Soil Survey Investigations Report No. 21

A Toposequence of Soils in Tonalite Grus in the Southern California Peninsular Range

SOIL CONSERVATION SERVICE/U.S. DEPARTMENT OF AGRICULTURE

Soil Survey Investigations Report No. 21

A Toposequence of Soils in Tonalite Grus in the Southern California Peninsular Range

by Wiley D. Nettleton, Klaus W. Flach, and George Borst, *soil scientists*

Soil Conservation Service

Soil Conservation Service
Washington, D.C.

U.S. Department of Agriculture
Issued August 1968

CONTENTS

HIGHLIGHTS AND CONCLUSIONS

This bulletin reports a study of four kinds of soil in the San Luis Rey watershed of northern San Diego County, California. These soils make up a large part of the farmland of southern California. They formed in weathered intrusive igneous rock and are classified as Xerochrepts, Haploxeralfs, Natrixeralfs, and Pelloxererts. In the 1938 system (Baldwin et al., 1938) soils in the Vista, Fallbrook, and Bonsall series were considered Noncalcic Brown soils and soils in the Bosanko series were considered Grumusols.

Harradine (1936) studied the morphology and genesis of some Noncalcic Brown soils formed in secondary materials. The major pedogenic features reported are a massive A horizon, low organic-carbon content, and several degrees of profile development. Harradine believed that genesis of these soils depends on a unique two-season climatic pattern within prescribed limits of precipitation and temperature. Although the different kinds of B horizon in Noncalcic Brown soils have not been studied in detail in California, Shaw (1927) and Harradine (1950) have suggested that the degree of profile expression is determined largely by geomorphic age. Preliminary studies in San Diego County by the soil survey staff, however, indicated that soils that differ in degree of profile expression occur on parts of the landscape that do not differ greatly in geomorphic age. The four kinds of soil studied represent the range of soil profile expression in the area.

Soils in the Vista, Fallbrook, and Bonsall series are members of a toposequence in tonalite grus and were sampled in each of two transects a few hundred feet long. Because the sampling sites are of the same geomorphic age, the soil differences must result from other causes. Although soils in the Bosanko series also formed in tonalite grus and occur in the same area, we could not lay out a transect that included all four kinds of soil. We sampled Bosanko soils at a site several miles from the two transects, but we did not attempt to relate them geomorphically to the other kinds of soil.

The grain size of the grus made it possible to study the weathering products of individual minerals. Vista and Fallbrook soils, in which primarily biotites have been decomposed, represent a weathering environment of low intensity. They occur on upper and middle back slopes and are slightly leached. The major weathering products of biotite are vermiculite in Vista soils and vermiculite and kaolinite in Fallbrook soils.

Bonsall soils on foot slopes represent a weathering environment of intermediate intensity. Vermiculite and kaolinite are the weathering products of biotite and montmorillonite is the weathering product of feldspar, which is about half decomposed. In the middle and lower part of the solum salts have accumulated, including enough exchangeable sodium to form a natric horizon. There is a weak *ca* horizon in the lower part of the natric horizon. Some amorphous silica has accumulated in pores of the B3 horizon.

Bosanko soils reflect an environment of maximum parent-rock decomposition. Biotite has weathered to vermiculite and montmorillonite and feldspar, to montmorillonite. The shrinking and swelling that accompany changes in moisture content have homogenized the soil material, and no B horizon has formed. A *ca* horizon has formed below the zone of mixing. Moderate amounts of salts are also present.

Only a small part of the sodium and calcium released by weathering of tonalite remains in the Bonsall and Bosanko soils. We think that the relocation and concentration of some of the sodium to form a natric horizon in Bonsall soils has come about by the movement of salts, as proposed by Peterson[1] and Wilding (1963).

Three degrees of B-horizon development are shown in these soils. Vista soils have a cambic horizon and evidence of some clay illuviation in the lower part of the solum. Fallbrook soils have a well-developed argillic horizon and clay skins in all parts of this horizon. Bonsall soils have a marked clay increase from the A horizon to the B but, except in the B3 horizon, have no clay skins. Bosanko soils have an AC profile.

These differences in horizon development are largely a result of differences in the weathering environment of the soils and of differences in the kind and amount of clay formed by the weathering of grus. Vista soils are dry for long periods, are less weathered than the other soils, and have been considerably mixed by rodents. This mixing is responsible in part for the absence of an argillic horizon. Furthermore much of the clay in these soils is in the form of silt- and sand-size biotite pseudomorphs and is not available for argillic-horizon development. In Fallbrook soils, weathering of biotite to kaolinite sand-size pseudomorphs and the subsequent dispersion of the pseudomorphs provided enough clay to form an argillic horizon. Bonsall soils have a more strongly developed

[1] Peterson, F. F. Solodized solonetz soils occurring on the uplands of the Palouse loess. Unpublished Ph.D. thesis, Washington State University. 1961.

argillic horizon than Fallbrook soils but have no distinct clay skins in the upper part of the Bt horizon. The stress produced by wetting and drying of montmorillonite apparently prevents formation of clay skins in this horizon or destroys them later. In Bosanko soils shrinking and swelling on wetting and drying have produced a soil with no distinct subsurface horizons.

Illite is an important clay mineral in the A horizon of Vista, Fallbrook, and Bonsall soils and in the B horizon of Fallbrook soils. This mineral occurs in all <2-mm fractions of these horizons. It probably is resynthesized mica since there is little or no mica in the C horizon and the potassium concentration of the soil solution of the A horizon favors fixation of potassium by mica and not release.

This study demonstrates the influence of topographic position on soil development and mineral weathering in an environment of marked alternation of wet and dry seasons. The soils differ greatly from one another in almost all measured soil properties and in the apparent paths of mineral weathering. These differences can be explained by the effect of topography on the soil-moisture relations.

SOILS

Geographic setting

Vista and Fallbrook soils are extensive in California but Bonsall and Bosanko soils are of only limited extent. In the San Luis Rey watershed of San Diego County, Calif., soils in the four series occupy typical positions on rolling upland. Their parent material is a uniform, medium-grained, light to dark gray rock that has been identified by Larsen (1951) as Bonsall tonalite. This rock is an intermediate member of the early Cretaceous complex of intrusive rocks that constitute the southern California batholith. In most places it has been deeply weathered to grus[2], in which a few unweathered boulders are embedded.

Vista and Fallbrook soils formed under xerophytic shrubs or chaparral vegetation. Bonsall and Bosanko soils, however, formed under annual grass vegetation and scattered California live oaks *(Quercus agrifolia)*. Most of the area of these soils is now cultivated.

The average January temperature in the study area is about 54° F., the average July temperature about 70° F., and the average annual temperature about 60° F. The average annual precipitation is about 15 inches, nearly all of which is rainfall during winter and early spring. Since evapotranspiration is low in this period, much of the rainfall is effective in weathering and in moving the weathering products in the soil.

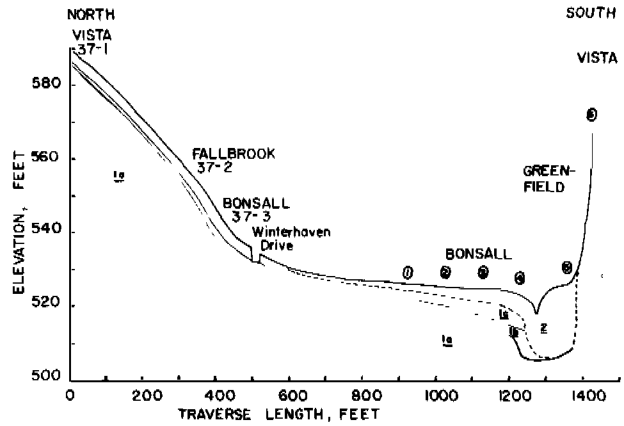


Figure 1.–Fallbrook High School transect showing the relation of the soils to the valley alluvium and colluvium. 1, auger traverse station; 1a, tonalite grus; 1b, C1 horizon in grus; 1c, soil sola in grus; 2, recent alluvium and colluvium.

Descriptions of these soils are in the appendix. We studied paired profiles of Vista, Fallbrook, and Bonsall soils in two transects about 500 feet long and 3 miles apart. Each transect crosses gently rolling ridgetops to lower back slopes; the average slope is about 10 percent. Pedons of the same series in the two transects are very much alike. Figure 1 is a diagram of the sampling sites at Fallbrook High School and the extension of the transect across the adjacent valley floor.

Vista soils are on smooth hilltops and upper back slopes. They have a dark brown sandy loam ochric epipedon and a yellowish brown cambic horizon of about the same texture. The two Vista pedons sampled are of a coarse-loamy, mixed, thermic family of Typic Xerochrepts. Fallbrook soils, on the middle and lower parts of back slopes, have a slightly lighter colored ochric epipedon and a reddish brown sandy clay loam argillic horizon. The two Fallbrook pedons sampled are of a fine-loamy, mixed, thermic family of Typic Haploxeralfs. Bonsall soils on foot slopes have a brown ochric epipedon and a yellowish brown natric horizon that is much finer in texture than the argillic horizon of the Fallbrook. In places there is a *ca* horizon. In the B3 horizon there is evidence of beginning duripan formation. Bonsall pedon S64 Calif–37-3 is of a fine montmorillonitic, thermic family and pedon S64 Calif–37-5 a fine-loamy, mixed, thermic family of Haplic

[2] Grus is defined in the American Geological Institute's Glossary of Geology and Related Sciences as "an accumulation of fragmental products derived from the weathering of granite in its passage from solid rock to soil." The grus has not been moved and it has retained the structure of the original rock.

Natrixeralfs. Pedon S64 Calif–37-5 is a taxadjunct to the Bonsall series.[3]

Bosanko soils, the fourth member of the toposequence, are not part of either transect. We studied one profile at a site about 10 miles south of Fallbrook and another at a site about 35 miles southeast of Fallbrook. Some Bosanko soils occupy positions below Vista, Fallbrook, or Bonsall soils, but we did not see a complete toposequence during this study. The relief is subdued, but Bosanko soils are too limited in extent to be assigned a distinct position in the landscape. We included them in this study because they seem to be part of the weathering sequence of soils on tonalite grus. Bosanko soils have a gray clay A horizon underlain by a brown heavy sandy clay loam ACca horizon. The pedons sampled are of a fine, montmorillonitic, thermic family of Chromic Pelloxererts.

Geomorphic setting

In Vista, Fallbrook, and Bosanko soils, the C horizon has the distinctive texture and structure of undisturbed tonalite grus. In the C horizon of Bonsall soils, however, the texture of the grus varies (see profile description in appendix), suggesting that Bonsall soils may have formed partly in pedisediments and partly in residual tonalite grus. To clarify this point, we made a transect across the valley adjacent to the Fallbrook High School site (descriptions in the appendix).

At this site on foot slopes (fig. 1) a thin deposit of recent alluvium overlies Bonsall soils. This alluvium resembles the Bonsall A horizon in color and texture although the silt content is slightly higher. The buried Bonsall soil extends almost across the valley. The alluvium is thicker toward the center of the valley and is as much as 18 feet thick in a former stream channel (station 5). At this point a Typic Xerochrept has formed in the alluvium, there is no buried soil, and the alluvium directly overlies the grus. We found a bottle at a depth of 8 feet in the alluvium about 1,000 feet upvalley from this transect. Thinness of the alluvium over a well-developed soil in major parts of the valley floor suggests that the area has been geomorphologically stable long enough for Bonsall soils, the most strongly developed of the transect, to form. The erosion giving rise to the thin alluvium on the valley floor may be related to tillage or disturbance of native vegetation since settlement of the area. It seems reasonable to conclude that the soils in the transect are of about the same age and that no major soil features were caused by erosion or deposition. Differences in the texture of the grus underlying Bonsall soils evidently were caused by weathering.

[3] Taxadjuncts are soils that are similar to a recognized series but are outside the taxon in which the series is classified. They do not differ enough to warrant their recognition in a separate series.

LABORATORY STUDIES

Laboratory data on the primary chemical, physical, and mineralogical properties of each of the soils sampled are in the appendix. The standard analytical methods used are described in Soil Survey Investigations Report No. 1 (1967), and the laboratory data sheets are coded by the code set up in that report. Tables in the text report data derived from the primary data, data from specialized studies, and data summarized for discussion. Any modifications of the standard methods and supplementary methods needed for particular determinations are described in the appropriate section in this report.

Soil moisture

After periods of heavy rain during winter, water seeps from the A2 horizon of Bonsall soils along the road that crosses the transect at Fallbrook High School. This is from a perched water table since the true water table in all these soils is very deep throughout the year. To measure water movement we installed piezometers late in 1965 and began to collect samples to measure soil moisture in January 1966. We took samples at 6-inch-depth intervals from two adjacent pedons of each of three of the kinds of soil, determined their moisture content gravimetrically, and averaged the measurements for each horizon.

Table 1 reports moisture content of the major horizons for the year 1966 and table 2, moisture-retention values. Data for duplicate samples collected during the first 6 months agree very well for a given sampling date. The average pedon-to-pedon variation in moisture content at a given site was 0.2 percent for Vista soils, 0.4 percent for Fallbrook soils, and 0.2 percent for Bonsall soils. The maximum difference in average moisture content of a given horizon of different pedons was 0.9 percent for Vista soils, 2.2 percent for Fallbrook soils, and 4.2 percent for Bonsall soils. The greatest difference was measured in the A horizon. Because the difference was slight, we sampled single pedons after June 1966, and table 1 reports moisture content of single pedons.

The moisture content of some horizons apparently exceeds that at field capacity for short periods during the rainy season. We measured a perched water table in Bonsall soils on January 1 and February 2, 1966, but none of the horizons of this soil was at field capacity when we collected samples on January 25 or March 5.

TABLE 1.--Water content of three kinds of soil in 1966[1]

[---indicates determination not made]

Soil	Horizon	1/25/66	3/5/66	3/30/66	4/27/66	6/14/66	7/13/66	9/13/66	11/7/66	12/29/66
		Pct.	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*	*Pct.*
Vista	A. . . .	7.5	7.0	4.5	3.8	2.9	2.0	2.0	2.2	9.2
	B. . . .	9.4	7.9	4.8	4.1	4.0	3.4	3.6	3.5	9.8
	C1 . . .	5.5	---	4.1	3.4	3.6	2.3	3.4	1.9	6.4
	C2 . . .	5.1	---	5.4	5.3	4.6	2.4	3.1	---	4.7
Fallbrook . . .	A. . . .	7.8	6.1	5.2	3.1	2.6	1.2	0.8	1.6	9.9
	B1 . . .	---	---	---	4.6	5.0	4.5	4.1	6.8	11.9
	B2t. . .	13.3	12.9	10.4	7.0	9.6	7.7	6.6	8.6	14.9
	B3t. . .	12.4	11.1	10.0	9.8	8.9	8.8	---	---	12.0
	C1 . . .	9.2	8.6	6.8	6.6	7.1	5.5	---	---	6.3
	C2 . . .	---	---	4.4	4.3	3.5	4.4	---	---	---
Bonsall	A. . . .	9.4	8.1	4.0	2.8	2.2	1.6	1.5	2.0	8.8
	B21t . .	15.6	15.7	10.7	10.0	10.4	9.9	8.4	10.8	16.2
	B22t . .	13.6	15.0	10.6	11.9	10.4	11.8	12.0	---	11.2
	B3t . .	11.2	13.6	10.1	11.8	10.2	14.6	14.4	---	---
	C1. . .	---	---	8.1	8.1	11.2	9.0	11.3	---	---
	C2. . .	---	---	5.8	---	---	---	---	---	---

[1] Water content was determined gravimetrically on samples collected at 6-inch-depth intervals. Water content for any given horizon represents the average for the samples from that horizon at a single site.

During summer and early fall the A horizon of the three kinds of soil approached airdryness, but only that of the Fallbrook pedon reached that level. The Vista solum reached the wilting point by July, i.e., held less water than held at 15-bar tension. The Fallbrook solum was at 15-bar tension to a depth of at least 36 inches by September. The lower part of the Bonsall solum did not reach the wilting point during the study though the soil was at 15-bar tension to a depth of 48 inches by September 13. The C horizon of some Bonsall pedons was dry throughout the year.

The water content predicted from a theoretical balance sheet for the soils (table 3) agrees closely with the observed values. Comparison of the measured data (table 2) with the derived data (table 3) shows that some leaching is to be expected in the Vista, Fallbrook, and Bosanko sola, but that the Bonsall solum is not likely to reach field capacity during the year. It should be noted that the wetting front in Bosanko soils is not likely to pass beyond the Cl horizon (28 to 45 inches). This may explain why only Bonsall and Bosanko soils of the four kinds contain significant amounts of water-soluble salts.

Assuming that the soils are at the wilting point at the start of the rainy season and that any surplus of soil water over that retained at field capacity is lost by leaching, we estimated the time at which the soils again become dry from the data in table 3. In an average year Vista soils become dry in May, Bosanko soils in June, and Fallbrook and Bonsall soils in July. The soils remain dry until the winter rainy season begins. In an average year each of the four kinds of soil is dry for at least 60 consecutive days.

Micromorphology

For selected features of thin sections we counted 300 points per thin section in three to five traverses, using an improvised point counter. The first traverse began 5 mm from the top of the slide and 5 mm from the left. Each subsequent traverse was 5 mm below the preceding traverse. If this procedure did not yield enough points, we counted points along additional traverses located midway between the original traverses. If a point fell on a boundary, we assigned the soil feature falling in the direction of the traverse to this point. We counted only one slide per horizon. For the differential thermal analyses we mixed three parts of calcined Al_2O_3 with one part sample and heated the mixture to 700° C.

Vista soils—From the A horizon of Vista soils into the C horizon skeleton grains are bound into aggregates by poorly oriented grain coatings consisting of a mixture of organic matter, silt, and clay (table 4). In the A horizon these coatings apparently are strong in places and weak in others, giving the horizon its moderate crumb structure. In the B horizon the coatings are thicker, which may be responsible for the massive appearance of this horizon. Because of their composition and poor optical orientation (fig. 2), these coatings cannot be considered clay skins. There are, however, a

TABLE 2.--Water retention values for the soils

[—indicates determination not made]

Soil, horizon, and depth		Water content			Water held at 1/3-bar tension	
		Airdry	At 15-bar tension	At 1/3-bar tension	Total	Available[1]
		Pct.[2]	*Pct.*[2]	*Pct.*[2]	*In.*	*In.*
Vista (S64Calif-37-1):						
A,	0-19 inches	1.4	3.4	10.2	2.9	1.9
B,	19-35 inches	1.4	3.7	10.5	2.4	1.6
C1,	35-44 inches	1.0	2.7	6.7	1.2	0.7
C2,	44-61+ inches	1.0	2.5	—	—	—
Fallbrook (S64Calif-37-2):						
A,	0-12 inches	.9	3.8	10.6	2.0	1.3
B2t,	12-28 inches	2.4	10.4	15.8	4.4	1.5
B3t,	28-47 inches	2.4	7.0	13.7	4.7	2.3
C1,	47-68 inches	2.0	4.8	10.9	4.1	2.3
C2,	68-85 inches	1.3	2.9	—	—	—
Bonsall (S64Calif-37-3):						
A,	0-10 inches	1.0	4.2	10.0	1.6	.9
B21t,	14-27 inches	3.4	12.8	17.7	—	—
B22tca,	27-38 inches	3.9	—	—	8.8	2.7
B3t,	38-60 inches	3.0	10.0	20.2	7.1	3.6
C1,	60-89 inches	3.3	10.8	15.4	7.5	2.2
IIC2,	89-110 inches	3.3	9.2	—	—	—
Bosanko (S64Calif-37-8):						
A,	0-22 inches	6.1	16.9	25.4	8.3	2.8
ACca,	22-28 inches	7.7	17.0	23.7	2.2	.6
C1,	28-45 inches.	8.1	13.5	19.4	5.2	1.6
C2,	47-57+ inches	7.5	11.9	15.5	3.2	.8

[1] Available water in percent equals water content at 1/3-bar tension less water content at 15-bar tension.
[2] Of ovendry weight.

TABLE 3.—Balance sheet for soil water by months

Item	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	March	April	May	June	Annual
	In.	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*
Precipitation (1965-66)[1] . .	0.38	0.00	0.22	0.00	8.82	5.18	1.28	1.14	0.30	0.00	0.00	0.00	17.32
Precipitation (normal)[2] . .	.01	.15	.21	.84	1.30	3.21	2.94	3.23	2.56	1.36	.32	.09	16.22
Potential evapotranspiration[3] . .	5.3	4.7	4.1	2.7	1.6	1.2	1.0	1.1	1.6	2.3	3.2	4.1	32.9
Net soil water added (1965-66)	0	0	0	0	7.2	4.0	.3	0	0	0	0	0	
Estimated soil-water balance (1965-66) for:													
Vista solum	0	0	0	0	[4]7.2	[4]9.3	[4]5.6	5.3	4.0	1.7	0	0	
Fallbrook solum . .	0	0	0	0	7.2	[4]11.2	[4]11.4	11.1	9.8	7.5	4.3	.2	
Bonsall solum . . .	0	0	0	0	7.2	11.2	11.5	11.5	10.2	7.9	4.7	.6	
Bosanko solum. . .	0	0	0	0	7.2	[4]11.2	[4]10.8	10.5	9.2	6.9	3.7	0	

[1] U.S. Weather Bureau station at Fallbrook, Calif.
[2] U.S. Weather Bureau station at Escondido, Calif.
[3] Potential evapotranspiration is the amount of water evaporated from the ground or transpired from the vegetation if there is no shortage of water at any time during the period of observation. It was calculated by using the nomogram developed by Van Hylckama (1959) for solving the Thornthwaite formula.
[4] Some leaching of soil water from the solum is expected during these months.

TABLE 4.--Summary of micromorphological characteristics[1]

Soil, horizon, and depth	Voids	Papules[2]	Cutans	Plasmic fabric
Vista (S64Calif-37-1):				
All, 0-3 inches . . .	Many unmodified simple packing voids.	Common, macro, reddish brown.	Thin brown clay cutans on skeleton grain surfaces; individual skeleton grains discrete.	None, skeletal.
B21, 19-28 inches . .	Many unmodified simple packing voids.	Few to common, macro, reddish brown.	Thin brown clay cutans on skeleton grain surfaces; cutans bind individual grains into aggregates of a few grains.	Insepic.[3]
C1, 35-44 inches . . .	Common to very common, randomly oriented fracture planes having irregular outline.	Common, macro, reddish brown.	Thin brown clay cutans on skeleton grain surfaces; skeleton grains and aggregates of rock structure discrete; few to common thin clay skins.	None, skeletal.
Fallbrook (S64Calif-37-2):				
All, 0-2 inches	Many unmodified simple packing voids.	Few, macro, reddish brown.	Brown clay cutans on skeleton grain surfaces; cutans form aggregates by bridging skeleton grains.	Insepic.
B22t, 20-28 inches . .	Common unmodified vughs,[4] skew planes, and channels.	Common, macro, reddish brown.	Common moderately thick reddish brown clay skins in voids and channels; common reddish brown clay bridges; clay skins almost continuous in voids.	Mosepic.[5]
C2, 68-85 inches . . .	Very common vughs, skew planes, and channels.	Common, macro, reddish brown.	Few to common reddish brown clay skins in voids; few clay bridges; clay skins very thin but continuous.	None, skeletal.
Bonsall (S64Calif-37-3):				
A1, 0-6 inches	Many unmodified simple packing voids and skew planes.	Few, macro, reddish brown.	Very thin brown discontinuous clay cutans.	Insepic.
A2, 6-10 inches. . . .	Few skew planes; common unmodified packing voids.	Few, macro, reddish brown.	Very thin brown continuous clay cutans.	Insepic.
B1, 10-14 inches . . .	Few skew planes and smoothed vughs.	None.	Stress cutans common in vughs and skew planes.	Lattisepic fabric[6] with very few skelsepic[7] and vosepic[8] areas.
B21t, 14-27 inches . .	Few skew planes and channels.	Few, macro, reddish brown.	Few brown cutans in channels.	Skel-omnisepic.[9]
B22tca, 27-38 inches.	Few unmodified vughs and smoothed vughs.	Common, macro, reddish brown.	Brown stress cutans continuous in vughs; clays lining skeleton grains stress oriented.	Skel-omnisepic.[9]
B31, 38-48 inches . .	Few unmodified vughs.	Common, macro, reddish brown.	Few very discontinuous clay skins in vughs; few channel coatings of carbonate and amorphous silica.	Skel-mosepic.
B32, 48-60 inches . .	Common unmodified vughs.	Common, macro, reddish brown.	Almost continuous thin grain argillans and a few clay skins; few void fillings of carbonate and amorphous silica.	Mo-skelsepic.
C1, 60-89 inches . . .	Common unmodified vughs.	Common, macro, reddish brown.	Very few clay skins; many lined with amorphous silica.	In-skelsepic.
Bosanko (S64Calif-37-8):				
All, 4-18 inches. . . .	Few smoothed vughs, skew planes, and root channels.	None.	None; a stress-oriented clay around grains and within s-matrix.	Vo-skel-masepic.[10]

TABLE 4.--Summary of micromorphological characteristics[1] -- continued

Soil, horizon, and depth	Voids	Papules[2]	Cutans	Plasmic fabric
ACca, 22-28 inches.	Few smoothed vughs and skew planes.	Few to common, yellowish brown.	Carbonate crystals line voids; stress-oriented clay lines grains.	Skelsepic-crystic-masepic.[10]
C1, 28-45 inches . .	Common skew planes and vughs.	Common, yellowish brown.	Stress-oriented clay within s-matrix; this may represent outlines of former feldspar grains now weathered to clay; few crystic areas.	Masepic.[10]
C2, 45-57 inches . .	Few skew planes.	Common, yellowish brown.	Stress-oriented clay within s-matrix in a pattern that may represent outlines of former feldspar grains now weathered to clay.	Masepic.[10]

[1] Terminology is that of Brewer (1964).

[2] Papules are clay mineral bodies of silt size or larger that exhibit a strong preferred orientation or lamellar fabric or both; they have sharp external boundaries and are usually prolate to equant and subrounded to well rounded. The papules listed are pseudomorphs after biotite.

[3] Insepic is a type of sepic plasmic fabric , i.e., one with plasma separations that have a striated extinction pattern; the separations are isolated patches or islands within the plasma.

[4] Vughs are voids of significantly larger size than would result from the normal packing of single grains.

[5] Mosepic is a type of sepic plasmic fabric; the numerous patches within the plasma may adjoin each other.

[6] Lattisepic is a type of sepic plasmic fabric; the separations are two sets of short prolate areas approximately at right angles to each other within the plasma.

[7] Skelsepic is a type of sepic plasmic fabric; the separations are close to and parallel to the surfaces of skeleton grains and nodules.

[8] Vosepic is a type of sepic plasmic fabric in which the separations are associated subcutanically with walls of voids. Since the zones of striated extinction around the void peripheries noted under crossed polarizers usually cannot be differentiated in plain light, they are not clay skins or illuviation argillans.

[9] Skel-omnisepic is a type of sepic plasmic fabric in which most of the plasma exhibits a complex striated extinction pattern and a smaller part of the plasma has a skelsepic plasmic fabric.

[10] Masepic is a type of sepic plasmic fabric; the separations occur through the soil plasma but are not associated with voids. A *vo-skel-masepic* plasmic fabric exhibits mostly the masepic plasmic fabric but has some skelsepic and fewer vosepic areas. A skelsepic-crystic-masepic plasmic fabric exhibits mostly masepic plasmic fabric with some areas of crystalline, more soluble, usually anisotropic plasma (carbonate), and less skelsepic plasmic fabric.

few thin clay skins in voids of the B22 and C horizons (table 5). The shape and random packing of the particles largely determine the shape of the voids, which are equant to prolate in overall dimensions. They have a rough periphery and are strongly interconnected.

Biotite pseudomorphs are weakly pleochroic. They have strong to moderate continuous optical orientation (fig. 3) and are sharply separated from adjoining mineral grains and clay skins by color and texture. These pseudomorphs consist of vermiculite. They are coarsest in the A1 and C horizons and appear somewhat fragmented in the B horizon. Some of them apparently have dispersed, releasing the plasma[4] that forms the few clay skins.

The B horizon is a cambic horizon; its structure is distinctly different from rock structure. Although illuvial clay constitutes more than 1 percent of the cross section of the lower part of the B horizon, the clay increase from the A horizon to the B is not enough to meet the requirements of an argillic horizon.

[4] Plasma of a soil material is that part which is capable of being or has been moved, reorganized, and/or concentrated by the processes of soil formation. It includes all the material, mineral or organic, of colloidal size and relatively soluble material which is not bound up in the skeleton grains. *In* Brewer 1964, p. 12.

Fallbrook soils—The A horizon of Fallbrook soils is massive; moderately thick grain coatings of silt and clay, darkened by organic matter, bind skeleton grains together. Thin to moderately thick reddish brown clay skins and clay bridges are present throughout the B horizon. Voids in the B horizon are less common in Fallbrook soils than in Vista soils, and more of the voids are tubular than interstitial. The walls of the voids are smoothed by clay skins (fig. 4).

There are fewer pseudomorphs in the B horizon than in the A although there are some throughout the solum. Some parts of the pseudomorphs have low birefringence and a low refractive index (fig. 5). These areas are kaolinite.

The B horizon is an argillic horizon. In cross section the area of clay skins reaches a maximum of nearly 12 percent (table 5) and clay bridges are common. Most of the remainder of the clay is in biotite pseudomorphs. The maximum expression of clay-skin development for the soils of the transect is in the B horizon of Fallbrook soils.

Bonsall soils—The A horizon of Bonsall soils contains more silt and fine sand and fewer aggregates of grus than the A horizon of either Vista or Fallbrook soils. Silt and clay, somewhat darkened by organic matter, form the

TABLE 5.—Relation between the volume estimate of clay skins, grain argillans, and biotite pseudomorphs in thin sections and the coefficient of linear extensibility of the fine-earth fraction (COLEf)

[—indicates determination not made]

Soil, horizon, and depth	Clay skins	Grain argillans	Biotite pseudomorphs	COLEf
	Pct.	*Pct.*	*Pct.*	*In. per in.*
Vista (S64Calif-37-1):				
A11, 0-3 inches . . .	0	0	7	0.062
B21, 19-28 inches . .	Trace	0	8	.021
B22, 28-35 inches . .	1	Trace	13	.014
C1, 35-44 inches . .	2	0	10	.008
C2, 44-61+ inches .	0	0	10	—
Fallbrook (S64Calif-37-2):				
A11, 0-2 inches . . .	0	0	3	.005
B21t, 12-20 inches . .	1	Trace	2	.025
B22t, 20-28 inches . .	4	3	4	.028
B3, 28-47 inches . .	6	6	12	.016
C1, 47-68 inches . .	6	2	21	.016
C2, 68-85 inches . .	2	1	8	—
C3, 85-90+ inches .	0	1	11	—
Bonsall (S64Calif-37-3):				
A11, 0-6 inches . . .	0	0	Trace	.006
A2, 6-10 inches . .	0	0	1	.003
B1, 10-14 inches . .	1	0	0	.047
B21t, 14-27 inches . .	0	0	Trace	.045
B22tca, 27-38 inches . .	0	0	5	—
B31, 38-48 inches . .	1	0	11	.035
B32, 48-60 inches . .	3	2	9	—
C1, 60-89 inches . .	0	0	11	.016
IIC2, 89-110 inches .	1	0	12	—
IIC3, 110-120+ inches	2	Trace	14	.020
Bosanko (S64Calif-37-8):				
A11, 4-18 inches . .	0	0	0	.050
ACca, 22-28 inches . .	0	0	3	.037
C1, 28-45 inches . .	0	0	11	.031

plasma of this massive horizon. In the B horizon clay-rich plasma is dominant in the cross section (figs. 6 and 7). The clay occurs mostly as s-matrix [5] and not as coatings on surfaces of peds and skeleton grains. At exposed surfaces, i.e., void peripheries and ped faces, the clay is well oriented but in plain light it cannot be distinguished from that of the s-matrix. Within the s-matrix the clay is well oriented near the surface of skeleton grains, especially around the largest grains. Away from skeleton grains clay orientation is patchy. The individual patches or islands do not seem to be oriented to each other. Only the lower part of the B horizon contains clay skins (table 5). Photomicrographs of the B32t horizon show a laminated well-oriented clay skin that differs from the matrix in both color and texture (figs. 8 and 9).

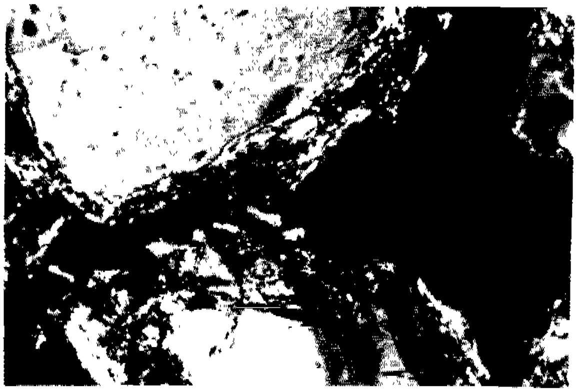
[5] S-matrix as used here is the material in which the pedological features occur. It consists of the plasma, skeleton grains, and voids that do not occur in pedological features other than plasma separations (Brewer 1964, p. 147).

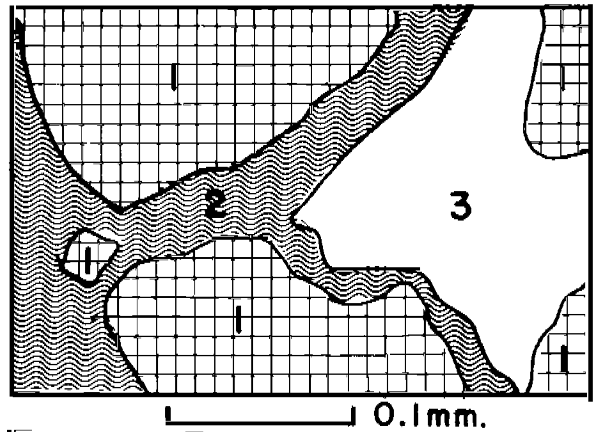
Figure 2.—Free grain cutans in the A11 horizon of Vista soils. Cutans bind skeleton grains into aggregates that are strong in places and weak in others, giving this horizon its moderate crumb structure. 1, sand grains; 2, cutans of silt, clay, and organic matter; 3, void. Crossed polarizers, x 240.

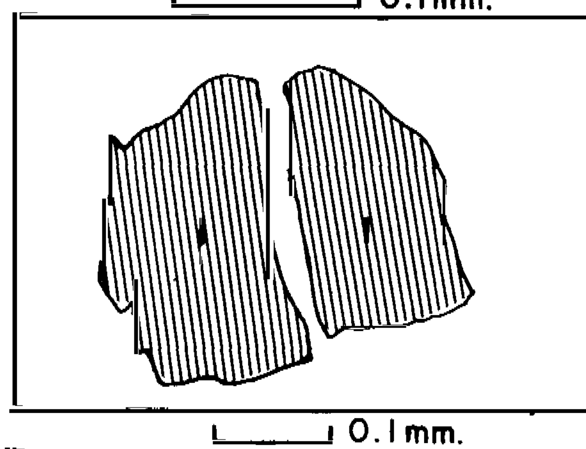
Figure 3.—Biotite pseudomorph in the C1 horizon of Vista soils. In these soils biotite pseudomorphs are pleochroic, have strong to moderate optical orientation, and consist mostly of vermiculite. Crossed polarizers, x 150.

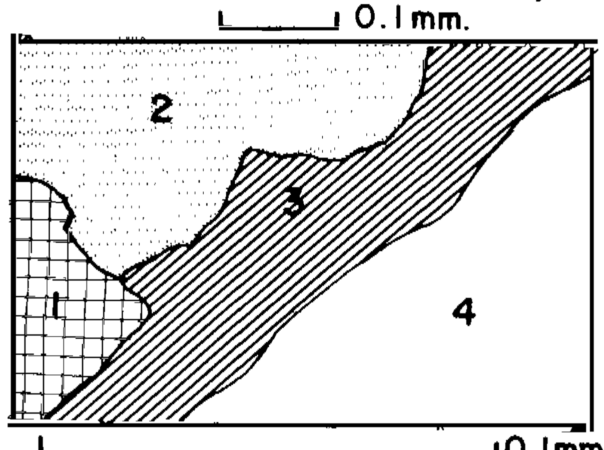
Figure 4.—Clay skin in the B2t horizon of Fallbrook soils. In these soils more voids are tubular than interstitial as in Vista soils. Many of the tubular voids are smoothed by clay skins. 1, sand grain; 2, plasma; 3, laminated clay skin (illuviation argillan); 4, void. Plain light, x 600.

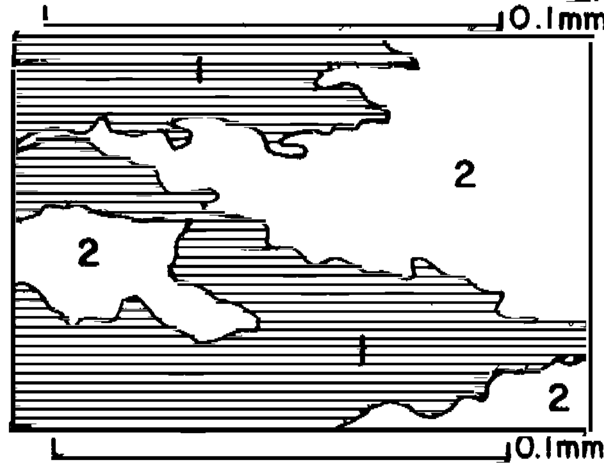
Figure 5.—Biotite pseudomorph in the B3t horizon of Fallbrook soils. In contrast to the biotite pseudomorph in figure 3, this one has weaker optical orientation and areas of lower birefringence, which are kaolinite. 1, area of high birefringence; 2, area of low birefringence. Crossed polarizers, x 600.




1
1
2
3
1
1
1
0.1mm.


0.1mm.


2
3
1
4
0.1mm.


1
2
2
1
2
0.1mm.

Bonsall soils have less void space than Fallbrook soils and much less than Vista soils. Some of the voids in the B horizon are "collapsing" voids that are present when the horizon is dry but collapse when the horizon is wet. Distribution of plasma and not distribution of skeleton grains determines void shape. As a consequence the periphery is smooth.

Within the solum biotite pseudomorphs are less common than in the solum of Fallbrook soils. We believe that this is a result partly of differences in weathering and partly of differences in pedoplasmation.[6] Feldspars are about 50-percent weathered in the B horizon. Montmorillonite is the clay mineral formed by weathering of the feldspar. A weathered feldspar from the IIC3 horizon is shown in the central part of figures 10 and 11. Less-weathered feldspar grains are in the lower center and upper left parts of these photomicrographs.

In the lower part of the B horizon there are some tubules of siliceous material that does not dissolve in 1*N* HCl and layers of clay and carbonates. The siliceous material in the tubules has a low refractive index and is isotropic. There are some carbonates in tubules and nodules in the B21t and B22tca horizons.

Bonsall soils have an argillic horizon, the upper part of which has been homogenized by shrinking and swelling. Clay skins occur only in the lower part of the horizon. There is not enough siliceous cementing material to classify the lower part of the B horizon as a duripan.

Bosanko soils–In these soils clay occurs as part of the s-matrix and not as coatings on free grains. Within the s-matrix the clay is well oriented next to skeleton grains and weakly to moderately well oriented as stringers and zones within the s-matrix. There are few voids and channels. In places stress-oriented clay lines ped faces, which is recognized in the field as slickensides. In the ACca horizon carbonate crystals line the voids. Biotite pseudomorphs, lacking in the A horizon, are common in the ACca and C horizons. Feldspars are about 75-percent weathered to clay and hornblende is slightly weathered in the upper horizons.

Particle-size distribution

The partly weathered mineral grains in grus break readily to fragments of about 5-mm diameter or less, but they may break to almost any "particle size," depending on the force applied. Therefore we determined particle-size distribution on the whole soil, including particles as large as 5-mm diameter. We used 20- to 40-g samples and

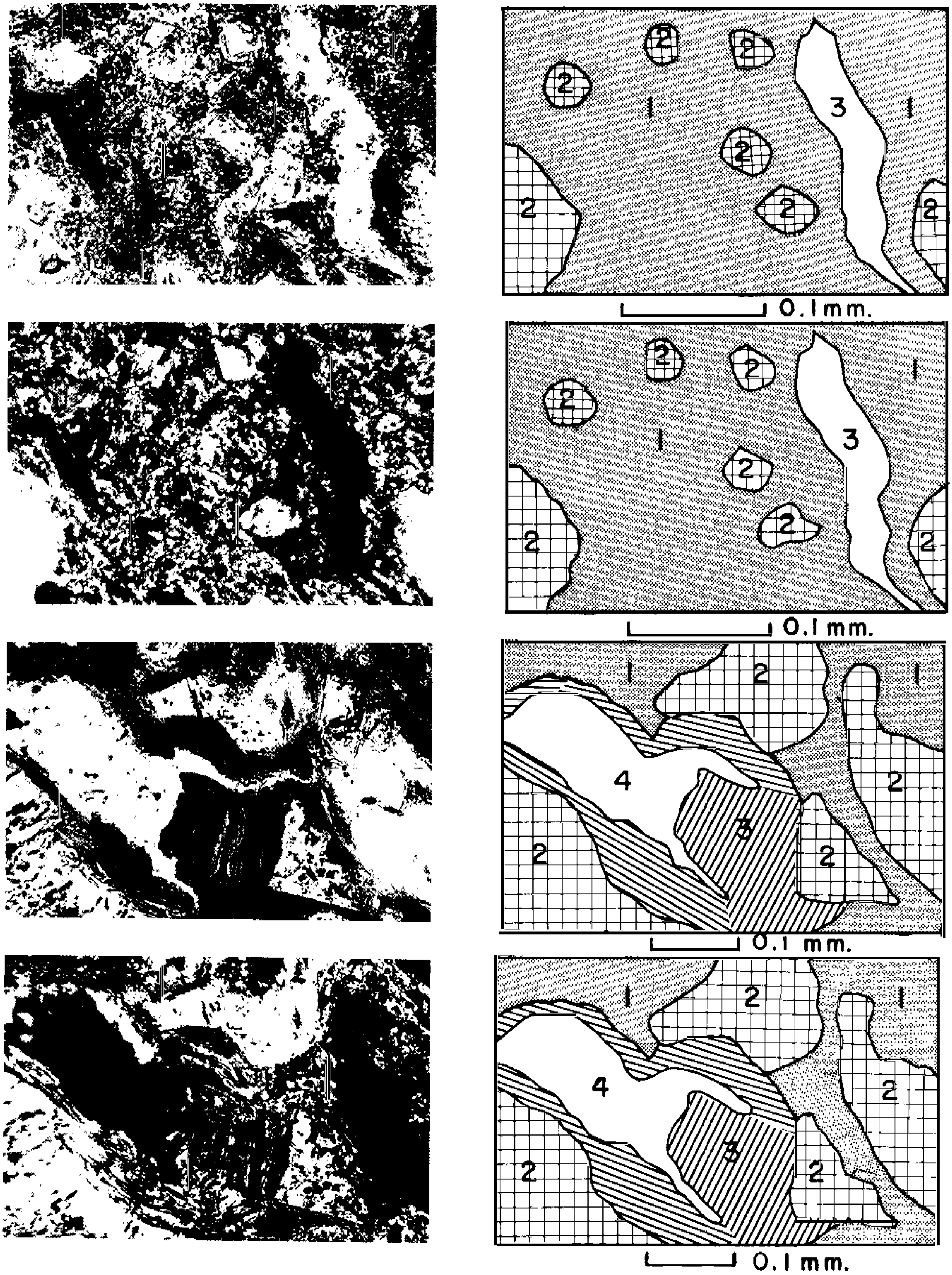
[6] Pedoplasmation (formation of plasma) is the homogenization of weathering products by mechanical destruction of pseudomorphs through shrinking and swelling on wetting and drying and through root action (Flach et al., 1968).

Figure 6.–Mosepic plasmic fabric in the B21t horizon of Bonsall soils. Plasma is dominant in the cross section. In plain light the plasma on void walls and ped faces is indistinguishable from that of the s-matrix. 1, plasma; 2, sand grains; 3, void. Plain light, × 240.

Figure 7.–Mosepic plasmic fabric of the area of the B21t horizon of Bonsall soils shown in figure 6. Within the s-matrix of the B horizon of these soils the clay is well oriented next to sand grains and around voids, but away from them orientation is patchy. 1, plasma; 2, sand grains; 3, void. Crossed polarizers, × 240.

Figure 8.–Clay skin in the B32t horizon of Bonsall soils. In these soils laminated clay skins occur only in the lower part of the solum. 1, plasma; 2, sand grains; 3, clay skin; 4, void. Plain light, × 150.

Figure 9.–Well-oriented laminated clay skin in the area of the B32t horizon of Bonsall soils shown in figure 8. 1, plasma; 2, sand grains; 3, clay skin; 4, void. Crossed polarizers, × 150.


0.1 mm.
0.1 mm.
0.1 mm.
0.1 mm.

separated the 2- to 5-mm fraction, which we reported on the whole-soil basis. For chemical and mineralogical investigations and for clay and silt determinations we crushed all samples to pass a 2-mm sieve. Otherwise the procedures were standard. The clay percentage in the crushed samples is slightly higher than that in the uncrushed samples, but the difference is generally within the range of experimental error. The data other than percent gravel were recalculated to percent or to milliequivalents per 100 g of the< 2-mm fraction. We assumed that the >2-mm fraction did not contribute to any of the properties measured.

There are indications, however, that neither method of sample preparation yielded complete dispersion in all horizons. The incomplete dispersion can be deduced from changes in the ratio of the measured clay percentage to the soil parameters largely controlled by clay such as cation-exchange capacity, 15-bar moisture retention, and surface area. Any change in these ratios is evidence of incomplete dispersion if there is no marked change in clay mineralogy or organic-matter content. The distribution of cation-exchange capacity and clay with depth is plotted in figure 12. The high exchange capacity in the A horizon reflects the contribution of organic matter, but any change in the relative position of the cation-exchange capacity and the clay curve below the A horizon must be attributed to contributions to the cation-exchange capacity from sources other than the clay fraction. The distribution of cation-exchange capacity and of clay suggests incomplete dispersion of all horizons of Vista soils and of the lower part of the B horizon and C horizon or of the AC and C horizons of Fallbrook, Bonsall, and Bosanko soils. A similar conclusion can be reached by comparing the total surface area or 15-bar water retention with the clay percentage. In spite of the evidence for incomplete dispersion, field estimates of texture agree more nearly with the measured particle-size distribution than with clay estimates based on cation-exchange capacity or 15-bar moisture retention. This is further evidence of the mechanical stability of the pseudomorphs.

Shrink-swell capacity and bulk density

We determined bulk density on clods after equilibration at 1/3-bar moisture tension and again after equilibration at 110° C. (Brasher et al., 1966). We calculated 1/3-bar moisture retention from the moisture content of equilibrated clods and measured the 15-bar moisture retention of crushed samples. All values, including bulk density, were calculated for the <2-mm fraction. The coefficient of linear extensibility (COLEf), an index of the shrink-swell capacity of the soil, was calculated from the bulk density of equilibrated and ovendry clods.

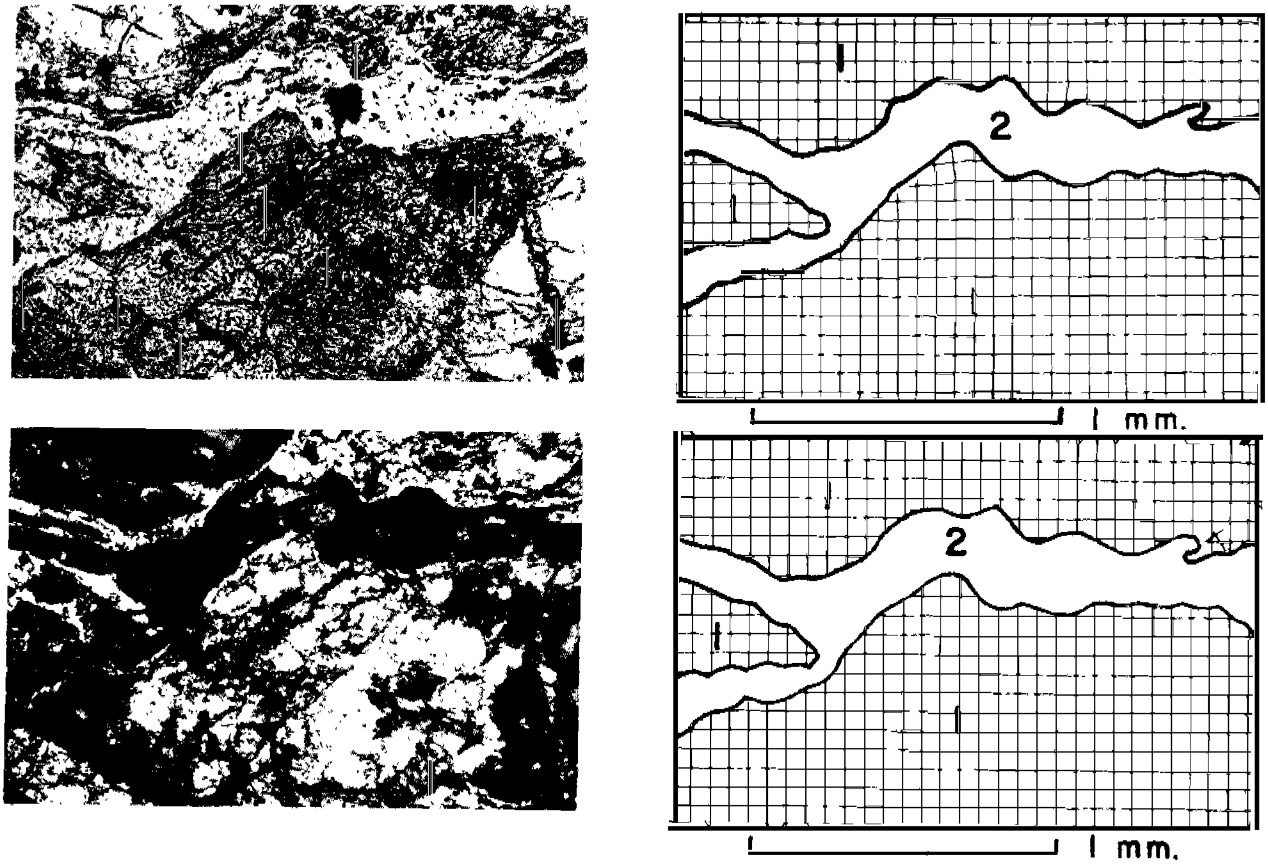
Figure 10.–Weathered feldspar grains in the IIC3 horizon of Bonsall soils. Weathered feldspar grains are common in the lower horizon of Bonsall and Bosanko soils. This earthy, pale green weathered grain has low relief and is montmorillonite. 1, Weathered feldspar grains; 2, void. Plain light, × 40.

Figure 11.–Weathered feldspar grains in the IIC3 horizon of Bonsall soils under crossed polarizers. Though weathering breaks up the feldspar grains, the fragments are intact in the products formed as shown here. Apparently, the montmorillonite disperses slowly, allowing feldspar pseudomorphs of montmorillonite to form. 1, weathered feldspar grains; 2, void. × 40.

Bulk-density values reflect differences in degree of weathering, shrink-swell potential, and soil structure. The bulk density in grams per cubic centimeter of the C horizon when dry is 1.97 in Vista soils, 1.90 in Fallbrook soils, and between 1.69 and 1.86 in Bonsall and Bosanko soils. The lowest bulk density between 1.4 and 1.5 (moist), is in the Al horizon of Bonsall and Fallbrook soils and in the A and B horizons of Vista soils. There is evidence that the B horizon of Vista soils has been extensively modified by soil fauna and in this respect closely resembles the A horizon. Strongly shrinking and swelling horizons, notably the A and AC horizons of Bosanko soils, have low moist bulk density. In Fallbrook and Bonsall soils horizons below the Al have high bulk density and correspondingly low porosity.

Although COLEf is related to clay content, the relation of clay percentage to COLEf is imperfect because of the incomplete dispersion of clay in some horizons. COLEf per unit of clay is distinctly higher for horizons in which montmorillonite is the dominant clay than for other horizons.

COLEf of Vista soils, particularly that of the A1 horizon, is much higher than that of other soils of similar texture. This probably is caused partly by the very high dry bulk density, which reflects dense packing



and a high degree of particle orientation, and partly by the sand- and silt-size vermiculite (biotite pseudomorphs) that forms bridges between skeleton grains (fig. 2). The potential swelling of the pseudomorphs on wetting, estimated from volume measurements of the pseudomorphs in water and in a nonpolar liquid, is about 10 percent (table 6). Expansion of these pseudomorphs, mainly along the C axis, which forces skeleton grains apart, may well explain the large volume increase of these clods on wetting.

TABLE 6.–Particle density of Vista and Fallbrook soil materials

Soil material	Particle density in water
	g per cc
Vista (S64Calif-37-1):	
A11, 0-3 inches	[1]2.4
B22, 28-35 inches	2.68
C1, 35-44 inches	2.68
Fallbrook (S64Calif-37-2):	
A11, 0-2 inches.	2.60
B22t, 20-28 inches	2.75
C1, 47-68 inches	2.63
Weathered biotite from Vista A11 horizon:	
Passing 0.18-mm sieve	[1]2.8
Retained by 0.18-mm sieve	[1]2.6

[1] Single determination. Both fractions of the weathered biotite from the Vista A11 horizon have a particle density of 3.0 grams per cubic centimeter in paint thinner, a nonpolar liquid that has a density of 0.748 at 28° C.

In the field the A horizon of Vista soils does not form cracks on drying. Its strong granular structure may allow rapid rearrangement of aggregates, removing field evidence of shrinking and swelling. Shrinking and swelling may, in fact, contribute to the strong granular structure.

Chemical properties

The Vista and Fallbrook soils of both transects are slightly leached. Base saturation is about 90 percent throughout Vista soils. In one Fallbrook pedon base saturation increases from 80 percent in the A horizon (69 percent based on cation-exchange capacity by the sodium acetate method) to 95 percent in the C horizon, but it is nearly uniform in the other pedon. This may reflect the introduction of bases from irrigation water at the latter site.

In contrast, free salts, exchangeable sodium, and free carbonates have accumulated in the lower part of the B horizon of Bonsall soils. Exchangeable sodium exceeds 15 percent, but neither pedon contains enough $CaCO_3$ to have a calcic horizon. Accumulation of sodium, salts, and carbonates is considerably less in the soils of one

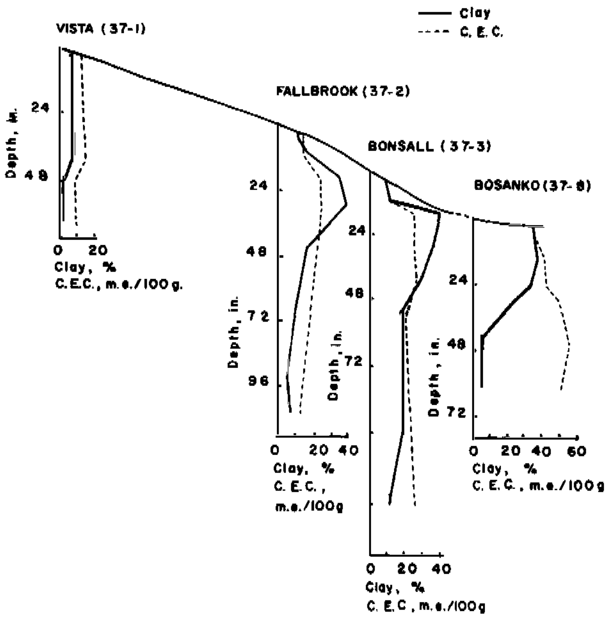


Figure 12.–Distribution of clay and cation-exchange capacity in the soils.

transect than in those of the other. Increasing exchangeable sodium in Bonsall soils is associated with the accumulation of exchangeable magnesium. In both Bosanko pedons base saturation is about 80 percent in the Ap horizon and between 90 and 100 percent in lower horizons.

Organic matter contributes slightly to the cation-exchange capacity of the A horizon of all soils in this study. Clay pseudomorphs in silt and sand fractions contribute to the cation-exchange capacity in all horizons of Vista soils and in the lower part of the B horizon and in the C horizon of Fallbrook, Bonsall, and Bosanko soils.

Extractable iron is low in all the soils. Slightly larger amounts of iron in the B horizon of Fallbrook and Bonsall soils reflect differences in weathering and some movement of iron into the argillic horizon. Impeded internal drainage in Bosanko soils may have caused some reduction and removal of iron.

Mineralogy

Because tonalite (quartz diorite) in the study area has weathered to grus to a depth of more than 100 feet, it was not practicable to sample fresh parent rock. We estimated the mineralogy of the parent rock from samples chipped from a nearby boulder (table 7). Plagioclase in this rock, determined by Michel-Levy's method (Rodgers and Kerr, 1942) is andesine containing 5.0 percent sodium and 6.2 percent calcium. Because of the zoning of the plagioclase, this determination may not represent precisely the average composition of the plagioclase. The specific gravity of tonalite, calculated from that of its component minerals, is 2.75, which is the same value reported by Spock (1953) for quartz diorite.

We studied the weathering products of tonalite that remained as pseudomorphs in sand and gravel fractions in thin section by X-ray and DTA methods and determined the cation-exchange capacity and specific gravity of the grains in biotite separates of sand fractions. We separated gravel-size feldspar and biotite grains manually and sand-size biotite by flotation and panning. We reduced the grains to <5 microns by grinding with mortar and pestle in acetone to dryness three times. Using standard procedures, we saturated samples with magnesium, magnesium plus glycerol, or potassium and let them dry on glass slides.

Though the feldspar of most horizons had evidence of weathering (table 8), only the IIC2 horizon of Bonsall soils and the C2 horizon of Bosanko soils retained clay-mineral weathering products–montmorillonite in both soils (table 9). The absence of detectable weathering products of feldspar in Vista and Fallbrook soils may be due to their removal in sample preparation or to surface alteration without the formation of secondary clay minerals.

We detected kaolinite, vermiculite, and hydrobiotite, a 12Å regularly interstratified mica vermiculite, in biotite pseudomorphs of the gravel fraction (table 9) of Vista and Fallbrook soils. Petrographic study confirmed the presence of kaolinite. In biotite pseudomorphs in the C horizon, vermiculite and some hydrobiotite are the only weathering products observed in Bonsall soils and vermiculite, hydrobiotite, and montmorillonite in Bosanko soils.

We separated weathered biotite from the sand fraction by flotation and panning. Impurities, mostly

TABLE 7.–Composition and specific gravity of a tonalite sample

Constituent	Volume	Specific gravity[1]	Calculated weight	
	cc		*g*	*Pct.*
Orthoclase	0.087	2.56	0.22	8.1
Plagioclase (andesine Ab57-An 43) . . .	.580	2.65	1.54	55.9
Quartz.	.094	2.65	.25	9.1
Green hornblende . .	.108	3.2	.35	12.6
Brown biotite	.131	3.0	.39	14.3
Total	1.000	2.75	2.75	100.0

[1] From standard mineralogy tables.

TABLE 8.–Morphology and mineral composition of the < 2-mm fraction of the soils

Soil, horizon, and depth	Minerals in order of abundance	Morphology of hornblende	Morphology of feldspars	Comments
Vista (S64Calif-37-1):				
A11, 0-3 inches. .	Rock fragments of feldspar, hornblende, and quartz; some grains of feldspar and quartz.	Clean hard surfaces; euhedral grains.	Clean hard surfaces but etched.	
B22, 28-35 inches .	Same.	Same.	Same.	
C1, 35-44 inches .	Coarse rock fragments of feldspar, hornblende, and quartz and some biotite.	Same.	Same.	
Fallbrook (S64Calif-37-2):				
A11, 0-2 inches. .	Rock fragments of feldspar, horblende, and quartz; a few grains of feldspar and quartz.	Hard surfaces; euhedral grains.	Commonly red stained and deeply etched but hard.	Most grains have a red stain.
B22t, 20-28 inches .	Same.	Same.	Commonly red stained and very deeply etched but hard.	Gravel is not stained; sample removed for X-ray analysis.
C3, 85-90+ inches	Same.	Same.	Clean and slightly etched but hard.	Same.
Bonsall (S64Calif-37-3):				
A11, 0-6 inches. .	Rock fragments of feldspar, hornblende, and quartz.	Hard surfaces; euhedral grains.	Deeply etched; some soft.	Reddish brown stain on all grains.
A11, 0-6 inches. .	Rock fragments of feldspar, hornblende, and	Hard surfaces; euhedral grains.	Deeply etched; some soft.	Reddish brown stain on all grains.
A2, 6-10 inches .	Similar to the A11 except that grains of quartz are common.	Deep reddish stain in some grains.	Deeply etched; commonly soft.	Same.
B21t, 14-27 inches .	Mostly quartz; some feldspar and hornblende.	Same.	Same.	Same.
B22tca, 27-38 inches .	Rock fragments of feldspar, hornblende, and quartz and similar amount of carbonate fragments.	Same.	Same.	Same.
B31, 38-48 inches .	Secondary aggregates of fine-grained rock material; one aggregate a tubule composed of successive layers of reddish brown clay and siliceous material.	None.	None.	Most aggregates slake in 1 *N* HCl but not the tubule.
B32, 48-60 inches .	Rock fragments of feldspar, hornblende, and quartz.	Hard surfaces; euhedral grains.	Slightly etched but hard.	A few feldspar grains are stained.
C1, 60-89 inches .	Same.	Same.	Slightly etched powdery surface but hard beneath.	A few feldspar grains are stained; sample removed for X-ray analysis.
IIC2, 89-110 inches	Same.	Same.	Finely etched earthy appearance; soft but grains not waxy.	Sample removed for X-ray analysis.
Bosanko (S64Calif-37-8):				
Ap, 0-4 inches. .	Quartz and some feldspar.	None.	Powdery and soft.	Very little gravel.
A11, 4-18 inches .	Quartz and some rock fragments of quartz, hornblende, and feldspar.	Hard surfaces; euhedral grains.	Etched but hard.	Same.
ACca, 22-28 inches .	Rock fragments of feldspar, hornblende, and quartz; a few quartz grains.	Same.	Soft, waxy, and pale green.	Same.
C2, 45-57+ inches	Rock fragments of feldspar, hornblende, and quartz.	Same.	Smooth surfaces; soft and waxy when scratched; pale green; feldspar cleavage retained.	Sample removed for X-ray analysis.

TABLE 9.--Secondary minerals detected in clay and sand fractions and in weathered biotite and feldspar minerals by X-ray analysis

[Relative amount based on height of diagnostic X-ray peaks is shown by the following symbols: o, none detected; tr, detected but very small; x, detected but small; xx, moderate; xxx, large; and xxxx, dominant]

Soil, horizon, and depth	Soil material	Montmorillonite	Vermiculite	Illite	Kaolinite	Hydrobiotite
Vista (S64Calif-37-1):						
All, 0-3 inches	Clay	0	0	xxxx	xx	tr
	Sand	0	tr	xxxx	x	0
A12, 3-9 inches	Clay	0	xxx	0	xx	x
A13, 9-19 inches	Clay	0	xxx	0	xx	x
B21, 19-28 inches	Clay	0	xxx	0	xx	x
B22, 28-35 inches	Clay	0	xx	tr	xxx	x
	Sand	0	xxx	0	tr	xxx
C1, 35-44 inches	Clay	0	xxxx	0	xx	tr
	Sand	0	xxx	0	tr	xxx
C2, 44-61+ inches	Clay	0	xxxx	0	xx	tr
	Sand	0	xxx	xx	tr	x
	Weathered biotite	0	x	0	tr	xxxx
	Weathered feldspar	0	0	tr	o	0
Fallbrook (S64Calif-37-2):						
All, 0-2 inches	Clay	0	0	xxxx	xx	tr
	Sand	0	0	xxxx	xx	0
A12, 2-6 inches	Clay	0	0	xxxx	xx	0
A3, 6-12 inches	Clay	0	0	x	xx	xxxx
B21t, 12-20 inches	Clay	0	x	x	xxx	xxx
B22t, 20-28 inches	Clay	0	tr	xx	xxxx	tr
	Sand	0	xx	x	x	xxx
	Weathered feldspar	0	0	0	0	0
B3, 28-47 inches	Clay	0	tr	xx	xxxx	tr
	Sand	0	xxx	0	x	xx
	Weathered biotite	0	xxx	0	x	xx
	Weathered feldspar	0	0	0	0	0
C1, 47-68 inches	Clay	0	x	xx	xxx	tr
	Sand	tr	xxx	0	x	xx
C3, 85-90+ inches	Clay	x	xx	xx	xx	tr
	Sand	0	xx	0	x	xxx
	Weathered biotite	0	xx	tr	0	xxxx
	Weathered feldspar	0	0	0	0	0
Bonsall (S64Calif-37-3):						
A1, 0-6 inches	Clay	0	tr	xxxx	xx	tr
	Sand	0	0	xx	xx	0
A2, 6-10 inches	Clay	xx	tr	x	xx	xx
B1, 10-14 inches	Clay	xx	x	tr	xxx	tr
B21t, 14-27 inches	Clay	xxx	tr	tr	xxx	tr
	Sand	0	0	0	0	0
	Weathered feldspar	0	0	0	0	0
B31, 38-48 inches	Clay	xxx	0	tr	xx	tr
	Sand	x	xxx	0	x	x
C1, 60-89 inches	Clay	xxx	0	tr	xx	tr
	Sand	x	xxx	0	x	x
	Weathered biotite	0	xxx	0	0	xx
	Weathered feldspar	0	0	0	0	0
IIC2, 89-110 inches	Weathered feldspar	xx	0	0	0	0
IIC3, 110-120+ inches	Clay	xxx	0	x	xx	tr
	Sand	xxxx	xx	0	tr	0

TABLE 9.--Secondary minerals detected in clay and sand fractions and in weathered biotite and feldspar minerals by X-ray analysis -- continued

Soil, horizon, and depth	Soil material	Montmorillonite	Vermiculite	Illite	Kaolinite	Hydrobiotite
	Weathered biotite	0	xx	0	0	xxx
	Weathered feldspar	xxx	0	0	0	0
Bosanko (S64Calif-37-8):						
All, 4-18 inches	Clay	xxxx	0	0	x	tr
	Sand	tr	0	0	0	0
C2, 45-57+ inches	Clay	xxxx	x	0	0	tr
	Sand	xx	xxxx	0	0	0
	Weathered biotite	0	xxx	0	0	xx
	Weathered feldspar	xxxx	0	0	0	0
Bosanko (S64Calif-37-9):						
All, 5-18 inches	Clay	xxxx	xx	0	tr	0
C1, 30-48+ inches	Clay	xxx	xxx	0	tr	0

hornblende grains, amounted to less than 10 percent of the sample. The samples, dried at 40° C., split into three density (grams per cubic centimeter) fractions (>2.96, 2.50 to 2.96, <2.50). All the weathered biotite is in the 2.50 to 2.96 fraction except that in the C2 horizon of Bosanko soils, some of which is in the <2.50 fraction. None of the weathered biotite from the soils is in the >2.96 fraction, but all the biotite from the hard rock is in this fraction.

We determined the cation-exchange capacity of some of this material ground to <5 microns in acetone (table 10). The exchange capacity of an unground sample of weathered mica of the All horizon of Vista soils is 28 meq per 100 g, and that of a ground sample is 33 meq per 100 g, indicating that grinding increases the exchange capacity only slightly. Weathered mica, illite, from the A11 horizon of Vista soils has a density of 2.50 to 2.96. Weathered mica from the A11 horizon of Fallbrook soils with the same range of particle density and the same composition has an exchange capacity of 21 meq per 100 g. Weathered mica of the B horizon of both soils has the same density range and consists of vermiculite and hydrobiotite, but the exchange capacity is higher than for illite. If we assume a cation-exchange capacity of about 40 meq per 100 g for hydrobiotite, the vermiculite would have an exchange capacity of about 105 meq per 100 g, a value near that determined by Rhoades (1967) for vermiculite from Vista soils and by LeRoux et al. (1963) for vermiculite from Hanford soils. The exchange capacity of weathered mica of the C horizon of Vista and Fallbrook soils (table 10), which is a mixture of vermiculite, hydrobiotite, and illite (table 9), also is higher than that of most illites. The clay minerals in ground samples of whole-sand fractions (table 9) account for the high ratio of cation-exchange capacity to clay content noted earlier.

Since the sum of the diagnostic peaks of the X-ray diffraction patterns is nearly constant (table 9), we could estimate the amount of individual clay minerals from the ratio of peak heights by the method of Coleman and Jackson (1945) and by similar methods, the amount of clay minerals in coarser fractions.

DISCUSSION

Origin of grus

Grus, the parent material of the soils of this study, is a product of the weathering of tonalite in place. The grus has retained the structure of tonalite but, where not cemented by illuviated clay from the overlying soil, it has loose consistence. Fragments are individual primary minerals or aggregates of a few primary minerals. In the field, the primary minerals of the grus underlying Vista and Fallbrook soils appear unweathered and those in the grus underlying Bonsall and Bosanko soils, only slightly weathered.

Wahrhaftig (1965) has proposed that grus formation results from shattering of tonalite by the partial alteration and expansion of biotite. Our results confirm the importance of this mechanism in the initial phases of weathering.

Tonalite in the San Luis Rey watershed of San Diego County is 14.3 percent biotite (table 7). In grus formed

TABLE 10.–Cation-exchange capacity and mineralogy of some density separates of weathered biotite samples[1]

[Relative amount based on height of diagnostic X-ray peaks is shown by the following symbols: 0, none detected; tr, detected but very small; x, detected but small; xx, moderate; xxx, large; and xxxx, dominant. —indicates that determination was not made]

Soil, horizon, and depth	Density separate	Weathered biotite in sample	Cation-exchange capacity (Na_2OAc)	Montmorillonite	Vermiculite	Illite	Hydrobiotite	Kaolinite
	g/cc	*Pct.*	*meq/100 g*					
Vista (S64Calif-37-1):								
All, 0-3 inches	2.50-2.96	97	33	0	tr	xxxx	tr	tr
B22, 28-35 inches	2.50-2.96	96	66	0	xx	0	xxx	tr
C2, 44-61 inches	2.50-2.96	93	46	—	—	—	—	—
Fallbrook (S64Calif-37-2):								
All, 0-2 inches	2.50-2.96	84	21	0	0	xxxx	0	tr
B22t, 20-28 inches	2.50-2.96	92	75	—	—	—	—	—
C3, 85-90+ inches	2.50-2.96	97	53	—	—	—	—	—
Bosanko (S64Calif-37-8):								
C2, 45-57 inches	2.50-2.96	26	82	—	—	—	—	—
	< 2.50	74	97	x	xxx	0	xx	0

[1] Sands were ground to dryness in acetone three times, yielding estimated particle size of < 5 microns.

from this tonalite the biotite has been almost completely changed to vermiculite. Grus fragments also contain grains of feldspar, quartz, and hornblende, but biotite is rare (table 8). Feldspars are etched but usually hard. Hornblende grains apparently are unweathered.

Inasmuch as the grus has retained the texture of tonalite and quartz veins in the same general area have not been displaced, we can assume that the spatial arrangement has not been greatly changed by weathering. Hence, we can use bulk density of the grus as a measure of the degree of weathering.

The bulk density of the C horizon on the whole-soil basis[7] is 2.20 in Vista soils, 2.00 in Fallbrook soils, and about 1.78 (average of that in C1 and IIC3) in Bonsall soils, reflecting an increasing degree of weathering in that sequence. Yet the bulk density of the C horizon of Vista soils is much lower than that of fresh tonalite, 2.75.

On the basis of its potential expansion on weathering, density of biotite should be reduced from 3.1 g per cubic centimeter to 2.2 g, yielding a particle density of about 2.6 g for the whole rock. Measured values (table 6) are of this order of magnitude. Since biotite grains are smaller than feldspar and hornblende grains, swelling of biotite produces many small cracks between the larger grains. By making different assumptions about the size and arrangement of biotite grains, we can calculate a maximum decrease of bulk density to about 1.9 g per cubic centimeter. Such expansion should cause some rock displacement and shifting of quartz veins, but grus retains the structure of the rock. Even if all the decrease in bulk density in Vista soils is caused by the swelling of biotite, any further decrease in bulk density must be caused by the loss of some constituents in weathering. There is abundant evidence of feldspar alteration in Bonsall soils but little in Fallbrook soils though the bulk density of the B horizon in both soils is the same. Hence some weathering of primary minerals in Fallbrook soils must occur without the formation of secondary minerals. It is also possible that the feldspar in Vista soils has undergone more weathering than is apparent. This assumption is supported by observations of etching and pitting of some feldspars in these soils (table 8). Expansion of biotite on weathering to vermiculite probably causes the rock mass to separate into grus granules, but the bulk density of the C horizon of Vista and Fallbrook soils cannot be explained fully on the basis of biotite expansion alone. Evidently some loss of constituents through weathering accompanies or follows rock fragmentation.

[7] The calculated bulk density of the < 2-mm fraction given in the data sheet is 1.97.

The differences in weathering patterns between these soils extend to the greatest depth studied. It is most likely that the patterns converge at greater depth, but deep sampling was not possible with the equipment available.

Weathering patterns

The mineralogical studies suggest three kinds of soil-weathering environment—that in Vista and Fallbrook soils, that in Bosanko soils, and an intermediate kind in Bonsall soils.

The Vista-Fallbrook environment is characterized by base saturation of less than 90 percent, the absence of salts in the soil solution, and small amounts of exchangeable magnesium and sodium. In this environment, biotite weathers to vermiculite and kaolinite. Other primary minerals seem to be stable. Kaolinite forms mostly within the solum, but vermiculite forms in and probably below the deepest horizon sampled. Fallbrook soils are the more weathered of the two kinds of soil. Their kaolinite content is about twice that of Vista soils and is a maximum for soils of the toposequence.

In contrast Bosanko soils have significant amounts of soluble salts and large amounts of exchangeable sodium and magnesium. In this environment biotite weathers to vermiculite and montmorillonite and feldspar weathers to montmorillonite. Secondary carbonate accumulates to form a thin *ca* horizon. Amorphous silica also occurs as tubules and linings around some voids of lower horizons, suggesting that feldspar weathering produced more silica than was removed by leaching and by montmorillonite formation.

The weathering environment of Bonsall soils is intermediate between that of the other kinds of soil. Their upper solum is slightly leached and some soluble ions, especially sodium, magnesium, and in places carbonates, have accumulated in the lower solum. Feldspar has weathered but to a lesser degree than in Bosanko soils; we identified montmorillonite in feldspar pseudomorphs. Biotite has weathered to vermiculite and kaolinite. In Bonsall soils the kaolinite maximum is in the upper part of the soil and is slightly smaller than that in Fallbrook soils. Apparently, kaolinite formation decreases as the conditions for montmorillonite formation become more favorable. Amorphous silica also occurs in the lower solum.

Weathering of individual mineral species, then, can be summarized as follows. Biotite weathers to vermiculite during the transformation of tonalite to grus. In the solum it weathers further to kaolinite, depending on the amount of leaching and on the composition of the leaching solution. Alteration of biotite to vermiculite under freely drained conditions has been reported by Denison et al. (1929), Walker (1949), and Kato (1964). Kaolinite pseudomorphs after biotite have been reported by Barshad (1948) and Sand (1956). Under alkaline conditions some biotite weathers to montmorillonite. Andesine seems to be more stable than biotite. It has not weathered to secondary minerals in the freely drained soils. In the soils having somewhat restricted drainage andesine is about 50-percent to 75-percent weathered. Montmorillonite is the weathering product of both andesine and hornblende. Montmorillonite as a weathering product of feldspar has been reported by Fournier (1965).

In order of increasing stability the sequence of minerals in grus is biotite, andesine, hornblende, and quartz. Kato (1964) observed the same sequence of mineral stability in grandiorite under oxidizing conditions in Japan. But this sequence does not agree with some of the more generally accepted sequences reported by Goldich (1938), Pettijohn (1941), and Jackson and Sherman (1953). The difference may be due to the weathering conditions or to the chemical composition of the biotite and hornblende reported in this study. Both Kato and we consider expansion to 14Å evidence of weathering, which may account for the difference in the position of biotite in the sequence. This "weathered" biotite, however, appears "unweathered" in grain mounts under a petrographic microscope.

Genesis of the natric horizon

The Bt horizon of Bonsall soils and the C horizon of Bosanko soils are horizons of sodium accumulation; the first meets the criteria of a natric horizon. The B horizon of Bonsall soils and the C horizon of Bosanko pedon S64 Calif–37-9 are also horizons of salt accumulation and are saline according to the definition of the U.S. Salinity Laboratory (Richards, 1954).

Inasmuch as chloride is the dominant anion in the saturation extract and tonalite contains almost no chloride, some chloride, presumably sodium chloride, must have been added from an outside source. Salts in rainwater and dust are the most likely sources. The only pedon that could have received salts from the leaching of nearby marine sediments, Bosanko S64 Calif–37-8, contains almost no chloride. The concentration of exchangeable sodium and salt in Bonsall soils, which occur on foot slopes, can be explained by the accumulation of salt and sodium introduced by laterally moving water. But the site of Bosanko pedon S64 Calif–37-9 does not receive water from surrounding areas. It is most likely that salts have accumulated in Bonsall and Bosanko soils and not in Vista and Fallbrook soils primarily because soils in the first group are slowly drained and those in the other are freely drained.

Inasmuch as the total amount of extractable sodium in the sodic and saline horizons greatly exceeds the amount of chloride, most of the sodium in Bonsall and Bosanko soils must have come from the release of sodium in the weathering of primary minerals. Since Bonsall and Bosanko soils are more highly weathered than Fallbrook and Vista soils, they can be expected to release more soluble cations. The amount of calcium and sodium released through weathering (table 11) greatly exceeds the amount of these cations retained as $CaCO_3$ and in exchangeable and soluble forms.

The accumulation of exchangeable sodium in the B and C horizons probably is caused by preferential adsorption of calcium and magnesium on the exchange complex in the A1 horizon and removal of calcium from the exchange reaction as $CaCO_3$ through a progressive

TABLE 11.–Sodium and calcium in Bonsall and Bosanko soils and in tonalite

Item	Bonsall soil to depth of 1.5 m	Bosanko soil to depth of 1.5 m
Weight ovendry soil[1] . . . . grams .	281.2	270.7
Extractable sodium in ovendry soil . . . . grams .	.21	.26
Extractable calcium in ovendry soil . . . . grams .	.65	1.66
Calcium in carbonate form[2] . . . . grams .	.67	.2
Extractable and carbonate calcüim (sum) . . . . . . grams .	1.32	1.86
Ratio of calcium to sodium	6.5	7.2
Tonalite		
Item	50-percent weathered[3]	75-percent weathered[4]
Sodium released . . . . grams .	3.93	5.67
Calcium released . . . . grams .	4.87	9.38

[1] Weight to depth of 1.5 m on basis of assumed volume of 152.4 cc.
[2] If pure $CaCO_3$.
[3] On basis of weathering of andesine, which is 55.9 percent by weight of tonalite (table 7). A weight equivalent to that of Bonsall soils (281.2 g) was used in the calculations. The degree of weathering was estimated from the proportion of andesine in the Bonsall solum and in tonalite.
[4] On basis of weathering of andesine, which is 55.9 percent by weight of tonalite (table 7). A weight equivalent to that of Bosanko soils (270.7 g) was used in the calculations.The degree of weathering was estimated from the proportion of andesine in the Bosanko solum and in tonalite.

concentration of the soil solution with depth as proposed by Peterson[8] and Wilding (1963). All the horizons of significant sodium accumulation contain measurable $CaCO_3$.

Origin of the illite of the A horizon

Leggett reported material with X-ray spacing of 10Å in the A horizon of soils that have no mica in lower horizons.[9] This distribution is common in soils of drier Western States and occurs in Vista, Fallbrook, and Bonsall soils. The 10Å material in the upper part of the solum of these soils suggests either that weathering intensity is less in the A horizon than in lower horizons or that a secondary process resynthesizes mica in the A horizon.

Supplementary studies of silt and sand fractions (tables 6, 9, and 10 and the discussion on p. 17) show that sand- and silt-size 10Å material from the A horizon approaches biotite in particle density, cation-exchange capacity, and refractive index. It differs significantly in these properties from weathered biotite pseudomorphs in the B horizon and slightly from fresh biotite in the parent rock.

The particle density in water of silt- and sand-size 10Å material in the A11 horizon of Vista and Fallbrook soils is 2.4 and 2.6, distinctly lower than that of fresh biotite (>2.94), but the density in a nonpolar liquid (3.0) is the same as that of fresh biotite. Hence, the 10Å material in the A11 horizon can expand on hydration.

The refractive index (Ny and Nz) of 1.64 to 1.65 of the 10Å material is slightly lower than that of fresh biotite (1.65 to 1.66). The flakes have a golden yellow color, many brown islands, and rough plane surfaces. The 10Å material in the A horizon is thus intermediate between vermiculite and biotite (Le Roux et al., 1963).

The cation-exchange capacity of biotite flakes from the A11 horizon of Vista and Fallbrook soils ground to <5 microns (table 10) is 33 meq per 100 g and 21 meq per 100 g, much less than that of weathered biotite pseudomorphs of the B and C horizons. The cation-exchange capacity, however, is within the accepted range for clay-size illite.

Alteration of biotite to vermiculite, the first step in grus formation, presumably occurred before the soils began to form. Though some sand-size hydrobiotite remains in the C horizon of Vista and Fallbrook soils, all the biotite in the B2 horizon has changed to vermiculite or kaolinite. Inasmuch as the A horizon must have formed from materials containing vermiculite instead of biotite, we would not expect the A horizon to contain primary mica. Furthermore, since there is no apparent difference in the cumulative percentages for nonclay fractions of the A and B horizons (fig. 13), we would not expect weathering in the A horizon to be any less intense than that in the B horizon. Hence we would not expect 10Å material of the A horizon and of the clay fraction of the B horizon of some soils to be relict biotite bypassed by the weathering front; it is more likely secondary mica (illite). Apparently the illite formed by the fixation of potassium and possibly of some ammonium by vermiculite, causing the collapse from a c spacing of 14Å to one of 10Å.

Homogenization of the B horizon

Data on clay content, moisture retention, and exchange capacity indicate that of the soils studied Bonsall soils have the most strongly expressed horizon of clay accumulation. Yet there is no morphological evidence of clay translocation in those parts of the B horizon having the highest proportion of clay. Hence, we must conclude that clay illuviation has not produced recognizable bodies of illuviated clay, or that the clay

[8] Peterson, F. F. Solodized solonetz soils occurring on the uplands of the Palouse loess. Unpublished Ph.D. thesis, Washington State Universitv. 1961.
[9] Leggett, G. E. Ammonium fixation in soils and minerals. Unpublished Ph.D. thesis, Washington State University, 1958.

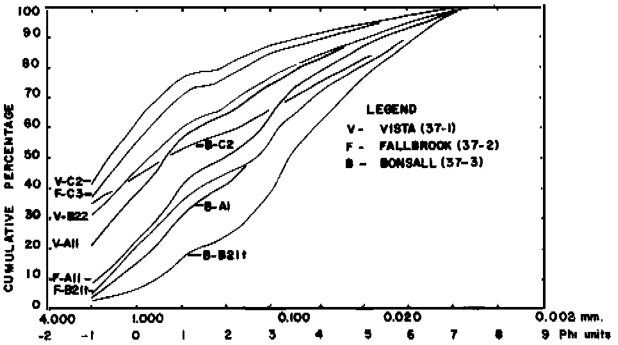


Figure 13.--Plot of cumulative percentages of nonclay fractions of Vista, Fallbrook, and Bonsall soils.

maximum in the B horizon formed through differential weathering as proposed by Nikiforoff (1937), or that the apparent clay increase in the Bt horizon reflects a lithological discontinuity and is not related to pedogenesis.

The particle-size distribution of the nonclay fractions (fig. 13) of the A and B horizons of Bonsall soils is similar enough to exclude the possibility that the apparent clay increase is due to differential weathering or to a lithologic discontinuity. Nor do the mineralogical studies (table 8) indicate a discontinuity or a distinctly different degree of weathering. The deficit of clay in the A horizon and the buildup of clay in the Bt horizon as compared to the C horizon suggests that the natric horizon of Bonsall soils formed by illuviation of clay from the A horizon. Several lines of evidence suggest that shrinking and swelling or drying and wetting either prevented the formation of clay skins or destroyed any clay skins that formed. The presence of clay skins in horizons having a COLE value of less than 0.04, such as the B32t horizon of Bonsall soils and the B2t horizon of Fallbrook soils and their absence in horizons of higher shrink-swell potential, such as the B2t horizon of Bonsall soils and the AC horizon of Bosanko soils, suggests a relation between the COLE value and the distribution of identifiable clay skins.

The distribution of biotite pseudomorphs is an independent measure of the degree of homogenization of clay skins. Although clay skins may not have formed in horizons where there are none now, biotite pseudomorphs were inherited from the parent material and must have been destroyed in horizons in which they are lacking now. Since they are lacking in horizons having a COLE value of more than 0.045, they probably were destroyed by pedoplasmation. Dispersion after weathering to kaolinite is another possible mechanism for destroying biotite pseudomorphs. But dispersion seems to be of minor importance since, in soils having a high COLE value in the B horizon, the A horizon commonly has more biotite pseudomorphs than the B horizon.

Biotite pseudomorphs are more stable than clay skins. Although clay skins are lacking in horizons with a COLE value of more than 0.037, there are a few biotite pseudomorphs in horizons with a value of 0.045 (table 5).

Probably some clay skins formed in an early stage of the development of Bonsall soils but were destroyed as additional highly shrinking and swelling clays accumulated. Any clay now moved into the Bt horizon is incorporated in the clay matrix during the next swelling cycle.

Genesis of the soils

Vista soils—Genesis of Vista soils is strongly influenced by topographic position and burrowing of ground squirrels. Vista soils are on the hilltops and upper back slopes in the toposequence. Most of the rainfall percolates through the soil, removing the more soluble weathering products, and there is little runoff. The solum is drier for more of the year than that of any of the other soils of the toposequence. Biotite weathers to vermiculite and smaller amounts of kaolinite, but the weathering products remain mostly in silt- and sand-size biotite pseudomorphs. Feldspar surfaces are slightly etched, but there are no identifiable weathering products.

Ground squirrels mix the A and B horizons with the underlying grus, resulting in a thickened A horizon, a very weakly expressed intermittent B horizon, and an irregular abrupt B-C boundary. Because of the scarcity of clay, the C horizon is more friable than that of the other soils and ground squirrels can burrow in it. In contrast ground squirrels seldom inhabit Fallbrook and Bonsall soils.

Although there are a few clay skins in the B horizon, not enough clay has accumulated for it to be an argillic horizon. The reason probably is twofold. First, weathering is so weak and the biotite pseudomorphs are so resistant to dispersion that not much fine clay susceptible to eluviation has formed. Second, mixing of horizons may have further retarded clay accumulation and weathering, although the weak weathering probably explains the preference of ground squirrels for this soil.

The B horizon has been changed enough to be a cambic horizon since there is no rock structure and the chroma in at least part of the horizon is stronger than that of the C horizon. The clay increase from the A horizon to the B is not enough to meet the requirements of an argillic horizon.

Fallbrook soils—Fallbrook soils are more intensely weathered than Vista soils. Soil-forming processes have extended to a greater depth, and more clay has been moved from the A horizon to the B. The stronger development of this soil may be due in part to water that has moved laterally from sites of Vista soils and in part to the greater water-holding capacity after soil formation began. Although apparently alteration of primary minerals in the C horizon is about the same as in Vista soils, the bulk density is less, suggesting more weathering than can be detected by mineralogical methods. Intense weathering in the Bt horizon is reflected by the high kaolinite content.

The clay in the Bt horizon may be due in part to formation in place as reflected by the high kaolinite content, in part to weathering and breakdown of silt- and sand-size pseudomorphs, and in part to illuviation of clay moved from the A horizon. In pedon S64 Calif–37-2 clay skins make up about one-fourth of the estimated total volume of clay in the B21t horizon and three-fourths of that in the B22t horizon (table 12). On this basis, if there is no eluviation from the B21t horizon, about one-half of the clay in the argillic horizon is illuvial. But estimates of clay translocation based on the clay content of the soil are somewhat lower. On the basis of 15-bar water retention illuviated clay is about one-fifth of the total clay in the B2t horizon of pedon S64 Calif–37-2 (fig. 14). The corresponding value for pedon S64 Calif–37-6, which has a less strongly expressed argillic horizon, is one-half.

It seems that at most clay illuviation accounts for one-half of the clay in the argillic horizon. Weathering of vermiculite and possibly of other minerals and disaggregation of biotite pseudomorphs in place must account for much of the remainder. But estimates of clay illuviation based on the volume of clay skins are too low if clay skins have been destroyed by shrinking and swelling of the soil mass, by root growth, or by soil fauna. Estimates based on the clay content of the soil are too low if part of the A horizon has been removed by erosion.

Bonsall soils–Bonsall soils typically occur on lower back slopes and foot slopes. Water accumulates through runoff and seepage from higher areas and the sites are wet for long periods. This causes more complete weathering than in Vista and Fallbrook soils, which in turn causes slower permeability and increased wetness. Biotite has weathered to vermiculite and kaolinite, and andesine has weathered partially to montmorillonite. The weathering environment is rich in silica and bases, notably sodium and magnesium, which favors the formation of montmorillonite and not kaolinite.

TABLE 12.--Calculated eluviation of clay in Vista, Fallbrook, and Bonsall soils

Soil, horizon, and depth		Volume of cross section			Weight of moved clay[1]	Ratio of moved clay to total clay (by weight)[2]
		Clay skins	Clay bridges	Total		
Vista (S64Calif-37-1):		*cc*	*cc*	*cc*	*g*	
All,	0-3 inches	0	0	0	0	0
B21,	19-28 inches	0.3	0	0.3	0.4	5
B22,	28-35 inches	1.3	0.3	1.6	2.0	15
C1,	35-44 inches	2.3	0	2.3	2.9	40
C2,	44-61+ inches	0	0	0	0	0
Fallbrook (S64Calif-37-2):						
All,	0-2 inches	0	0	0	0	0
B21t,	12-20 inches	1.3	0.3	1.6	2.0	10
B22t,	20-28 inches	3.7	2.7	6.4	8.2	30
B3,	28-47 inches	6.0	5.7	11.7	15.0	80
C1,	47-68 inches	5.7	1.7	7.4	9.5	70
C2,	68-85 inches	2.3	1.0	3.3	4.2	30
C3,	85-90+ inches	.3	.7	1.0	1.3	10
Bonsall (S64Calif-37-3):						
A1,	0-6 inches	0	0	0	0	0
A2,	6-10 inches	0	0	0	0	0
B1,	10-14 inches	1.0	0	1.0	1.3	5
B21t,	14-27 inches	0	0	0	0	0
B22tca,	27-38 inches	0	0	0	0	0
B31,	38-48 inches	1.0	0	1.0	1.3	5
B32,	48-60 inches	3.3	2.3	5.6	7.2	25
C1,	60-89 inches	0	0	0	0	0

[1] Weight of argillans equals volume of argillans in cubic centimeters × 1.28 g per cubic centimeter. Bulk density of argillans was estimated by allocating all the ovendry porosity of the A12 horizon of Bosanko pedon (S64Calif-37-8-3) to the clay fraction and assuming a particle density of 2.65.

[2] Some horizons of these soils contain clays that disperse poorly. Estimates of clay content are therefore based on water-retention data, e.g., 2.8 percent clay equals 1 percent water at 15-bar tension. Values are reported to the nearest 5 percent.

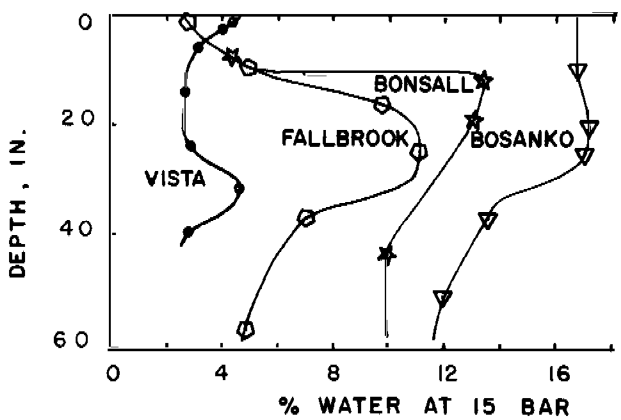


Figure 14.–Distribution of clay as estimated by 15-bar water.

We believe that a good deal of clay has moved though the major evidence is the significant clay increase from the A horizon to the B. Distinct clay skins occur only in the lower solum. There are two possible explanations for the absence of clay skins in the upper part of the B horizon. Either none or only a few formed because of the instability of ped faces and pores or soil movement destroyed any that formed.

Bosanko soils–Bosanko soils are in places of subdued relief. Like Bonsall soils they receive surface runoff and perhaps some seepage. Because of these external contributions of water and their large capacity for holding water, Bosanko soils are wet for longer periods than Vista or Fallbrook soils. Salts accumulate within the solum since the rate of leaching is not fast enough to remove weathering products as they form. Hence weathering is active longer and in a more basic environment than in the other soils. Many minerals have been completely decomposed. Montmorillonite is the major clay mineral formed from the weathering of andesine. Biotite weathers to montmorillonite as well as to vermiculite. Because of the large amount of shrinking and swelling and the intense churning, no B horizon has formed. The uniform A horizon extends to a depth of about 2 feet, and salts are distributed uniformly. Much of the C horizon, like that of Bonsall soils, has weathered to clay. Most of the clay, however, has some of the physical properties of a loamy sand and is not dispersed by standard mechanical-analysis procedures.

LITERATURE CITED

Baldwin, Mark, C. E. Kellogg, and J. Thorp. 1938. Soil classification. *In* U.S. Dept. Agr. Ybk., Soils and Men. 1232 pp.

Barshad, I. 1948. Vermiculite and its relation to biotite as revealed by base exchange reactions, x-ray analysis, differential thermal curves and water content. Amer. Miner. 33: 655-678.

Brasher, B. R., D. P. Franzmeier, V. T. Valassis, and S. E. Davidson. 1966. Use of Saran resin to coat natural soil clods for bulk density and water-retention measurements. Soil Sci. 101: 108.

Brewer, Roy. 1964. Fabric and mineral analysis of soils. John Wiley and Sons, Inc., New York. 470 pp.

Coleman, R., and M. L. Jackson. 1945. Mineral composition of the clay fraction of several coastal plain soils of southeastern United States. Soil Sci. Soc. Amer. Proc. 10: 381-391.

Denison, I. A., W. H. Fry, and P. L. Gile. 1929. Alteration of muscovite and biotite in soil. U.S. Dept. Agr. Tech. Bull. 128. 32 pp.

Flach, K. W., J. G. Cady, and W. D. Nettleton. 1968. Pedogenic alteration of highly weathered parent materials. Trans. 9th Internatl. Cong. Soil Sci., Adelaide, Australia, 4. (In press).

Fournier, R. O. 1965. Montmorillonite pseudomorphic after plagioclase in a porphyry copper deposit. Amer. Miner. 50: 771-777.

Goldich, S. S. 1938. A study in rock weathering. J. Geol. 46: 17-58.

Harradine, F. F. 1950. The variability of soil properties in relation to stage of profile development. Soil Sci. Soc. Amer. Proc. 14: 302-311.

Harradine, F. F. 1963. Morphology and genesis of noncalcic brown soils in California. Soil Sci. 96: 277-287.

Jackson, M. L., and G. D. Sherman. 1953. Chemical weathering of minerals in soils. *In* Advn. Agrom. (A. G. Norman, ed.) 5, pp. 219-318.

Kato, Yoshiro. 1964. Mineralogical study of weathering products of granodiorite at Shinshiro City: (1) Occurrence and environmental conditions. Soil Sci. and Plant Nutr. 10: 258-263.

Larsen, E. S. 1951. Crystalline rocks of the Corona, Elsinore, and San Luis Rey quadrangles, southern California. *In* Crystalline rocks of southwestern California. Calif. Dept. Nat. Resources, Div. Mines Bull. 159. 136 pp.

Le Roux, F. H., J. G. Cady, and N. T. Coleman. 1963. Mineralogy of soil separates and alkali-ion and exchange-sorption. Soil Sci. Soc. Amer. Proc. 27: 534-538.

Mehra, O. P., and M. L. Jackson. 1959. Constancy of the sum of mica unit cell potassium surface and interlayer sorption surface in vermiculite-illite clays. Soil Sci. Soc. Amer. Proc. 23: 101-105.

Mortland, M. M. 1958. Kinetics of potassium release from biotite. Soil Sci. Soc. Amer. Proc. 22: 503-508.

Nikiforoff, C. C. 1937. General trends of the desert type of soil formation. Soil Sci. 43: 105-131.

Pettijohn, F. J. 1941. Persistence of heavy minerals and geologic age. J. Geol. 49: 610-625.

Rausell-Colom, J. A., T. R. Sweatman, C. B. Wells, and K. Norrish. 1965. Studies in the artificial weathering of mica. *In* Experimental Pedology, pp. 40-72. Proc. 11th Easter School in Agr. Sci., Univ. Nottingham, 1964. E. G. Hallsworth and D. V. Crawford, ed. Butterworths, London.

Rhoades, J. D. 1967. Cation exchange reactions of soil and specimen vermiculites. Soil Sci. Soc. Amer. Proc. 31: 361-365.

Richards, L. A., ed. 1954. Diagnosis and improvement of saline and alkali soils. U.S. Salinity Laboratory. U.S. Dept. Agr. Hdbk. No. 60. 160 pp.

Rogers, A. F., and P. F. Kerr. 1942. Optical mineralogy, 2nd ed. McGraw-Hill, New York.

Sand, L. B. 1956. On the genesis of residual kaolins. Amer. Miner. 41: 28-40.

Shaw, C. F. 1928. Profile development and the relationship of soils in California. 1st Internatl. Cong. Soil Sci., Washington, 1927, Proc. and Papers 4: 291-317.

Spock, L. E. 1953. Guide to the study of rocks. Harper Bros. New York.

U.S. Soil Conservation Service. 1967. Soil survey laboratory methods and procedures for collecting soil samples. Soil Survey Invest. Rpt. No. 1. 50 pp.

Van Hylckama, T.E.A. 1959. A nomogram to determine monthly potential evapotranspiration. U.S. Weather Bureau, Monthly Weather Rev. 87: 107-110.

Wahrhaftig, C. 1965. Stepped topography of the southern Sierra Nevada, California. Geol. Soc. Amer. Bull. 76: 1165-1189.

Walker, G. F. 1949. The decomposition of biotite in the soil. Miner. Mag. 28: 693-703.

Wilding, L. P., R. T. Odell, J. B. Fehrenbacher, and A. H. Beavers. 1963. Source and distribution of sodium in solonetzic soils in Illinois. Soil Sci. Soc. Amer. Proc. 27: 432-438.

APPENDIX

Auger traverse

Station 1 (fig. 1)

A11 0 to 5 inches, dark brown (7.5YR 3/2) loam (moist); common medium sand grains; massive; very hard when dry; clear smooth boundary.

A12 5 to 12 inches, grayish brown (10YR 5/2) medium to coarse sandy loam, dark brown (10YR 3/3) moist; massive; very hard when dry; gradual smooth boundary.

A13 12 to 20 inches, brown (10YR 5/3) heavy medium sandy loam, brown to dark brown (10YR 4/3) moist; hard when dry; base of alluvial material; clear smooth boundary.

IIA3 20 to 30 inches, yellowish brown (10YR 5/4) coarse sandy loam, brown to dark brown (7.5YR 4/4) moist; massive; hard when dry; base of pit, auger-sample observations below this depth; clear smooth boundary.

IIB2t 30 to 40 inches, light yellowish brown (10YR 6/4) coarse sandy clay loam, brown to dark brown (7.5YR 4/4) moist; common thin to thick clay films in voids and on peds; clear boundary.

IIB3t 40 to 48 inches, light yellowish brown (10YR 6/4) gravelly coarse sandy loam, dark yellowish brown (10YR 4/4) moist; common thin clay films in pores, thick films in joints and cracks; fragments of tonalite common; clear boundary.

IIC1 48 inches +, weathered tonalite grus.

Station 2 (fig. 1)

A1 0 to 30 inches, brown (10YR 5/3) medium sandy loam (silty), dark brown (10YR 3/3) moist; massive; very hard when dry; clear smooth boundary.

IIA2b 30 to 35 inches, pale brown (10YR 6/3) sandy loam, brown to dark brown (10YR 4/3) moist; massive; very hard when dry; abrupt smooth boundary.

IIB21tb 35 to 44 inches, brown (10YR 5/3) clay, dark brown (10YR 3/3) moist; many slickensides; very sticky, very plastic; base of pit, auger-sample observations below this depth; clear boundary.

IIB22tb 44 to 59 inches, light olive brown (2.5Y 5/4) clay, olive brown (2.5Y 4/4) moist; common moderately thick clay films in pores and on ped faces; very sticky, very plastic; clear boundary.

IIC 59 to 93 inches, weathered tonalite grus.

Station 3 (fig. 1)

A 0 to 55 inches, brown (10YR 5/3) sandy loam; common fine gravel; description below 40 inches from auger-sample observations; abrupt boundary.

B2tb 55 to 78 inches, brown (10YR 5/3) clay; common discontinuous very dark brown (10YR 2/2) coatings on ped surfaces; clay films in a few pores; clear boundary.

B3tb 78 to 96 inches, brown to dark brown (7.5YR 4/4) (moist), sandy clay loam; common medium discontinuous clay films on ped faces; feldspars soft; clear boundary.

C1g 96 to 122 inches, mottled olive (5Y 5/3), dark grayish brown (10YR 4/2), pale brown (10YR 6/3), and yellowish brown (10YR 5/8) (moist) clay; clear boundary.

C2 122 to 130 inches, weathered tonalite grus; brown to dark brown (7.5YR 4/4) (moist) sandy clay loam; few fine roots; few clay bridges and clay films in voids.

Station 4 (fig. 1)

Al 0 to 72 inches, brown (10YR 5/3) sandy loam; common fine gravel; auger-sample description; abrupt boundary.

IIB2tb 72 to 92 inches, dark brown (7.5YR 3/4) (moist) "gritty" clay; many small weathered feldspar particles; some slickensides; clear boundary.

IIB3tb 92 to 110 inches, brown to dark brown (7.5YR 4/4) (moist) "gritty" clay loam; clear boundary.

IIC1 110 to 135 inches, dark brown (10YR 3/3) (moist) coarse sandy loam; brittle when moist, may be the matrix of a weak duripan; clear boundary.

IIC2g 135 to 164 inches, olive (5Y 4/3) (moist) "gritty" clay; more weathered than IIC1; clear boundary.

IIC2 164 to 187 inches, olive brown (2.5Y 4/4) micaceous clay loam; clear boundary.

IIC3 187 inches +, weathered tonalite grus.

Station 5 (fig. 1)

AC 0 to 72 inches, grayish brown (10YR 5/2) coarse sandy loam, very dark brown (10YR 2/2) moist; much fine angular gravel; massive; description from auger sample; gradual boundary.

Cl 72 to 170 inches; yellowish brown (10YR 5/4) coarse sandy loam, dark yellowish brown (10YR 4/4) moist; much fine angular gravel; gradual boundary.

C2 170 to 223 inches, brown to dark brown (7.5YR 4/2) sandy loam (moist); wet in lower part; clear boundary.

IIC3 223 inches +, wet tonalite grus.

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Bonsall sandy loam SOIL Nos. S64Calif-37-3 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6430 - 6439

Depth (In.)	Horizon	1B1b Total: Sand (2–0.05)	Silt (0.05–0.002)	Clay (< 0.002)	Size class and particle diameter (mm) 3A1 — Sand: Very coarse (2–1)	Coarse (1–0.5)	Medium (0.5–0.25)	Fine (0.25–0.1)	Very fine (0.1–0.05)	Silt: 0.05–0.02	Int III (0.02–0.002)	Int II (0.2–0.02)	(2–0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a: > 2	2 – 19	19 – 76
		Pct of < 2 mm														Pct	Pct. of < 76 mm	
0- 6	A1	68.0	23.3	8.7	11.0	15.0	9.8	19.4	12.8	13.3	10.0	36.2	55.2	8.4	8.1	4	4	0
6-10	A2	62.9	24.7	12.4	9.3	13.6	9.0	18.6	12.4	13.9	10.8	36.2	50.5	11.0	10.7	3	3	0
10-14	B1	42.4	18.7	38.9	6.0	8.3	5.9	13.0	9.2	10.4	8.3	27.0	33.2	40.5	38.9	4	4	0
14-27	B21t	40.6	21.1	38.3	2.8	6.1	5.1	15.0	11.6	11.9	9.2	32.5	29.0	36.3	35.7	2	2	0
27-38	B22tca	48.2	23.3	28.5	2.0	4.1	5.5	20.8	15.8	13.8	9.5	42.3	32.4	29.0	28.1	3	3	0
38-48	B31	64.3	17.2	18.5	1.6	7.4	10.3	28.7	16.3	9.8	7.4	42.4	48.0	18.0	17.9	1	1	0
48-60	B32	69.8	10.8	19.4	3.3	14.1	16.4	27.9	8.1	7.2	3.6	29.0	61.7	19.6	19.1	2	2	0
60-89	C1	52.2	26.5	21.3	5.5	8.9	8.6	18.5	10.7	16.7	9.8	37.9	41.5	21.6	20.2	7	7	0
89-110	IIC2	56.5	29.3	14.2	12.8	12.1	6.9	13.8	10.9	12.6	16.7	30.8	45.6	20.4	12.0	31	31	0
110-120+	IIC3	50.5	32.5	17.0	3.3	10.8	8.0	16.2	12.2	12.7	19.8	33.8	38.3	18.4	17.2	7	7	0

Depth (In.)	6A1a * Organic carbon	6B1a * Nitrogen	C/N	*6C2a Ext. Iron as Fe	6E1b ** Carbonate as $CaCO_3$		Bulk density 4A1f 1/3 bar	4A1h Oven dry		3B2 C'	Water content	4B1c 1/3 bar	4B2* 15 bar	4D1 Extensibility COLEF	4D1 Extensibility COLE	pH 8C1b Saturated Paste	8C1a H_2O 1:1	8C1a H_2O 1:10
	Pct	Pct		Pct.	Pct.		g/cc	g/cc	g/cc		Pct.	Pct.	Pct.	in./in.	in./in.			
0- 6	0.70	0.054	13	0.7			1.51	1.54		0.98		10.6	4.2	0.006	0.006	6.5	6.6	
6-10	0.28	0.033	8	0.8			1.76	1.78		0.98		9.5	4.5	0.003	0.003	6.4	6.8	
10-14	0.47	0.047	10	1.6			1.60	1.85		0.98		20.1	13.9	0.049	0.048	6.5	6.8	
14-27	0.21			1.0			1.73	1.99		0.99		17.7	13.1	0.047	0.047	7.6	8.0	
27-38	0.11			0.9	3								12.6			7.8	8.1	
38-48	0.02			1.3			1.60	1.78		0.99		20.2	10.6	0.036	0.036	7.7	8.0	
48-60	0.02			1.2									9.4			7.6	8.0	
60-89	0.02			1.2			1.67	1.76		0.95		15.4	11.7	0.018	0.017	7.7	8.0	
89-110	<0.01			1.4									13.3			7.9	8.3	
110-120+	<0.01			1.3			1.59	1.69		0.96		20.8	15.0	0.021	0.020	7.7	8.1	

Depth (In.)	Extractable bases 5B1a: 6N2a* Ca	6O2a* Mg	6P2a* Na	6Q2a* K	Sum* of bases	6H2a* Ext. Acidity	Cation Exch. Capacity 5A2a* NaOAc	5A3a* Sum	Water extract from saturated paste 8A1: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 6	4.3	1.7	0.3	0.2	6.5	1.8	8.7	8.3	2.7	2.2	1.6	0.2		-	4.8	0.6		0.57
6-10	4.7	2.4	0.6	0.1	7.8	1.8	10.2	9.6	0.7	1.0	2.4	0.1		-	1.8	0.6		0.34
10-14	11.2	8.8	2.1	0.2	22.3	3.1	25.6	25.4	0.9	0.6	5.0	0.1		-	1.4	3.0		0.66
14-27	13.8	8.2	3.5	0.2	25.7	0.6	24.7	26.3	2.1	2.9	15.3	0.2		-	2.2	14.3		2.16
27-38	20.2	10.1	6.7	0.2	37.2	0.2	26.8	37.4	5.4	6.4	33.8	0.2		-	2.2	38.5		4.80
38-48	10.2	7.5	6.3	0.1	24.1	0.6	23.0	24.7	5.5	6.6	39.8	0.1		-	1.5	46.4		5.65
48-60	8.5	6.2	5.1	0.1	19.9	0.8	20.1	20.7	3.5	3.5	30.2	0.1		-	1.0	33.9		4.07
60-89	10.6	7.4	5.9	0.1	24.0	0.8	24.6	24.8	2.1	2.9	27.5	0.1		-	0.9	29.2		3.56
89-110	18.1	8.4	7.1	0.1	33.7	1.3	36.7	35.0	1.0	0.8	13.2	0.1		-	2.6	11.7		1.79
110-120+	14.1	8.6	5.9	0.1	28.7	1.3	31.0	30.0	1.0	0.8	12.8	0.1		-	1.0	13.1		1.74

Depth (In.)	8A Water at Saturation	5D2 Exchangeable Na	5F SAR	Base Sat. Cations	Base Sat. NaOAc CEC	Clay mineralogy (<0.002 mm) 7A — Relative abundance based on height of diagnostic X-ray peak 7A2: Mont.	Verm.	Hydrobiotite	Mica	Kaol.	% Kaol. (DTA) 7A3	% Kaol. in ground whole soil (DTA)
	Pct.	Pct		Pct.	Pct.	X-ray						
0- 6	25.8	2	1	78	73	-	t	t	xxxx	xx	15	1
6-10	19.8	5	3	83	77	xx	t	xx	x	xx		
10-14	44.7	7	6	88	86	xx	x	t	t	xxx		
14-27	50.8	11	10	98	101	xxx	t	t	t	xxx	26	14
27-38	49.6	19	14	99	133							
38-48	38.7	20	16	97	98	xxx	-	t	t	xx	20	10
48-60	33.9	20	16	96	94							
60-89	39.4	20	17	97	93						11	10
89-110	47.1	18	14	95	90							
110-120+	47.2	17	14	96	91						5	7

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis

** Analysis of ground whole soil; results expressed on whole-soil basis.

- \- = looked for but not found
- t = trace
- x = small
- xx = moderate
- xxx = abundant
- xxxx = dominant

BONSALL SANDY LOAM
S64Calif-37-3

Location: San Diego County, California. A soil profile pit located 2-1/4 miles south, 3/4 mile east of Fallbrook in the NE1/4 of the SW1/4 of section 31, T. 9 S., R. 3 W. Date of Sampling: February 18, 1964.
Description By: David C. Estrada and Gerald Kester. Collectors: Klaus Flach, George Borst, Gerald Kester, David C. Estrada and Leo Klameth.
Classification: Noncalcic Brown soil, Haplic Natrixeralf.
Vegetation: Annual grasses and annual weeds. Climate: This soil occurs under 15 inches of rainfall. The mean annual temperature is 60° F., the mean January temperature 54° F., and the mean July temperature 70° F. Parent Material: Tonalite grus. Topography: South-facing, smooth 8% slopes in lower backslope positions on rolling upland. Elevation: 545 feet above sea level. Drainage: Moderately well drained; very slowly permeable. Soil Moisture: Profile moist to about 15 inches.
Remarks: The texture of the C1 horizon is finer than the IIC2 or IIC3 horizons. This may reflect variation in grain size of the grus, differences in weathering of the horizons, or soil creep.

HORIZON	DESCRIPTION
A1 RSL No. 6430	0 to 6 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; moderate fine to medium crumb structure; hard, friable, slightly sticky and nonplastic; abundant very fine and fine, and few medium roots; many very fine and fine tubular pores; slightly acid (pH 6.2); abrupt smooth boundary.
A2 RSL No. 6431	6 to 10 inches, same as above except the horizon is massive, roots are plentiful, and pores common; abrupt smooth boundary.
B1 RSL No. 6432	10 to 14 inches, brown (7.5YR 5/4) heavy clay loam, dark brown (7.5YR 4/4) moist; moderate medium angular blocky structure; very hard, firm, sticky, and plastic; plentiful very fine and fine, and few medium roots; few fine and medium tubular pores; slightly acid (pH 6.5); clear smooth boundary.
B21t * RSL No. 6433	14 to 27 inches, yellowish brown (10YR 5/4) light clay, dark yellowish brown (10YR 4/4) moist; strong coarse prismatic structure; extremely hard, very firm, sticky and plastic; few very fine, fine and medium roots; few fine and medium tubular pores; many moderately thick clay skins on ped faces; mildly alkaline (pH 7.8); slightly effervescent; clear smooth boundary.
B22tca RSL No. 6434	27 to 38 inches, light yellowish brown (10YR 6/4) light clay, yellowish brown (10YR 5/4) moist; structure, consistence, roots, pores, clay skins and boundary same as above; moderately alkaline (pH 8.0); strongly effervescent; clear smooth boundary.
B31m RSL No. 6435	38 to 48 inches, brown (7.5YR 5/4) and reddish brown (2.5YR 5/4) sandy loam, dark brown (7.5YR 4/4) and reddish brown (2.5YR 4/4) moist; massive; very hard, firm, nonsticky and slightly plastic; few medium roots; few medium tubular pores; mildly alkaline (pH 7.8); clear smooth boundary.
B32 * RSL No. 6436	48 to 60 inches, same as above except this horizon is brown (7.5YR 4/4) when dry or moist.
C1 RSL No. 6437	60 to 89 inches, light brown (7.5YR 6/4) sandy clay loam, brown (7.5YR 5/4) moist; massive; very hard, friable, slightly sticky and slightly plastic; very few medium roots; few medium tubular pores; mildly alkaline (pH 7.8); clear smooth boundary.
IIC2 RSL No. 6438	89 to 110 inches, very pale brown (10YR 8/3), light yellowish brown (10YR 6/4) and very dark gray (10YR 3/1) tonalite grus of loamy coarse sand texture; mildly alkaline (pH 7.5); clear smooth boundary.
IIC3 RSL No. 6439	110 to 120 inches +, pale yellow (2.5Y 7/4-8/4) tonalite grus, loamy coarse sand in texture; neutral (pH 7.0); slightly less coherent than the IIC2 horizon.

* Soil horizons sampled for BPR

SOIL Bonsall sandy loam SOIL Nos. S64Calif-37-5 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6440 - 6449

Depth (In.)	Horizon	1B1b Total: Sand (2-0.05)	Total: Silt (0.05-0.002)	Total: Clay (< 0.002)	Size class and particle diameter (mm) 3A1 — Sand: Very coarse (2-1)	Sand: Coarse (1-0.5)	Sand: Medium (0.5-0.25)	Sand: Fine (0.25-0.1)	Sand: Very fine (0.1-0.05)	Silt: 0.05-0.02	Silt: Int. III (0.02-0.002)	Int. II (0.2-0.02)	(2-0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a: > 2 Pct.	2 - 19	19 - 76
		Pct. of < 2 mm														Pct.	Pct. of < 76 mm	
0-10	Ap	60.2	30.7	9.1	7.2	13.4	9.1	17.8	12.7	16.8	13.9	38.9	47.5	8.4	8.1	3	3	0
10-15	A2	58.9	30.3	10.8	8.1	13.2	8.6	16.8	12.2	16.4	13.9	37.9	46.7	10.7	10.4	3	3	0
15-20	B1	57.7	28.2	14.1	9.2	12.6	8.5	15.9	11.5	15.3	12.9	35.3	46.2	14.6	13.9	5	5	0
20-29	B21t	52.3	23.3	24.4	9.6	12.1	7.8	13.7	9.1	11.0	12.3	27.2	43.2	25.6	23.7	8	8	0
29-41	B22t	52.8	24.5	22.7	8.8	11.6	7.5	14.9	10.0	11.8	12.7	30.1	42.8	22.4	21.5	4	4	0
41-59	B23t	59.4	24.2	16.4	11.3	12.4	7.4	16.1	12.2	11.8	12.4	33.4	47.2	17.2	15.3	11	11	0
59-73	B24t	55.8	26.3	17.9	12.0	12.0	7.0	14.2	10.6	12.1	14.2	30.4	45.2	21.1	18.3	11	11	0
73-85	B25t	48.7	29.7	21.6	7.7	10.4	6.6	13.3	10.7	13.2	16.5	31.6	38.0	22.3	20.6	8	8	0
85-92	B3	45.8	33.2	21.0	9.4	10.3	5.8	11.3	9.0	12.2	21.0	27.5	36.8	21.8	18.7	14	14	0
92-100+	C	52.5	33.6	13.9	15.7	11.7	5.7	11.0	8.4	13.8	19.8	28.3	44.1	15.3	11.0	28	28	0

Depth (In.)	6A1a * Organic carbon Pct.	6B1a * Nitrogen Pct.	C/N	* 6C2a Ext. Iron as Fe Pct.	6E1b ** Carbonate as $CaCO_3$ Pct.		Bulk density: 4A1f 1/3 bar g/cc	Bulk density: 4A1h Oven dry g/cc	g/cc	3B2 C'	Pct.	Water content: 4B1c 1/3 bar Pct.	Water content: 4B2* 15 bar Pct.	4D1 Extensibility COLEF in./in.	4D1 Extensibility COLE in./in.	pH: 8C1b Saturated Paste	pH: 8C1a H_2O 1:1	pH: 8C1a H_2O 1:10
0-10	0.94	0.080	12	0.8			1.53	1.54		0.98		11.5	4.7	0.002	0.002	6.7	6.8	
10-15	0.26			0.8			1.59	1.60		0.98		13.0	5.2	0.002	0.002	7.0	7.2	
15-20	0.15			1.1			1.78	1.83		0.97		12.9	6.4	0.009	0.009	6.7	6.9	
20-29	0.16			1.2			1.75	1.85		0.95		16.2	10.6	0.019	0.018	6.8	7.1	
29-41	0.06			1.1									10.2			7.6	8.0	
41-59	0.04			1.0			1.66	1.71		0.93		21.9	8.5	0.010	0.009	7.8	8.1	
59-73	0.03			0.9									10.2			7.8	8.3	
73-85	0.04			1.1	<1		1.77	1.85		0.95		16.8	11.7	0.015	0.014	7.7	8.1	
85-92	0.01			1.2									13.5			7.6	8.0	
92-100+	0.01			1.5			1.65	1.71		0.81		19.5	12.0	0.012	0.010	7.7	8.1	

Depth (In.)	Extractable bases 5B1a: 6N2a * Ca	6O2a* Mg	6P2a* Na	6Q2a* K	Sum of bases	6H2a* Ext. Acidity	Cation Exch. Capacity: 5A2a* NaOAc	Cation Exch. Capacity: 5A3a* Sum	Water extract from saturated paste 8A1 **: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0-10	5.0	2.2	0.2	0.3	7.7	1.6	9.7	9.3	2.9	2.2	1.5	0.3		-	5.4	0.3		0.58
10-15	5.3	2.4	0.4	0.1	8.2	1.4	10.7	9.6	1.4	1.0	3.1	tr.		-	2.8	1.0		0.52
15-20	5.9	3.4	0.8	0.1	10.2	1.9	12.6	12.1	1.8	1.8	5.6	0.1		-	1.2	5.4		1.00
20-29	8.7	6.0	1.3	0.1	16.1	2.3	19.6	18.4	1.5	2.6	6.5	0.1		-	1.0	5.9		1.11
29-41	10.2	6.4	1.6	0.1	18.3	2.0	19.8	20.3	2.5	2.3	7.9	0.1		-	3.2	6.8		1.33
41-59	9.7	5.8	1.9	0.1	17.5	1.0	19.0	18.5	2.3	2.3	10.4	tr.		-	2.9	9.2		1.55
59-73	13.4	7.5	3.7	0.1	24.7	1.2	25.3	25.9	1.9	1.6	13.5	tr.		-	2.9	11.0		1.78
73-85	14.4	8.4	4.5	0.1	27.4	1.0	27.1	28.4	1.8	1.7	14.1	0.1		-	2.6	11.6		1.90
85-92	17.6	9.7	6.6	0.1	34.0	1.4	34.7	35.4	1.2	1.4	13.4	tr.		-	2.0	11.6		1.74
92-100+	18.1	8.8	7.1	0.1	34.1	1.2	33.6	35.3	1.0	0.8	11.1	tr.		-	1.8	9.2		1.46

Depth (In.)	8A * Water at Saturation Pct	5D2 Exchangeable Na Pct	5F SAR	Base Sat. Cations Pct.	Base Sat. NaOAc CEC Pct.	Clay mineralogy (<0.002 mm) 7A: Mont.	Verm.	Mica	Kaolin.	
						<—— X-ray ——>				
0-10	27.7	2	1	82	80					
10-15	21.6	4	3	85	76					
15-20	26.2	5	4	84	79					
20-29	39.0	6	5	87	81					
29-41	38.9	6	5	90	91					
41-59	37.6	8	7	94	91					
59-73	41.1	12	10	95	96					
73-85	43.3	14	11	96	99					
85-92	47.0	17	12	96	96					
92-100+	42.8	19	12	96	100					

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis.

** Analysis of ground whole soil; results expressed on whole-soil basis.

BONSALL SANDY LOAM
S64Calif-37-5

Location: San Diego County, California. A soil profile pit located 1.5 miles south and 1.5 miles east of Fallbrook in the SW1/4 of the NW1/4 of section 29, T. 9 S., R. 3 W. Date of Sampling: February 19, 1964.
Description By: David C. Estrada and Gerald Kester. Collectors: Klaus Flach, Gerald Kester, George Borst, Clifford Henry, Roy Bowman, and Gerald Anderson.
Classification: Noncalcic Brown soil; Haplic Natrixeralf.
Vegetation: Idle at present (few annual weeds and grasses). Climate: The annual rainfall is 15 inches. The mean annual temperature is 60° F., the mean January temperature 54° F., and the mean July temperature 70° F. Parent Material: Tonalite grus. Topography: East-facing, smooth concave 7% slopes in lower backslope positions on rolling upland. Elevation: 665 feet above sea level. Drainage: Moderately well drained; very slowly permeable. Soil Moisture: Profile dry.
Remarks: The parent material is deeply weathered. In the B23t and B25t horizons the roots are concentrated in the ped faces and are predominantly very fine. Manganese staining increases from the B23t to B25t horizon.

HORIZON	DESCRIPTION
Ap RSL No. 6440	0 to 10 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; moderate medium to fine crumb structure; hard, friable, slightly sticky and nonplastic; abundant fine roots; common fine and very fine tubular pores; slightly acid (pH 6.5); abrupt smooth boundary.
A2 RSL No. 6441	10 to 15 inches, color, texture, and consistence same as above, massive; few fine and very fine roots; common fine and very fine tubular pores; neutral (pH 7.0); abrupt smooth boundary.
B1 RSL No. 6442	15 to 20 inches, brown (7.5YR 5/4) coarse sandy loam, dark brown (7.5YR 4/4) moist; massive; very hard, friable, slightly sticky and nonplastic; plentiful very fine roots; common fine and very fine tubular pores; slightly acid (pH 6.3); gradual smooth boundary.
B21t RSL No. 6443	20 to 29 inches, brown (7.5YR 5/4) heavy sandy clay loam, dark brown (7.5YR 4/4) moist; moderate medium to coarse prismatic structure; extremely hard, very firm, sticky and slightly plastic; few very fine roots; common very fine tubular pores; many moderately thick clay skins on ped surfaces; slightly acid (pH 6.3); gradual smooth boundary.
B22t RSL No. 6444	29 to 41 inches, brown (10YR 5/3) sandy clay loam, dark brown (10YR 4/3) moist, with brown (7.5YR 5/4) coatings on ped surfaces; moderate medium to coarse prismatic structure; extremely hard, very firm, sticky and slightly plastic; few very fine roots; common very fine tubular pores; continuous thick clay skins on ped surfaces; mildly alkaline; gradual smooth boundary.
B23t RSL No. 6445	41 to 59 inches, same as above except for black manganese stains on ped surfaces.
B24t RSL No. 6446	59 to 73 inches, light brownish gray (2.5Y 6/2) sandy clay loam, dark grayish brown (2.5Y 4/2) moist, with yellowish brown (10YR 5/4) coatings on ped surfaces; moderate coarse prismatic structure; extremely hard, very firm, sticky and slightly plastic; very few very fine roots and few very fine tubular pores; many moderately thick clay skins and manganese stains on ped surfaces; mildly alkaline (pH 7.8); gradual smooth boundary.
B25t RSL No. 6447	73 to 85 inches, same as above except texture is heavy clay loam; no roots; common thick clay skins on ped surfaces; moderately alkaline (pH 8.0); clear smooth boundary.
B3 RSL No. 6448	85 to 92 inches, pale brown (10YR 6/3) clay loam, brown (10YR 5/3) moist; massive; very hard, friable, sticky and slightly plastic; common thick clay skins; moderately alkaline (pH 8.0); abrupt smooth boundary.
C1 RSL No. 6449	92 to 100 inches +, light gray (10YR 7/2) and yellowish brown (10YR 5/4) tonalite grus; mildly alkaline (pH 7.5).

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Bosanko clay SOIL Nos. S64Calif-37-8 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6450 - 6455

Depth (In)	Horizon	1B1b Total: Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Size class and particle diameter (mm) 3A1 — Sand: Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	Silt: 0.05-0.02	Int. III (0.02-0.002)	Int. II (0.2-0.02)	(2-0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a: > 2	2 - 19	19 - 76
		←					Pct of < 2 mm								→	Pct	Pct of < 76 mm	
0- 4	Ap	38.5	25.5	36.0	2.4	6.6	6.4	13.9	9.1	11.7	13.8	28.9	29.4	35.4	35.2	1	1	0
4-18	A11	33.3	28.8	37.9	2.4	6.2	5.9	11.5	7.3	15.7	13.1	29.6	26.0	39.1	38.4	2	2	0
18-22	A12	35.1	26.6	38.3	2.5	6.2	5.3	12.5	8.6	15.9	10.7	32.0	26.5	34.4	34.2	1	1	0
22-28	ACca	50.7	22.9	26.4	1.6	6.6	8.1	20.4	14.0	11.2	11.7	36.9	36.7	24.5	24.3	1	1	0
28-45	C1	79.6	11.1	9.3	7.0	19.6	14.3	29.3	9.4	6.6	4.5	25.8	70.2	6.7	5.9	12	12	0
45-57+	C2	81.5	11.3	7.2	5.3	19.3	14.2	32.0	10.7	6.8	4.5	29.0	70.8	5.4	4.5	17	17	0

Depth (In)	6A1a * Organic carbon	6B1a* Nitrogen	C/N	* 6C2a Ext. Iron as Fe	6E1b ** Carbonate as $CaCO_3$		Bulk density: 4A1f 1/3 bar	4A1h Oven dry		3B2 C'	Water content:	4B1c 1/3 bar	4B2* 15 bar	4D1 Extensibility COLEF	4D1 Extensibility COLE	pH: 8C1b Saturated Paste	8C1a H_2O 1:1	8C1a H_2O 1:10
	Pct.	Pct		Pct.	Pct.		g/cc	g/cc	g/cc		Pct	Pct.	Pct	in./in.	in./in.			
0- 4	1.59	0.131	12	0.6	-								15.6			5.5	5.9	
4-18	0.54	0.057	9	0.6	-		1.50	1.75		0.99		25.0	17.0	0.053	0.052	6.7	7.1	
18-22	0.44	0.045	10	0.5	1		1.50	1.81		0.99		25.7	17.3	0.065	0.064	7.8	8.2	
22-28	0.28			0.5	1		1.53	1.71		0.99		23.7	17.2	0.038	0.037	7.8	8.4	
28-45	0.01			0.5	-		1.59	1.74		0.92		19.4	15.4	0.031	0.028	8.0	8.7	
45-57+	-			0.5	-		1.73	1.86		0.92		15.5	14.3	0.025	0.022	8.2	8.7	

Depth (In)	Extractable bases 5B1a: 6N2a * Ca	6O2a* Mg	6P2a* Na	6Q2a* K	Sum* of bases	6H2a* Ext. Acidity	Cation Exch. Capacity: 5A2a* NaOAc	5A3a* Sum	Water extract from saturated paste 8A1 **: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	←				meq/100 g			→	←			meq/liter					→	mmho/cm
0- 4	17.2	12.5	0.6	1.0	31.3	4.5	34.7	35.8	2.1	2.1	2.3	0.3		-	3.6	2.4		0.65
4-18	23.2	14.6	1.4	0.3	39.5	1.5	41.7	41.0	1.2	0.7	3.0	tr.		-	3.4	1.4		0.52
18-22	31.9	14.7	2.5	0.3	49.4	-	44.7	49.4	0.7	0.8	4.7	tr.		-	4.5	0.4		0.55
22-28	36.4	17.2	3.9	0.2	57.7	-	53.3	57.7	0.6	0.8	5.5	tr.		-	4.8	0.5		0.62
28-45	38.9	23.3	7.6	0.1	69.9	1.4	65.7	71.3	0.4	0.4	5.8	tr.		-	3.5	0.7		0.63
45-57+	42.1	20.3	6.6	0.1	69.1	0.2	64.0	69.3	0.7	0.3	6.1	0.1		-	3.8	0.8		0.70

Depth (In.)	8A Water at Saturation	5D2 Exchangeable Na	5F SAR	Gypsum	Base Sat.	Clay mineralogy (<0.002 mm) 7A — Relative abundance based on height of diagnostic X-ray peak 7A2: Mont.	Verm.	Intev.	Mica	Kaol.	% Kaolinite (DTA)	*** % Mont. & Verm.	Charge density meq x10³/m²	3D1 Ethylene glycol retention m²/gram
	Pct.	Pct		Pct.	Pct.	←		X-ray		→				
0- 4	54.5	2	2		87									
4-18	61.0	3	3		96	xxxx	-	t	-	x	-	25	2.04	200
18-22	58.0	5	5		100									
22-28	51.9	7	7		100									
28-45	49.0	11	9		98									
45-57+	48.7	10	9		100	xxxx	x	t	-	-	-	34	2.03	262

1/, *, and **: Same as for Bonsall 37-5

*** Mehra and Jackson 1959 Constancy of the sum of mica unit cell potassium surface and interlayer sorption surface in vermiculite-illite clays. Soil Sci. Soc. Amer. Proc. 23:101-105.

- = looked for but not found
- t = trace
- x = small
- xx = moderate
- xxx = abundant
- xxxx = dominant

BOSANKO CLAY
S64Calif-37-8

Location: San Diego County, California. A soil profile pit located 120 feet east of the center line of Camp Pendleton Road and 150 feet north, 200 feet west of the southeast 1/4 corner of the northeast 1/4 of section 33, T. 10 S., R. 4 W. Date of Sampling: March 11, 1964.
Description By: Roy H. Bowman and Gerald Kester. Collectors: Reuben E. Nelson, George Borst, Gerald Kester, Lothair Grant, Roy H. Bowman and Donald Markewich.
Classification: Grumusol; Chromic Pelloxerert.
Vegetation: Wild oats, mustard. Climate: Annual precipitation is 13 inches and mean annual temperature is 59° F. Parent Material: Tonalite grus. Topography: West-facing, smooth 4% slopes on rolling upland. Elevation: 145 feet above sea level. Drainage: Well drained; medium to rapid runoff; slowly permeable. Soil Moisture: Slightly moist.

HORIZON	DESCRIPTION
Ap RSL No. 6450	0 to 4 inches, dark gray (10YR 4/1) clay, very dark gray (10YR 3/1) moist; moderate coarse to fine granular structure; very hard, firm, sticky and plastic; abundant very fine and fine roots; many fine tubular and many fine to medium interstitial pores; slightly acid (pH 6.2); abrupt smooth boundary.
A11 RSL No. 6451	4 to 18 inches, dark gray (10YR 4/1) clay, very dark gray (10YR 3/1) moist; moderate medium angular blocky structure; extremely hard, very firm, sticky and plastic; few very fine and fine roots; common very fine and fine tubular pores; few slickensides; slightly acid (pH 6.5); abrupt wavy boundary.
A12 RSL No. 6452	18 to 22 inches, grayish brown (10YR 5/2) clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; extremely hard, very firm, sticky and plastic; very few, very fine roots; few very fine to fine tubular pores; few slickensides; few small soft masses of lime; mildly alkaline (pH 7.8), slightly effervescent; clear wavy boundary.
ACca RSL No. 6453	22 to 28 inches, grayish brown (10YR 5/2) clay, very dark grayish brown (10YR 3/2) moist; moderate medium angular blocky structure; very hard, very firm, sticky and plastic; very few very fine roots; very few very fine tubular pores; moderately alkaline (pH 8.0), slightly to strongly effervescent; many medium to small soft masses of lime; contains features of rock structure of the underlying material; clear wavy boundary.
C1 RSL No. 6454	28 to 45 inches, pale brown tonalite grus, fine gravelly loamy sand in texture; massive; very hard, firm, nonsticky and nonplastic; seams of lime about 1/2 inch thick, 6 to 12 inches apart, extending obliquely into the underlying horizon; mildly alkaline (pH 7.5); strongly effervescent; clear smooth boundary.
C2 RSL No. 6455	45 to 57 inches +, pale yellow tonalite grus, fine gravelly loamy sand in texture; massive; very hard, firm, nonsticky and nonplastic; oblique seams of lime about 1/2 inch thick, 6 to 12 inches apart, occur to the depth of sampling; mildly alkaline (pH 7.5) and strongly effervescent.

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Bosanko clay SOIL Nos. S64Calif-37-9 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6456 - 6460

Depth (In.)	Horizon	1B1b Total Sand (2–0.05)	Silt (0.05–0.002)	Clay (< 0.002)	Sand Very coarse (2–1)	Coarse (1–0.5)	Medium (0.5–0.25)	Fine (0.25–0.1)	Very fine (0.1–0.05)	Silt 0.05–0.02	Int. III (0.02–0.002)	Int. II (0.2–0.02)	(2–0.1)			1/ Coarse fragments 1A2a > 2	2 – 19	19 - 76
		Pct. of < 2 mm (Size class and particle diameter (mm) 3A1)														Pct.	Pct. of < 76 mm	
0- 5	Ap	50.5	28.9	20.6	4.9	10.8	8.5	15.6	10.7	13.8	15.1	33.1	39.8			4	4	0
5-18	A11	39.0	24.0	37.0	3.9	8.5	6.3	12.0	8.3	10.8	13.2	25.6	30.7			9	9	0
18-23	A12	43.4	19.4	37.2	7.3	10.7	6.7	11.7	7.0	9.2	10.2	22.6	36.4			11	11	0
23-30	ACca	61.5	11.7	26.8	13.1	20.4	9.2	13.8	5.0	3.9	7.8	15.4	56.5			14	14	0
30-48+	C1	75.8	9.7	14.5	16.5	26.7	10.5	16.4	5.7	2.8	6.9	16.4	70.1			22	22	0

Depth (In.)	6A1a Organic carbon	6B1a Nitrogen	C/N	6C2a Ext. Iron as Fe	6E1b Carbonate as $CaCO_3$		Exch. Bases Na	K		3B2 C'	Water content	4B1c 1/3 bar	4B2 15 bar	4D1 Extensibility COLEF	4D1 Extensibility COLE	pH 8C1b Saturated Paste	8C1a H_2O 1:1	8C1a H_2O 1:10
	Pct.	Pct.		Pct.	Pct.		meq /100 g		g/cc		Pct.	Pct.	Pct.	in./in.	in./in.			
0- 5	0.86	0.075	11	0.5			0.5	0.4					8.9			5.7	6.0	
5-18	0.34			0.6			2.1	0.2					16.0			6.6	7.0	
18-23	0.32			0.5			3.3	0.2					16.7			7.4	7.7	
23-30	0.12			0.4	1		5.3	0.1					16.7			7.6	8.0	
30-48+	0.02			0.6	<1		4.9	0.1					12.9			7.6	8.0	

Depth (In.)	Extractable bases 5B1a 6N2a Ca	6O2a Mg	6P2a Na	6Q2a K	Sum of bases	6H2a Ext. Acidity	Cation Exch. Capacity 5A2a NaOAc	5A3a Sum	Water extract from saturated paste 8A1 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 5	7.4	6.9	0.6	0.4		3.3	18.6	18.5	0.9	1.2	2.4	0.1		-	2.2	1.5		0.46
5-18	18.5	10.4	2.4	0.2		2.0	33.4	33.2	1.3	1.2	6.2	0.1		-	2.6	5.9		0.95
18-23	22.3	10.1	4.2	0.2		1.1	38.4	37.0	3.1	4.2	14.2	0.1		-	2.0	18.4		2.33
23-30	31.2	12.0	6.6	0.1		0.8	46.0	49.4	8.4	8.7	24.6	0.1		-	2.0	35.6		4.08
30-48+	22.0	9.5	6.2	0.1		1.5	38.2	39.3	10.2	11.8	29.4	0.1		-	1.3	48.9		5.33

Depth (In.)	8A Water at Saturation	5D2 Exchangeable Na	5F SAR	Base Sat. Cations	Base Sat. NaOAc CEC	Clay mineralogy (<0.002 mm) 7A Relative abundance based on height of diagnostic X-ray peak 7A2 Mont.	Verm.	Int.	Mica	Kaol.
	Pct.	Pct.		Pct.	Pct.	X-ray				
0- 5	36.5	3	3	82	82					
5-18	50.8	6	5	94	93	xxxx	xx	-	-	t
18-23	59.2	9	7	97	93					
23-30	56.2	12	8	98	100+					
30-48+	44.9	13	9	96	99	xxx	xxx	-	-	t

1/ From characterization sample.

- - = looked for but not found
- t = trace
- x = small
- xx = moderate
- xxx = abundant
- xxxx = dominant

BOSANKO CLAY
S64Calif-37-9

Location: San Diego County, California. A soil profile pit located 3700 feet north of Haverford Road and 140 feet west of Lilac Road in the SW1/4 of the NE1/4 of assumed section 3, T. 13 S., R. 1 E., on photo 6054NE. Date of Sampling: March 11, 1964.
Description By: David C. Estrada and Gerald Kester. Collectors: Reuben Nelson, Lothair Grant, George Borst, Gerald Kester, David C. Estrada and Roy H. Bowman.
Classification: Grumusol; Chromic Pelloxerert.
Vegetation: Wild oats and other annual grasses and weeds. Climate: The average annual precipitation is 17 inches. The mean annual temperature is 61° F., the mean January temperature 53° F., and the mean July temperature 71° F. Parent Material: Tonalite grus. Topography: Nearly level positions of 2% slope on rolling upland. Elevation: 1550 feet above sea level. Drainage: Well drained; medium runoff; very slowly permeable. Soil Moisture: Moist.
Remarks: Quartz fragments from 2 mm to 2 cm in size commonly occur throughout the profile.

HORIZON	DESCRIPTION
Ap RSL No. 6456	0 to 5 inches, gray (10YR 5/1) clay, very dark gray (10YR 3/1) moist; moderate to fine granular structure; very hard, firm, sticky and plastic; abundant very fine and fine vertical roots; many very fine and fine tubular and interstitial pores; slightly acid (pH 6.3); abrupt smooth boundary.
A11 RSL No. 6457	5 to 18 inches, gray (10YR 5/1) clay, very dark gray (10YR 3/1) moist; strong medium to coarse angular blocky structure; extremely hard, very firm, very sticky and very plastic; abundant very fine and fine roots; common very fine and fine tubular pores; neutral (pH 6.7); few slickensides; clear smooth boundary.
A12 RSL No. 6458	18 to 23 inches, color and texture same as above; moderate medium angular blocky structure; very hard, firm, very sticky and very plastic; plentiful very fine roots; common very fine, few fine tubular pores; mildly alkaline (pH 8.0); few intersecting slickensides; clear smooth boundary.
ACca RSL No. 6459	23 to 30 inches, brown (10YR 5/3) and white (10YR 8/1) heavy sandy clay loam, dark brown (10YR 4/3) and light gray (10YR 7/2) moist; moderate medium angular blocky structure; hard, friable, sticky and plastic; very few very fine roots; common very fine tubular pores; moderately alkaline (pH 8.2); slightly effervescent with disseminated lime, violently effervescent in soft masses; clear smooth boundary.
C1 RSL No. 6460	30 to 48 inches +, pale brown (10YR 6/3) tonalite grus of loamy coarse sand texture; moderately alkaline (pH 8.3).

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Fallbrook sandy loam SOIL Nos. S64Calif-37-2 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6414 - 6422

Depth (In.)	Horizon	1B1b Total: Sand (2-0.05)	Total: Silt (0.05-0.002)	Total: Clay (< 0.002)	Sand: Very coarse (2-1)	Sand: Coarse (1-0.5)	Sand: Medium (0.5-0.25)	Sand: Fine (0.25-0.1)	Sand: Very fine (0.1-0.05)	Silt: 0.05-0.02	Silt: Int. III (0.02-0.002)	Int. II (0.2-0.02)	(2-0.1)	* Clay <.002	** Clay <.002	Coarse fragments 1A2a: > 2	2 - 19	19 - 76
		Pct. of < 2 mm (Size class and particle diameter (mm) 3A1)														Pct.	Pct. of < 76 mm	
0- 2	A11	72.9	19.5	7.6	13.3	19.2	10.2	19.5	10.7	10.1	9.4	31.3	62.2	7.8	7.2	8	8	0
2- 6	A12	72.4	19.4	8.2	13.1	18.2	10.1	19.7	11.3	9.6	9.8	31.5	61.1	8.6	7.8	9	9	0
6-12	A3	66.4	21.0	12.6	11.8	16.4	9.4	18.3	10.5	9.4	11.6	29.3	55.9	12.5	11.6	3	3	0
12-20	B21t	54.4	19.5	26.1	11.6	12.1	7.6	14.1	9.0	8.4	11.1	25.1	45.4	28.0	27.0	4	4	0
20-28	B22t	51.8	17.0	31.2	12.1	11.6	7.4	13.4	7.3	7.0	10.0	21.3	44.5	31.4	30.4	3	3	0
28-47	B3	72.4	12.8	14.8	17.0	21.6	10.5	16.7	6.6	5.1	7.7	19.7	65.8	13.6	12.1	11	11	0
47-68	C1	79.6	11.2	9.2	23.8	25.8	9.6	14.9	5.5	4.1	7.1	16.3	74.1	8.3	6.7	19	19	0
68-85	C2	80.7	13.9	5.4	21.7	25.0	10.4	16.9	6.7	6.7	7.2	21.8	74.0	4.5	3.6	21	21	0
85-90+	C3	80.2	14.7	5.1	27.1	23.4	9.1	14.8	5.8	7.6	7.1	20.3	74.4	8.1	5.2	36	36	0

Depth (In.)	6A1a * Organic carbon Pct	6B1a* Nitrogen Pct.	C/N	*6C2a Ext. Iron as Fe Pct.	6E1b Carbonate as $CaCO_3$ Pct.		Bulk density: 4A1f 1/3 bar g/cc	Bulk density: 4A1h Oven dry g/cc	g/cc	3B2 C'	Water content: Pct	Water content: 4B1c 1/3 bar Pct	Water content: 4B2* 15 bar Pct	4D1 Extensibility COLEF in./in.	4D1 Extensibility COLE in./in.	pH: 8C1b Saturated Paste	pH: 8C1a H_2O 1:1	pH: 8C1a H_2O 1:10
0- 2	0.73	0.070	10	0.8			1.42	1.44		0.96		10.2	2.9	0.005	0.004	6.4	6.6	
2- 6	0.50	0.047	10	0.7			1.60	1.62		0.94		10.5	3.6	0.003	0.003	6.3	6.5	
6-12	0.30			0.7			1.78	1.85		0.98		11.0	5.0	0.013	0.013	6.5	6.8	
12-20	0.27			1.4			1.78	1.92		0.97		15.0	10.1	0.026	0.025	6.6	6.8	
20-28	0.24			1.4			1.73	1.89		0.98		16.5	11.3	0.029	0.029	6.7	7.0	
28-47	0.07			0.9			1.80	1.89		0.92		13.7	7.8	0.016	0.015	7.0	7.4	
47-68	0.02			0.7			1.81	1.90		0.86		10.9	5.9	0.016	0.014	7.4	7.6	
68-85	0.01			0.6									3.7			7.9	8.2	
85-90+	0.02			0.8									4.2			7.9	8.1	

Depth (In.)	Extractable bases 5B1a: 6N2a * Ca	6O2a* Mg	6P2a* Na	6Q2a* K	Sum of bases	6H2a Ext.* Acidity	Cation Exch. Capacity: 5A2a* NaOAc	Cation Exch. Capacity: 5A3a * Sum	Water extract from saturated paste 8A1 **: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 2	4.6	1.3	0.3	0.4		1.5	9.6	8.1										
2- 6	5.2	1.3	0.3	0.1		1.6	9.2	8.5										
6-12	6.5	2.0	0.4	0.1		1.9	10.8	10.9										
12-20	10.0	4.7	0.4	0.1		2.9	18.3	18.1										
20-28	10.0	5.0	0.5	0.1		2.9	19.7	18.5										
28-47	11.3	5.0	0.9	0.1		1.7	19.3	19.0										
47-68	10.3	4.3	0.9	0.1		1.2	16.7	16.8			1.1	t						0.18
68-85	8.5	3.9	0.8	tr.		0.8	13.7	14.0										
85-90+	9.4	3.7	0.9	0.2		0.8	15.1	15.0			0.8	tr.						0.07

Depth (In.)	8A Water at Saturation Pct.	5D2 Exchangeable Na Pct	5B1b Exch. Na meq / 100g	Base Sat. Cations Pct	Base Sat. NaOAc CEC Pct.	Clay mineralogy (<0.002 mm) 7A — Relative abundance based on height of diagnostic X-ray peak (7A2): Mont.	Verm.	Hydro-bio-tite	Illite	Kaol.	% Kaol. (DTA) 7A3	% Kaol. in ground whole soil (DTA)
						← X-ray				→		
0- 2		3		81	69	-	-	t	xxxx	xx	20	tr.
2- 6		4		82	75	-	-	-	xxxx	xx		
6-12		4		82	81	-	-	xxxx	x	xx		
12-20		2		84	83	-	x	xxx	x	xxx		
20-28		3		84	80	-	t	t	xx	xxxx	33	17
28-47		5		91	90	-	t	t	xx	xxxx	29	12
47-68	38.2	5		93	93	-	x	t	xx	xxx	12	tr.
68-85		6		94	96							
85-90+	44.1	6		95	94	x	xx	t	xx	xx	0	1

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis.

** Analysis of ground whole soil; results expressed on whole-soil basis.

- \- = looked for but not found
- t = trace
- x = small
- xx = moderate
- xxx = abundant
- xxxx = dominant

FALLBROOK SANDY LOAM
S64Calif-37-2

Location: San Diego County, California. A soil profile pit located about 2-1/4 miles south and 3/4 mile east of Fallbrook in the NE1/4 of the SW1/4 of section 31, T. 9 S., R. 3 W. Date of Sampling: February 17, 1964.
Description By: Roy H. Bowman and Gerald Kester. Collectors: Klaus Flach, Gerald Kester, George Borst, Benny Brasher and R. E. Nelson.
Classification: Noncalcic Brown soil; Typic Haploxeralf.
Vegetation: Wild oats, annual weeds and grasses. Climate: Annual precipitation is 15 inches and mean annual temperature is 60° F. Parent Material: Tonalite grus. Topography: Southwest-facing, smooth 12% slopes in middle backslope position on rolling upland. Elevation: 555 feet. Drainage: Well drained; medium runoff; moderately slow permeability. Soil Moisture: Dry when sampled.
Remarks: The B3 horizon appears to be the most dense of the profile, and the B3 horizon the lowest in permeability. This soil occurs on a slope 320 feet SE of the Vista site S64Calif-37-1.

HORIZON	DESCRIPTION
A11 RSL No. 6414	0 to 2 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; weak fine crumb structure; slightly hard, very friable, nonsticky and nonplastic; abundant very fine to medium roots; many very fine and fine interstitial pores; slightly acid (pH 6.4); clear smooth boundary.
A12 RSL No. 6415	2 to 6 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; massive; hard, friable, nonsticky and nonplastic; plentiful very fine to medium roots; common very fine to fine tubular pores; slightly acid (pH 6.4); abrupt smooth boundary.
A3 RSL No. 6416	6 to 12 inches, reddish brown (5YR 5/3) loam, dark reddish brown (5YR 3/3) moist; weak coarse subangular blocky structure; hard, friable, slightly sticky and nonplastic; plentiful very fine and fine roots; common very fine and fine tubular pores; few thin clay films in pores, few bridges; slightly acid (pH 6.3); clear smooth boundary.
B21t * RSL No. 6417	12 to 20 inches, reddish brown (5YR 5/4) sandy clay loam, dark reddish brown (5YR 3/4) moist; moderate medium prismatic structure; very hard, firm, slightly sticky and slightly plastic; plentiful very fine and fine roots; common very fine and fine tubular pores; continuous thick clay skins on ped faces; slightly acid (pH 6.4); gradual smooth boundary.
B22t RSL No. 6418	20 to 28 inches, color, texture, structure, consistence, clay skins and reaction are the same as the B21t horizon; plentiful very fine roots; few very fine tubular pores; clear wavy boundary.
B3 RSL No. 6419	28 to 47 inches, light reddish brown (5YR 6/4) loam, reddish brown (5YR 4/4) moist; weak coarse subangular blocky structure; hard, friable, slightly sticky and nonplastic; few very fine roots; few very fine tubular pores; common moderately thick clay skins on ped faces; neutral (pH 6.6); gradual smooth boundary.
C1 * RSL No. 6420	47 to 68 inches, dark reddish brown (2.5YR 4/4), light red (2.5YR 6/6), and pale red (2.5YR 6/2) tonalite grus of loamy coarse sand texture; massive; hard, loose, nonsticky and nonplastic; very few very fine roots; slightly acid (pH 6.5); gradual smooth boundary.
C2 RSL No. 6421	68 to 85 inches, reddish brown (5YR 5/4), pink (5YR 7/3), and black (5YR 2/1) tonalite grus of fine gravelly sand texture; medium acid (pH 6.0); gradual smooth boundary.
C3 RSL No. 6422	85 to 90 inches +, white (10YR 8/1), light brownish gray (10YR 6/2), and black (10YR 2/1) tonalite grus of fine gravelly sand texture; medium acid (pH 6.0).

*Soil horizons sampled for BFR

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Fallbrook sandy loam SOIL Nos. S64Calif-37-6 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 6423 - 6429

Depth (In.)	Horizon	1B1b Total: Sand (2-0.05)	Total: Silt (0.05-0.002)	Total: Clay (< 0.002)	Size class and particle diameter (mm) 3A1 — Sand: Very coarse (2-1)	Sand: Coarse (1-0.5)	Sand: Medium (0.5-0.25)	Sand: Fine (0.25-0.1)	Sand: Very fine (0.1-0.05)	Silt: 0.05-0.02	Silt: Int. III (0.02-0.002)	Int. II (0.2-0.02)	(2-0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a: > 2 Pct	2 - 19 Pct of < 76 mm	19 - 76 Pct of < 76 mm
		Pct of < 2 mm																
0- 3	Ap	64.8	26.4	8.8	10.2	14.7	10.0	17.8	12.1	13.6	12.8	35.5	52.7	8.5	8.1	5	5	0
3-13	A12	61.6	26.2	12.2	7.9	13.9	9.0	17.9	12.9	12.8	13.4	35.0	48.7	9.8	9.4	4	4	0
13-18	B1	58.5	25.2	16.3	8.6	13.7	8.5	16.6	11.1	12.1	13.1	32.4	47.4	18.4	17.3	6	6	0
18-27	B21t	52.8	22.6	24.6	7.7	11.4	7.5	15.7	10.5	10.6	12.0	30.1	42.3	23.3	22.0	5	5	0
27-41	B22t	56.9	23.7	19.4	8.1	12.1	8.0	17.1	11.6	11.3	12.4	32.0	45.3	19.3	17.6	9	9	0
41-62	C1	73.9	14.7	11.4	20.8	19.1	8.4	17.0	8.6	6.7	8.0	24.3	65.3	11.1	7.9	29	29	0
62-70+	C2	76.6	16.4	7.0	23.4	19.4	8.6	16.4	8.8	7.1	9.3	23.9	67.8	6.7	4.6	31	31	0

Depth (In.)	* 6A1a Organic carbon Pct.	6B1a * Nitrogen Pct	C/N	* 6C2a Ext. Iron as Fe Pct.	6E1b Carbonate as $CaCO_3$ Pct.		Bulk density 4A1f 1/3 bar g/cc	Bulk density 4A1h Oven dry g/cc	g/cc	3B2 C'	Water content Pct.	4B1c 1/3 bar Pct.	4B2* 15 bar Pct.	4D1 Extensibility COLEF in./in.	4D1 Extensibility COLE in./in.	pH 8C1b Saturated Paste	pH 8C1a H_2O 1:1	pH 8C1a H_2O 1:10
0- 3	2.1	0.178	12	0.6									6.6			7.0	7.2	
3-13	0.83	0.042	20	0.8									5.1			6.9	7.3	
13-18	0.30			1.3									7.8			6.9	7.2	
18-27	0.23			1.2									9.5			6.8	7.0	
27-41	0.16			1.1									8.5			6.8	7.0	
41-62	0.03			1.1									7.3			7.0	7.2	
62-70+	0.01			1.0									5.7			7.2	7.3	

Depth (In.)	Extractable bases 5B1a: 6N2a* Ca	6O2a* Mg	6P2a* Na	6Q2a* K	* Sum of bases	6H2a* Ext. Acidity	Cation Exch. Capacity 5A2a* NaOAc	Cation Exch. Capacity 5A3a* Sum	Water extract from saturated paste 8A1: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 3	8.8	4.2	0.5	0.6	14.1	2.0	16.2	16.1										
3-13	6.6	3.1	0.7	0.1	10.5	1.5	12.4	12.0										
13-18	10.2	4.0	1.3	0.1	15.6	1.9	18.1	17.5										
18-27	11.0	4.6	1.6	0.1	17.3	2.3	20.9	19.6										
27-41	11.3	5.1	1.8	0.1	18.3	2.0	18.7	20.3										
41-62	16.1	6.1	1.6	0.1	23.9	1.4	25.1	25.3										
62-70+	17.3	4.9	2.0	0.1	24.3	1.0	24.8	25.3										

Depth (In.)	8A Water at Saturation Pct.	5D2 Exchangeable Na Pct.	5B1b Exch. Na meq / 100g	Base Sat. Cations Pct.	Base Sat. NaOAc CEC Pct.	Clay mineralogy (<0.002 mm) 7A: Mont.	Verm.	Mica	Kaolin.	
						X-ray				
0- 3		3		88	88					
3-13		6		85	85					
13-18		7		89	86					
18-27		8		88	83					
27-41		9		90	98					
41-62		6		94	95					
62-70+		8		96	98					

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis.

** Analysis of ground whole soil; results expressed on whole-soil basis.

FALLBROOK SANDY LOAM
S64Calif-37-6

Location: San Diego County, California. A soil profile pit located about 1-1/2 miles south and 1-1/2 miles east of Fallbrook in the SW1/4 of the NW1/4 of section 29, T. 9 S., R. 3 W. Date of Sampling: February 20, 1964.
Description By: Roy H. Bowman, Gerald Kester. Collectors: Klaus Flach, Gerald Kester, George Borst, Lothair Grant and Donald Markewich.
Classification: Noncalcic Brown soil; Typic Haploxeralf.
Vegetation: Wild oats and annual weeds. Climate: Annual precipitation is 15 inches and mean annual temperature is 60° F. Parent Material: Tonalite grus. Topography: East-facing, smooth 9% slopes in middle backslope positions on rolling upland. Elevation: 685 feet above sea level. Drainage: Well drained; medium runoff; moderately slowly permeable. Soil Moisture: Moist to 18 inches.

HORIZON	DESCRIPTION
Ap RSL No. 6423	0 to 3 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; weak fine crumb structure; slightly hard, very friable, slightly sticky and nonplastic; abundant very fine and fine roots; many very fine and fine interstitial pores; neutral (pH 6.6); abrupt smooth boundary.
A12 RSL No. 6424	3 to 13 inches, brown (10YR 5/3) sandy loam, dark brown (10YR 3/3) moist; massive; hard, friable, slightly sticky and nonplastic; abundant very fine and fine roots; many very fine to medium tubular pores; slightly acid (pH 6.5); clear smooth boundary.
B1 RSL No. 6425	13 to 18 inches, reddish brown (5YR 5/3) sandy clay loam, dark reddish brown (5YR 3/3) moist; weak coarse subangular blocky structure; hard, firm, slightly sticky and slightly plastic; plentiful very fine roots; common very fine and fine tubular pores; slightly acid (pH 6.3); clear smooth boundary.
B21t RSL No. 6426	18 to 27 inches, reddish brown (5YR 4/3) sandy clay loam, dark reddish brown (5YR 3/3) moist; moderate coarse prismatic structure; very hard, firm, sticky and plastic; few very fine roots; common very fine and fine tubular pores; common moderately thick clay skins on ped faces; slightly acid (pH 6.3); clear smooth boundary.
B22t RSL No. 6427	27 to 41 inches, reddish brown (5YR 5/4) sandy clay loam, dark reddish brown (5YR 3/4) moist; weak coarse prismatic structure; very hard, firm, sticky and plastic; few very fine roots; few very fine tubular pores; slightly acid (pH 6.3); clear wavy boundary.
C1 RSL No. 6428	41 to 62 inches, dark reddish brown (5YR 3/2) to light reddish brown (5YR 6/4) and pinkish gray (5YR 6/2) tonalite grus of fine gravelly sand texture; slightly acid (pH 6.2); clear wavy boundary.
C2 RSL No. 6429	62 to 70 inches, reddish brown (5YR 5/4) to light gray (10YR 7/2) tonalite grus of fine gravelly sand texture; slightly acid (pH 6.2).

SCS-420
10-64

U S DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Vista coarse sandy loam, SOIL Nos. S64Calif-37-1 LOCATION San Diego County, California

SOIL SURVEY LABORATORY Riverside, California LAB. Nos. 641 - 647

Depth (In.)	Horizon	1B1b Total Sand (2-0.05)	Silt (0.05-0.002)	Clay (< 0.002)	Sand Very coarse (2-1)	Coarse (1-0.5)	Medium (0.5-0.25)	Fine (0.25-0.1)	Very fine (0.1-0.05)	Silt 0.05-0.02	Int. III (0.02-0.002)	Int. II (0.2-0.02)	(2-0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a > 2 Pct	2 - 19 Pct of < 76 mm	19 - 76
		Size class and particle diameter (mm) 3A1, Pct of < 2 mm																
0- 3	A11	72.7	17.1	10.2	19.5	21.2	9.0	14.8	8.2	8.4	8.7	24.2	64.5	11.5	9.3	19	19	0
3- 9	A12	70.9	18.5	10.6	17.8	18.0	9.0	17.2	8.9	9.0	9.5	26.8	62.0	10.9	8.5	22	22	0
9-19	A13	70.3	18.2	11.5	18.2	18.4	8.9	16.0	8.8	8.4	9.8	25.8	61.5	12.2	9.3	23	23	0
19-28	B21	68.7	19.4	11.9	16.2	17.0	8.6	16.3	10.6	9.5	9.9	28.2	58.1	12.5	9.5	24	24	0
28-35	B22	70.6	18.5	10.9	19.5	18.0	8.5	16.1	8.5	8.7	9.8	26.0	62.1	12.4	8.9	28	28	0
35-44	C1	82.3	12.5	5.2	35.3	23.2	6.9	11.8	5.1	6.0	6.5	17.0	77.2	4.1	2.4	41	41	0
44-61+	C2	82.9	12.5	4.6	32.5	23.9	7.8	12.9	5.8	6.0	6.5	18.1	77.1	4.5	2.7	40	40	0

Depth (In.)	* 6A1a Organic carbon Pct	*6B1a Nitrogen Pct.	C/N	* 6C2a Ext. Iron as Fe Pct.	6E1b Carbonate as $CaCO_3$ Pct		Bulk density 4A1f 1/3 bar g/cc	Bulk density 4A1h Oven dry g/cc	g/cc	3B2 C'	Water content Pct	Water content 4B1c 1/3 bar Pct.	Water content *4B2 15 bar Pct	4D1 Extensibility COLEF in./in.	4D1 Extensibility COLE in./in.	pH 8C1b Saturated Paste	pH 8C1a H_2O 1:1	pH 8C1a H_2O 1:10
0- 3	0.96	0.080	12	1.0			1.55	1.89		0.88		8.7	5.4	0.066	0.059	6.7	6.9	
3- 9	0.56	0.055	10	0.9			1.51	1.86		0.86		9.8	4.0	0.072	0.061	6.5	6.6	
9-19	0.34			1.0			1.46	1.51		0.86		12.0	3.1	0.010	0.010	6.6	6.8	
19-28	0.28			0.9			1.43	1.52		0.85		10.1	3.7	0.021	0.017	6.6	6.7	
28-35	0.10			1.1			1.46	1.52		0.82		10.9	6.4	0.014	0.011	6.7	6.9	
35-44	0.03			0.7			1.92	1.97		0.67		6.7	4.6	0.008	0.006	7.2	7.1	
44-61+	0.03			0.8									4.2			7.3	7.4	

Depth (In.)	Extractable bases 5B1a 6N2a * Ca	6O2a* Mg	6P2a* Na	6Q2a* K	Sum of bases	6H2a* Ext. Acidity	Cation Exch. Capacity 5A2a* NaOAc	Cation Exch. Capacity 5A3a* Sum	Water extract from saturated paste 8A1 6N1a Ca	6O1a Mg	6P1a ** Na	6Q1a ** K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 3	10.5	3.4	1.4	0.2		1.7	16.9	17.2										
3- 9	10.5	2.8	0.4	0.1		2.3	18.6	16.1										
9-19	13.0	4.0	0.4	0.1		2.2	19.8	19.7										
19-28	11.1	4.0	0.4	0.1		1.8	19.1	17.4										
28-35	13.5	5.1	0.4	0.1		2.1	22.8	21.2										
35-44	9.1	3.7	0.5	tr.		1.2	14.9	14.5			0.7	tr.						0.08
44-61+	9.0	3.7	0.7	0.2		0.8	16.2	14.4										

Depth (In.)	* 8A Water at Saturation Pct.	5D2 Exchangeable Na Pct	5B1b Exch. Na meq / 100g	Base Sat. Cations Pct.	Base Sat. NaOAc CEC Pct.	Clay mineralogy (<0.002 mm) 7A — Relative abundance based on height of diagnostic X-ray peak 7A2: Mont.	Verm.	Hydrobiotite	Illite	Kaolin	% Kaolin DTA 7A3	% Kaolin in ground whole soil (DTA)
						X-ray						
0- 3		8		90	92	-	-	t	xxxx	xx	7	-
3- 9		2		86	74	-	xxx	x	-	xx		
9-19		2		89	89	-	xxx	x	-	xx		
19-28		2		89	81	-	xxx	x	-	xx		
28-35		2		90	84	-	xx	x	t	xxx	12	2
35-44	44.4	3		92	90	-	xxxx	t	-	xx	6	-
44-61+		4		92	84	-	xxxx	t	-	xx	16	tr.

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis.

** Analysis of ground whole soil; results expressed on whole-soil basis.

- \- = looked for but not found
- t = trace
- x = small
- xx = moderate
- xxx = abundant
- xxxx = dominant

VISTA SANDY LOAM
S64Calif-37-1

Location: San Diego County, California. A soil profile pit located 2-1/4 miles south and 3/4 mile east of Fallbrook in the NE1/4 of the SW1/4 of section 31, T. 9 S., R. 3 W.
Date of Sampling: February 17, 1964.
Description By: David C. Estrada and Gerald Kester. Collectors: Klaus Flach, Gerald Kester, George Borst, Clifford Henry, Roy Bowman and Gerald Anderson.
Classification: Regosol; Typic Xerochrept.
Vegetation: Annual weeds and grasses. Climate: The annual precipitation is 15 inches with a mean annual temperature of 60° F., a mean January temperature of 54° F., and a mean July temperature of 70° F. Parent Material: Tonalite grus. Topography: Southwest-facing, smooth 8% slopes in hilltop and upper backslope positions on rolling upland. Elevation: 590 feet above sea level. Drainage: Well drained; medium runoff; moderately rapid permeability. Soil Moisture: This profile was moist to about 15 inches.
Remarks: There is much rodent activity by ground squirrels. The irregular boundary between the B22 and C1 horizons may be the result of this activity. In a nearby pit burrow holes occur in the C1 horizon. Isolated bodies of C horizon occur within, or surrounded by, material of the B horizon.

HORIZON	DESCRIPTION
A11 RSL No. 641	0 to 3 inches, dark grayish brown (10YR 4/2) coarse sandy loam, dark brown (10YR 3/3) moist; moderate, fine to medium crumb structure; soft, very friable, nonsticky and nonplastic; plentiful very fine and fine roots; many very fine and fine random pores; neutral (pH 6.7); abrupt smooth boundary.
A12 RSL No. 642	3 to 9 inches, dark brown (10YR 4/3) coarse sandy loam, dark brown (10YR 3/3) moist; weak fine to medium granular structure; slightly hard, very friable, nonsticky and nonplastic; plentiful very fine and fine roots; common very fine and fine tubular and interstitial pores; neutral (pH 6.7); diffuse to clear irregular boundary. Krotovinas filled with this material, 3 to 4 inches wide, extend into the underlying horizons, in places extending into the upper part of the C horizon.
A13 RSL No. 643	9 to 19 inches, dark brown (10YR 4/3) coarse sandy loam, dark brown (10YR 3/3) moist; weak fine to medium granular structure; slightly hard, very friable, nonsticky and nonplastic; few very fine and fine roots; common very fine and fine tubular and interstitial pores; slightly acid (pH 6.5); clear wavy boundary.
B21 * RSL No. 644	19 to 28 inches, dark brown (10YR 4/3) coarse sandy loam, dark brown (10YR 3/3) moist; massive; hard, friable, nonsticky and nonplastic; few very fine and fine roots; common very fine and fine tubular and interstitial pores; slightly acid (pH 6.3); clear smooth boundary.
B22 RSL No. 645	28 to 35 inches, yellowish brown (10YR 5/4) coarse sandy loam, dark yellowish brown (10YR 3/4) moist; massive; hard, friable, nonsticky and nonplastic; very few very fine and fine roots; common very fine and fine interstitial, few fine tubular pores; slightly acid (pH 6.3); abrupt irregular to broken boundary.
C1 RSL No. 646	35 to 44 inches, yellowish brown (10YR 5/4) and very pale brown (10YR 7/4) tonalite grus composed mostly of quartz, feldspar, hornblende, and accessory dark-colored minerals; clear irregular boundary.
C2 * RSL No. 647	44 to 61 inches +, brown (10YR 5/3) and very pale brown (10YR 7/3) tonalite grus composed mostly of quartz, feldspar, hornblende, and other dark-colored minerals, mostly unweathered.

*Soil horizons sampled for BPR

SCS-420
10-64

U. S. DEPARTMENT OF AGRICULTURE
SOIL CONSERVATION SERVICE

SOIL Vista sandy loam SOIL Nos. S64Calif-37-4 LOCATION San Diego County, California

SOIL SURVEY LABORATORY **Riverside, California** LAB. Nos. 648 - 6413

Depth (In.)	Horizon	1B1b Total: Sand (2–0.05)	Silt (0.05–0.002)	Clay (< 0.002)	Sand: Very coarse (2–1)	Coarse (1–0.5)	Medium (0.5–0.25)	Fine (0.25–0.1)	Very fine (0.1–0.05)	Silt: 0.05–0.02	Int III (0.02–0.002)	Int II (0.2–0.02)	(2–0.1)	* Clay <.002	** Clay <.002	1/ Coarse fragments 1A2a: > 2 Pct.	2 – 19 Pct. of < 76 mm	19 – 76
		Size class and particle diameter (mm) 3A1 — Pct. of < 2 mm																
0- 8	Ap	64.0	22.3	13.7	13.2	15.3	9.1	17.0	9.4	9.6	12.7	28.2	54.6	14.3	12.2	15	15	0
8-15	B12	64.0	22.7	13.3	13.3	15.5	8.7	16.8	9.7	10.6	12.1	29.4	54.3	14.6	12.9	12	12	0
15-24	B21	62.8	23.8	13.4	12.8	13.2	8.3	17.9	10.6	11.1	12.7	31.7	52.2	15.1	12.5	18	18	0
24-36	B22	64.8	22.0	13.2	13.1	15.6	8.8	17.7	9.6	9.8	12.2	28.4	55.2	13.9	11.7	16	16	0
36-47	C1	77.3	16.3	6.4	24.0	20.1	7.5	17.1	8.6	6.9	9.4	24.7	68.7	5.1	3.3	35	35	0
47-56+	C2	70.8	22.3	6.9	21.6	17.6	7.3	15.4	8.9	8.3	14.0	25.6	61.9	6.4	3.5	45	45	0

Depth (In.)	* 6A1a Organic carbon Pct	6B1a * Nitrogen Pct	C/N	*6C2a Ext. Iron as Fe Pct.	6E1b Carbonate as $CaCO_3$ Pct.		Bulk density 4A1f 1/3 bar g/cc	4A1h Oven dry g/cc	g/cc	3B2 C'	Water content Pct.	4B1c 1/3 bar Pct.	4B2* 15 bar Pct.	4D1 Extensibility COLEF in./in.	4D1 Extensibility COLE in./in.	pH 8C1b Saturated Paste	8C1a H_2O 1:1	8C1a H_2O 1:10
0- 8	0.53	0.064	8	0.9									6.1			6.4	6.7	
8-15	0.41	0.038	11	0.9									6.5			6.8	7.0	
15-24	0.29			0.9									6.8			6.9	7.2	
24-36	0.23			1.0									6.5			6.9	7.2	
36-47	0.05			0.8									4.8			7.1	7.2	
47-56+	0.07			1.1									4.4			7.0	7.2	

Depth (In.)	Extractable bases 5B1a: 6N2a* Ca	6O2a* Mg	6P2a* Na	6Q2a* K	* Sum of bases	6H2a* Ext. Acidity	Cation Exch. Capacity 5A2a* NaOAc	5A3a* Sum	Water extract from saturated paste 8A1: 6N1a Ca	6O1a Mg	6P1a Na	6Q1a K		6I1a CO_3	6J1a HCO_3	6K1a Cl	SO_4	8A1a Electrical conductivity
	meq/100 g								meq/liter									mmho/cm
0- 8	11.9	3.0	0.8	0.2	15.9	2.0	17.9	17.9										
8-15	12.2	3.0	0.8	0.1	16.1	1.7	18.0	17.8										
15-24	13.3	3.5	1.0	0.1	17.9	1.6	20.3	19.5										
24-36	13.0	4.0	1.0	0.1	18.1	1.5	20.8	19.6										
36-47	10.3	4.2	0.9	0.2	15.6	0.9	18.0	16.5										
47-56+	12.2	4.4	1.5	0.2	18.3	1.1	24.6	19.4										

Depth (In.)	8A Water at Saturation Pct	5D2 Exchangeable Na Pct.	5B1b Exch. Na meq / 100g	Base Sat. Cations Pct.	Base Sat. NaOAc CEC Pct.	Clay mineralogy (<0.002 mm) 7A: Mont.	Verm.	Mica	Kaolin	
						<—— X-ray ——>				
0- 8		5		89	89					
8-15		4		90	89					
15-24		5		92	89					
24-36		5		92	87					
36-47		5		94	86					
47-56+		6		94	74					

1/ From characterization sample; determined by shaking overnight in a sodium hexametaphosphate solution.

* Analysis of ground whole soil; results expressed on <2-mm basis.

** Analysis of ground whole soil; results expressed on whole-soil basis.

VISTA SANDY LOAM
S64Calif-37-4

Location: San Diego County, California. A soil profile pit located 1.5 miles south and 1.5 miles east of Fallbrook in the SE1/4 of the NE1/4 of section 30, T. 9 S., R. 3 W.
Date of Sampling: February 19, 1964.
Description By: David C. Estrada and Gerald Kester. Collectors: Klaus Flach, Gerald Kester, George Borst, Clifford Henry, Roy Bowman and Gerald Anderson.
Classification: Regosol; Typic Xerochrept.
Vegetation: Annual weeds and grasses. Climate: This soil occurs under about 15 inches of annual rainfall. The mean annual temperature is about 60°F., the mean January temperature about 54° F., and the mean July temperature about 70° F. Parent Material: Tonalite grus. Topography: Southeast-facing, smooth to slightly convex 7% slopes in hilltop and upper backslope positions on rolling upland. Elevation: 710 feet above sea level. Drainage: Well drained; medium runoff; moderately rapid permeability. Soil Moisture: Profile moist to 15 inches.
Remarks: This soil occurs on a hilltop above sample sites of the Fallbrook and Bonsall soils. There is much rodent activity by ground squirrels. The abrupt and irregular boundary between the B22 and the C1 may be the result of this activity.

HORIZON	DESCRIPTION
A11 RSL No. 648	0 to 8 inches, dark brown (10YR 4/3) coarse sandy loam, dark brown (10YR 3/3) moist; moderate fine to medium crumb structure; slightly hard, very friable, nonsticky and nonplastic; plentiful medium, very fine and fine roots; many very fine and fine interstitial pores; slightly acid (pH 6.5); abrupt wavy boundary.
A12 RSL No. 649	8 to 15 inches, color, texture, consistence and reaction same as above; weak medium to coarse angular blocky structure; very few medium and few very fine and fine roots; common very fine and fine tubular and interstitial pores; abrupt irregular boundary.
B21 RSL No. 6410	15 to 24 inches, brown (10YR 4/3) heavy sandy loam, dark brown (10YR 3/3) moist; massive; slightly hard, friable, nonsticky and nonplastic; roots, pores and reaction same as above; clear smooth boundary.
B22 RSL No. 6411	24 to 36 inches, color, texture, structure, consistence and pores same as above; few very fine and fine roots; abrupt irregular boundary.
C1 RSL No. 6412	36 to 47 inches, brownish yellow (10YR 6/6), very pale brown (10YR 8/3), yellowish brown (10YR 5/4) and very dark gray (10YR 3/1) tonalite grus, fine gravelly sand in texture; neutral (pH 6.7); clear irregular boundary.
C2 RSL No. 6413	47 to 56 inches +, white (10YR 8/2), pale brown (10YR 6/3) and very dark gray (10YR 3/1) tonalite grus.

U. S. GOVERNMENT PRINTING OFFICE : 1968 O - 310-764