SOILS OF THE EASTSIDE PINE TYPE AND THEIR PROPERTIES IN RELATION TO FOREST MANAGEMENT

Dr. Paul J. Zinke

Associate Professor of Forestry,
University of California, Berkeley.

ABSTRACT

Numerous soils have been classified and mapped during the past seventy years in the eastside pine region of California. The recent soil taxonomy in the U.S. has split these still further until many soil series have similar forest management requirements. This paper has grouped these series into management units based upon degree of development on various parent materials characteristic of the region. These allow the forester to be site specific in rating the soil of an area in regard to available soil moisture storage or fertility element storage relative to site quality or various forest management constraints.

INTRODUCTION

The forester's concerns with the soils of the eastside pine type will be to the extent that they offer constraints on forest management or offer limitations to site productivity. Since the area is at the borderline between arid brushlands of the Great Basin country, and the more moist and productive timberlands to the west and north, much of this concern focuses on soil properties related to soil moisture storage, and to fertility element and organic matter storage.

SOILS OF AREA

Environmental Factors

The numerous soil series which have been mapped in the various surveys in the area, and their properties are related to the key soil forming factors. The properties of the soils in the area are determined by climate, parent rocks weathering to form the soil, the topography upon which the soils develop, and ages of the surfaces and lengths of time soil has developed upon them. The variation in the soil landscape which we see in the eastside pine country is correlated with variation in these soil forming factors.

Climate

The climatic factor, in the eastside pine region is characterized by cold wet winters and warm dry summers. Annual precipitation ranges from more than 40" per year in the higher elevations along the westside of the region, to the lower limit of rainfall for commercial timberland of about 15" per year on the eastern side of the region. Soils in the wetter areas are usually leached and immature. Those in the drier areas may be more developed; and, at the lower of rainfalls, calcium carbonate accumulations may occur in the subsoil because of lack of leaching. The long dry periods of the area accentuate the need of adequate soil moisture storage for the growing season.

Parent Material

The geologic parent materials for the soils of the eastside area are usually basic igneous lava flows (andesite and basalt) of various ages, occasional deposits of pumice, cinders, and volcanic ash, and a smaller area of granitic rocks. The basic igneous lava flow areas cover most of the region from North Lake Tahoe to Sierra Valley, and Lake Almanor to the Oregon border. However, granitic rocks occur along the eastern side of Lake Tahoe, north along the Nevada border and in eastern Plumas county. The pumice and cinder materials occur in fallout patches over the lava areas and are widespread in the Medicine Lake Highlands. Alluvial and moraine deposits occur as soil parent materials around valleys such as Sierra Valley, Honey Lake Valley, and along the Pit River Valley, and the upper Sacramento and Klamath Rivers. Localized diatomaceous earth lake deposits occur in basins and former lake beds forming typical soils on alluvial parent materials nearly white in color.

The soils derived from the basic igneous rocks tend to be finer in texture and richer in basic elements than the sandier soils derived from granitic parent materials and from moraine and alluvial deposits. However, the soils on basalt and andesite flows may also be very stony. Those derived from moraine deposits are almost always extremely stony.

Topography

The topography of the eastside pine type is usually gentle on lava flows except for steep rim-rock areas. The topography of the areas of granitic rocks is generally steeper, and thus the soils more susceptible to erosion. Basins and valleys will contain nearly flat deposits of alluvial material which are often too clayey for optimum tree growth.

Vegetation

Vegetation, in terms of the flora of the eastside region, the conifer forests, and brush and grass stands, all have had an influence on soils that have formed under them. The influence of woody vegetation is generally to concentrate organic matter and fertility in the surface horizons of the soil, compared to grass which tends to distribute organic matter and fertility to a deeper depth due to effects of root decomposition. In forests, older individual trees of various species will have different influences upon soil properties creating a mosaic of variability related to their occurrence. Thus, incense cedar, white fir, and western juniper tend to raise soil pH, while ponderosa, washoe, and Jeffrey pine tend to decrease soil pH. Brush species such as bitterbrush and ceanothus tend to increase soil nitrogen because of their symbiotic nitrogen fixing abilities. The general effect of eastside pine vegetation has been to create soils with organic matter and fertility accumulation in surface horizons, with a mosaic of local soil variability related to species of old trees on the site and intervening openings. This old mosaic of trees influence patterns persists even after timber harvest or fire.

Time of Development

The age or time of weathering of the parent material will determine the degree of development of the soil which will be apparent in more clay in the subsoil and usually a redder color with time. Usually stoniness of the soil decreases with time of development. These changes are most apparent in areas of andesite or basalt lava flows of different ages. The most recent flows may be rock land and scabland, while the older flows will have reddish-brown deep soils.

SOIL SERIES & SOIL SURVEYS

As a result of the variation in the soil forming factors in the eastside pine area, numerous soil series will be observed and many of these have been defined in the various soil surveys which been made in the area. Surveys have been made for the past seventy years in the area, and each one is useful and better than no survey. In addition, the forester may be using maps from old surveys as well as recent surveys, so all the soil series used in the years of mapping in the area need to be considered in this paper. For example, the Olympic soil series has gone through several name changes; Underwood, Patterson, to Tournquist, and subdivided into Tourn. The field soil properties still offer similar response to forest management, and constraints on site. However, these surveys do differ in the intensity of the information and its usefulness for forest management problems. The literature cited contains a list of soil surveys pertinent to the eastside pine region in California. There are others that pertain to this region from similar areas in Washington, Oregon, Idaho, and Nevada. Some of these are summarized in the joint publication on Soils of the Western U.S. by the Land Grand Universities (1964).

Generally the forester is concerned with soil properties related to the amount of storage of nutrients and water for the long growth periods of a rotation age. These properties of the site are soil depth, stoniness, degree of subsoil clay formation, and resulting infiltration drainage, and aeration characteristics. These in turn will vary with the major geologic rock and substrate categories and with the degree of soil development with time on them. Based upon this, the forester can place soils into broad groups having similar forest management requirements. These soil development categories have similar response to management practices and offer similar constraints to site productivity. Table 1 presents the soil series that have been used in the various surveys in the eastside pine region.

In Table 1, the main forest soils series that have been used in the surveys in the region have been grouped according to degree of development and parent rock. There are many other forest soils for which description and series classification have not been made and these can be placed approximately in the table. For example, a red soil that is five feet deep and developed on basalt or andesite could be located in the table as similar to Aiken or Jimerson and the properties of these soils used to characterize the unknown soil. The placement of the soils listed in Table 1 in the current Soil Taxonomy can be obtained by consulting the Index to Forest Soil Series in California prepared by Stangenberger & Mallcry (1981).

SOIL PROPERTIES

Data obtained during the various surveys and research projects conducted in the eastside pine region form the basis for the following discussion of physical and chemical properties of the soils.

Physical Properties

The physical properties of major concern to the forester in this region are those related to the ability of the soil to store moisture for the summer drought period, and related to the erodibility of the soil.

The available soil moisture storage capacities associated with soils in various degrees of development on major parent materials are shown in Table 2. Assuming a water use by a fully stocked forest of 0.1" per day, it can be seen that for shallow, stony, immature soils there may be only 20 days of growth into the summer drought period; whereas for deep well developed soils this water use period during the summer drought may extend for more than 40 days. Of course, if there is a wet summer with thunderstorms even the shallow soils may be wet at frequent enough intervals to maintain a longer growing period. These data are based upon cumulative storage calculations to standard depths from my own data and data from the California Cooperative Soil-Vegetation survey.

The forester can make an estimate of the soil moisture storage capacity using this table. For example, for an area of stony and coarse textured soils, the lower range value should be used to the depth of the soil as observed in the field (road cut exposure, or dug hole). Soil derived from moraine deposits, recent lava flows, or young granitic soils will be in this category.

The soils with higher moisture storage will be those deeper than four feet, higher in organic matter content, finer in texture, and with few rocks.

Erodibility of the soil will depend upon the aggregate stability of the soil and upon the degree of slope. The granitic soils of the area offer the greatest erosion potential because of the steepness of the slopes on which they occur, and because of their coarse grain sandy nature giving little coherence between soil particles. In addition, the sugary soils derived from rhyolitic material near Sugar Hill in the north Warner Mountains are also susceptible to erosion. The soils derived from basalt and andesite tend to have much better aggregate stability and thus will be less erodible.

Chemical Properties

The soil chemical properties are those which affect the fertility of the site. The major fertility problems of eastside pine forests are those in which organic matter content, nitrogen content, and phosphorus availability offer constraints on site productivity. Frequently this is a given of the site due to the soil forming factors and their process at the site, but it behooves the intelligent forester not to make these conditions worse. In effect, soil is the site, and it is the forester's highest priority to maintain and to improve it if possible. The maintenance of organic matter, nitrogen content, and phosphorus availability become more of a problem near the arid margins of the eastside pine belt.

The total storage of carbon (representing organic matter), and of nitrogen for some soils characteristic of the eastside pine region are shown in Table 3. Some of the soils developed on granite have the lowest carbon and nitrogen contents, such as the soil at Incline Village (Toem), and the soil at Portola; whereas the soils developed on basalt and andesite generally have higher contents of organic matter and nitrogen.

Table 1--Major forest soil series mapped in the eastside pine area of California from the Tahoe Basin north.

PARENT MATERIAL	DEGREE OF SOIL DEVELOPMENT 1 Little (Grayish) enti-inceptisols	2 Moderate (Brown-redbrn) mollisols alfisols	3 Strong (Reddish) alfi to ultisols
Andesite or Basalt	(Fordice) Gleason (Germany) Hencratt Inskip Iller Longval Lytton McCarthy Nikal Ney Sheld (Smarts) Snag Umpa Revit(Verit) Waca* Windy*	Cohasset Fugawee Jacks Jorge Olympic Sattley Sattley Tahoma Tourn Tournquist Trojan Underwood	Burney Arkright Aiken Jimmerson Sierraville
Ashes, Tuffs, Pumice	Ahart Oosen Avis Ponto Deetz Portola Forward Lapine Tourn Lamondi Cone Letterbox McCarthy	Delleker*	
Lake sediment	Britton		
Granitic Rocks	Bonta Toem Corbett Toiyabe Haypress Graylock		
Glacial Moraines outwash, till & alluvium from basic rocks	Nanny Odas Shasta Stoner Shastina Tallac	Innville Martis	
Glacial moraine from granitic rocks	Celio Meeks Elmira Mottsville Gefo	Jabu	

Parenthetical names by themselves indicate proposed series. Parenthetical name following a series named indicate former name in area. Names with asterisk are also found on volcanic mudflow breccias. Tournquist was previously Underwood, later Olympic, and Patterson in this area.

Table 2--Ranges of soil moisture stroage capacities calculated from data for soils typical of parent materials and degree of soil development for eastside pine soils. Data presented as cumulative inches storage capacity to one foot depth increments.

PARENT MATERIAL & DEPTH (inches)	DEGREE OF SOIL DEVELOPMENT 1 Range low	high	2 Range low	high	3 Range low	high
Andesite-basalt soil depth						
12"	.3	1.8	.7	1.7	1.3	1.9
24"	.7	3.0	1.7	3.3	2.3	3.6
36"	1.1	4.5	2.8	5.1	3.2	5.6
48"	2.6	7.2	3.8	7.1	4.0	7.9
Ash-cinders Soil depth						
12"	.5	1.4				
24"	1.2	2.6				
36"	1.9	2.7				
48"	2.9	2.9*				
Granite Soil depth						
12"	.7	1.0	1.3	2.6		
24"	1.3	1.6	2.2	4.7		
36"	1.9	2.3	3.1	6.7		
48"	2.5	3.0	4.3	8.7		
Stony moraine Soil depth						
12"	.5	0.8				
24"	.9	1.4				
36"	1.3	1.8				
48"	1.4	2.4				

Data are from soils typical of these parent materials and degree of development, courtesy of the California Soil Vegetation survey. Ashcinder soils only 2, Forward (highest) & Cone (lowest).

Table 3--Total carbon, and total nitrogen storages cumulated to uniform soil depths for representative eastside pine soils from granitic and basic igneous parent materials.

	Total Carbon Storage -kilograms per square meter					
	Soils from Granite			Soils from Andesite		
Soil Depth	Toem	Toem	Corbett	Burney	Tournquist	Tournquist
6"	7.1	2.5	3.4	6.7	4.4	3.1
12"	9.1	3.8	4.8	8.1	6.2	4.2
24"	10.2	6.5	6.5	10.6	8.5	5.2
36"			8.1		10.1	5.3
48"			9.6			5.4
	Total Nitrogen Storage - grams per square meter					
6"	290	65	166	193	197	89
12"	361	110	273	276	285	127
24"	441	201	426	404	415	197
36"			530		512	255
48"			633			314
Locality	Susanvl.	Incline	Portola	Burney	Ambrose	Susanvl.

For pounds per acre multiply grams per sq. meter by 8.94. Ambrose Summit is immediately northwest of Canby.

An important ovservation to make is that there is a considerable amount of the total organic matter and nitrogen of the site stored in the top foot of the soil; obviously a greater proportion in the shallower soils. This organic matter content is important in that it represents a large proportion of the water-holding capacity of sandy granitic soils.

Dickson & Crocker (1953) made one of the few studies on the development of soil properties under the influence of a forest on the mudflows from Mt. Shasta near McCloud. Data derived from their study were used to calculate total storages of carbon and nitrogen presented in Table 4. The development of these storage amounts on soils of ages varying from 27 to more than 1,200 years were evaluated. The vegetation sequence accompanying this initial invasion by bitterbrush, ponderosa pine, and incense cedar, and the eventual development of a mature ponderosa pine forest, and its break up by the 1,200 years. The data shown in Table 4 show that at the beginning of the development of the site, there was very little storage of nitrogen or carbon, and that by five hundred years, values typical of immature soils had been achieved. Presumably later increments of fertility will await the slower processes of soil mineral weathering. However, it is apparent that the forest can add a sizeable increment of organic matter and nitrogen to the soil during growth on a site in this area. The forester thus manages the major process in soil site formation.

Soil organic matter and nitrogen storage can also be expected to vary with the climatic sequences in the eastside region. This can be evaluated by analyzing soils from sampling sites representing climatic profiles across the area. Data from two such sampling sequences I have carried out are presented in Table 5. The one from Mineral to Susanville (Zinke, 1969), represented the extreme range of climate in the area, and the one from Ambrose summit toward Tulelake and Clear Lake is a smaller rainfall change and cross sections the forest and arid brushland ecotone.

Forest site quality is roughly proportional to total nitrogen storage and is represented by the following regression (Zinke, 1961):

$$\text{Height in meters (300 year tree)} = 49.4 (\log Q_N) - 90 \qquad (1)$$

Multiply by 3.28 if you want it in feet. This indicates that when your site has less than 200 grams of nitrogen to a depth of a meter, it is a poor site. Also, if one brings about a loss of nitrogen to this level, an equivalent deterioration in site quality may occur! This could be a major problem in the eastside region where many soils are already low in fertility storage at the low rainfall limit of the forest.

Phosphorus solubility in the eastside pine soils varies widely depending upon the pH of the soil in relation to the constraints of iron and calcium forming various insoluble compounds at various pH's. The soils with a greater degree of development will have a tendency to fix phosphorus as compounds with iron especially around pH's of 5.0-5.5. Solubility increases when pH is lower or higher. However, if calcium is also present in abundance, as is the case as the lower precipitation areas, than solubility of phosphorus decreases above pH's of 7.0. Manipulation of soil pH by species influence effects may alter phosphorus availability. For example, it is interesting to observe that in the eastside region, soil pH's of 7.5 or more may be obtained immediately under juniper litter in the more arid areas, while pH under pine litter will be around 5.0. Following the Plumridge and the Mears burns, I observed the soil pH under the ash near ponderosa pine to remain at 6.0 or less while away from the trees pH was 7.0 or more and tended to favor Bromus tectorum. These pH effects if too alkaline also restrict phosphorus availability if calcium is present. Fertilizing when pH is at a minimum solubility point for phosphorus may mean tieing up the fertilizer in a form unavailable to trees as demonstrated by Powers, etal (1975).

SOILS OF NONCOMMERCIAL SITES

A list of soil series and land classifications used in soil surveys of the eastside pine region which represent sites that are unsuited for forest management is shown in Table 6. Many soils in the region are unsuited for tree growth due to excessive moisture at times, due to low soil moisture storage capacity, or due to chemical and fertility limitations.

A problem peculiar to the eastside pine belt, particularly on volcanic parent materials is the occurrence of large areas of soil in basin like situations in the topography between lava flows. Here, due to heavy clay, and to drainage water

Table 4--Total Carbon kg/m^2 to a meter depth, and total nitrogen storage gm^2 to a meter depth on soils derived from Mudflows of various ages near McCloud. Shasta Soil Series. Calculated from data of Dickson & Crocker (1953).

Age of deposit (years)	27	60	205	566	1200+
Vegetation	Ba Ptr Y	Y	Y B I	Y W I B	Y I W
Carbon Storage	0.1	1.4	1.9	5.7	3.8
Nitrogen Storage	18	118	148	256	247

Vegetation: Ba, barren; Ptr, *Purshia tridentata*; Y, *Pinus ponderosa*; B, *Quercus kelloggi*; I, *Calocedrus decurrens*; W, *Abies concolor*. Oldest site was cutover in the 1920's.

Table 5--Total carbon, kgm^2, and nitrogen $gramsm^2$ to a meter depth in eastside pine soils sampled to represent two climatic sequences on andesitic parent material.

Location	Mineral	Chester	Susanville
Ann. Precip.	55"	35"	15"
Vegetation	Mixed Conifer	Mixed Conifer	Ponderosa pine
Carbon storage	29.5	16.0	5.4
Nitrogen storage	1207	685	272

Location	Ambrose Sum.	Hackamore	Mears	Timber Mtns.	Clear Lake
Ann. Precip.	20"	18"	16"	15"	12"
Vegetation	pine	pine	pine	ann. grass	brush
Carbon storage	10.0	11.7	5.0	2.8	4.5
Nitrogen storage	515	476	231	184	327

Table 6--Soils series & land types* to avoid for forest management in the eastside pine region, with footnotes for characteristics involved.

Agate 4	Correco	Lovejoy 6	Reba 1
Aldax 5	Ditchcamp 5	Marsh* 4	Reno 1
Badenaugh 4	Foster 4	Martineck 5	Saralegui 1,4
Balman 4	Galeppi 1	Millich 5	Scabland* 5
Beckwourth 4	Gerry 5	Mottsville 1,5	Shingletown 4
Bellavista 3	Glean 5	Muck* 4	Silva 5
Bieber 4	Glenbrook 5	Ormsby 4	Smithneck 1
Bidwell 3	Gould 3	Packwood 4	Stacy 1
Bunselmeier 5	Hovey	Pasquetti 4	Standish 2,3
Buntingville 4	Iron Mtn. 5	Peat* 4	Surprise 3
Canby 4	James Canyon 4	Pentz 5	Toomes 5
Calpine 4	Johnstonville 2	Pit 4	Trosi 2,6
Carson 4	Lahontan 4	Preston 4	Tuscan 5
Churchill 3	Lassen 3,6	Quincy 7	Wagontire 4,5,6
Coolbrith 4	Loyalton 4	Ramelli 4	

Reasons for avoiding: 1. Alluvial coarse textured or occ. flooding; 2. Terrace with stones or high pH; 3. Excess carbonate or high pH; 4. Poor drainage at some time of year; 5. Shallow, stony, or both; 6. Extra heavy texture or clay pan; 7. Sands subject to wind erosion low available water storage.

accumulations there may be intermittent periods of high water table and flooding which will be adverse to tree growth. These periods occur in the early spring, and often may not be observed. Nevertheless, the result is a noncommercial tree site usually with dwarf sagebrush vegetation or meadow vegetation as an indicator. The heavy soils are susceptible to cracking when they dry out, and they may also be too alkaline for tree growth.

Another type of noncommercial soil in the area is the open rocky scabland of the recent lava flows where very little soil has formed. This will be obvious to the forester. Often stone strips on slopes, and circular stone patterns form on these adverse soil sites (Masson, 1949), and serve to identify them. The Wagontire soil series as mapped by Bradshaw (1952) is readily identifiable on aerial photographs by stone circles which often elongate in an oval shape down slope. They are apparently due to frost heaving of rocks in circular patterns as the clayey soil freezes.

Soils with heavy accumulations of lime (caliche) or calcium carbonate pans (i.e. Lassen Soil Series) are also usually noncommercial for tree growth, and are best reserved for range in this area. The presence of caliche layers in the subsoil offer a restriction to the rooting of ponderosa pine, for example, and thus are a constraint on site productivity for timber production. Soil pH can be used as a quick field indicator of chemical problems. If pH's are greater than 7.0 this usually indicates problems for ponderosa pine probably due to excess bases rendering some elements unavailable, and if pH's are below 4.5, problems due to excessive leaching and possible manganese toxicities or related iron deficiencies. The usual eastside problem is related to high pH's at the arid end of the range of commercial tree species. There are numerous soil series classified in this area which offer such problems. Avoid any of the soils listed in Table 6 unless you are willing to do a lot of site preparation. Any such area could grow trees if you are willing to import soil, irrigate, and do similar costly site renovation measures.

FOREST MANAGEMENT ASPECTS OF SOIL

A major concern on the most arid of the eastside pine sites is to avoid losing the site to timber production by losing the sheltering influence and the organic matter productivity of the tree cover to the soil. In Table 3 it is apparent that a large proportion of the soil organic matter and nitrogen is contained in the surface foot of these soils. Anywhere from 50% to more than 80% of the total storage of soil carbon is contained in the top foot of the soil; while from 41% to more than 80% of the nitrogen is stored in this top foot. Thus if disturbance of any kind removes the top foot of the soil further than the rooting radius of the trees, there may be a serious removal of fertility and water storing soil organic matter. Erosion of the top foot of soil on granitic areas will bring about a similar serious loss of organic matter and nitrogen. Table 4 indicates that by 500 years of tree growth on a site the organic matter supply can be replenished by an amount of 5 kg per square meter (44,700 pounds per acre). We need to weigh the advantages of such disturbance against the potential loss of this material to the site.

In making a decision which will result in such soil removal, the forester should check areas of the same soil to which similar treatment has occurred and see whether such removal has resulted in a deleterious effect on subsequent tree growth on the site.

In dealing with the sites of the eastside region, thoughtful appraisal of local soil conditions and the responses of the forest to management practices on these soils is essential. The generalities presented here, although true for particular areas, may not always fit the situation at hand. They should be regarded as hypotheses to be given a site specific test. Hopefully, the forester will record observations, and the soil series or condition can be used as a reference for such site specific experience.

LITERATURE CITED

Bradshaw, K. 1952. Vegetation-Soil Classification & Survey. Adin Quadrangle S.W. Map + legend tables. California Soil-Vegetation Survey.

Bradshaw, K. and G. Tourtillot. 1952. Vegetation Soil Classification and Survey Bieber Quadrangel NW #16D4 Lassen County, Calif. California Coop. Soil & Vegetation Survey. Map + legend tables.

Bradshaw, K. and G. Tourtillot. 1952. Vegetation-Soil Classification and Survey. Adin Quadrangle N.E. California Soil-Vegetation Survey. Map + legend tables.

Carpenter, E. J. and R. E. Storie. 1931. Soil Survey of the Alturas Area, Calif. 54 p. 2 figs., 8 tables, 1 plate, and map insert. Report #23 U.S. Bureau of Chemistry and Soils, Soil Survey, Govt. Printing office, Washington, D.C.

Dickson, B. A. and R. L. Crocker. 1953. A chronosequence of soils and vegetation near Mt. Shasta, Calif. Parts I and II; Journal of Soil Science 4:2.

Dixon, R. G. and J. I. Mallory. 1978. Soil Vegetation Classification & Survey. Bartle Quad. S.W. #15B-3 Siskiyou County, Calif. Map + 6 legend tables.

Guernsey, J. E. 1917. Soil Survey of the Honey Lake Area, Calif. 64 p. 19 tables, 1 fig., and 4 plates. USDA Bureau of Soils.

Mallory J. I. and W. R. Powell. 1979. Soil Vegetation Map, Pondosa Quad. S.W. #15D-3 Shasta County, Calif. Map + 6 legend tables. Calif. Soil-Vegetation Survey.

Mallory, J. I., R. G. Dixon, and W. R. Powell. 1978. Soil Vegetation Map, Shasta Quadrangle S.W. #14A-3 Siskiyou County, Calif. Map + 6 legend tables. Calif. Coop. Soil-Vegetation Survey.

Mallory, J. I. and W. R. Powell. 1979. Soil Vegetation Map, Pondosa Quad. S.E. #15D-4. Shasta County, Calif. Map + 6 legend tables. Calif. Soil-Vegetation Survey.

Mallory, J. I. and W. R. Powell. 1978. Soil Vegetation Classification & Survey. Bartle Quad. S.E. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Mallory, J. I. and W. R. Powell. 1978. Soil Vegetation Survey, Shasta Quadrangle S.E. #14A-4. Map + 6 legend tables. Calif. Coop. Soil Vegetation Survey.

Mallory, J. I. and W. R. Powell. 1978. Soil Vegetation Map, Pondosa Quad. N.E. #15D-1. Shasta County, Calif. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Mallory, J. I., B. F. Smith, and W. R. Powell. 1979. Soil Vegetation Map Big Bend Quadrangle N.E. #15C-1. Siskiyou & Shasta Counties, Calif. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Mallory, J. I., R. G. Dixon, and W. R. Powell. 1978. Soil Vegetation Map, Big Bend Quad. N.E. #15C-2. Siskiyou County, Calif. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Mallory, J. I., R. G. Dixon, and W. R. Powell. 1978. Soil Vegetation Map, Shoeinhorse Mountain Quadrangle N.W. Map + 6 legend tables. Calif. Coop. Soil Veg. Survey.

Masson, P. H. 1949. Circular Soil Structures in northeastern California. pp. 61-71 in Bul. #151 State of Calif. Div. Mines Pub. of Geology of MacDoel Quadrangle by Howell Williams.

Powers, R. K., K. Isik, and P. Zinke. 1975. Adding Phosphorus to Forest Soils. Bull. of Environmental Contamination & Toxicology. 14:3 257-264.

Sketchley, H. R. 1975. Soil Survey of Sierra Valley Area, Calif., parts of Sierra, Plumas, and Lassen counties. 121 p. 29 figs., 10 tables, 17 insert maps, and general soil map. USDA Soil Conservation Service and Forest Service.

Smith B. F., J. I, Mallory, and W. R. Powell. 1978. Soil Vegetation Map Big Bend Quad. N.E. #15C-1 Siskiyou County, Calif. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Stangenberger, A. G. and J. I. Mallory. 1981. Index to Forest and Range Soil Series in Calif. 49 p. 3 tables. Calif. Dept. of Forestry, Soil-Vegetation Survey, University Calif. Dept. of Forestry. U.C. Berkeley.

Stone, C. O., J. I. Mallory, and W. R. Powell. 1979. Soil Vegetation Map, Big Bend Quad. S.E. #15C-4. Shasta County, Calif. Map + 6 legend tables. Calif. Soil Vegetation Survey.

Strahorn, A. & E. Watson. 1914. Soil Survey of the Hood River - White Salmon Area, Oregon-Washington. 45 p. Tables, figs., and color map. USDA Bureau of Soils. Washington. Govt. Printing Office. (Has original Underwood description).

Summerfield, H. & D. Bagley. 1974. Surprise Valley-Home Camp area, Calif.-Nevada. Soil Survey. 130 p. 7 tables, 2 figs., gen. soil map, and 63 map sheets.

Tourtillot, G. 1952. Vegetation-Soil Classification & Survey Adin Quad. S.E. #17C-4 Map + legend tables. Calif. Coop. Soil Vegetation Survey.

Tourtillot, G. 1953. Vegetation-Soil Survey Likely Quad. S.W. #17D-3 & #20A-2. Lassen County, Calif. Map + legend tables. Calif. Coop. Soil-Vegetation Survey.

USDA, Soil Conservation Service. 1974. Soil Survey. Tahoe Basin Area, California & Nevada. 84 p. 20 tables, IV PLates, Gen. Soil Map, legends & 11 map sheets.

Watson, E. B. 1923. Soil Survey of the Shasta Valley Area, Calif. 55 p. 24 tables, 1 fig., map insert, and 4 plates. USDA Bureau of Soils.

Watson, E. B. 1924. Soil Survey of the Big Valley, Calif. 27 p. 17 tables, 1 fig., 3 plates, and map insert. USDA Bureau of Soils.

Watson, E. B. & R. E. Storie. 1924. Soil Survey of the Bishop Area, Calif. 95 p. 3 plates, 1 fig., 10 tables, and 2 map inserts. USDA Bureau of Soils Report #3 (1928).

Western States Land-Grant Univ. & Colleges, Ag. Expt. Stations. 1964. Soils of the Western United States. 69 p. Figs., app., and 1 map Western U.S.

Zinke, P. 1969. Nitrogen Storage of several California Soil-Vegetation Systems. pp. 40-53 in Conf. Proc. Biology & Ecology of Nitrogen. Nat. Acad. of Sciences, Wash. D.C.

Zinke, P. 1961. Forest Site Quality as related to soil nitrogen content. Int. Soc. Soil Sci. Seventh Int. Cong. Proc. Comm. IV. pp. 411-418.