DIVISION S-5—SOIL GENESIS, MORPHOLOGY, AND CLASSIFICATION

Eolian Influence on Development and Weathering of Some Soils of Point Reyes Peninsula, California[1]

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ABSTRACT

Wind-deposited sands have influenced characteristics of soils on Tomales Point at the northern end of Point Reyes Peninsula in California. The distribution of eolian materials, the interface between eolian and residual granitic parent materials, and mineral weathering were investigated in five pedons along a transect from near the edge of a wave-cut bluff fronting on the Pacific Ocean to near the crest of a stabilized dune. Based upon distinct textural discontinuities, proportions of rounded and angular sands, organic carbon, and phyllosilicate species in silt and clay fractions, nonconforming zones of eolian materials over granitic residuum were clearly distinguished. The soils along the transect include members of coarse-loamy, mixed, isomesic Pachic Haplustolls, coarse-loamy, mixed, isomesic "Entic" Dystropepts, sandy, mixed, isomesic ustic Dystropepts, and mixed, isomesic Typic Ustipsamment families. A mineral weathering sequence involving the transformation biotite → vermiculite → smectite is evident within the buried granitic residuum along the transect.

Additional Index Words: **eolian parent material, trioctahedral phyllosilicate weathering, lithologic discontinuity.**

Crawford, Jr., T. W., L. D. Whittig, E. L. Begg, and G. L. Huntington. 1983. Eolian influence on development and weathering of soils. Soil Sci. Soc. Am. J. 47:1179–1185.

POINT REYES PENINSULA occupies an area of 259 km^2 in western Marin County, California, bounded on the west by the Pacific Ocean and on the east by Tomales Bay (Fig. 1). The core of the peninsula is an isolated body of Cretaceous plutonic rocks (Curtis et al., 1958) separated from the Jurassic Franciscan rocks of the mainland (Bailey et al., 1964) by the northwest-southeast trending San Andreas fault. The rocks of the peninsula have been moved from their original position many kilometers to the south by northward translocation along the fault over the past tens of millions of years (Galloway, 1977). The plutonic rocks of the peninsula, ranging in composition from biotite-quartz diorite through granodiorite to ademellite, are described in general terms as granitic by Galloway (1977). The granitic rocks are exposed above sea level at Point Reyes on the south, along Inverness Ridge on the east and at Tomales Point at the northern tip of the peninsula (Weaver, 1949). At Tomales Point, the rocks form wave-cut bluffs up to 45 m above the shoreline. Strong westerly and northwesterly winds have formed a number of prominent dunes resting on the granitic rocks of Tomales Point. The dune materials are considered to be wind-transported beach deposits derived largely from sources east of the San Andreas fault (Minard, 1971).

The major portion of Point Reyes Peninsula has been managed by the National Park Service as the Point Reyes National Seashore since 1962. Tomales Point, an area of approximately 890 ha, was recently designated as a wilderness area after having been utilized for grazing by a mix of domestic and native animals for more than a century. Domestic animals are now excluded from Tomales Point and the area is being managed as natural habitat for native species.

The unique geographic environment and the natural preserve status of the area has prompted a number of studies in recent years. The area has been included in a soil survey of Marin County, California (USDA, 1979) and the identification and distribution of plant species and biomass production capability of Point Reyes Peninsula rangelands have been included in studies by Barrett and Gogan (1981) and Barrett et al. (1981).

The present investigation was designed to study the distribution of eolian materials, the interface between eolian and residual granitic parent materials and mineral weathering as they have influenced morphological characteristics of soils along a selected transect on To-

Fig. 1—Location of study area.

[1] Contribution from the Dep. of Land, Air, and Water Resources, Univ. of California, Davis, CA 95616. Received 29 July 1982. Approved 1 July 1983.

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Table 1—Slope, aspect, and vegetation associated with pedons.

Pedon	Slope, %	Aspect	Plant cover, %	Principal species†
1	7–8	NW	100	*Bromus mollis* *Hordeum brachyanethrum* *Baccaris pilularus*
2	7–8	NW	100	*Bromus mollis* *Festuca dirtonensis* *Hordeum brachyanethrum*
3	8	SW	100	*Loleum perenne* *Loleum multiflora* *Festuca dirtonensis* *Madia sativa*
4	11	S	70–80	*Amsinchia spectibilis* *Lupinus arboreus*
5	15	SE	40–50	*Lupinus arboreus* *Cirsium occidentale*

† Listed in decreasing order of abundance as observed in 1982. Species abundance and distribution have been observed to vary with seasons and with grazing pressure.

males Point. Although restricted to a limited area, the study has relevance for characterization and management of a recently designated wilderness area.

SOILS AND THEIR ENVIRONMENT

Soil investigated in this study lie within map units of the Sirdrak series (Ustic Dystropepts) and the Kehoe Variant (Pachic Haplustolls) reported in the recent soil survey. The climate of the area is characterized by cool, moist-foggy but rainless summers and cool, rainy winters. Annual precipitation ranges between 76 and 81 cm (Galloway, 1977).

Representative profiles of five pedons situated along a north-south transect near the northern end of Tomales Point were selected for study. The transect (Fig. 2) extends 44.4 m from near the edge of a wave-cut bluff at the ocean front in a Kehoe Variant map unit (pedon 1), to the leeward toe of the prominent wind-formed relief of a Sirdrak map unit (pedon 4). The fifth pedon is situated with the latter unit near the crest of the dune-like relief.

An aerial view of the study area (Fig. 3) reveals a distinct ecotone, marked by an abrupt boundary between plant communities, in a line normal to the transect and between pedons 3 and 4. Ground observations reveal additional plant variations along the transect both north and south of this prominent ecotone (Table 1). The terrain south of the ecotone boundary slopes upward in both southward and eastward directions. Pedon 3 is 4.0 m lower in elevation than pedon 1 and pedon 5 is 4.7 m higher than pedon 3. Natural drainage is toward pedon 3 from three directions. Drainage water seeps from a spring located at the edge of the bluff in line with the ecotone boundary. Grasses and forbs exhibit most lush growth in the vicinity of pedon 3.

METHODS

Pedons 1 through 4 were sampled in vertical increments to bedrock. Pedon 5, at the crest of the dune north of the ecotone, was sampled in three 30-cm increments from the surface. Depth of sampling required for characterization of pedons 1 through 4 and necessity for maintenance of the natural landscape of the Point Reyes National Seashore precluded excavations to expose profiles for detailed horizon delineations and descriptions. The profiles representing each of the pedons were carefully sampled for the purpose of this study by means of a regular bucket-type auger with extensions for depths > 1.5 m. Preliminary delineation of horizons was done on the basis of texture and color as determined in the field. Horizon designations, as indicated in

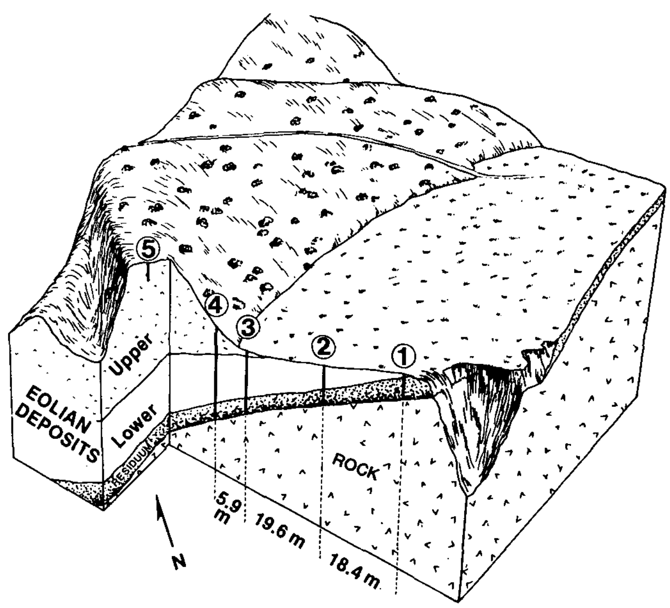

Fig. 2—Cross-section of Tomales Point, Point Reyes Peninsula, showing parent material variation in relation to the pedons sampled.

Tables 2 and 3, were assigned after evaluation of data from sample analyses. Textural classes (Table 2) are based on particle-size distributions as determined in the laboratory.

All samples were air dried and passed through a 2-mm sieve. Representative portions were taken for subsequent analyses. Colors were determined with Munsell color charts, organic carbon was analyzed by CO_2 evolution using a Leco induction furnace, and pH was determined on saturated pastes with a glass electrode. Soil moisture retention at 15 and 0.33 bar (0.10 bar for some samples) was determined for sieved samples by equilibration at the respective pressures in a pressure extractor. Base saturation was determined for selected samples by equating NH_4OAc-extractable bases to cation exchange capacity determined with NH_4.

Portions of each sample were treated successively on a steam bath with 1*N* NaOAc (pH 5) and with 30% H_2O_2 to remove divalent cations and organic matter, respectively (Jackson, 1975). Treated samples were washed with distilled water by centrifugation and decantation until they began to disperse. Sands were separated from silt and clay by wet sieving and the sands, after drying, were separated into standard U.S.D.A. fractions by dry sieving. Particles < 50 μm in diameter were separated into silt (50–2 μm) and clay (< 2 μm) fractions by repeated centrifugation and decantation employing an International no. 2 centrifuge (Jackson, 1975). A solution of Na_2CO_3 (pH 9.5) was used for particle suspension during fractionation. Separated clay was flocculated with NaCl and washed successively with 50, 80, and 95% ethanol to remove salts and reduce suspension volumes. Clay and silt fractions were resuspended in water prior to further analyses. Aliquots of suspensions were dried at 110°C and weighed. Contents of silt and clay in the samples were calculated as percentages of total recovered mineral matter.

Approximately 15-mg samples of each silt and clay fraction were prepared as oriented aggregates mounted on porous ceramic plates for analysis with a Diano XRD 8000 x-ray diffractometer generating Cu radiation and equipped with a graphite monochrometer. Aggregates were x-rayed successively after treatments with $MgCl_2$, glycerol, KCl, and 550°C heating (Jackson, 1975). A separate sample of silt from the Cr horizon of pedon 1 was also x-rayed as a random powder to ascertain dioctahedral or trioctahedral character of the dominant phyllosilicate species. Sand separates were ex-

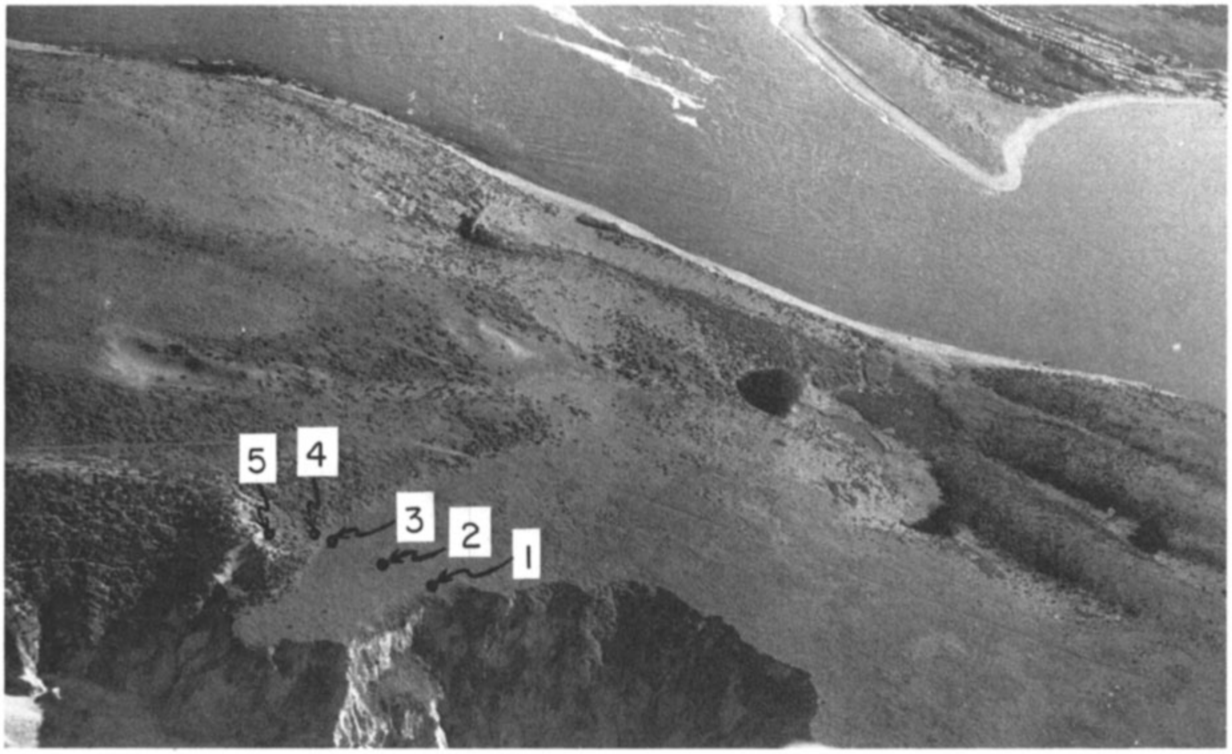

Fig. 3—Aerial photograph of Tomales Point, Point Reyes Peninsula, showing the sampling locations.

amined with a binocular microscope to determine grain colors and shapes as one means for physically distinguishing parent material discontinuities. Mineralogical compositions of sands were not determined.

RESULTS AND DISCUSSON

Chemical, physical, and clay mineralogical data reveal the presence of lithologic discontinuities within profiles of at least three of the five pedons sampled (Fig. 2). The data indicate at least two zones of nonconforming eolian parent material overlying granitic residuum in pedons 3 and 4 nearest to and on opposite sides of the ecotone. The eolian mantle decreases in thickness toward the southern end of the transect. The upper 122 cm of pedon 2 (A and AC horizons) is largely eolian, whereas pedon 1 has developed primarily from underlying residual granitic materials.

Texture and Moisture Retention

All horizons of pedon 5, sampled at the crest of the dune, and the A1 and A2 horizons of pedon 4 are of sand texture (Table 1). With exception of horizon 3C1 of pedon 3 (loam), all other horizons within pedons 1 through 4 fall within either loamy sand or sandy loam textural classes. Sand content of surface horizons decreases progressively along the transect from 99.1% (pedon 5) to 68.5% (pedon 1). Conversely, silt in surface horizons increases progressively from 0.5 to 20.2% along the same transect. Clay also increases with increasing percentages of silt. The most marked differences in sand and silt contents of surface horizons between successive pedons in the transect occur between pedons 3 and 4, which are on opposite sides of the ecotone boundary and which are separated by only 5.9 m. Abrupt changes in percentages of either or both sand and silt between adjacent horizons are evident at one level in pedon 2 and at two levels in pedons 3 and 4. These abrupt textural differences, coupled with other evidences, mark lithologic discontinuities within those profiles at or near the following depths: pedon 2, 122 cm; pedon 3, 30 and 208 cm; pedon 4, 168 and 411 cm. Distribution of particle-size fractions between the 168- and 411-cm depth in pedon 4 is very similar to that between 30 and 208 cm in pedon 3, and from 0 to 122 cm in pedon 2, suggesting a common eolian deposition.

Relatively low soil moisture retention by pedon horizons with sand texture is shown in Table 2. The three sampled horizons of pedon 5 and the A1 and A2 horizons of pedon 4 are particularly low in their moisture holding capacity. Texturally related differences in moisture retention are also noted between the lithologically discontinuous horizons of pedon 3.

Chemical Properties

Reactions of pedon horizons in the transect (Table 2) range from strongly to slightly acidic. The three horizons of pedon 5 and the A1 and A2 horizons of pedon 4, all of sand texture, are strongly acidic (pH 5.1–5.5). The pH of surface and subsurface horizons of pedons 1 through 3 south of the ecotone reflect moderate to slight acidity (pH 5.7–6.5). The higher pH values (6.0 and above) of the lower horizons of pedons 1 through 4 are representative of zones which, on the basis of physical characteristics, are considered to be residuum from weathering of underlying granitic rock.

Organic carbon content (Table 2) is lowest (0.5% or less) in pedon 5 at the crest of the dune. Organic carbon is highest in surface horizons of all pedons with

Table 2—Chemical and physical properties of Point Reyes Peninsula pedons.

		Particle size distribution, mm						Color		Moisture retention, bar			
Horizon	Depth	Sand 2–0.05	Silt 0.05–0.002	Clay <0.002	Organic C	Textural class†	pH	Moist	Dry	0.10	0.33	15	Base sat.‡
	cm	%								%			
Pedon 1—Kehoe Variant, coarse-loamy, mixed, isomesic Pachic Haplustolls													
A	0-76	68.5	20.2	11.3	2.1	sl	5.7	10YR2/1	10YR3/2		16.8	10.8	54.4
C	76-107	67.2	26.6	6.2	0.3	sl	5.7	10YR3/3	10YR6/3		23.1	7.8	ND
Cr	107-137	76.1	20.9	3.0	0.3	ls	5.7	10YR4/4	10YR6/4		13.8	7.3	105.0
Pedon 2—Coarse-loamy, mixed isomesic "Entic" Dystropepts													
A	0-91	70.2	16.0	13.8	1.9	sl	5.7	10YR2/1	10YR3/2		15.7	10.4	44.1
AC	91-122	74.2	16.6	7.2	0.4	sl	5.7	10YR3/4	10YR5/3		21.7	5.5	ND
2C	122-152	80.8	10.9	8.3	0.2	ls	5.9	10YR4/4	10YR5/4		--	–	ND
Pedon 3—Coarse-loamy, mixed, isomesic Pachic Haplustolls													
A	0-30	81.4	13.5	5.1	2.8	ls	6.0	10YR2/1	10YR2/2		15.8	12.1	58.1
2Ab1	30-61	71.8	14.2	14.0	2.6	sl	6.0	10YR2/1	10YR2/2		14.5	10.8	ND
2AB2	61-91	66.4	16.1	17.5	1.9	sl	6.0	10YR2/1	10YR2/2		22.1	11.0	ND
2Ab3	91-132	66.5	17.5	16.0	1.7	sl	5.9	10YR2/1	2.5Y3/1	15.4	15.4	9.9	56.6
2C1	132-208	66.7	23.1	10.2	0.6	sl	6.0	10YR3/2	10YR4/2		--	–	ND
3C2	208-244	47.6	39.5	12.9	<0.1	l	6.0	2.5Y5/4	2.5Y7/4		27.1	12.8	ND
3C3	244-274	54.7	37.2	8.1	0.1	sl	6.1	2.5Y5/4	2.5Y7/4		18.3	9.6	ND
3Cr	274-305	79.7	17.8	2.5	<0.1	ls	6.5	2.5Y5/4	10YR6/6		12.2	5.4	ND
3Cr2	305-315	85.5	12.7	1.8	0.1	ls	6.4	2.5Y5/4	2.5Y6/4		11.6	5.5	ND
Pedon 4—Sirdrak, sandy, mixed, isomesic ustic Dystropepts													
A1	0-61	94.0	3.0	3.0	2.6	s	5.1	10YR2/1	2.5Y3/2	9.2		5.7	58.7
A2	61-168	91.0	4.7	4.3	1.2	s	5.5	10YR2/1	2.5Y3/2	7.9		4.6	28.3
2Ab1	168-193	70.3	14.3	15.4	1.9	sl	5.8	10YR2/1	5Y3/2		14.3	9.7	ND
2Ab2	193-305	67.1	17.7	15.2	1.5	sl	5.9	10YR2/1	2.5Y3/2		15.0	9.6	ND
2ACb	305-411	67.4	19.7	12.9	0.7	sl	6.3	5Y3/2	2.5Y4/2		16.8	9.3	ND
3C	411-437	78.5	16.1	5.4	0.2	ls	6.4	2.5Y4/2	2.5Y5/2		13.5	5.3	ND
3Cr1	437-447	57.5	35.6	6.9	0.1	sl	6.3	2.5Y5/4	2.5Y7/3		20.1	7.0	ND
3Cr2	447-478	78.1	19.7	2.2	0.1	ls	6.5	2.5Y5/6	2.5Y7/3		13.0	5.2	ND
3Cr3	478-503	60.8	34.4	4.8	0.1	sl	6.3	5Y5/4	2.5Y7/4		21.2	8.4	ND
Pedon 5—Mixed, isomesic Typic Ustipsamment													
A	0-30	99.1	0.5	0.4	0.5	s	5.3	10YR4/2	10YR4/4	2.2		1.3	36.9
C1	30-60	99.1	0.5	0.3	0.3	s	5.3	10YR4/2	10YR4/4	2.5		1.6	38.3
C2	60-90	98.3	0.3	1.4	0.2	s	5.5	10YR4/2	10YR4/4	2.6		1.6	65.9

† s = sand, ls = loamy sand, sl = sandy loam, l = loam. ‡ Base sat. = Base saturation. ND = Not determined.

a maximum of 2.8% in the A1 horizon of pedon 3 immediately south of the ecotone boundary under grass vegetation. With exception of pedon 4, organic carbon progressively decreases with depth within profiles. In pedon 4, however, organic carbon contents of 2Ab1 and 2Ab2 horizons are higher than in the A2 horizon immediately above. The increase in organic carbon at 168 cm in pedon 4 suggests burial of a former soil surface by more recent deposition. Black coloration (10YR2/1 moist), correlated with organic carbon contents of more than 1%, extends to increasingly greater depths of 76, 91, 132, and 305 cm in pedons 1 through 4, respectively. This further suggests gradual deposition of transported mineral materials over vegetated surfaces with decreasing thickness in a southerly direction toward the cliff edge. Direct evidence of burial of distinct former A horizons cannot be deduced clearly from the data for profiles other than that represented by pedon 4. In pedon 3, particle-size analyses and the relatively high organic matter content to greater depths suggest that a preexisting A/C profile has been overlain by the present surface horizon.

Physical Characteristics of Sands

Concentration of sand grains within rather narrow size limits, indicative of sorting during transport and deposition (Bagnold, 1937; 1939), is very evident throughout the depth of sampling in pedon 5 and in the A1 and A2 horizons of pedon 4 (Table 3). Less conspicuous but neveretheless evident sand sorting is also exemplified between 168 and 411 cm in pedon 4, in the upper 208 cm of pedon 3 and in the upper 122 cm of pedon 2. Just as the content of total sand in surface horizons decreases from pedon 5 toward pedon 1, the proportions of very coarse (2–1 mm) and very fine (0.1–0.05 mm) particles in the sand fractions within the eolian strata decrease along the transect. These gradations imply that lesser quantities of eolian materials have been deposited toward the cliff edge to the south. The more uniform distributions of sand-size particles below 411 cm in pedon 4 and in progressively increasing proximity to the surface toward pedon 1 are more typical of residual parent materials.

Colors and shapes of sand particles further corroborate the existence of eolian deposits over residual parent materials in this area of Tomales Point. Coarse sand particles in the A horizon of pedon 5 are perceptibly rounded (Fig. 4A) and of various colors, including green, orange, black, milky-white and clear. In sharp contrast, coarse sand particles in the Cr horizon of pedon 1 are angular (Fig. 4B). The latter sand includes gold-colored, plate-like, opaque-angular, and clear-angular particles. The plate-like and angular characteristics of these particles are typical of residuum from rock which has cleaved along planes of

Table 3—Sand-size distribution in Point Reyes Peninsula pedons and ratios of rounded to angular grains in coarse (1–0.5 mm) sand.

		Sand-size distribution, mm†					
Horizon	Depth	2–1	1–0.5	0.5–0.25	0.25–0.1	0.1–0.05	Rounded/angular
	cm			%			
			Pedon 1				
A	0–76	12.5	29.0	20.7	25.8	12.0	20/80
C	76–107	10.0	25.3	17.5	29.9	17.3	5/95
Cr	107–137	11.6	27.0	16.1	30.0	15.3	0/100
			Pedon 2				
A	0–91	7.0	29.7	25.5	26.8	11.0	70/30
AC	91–122	4.9	29.7	26.6	27.8	11.0	60/40
2C	122–152	25.5	29.3	16.9	20.1	8.2	40/60
			Pedon 3				
A	0–30	3.2	32.8	33.2	23.3	7.5	80/20
2Ab1	30–61	2.4	28.2	31.8	27.6	10.0	70/30
2Ab2	61–91	3.1	22.5	30.1	31.7	12.6	70/30
2Ab3	91–132	3.6	23.8	30.2	30.7	11.7	70/30
2C1	132–208	3.5	23.5	29.3	29.7	14.0	60/40
2C2	208–244	9.6	17.7	15.1	32.5	25.1	0/100
3C3	244–274	11.7	20.0	15.9	29.7	22.7	0/100
3Cr1	274–305	20.8	23.8	14.6	24.1	16.7	0/100
3Cr2	305–315	26.2	25.2	15.2	22.2	11.2	0/100
			Pedon 4				
A1	0–61	1.4	44.8	37.4	14.6	1.8	75/25
A2	61–168	1.4	44.4	35.0	16.3	2.9	75/25
2Ab1	168–193	4.3	24.5	29.5	30.9	10.8	65/35
2Ab2	193–305	3.9	27.4	29.5	27.7	11.5	65/35
2ACb	305–411	5.9	23.9	25.2	30.9	14.1	20/80
3C	411–437	17.3	24.7	17.6	26.7	13.7	5/95
3Cr1	437–447	11.4	18.8	14.6	30.8	24.4	1/99
3Cr2	447–478	19.4	23.2	15.4	26.6	15.4	0/100
3Cr3	478–503	8.7	20.8	16.5	30.9	23.1	0/100
			Pedon 5				
A	0–30	0.2	40.7	40.5	18.0	0.6	100/0
C1	30–60	0.2	46.5	37.0	15.9	0.4	100/0
C2	60–90	0.6	38.8	40.9	19.2	0.5	100/0

† Percent of total sand.

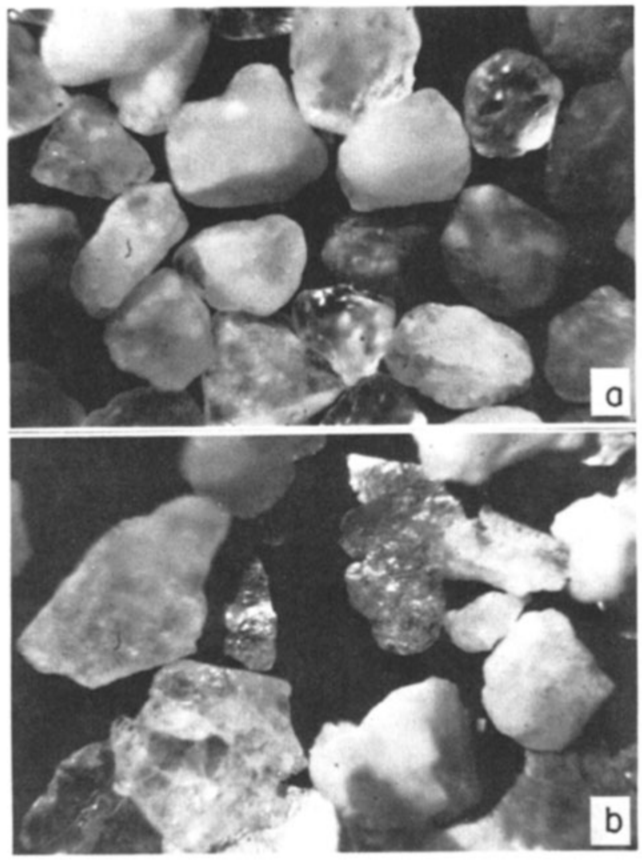

Fig. 4—Photomicrographs of coarse (1–0.5 mm) sand from selected horizons of Point Reyes Peninsula pedons: *a*—rounded grains (A horizon, pedon 5) typical of aeolian deposits; *b*—angular grains (Cr, pedon 1) typical of granitic residuum.

weakness and which has not been severely weathered. These coarse particles appear to have undergone some chemical weathering as evidenced by the golden color of the micaeous plates, but there appears to be little physical weathering other than cleavage into smaller particles.

Microscopic examination of the coarse sand separates from all horizons reveals that the proportions of rounded and angular particles vary among the horizons (Table 3). Essentially all of the eolian material at the crest of the dune (pedon 5) is rounded and smooth. In contrast, the coarse sand particles in the 3C and 3Cr horizons of pedons 3 and 4, and the C and Cr horizons of pedon 1 contain 95% or more angular particles, indicating predominance of residuum. The proportions of rounded and angular particles in the coarse sand separates which fall between these extremes represent parent material of mixed eolian and residual origin.

Silt and Clay Mineralogy

X-ray diffraction analyses of silt and clay fractions provide further evidence of existence of lithologic discontinuities within pedons of the transect. The x-ray analyses also reveal distinctive phyllosilicate weathering progressions within the granitic residuum in reltion to particle size, pedon depth and horizontal position. Mica, vermiculite, smectite and regularly alternating interstratified mica-vermiculite provide evidence for these observations. Selected x-ray diffractograms, chosen to illustrate discontinuities and weathering progressions, are shown in Fig. 5, 6, and 7.

Discrete phyllosilicate species were not distinguishable by X-ray diffraction in either silt or clay fractions of pedon 5, or above horizons 2ACb of pedon 4, 2C1 of pedon 3 and AC of pedon 2. Neither were discrete phyllosilicates distinguishable in the silt fraction above horizon C in pedon 1. In sharp contrast, the silt fractions of C, Cr and 2C horizons in pedons 1 and 2 contain abundant vermiculite (14.2 Å maximum) and regularly alternating interstratified mica-vermiculite (25.2Å and 12.3Å maxima) as exemplified by the diffractogram in Fig. 6. Both vermiculite and mica are present in clay fractions of all horizons of pedons 1 and 2 (not shown). The proportions of vermiculite, relative to mica, are lower in clay fractions of A horizons than in underlying horizons of the two pedons. Situations in which mica increases toward the soil surface, relative to dominant vermiculite deeper within profiles, have been reported for soils of arid climates by Nettleton et al. (1973) and Majhoory (1975).

That lithologic discontinuities exist at depths below 132 cm in pedon 3 and below 305 cm in pedon 4 is

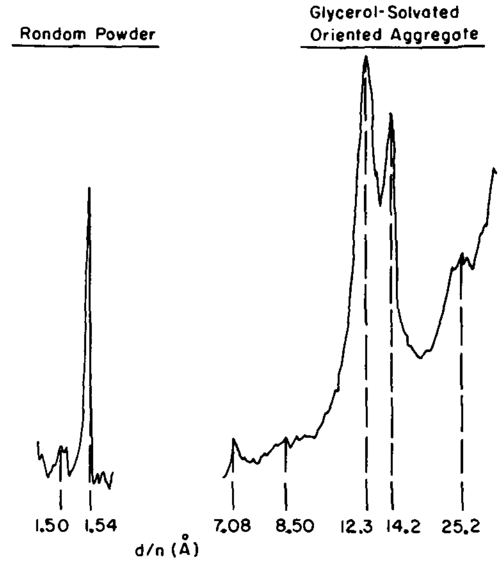

Fig. 5—X-ray diffractograms of the silt (0.05–0.002 mm) fraction from the Cr horizon of pedon 1, Point Reyes Peninsula.

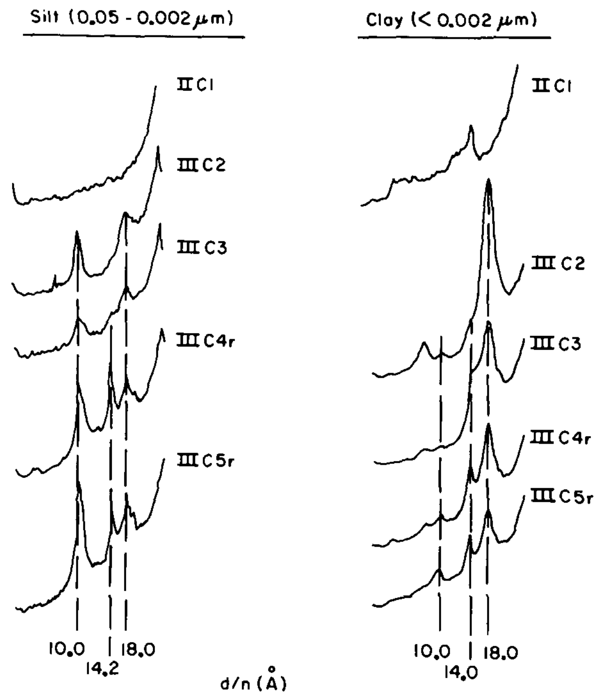

Fig. 6—X-ray diffractograms of Mg-glycerol silt and clay fractions from selected horizons of pedon 3, Point Reyes Peninsula.

clearly evident from marked contrast in phyllosilicate abundance and distribution in the eolian and residual portions of the pedons. This is illustrated for pedon 3 in Fig. 6. In both pedons 3 and 4, a transition zone appears to exist (horizon 2C1, pedon 3; horizon 2ACb, pedon 4). The apparent zone of transition between sharply contrasting materials may be due to material admixture during or after deposition of eolian materials, or it may be an artifact resulting from the manner of sampling these pedons. Nevertheless, the presence of the discontinuity is clear from the markedly different mineralogy above and below these zones. In the silt fractions of pedon 3, for example, there were virtually no discernible phyllosilicates above the 3C2 horizon, whereas mica (10.0Å), smectite (18.0Å), and vermiculite (14Å) were clearly evident in horizon 3C2 and below. The presence of abundant smectite, together with some mica and vermiculite, in the clay fraction of horizon 3C2 strongly suggests that the granitic residuum extends upward at least through this zone. Similar mineralogical evidence suggests that the discontinuity between granitic residuum and aeloian deposit in pedon 4 occurs in the zone designated as horizon 2ACb. The horizons below 411 cm have clearly developed in granitic residuum. The horizons above 305 cm have clearly developed in eolian materials.

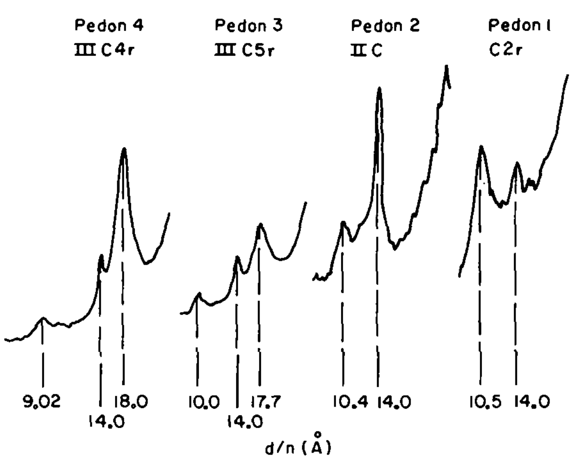

Fig. 7—X-ray diffractograms of Mg-glycerol clay (<0.002 mm) fractions from the deepest horizons within granitic residuum of pedons 1 through 4, Point Reyes Peninsula.

Primary trioctahedral mica in the granodiorite has served as the parent for the secondary phyllosilicates in the granitic residuum. This is verified by the representative x-ray diffraction patterns of silt from horizon Cr of pedon 1 (Fig. 5). Vermiculite (14.2 and 7.08Å) and regularly interstratified mica-vermiculite (25.2, 12.3, and 8.50Å) are abundant in this silt. This phyllosilicate assemblage yields a prominent diagnostic trioctahedral 060 diffraction maximum at 1.54Å and no significant diagnostic dioctahedral maximum at 1.50Å. These x-ray diffraction data are consistent with the observations of biotite in the Point Reyes Peninsula granitic rocks (Anderson, 1899; Minard, 1971; Galloway, 1977).

A weathering sequence, biotite → vermiculite → smectite, is evident in the clay fractions of the lowest horizons of pedon 1 to 4 (Fig. 7). There is a progressive change in species dominance from the mica, biotite, (10.0–10.5Å) in horizon Cr of pedon 1 to vermiculite (14.0Å) in horizon 2C of pedon 2 to smectite (17.7–18.0Å) in horizons 3Cr2 and 3Cr3 of pedons 3 and 4, respectively. A similarly progressive change in phyllosilicate species dominance, indicative of weathering sequence from vermiculite to smectite, is also evident within the clay fractions from horizon 3Cr2 upward through horizon 3C2 of pedon 3 (Fig. 6). Vermiculite progressively decreases and smectite progressively increases with proximity to the surface of this buried, residual profile. This trend in pedon 3 is in contrast to the vertical trend only 5.9 m distant in pedon 4, where smectite is most prominent in the lowest horizon. The weathering progression, biotite →

vermiculite → smectite, has been documented in other weathering environments (Jackson and Sherman, 1953; Coleman et al., 1963; Robert, 1973). Regularly alternating, interstratified biotite-vermiculite has been observed by a number of investigators (Gruner, 1934; Bassett, 1959; Boettcher, 1966). Sridhar et al. (1972) artificially transformed micaceous vermiculite to smectite in the laboratory.

The phyllosilicate weathering progression observed in the present instance is conceivably a reflection of moisture regime within the buried residuum along the transect. The underlying granitic body and the weathered residuum slope perceptibly downward along the approximately 44-m transect from pedon 1 to pedon 4. It is probable that lower portions of the residuum receive progressively increasing quantities of water, from both vertical and horizontal drainage toward pedon 4. Increasing moisture along the sloping transect would be conducive to increased intensity of weathering. It was observed during sampling that the residuum at pedon 4 was extremely wet compared to other positions along the transect. It was also noted that drainage waters form a spring beneath the cliff surface west of and in line with the ecotone boundary adjacent to pedons 3 and 4. The apparent progression from biotite to smectite in an upward direction within the residuum of pedon 3 is thought to be a normal progression of increased weathering with proximity to the surface. Increase in vermiculite and concomitant decrease in biotite from lower to upper horizons within the granitic residuum provide evidence of the weathering depth function in pedons 1 and 2. In neither of these pedons, however, has the weathering progression advanced to smectite. This may be due to shallower pedon depths at these locations.

SUMMARY

The data from this investigation clearly support the existence of profile discontinuities caused by deposition of aeolian materials over granitic residuum within pedons on Tomales Point at the northern end of Point Reyes Peninsula. Additionally, data reveal a weathering sequence within the buried granitic residuum involving the progression biotite → vermiculite → smectite.

According to soil taxonomy criteria (Soil Survey Staff, 1975), soils along the selected transect are identified in the following families: pedons 1 and 3 are members of the coarse-loamy, mixed, isomesic Pachic Haplustolls; pedon 2 is a coarse-loamy, mixed isomesic Entic Dystropept;[3] pedon 4 is a sandy, mixed, isomesic Ustic Dystropept; pedon 5 is a mixed, isomesic Typic Ustipsamment. This taxonomy is consistent with the physical and chemical data, including % base saturation (Table 2).

Plant species variations along the transect, including the abrupt ecotone boundary between pedons 3 and 4, present interesting contrasts associated with the soils. Reasons for these variations were not specifically addressed in this investigation. However, the abrupt boundary between the deeper-rooted plants on the recent dune materials north of the ecotone and the grasses and forbs south of the ecotone is, in all probability, related to the contrasting soil moisture regimes of surface or near-surface horizons on opposite sides of the ecotone.

[3] Not a formally recognized family. "Entic" relates to the lack of a cambic horizon in relation to Typic Dystropepts. The recognized subgroup, Fluventic Dystropepts, and its description is inappropriate for this soil developed in residuum.

ACKNOWLEDGMENT

The authors express appreciation to William R. Allardice, Jeanne T. Crawford, David Bannan, and Mark Akeson for their expert technical assistance.

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