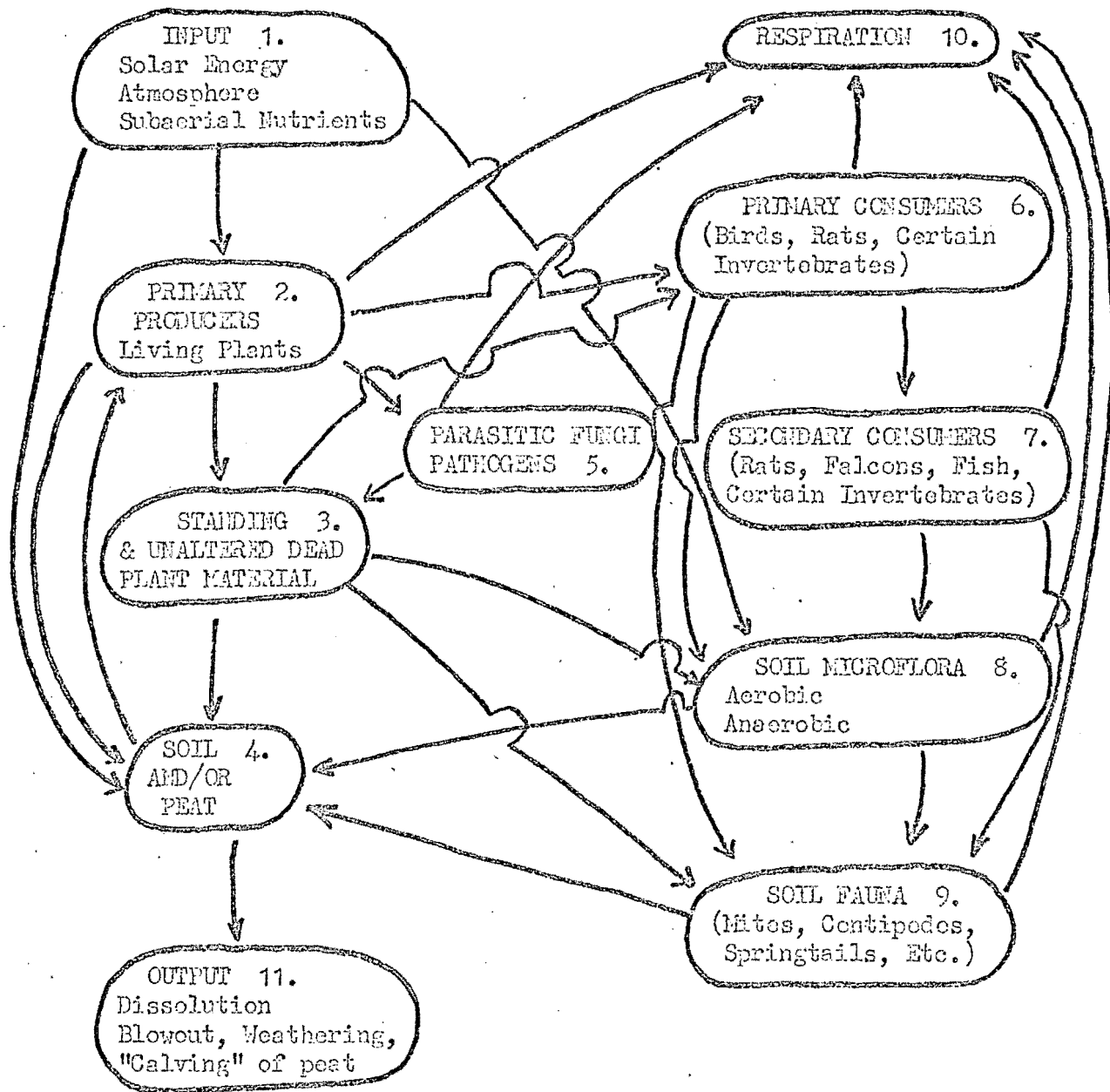


Figure 3. A model of the Amchitka Island terrestrial ecosystem. A discussion of the compartments is on page 24.

Figure 3. compartment discussion (see preceding page).

1. **INPUT:** There is no solar energy input record available for Amchitka. The work of Budyko (1956. The heat balance of the Earth's surface. Translation from Office of Technical Services, U. S. Department of Commerce, Washington D. C.) indicates the expected annual net radiation for the central Aleutians to be between 40 and 60 kg-cal/cm²/year. This is probably high, and a figure of 20 to 40 kg-cal/cm²/year should be more realistic.
Subaerial nutrients include salt spray, animal feces, dissolved nutrients in rain and snow, etc. Atmospheric contributions include nitrogen fixed by soil microflora.
2. **PRIMARY PRODUCERS:** This includes cryptogams and phanerogams. Basic annual productivity studies are under way.
3. **STANDING AND UNALTERED DEAD PLANT MATERIAL:** This includes the previous year's crop as well as fresh litter. Samples of standing dead grasses have been sent to BMT for analyses.
4. **SOIL AND/OR PEAT:** This compartment represents mineral soil as well as altered dead organic material. Samples of soil and peat have been sent to BMT for analyses.
5. **PARASITIC FUNGI, PATHOGENS:** Smuts and rusts have been seen on grasses. A lichen of the genus lycoblastis appears to be pathogenic to the crowberry. The activity of the lichen is being investigated.
6. **PRIMARY CONSUMERS:** Bird crops and stomachs indicate the consumption of fruits and leaves of many species. Rats are known to eat the underground parts of certain orchids and lilies. Invertebrates eat living plant material as well as dead. Samples indicate that springtails, mites, spiders and centipedes are present in the vegetation and in the litter at all times of the year.
7. **SECONDARY CONSUMERS:** The predation of falcons and rats is probably of only slight importance. Eagles have been seen attempting to take rats. Fish take a good number of invertebrates. Certain invertebrates, such as spiders, prey heavily on other invertebrates.
8. **SOIL MICROFLORA:** Although bacteria do not normally flourish in acid peat, nitrogen fixing bacteria are associated with the native lupine, and evidence indicates the presence of both sulfur and iron reducing bacteria. Lichenized fungi are very common, and blotter plates have been planted to attempt to cultivate other fungi.

Figure 3. compartment discussion (continued).

9. SOIL FAUNA: The presence of soil invertebrates at all seasons of the year, even in frozen litter, implies the importance of the soil fauna. Berlese samples have been run in fall, winter and spring. Identifications are incomplete to this point.
10. RESPIRATION: Before the plant ecology effort had to be reduced, plans included some determination of the respiration rates of important plants. The category is included to indicate that gross as well as net productivity is being considered.
11. OUTPUT: Hydric solution of peat, run-off which carries suspended organic and mineral matter, mineral weathering, blowout and the observed "calving" of peat are included in this compartment.

present are few reduces the possibility of a sustaining balance.

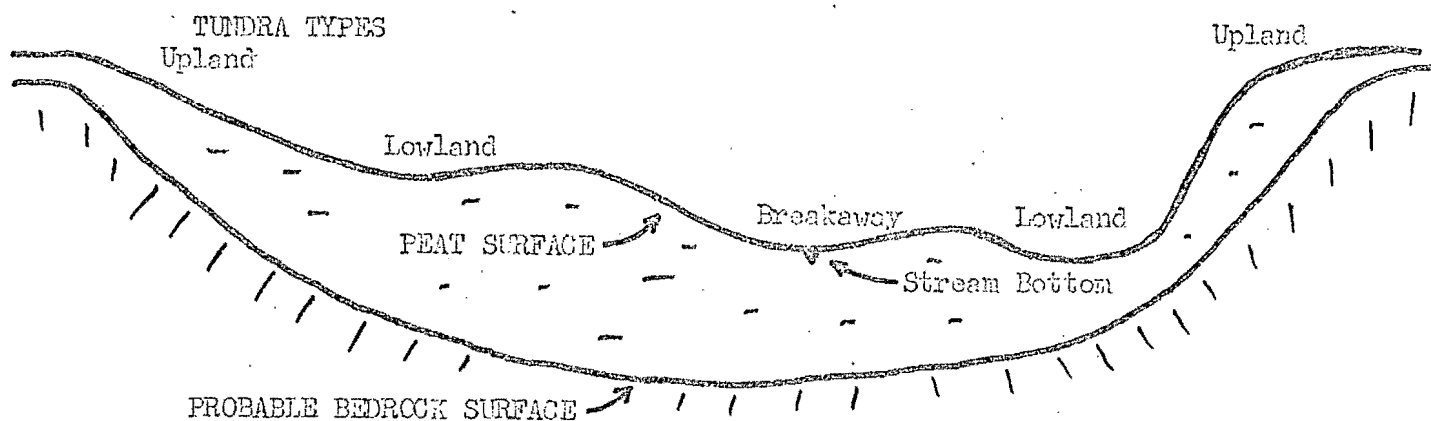
Although there is a sub-aerial supply of certain necessary nutrients from bird droppings, rat scat, insect casts, sea spray and other phenomena, the system is heavily weighted on the producing side. This imbalance has resulted in a continuing accumulation of plant residues and altered organic matter which has produced a rather thick layer of peat on flat to moderately sloping topography.

The system is complicated by the slow plastic flow of this peat towards stream bottoms and sea cliffs. This flow is apparent in flow lines, crevasses, and "peat falls" or "calving" over abrupt subsurface topography. The fact that the deepest peat is not found in the stream bottoms (Figure 4) indicates that a hydric solution of the organic material does occur, and the brownish coloration of many streams indicates that a considerable amount of organic material is carried in solution and suspension.

The movement of the peat occasions slowly but nearly continually changing drainage patterns. The fact that many streams flow over peat which is not derived from fully aquatic plants indicates stream migration as the peat flow has pushed the streams over and new channels have been cut through the peat. Lobes and large blocks of peat which have been observed in the streams also indicate the peat override of existing channels.

Naturally occurring earthquake shocks are known to have greatly accelerated the peat flow on steeper topography and at the top of the sea cliffs. Large slide and slump scars are conspicuous on steeper topography.

Figure 4. A graphic representation of an idealized peat depth profile through an upland tundra — lowland tundra transition basin, based on six peat depth grids taken in different areas supporting this vegetation. The upper line represents the peat surface. The vertical exaggeration is 10 - 1. The maximum peat depth represented is 10 feet, the width of the area is 750 feet.



Succession

In view of the continuum exhibited by the island vegetation across the moisture gradient which is dependent on local topography, the concept of succession towards a mesophytic "climax" does not apply on Amchitka. Although there are seral expressions, such as the examples of secondary succession on gravel surfaces and road berms, long term successional processes are not unidirectional. The constantly changing drainage, resulting from peat accumulation and movement, causes long term alternate drying and swamping over local areas and precludes local stability in time. The succession that does occur is rather multidirectional, progressive towards a mesophytic climax in some cases, and regressive towards a hydrophytic climax in others. Within this dynamic process, the overall vegetation of the island will change little in time but considerably in space.

A further complication which discourages a "classical" approach to the Amchitka terrestrial landscape is the depauperate flora. This lack of species, coupled with the existing edaphic and climatic factors, precludes direct comparisons of the Amchitka ecosystems with other better known ecosystems. In the poor and relatively isolated Amchitka flora, ecotypes have developed (as in Lupinus nootkatensis) which have adapted to a wide range of habitats and are more or less conspicuous as a result.

Given the dynamic ecosystem and the poor flora, only a major impact will create significant changes with time.

The Effects of Man's Past and Present Activities on Amchitka

The landscape of Amchitka has been affected to varying degrees by military and subsequent civilian activities on the island. The more obvious causes of change have been military construction of roads, and buildings, current construction of roads and drill sites, waste disposal, and traffic over fragile tundra. Denudation, caused by such agents as fire, has been inconsequential to this point, since the peat never appears to dry out enough to burn, although the standing dead material has carried fire.

In the preceding discussion of various community expressions of the upland tundra vegetation, it was pointed out that secondary succession to indigenous vegetation has progressed relatively well, although slowly, on the berms around old roads and buildings, and is occurring, very slowly, on abandoned gravel roads. These types of construction disturbances have generally improved drainage, and the extant seres reflect these drainage changes. If the current construction were to be abandoned at this point, similar succession would occur over a period of time. The extensive up-grading of Infantry Road from the harbor—camp area to Aleut Point will perhaps cause a somewhat more complex reaction, e.g., wind baffling and creation of lees in association with cuts and fills, blockage of drainage, increased exposure of previously less exposed areas, addition of silt to produce local mucks, and the like. The resulting succession after the site is abandoned, however, barring a radical increase in activity, will be about the same as that now in evidence some 25 years after the extensive military activity.

The consequences of the disposal of liquid organic and inorganic materials and solid waste are not so easily predicted. The leakage of the

highly basic, oil containing drill mud from sumps at the drill sites has killed some vegetation, but not a significant amount on an areal basis. The "mud sump" and the drainage ditch from it at the Longshot site do not support any higher vegetation even after a period of nearly three years. The addition of abrasive materials to the streams through this same leakage may increase the rate of downcutting of the peat floored streams, resulting in some improvement in drainage in certain areas, with resultant community shifts. A minimal experiment is under way to determine the chemical effects of the drill mud on tundra vegetation which has been transplanted into a cold frame. The reaction of the highly acid bog peat substrate to varying concentrations of the highly basic drill mud should not be predicted in advance of further observations.

Organic pollution, such as that in the stream flowing into Clevenger Lake, has no doubt improved nutrient levels which will aid plant development along the stream, but the organic pollution is complicated by oil in the Clevenger stream.

The disposal of solid wastes in dumps has more impact on the aesthetics of the landscape than on the vegetation, except for the danger of needless injury to man caused by the random and careless dispersal of junk and debris around centers of activity.

The gouges left by tracked vehicles 25 years ago are striking evidence of the fragility of the tundra, and the very slow rate of recovery of certain communities. Many of the old tracks are water filled during the rainy seasons, and support little higher vegetation at any season. The natural eradication of these tracks, and some heavily used footpaths as well, will be a matter of a good many more years. The light ground pressure tracked vehicles now in use on the island ("Sno-Tracs") cause relatively little damage, except on the extremely fragile "breakaway" tundra. Staking of frequently used

trails to discourage random driving would reduce this damage by confining the impact to the marked trails.

Probable Effects of Nuclear Test Shock on the Amchitka Terrestrial Ecosystem

The changes in the terrestrial ecosystem that will result from the underground shock of nuclear testing depend on the intensity of the shock and the amount of excess water in the peat and soil substrates at the time of the test. It has been noted that recent earthquake shock has caused conspicuous slump and slide activity. There is no way to deduce how wet the substrate was at the time of these earthquake shocks, and no way to guess the local intensity necessary to cause the disturbances that did occur. The effects of nuclear shock will be similar in expression, greater or lesser, in respect to the greater or lesser intensity of shock.

Barring a shock of such great intensity that catastrophic land movement occurs, the chief effect will be the acceleration of peat movement rates and a resulting more rapid shift in drainage patterns. The communities that are most widely distributed on the island are sensitive to the degree of drainage restriction, and as the drainage restriction is increased or decreased, the composition and structure of the plant communities will change correspondingly.

In addition to the acceleration of peat movement rates, and the resulting drainage changes as the peat surface topography is altered, a severe shock might fracture the lithified breccia layer which prevents the deep percolation of the surface water. This type of drainage will drive the plant communities towards the drier expressions of the continuum now extant, and may also result in local flushes of nutrient rich geogenous water that will accelerate plant growth and development for a time. The effects of such fracturing on the vegetation are not likely to be permanent, however. Considering the nature of the tundra bog ecosystem, and the amount of clay

in the deep gleyed soil, the fractures will plug up (the time necessary depending on just how wide they are) and the present system will most likely be again in operation after this recovery.

The testing would have the least effect on the vegetation of the island if it were conducted at a time when the tundra were very dry or very well frozen. Unfortunately, the meteorological data available for the island are so incomplete as to preclude any generalization as to the driest periods, and although mid-winter is the most likely time to find the tundra well frozen, complete thaws were observed this past winter.

Should any leakage of radioactivity occur, it would have the greatest impact on the terrestrial vegetation during the late spring flush of growth and during the summer period when the perennial plants are producing photosynthate for current growth and carbohydrate storage. There apparently is no season on the island when all growth ceases, at least in the common grasses. Sea grass, reed grass, fescue, and Bromus sitchensis (as well as certain ferns) were all observed to be actively "tillering" throughout the fall, winter, and early spring season. It is unfortunate that the plant ecology study must be phased out before quantitative analyses can be performed on this "off season" growth as well as on the vernal-aestival growth rates and growth amounts of dominant plants. There will also be a gap in any predictions of the effect of nuclear testing as a result of the lack of information on mineral cycling which was in the original study proposal for F.Y. 1969.

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