SYSTEMATIC CONSIDERATIONS AS INFLUENCED BY CERTAIN ECOLOGICAL FACTORS RELATED TO PLANT DISTRIBUTION ON SERPENTINE SOIL IN CENTRAL CALIFORNIA

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SYSTEMATIC CONSIDERATIONS AS INFLUENCED BY CERTAIN ECOLOGICAL FACTORS RELATED TO PLANT DISTRIBUTION ON SERPENTINE SOIL IN CENTRAL CALIFORNIA

INTRODUCTION

The serpentine soil is derived from ultrabasic rock especially rich in magnesium and iron. Serpentine rocks and soils are known to occur all over the world, and the distribution of vegetation on these soils is distinctive in contrast to the plants on non-serpentine soils in the same regions. Rocks related to serpentine are usually included in the study of vegetation on serpentine soils.

The chemical composition of serpentine is quite variable due to vast differences in weathering action. In the moist tropics and other regions of heavy rainfall most of the magnesium is leached out, whereas it is retained in areas of less precipitation (41, p.19). It is believed that chromium and nickel, which also occur excessively in serpentine soils, are toxic to plants (41, pp.1-28). The low content of molybdenum, in certain serpentine soils, has been shown recently by Walker (55, pp.473-475) to curtail normal growth of certain cultivated plants. It is in agreement with the views of most workers that chemical effects reduce the number of species of plants on serpentine soils. However, a relatively small number of mechanical analyses of the soil have been made, and it is possible that the physical nature of the soil is responsible for the reduction in number of species to a greater extent than previously expected, particularly in a region where precipitation is comparatively low.

Floras of the serpentine soil have been investigated to a great extent in Europe, North America, and recently in Japan. In North America, serpentine floras have been studied in eastern Canada, Cuba, and in a few of the eastern states and the three Pacific coast states of this country.

A preliminary investigation by the writer showed that a strikingly abnormal distribution of vegetation occurs on the serpentine soil of the Sierra Nevada, thirty-five miles east of Fresno, California (21, pp.1-41). Trees and shrubs are usually absent on the drier slopes of serpentine soil, and many species of plants, other than trees and shrubs, which are lacking on serpentine soil, are found on adjacent non-serpentine soils. There are two areas of serpentine in the foothills of the Sierra Nevada of Central California (30, pp.215-285). The larger area is located in Fresno County, with a spread of approximately thirty square miles. The other is in Tulare County (13, pp.1-118), just east of Exeter and Lindsay, with about nine square miles. This study involves a general investigation of the serpentine flora in Fresno County and a brief treatment of the one in Tulare County. Analysis of the flora; clone transplants of *Stipa pulchra* Hitch.; germination tests and seedling cultures of *Brodiaea pulchella* (Salisb.) Greene, *Lupinus benthami* Hel., and *Helianthus annuus* L. were made in this study. Voucher specimens are deposited in the Oregon State College Herbarium and duplicates in most instances are also deposited in that of Fresno State College. Chemical and physical properties of the serpentine and non-serpentine soils are compared.

REVIEW OF LITERATURE

The peculiarities of vegetation of serpentine soils were first observed by Pančič (37, p.6) in the mountains of Middle Serbia (Yugoslavia). It was not until Lämmermayr in 1926 (26, pp.369-407; 27, pp.520-539) followed with a series of papers which described the serpentine flora of the Austrian Alps that the subject was discussed in detail. Lämmermayr pointed out that serpentinomorphoses (serpentine races that show distinct morphological changes) are caused by the increased light on the serpentine areas devoid of vegetation.

Loew and May (28, pp.1-53) examined the calcium and magnesium of many soils and concluded that when the ratio of calcium to magnesium in the soil becomes less than one, the proper growth of plants is impeded. However, Vlamis and Jenny (53, p.549) proposed that the excess magnesium merely makes calcium less available for normal plant growth. In this connection, Walker (54, pp.1-103; 56, pp.264-265) prepared lots of soil that varied from 5-80 per cent calcium of the total exchangeable cation with 94-19 per cent magnesium in a complementary manner. Leaf-tissue analyses of the tomato, Lycopersicon esculentum Mill. and serpentine endemic Streptanthus glandulosus Hook. var. pulchellus (Greene) Jeps. grown on the various soils showed that the tomato plant absorbed large amounts of magnesium at low levels of calcium, whereas Streptanthus absorbed approximately half as much at the same low levels. On this basis, Walker (54, p.100; 56, p.265) hypothesized that the species endemic to serpentine are tolerant to the low calcium level so prevalent in serpentine soils, while intolerant species are unable to make the adjustment.

In addition to higher tolerance of serpentine strains to high magnesium and to low amounts of calcium, phosphorus, and potassium, Tadros (46, pp.14-23) has shown that Emmenanthe rosea (Brand) Constance, a species found only on serpentine in certain areas of the California Coast Range, was more susceptible to fungal decay than E. penduliflora Benth., a non-serpentine species, in the early seedling stage. Tadros concludes that excess or deficiency of certain soil nutrients may suppress the normal growth of micro-organisms; thus certain species have become adapted to the presence or absence of micro-organisms.

Gordon and Lipman (14, pp.291-302) proposed the idea that the low amounts of nitrogen, phosphorus, and potassium caused the infertility of serpentine soils. The growth of plants was increased by the addition of these deficient elements in California serpentine soils by Vlamis (52, pp.453-466) without changing the calcium content of the soil.

Anderson and Hubricht (3, pp.396-402) first introduced the term "introgressive hybridization" to explain the crossing of two species and the hybrids repeatedly backcrossing to either of the parent. By successive backcrossing, genes of one species may infiltrate the germ plasm of another usually because of partially sterile F_1 hybrids. The stability of the introduced genes will depend upon selection advantages or no selection disadvantages. Anderson and Hubricht were able to show that Tradescantia canaliculata Raf. introgressed into T. occidentalis (Britt.) Smyth and T. bracteata Small. The introgressive types are established in habitats with ecological niches that are intermediate between parent species.

Heiser (17, pp.1-127) crossed Helianthus annuus L. and H. bolanderi Gray ssp. exilis (Gray) Heiser in the greenhouse. H. annuus is a weed found throughout most of the United States and parts of adjacent Canada and Mexico; and H. bolanderi ssp. exilis is almost restricted to serpentine areas of California. Both species have 17 pairs of chromosomes and the hybrids have meiotic irregularities. The F_1 hybrids are highly sterile; good pollen and seeds are few. Heiser concluded from the study of field specimens and herbarium sheets that

_H_. _bolanderi_ (Gray) ssp. _bolanderi_ (Gray) Heiser, a valley weed form, is the result of hybridization of _H_. _annuus_ and _H_. _bolanderi_ ssp. _exilis_. Hybridization probably started as recently as a few hundred years ago when the American Indians introduced _H_. _annuus_ into California. The hybrid has been able to invade the valley as a weed, where it is now very common. The great variability of _H_. _bolanderi_ ssp. _bolanderi_ is due to introgressive hybridization of _H_. _annuus_ into _H_. _bolanderi_ ssp. _exilis_, and several hybrid swarms are located in central California. Heiser concluded that _H_. _bolanderi_ ssp. _bolanderi_ is the result of hybridization rather than gene mutation because hybridization is known to occur.

The serpentine flora and the problems generally relating to it as found in the Upper Tiber Valley in Tuscany were recently reported by Pichi-Sermolli (40, pp.1-378). In addition to chemical analyses the author made soil moisture and mechanical analyses, pointing out peculiar types of plant communities. Pichi-Sermolli believes that the pasture represents the most advanced communities, and that the wood community originated elsewhere in the area and not on the serpentine. Of the various ecological factors such as edaphic, microclimatic, topographic, biotic and historic, that influence the life of plants, he concluded that edaphic factors are the most important.

In dealing with the plants found only on the serpentine soil Pichi-Sermolli classified them into three groups: the typical serpentinophytes, which grow on serpentine soils only; the preferential serpentinophytes, which exist particularly on serpentine soil, but occassionally on other magnesium soils; and the serpentinicolous relics, which were widely distributed on other kinds of soil in past geological times, but are found exclusively or predominantly on serpentine at the present.

Morphological changes are brought about by the serpentine environment, and the author lists the following as the most important: stenophyllism, glabrescence, plagiotropism, nanism, greater development of the root system, and glaucescence.

A partial solution to the problem of serpentine endemism was approached through experimental taxonomy by Kruckeberg (23, pp.1-154; 24, pp.408-419; 25, pp.267-274). By using near endemic subspecies *Streptanthus glandulosus* Hook, ssp. *secundus* Morr., and S. *glandulosus* Hook. ssp. *typicus* Morr., and several species called *bodenvag* species (species which occur both on and off serpentine), Kruckeberg demonstrated that these plants can be divided into serpentine-tolerant and serpentine-intolerant races.

The same researcher also seeded identical mixtures of several non-endemic weed species and an endemic species in competition bins containing three different soils--a non-serpentine soil, a calcium-amended serpentine soil, and an unaltered serpentine soil. Germination and growth of the non-endemic (weed) species on the non-serpentine and altered serpentine soils was normal, but the serpentine-endemic species were almost absent. On the unaltered serpentine soil, the weed species were greatly stunted, and eventually died or were completely absent, while the serpentine-endemic species were normal. From this experiment Kruckeberg concluded that serpentine plants are restricted to serpentine soils due to edaphic and biotic factors.

Rune (42, pp.1-139) found 140 species of vascular plants in the forty-one ultrabasic rock areas in North Sweden, where the altitude varied from 350-1400 meters. The author states that the flora is very poor in species, for this is 25 per cent of the total number of species in the region.

Rune made no attempt to obtain a complete chemical analysis of the serpentine soil, but made analyses only for total calcium oxide content, soluble potassium and phosphates, and pH. Mechanical analyses of two serpentine soils, one with coarse material and one without, both from one locality, were made. The composition of the soil with coarse material was as follows: gravel (20-2mm.), 18.72 per cent; sand (2-0.02 mm.), 42.96 per cent; silt (0.02-0.002 mm.), 24.29 per cent; clay (0.002-0.000 mm.), 15.15 per cent. The soil without coarse material showed 30.77 and 8.80 per cent silt and clay respectively.

The author groups the plants growing on serpentines and other ultrabasic rocks as follows:

A. Serpentine-characteristic plants.

B. Serpentine-indifferent plants.

C. Serpentine-accidental plants.

Groups A and B included 17 species and varieties each, and group C contained 106 species and varieties. In group A, four new varieties endemic to serpentine are described. For each annotated list of species, its distribution outside of serpentine is given.

Rune came to the conclusion that the number of serpentinophytes is very small because all northern serpentine floras are young, caused by post-glacial differentiation as compared to serpentine areas of Southern Europe.

The method in grouping plants of serpentine soils used by Rune is not entirely new, for Pennell's (38, pp.541-584) 39, pp.520-539) study of the flora of the Conowingo Barrens of southeastern Pennsylvania grouped the plants in the following three main categories of species:

I. Those commonly found on the barrens.

A. Those quite or nearly confined to the barrens.

B. Those mainly occurring on the barrens.

II. Occasional species of the barrens, mostly straggling from surrounding flora.

III. Some prominent introduced species.

Pennell's study covered part of the many serpentine areas that occur as small isolated areas, stretching in a much-broken chain close to the coastward edge of the Piedmont Plateau from New England to North Carolina.

The most recent floristic study of the Siskiyou Mountains by Whitaker (59, pp.275-288) showed that the serpentine flora in that area is not necessarily destitute floristically. It was the serpentine that was higher in number of species (113) than the non-serpentine diorite which had only 101. These numbers were based on fifty transect samples, and where a species occurred only once or twice in the total number of transects, it was not included. The contrast was further shown by the coefficient of community ("Of the lists of 101 and 113 species, 22 are shared of a total of 192 species occurring in either or both." Therefore, the coefficient equals 100 x 22/192.), which was only 11.5 per cent. A transect diagram of vegetation patterns on serpentine and non-serpentine soils of the various slopes of the Siskiyou Mountains of southwestern Oregon indicates differences related to different soil types. The analysis of vegetation types shows that the serpentine is richer in herbs but poorer in shrubs, and particularly so in trees. Analysis by floristic areas shows that about twice as many species extend their range to the south on serpentine as on diorite and twice as many extend their range to the north on diorite as on serpentine.

Although the composition of the serpentine flora may differ from one region to another, its general characteristics are about the same in different parts of the world. Its vegetation is relatively poor in individuals as well as in species. Its "infertility" has been attributed primarily to excess magnesium and to the deficiency of nitrogen, phosphorus, and potassium. A biotic factor in the form of micro-organisms indicates that certain serpentine species are less tolerant to fungal decay than other non-serpentine species.

GEOLOGY OF THE STUDY AREAS

The serpentine area in Fresno County is situated along the western border of the central Sierra Nevada between the Kings River and the main highway from Fresno to Huntington Lake at the northern edge of the Dinuba Quadrangle. The area studied and mapped by Macdonald (30, pp.215-285), shows a single major outcrop covering approximately twenty-nine square miles and three small outcrops totaling less than 1 square mile.

The topography of the area is rugged, and the relief lies between 500 and 3,000 feet. The crests of the ridges, which are oriented primarily northwest and southeast, are sharp, and the valleys are mostly V-shaped. The region contains rocks of the Bedrock Complex and the Superjacent Series of the Sierra Nevada. The serpentine rocks, the older of the metamorphosed igneous rocks, occur here in great sills which intruded into volcanic rocks and sediments and are estimated to be 8,000 feet thick.

The sills of serpentine rocks were formed during the Late Paleozoic or Early Mesozoic eras and subsequently folded in mountain-building and metamorphosed by dynamothermal action and by the intrusion of quartz-diorite contact action. Recrystalization in various stages of the serpentine occur due to this later metamorphism. No trace of unmetamorphosed serpentine rocks is found in this area, but the least metamorphosed rocks containing minute grains of iron ore in antigorite occur near the top of Hog Mountain, about 1.7 miles southwest of Trimmer. The freshly exposed dense serpentine rock is dark-greenish gray to brownish gray, and sometimes medium green in color, which changes to reddish brown because of weathering.

The ultrabasic rock was in large part dunite originally, and the pyroxene has been altered to talc and talc-tremolite, whereas the magnesium-rich olivine is found in most of the serpentine specimens. Clinochlore, a very common constituent of the serpentines, is present in amounts from almost nil to 30 per cent of the rock. Generally speaking, the minerals that make up serpentine rocks are not many.

Alumina, in most specimens, amounts to only 2 or 3 per cent, but some rocks contain as much as 16 per cent. It is believed that the original serpentine may have contributed to the presence of alumina where the content is low, and it is possible that additional alumina was introduced in the serpentinization of the peridotite. Another explanation is that the granitic intrusions added the alumina.

Meta-gabbro, also an ultrabasic igneous rock, resembles serpentine rocks in physical appearance and has somewhat similar chemical composition. The largest area of these rocks occurs at the southwest end of Black Mountain, covering an almost circular area of three-quarters of a square mile. Two smaller areas are found within one-half mile of Piedra. The non-serpentine rocks of this area of study include hornblende biotite, quartz diorite, hornblende gabbro and diorite, meta-volcanic, and meta-sedimentary.

Fifty miles southeast, an area of approximately nine square miles of serpentine which occurs in 7 variable sizes within a radius of two and one-half miles surrounds the Yokohl Valley in Tulare County (13, pp.1-118). In every case the serpentine and meta-gabbro are adjacent to each other, and the contact between the rocks is gradational or intermingled. Sills of serpentine and meta-gabbro of Woodlake Mountain to the northwest are not mapped, due to the small and complex intrusions.

The rocks of the Tulare County region also belong to the "Bedrock Complex" of the Sierra Nevada, and were involved in the Nevadan Revolution of the Late Jurassic. The pregranitic rock, now altered to serpentine, intruded the volcanic and sedimentary rocks. Serpentine rocks originated largely from peridotite, some dunite and pyroxenite; and meta-gabbro in part from olivine gabbro.

The topography of the Yokohl Valley area is not quite as rugged as the serpentine area in eastern Fresno County, and the elevation is lower--between 500 and 2,000 feet. Bold outcrops of serpentine are not as conspicuous as in Fresno County.

CLIMATIC FACTORS

Like most parts of California, both areas have a wet and a dry season. Usually, more than seventy-five per cent of the precipitation occurs during the months between November and March, with those between May and September receiving very little or no rain. The higher ridges occasionally have snow. In the summer months, the influence of the desiccating northwesterly winds from the Great Interior Valley is considerable. Fog is common in winter.

Piedra, at the southern end, and Auberry, eight miles to the north of the serpentine area of Fresno County were selected for their climatological data. Since there are no temperature records for Piedra, records of Friant, twenty-four miles to the northwest were substituted. In Tulare County, the serpentine area lies between Lemon Cove and Lindsay. The temperature records of the two areas did not vary much, except that Auberry, which is located at a higher elevation, had a lower temperature. Altitude is an important temperature control in the Sierra Nevada, and the daily and seasonal ranges are large. Tables I and II show climatological data (50, pp.1-393) of the two areas investigated.

Largely owing to the influence of mountains, marked differences in climate occur within short distances because of the local topography. The serpentine area of Tulare County has considerably less precipitation than Fresno. The difference is because of the lower elevation and the more gentle slopes of the serpentine area in Tulare County.

High extreme summer temperatures as found in Central California undoubtedly exclude numerous species from serpentine, because of the nature of the habitat, a fact tending to support the importance of temperature extremes in the distribution of certain species of plants (8, pp.86-103; 31, p.190; 32, pp.181-190; 47, p.374). It is the periodic extreme temperatures that determine the distribution of species rather than the mean temperatures.

TABLE I

MONTHLY AVERAGE MAXIMUM AND MINIMUM TEMPERATURE (DEGREES F.) RECORDS AT VARIOUS LOCATIONS FOR 1955

	Fresno County				Tulare County			
	Auberry 1985**		Friant Govt. Camp* 410		Lemon Cove 513		Lindsay 395	
Month	Max.	Min.	Max.	Min.	Max.	Min.	Max.	Min.
Jan.	50.2	28.3	51.1	33.0	51.4	34.1	51.0	32.7
Feb.	56.7	29.8	61.0	35.1	60.9	36.4	59.9	31.6
Mar.	63.0	34.4	68.4	38.1	69.7	41.5	69.1	35.7
Apr.	63.7	35.1	70.7	38.1	71.5	42.8	71.9	39.0
May	76.9	45.4	81.3	49.7	82.9	53.0	82.8	49.7
June	85.0	48.2	91.3	53.9	91.5	57.2	90.4	54.7
July	89.8	54.5	96.6	57.4	96.4	59.7	94.4	57.4
Aug.	97.2	61.6	102.0	61.4	100.3	61.7	98.9	60.5
Sept.	90.6	54.7	94.8	56.3	92.2	57.4	92.1	55.2
Oct.	80.0	44.7	84.1	48.9	83.1	49.1	81.8	46.7
Nov.	62.9	34.8	65.0	39.5	64.8	39.9	65.2	36.7
Dec.	53.9	37.7	57.0	43.6	56.6	43.8	57.7	43.1

* No temperature records for Piedra (Elev. 580 ft.); Friant Government Camp is 25 miles to the northwest.

** Numbers indicate elevation in feet.

TABLE II

AVERAGE MONTHLY AND ANNUAL PRECIPITATION (INCHES) RECORDS AT VARIOUS LOCATIONS

Month	Fresno County		Tulare County	
	Auberry	Piedra	Lemon Cove	Lindsay
Jan.	3.82	2.91	2.59	2.06
Feb.	5.15	3.47	2.68	2.12
Mar.	4.19	2.99	2.56	1.87
Apr.	2.04	1.53	1.44	1.01
May	.83	.42	.68	.45
June	.12	.08	.14	.11
July	.03	.03	.01	.00
Aug.	.02	.00	.02	.01
Sept.	.29	.16	.16	.08
Oct.	1.27	.83	.68	.48
Nov.	2.33	1.36	1.24	.81
Dec.	4.17	2.78	2.02	1.88
TOTALS	24.26	16.56	14.22	10.88

THE SERPENTINE SOILS

The soil derived from serpentine rocks in the Central Sierra Nevada foothills is characteristically reddish-brown, frequently brown, or occasionally gray in color. The soil mantle varies from a few to several inches, and very seldom becomes more than a foot deep. Mixed with the soil are varying amounts of sharp angular rock fragments of different sizes.

The non-serpentine soils in the area are formed primarily from rocks of hornblende gabbro, diorite, and hornblende biotite quartz diorite. The soil is deeper than serpentine, varying from several inches to three feet or more. Certain areas have large granitic boulders, and color varies from light to dark gray and the texture is usually quite coarse.

The field samples of soil for chemical and texture analyses weighed at least three kilograms and were taken from the top twelve inches, or less in the case of serpentine. The various sources of the samples are shown in Table III, and their chemical analyses in Table IV were determined by the Oregon State College Department of Soils, using its regular laboratory procedures. The pH of the soil was determined in the laboratory of the Fresno State College by the electrometric method. The texture analyses shown in Table V were made by the use of soil

TABLE III

THE VARIOUS SOURCES OF SOIL SAMPLES

Sample No.	Location*	Parent material	Soil series
55-3	Hog Mt., T.12 S. R.24 E. Sect.24, s.w. corner	serpentine	Delpiedra
55-6	Hog Mt., T.12 S. R.24 E. Sect.24, s.e. corner	serpentine	Delpiedra
55-8	Tulare Co., 3 mi. s.e. of Yokohl Valley	serpentine-alluvium	-------
55-4	Granite Ridge, T.12 S. R. 24 E. Sect.16, s.e. corner	hornblende biotite quartz diorite	Vista
55-5	Clovis, n.w. corner of Copper and Willow Aves.	granitic-alluvium	Ramona
55-7	Hog Mt., T.12 S. R.24 E. Sect.19, s.w. corner	hornblende gabbro and diorite	Tivy

* All samples from Fresno County unless otherwise specified.

screens for the coarser portion, and the finer particles were further analyzed by the hydrometer method (6, pp.225-230).

The results of the chemical analyses, Table IV, show that the exchangeable cation ratio of calcium to magnesium was less than 1.0 in both samples of serpentine soil, which is characteristic of many similar soils. As observed in two samples the ratio is low, because of the very high content of exchangeable-magnesium, and not necessarily because of the low exchangeable-calcium. Numbers 55-4 and 55-5 actually had less exchangeable-calcium, but at the same time had proportionally low quantities of exchangeable-magnesium. Number 55-8, obtained from the serpentine area in Tulare County, was thought to be serpentine; however, careful study of the area showed that it was from a contact area of serpentine and non-serpentine soils. For that reason, the sample is relatively high in magnesium, but again comparatively high in calcium, thus making the ratio still greater than 1.0.

Both serpentine samples had greater quantities of nitrogen and potassium and one sample had a greater amount of phosphorus. Although these elements were more abundant in serpentine soils, except in a single case, it is common for many soil types of various origins to be

TABLE IV

CERTAIN CHEMICAL CHARACTERISTICS OF SERPENTINE SOILS (S) COMPARED WITH NON-SERPENTINE SOILS (NS)*

Soil no.	S and/or NS	pH	% N	Milli-equivalents/100 gm. soil: P	K	Ca	Mg	Ca/Mg ratio
55-3	S	7.15	.064	.107	.639	3.8	10.7	.36
55-6	S	7.05	.117	.029	.767	3.9	14.3	.27
55-8	S & NS	7.20	.043	.019	.216	11.0	9.0	1.22
55-4	NS	6.30	.043	.063	.179	2.9	0.9	3.22
55-5	NS	6.60	.043	.029	.257	2.1	0.9	2.33
55-7	NS	7.00	.053	.063	.243	8.6	1.9	4.53

* Numbers 55-3, and 55-4 were used in transplants and seedling cultures. Clones of <u>Stipa pulchra</u> were from soil numbers 55-3, and 55-5.

TABLE V

MECHANICAL COMPOSITION OF SAME SOILS SHOWN IN TABLE III

	Per 100 gm. soil			Analyses below 2 mm. %		
Soil No.	Above 5 mm.	5-2 mm.	Below 2 mm.*	Fine gravel and sands**	Silt .05-.002 mm.	Clay <0.002 mm.
55-3	17.98	8.71	73.31	50.80	25.77	23.43
55-6	16.50	9.00	74.50	54.98	27.18	17.84
55-8	22.00	12.25	65.75	53.16	25.50	21.34
55-4	.71	6.05	93.24	83.62	11.46	4.92
55-5	.46	1.39	98.15	66.80	24.28	8.92
55-7	9.50	8.50	82.00	73.98	19.18	6.84

* The portions above 2 mm. were hand screened and those below 2 mm. were determined by the hydrometer method.

** Fine gravel, 2-1 mm.; total combined sands, 1-0.05 mm.

deficient in them. Of course, as has been observed, water or other factors may also limit proper plant growth.

Texture analyses, Table V, of the two different soil types substantiated the assumption of a rather higher content of clay and silt in the serpentine soils. The two contrasting soils used in the clone transplants and seedling cultures, serpentine (No. 55-3) and non-serpentine (No. 55-4) may be classified (29, p.48) as clay loam and sand respectively, based on the portion below 2 millimeters. However, it must be kept in mind that the serpentine soils contain varying amounts of rock fragments. The finer particles of the serpentine soil indicate a higher water-holding capacity in this portion of the soil. Tests for moisture equivalent were made by the centrifuge method, and the results were 18.7 per cent for serpentine and 5.8 per cent for the non-serpentine soil, using the portion below two millimeters. The value for serpentine soil is more than three times greater than for non-serpentine; however, it must be taken into account that the "permanent wilting percentage" for clay loam soil is higher than for sand (51, pp.285-304).

Chemical analyses and mechanical composition have shown that the serpentine soils of Fresno County are quite different from those of Northern California (24, p.410). Serpentine soils of Fresno County have greater amounts of nitrogen, phosphorus, and potassium, and have finer texture. Earlier workers (41, pp.1-28; 56, p.262) concluded that the physical properties of serpentine soil do not explain the peculiar plant distribution that this soil displays. This may be true in regions of higher precipitation, but in semi-arid regions, the physical properties of the soil may be very important.

THE SERPENTINE FLORA

The flora of serpentines on the western slope of the Central Sierra Nevada presents a great degree of contrast in vegetation to a non-serpentine flora. Rune (42, p.45) mentions that serpentine flora in North Sweden gives an impression of a high arctic or alpine flora in appearance. A somewhat similar barren situation is found on the steep upper north slopes and ridges of the serpentine mountain just east of Humphreys Station. Here, the soil is very shallow, high in rock fragments, and outcrops of rocks are common. Species of plants such as Castilleja miniata Dougl., Lomatium vaseyi C. & R., Dudleya cymosa (Lem.) Britt. & Rose, Chlorogalum pomeridianum (DC.) Kunth and Melica bulbosa Geyer are found in the spring. The warmer south and southwest slopes generally have patches of Eriophyllum heermannii (Dur.) Greene, Eschscholtzia lobbii Greene, Stipa pulchra Hitchc., Eriogonum latifolium Sm. ssp. nudum (Dougl.) Stokes, and Platystemon californicus Benth. The vegetation is quite variable, because of micro-environmental differences. Various types of vegetation respond to differences in elevation and slope. Figures 1, 2, and 3 illustrate such differences.

In Tulare County where the elevation of the serpentine area is lower and the precipitation is considerably less, trees and shrubs are almost absent

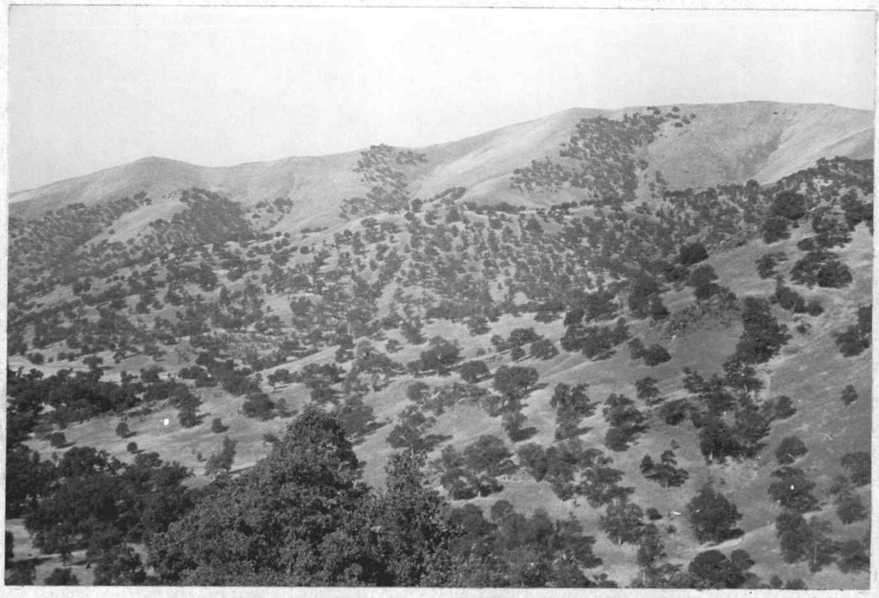

Figure 1. South end of Red Mt. looking west. Serpentine barren, except for the steeper northeast slopes with Quercus douglasii. Hills in the foreground are granitic.

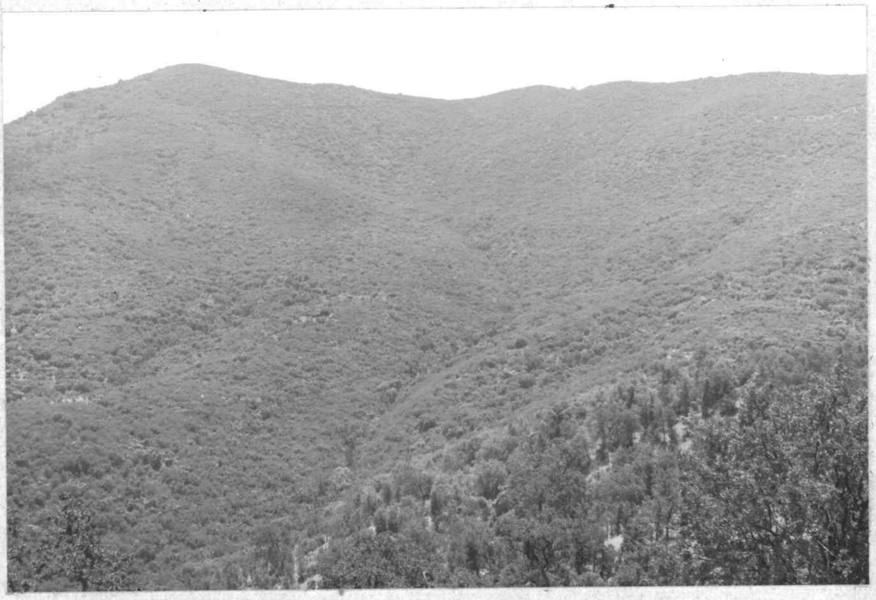

Figure 2. Southeast end of Hog Mt. with chaparral on northeast and east slopes on serpentine. Tree species on lower right are on non-serpentine.

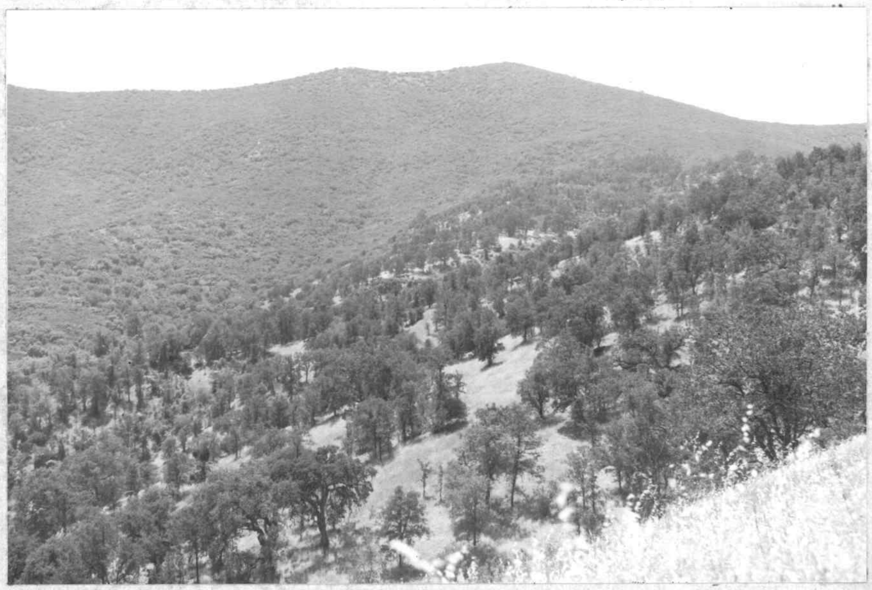

Figure 3. Extension of the picture above to the right. Trees in foreground are primarily Quercus douglasii, Pinus sabiniana along line of contact of the two different soil types.

even on north slopes. The non-serpentine soils have primarily Quercus douglasii Hook. & Arn. and Q. wislizenii A. DC., but scattered to a greater extent (Figures 4 and 5). Shrubs such as Ceanothus cuneatus (Hook.) Nutt. and Arctostaphylos mariposa Dudley are very scarce even on the north slopes of non-serpentine soils because of the drier environment.

The summer flora of the serpentine in Fresno County is limited to about a dozen species. It is dominated primarily by the tarweed, Hemizonia virgata Gray, on the south and gentler north slopes where the soil is at least a few inches deep. On the drier south slopes where the soil is very shallow and highly mixed with rock fragments H. virgata is replaced by the perennial grass, Aristida divaricata Humb. & Bonpl., which was preceded by Navarretia pubescens (Benth.) Hook. & Arn. in late spring or early summer. Hemizonia truncata Gray is primarily on the gentler north slopes, but its distribution is restricted to deeper soils. Although not entirely a summer plant, Eriogonum latifolium ssp. nudum is widely distributed on soils of varying depth, but more abundant on shallower soils and south slopes and crests of ridges. Eriogonum gracile Benth. is sometimes found in ravines, on north slopes and less frequently on south slopes. The bottoms of ravines protected from an all-day exposure to

Figure 4. Tulare Co., several miles southeast of Yokohl Valley with Quercus douglasii on non-serpentine soil; looking northwest.

Figure 5. Tulare Co., south slope of Rocky Hill. Barren serpentine on the left, and Quercus wislizenii on non-serpentine (quartz diorite).

sunlight present an ideal habitat for Lessingia leptoclada Gray. Other species with more limited distribution include Trichostema lanceolata Benth. usually on deeper soil of south slopes and Eremocarpus setigerus (Hook.) Benth. are found on disturbed soils along mine and animal trails.

Evidences are many and distinct that the climatic factor is unable to superimpose edaphic factors. In any given area the nature of variation within a given soil type presents the potential of great diversity of habitats (33, pp.209-226). Figures 6, 7, and 8 illustrate the response of vegetation on these diverse habitats. However, there is variation in the vegetational response to serpentine soils (42, pp.45-50).

The study of the south-facing road cut-banks on the southeast end of Hog Mountain shows that the species first to be established on serpentine are Melica bulbosa, Eriogonum latifolium ssp. nudum, Stephanomeria virgata Benth., Mentzelia lindleyi T. & G., and Navarretia pubescens (Figure 9). On the non-serpentine cut-bank less than one hundred yards away with similar exposure are Lotus scoparium (Nutt.) Ottley, Eriodictyon californicum (H. & A.) Greene, Pinus sabiniana Dougl., and Pentstemon laetus Gray (Figure 10). At some of the serpentine and non-serpentine contacts Pinus sabiniana

Figure 6. Upper end of the West Fork of Hughes Creek with Ceanothus cuneatus and Quercus douglasii on non-serpentine. Looking north.

Figure 7. One mile northeast of Wildcat Mt. A comparatively gentle north slope with Ceanothus cuneatus on non-serpentine. Looking west with Quercus douglasii in background.

Figure 8. South slope of the mountain a mile east of Humphreys Station. Note the *Pinus sabiniana* growing up the ravine.

Figure 9. Road cut-bank on southeast end of Hog Mt. Serpentine. The picture below is less than one hundred yards to the east.

Figure 10. Road cut-bank also on woutheast end of Hog Mt. Non-serpentine (hornblende gabbro and diorite). Established are typical Foothill Woodland Community species. On the cut-bank are primarily <u>Lotus scoparius</u> and <u>Eriodictyon californicum</u>.

appears to be the most tolerant woody species.

In order to afford a more complete understanding of the serpentine flora, the writer here presents a list of the species of vascular plants, Table VI, found on the serpentine area studied in Fresno County. The forty-eight different families are arranged according to Engler's system (12, pp.1-419). The genera and species are arranged alphabetically within their respective families. Except for a single species of *Juncus*, it was possible to identify all of the plants.

The flora of the serpentine area in Fresno County is represented by 130 different species. An analysis of the flora according to growth-forms shows only four tree species. These are *Pinus sabiniana*, *Quercus douglasii*, *Q. wislizenii*, and *Aesculus californica* (Spach) Nutt. The distribution of *Pinus* and *Aesculus* is limited to serpentine soil. Other tree species normally found on non-serpentine soil in this area are *Q. chrysolepis* Liebm., *Platanus racemosa* Nutt., and *Salix gooddingii* Ball. One half of the following shrub species are restricted to higher elevation or north and northeast slopes (21, pp.1-41): *Q. dumosa* Nutt., *Umbellularia californica* (Hook. & Arn.) Nutt., *Ribes roezlii* Regel, *Cercocarpus betuloides* Nutt., *Lupinus albifrons* Benth., *Psoralea macrostachys* DC., *Rhus diversiloba* T. & G., *Ceanothus* *duneatus*, *Rhamnus crocea* Nutt. var. *illicifolia* Greene, *Arctostaphylos mariposa*, and *Eriodictyon californicum*.

TABLE VI

LIST OF PLANTS ON SERPENTINE IN THE FOOTHILLS OF THE SIERRA NEVADA OF FRESNO COUNTY, AND THEIR CORRELATION WITH SERPENTINE

Species	Correlation* A	B	C
Cheilanthes californica (Hook.) Mett.			x
Pellaea mucronata (D.C. Eaton) D.C. Eaton		x	
Pityrogramma triangularis (Kaulf.) Maxon		x	
Azolla filiculoides Lam.			x
Selaginella hanseni Hieron.	x		
Pinus sabiniana Dougl.			x
Aristida divaricata Humb. & Bonpl.	x		
Avena barbata Brot.		x	
Bromus mollis L.		x	
Bromus rigidus Roth		x	
Bromus rubens L.		x	
Cynodon dactylon (L.) Pers.			x
Festuca pacifica Piper		x	
Hordeum brachyantherum Nevski			x

* A (serpentine-characteristic plants),
B (serpentine-indifferent plants),
C (serpentine-accidental plants).

TABLE VI--continued

Species	Correlation A	B	C
Hordeum leporinum Link			x
Melica bulbosa Geyer	x		
Muhlenbergia rigens (Benth.) Hitchc.	x		
Paspalum distichum L.			x
Poa scabrella (Thurb.) Benth.			x
Polypogon monspeliensis (L.) Desf.		x	
Sitanion jubatum J.G. Smith		x	
Stipa pulchra Hitchc.	x		
Cyperus melanostachyus H.B.K.		x	
Lemna minor L.			x
Juncus balticus Willd.		x	
Juncus sp.		x	
Brodiaea ixioides (Ait. f.) Wats.		x	
Brodiaea laxa (Benth.) S. Wats.		x	
Brodiaea pulchella (Salisb.) Greene		x	
Calochortus venustus Dougl.		x	
Chlorogalum pomeridianum (DC.) Kunth.	x		
Quercus douglasii (Hook. & Arn.)			x
Quercus dumosa Nutt.	x		
Quercus wislizenii A. DC.			x
Urtica holosericea Nutt.			x
Phoradendron villosum Nutt.		x	

TABLE VI--continued

Species	Correlation A	B	C
Chorizanthe membranacea Benth.	x		
Eriogonum gracile Benth.	x		
Eriogonum latifolium Sm. ssp. nudum (Dougl.) Stokes	x		
Polygonum punctatum Elliott		x	
Calandrinia ciliata (Ruiz & Pavon) DC. var. menziesii (Hook.) J.G. Macbride		x	
Montia perfoliata (Donn) Howell		x	
Arenaria californica (Gray) Brewer			x
Silene gallica L.			x
Delphinium decorum Fisch. & Mey. var. patens (Benth.) Gray			x
Delphinium hesperium Gray	x		
Calycanthus occidentalis Hook. & Arn.			x
Umbellularia californica (Hook. & Arn.) Nutt.			x
Eschscholtzia lobbii Greene	x		
Platystemon californicus Benth.		x	
Caulanthus coulteri S. Wats.		x	
Erysimum capitatum (Dougl.) Greene		x	
Lepidium nitidum Nutt.		x	
Rorippa nasturtium-aquaticum (L.) Schinz & Thell.		x	
Thysanocarpus curvipes Hook. var. elegans (Fisch. & Mey.) Robinson		x	

TABLE VI--continued

Species	Correlation A	B	C
Dudleya cymosa (Lem.) Britt. & Rose	x		
Lithophragma bulbifera Rydb.		x	
Saxifraga californica Greene		x	
Ribes roezlii Regel		x	
Cercocarpus betuloides Nutt.			x
Lotus humistratus Greene		x	
Lotus purshianus Clements & Clements		x	
Lupinus albifrons Benth.		x	
Lupinus benthami Hel.		x	
Lupinus nanus Dougl. ssp. latifolius (Benth.) Dunn	x		
Psoralea macrostachya DC.		x	
Trifolium albopurpureum T. & G.		x	
Trifolium ciliolatum Benth.		x	
Trifolium microcephalum Pursh		x	
Trifolium tridentatum Lindl.		x	
Erodium botrys Bertol.		x	
Erodium cicutarium L'Her.		x	
Eremocarpus setigerus (Hook.) Benth.		x	
Euphorbia ocellata Dur. & Hilg.	x		
Rhus diversiloba T. & G.		x	
Aesculus californica (Spach) Nutt.			x

TABLE VI--continued

Species	Correlation A	B	C
<u>Ceanothus</u> <u>cuneatus</u> (Hook.) Nutt.			x
<u>Rhamnus</u> <u>crocea</u> Nutt. var. <u>illicifolia</u> Greene			x
<u>Viola</u> <u>purpurea</u> Kell.		x	
<u>Mentzelia</u> <u>lindleyi</u> T. & G.	x		
<u>Clarkia</u> <u>elegans</u> Dougl.			x
<u>Godetia</u> <u>dudleyana</u> Abrams		x	
<u>Lomatium</u> <u>caruifolium</u> (T. & G.) C. & R.		x	
<u>Lomatium</u> <u>vaseyi</u> C. & R.		x	
<u>Sanicula</u> <u>bipinnatifida</u> Dougl.		x	
<u>Arctostaphylos</u> <u>mariposa</u> Dudley			x
<u>Dodecatheon</u> <u>hansenii</u> Greene		x	
<u>Asclepias</u> <u>californica</u> Greene		x	
<u>Asclepias</u> <u>eriocarpa</u> Benth.			x
<u>Convolvulus</u> <u>fulcratus</u> Greene			x
Gilia <u>capitata</u> Dougl. var. <u>achilleaefolia</u> Mason		x	
<u>Gilia</u> <u>tricolor</u> <u>Benth</u>.		x	
<u>Linanthus</u> <u>ciliatus</u> (Benth.) Greene		x	
<u>Linanthus</u> <u>montanus</u> Greene		x	
<u>Navarretia</u> <u>pubescens</u> (Benth.) Hook. & Arn.	x		
<u>Phlox</u> <u>gracilis</u> (Hook.) Greene		x	
<u>Eriodictyon</u> <u>californicum</u> (Hook. & Arn.) Greene			x

TABLE VI--continued

Species	Correlation A	Correlation B	Correlation C
Nemophila pulchella Eastw.		x	
Phacelia cicutaria Greene		x	
Amsinckia douglasiana DC.		x	
Cryptantha flaccida (Dougl.) Greene		x	
Salvia columbariae Benth.			x
Stachys albens Gray		x	
Trichostema lanceolatum Benth.		x	
Castilleia miniata Dougl.	x		
Collinsia heterophylla Buist		x	
Mimulus douglasii (Benth.) Gray			x
Mimulus guttatus Fischer		x	
Orthocarpus linearilobus Benth.		x	
Orobanche faciculata Nutt.	x		
Plantago erecta Morris	x		
Lonicera interrupta Benth.			x
Plectritis ciliosa Jep.		x	
Echinocystis fabacea Naud.		x	
Achyrachaena mollis Schauer		x	
Agoseris heterophylla (Nutt.) Greene var. crenulata Jepson		x	
Baeria chrysostoma Fisch. & Mey.		x	
Calycadenia multiglandulosa DC. var. bicolor (Greene) Keck	x		

TABLE VI--continued

Species	Correlation A	B	C
Centromadia pungens (T. & G.) Greene		x	
Chaenactis glabriuscula DC.		x	
Circium californicum Gray		x	
Eriophyllum heermannii (Dur.) Greene		x	
Gnaphalium luteo-album L.		x	
Helianthus annuus L.			x
Helianthus bolanderi Gray ssp. exilis (gray) Heiser	x		
Hemizonia truncata Gray	x		
Hemizonia virgata Gray	x		
Lessingia leptoclada Gray	x		
Stephanomeria virgata Benth.	x		
Xanthium canadense			x
TOTALS	26	73	31

Eighty-nine per cent or 115 of the total species, are herbaceous plants, of which sixty-seven species are annuals and three biennials, and forty-five species are perennials. Further analyses of the herbaceous plants show that the families best represented are the grasses and composites with sixteen species each. The legumes are well represented with ten species; other families varied from one to several.

There have been different ways of grouping plants in relation to serpentine soils (24, p.411; 38, pp.541-584; 40, p.243; 42, p.50). In the practice of the writer, rather than to introduce a new method of classification which will add further inconsistencies, the categories used by Rune (42, p.50) will be accepted here with special comments as needed.

The species growing on serpentine soil may be grouped as follows:

A. Serpentine-characteristic plants..26 species (20%).
B. Serpentine-indifferent plants.....73 species (56%).
C. Serpentine-accidental plants......31 species (24%).

In group A, there was only one species endemic to the serpentine soil: the ecotype of _Helianthus bolanderi_ Gray ssp. _exilis_ (Gray) Heiser. Another species with a unique distribution is the parasite _Orobanche fasiculata_ Nutt. predominantly on serpentine, but also found at the contact of serpentine and granitic rocks in association with _Eriodictyon californicum_. The "serpentine-accidental" _Helianthus annuus_ L. is discussed separately.

To arrive at a logical conclusion through the comparison of the different floras of serpentine soils does not seem possible, for the flora of each region varies considerably. However, comparison with the adjacent flora of non-serpentine soils does reveal that the total number of species is reduced considerably on the serpentine. Certain families or certain genera are better represented than others on serpentine. In the summer, a relatively small number of species dominate the vegatation. Some species appear to be represented by ecotypes (particular races) differing ecologically and also morphologically from the type races of the species. Many species occur very disjunctively on serpentine.

DISTRIBUTION AND POSSIBLE HYBRIDIZATION BETWEEN SPECIES OF *HELIANTHUS* L.

Helianthus bolanderi Gray ssp. *exilis* (Gray) Heiser, a foothill entity confined to serpentine outcroppings, has been collected in Siskiyou, Trinity, Humboldt, Plumas, Tehama, Mendocino, Colusa, Lake, Napa, Amador, Tuolumne, and San Luis Obispo counties (17, pp.1-127; 19, pp.157-208). The occurrence of this subspecies in Fresno County has not been reported previously, but is still not entirely surprising, inasmuch as it was found growing only on serpentine soil.

In Fresno County, a small colony of *Helianthus bolanderi* ssp. *exilis* was first found (*2916*)[1] on Hog Mountain two miles southwest of Trimmer. Subsequently, larger colonies were located one-half mile northwest of Piedra, three-fourths of a mile north of Wildcat Mountain, along the upper part of Holland Creek (Figure 11) and along much of Fish Creek (*3302*, *3306*, *3314*, *3331*). The colony was in each case either growing on the south or southwest slope where the seepage of water appears to last until late spring or middle of the summer, or in creek beds and along the creeks.

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[1]Italicized numbers indicate the collection numbers of the writer.

Since the subspecies grows primarily in the summer it appears that it has little competition with other plants and grows to a height of 9-10 feet in a rather thick colony and even provides sufficient shade to attract a deer, which was observed on one occasion (Figure 12). Where it grows along the creeks, it is shorter and scattered because of the rockiness of banks of the creeks (Figure 13).

Figure 11. Helianthus bolanderi ssp. exilis in bed of upper end of Holland Creek which is serpentine. Looking west.

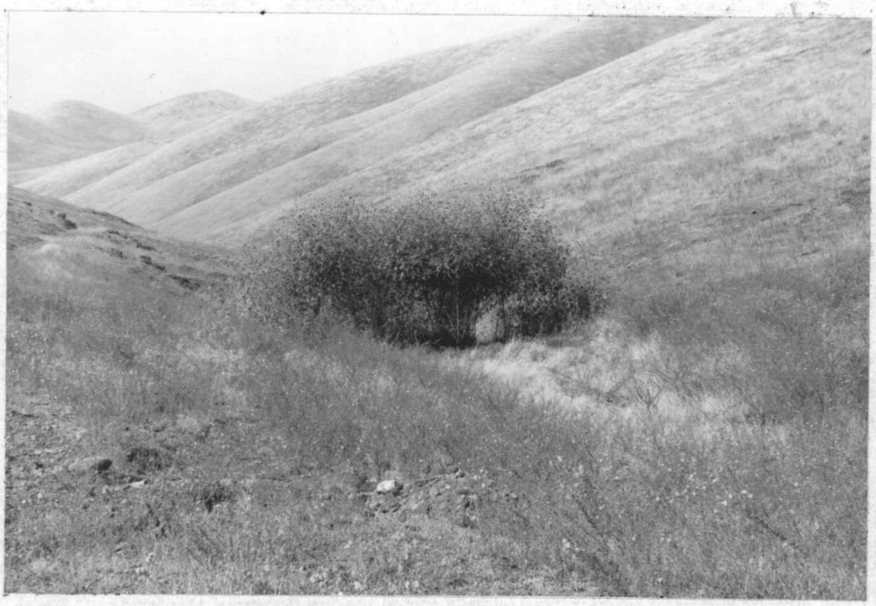

Figure 12. *Helianthus bolanderi* ssp. *exilis* on serpentine one mile northwest of Piedra. Plants blooming in foreground are *Hemizonia virgata*.

Figure 13. *Helianthus bolanderi* ssp. *exilis* on serpentine along Fish Creek. The grass along the creek is primarily *Polypogon monspeliensis*.

What appear to be hybrids (3319, 3332; Figures 14 and 15) of *H. annuus* and *H. bolanderi* ssp. *exilis* were found growing at Piedra. The location is a natural site for hybridization to occur because the valley species *H. annuus* grows along the Kings River which is deposited with non-serpentine alluvial soil, and the *H. bolanderi* ssp. *exilis* is restricted to the adjacent serpentine soil. The hybrids are easily distinguished by the shape of the involucral bracts. However, the hybrids are quite variable and "introgressive hybridization" (3, p.396) probably has occurred, although to find its direction and degree is beyond the scope and intention of this paper. Inasmuch as Heiser (17, pp.1-127; 19, pp.157-208) has investigated the hybridization of the two species, no hybridization was done by the author.

In the serpentine area of Tulare County, hybrids (3335) similar to the ones found at Piedra were located in the Yokohl Valley where the alluvial soil is highly mixed with serpentine. Although no subspecies *exilis* or *H. bolanderi* Gray ssp. *bolanderi* (Gray) Heiser was found by the investigator, Heiser (*loc. cit.*) reports the subspecies *bolanderi* to occur in Tulare County. Inasmuch as the subspecies *exilis* occurs primarily on serpentine and the subspecies *bolanderi* grows in the valley, it is possible that the hybridization is between *H. annuus* and

H. bolanderi ssp. *exilis* rather than between *H. annuus* and *H. bolanderi* ssp. *bolanderi*. There is no absolute proof, however, since no subspecies *exilis* was found thus far in the serpentine area of Tulare County.

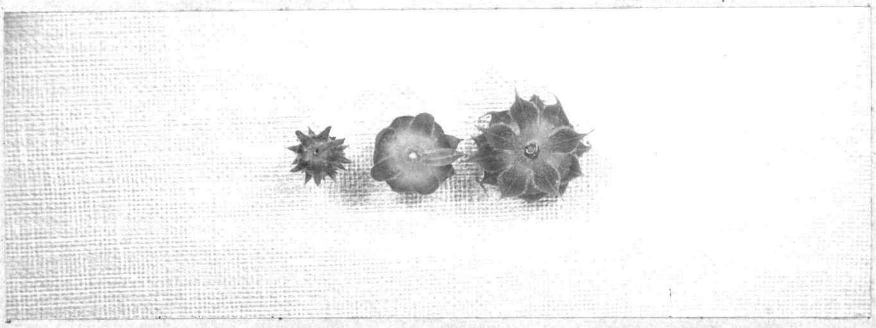

Figure 14. Shown are involucral bracts of *Helianthus bolanderi* ssp. *exilis* (left), *H. annuus* (right), and their hybrid (center). X 1/3.

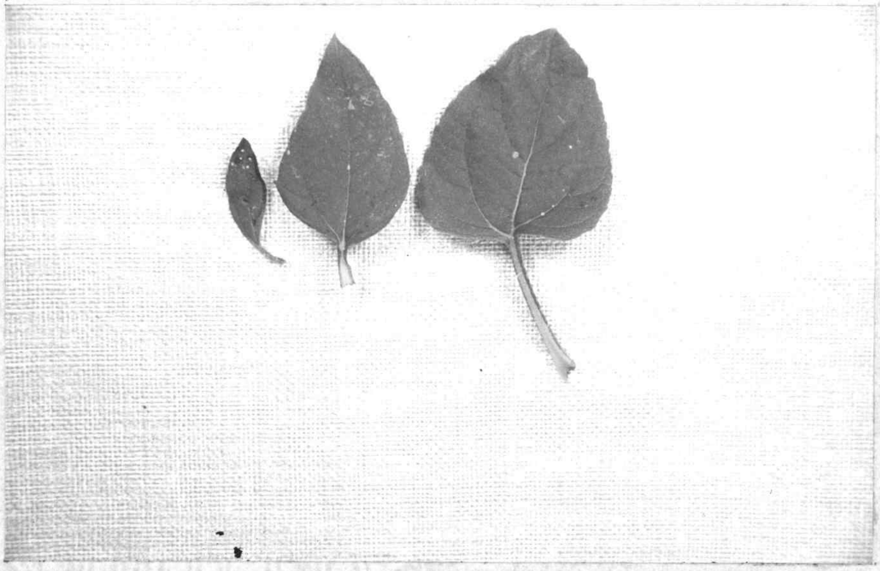

Figure 15. Leaves of *H. bolanderi* ssp. *exilis* (left), *H. annuus* (right), and their hybrid (center). X 1/3.

CLONE TRANSPLANTS OF STIPA PULCHRA HITCHC.

The use of clone transplants to test the genetic variability of a given species was introduced by Turesson (49, pp.211-350) who grew clones from various environmental sources in a uniform habitat. Later, the technique was refined by Clausen, Keck, and Hiesey (10, pp.1-452; 11, pp.1-129) and inferences drawn from the results were universally accepted.

The species selected for this particular experiment was *Stipa pulchra*, a perennial grass native to this region. It was chosen because of its availability on both serpentine and non-serpentine soils and its potential value as a range improvement species. Since *S. pulchra* does not grow in the Foothill Woodland Community except in serpentine areas the clones were obtained from two locations separated by 40 miles: those growing on serpentine from a rather steep southwest slope of Hog Mountain two miles southwest of Trimmer at an elevation of approximately 1,100 feet, and those from the non-serpentine soil from a rather level undisturbed area five miles northwest of Clovis at an elevation of about 300 feet.

The serpentine soil for the transplants was obtained from very near the place where the plants grew. The non-serpentine soil was obtained from Granite Ridge, one and one-half miles south and four and one-half miles west of Trimmer, or two miles west from where the serpentine soil was obtained. Only the top 4-6 inches of serpentine soil was available whereas the top 12 inches of the non-serpentine soil was used. Both were put in "number 10" cans previously coated inside with black asphalt paint.

Each of the fifty-five clones removed from the serpentine was equally divided to a size of one-half inch stem base, clipped to a height of two inches, and planted in the two soil types on November 27, 1955. A coin was flipped to determine which propagule (clone member) was to be planted in which soil. Similarly, each of the fifty-five clones from the non-serpentine soil was planted in the two soil types a week later and watered to field capacity with distilled water. Fifty clones from each soil type were placed out-of-doors at the Fresno State College Farm School and received no further water except natural precipitation. Five clones from each soil type were placed in the greenhouse and continued to receive distilled water sparingly until the end of the experiment.

The clone transplants of Stipa established themselves exceedingly well. There was not a single case in which both propagules died. The growth of the clones placed out-of-doors was not as much as that placed in the greenhouse. Determinations were made by using the sign method; a propagule that visually showed greater growth was indicated with a plus sign and the other propagule from the same clone showing less growth was marked with a minus sign. Twenty-six per cent of the transplants from serpentine soil grew larger on serpentine while 20 per cent of those from non-serpentine soil grew larger on serpentine. Of those placed in the greenhouse, only one out of 5, or 20 per cent, of the propagules from serpentine grew larger when transplanted back on to serpentine, and none grew larger on serpentine for those propagules from non-serpentine.

Regardless of the origin of the clones the ones transplanted on the non-serpentine soil grew much larger (Figures 16 and 17). However, the contrast in the quantity of growth between the plants on the two different soil types was greater where the clones originated from the non-serpentine soil, while the difference was slight when the clones were originally from serpentine. There was a noticeable morphological difference in the leaves of the plants from the two sources, those from the serpentine soil having broader and darker blades. The clones from non-serpentine developed inflorescences before those from serpentine soil.

Difference in the amount of growth of the root system in the two different soil types was noticed in the process of preparing the plants for preservation. The propagules in the coarser non-serpentine soil developed a greater amount of root system than those planted in the serpentine, even when the amount of growth of stems and leaves was about equal for the two soil types (3217, 3274). This result is contrary to one of the characteristics of serpentinomorphosis as described by Pichi-Sermolli (40, p.309), who declared that serpentine soil caused greater development of the root system. Mechanical analyses made by Pichi-Sermolli indicate a serpentine soil of coarser texture (*op.cit.*, p.26). Generally accepted is the fact that well drained coarser soils tend to encourage greater root development, particularly when the amount of moisture available is limited.

There are two major factors which may have caused less development of the root system in the serpentine soil in the case of clone transplants of *Stipa*. First, since both types of soil were watered to field capacity at the beginning of the experiment and the moisture equivalent of the serpentine soil was greater, clone members planted in serpentine may have had more available moisture resulting in less extensive development of the root system. Second, the finer texture of the serpentine soil, Table V, could have physically hindered the

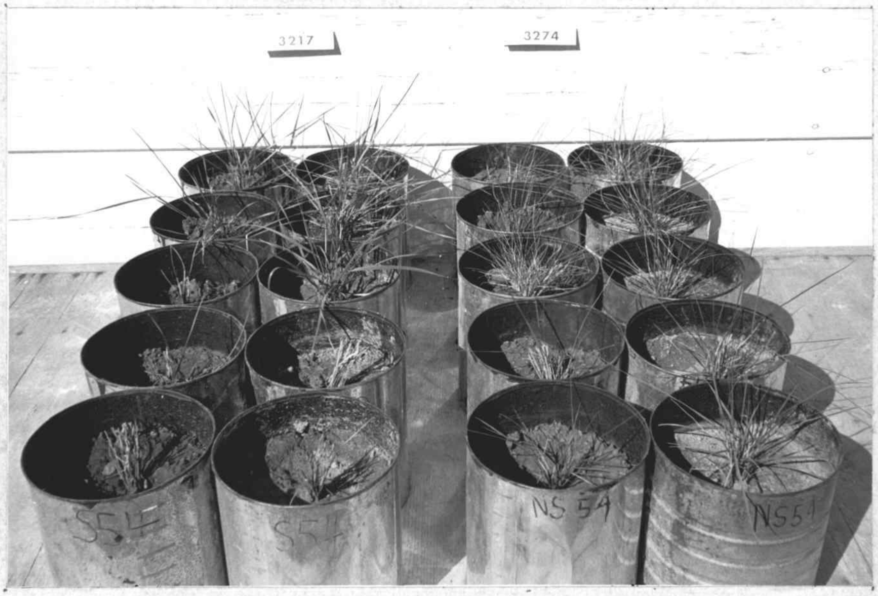

Figure 16. Stipa pulchra clone members reciprocally transplanted. Serpentine strain on the left two rows and non-serpentine strain on the right; serpentine soil on the left in each case. Grown in greenhouse, fourteen weeks after transplanting.

Figure 17. Some of the clones grown out-of-doors, brought indoors for photographing. Clones and soils arranged similar to above figure. Nineteen weeks after transplanting.

development of the root system.

The results of clone transplants indicate that there is some difference in the amount of growth between the two sources of <u>Stipa pulchra</u>, but the difference is very little. The implication here is that even though the serpentine strain produced more foliage on non-serpentine soil, the possible origin of serpentine strain from pre-existing non-serpentine populations (23, pp.1-154) is indicated. Therefore, if the species is to be used to improve the range on serpentine soil, it would be probably advantageous to use seeds of plants or clones growing on serpentine soil, since the experimental clones from serpentine were more vigorous vegetatively. Although the reciprocal transplants of <u>Stipa</u> clones on the two types of soils suggests some difference in the magnitude of serpentine tolerance, the results are not conclusive in entirety because the length of time of the experiment for a perennial species was not as long as desired and the factor of pre-conditioning of the clones differs in the two environments.

SEEDLING CULTURES, PRELIMINARY TESTS

Seeds of Helianthus annuus, Lupinus benthami, and Brodiaea pulchella were collected from plants growing on the two different soil types. The seeds were then planted on December 3, 1955 in serpentine and non-serpentine soils obtained and prepared in a manner similar to that used for the cultivating of clone transplants of Stipa. Twenty-five seeds were planted in each of H. annuus, 10 seeds of L. benthami, and fifty seeds of B. pulchella. There were five replications of each. They were placed in the greenhouse and watered sparsely with distilled water until the end of the experiment.

Helianthus annuus L.

No appreciable difference in serpentine-tolerance between the serpentine and non-serpentine strains of Helianthus bolanderi ssp. bolanderi and H. bolanderi ssp. exilis was found by Kruckeberg (23, p.103). Similar test for H. annuus had not been made, primarily because it is not known to occur on serpentine. However, on the north bank of the Kings River just below the Pine Flat Dam there is a colony of H. annuus which is on serpentine soil unmapped by Macdonald (30, p.285). The very unusual characteristic of this colony is that it blooms vigorously during the winter months as well as the rest of the year.

Whether this ability to flower in the winter is due to frost resistance of the plants or because the area is relatively free from killing frost has not been established. In any event, the plants are exceedingly vigorous (2925, 3181, 3333) and live as long as one and one-half years, developing a stem as large as three inches in diameter in some instances.

At the end of thirteen weeks the serpentine strain obtained at Pine Flat Dam was more vigorous and generally larger in each soil type than the non-serpentine strain obtained at the Fresno State College Farm School (Figure 18; 3276, 3305). The plants on the non-serpentine soil generally grew larger than those on serpentine.

The germination rate of the serpentine strain seeds was considerably lower than that of the non-serpentine strain seeds. The average number of plants for each replication on serpentine and non-serpentine soils was 3.6 and 3.2 respectively for the serpentine strain seeds. For the non-serpentine strain seeds, the average was 8.0 and 7.8 respectively for each replication of serpentine and non-serpentine soils. Whether the difference in germination affected the difference in the total growth is difficult to determine.

The preliminary results of the experiment suggest that the strain of *Helianthus annuus* growing in the Pine

Flat Dam area is more tolerant of serpentine soil than the plants grown from seeds collected at the Fresno State College Farm School. It further shows that under greenhouse conditions the non-serpentine strain is not completely intolerant of the serpentine soil, for one of them grew taller than the serpentine strain on serpentine soil.

Lupinus benthami Hel.

Seedling cultures of the *Lupinus benthami* seeds from the two different soil types showed little difference (Figure 19; 3269, 3271) between the two strains. Similar to the cultures of *Helianthus annuus*, the seedlings on the non-serpentine soil grew better than the plants on serpentine soil, regardless of seed source. The individual plants on the non-serpentine soil were quite variable in size, but the ones on serpentine were quite uniformly dwarfed.

L. benthami showed no separation into serpentine-tolerant and serpentine-intolerant strains in the preliminary tests.

Brodiaea pulchella (Salisb.) Greene

Unlike the other two species of seedlings grown, the *Brodiaea* seedlings of seeds from the serpentine soil

Figure 18. Helianthus annuus seedlings; serpentine strain on left two rows, non-serpentine strain on the right two rows. Serpentine soil on the left in each case.

Figure 19. Lupinus benthami seedlings; serpentine strain on left two rows, non-serpentine strain on the right two rows. Serpentine soil on the left in each case.

showed better growth on serpentine than on the non-serpentine soil (Figure 20; 3272). Results of this nature have not been reported previously. The number of seedlings that survived until the end of the experiment was fifty-one and 47 on serpentine and non-serpentine soils respectively. Whether the seedlings growing in the serpentine soil would continue to do better by extending the period of the test is unknown.

Unfortunately, the germination of seeds on non-serpentine was too low, seven on serpentine and 16 on non-serpentine for evaluation. It is possible that these particular seeds have a longer period of dormancy than the others used in this experiment, for some were still germinating at the end of the thirteenth week. The seeds from the two different sources were collected the same day and appeared to be equally mature, although the seeds from the non-serpentine plants were considerably smaller.

A precise conclusion cannot be drawn from this particular experiment because of the incomplete data. However, it has thrown a different light on the subject of serpentine tolerance when the Brodiaea seedlings of seeds from serpentine soil grew larger on serpentine than on non-serpentine. If any conclusion is to be drawn, one can state that certain species react differently, and it is possible that the serpentine soil is more suitable than the non-serpentine in the case of <u>Brodiaea pulchella</u>.

Figure 20. <u>Brodiaea pulchella</u> seedlings. Serpentine strain on the left two rows, non-serpentine strain on the right two rows. Serpentine soil on the left in each case. Note the greater growth on the serpentine soil of the serpentine strain.

GERMINATION TESTS AND FURTHER SEEDLING CULTURES

Helianthus annuus L.

Germination tests of *Helianthus annuus* seeds from serpentine and non-serpentine strains, Table VII, were made prior to planting in large wooden bins. Fifty seeds were used from each source. The results at temperatures prevalent for the season, September 23 to October, 1956, are shown in Table VIII.

TABLE VII

SOURCES OF HELIANTHUS ANNUUS SEEDS TESTED FOR REACTION TO SERPENTINE AND NON-SERPENTINE SOILS

Col. no.	Soil series	Location	Date
S-3339*	Delpiedra	Pine Flat Dam	Nov. 6, 1955
S-3340	Delpiedra	Pine Flat Dam	Nov. 6, 1955
S-3369	Delpiedra	Pine Flat Dam	July 4, 1956
NS-3378	Vista	1 mi. w. Pine Flat Dam	Aug. 18, 1956
NS-3379	Vista	½ mi. n. Pine Flat Resv.	Aug. 18, 1956
NS-3381	-----**	1 mi. s.e. Copper King Mine	Aug. 18, 1956

* Plants of serpentine origin are prefixed with an "S," and plants of non-serpentine with "NS."

** Non-serpentine, metavolcanic origin.

TABLE VIII

GERMINATION TEST OF <u>HELIANTHUS</u> <u>ANNUUS</u>. FALL, 1956.

Col. no.	Per cent germination
S-<u>3339</u>	6
S-<u>3340</u>	6
S-<u>3369</u>	4
NS-<u>3378</u>	6
NS-<u>3379</u>	4
NS-<u>3381</u>	4

The very low germination is not clearly understood; it could not be dormancy entirely due to time between harvest and planting for some of the seeds were collected almost 11 months prior to the test. Germination tests made later in the spring of 1957 showed increases in some of the seeds particularly after the seeds were chilled.

Also made were germination tests at the AMM Seed Testing Laboratory in Fresno at 20 degrees C. (night) and 30 degrees C. (day) during February 22 to March 21, 1957, using 100 seeds treated with Arasan. At the end of the second week, the seeds were chilled for five consecutive days and nights at 10 degrees C. and returned to temperatures prescribed above. The results of the tests are shown in Table IX below.

TABLE IX

LABORATORY GERMINATION TESTS OF HELIANTHUS ANNUUS. SPRING, 1957

Collection Number	Days counts made						Per cent and total
	4	7	10	14	21	28	
S-3339	5	5	0	0	2	6	18
S-3340	2	7	0	1	3	4	17
S-3369	0	2	0	0	0	1	3
NS-3378	0	2	6	3	7	30	48
NS-3379	0	0	0	0	1	3	4
NS-3381	0	0	0	0	0	11	11

Further germination tests were made in nursery flats containing the two different types of soils obtained from the same location as the previous year using 100 seeds from each source. Due to insufficient number of seeds the collection numbers S-3369 and NS-3378 were not used. The seeds treated with the fungicide Semesan were planted on February 23, and grown until April 5, 1957. The rate and total germination of the Heliānthus seeds are shown in Table X, and the growth of the plants in the two soil types are shown in Figures 21 and 22.

TABLE X

GERMINATION TESTS OF HELIANTHUS ANNUUS IN NURSERY FLATS. SPRING, 1957

Collection Number	Days counts made								Totals at end of	
	5	7	10	14	21	28	35	42	4 wks.	6 wks.
Serpentine Soil										
S-3339	7	4	4	0	0	0	1	0	15	16
S-3340	9	3	3	2	0	0	0	0	17	17
NS-3379	0	0	2	0	0	1	0	0	3	3
NS-3381	0	0	0	2	0	0	0	0	2	2
Non-Serpentine Soil										
S-3339	6	3	4	2	0	0	0	0	15	15
S-3340	11	5	4	1	0	1	1	0	22	23
NS-3379	0	0	0	0	1	0	0	0	1	1
NS-3381	0	0	0	1	1	0	0	1	2	3

The seeds of serpentine strain sown in both types of soils showed similar results in the laboratory tests

Figure 21. <u>Helianthus</u> <u>annuus</u> on serpentine soil. Serpentine strain on left, non-serpentine strains on right. Five weeks.

Figure 22. <u>H</u>. <u>annuus</u> on non-serpentine soil. Serpentine strain on left, non-serpentine strains on right. Five weeks.

which were run concurrently. Whereas, the seeds of non-serpentine strain were very low in germination in either type of soil, Table X indicates that most of the seeds germinated by the end of 14 days. When Tables IX and X are compared, it suggests that the chilling of the seeds increased germination, particularly of the seeds of non-serpentine strain. Since the seeds numbers S-3339 and S-3340, which are from serpentine origin, were collected in November, 1955, they were exposed to natural chilling and there was a greater length of time between harvest and planting; the others were collected during the summer of 1956 when chilling of the seeds was not probable in their natural environment and the duration of harvest to planting time was comparatively shorter. Seeds exposed to chilling during after-ripening or during germination have been known to increase germination (5, pp.428-431).

At the end of five weeks, the serpentine strains were considerably larger than the non-serpentine strains on both types of soils (Figures 21 and 22). Also, one of the serpentine strains, S-3339, grew the largest on the non-serpentine soil. The greater magnitude of difference in the amount of growth on the two types of soils is brought out in the tests made for a longer period.

Serpentine and non-serpentine soils were placed in two separate large wooden bins, $3\frac{1}{2}$ by 9 feet and $8\frac{1}{2}$

inches deep, located in a greenhouse. Planted in randomized rows (43, pp.10-13) on October 7, 1956, were 50 seeds from each source. The plants were subsequently watered with distilled water throughout the 21-week growth period ending March 3, 1957.

The seeds were very slow to germinate; there was no germination on the non-serpentine soil until the end of the fifth week and on serpentine none until the end of the sixth week. The per cent stand (number of plants divided by the number of seeds sown) at the end of 21 weeks is shown in Table XI. The total number of plants on the non-serpentine was 50 per cent greater than on the serpentine. Only a single plant from NS-3379 was lost which occurred on the non-serpentine soil. The lower per cent of germination in serpentine soil was possibly caused by the tendency of the serpentine to become drier than the non-serpentine soil in the dry atmospheric condition in the fall. While seeds sown in nursery flats during the following spring showed less difference in the per cent of germination; this was possibly due to the better germinating conditions and the use of wet burlap cloths until the end of the third day after planting when it became necessary to remove the burlaps.

Regardless of seed origin the dry weights of the largest plants and the total weights were greater for plants grown on non-serpentine soil than those grown on serpentine. On serpentine, each of the largest plants of serpentine strain weighed more than any of the plants of non-serpentine strain. With the exception of S-3339, the largest plants of serpentine strain weighed more than any of the plants of non-serpentine strain when grown on non-serpentine soil.

On serpentine soil, the height of each of the tallest plants of serpentine strain was greater than plants of non-serpentine strain. Again the tallest plant regardless of origin was on the non-serpentine soil. Although the tallest plant S-3369 on non-serpentine soil was of serpentine strain, two of the tallest plants of non-serpentine strain were taller than two of the tallest plants of serpentine strain. Figures 28-28 show the plants on the two types of soils.

It has been shown that the non-serpentine soil is more suitable for the growth of *Helianthus annuus* regardless of seed origin, and there is a tendency of plants of serpentine strain to be more vigorous than plants of non-serpentine strain on both types of soils. Height measurements and dry weights of plants grown on the two types of soils under greenhouse conditions, and field observation indicate that there is a colony of *H. annuus* at the Pine Flat Dam area which is well adapted

TABLE XI

HEIGHTS, DRY WEIGHTS, AND PER CENT STAND OF HELIANTHUS ANNUUS GROWN IN SERPENTINE AND NON-SERPENTINE SOILS CONTAINED IN LARGE WOODEN BINS

Collection Number	Tallest plant, cm.	Largest plant, gm.	Wgt. per plant, gm.	Total wgt.gm.	Total no. plants	Per cent stand
Serpentine Soil						
S-3339	18.9	0.79	0.790	0.79	1	2
S-3340	21.1	0.57	0.198	0.79	4	8
S-3369	17.3	1.39	0.385	2.31	6	12
NS-3378	10.4	0.48	0.163	1.30	8	16
NS-3379	----	----	-----	----	0	0
NS-3381	5.7	0.12	0.050	0.20	4	8
Non-Serpentine Soil						
S-3339	25.0	0.86	0.360	2.52	7	14
S-3340	44.0	5.30	1.528	12.22	8	16
S-3369	69.2	8.52	3.102	15.51	5	10
NS-3378	55.7	4.51	1.357	9.50	7	14
NS-3379	47.4	3.21	1.518	9.41	6	12
NS-3381	30.7	1.31	0.367	2.20	6	12

to serpentine soil. The isolation mechanisms operating in serpentine habitats tend to increase evolution. For many species of plants the serpentine environment is not desirable, but species that have established themselves on the serpentine usually thrive well because of the lack of competition. A number of serpentine endemics have risen in a single isolated area (33, pp.215-218). Inasmuch as *H. annuus* is an introduced species from the Great Plains

(22, p.1076), the serpentine-tolerant strain established at the Pine Flat Dam area is an "insular" biotype rather than a "depleted" biotype (44, p.244).

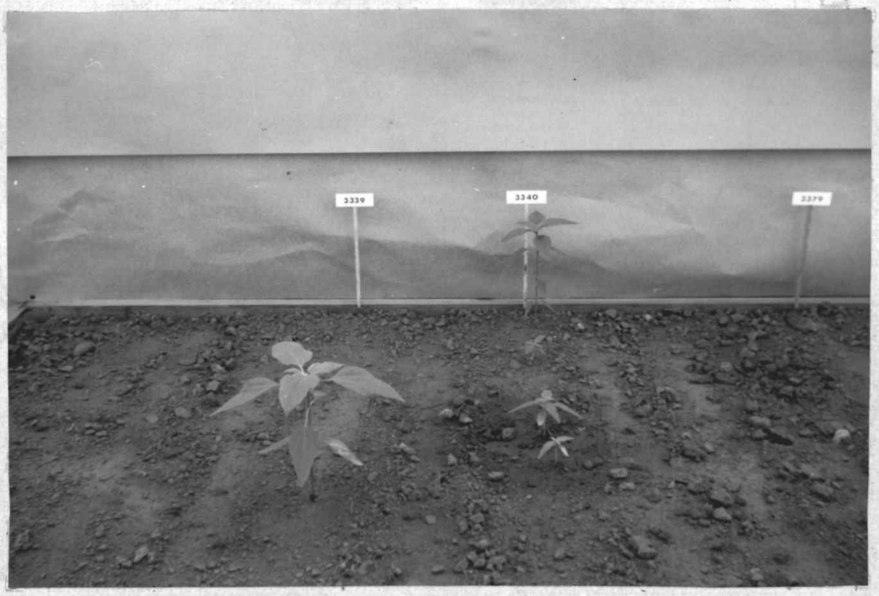

Figure 23. Serpentine strain of Helianthus annuus on the serpentine soil. Twenty-one weeks.

Figure 24. Serpentine strain of H. annuus on non-serpentine soil. Twenty-one weeks.

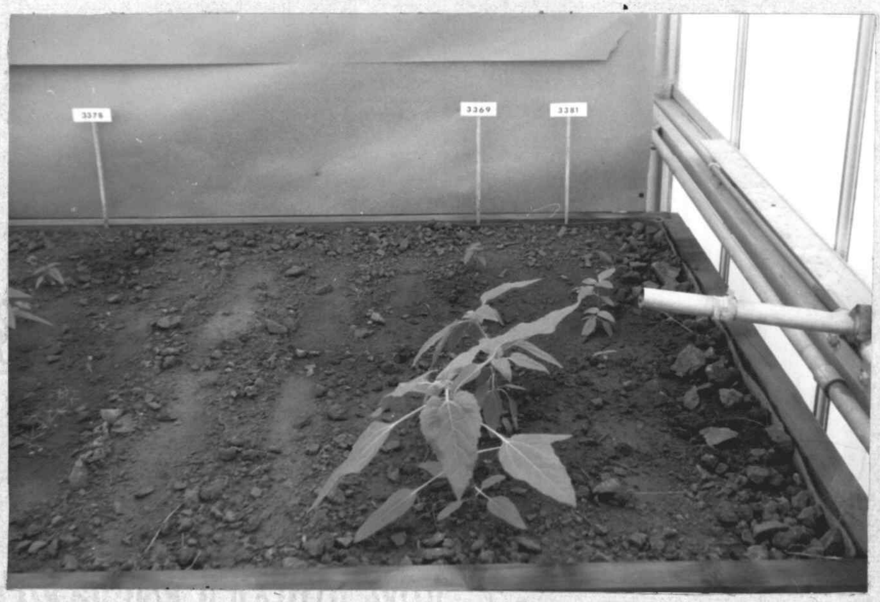

Figure 25. *Helianthus annuus* on serpentine soil. S-3369, a serpentine strain; NS-3381, a non-serpentine strain. Twenty-one weeks.

Figure 26. Non-serpentine strain of *H. annuus* on non-serpentine soil. Twenty-one weeks.

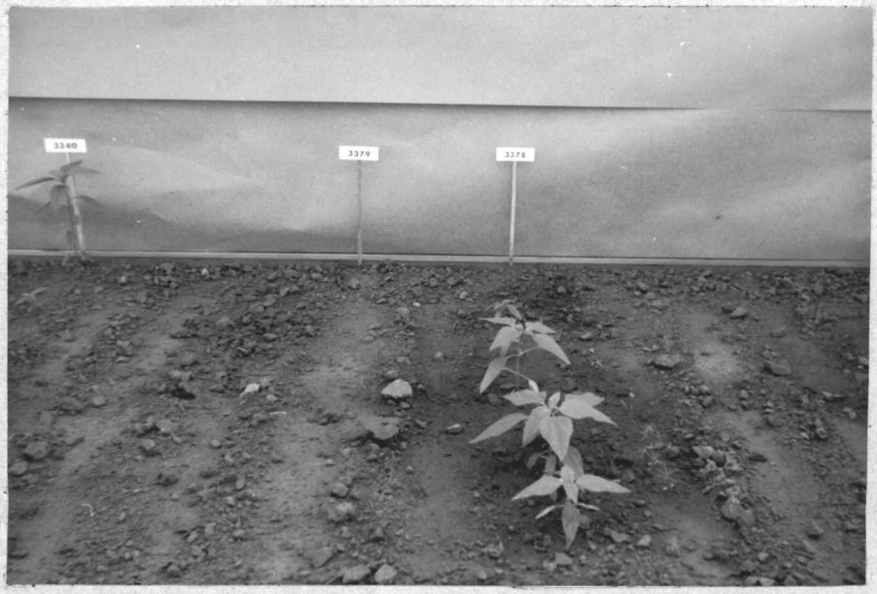

Figure 27. Non-serpentine strains of *Helianthus annuus* on serpentine soil. No germination of NS-3379. Twenty-one weeks.

Figure 28. *H. annuus* on non-serpentine soil. S-3369 is a serpentine strain; NS-3378 and NS-3379 are non-serpentine strains. 21 weeks.

Lupinus benthami Hel.

Planted similarly to Helianthus annuus in large wooden bins on October 7, 1956, were Lupinus benthami, using 50 seeds from each source, Table XII. The plants were watered also with distilled water for a period of 16 weeks ending January 26, 1957, and harvested for dry weight determinations.

TABLE XII

SOURCES OF LUPINUS BENTHAMI TESTED FOR REACTION TO SERPENTINE AND NON-SERPENTINE SOILS

Col.no.	Soil series	Location	Date
S-3350	Delpiedra	Palmer's, near Edison Flat	Apr. 19, 1956
S-3351	Delpiedra	Lombardo's Fishing Village	Apr. 19, 1956
S-3352	Delpiedra	1 mi. e. Copper King Mine	Apr. 19, 1956
NS-3346	Tivy	Edison Flat	Apr. 19, 1956
NS-3353	Vista	3/4 mi. s.e. Copper King Mine	Apr. 19, 1956
NS-3356	Vista	1 mi. w. Pine Flat Dam	Apr. 19, 1956

Germination was lower in the non-serpentine soil than in the serpentine soil with the exception of S-3352;

this is contrary to the germination tests made later in nursery flats, Table XIII. The lower germination was possibly because the seeds were not treated with a fungicide as done with those sown in flats. A total of 10 plants of serpentine strain were lost apparently due to damping-off; 8 from one seed source and one each from two other sources. Eight plants of non-serpentine strain were lost; the seeds were from a single source. All of the losses occurred on the non-serpentine soil; no plant was lost on the serpentine soil regardless of seed source. Although more plants were lost of serpentine strain than plants of non-serpentine strain, it is not sufficiently indicative that plants of non-serpentine strain are more resistant to damping-off than plants of serpentine strain. However, since no plant was lost in the serpentine soil, it suggests that the serpentine soil is a poorer medium for the growth of certain fungi (46, pp.13-23).

The differences in the amount of growth of the plants on the two types of soils are shown in Figures 29 and 30. The average oven dry weights of 3-largest plants grown on non-serpentine soil were approximately 12 and three times greater than on serpentine for plants of serpentine strains and for plants of non-serpentine strains respectively. On the non-serpentine soil, the plants of serpentine strains weighed twice as much as

TABLE XIII

DRY WEIGHT DETERMINATIONS AND PER CENT STAND OF *LUPINUS BENTHAMI* GROWN ON SERPENTINE AND NON-SERPENTINE SOILS

Collection Number	3 largest plant, gm.	Total gm.	No. Plants	Per cent Stand	No. Lost
Serpentine Soil					
S-3350	0.6	2.4	21	42	0
S-3351	1.9	4.8	34	68	0
S-3352	0.4	1.5	15	30	0
(Average)	0.97	2.9	23.3	46.7	0
NS-3346	1.7	3.9	29	58	0
NS-3353	1.8	5.7	37	74	0
NS-3356	1.7	4.1	25	50	0
(Average)	1.73	4.57	30.3	60	0
Non-Serpentine Soil					
S-3350	13.1	25.0	15	30	8
S-3351	12.9	19.1	22	44	1
S-3352	8.6	14.1	20	40	1
(Average)	11.53	19.40	19	38	3.3
NS-3346	3.9	4.9	19	38	0
NS-3353	9.8	17.2	24	48	8
NS-3356	3.2	6.2	21	42	0
(Average)	5.63	9.47	21.3	42.7	2.7

the plants of non-serpentine strains; however, on the serpentine soil, plants of serpentine strains on the average of 3-largest plants weighed half as much as the plants of non-serpentine strains.

A total of 6 plants bloomed on the non-serpentine soil; 2 each from two different serpentine sources, and 2 from a single non-serpentine source. None of the plants bloomed that were on serpentine soil. Lupinus benthami in its natural environment showed little difference in the time of blooming on the two different types of soils.

Figure 29. Lupinus benthami on serpentine soil. NS-3346, NS-3353, and NS-3356 are non-serpentine strains. S-3350 and S-3351 are serpentine strains. Sixteen weeks.

Figure 30. Lupinus benthami on non-serpentine soil. S-3350 and S-3352 are serpentine strains. NS-3353 and NS-3356 are non-serpentine strains. Sixteen weeks.

Because of the prolonged period of germination of Lupinus benthami, germination tests were conducted in the laboratory and in nursery flats using the two different types of soils. Temperature in the laboratory was 20 degrees C. and for a period of 4 weeks, the method normally used for testing ornamental varieties of lupine. The fungicide Arasan was used in the laboratory tests. The seeds treated with Semesan for germination tests in flats, located in the greenhouse, were watered with distilled water. Fifty seeds from each source were used in all of the tests.

In the laboratory tests, all of the seeds of serpentine strains showed greater germination than seeds of non-serpentine strains at the end of four weeks, Table XIV. Similar results were found with a species of Gilia by Kruckeberg (24, pp.412-413). In the flat tests, regardless of seed source the germination was greater in non-serpentine than in serpentine soil at the end of 6 weeks, which was not entirely the case at the end of 4 weeks. Figures 31-34 show the seedling cultures in flats containing the two types of soils.

TABLE XIV

GERMINATION TESTS OF LUPINUS BENTHAMI IN THE LABORATORY, AND IN SERPENTINE AND NON-SERPENTINE SOILS

Collection Number	Per cent germination				
	Lab.	Flats			
		End of 4 weeks		End of 6 weeks	
		Serp.	N-Serp.	Serp.	N-Serp.
S-3350	40	32	42	42	52
S-3351	40	22	26	22	40
S-3352	60	28	26	32	48
Average	46.7	27.3	31.3	32	46.7
NS - 3346	32	16	24	20	34
NS - 3353	26	28	16	32	34
NS - 3356	36	24	32	36	46
Average	31.3	22.7	24	29.3	38

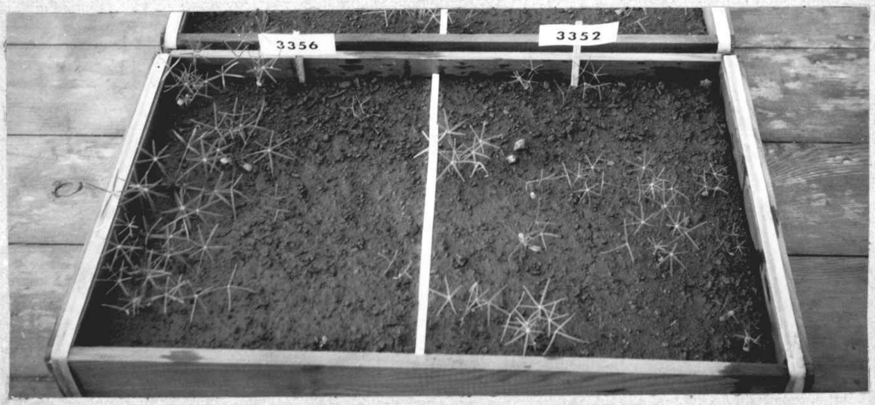

Figure 31. L. benthami on serpentine soil. Non-serpentine strain on left, serpentine strain on right. Four weeks.

Figure 32. Lupinus benthami on serpentine soil. Non-serpentine strains on left, serpentine strains on right. Six weeks.

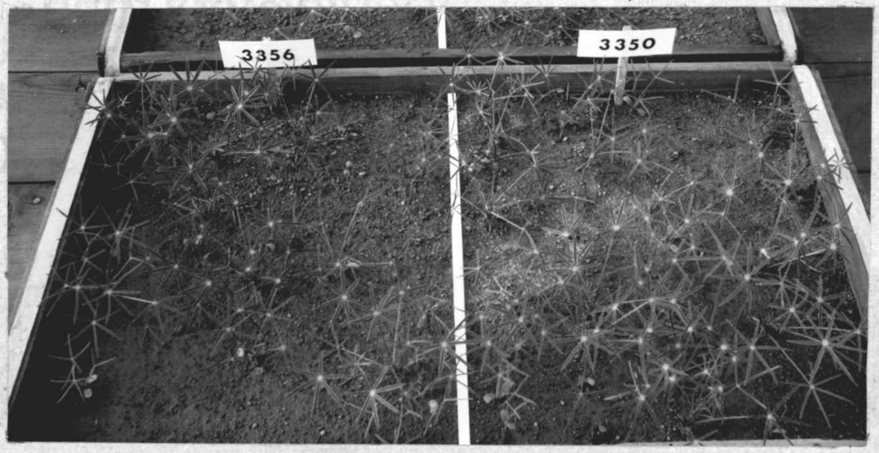

Figure 33. L. benthami on non-serpentine soil. Non-serpentine strain on left, serpentine strain on right. Six weeks.

Figure 34. Lupinus benthami on non-serpentine soil. Non-serpentine strains on left, serpentine strains on right. Six weeks.

Germination tests and seedling cultures have shown that the serpentine soil is less suitable than non-serpentine for the growth of _L. benthami_. The loss of plants was entirely on the non-serpentine soil and the low germination of seeds untreated with a fungicide planted in large wooden bins indicates that the serpentine soil is a poorer medium for the growth of micro-organisms. The development of inflorescences indicated earlier maturation of plants on the non-serpentine soil than on serpentine. Unexplained is the fact that the dry weights of the plants of serpentine strain were considerably greater than of the plants of non-serpentine strain on the non-serpentine soil, while the plants of serpentine strain performed rather poorly on their native soil type. Evidences presented show little indication of differentiation into serpentine-tolerant and serpentine-intolerant races or ecotypes of _L. benthami_.

SUMMARY

Serpentine soils are commonly rich in magnesium, iron, chromium and nickel, and low in calcium, nitrogen, phosphorus, and potassium. They are found throughout the world, and display a different distribution pattern of vegetation than do non-serpentine soils in the same regions. In addition to the effects of these chemicals, the physical properties of serpentine soil are important in a semi-arid region as found in the western slopes of the Central Sierra Nevada, where the contrast in vegetation is greatly pronounced.

The investigation involved a detailed study of the serpentine flora approximately twenty-five miles east of Fresno, California, and a general treatment of the serpentine area in the Yokohl Valley area of Tulare County to the southeast. Chemical and physical analyses of the two different types of soils, transplants of clones, germination tests, and the culture of seedlings are features of the investigation.

The unusual pattern of plant distribution on serpentine was reported as early as 1859, but it was not studied in detail until 1926. In the past several years interest in the study was renewed, particularly in Europe and in the Pacific coast states of this country, from the standpoint of taxonomy and ecology. Among the

several methods used to group the various plants of the serpentine, those of Pichi-Sermolli, Kruckeberg, Rune, and Pennell are here discussed.

The importance of the calcium:magnesium ratio was recognized by Loew and May in 1901, and the deficiencies of nitrogen, phosphorus, and potassium in most serpentine soils were reported in 1926 by Gordon and Lipman. Since 1948, various workers, primarily in California, have experimented with a number of species native to serpentine and crop plants using varying amounts of elements in which the soils were deficient.

The geology and topography of the two study areas are described. The steep and rugged mountains, varying from 500 to 3,000 feet in elevation, oriented northwest and southeast, contain sills of serpentine rocks formed during the Late Paleozoic and later involved in the Nevadan Revolution. They were for the most part originally dunite in Fresno County serpentine, and peridotite in those of Tulare County. The non-serpentine rocks of the areas are primarily hornblende biotite, quartz diorite, hornblende gabbro and diorite, and to a lesser extent meta-volcanic and meta-sedimentary.

Climatological data show that the average maximum and minimum temperatures do not vary greatly between the two sites, but the total precipitation of the area in

Fresno County varies from 16.56 to 24.26 inches, while that of Tulare County, fifty miles to the southeast, ranges from 10.88 to 14.22 inches. It is almost entirely in the form of rain during the winter months, and practically non-existent in the summer months.

The results of the chemical analyses of the six soil samples indicate that serpentine is not entirely poorer than non-serpentine. Except in one instance, the serpentine soils contained greater quantities of nitrogen, phosphorus, and potassium. Characteristically, the calcium:magnesium ratios of the serpentine soils were less than one, while those of non-serpentine were greater. The serpentine soils with many rock fragments are actually of finer texture, and they may be classified as clay loam, while non-serpentine may be grouped as sand. Moisture equivalent was 18.7 per cent for serpentine and 5.8 per cent for non-serpentine.

The vegetation on various slopes, elevations, and soil conditions is reviewed by enumerating many spring and summer species for the serpentine area in Fresno County. The serpentine area in Tulare County has very few trees, and, where they occur on non-serpentine soil, they are scattered to a greater extent than on similar soils to the northwest.

The 130 species of vascular plants on serpentine of Fresno County may be grouped, as listed in Table VI, according to Rune's method as follows: 26 species serpentine-characteristic, 73 species serpentine-indifferent, 31 species serpentine-accidental. Helianthus bolanderi ssp. exilis was the only species endemic to serpentine, and it had not been reported previously from this area. When the same species were grouped according to growth-forms, there were only four of trees, 11 of shrubs, and 115 of herbs.

The serpentine-endemic species, Helianthus bolanderi ssp. exilis, was found mostly along creeks between Piedra and Wildcat Mountain. Possible hybrids between this species and Helianthus annuus were found at Piedra, and similar hybrids were located in the Yokohl Valley to the southeast.

Clones of Stipa pulchra from two different types of soil were reciprocally transplanted back on to the two types of soil, and determinations were made by the sign method. The results appeared to indicate that the serpentine strain is somewhat better adapted to the serpentine, and propagules grown on non-serpentine soil grew larger. The contrast in the amount of growth between the clone members from the same clone on the two different types of soil was greater where the clones originated from the non-serpentine. The propagules appeared to develop greater root systems in the coarser non-serpentine soil.

In the preliminary tests, seeds of _Helianthus annuus_, _Lupinus benthami_, and _Brodiaea pulchella_ collected from plants on the two different types of soils were planted in a manner similar to clone transplants. _H. annuus_ showed possible differentiation into serpentine-tolerant and serpentine-intolerant races. The seedlings of _L. benthami_ were considerably dwarfed on the serpentine, and indicated no difference between the two strains. The germination of _B. pulchella_ seeds from non-serpentine was too low for evaluation, but unlike other species grown in this particular experiment, the seedlings grown from seeds of serpentine origin grew larger on serpentine than on non-serpentine soil.

Germination tests in the laboratory showed that _Helianthus annuus_ seeds are possibly influenced by chilling during certain period of germination. Germination tests in the two different types of soils contained in flats indicate very little difference at the end of four weeks and six weeks. However, seedling cultures in the two types of soils contained in large wooden bins grown for a period of 21 weeks resulted in higher germination on the non-serpentine than in the serpentine soil, and the amount of dry matter produced was greater by the serpentine strain on both types of soils. Under greenhouse conditions, the two strains of H. annuus showed different magnitude of serpentine tolerance.

Laboratory germination tests of Lupinus benthami showed that the serpentine strain had higher germination than the non-serpentine strain, and in flats containing the two types of soils indicated that at the end of 6 weeks germination was higher in non-serpentine soil than in serpentine soil. The amount of dry matter produced on the non-serpentine soil was considerably greater than on the serpentine, but it was not possible to differentiate the two strains into serpentine-tolerant and serpentine-intolerant races.

When compared to the adjacent non-serpentine flora the flora of the serpentine is poorer in number of species. Certain species have separated into strains that are more tolerant to serpentine, while others show no difference. The peculiarities in the distribution of vegetation on serpentine are still not fully explained. Chemical and physical analyses of the soil have added much information. Many of the problems are ecological, and a physiological approach will undoubtedly add much light to the study.

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