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MEEKS TABLE RESEARCH NATURAL AREA

REFERENCE SAMPLING AND HABITAT CLASSIFICATION

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MEEKS TABLE

MEEKS TABLE RESEARCH NATURAL AREA--REFERENCE SAMPLING AND HABITAT CLASSIFICATION

Reference Abstract

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1977. Meeks table research natural area--reference sampling and habitat classification. USDA For. Serv. Res. Pap. PNW-223, 19 p., illus. Pacific Northwest Forest and Range Experiment Station, Portland, Oregon.

Studies of vegetation cover and composition and physical and chemical characteristics of soil indicate the presence of three shrub-grass and two forested communities on Meeks Table Research Natural Area. Development of these communities appears to be linked to depth of volcanic ash.

KEYWORDS: Research Natural Areas, Meeks Table Research Natural Area, soil nutrients, communities (plant), habitat classification.

RESEARCH SUMMARY

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Similarity analyses of cover and composition of shrub and herbaceous vegetation and comparisons of physical and chemical soil properties on Meeks Table Research Natural Area indicate the presence of three shrub-grass and two forested communities on three dominant soil associations and two subassociations. Shrub-grass communities in order of degrees of development and amount of vegetal cover are *Artemisia/Poa/Eriogonum*, *Artemisia/Poa/Sedum*, and *Artemisia/Stipa/Phlox*. The two forested communities are *Pinus/Calamagrostis/Lupinus* and *Abies/Calamagrostis/Arnica*. Development of vegetation communities appears to be closely linked to the depth of volcanic ash and climatic factors (wind and water erosion) that have governed the stability of ash deposits.

Levels of plant nutrients in the upper 7.5 cm of soil generally increased in the order *Artemisia/Poa/Eriogonum* < *Abies/Calamagrostis/Arnica* < *Artemisia/Poa/Sedum* ≤ *Artemisia/Stipa/Phlox* < *Pinus/Calamagrostis/Lupinus*. Because of differences in soil depths among communities, total quantities of nutrients were arrayed as follows: *Artemisia/Poa/Eriogonum* < *Artemisia/Poa/Sedum* < *Abies/Calamagrostis/Arnica* ≤ *Artemisia/Stipa/Phlox* < *Pinus/Calamagrostis/Lupinus*.

These differences in levels and total capitals of nutrients among communities suggest a need to determine relationships among soil nutrient levels, soil nutrient availability, and biomass productivity of forest and range sites of the eastern Cascades as a basis for understanding effects of land use practices on future site productivity.

Introduction

Intensified use and manipulation of wildlands in recent years have focused attention on the need to maintain productive, stable, high quality resource management programs. Such programs require characterization of the undisturbed environment for each ecosystem being managed. Baseline vegetation and soils data, two basic components of environmental information, can be collected on Research Natural Areas established for this purpose. Research Natural Areas on Federal lands provide examples of ecosystems in essentially natural conditions. These areas can be used for the collection of baseline data and long term monitoring of environmental quality; studies of the structure and function of natural ecosystems; preservation of gene pools of natural organisms; and education and training (Franklin et al. 1972, Moir 1972, and Romancier 1974).

Meeks Table, a 27-ha isolated basalt-capped plateau, was established as a Research Natural Area in 1948 to exemplify undisturbed east Cascade *Pinus ponderosa-Pseudotsuga menziesii-Calamagrostis rubescens* and associated shrub-grass habitats on soils derived from basalt parent material (Tiedemann et al. 1972). The area was never logged or grazed. There is, however, a history of periodic fire on the table.

Since the area was established, there are new classifications for forest and steppe vegetation for eastern Washington (Daubenmire and Daubenmire 1968, Daubenmire 1970), and a comprehensive description of the vegetation in Oregon and Washington (Franklin and Dyrness 1973).

This study was conducted to describe and classify the communities of Meeks Table, generate reference level (baseline) information on vegetation and soils of each described community, and focus on the management implications of the baseline information.

Previous Work

Rummell (1951) was instrumental in establishing Meeks Table as a Research Natural Area and conducted the first documented study of the vegetation and soils of the area. The objective of his study was to determine the effects of grazing on regeneration of ponderosa pine. His approach was to compare vegetation and soils of ungrazed Meeks Table with those of adjacent Devil's Table where livestock use was occurring. Neither area had been logged. In his study he recognized three vegetative communities on Meeks Table: *Pinus ponderosa/Calamagrostis rubescens-Carex geyeri*, *Pseudotsuga menziesii/C. rubescens-C. geyeri*, and *Stipa occidentalis-Poa sandbergii*. Rummell noted striking differences in density (cover) of *C. rubescens* between Meeks and Devil's Tables. He concluded that tree reproduction on Meeks Table was sparse because of the dense herbaceous cover, whereas tree reproduction was abundant on Devil's Table where heavy grazing had reduced the cover of understory vegetation.

Rummell also described typical soil profiles for the forested and open grassland communities of Meeks Table. From his observations, soils in forested areas can be classed as andic xerochrepts. Soils in grassland areas are lithic xerochrepts.[1/]

Studies of a similar nature have been conducted by Jameson et al. (1962) and Schmutz et al. (1967) for isolated plateaus in Arizona. Both studies utilized comparisons between the isolated, undisturbed area and

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1/ Personal communications from Mr. Philip McColley and Mr. Robert Mitchell, Soil Scientists, Wenatchee and Umatilla National Forests, respectively.

mainland conditions where use was occurring. Vegetative composition between isolated and mainland conditions was strikingly different in both studies.

Physical Environment

Meeks Table is an isolated, flat-topped butte rising 150 m above the surrounding rolling terrain (fig. 1). It is a remnant of a larger plateau isolated by river action. Elevation on the table varies from 1 280 to 1 585 m. Access is by a steep, narrow trail up the knife-like ridge at the northwest end.

Figure 1.--Meeks Table Research Natural Area - a 27-ha isolated, basalt-capped plateau.

A modified continental climate prevails. Most precipitation occurs as snow during the cool, cloudy winter. Summers are warm, generally low in precipitation, and largely cloudless. One to 3 months of drought are common. United States Weather Bureau (1965) climatic data from Bumping Lake located at 1 400-m elevation in a valley 16 km west of Meeks Table are as follows:

Mean annual temperature..........	4.7°C
Mean January temperature.........	-4.9°C
Mean July temperature............	14.5°C
Mean January minimum temperature..	-10.0°C
Mean July maximum temperature.....	23.6°C
Average annual precipitation....	1 214. mm
July through August precipitation..	69. mm
Average annual snowfall...........	554. cm

Methods

In July 1968 vegetative cover and composition were sampled on 48 plots spaced at 50-m intervals from a random start along four lines traversing the table from northwest to southeast. Cover and compostion of herbaceous and shrubby vegetation were measured with a 100-pin point frame 60 x 60 cm (Brown 1954). Using the center of the point frame as a plot center, cover of tree overstory was measured with a spherical densiometer. Height of the tallest tree and diameter at breast height of all trees on a 0.08-ha circular plot was recorded by species.

Soil cores and loose soil samples were collected on every third plot to a depth of 7.5 cm at the plot center.

Chemical analyses of soils conducted were: pH and total carbon (Black et al. 1965a); total N (Keeney and Bremner 1967); total S (Tiedemann and Anderson 1971); cation exchange capacity (Chapman and Pratt 1961, Ballentine and Gregg 1947); exchangeable cations by atomic absorption spectroscopy (Robinson 1966). Physical analyses were: bulk density, texture, aggregate stability, and available soil moisture (Black et al. 1965b).

Vegetation and soils were highly variable among plots on these transects.

Stratification of plots into groups with similar overstory and understory vegetation indicated the presence of three shrub-grass and two forested communities. These tentative communities were:

Artemisia rigida/Poa sandbergii/ Eriogonum douglassii

A. rigida/P. sandbergii/Sedum stenopetallum

A. rigida/Stipa occidentalis/ Phlox diffusa

Pinus ponderosa/Calamagrostis rubescens/Lupinus laxiflorus

Abies grandis/Calamagrostis rubescens/ Arnica cordifolia

Soils data indicate that these five plant communities reflect the growth response on three dominant soil associations with two of the three associations stratified into two subassociations.

Sampling of herbaceous and shrubby vegetation was stratified for the second occasion to provide a more adequate sample. Numbers of plots needed to be within 10 percent of the true mean for 90 percent of the time were determined for each tentative community using mean (x) and variance (s^2) of understory vegetative cover from the first sample occasion for one or two herbaceous or shrubby species with frequency greater than 60 percent. This choice will no doubt lessen the confidence of measurements on species with lower frequencies. There were not sufficient data, however, on samples with lower frequencies for a valid estimate of s^2. Also, the high variability among plots would have resulted in an unreasonable requirement for number of plots. Variability of soil nitrogen within each tentative community was the criterion used to determine number of soil samples needed.

The second sample of understory vegetation was taken using a 20-pin point frame 60 x 120 cm. In addition to foliar hits by pins for vegetal cover, presence of each species in the confines of the 60- x 120-cm plot was recorded for frequency.

Plots were systematically spaced 11 m apart by random direction from the center of each tentative community until another community was encountered or the desired number of plots taken. Each tentative community was represented by several discrete units on the table and each unit was sampled.

Size distribution among tree species was determined in August 1975 for the two forested communities by measuring d.b.h. of all trees on six 25- x 25-m plots in the *Pinus* community and seven 25- x 25-m plots in the *Abies* community. Data from the 1968 sample of tree species were not included because many of the plots encompassed more than one community and would not accurately represent the individual forested communities.

Soil samples were collected in each tentative community with the randomization technique used for vegetation sampling. Where possible, soil cores were collected from 0 to 7.5 cm, 15 to 22.5 cm, and 30.5 to 38 cm. Samples were analyzed as described earlier. Shrub and herbaceous vegetation data were summarized by cover and frequency. Indices of similarity among the 186 individual plots were computed (Oosting 1956) using

$$c = \frac{2w}{a + b} \times 100;$$

where,

c = percent similarity,
a = sum of quantitative measures of plants in one stand,
b = sum of quantitative measures of plants in a second stand,
w = sum of the lesser value for those species in common between the two stands.

No frequency data were generated for vegetation within individual plots. A dendogram was constructed to enable a more objective separation of communities (Mueggler and Harris 1969). Indices of similarity were also calculated among tentative communities using frequency of individual plant species.

Differences in soil properties among communities were evaluated using analysis of variance and a Duncan multiple range test for separation of means (Steel and Torrie 1960).

Results and Discussion

VEGETATION

Similarity analyses and the dendogram for the entire 186 plots resulted in numerous clusters of plots at any selected similarity value greater than 20 or 30 percent. Cover values from the point frame data were apparently not sensitive enough to enable us to make community separations from similarity analyses among the 186 plots. Mueggler and Harris (1969) also found that ordinations of grassland sites failed to group areas over the 30-percent level of similarity. They concluded that this was an indication of non-uniformity among sites and strong sensitivity of the vegetation to site dissimilarities. We next made similarity comparisons among the five tentative communities using frequency of individual species within each community (table 1).

Similarity among the three shrub-grass communities ranged from 41 to 59 percent. Similarity of shrub-grass to forested communities for understory vegetation ranged from 5 to 16 percent. The two forested communities had a similarity of 51 percent. Thus, if 60 percent is established as a reasonable level of similarity at which two communities are the same, there are five distinct communities on Meeks Table.

Table 1--*Similarity matrix for five communities on Meeks Table*

	Artemisia/ Stipa/ Phlox	*Artemisia/ Poa/ Eriogonum*	*Artemisia/ Poa/ Sedum*	*Pinus Calamagrostis/ Lupinus*	*Abies/ Calamagrostis/ Arnica*
Artemisia/ Stipa/ Phlox	100	41	59	16	11
Artemisia/ Poa/ Eriogonum		100	49	7	5
Artemisia/ Poa/ Sedum			100	10	9
Pinus Calamagrostis/ Lupinus				100	51
Abies Calamagrostis/ Arnica					100

The *Artemisia rigida/Poa sandbergii/ Eriogonum douglassii* community covers 3 ha and occupies almost the entire southern rim of Meeks Table (fig. 2). It is characterized by a harsh, rocky, poorly developed soil with sparse vegetative cover (20 percent) (fig. 3). We documented 32 plant species in this

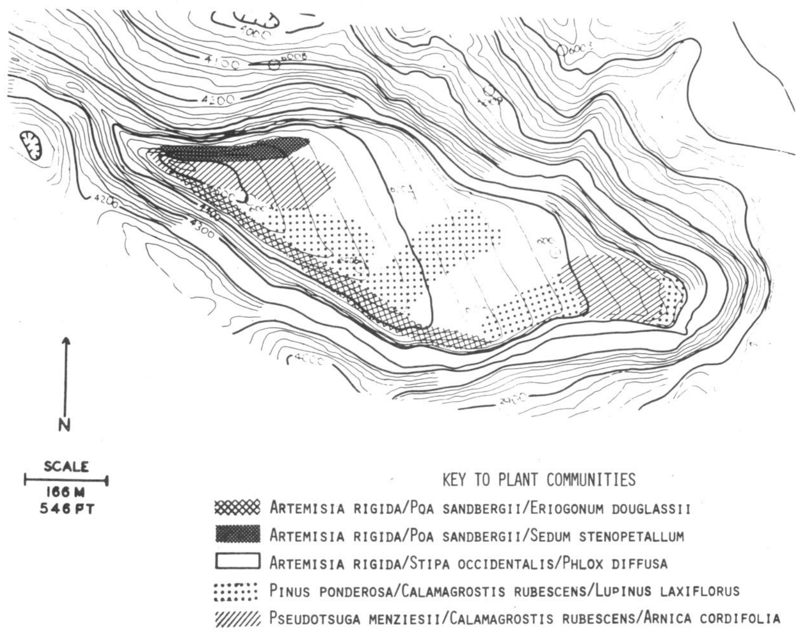

Figure 2.--Distribution of plant communities on Meeks Table Research Natural Area. Contour interval is 6 m (20 ft).

Figure 3.--The Artemisia/ Poa/Eriogonum community is characterized by a harsh, rocky, poorly developed soil and sparse vegetative cover.

community, many of which Daubenmire (1970) includes in his descriptions of lithosolic habitats (table 2). *Artemisia rigida*[2/] provides only 1.5-percent cover, but is the principal shrubby species in this community. *Purshia tridentata* cover is 2.9-percent, but this species occurs primarily in a transition with the *Pinus ponderosa* community.

Poa sandbergii was found on 93 percent of the plots and provides 2.2-percent ground cover. *Sitanion hystrix* var. *hordeoides* and *Bromus tectorum*, two species common to harsh, rocky sites in the Pacific Northwest, provide 1.2- and 0.9-percent cover, respectively. The most ubiquitous forbs are *Eriogonum douglassii*, *Antennaria dimorpha*, and *Penstemon gairdneri*. *Lewisia rediviva*, a harsh site indicator plant, was found on 28 percent of the plots. This community appears to be analogous to the *Artemisia rigida/Poa* or *Eriogonum/Poa* habitat types described by Daubenmire (1970), and is similar to the *Artemisia/Poa/Eriogonum* communities described by Hall (1973) in the Blue Mountains of Oregon. Hall notes that good condition range of this type has the same appearance as poor condition *Artemisia tridentata* range.

The extreme northern rim at the western end of the table supports a 1-ha community of *Artemisia rigida/Poa sandbergii/Sedum stenopetalum*. This area differs principally from the southern rim in greater total vegetative cover (28.5 percent), conspicuously less cover and lower frequency of *L. rediviva*, *P. sandbergii*, and *P. gairdneri*, and greater cover and frequency of *Arenaria congesta*, *Lupinus laxiflorus*, *Danthonia unispicata*, and *Stipa occidentalis* (fig. 4).

The most extensive area on the table is the *Artemisia rigida/Stipa occidentalis/Phlox diffusa* community occupying 11 ha of the center and northern rim in large openings between forested communities (fig. 5). Average vegetal cover of this community is 45 percent. Of the 53 species found here, *S. occidentalis* is the most abundant, providing nearly one-fourth of the total cover with 90-percent frequency of occurrence. *Artemisia rigida* provides 3.8-percent cover and has a frequency of 49 percent. Cover of *P. diffusa* is 4.3 percent and frequency is 50 percent. One especially notable feature of this community is the abundance of annual plants such as *Cryptantha torreyana*, *Polygonum kelloggii*, *Linanthus harknessii*, and *Collinsia parviflora*. Daubenmire (1970) and Meuggler and Harris (1969) indicate that abundant annuals are a normal part of the vegetation complex of these grassland communities--even in an undisturbed state. Several of the habitat types described by Daubenmire (1970) include *S. occidentalis*, but cover and frequency were lower than we observed on Meeks Table. According to Franklin and Dyrness (1973), this community is an early stage of retrogression of *Agropyron* and *Festuca* associations in response to grazing of eastern foothills of the Cascade Range in Washington. Tiedemann (1972) found extensive areas of *S. occidentalis* at elevations of 1 850 m on Table Mountain, a basalt-capped plateau in central Washington, which has a history of use by both sheep and cattle.

The observed abundance of *S. occidentalis* on Meeks Table indicates that this plant may be a major component of developing shrub-grass communities, as well as an early indicator of retrogression from climax of *Agropyron* and *Festuca* communities in response to livestock use.

[2/] Species determinations by Drs. F. J. Hermann and C. Feddema, U.S. Forest Service Herbarium, Fort Collins, Colorado. Plant nomenclature follows Hitchcock and Cronquist (1973).

Table 2--*Percent cover and frequency of shrub and herbaceous vegetation on Meeks Table*

Species	*Artemisia/Poa/ Eriogonum*		*Artemisia/Poa/ Sedum*		*Artemisia/Stipa/ Phlox*		*Pinus/Calamagrostis/ Lupinus*		*Abies/Calamagrostis/ Arnica*	
	Cover	Frequency (40 plots)	Cover	Frequency (10 plots)	Cover	Frequency (76 plots)	Cover	Frequency (30 plots)	Cover	Frequency (30 plots)
SHRUBS										
Artemisia rigida	1.5	28	1.0	20	3.8	49				
Purshia tridentata	2.9	15								
Arctostaphylos uva-ursi					0.8	3				
Holodiscus discolor								3	0.5	11
Amelanchier alnifolia										3
Total shrubs	4.4		1.0		4.6					
GRASSES AND SEDGES										
Bromus tectorum	0.9	58								
Poa sandbergii	2.2	93	0.5	20	1.7	71				
Sitanion hystrix var. *hordeoides*	1.2	33	0.5	20	0.5	33				
Stipa occidentalis var. *minor*	0.2	20	1.5	60	10.1	90				
Danthonia unispicata		18	1.0	40	0.9	21				
Festuca idahoensis	0.1	5	0	10	0.1	3				
Koeleria cristata	0	5			0.1	4				
Carex geyeri	0	3	1.5	40	0.8	18	11.0	90	12.5	97
Bromus marginatus					0.4	12	1.2	3		
Calamagrostis rubescens					2.4	13	42.7	100	19.5	77
Danthonia intermedia							0.2	3	0	3
Total grasses and shrubs	4.6		5.0		17.0		55.1		32.0	
FORBS AND HALFSHRUBS										
Haplopappus stenophyllus	0.3	18								
Lewisia rediviva	0.1	28								
Erigeron bloomeri	0.4	48	2.5	50						
Allium acuminatum	0.1	35				11				
Penstemon gairdneri	1.0	43			0.3	18				
Antennaria dimorpha	1.6	65	1.5	40	0.5	16				
Agoseris glauca	0.1	3	0	10	1.0	59				
Balsamorhiza sagitatta	0.1	3		10		5				
Castilleja thompsonii	0.3	5	0	10	0.3	33				
Eriogonum compositum	0.4	3	0	20		8				
Eriogonum douglasii	2.4	65	1.5	20		1				
Phlox diffusa	0.9	28	0.5	30	4.3	50				
Polygonum kelloggii		3	0.5	50	0.7	50				
Viola trinervata	0.2	23		20		4				
Arenaria congesta	0.8	70	2.5	100	0.9	43	0	3		
Collinsia parviflora	0	8	0	90	0.1	47	0	3		
Lomatium nudicaule	0.6	8	0.5	50	2.0	84	0.2	3		
Sisyrinchium douglasii	0.4	10	2.0	70	1.3	41	0.2	7		
Sedum stenopetallum	0.6	63	4.5	100	1.4	84		3		
Antennaria rosea	0.5	23			0.4	16	0.2	10		
Cryptantha torreyana	0	23	0	10	1.4	95	0	7		
Lupinus laxiflorus	0.1	5	4.0	50	1.2	37	8.3	97	1.5	43
Achillea millefolium				10	0.1	28	3.3	63	0.7	13
Lithophragma bulbifera				10		7				
Lomatium dissectum				30	0.8	41				
Antennaria luzuloides			2.5	30	2.6	49				
Haplopappus lanuginosus			0	10	0.1	9				
Anaphalis margaritacea						3	0.8	50		
Fritillaria pudica						1	0.3	23		
Geum triflorum					0.1	11	0.7	20		
Hieracium cynoglossoides					0.1	12	0.7	40		
Silene oregana						3		3		
Arnica fulgens						4			0.3	7
Antennaria racemosa					0.1	3				
Agoseris heterophylla					0.1	4				
Arabis divaricarpa					0.1	1				
Castilleja miniata					0.2	7				
Crepis spp.					0.2	3				
Erigeron linearis					1.1	29				
Haplopappus carthamoides						1				
Linanthus harknessii					0.6	50				
Madia glomerata					0.9	41				
Potentilla fruticosa					0.1	5				
Phacelia sericea					0.1	5				
Zigadenus paniculatus					0.3	15				
Arnica cordifolia							3.0	7	6.8	90
Erythronium grandiflorum							0.7	47	0.7	40
Epilobium angustifolium							0	7	0.5	20
Frasera speciosa							1.5	23	1.0	13
Pedicularis racemosa								10		3
Lomatium triternatum								17		3
Potentilla arguta							0.3	3		
Luina nardosmia									0.2	3
Osmorhiza chilensis										[1]P
Chimaphila umbellata										[1]P
Arenaria macrophylla									0.7	10
Pachistima myrsinites										[1]P
Total forbs and halfshrubs	10.9		22.5		23.7		20.2		12.4	
Total all classes	19.9		28.5		45.3		75.3		44.9	

[1] Present in the community but not found in any plot.

Figure 4.--*The Artemisia/ Poa/Sedum* community on the north rim of Meeks Table.

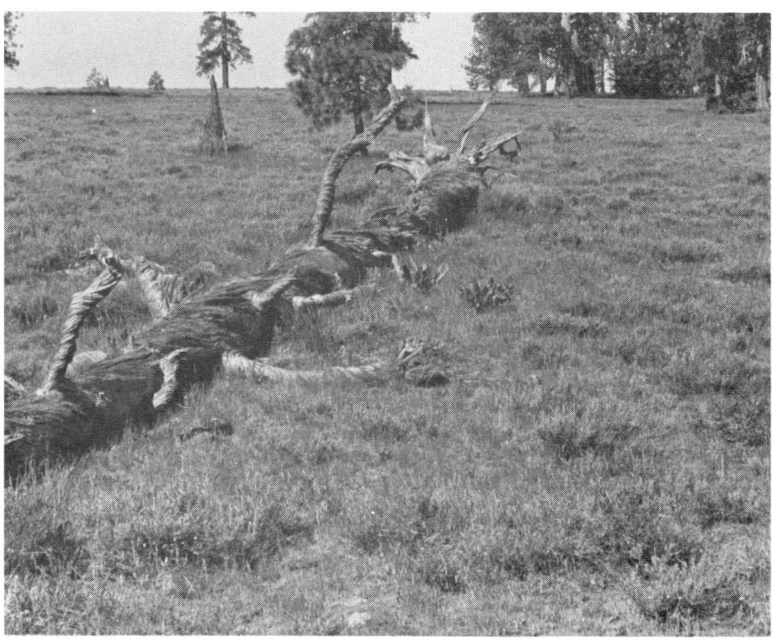

Figure 5.--The *Artemisia/ Stipa/Phlox* community occupies large openings between forested areas.

The *Pinus ponderosa/Calamagrostis rubescens/Lupinus laxiflorus* community occupies 7 ha and has a density of 192 trees per ha (fig. 6). Cover of the overstory averages 26 percent but is as great as 70 percent in places. Density of *P. ponderosa* ranged from 30 to 50 trees per ha among the size classes from 1 to 80-cm d.b.h. (fig.7). Density of trees greater than 80 cm dropped sharply. *Pseudotsuga menziesii* represents less than 10 percent of the total tree density in this community.

Figure 6.--Savannah-like appearance of the Pinus/ Calamagrostis/Lupinus community.

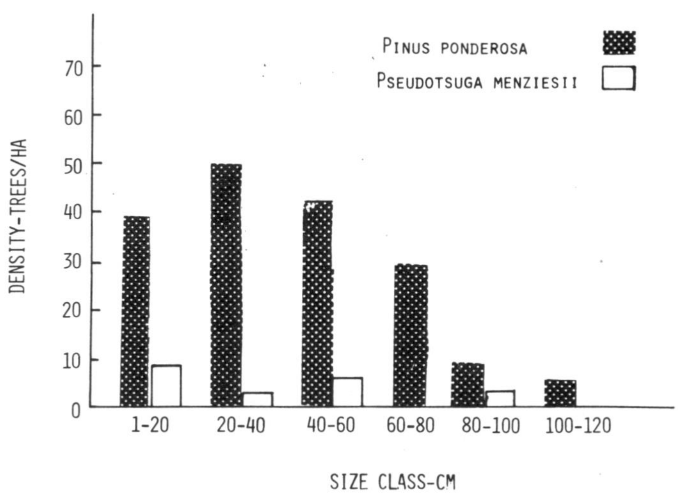

Figure 7.--Density of tree species by size class in the Pinus/Calamagrostis/ Lupinus community.

Reproduction in this community was sparse for both species, but especially for *P. menziesii*, as shown by densities in the 1- to 20-cm class.

Cover of understory vegetation is 75 percent and clearly dominated by *C. rubescens* (43-percent cover) and *Carex geyeri* (11-percent cover). These two species comprise two-thirds of the understory cover. *Calamagrostis rubescens* frequency was 100 percent. *Lupinus laxiflorus* is the most abundant forb.

The *Abies grandis/Calamagrostis rubescens/Arnica cordifolia* community is strikingly different from the *Pinus/Calamagrostis/Lupinus* community in composition and cover of both overstory and understory and in tree density (fig. 8). This community occupies 6 ha and has a tree density of 480 stems per ha (fig. 9). The majority of trees (293 per ha) are *P. menziesii*. *Abies grandis*, *P. ponderosa*, and *Larix occidentalis* comprise the major portion of the remaining stems. *Picea engelmannii* and *P. contorta* are minor components of the tree composition with densities of three trees per ha. Tree cover ranges from 20 to 100 percent and averages 51 percent. For this percentage of tree cover, 45-percent foliar cover of understory vegetation is surprisingly high. More than three-fourths of this cover is *C. rubescens* (19.5 percent) and *C. geyeri* (12.5 percent). *Arnica cordifolia* Hook. is the predominant forb, providing 6.8-percent cover with 90-percent frequency. We classified this community as an *Abies/Calamagrostis/Arnica* community because *A. grandis* is present and reproducing and because of the dominance of *C. rubescens* and *A. cordifolia* in the understory. This association appears to be analagous to those occurring on volcanic and ash soils in the Blue and Ochoco Mountains described by Franklin and Dyrness (1973). The community has a strong affinity for *Pseudotsuga/Abies/Calamagrostis* on ash soil described by Hall (1973) in the Blue Mountains. According to Franklin and Dyrness, any of the four common associates, *P. menziesii*, *Larix occidentalis*, *P. ponderosa*, or *P. contorta*, may dominate seral forest stands of this association.

There are some differences between our observations and those of Rummell (1951). Rummell lists only three communities because he did not measure vegetation of the south or north rims. The *Stipa occidentalis/Poa sandbergii* open grassland type he described is the same as the *Artemisia/Stipa/Phlox* community of the present study. The open *P. ponderosa*, *P. menziesii* with *C. rubescens* and *C. geyeri* understory appears to be the same as the *Abies/Calamagrostis/Arnica* community.

The most important differences between the two studies were in numbers of species encountered and amount of vegetative coverage in each community. We encountered twice as many species in the *Artemisia/Stipa/Phlox* community as Rummell. This difference can likely be attributed to time of sampling. Our sampling was in late June when bulbous vernal perennials such as *Sisyrinchium* sp. and *Fritillaria pudica* were still identifiable and annuals such as *Polygonum kelloggii*, *Cryptantha torreyana* and *Madia glomerata* were at their peak development. Rummell did not indicate time of sampling; but since he lists none of the bulbous plants and only two of the annuals, it was likely in late summer. Cover of shrubby and herbaceous vegetation was approximately double the values obtained by Rummell. Disparities in vegetative cover between the two studies are probably a result of a difference in method of measurement. Rummell used the square-foot density method from Stewart and Hutchings (1936) for plots 100 square feet in area.

The point frame method we used probably overestimated cover since we recorded all hits by a pin encountered in a path to the soil surface. Cover by this method could exceed 100 percent for any one plot. An advantage, however, is that it provides cover values for all species in a stratified shrub/grass/forb community.

Figure 8.--The Abies/ Calamagrostis/Arnica community.

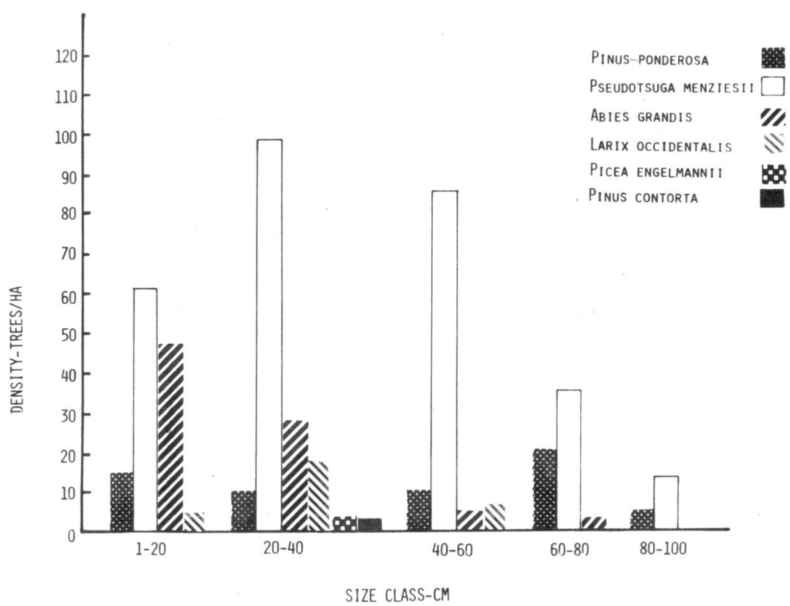

Figure 9.--Density of tree species by size class in the Abies/ Calamagrostis/Arnica community.

SOILS

As pointed out earlier, our first sample occasion showed that each of the major soil associations found on Meeks Table support different plant communities. The *Artemisia/Poa/Erigonum* and *Artemisia/Poa/Sedum* plant communities occupy the shallow rockland association which can be separated into two subassociations, S1A and S1B, respectively. The *Artemisia/Stipa/Phlox* and the *Pinus/Calamagrostis/Lupinus* plant communities are found on soil association S2 characterized by "biscuit-swale" microtopography, hereafter referred to as subassociations S2A and S2B, respectively. The *Abies/Calamagrostis/Arnica* community is found on association S3 characterized by a rather uniform moderate depth of volcanic ash.

Recent geologic history and climate have played an important part in the development of these soil associations and the subsequent vegetation composition and cover on Meeks Table. During the Miocene epoch, the table was formed by extrusive Yakima basalt flows apparently associated with the formation of the Columbia Plateau. From a soil formation standpoint, the plateau basalts are significant since the basaltic rock has quite different chemical and physical properties than granitic and other kinds of felsic rock that more typically make up the continental surface. Maific mineral constituents of basalt produce distinctive soils rich in calcium, magnesium, and iron.

During the late Salmon Springs stage of the Wisconsinan age of glaciation earlier than 10,000 to 18,000 years B.P. (Crandell and Miller 1974), the non-glaciated upper slopes of the east Cascades, including Meeks Table, appear to have been under the influence of mesic subalpine climatic conditions. Most likely, geologic denudation was very active during this period. However, soil profile examination gives evidence that small areas of soil developed earlier or during this time of subalpine climatic conditions resisted complete denudation on Meeks Table. These soil remnants are found as compact, fine-textured gley material in immediate contact with the basalt parent material.

Following the last stage of glaciation, considerable volcanic activity covered the east Cascade slopes with layers of volcanic ash and pumice. Most of the present surface microtopography of Meeks Table appears to be the result of aeolian deposition of volcanic ash. Although the primary source has not been positively identified by geochemical or petrological analyses, the ash appears to be predominantly Mount Rainier layer R, O, and C composition (Mullineaux 1974). Most of the present volcanic ash surface is covered 0.5 to 5 cm deep with the grey to white layer T or post T ash from Mount St. Helens (Okazaki 1972).

Depth and location of the present volcanic ash layer appears to be a result of wind currents and soil remnants spared by earlier denudation. Essentially no volcanic ash is present nor do we find earlier soil remnants on the wind-swept south and north rims occupied by the *Artemisia/Poa/Eriogonum* and the *Artemisia/Poa/Sedum* communities. These two plant communities are found on the same shallow rockland soil subassociations, S1A and S1B. Differences in plant cover and composition reflect differences in texture, depth, rock cover, and available moisture between the rim land on the windward side of the table as compared with the leeward side. Upslope drainage also adds to the moisture availability for the *Artemisia/Poa/Sedum* community.

The *Artemisia/Stipa/Phlox* and the *Pinus/Calamagrostis/Lupinus* communities are found on the soil association S2A and S2B characterized by "biscuit-swale" microtopography. Here the "biscuit" areas are dunes of volcanic ash and the "swale" areas are easily recognized by their rock content in the weathered basalt residuum surface. Subassociation S2B is distinguished from S2A by a significantly greater proportion of the land surface covered with dunes (biscuits) than swales. The S2A subassociation has only scattered dune areas.

The residuum surface is continuous under the volcanic ash dunes which range from a few to near 60 cm deep. Under some part of the larger dunes, however, most often the southwest side, a gritty gley material with a strongly developed blocky structure is situated between the residuum and the volcanic ash. Volcanic dune position appears to be closely related to the presence or absence of the gley material.

The plant communities found on soil subassociations S2A and S2B appear to reflect the frequency of the volcanic dunes. Although both *Pinus/Calamagrostis/Lupinus* and *Artemisia/Stipa/Phlox* communities have developed under summer drought conditions, adequate soil moisture appears to be available to support a forest community only in the area with more frequent dunes. Soil moisture utilization by the present forest community on subassociation S2B, however, appears to be sufficient to restrict conifer regeneration in this area as indicated by the sparse tree density in the 1- to 20-cm size class. The dense understory of *C. rubescens* and *C. geyeri* and the deep litter mat are factors that further limit regeneration in the *Pinus/Calamagrostis/Lupinus* community because of competition for moisture and lack of a suitable seedbed. Overland water flow during spring snowmelt has been observed in the area occupied by the *Artemisia/Stipa/Phlox* community and small drainage patterns are developing. Evidence of overland flow has not been observed elsewhere on the table.

Soil association S3 supporting the *Abies/Calamagrostis/Arnica* community is generally characterized by a continuous volcanic ash layer 30- to 60-cm over a 10- to 30-cm gley layer, on top of the basalt residuum. It appears that soil moisture retention of this soil association is sufficient to support the plant community requiring more mesic conditions (Daubenmire 1968) than any of the other communities located on the table. With the exception of snow deposition differences due to wind patterns and interception, precipitation should be uniform across the table. Thus, the plant community on each soil association predominantly reflects the capacity of the soil to provide sufficient moisture during the droughty summer months and conform with the factors controlling vegetation patterns as pointed out by Daubenmire (1943).

Differences in soil associations described above are reflected in the soil chemical characteristics as well as their physical properties (table 3). Results of our soil analyses reinforce community distinctions based on similarity analyses of shrubby and herbaceous vegetation.

Of the plant nutrients active in biogeochemical cycling, total nitrogen, carbon, and sulfur levels in the surface 7.5 cm showed the widest spread among soil associations of any constituents studied (table 3). Total soil nitrogen was lowest in the S1A association (0.06 percent) and highest in the S2B association (0.19 percent). Total N increased significantly ($P = 0.05$) in the order S1A < S3 < S1B = S2A < S2B. The surface 7.5 cm of soil in the S2B association contained six times more total organic carbon (3.4 percent) than the S1A association (0.5 percent). Total organic carbon was significantly different ($P = 0.05$) among all communities. Both total nitrogen and total carbon values declined with depth.

Total sulfur in the surface 7.5 cm was the same in S1A and S3 (0.010 percent) but significantly lower than the other three soil associations. Total sulfur in S2A was significantly higher ($P = 0.05$) (0.019 percent) than in S2B (0.016) but

Table 3--*Summary of soil characteristics, Meeks Table*[1/]

Constituent or characteristic	Depth (cm)	Soil Association and Community				
		S1A (*Artemisia/ Poa/ Eriogonum*)	S1B (*Artemisia/ Poa/ Sedum*)	S2A (*Artemisia/ Stipa/ Phlox*)	S2B (*Pinus/ Calamagrostis/ Lupinus*)	S3 (*Abies/ Calamagrostis/ Arnica*)
Percent total nitrogen	0-7.5	0.06^{a}	0.13^{b}	0.14^{b}	0.19^{d}	0.11^{c}
	15-22.5			0.13	0.15	0.09
	30.5-38				0.12	0.07
Percent total carbon	0-7.5	0.5^{a}	1.5^{b}	1.7^{c}	3.4^{d}	2.4^{e}
	15-22.5			1.3	2.8	1.8
	30.5-38				2.2	1.4
Percent total sulfur	0-7.5	0.010^{a}	0.017^{bc}	0.019^{b}	0.016^{c}	0.010^{a}
	15-22.5			0.021	0.016	0.011
	30.5-38				0.018	0.012
pH	0-7.5	6.28^{a}	5.76^{b}	5.86^{b}	5.47^{c}	5.77^{b}
	15-22.5			5.67	5.61	5.66
	30.5-38				5.68	5.57
Cation exch. cap. me/100 g	0-7.5	14.5^{a}	16.1^{a}	20.9^{b}	27.6^{c}	22.6^{bc}
	15-22.5			23.2	29.0	24.8
	30.5-38				31.4	26.8
Exchangeable Na me/100 g	0-7.5	0.127^{a}	0.131^{a}	0.139^{a}	0.127^{a}	0.103^{b}
	15-22.5			0.155	0.130	0.123
	30.5-38				0.149	0.131
Exchangeable Ca me/100 g	0-7.5	4.70^{a}	5.17^{a}	5.78^{a}	5.74^{a}	5.84^{a}
	15-22.5			6.49	6.33	6.71
	30.5-38				6.60	6.41
Exchangeable Mg me/100 g	0-7.5	1.36^{a}	1.01^{b}	1.34^{a}	1.26^{a}	0.94^{b}
	15-22.5			1.61	1.42	1.47
	30.5-38				1.68	1.83
Exchangeable K me/100 g	0-7.5	0.41^{a}	0.46^{a}	0.51^{a}	0.94^{b}	0.89^{b}
	15-22.5			0.43	0.92	0.77
	30.5-38				0.76	0.69
Bulk density g/cm^3	0-7.5	1.5^{a}	1.4^{a}	1.3^{b}	1.0^{c}	0.9^{d}
	15-22.5			1.2	0.9	0.9
	30.5-38				1.0	0.9
Percent sand	0-7.5	50.5^{a}	50.8^{a}	46.6^{ab}	41.3^{c}	43.8^{bc}
	15-22.5			44.5	36.2	40.1
	30.5-38				37.7	35.5
Percent silt	0-7.5	38.5^{ab}	34.6^{b}	35.1^{b}	39.3^{a}	41.8^{a}
	15-22.5			35.6	41.8	41.8
	30.5-38				39.8	41.9
Percent clay	0-7.5	11.0^{a}	14.6^{b}	18.5^{c}	19.4^{c}	14.4^{b}
	15-22.5			19.9	22.0	18.1
	30.5-38				22.5	22.6
Percent available soil moisture 0.1 to 15 bars	0-7.5			11^{a}	14^{b}	13^{ab}
	15-22.5				15	11
	30.5-38				13	12

[1/] Values for communities with the same superscript letter are not significantly different at $P = 0.05$.

there were no significant differences in total sulfur between either of these and S1B. Total sulfur values, in contrast to those of total nitrogen and carbon, increased with depth.

Hydrogen ion activity (pH) of the surface 7.5 cm was significantly higher in the S1A association than any other soil association. This may be an anomalous measurement since the base saturation level for S1A is lower than the other soil associations.

Concentrations of calcium ranged from 4.7 to 5.8 me/100 g in the surface 7.5 cm of soil. Although there were some significant differences among soil associations supporting different plant communities for exchangeable magnesium and sodium, differences are probably not great enough to isolate one community from another on this basis alone. Exchangeable potassium in the surface 7.5 cm was, however, approximately twice as great in the soil association supporting the forested communities as those associations supporting the shrub-grass communities. Exchangeable potassium decreased with depth whereas concentrations of calcium, magnesium, and sodium increased.

We do not have data on total potassium concentration or the distribution of potassium in the litter layer which could help determine the reason for the difference in exchangeable potassium between forested and shrub-grass-covered soil associations. It appears that organic matter may influence this difference since exchangeable potassium trends follow those of organic carbon. Differences in soil depth and area of soil exploration by roots of different plant species may be other contributing factors.

Bulk density was closely related to the presence or absence of volcanic ash. Thus, the ash-free soils of association S1 had a density range of 1.4 to 1.5 grams per cubic centimeter while the predominantly volcanic ash soils of association S3 were about 0.9 grams per cubic centimeter. Soil texture was also influenced by the presence or absence of predominantly silt and fine sand-size volcanic ash. Soil moisture retention characteristics for each sampled depth were highly influenced by the organic matter content as well as the volcanic ash content of each association. Available soil moisture may be a misleading parameter for an assessment of the total moisture available for plant growth in S2B and S3 soils. Available soil moisture in the upper 38 cm was the same in both soils (table 3). Because of the undulating dunes resulting in a "biscuit-swale" formation, however, we conclude that there is less total volcanic ash (soil) in S2B than S3 and therefore a lower total moisture capacity for the community.

The total capital of soil nutrients also governs the potential development of vegetation on a particular soil association. The capital (kg/ha) of nutrients in the measured profile of each soil association and subassociation are presented in table 3. Total capital of nitrogen and sulfur increased in the following order of soil associations and subassociations: S1A < S1B < S3 < S2A < S2B (table 4). For nitrogen and sulfur, this order follows the apparent productivity of the various associations except association S3. A possible higher percentage of the total site nutrient capital in the biomass and litter of the *Abies/Calamagrostis/Arnica* community than in other plant communities may account for this difference.

Capitals of exchangeable Ca, Mg, and Na in S1A and S1B were similar, but only 20 to 30 percent of the amounts found in S2A, S2B, and S3. Exchangeable K capital reflected the differences in concentration among communities--S1A and S1B (180 and 189 kg/ha) and in S2B and S3 (1 048 and 1 211 kg/ha), but intermediate in S2A (576 kg/ha).

Table 4--*Total capital of nutrient constituents in soil of Meeks Table*

Constituent	Soil association and community				
	S1A (depth, 7.5 cm), *Artemisia/ Poa/ Eriogonum*	S1B (depth, 7.5 cm), *Artemisia/ Poa/ Sedum*	S2A (depth, 22.5 cm), *Artemisia/ Stipa/ Phlox*	S2B (depth, 38.0 cm), *Pinus/ Calamagrostis/ Lupinus*	S3 (depth, 38.0 cm), *Abies/ Calamagrostis/ Arnica*
	kg/ha				
Organic carbon	5,625	15,750	47,250	99,316	63,954
Total nitrogen	675	1,365	4,252	5,439	3,078
Total sulfur	113	178	614	591	338
Exchangeable Ca	1,322	1,088	3,872	4,426	4,334
Exchangeable Mg	185	128	563	624	586
Exchangeable K	180	189	579	1,211	1,048
Exchangeable Na	33	32	106	110	94

Conclusions

The array of vegetation communities observed on Meeks Table appears to be a successional response to soil formation and climatic factors. Each community appears to be near equilibrium with the dominant controlling factor, in this case soil moisture availability during the summer months. Subsequent successional stages are not immediately anticipated until there is significant stand structure alteration by fire, insects, or forest management.

Forest management alternatives which influence soil moisture relations will have an important effect on the composition of future plant communities including natural conifer regeneration on this table or other areas in the interior Pacific Northwest that have developed in a similar manner.

Information on soil nutrient levels for the east Cascades is sparse and there appears to be no characterization for any single community (or habitat type) throughout its range. Extension of information from one area such as Meeks Table to other areas should therefore be made with some caution.

Nitrogen levels in the *Pinus* community correspond to Jenny's (1930) value for 5°C MAT in a forested region whereas total N in the *Abies* community was substantially lower than Jenny's values. Our results for total N correspond closely to those reported by Geist and Strickler (1970) for similar soils and vegetation communities of the Starkey Experimental Range in eastern Oregon.

High levels of N in the *Pinus/Calamagrostis/Lupinus* community may be an indication that *Lupinus laxiflorus* plays an important role in the nitrogen economy of these plant communities. Alexander (1961) lists *Lupinus* as one of the more vigorous nitrogen fixers and cites values of N fixation in excess of 100 kg/ha/year under farm conditions with well nodulated roots and favorable meteorological conditions. Fixation rates, however, in wildland situations such as Meeks Table are probably much lower.

The importance of sulfur as a major nutrient in wildland soils has not been emphasized until recently. Tiedemann (1972) and Klock et al. (1971) have found sulfur to be limiting in both amount and availability on soils derived from ash, basalt, and mixtures of ash, pumice and granitic materials. Most total sulfur levels observed to date are at the lower end of the range reported for the United States of 0.01 to 0.06 percent (Burns 1968). Soils of Meeks Table are no exception.

The ratio of carbon to nitrogen to sulfur (C:N:S) was favorable in the three shrub-grass communities, varying from 48:5:1 to 96:8:1. In the forested communities, however, the ratio was 214:12:1 and 230:10:1 for *Abies* and *Pinus* communities, respectively. The high ratio of C:N is not uncommon in forested communities of the east Cascades (Anderson and Tiedemann 1970; Tiedemann 1972; and Geist and Strickler 1970). The C:N ratios, however, are in the critical range given by Black (1968) of 15:1 to 33:1. By this standard, which was developed for agricultural soils, high C:N ratios would affect N availability in the two forested communities of Meeks Table. The N:S ratio was in the range for optimal utilization of N by plants in all Meeks Table communities. Burns (1968) concludes that the favorable ratio for N:S is 10:1. The ratio is probably meaningless in the *Artemisia/Poa/Eriogonum* community because of the very low nitrogen and sulfur levels.

These results suggest a need to study the relationships among soil nutrient levels, soil nutrient availability, and biomass production for forest and range sites of the east Cascades. This information, along with information on soil moisture availability, is basic to an understanding of the effects of land use practices on future site productivity.

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