TECTONIC GEOMORPHOLOGY AND EARTHQUAKE HAZARD NORTH FLANK, CENTRAL VENTURA BASIN, CALIFORNIA

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Tectonic Geomorphology and Earthquake Hazard
North Flank, Central Ventura Basin, California

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Tectonic Geomorphology and Earthquake Hazard: Northern Flank, Central Ventura Basin, California

by

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ABSTRACT

A zone of active and potentially active reverse faults near Oak View, California indicates a need for a reevaluation of the significance of the Ojai Valley to the tectonics of the Western Transverse Ranges. The zone is more than 15 kilometers in length, up to 7 kilometers wide, strikes approximately east-west, and contains at least 7 mappable faults that cut terrace gravels of late Pleistocene age. Individual faults are south-dipping and displacements range from high angle reverse to thrust. The south-side-up relative displacement is in marked contrast with the seismically active San Cayetano and Red Mountain north-dipping faults which bound the zone to the northeast and southwest respectively.

The Red Mountain fault is interpreted to die-out to the east in a set of tight overturned folds east of the Ventura River. Crustal shortening between the San Cayetano fault which apparently terminates to the west near Ojai and the Red Mountain fault may be taken up in part by the newly identified zone of south-dipping, south-side-up faults.

Geomorphic expression of faulting which suggests late Pleistocene tectonism includes: 1) linear escarpments separating several levels of the Oak View strath terrace (dated by radiocarbon at 39,360 ± 2610 B.P.) along which faults crop out in several exposures, faulting Miocene sedimentary rocks over Oak View terrace gravels; and 2) tilted Oak View terrace surfaces with sag ponds, internal drainage and possible drainage reversals.

Several active and potentially active faults near Oak View show bedding-plane or flexural-slip that offset the Oak View terrace as well as Holocene colluvium and soil. Faulted surfaces tilt toward the axis of an underlying synclinorium which suggests that movement along the bedding-plane faults is due to folding of the syncline. Fault planes project along bedding planes into the underlying synclinal trough region rather than cut across the structure. Movement along bedding planes occurs in part on incompetent bentonitic layers and apparently does not extend downward into the basement complex. Thus, it is concluded that movements along these faults (at Oak View) are only capable of producing earthquakes of small magnitude. Since the faults are several kilometers long and some of them are active (cut Holocene material), according to published fault length-magnitude earthquake relationships, they may be incorrectly evaluated as capable of producing earthquakes of moderate to large magnitude. However, several kilometers to the east, the faults apparently coalesce and probably are capable of producing larger earthquakes.

The Oak View faults do present a potential ground rupture hazard. The displacement rate associated with the Oak View flexural-slip faulting is estimated to be 3.5 mm per year during the last 30 to 40 thousand years. Surface rupture may be intrinsically induced by compression associated with folding of the bedrock, or sympathetically triggered by earthquakes along major faults in the area such as the Lion, Red Mountain or San Cayetano faults. Thus Ojai and nearby cities and towns are located in a seismically active area and will remain subject to potentially damaging seismic shaking. In addition, continued vertical displacement along the flexural-slip faults is a potential ground rupture hazard which may damage any structure or road constructed across these faults. A potential landslide hazard associated with unconsolidated terrace deposits along the fault scarps also exists.

Pleistocene and Holocene alluvial fans on the north side of the Santa Clara River Valley, California, are being actively deformed in conjunction with active thrust faulting along the San Cayetano fault. Several generations of alluvial fans in Orcutt Canyon display tilting, faulting and uplift in proportion to their relative ages as determined from soil profile development. The oldest fan remnants are tilted to 17° with intrafan fault offsets of up to 100 m. Present fans have slopes of about 5.5° at the same proximity to the San Cayetano fault indicating at least 11.5° of basinward tilting. Faulting of the fans occurs both directly by the San Cayetano fault and by bedding plane faults induced by regional north-south convergence.

In Orcutt Canyon, alluvial fans begin at the main fault trace where bedrock is faulted up and eroded off, forming long, narrow valley-fill fan deposits. These deposits are faulted by flexural-slip induced bedding plane faults with scarps up to 100 m high in the oldest deposits. Moderate- to large-magnitude earthquakes would only be expected to be generated along the main San Cayetano fault zone which juxtaposes Eocene sandstones and shales over early to mid-Pleistocene conglomerates. The bedding plane faults probably only produce small-magnitude earthquakes as they do not extend to depths where larger earthquakes are generated. They do, however, produce a potential ground rupture hazard.

The San Cayetano fault is potentially active with both a seismic shaking and ground rupture hazard; probably capable of producing a San Fernando (1971) type earthquake of M6 to M7 (Yeats, Clark, Keller and Rockwell, in preparation). At Sisar Canyon, the main trace of the San Cayetano fault is represented by a 65 m scarp in mid to late Pleistocene alluvial fan deposits, and at Bear Canyon alluvial fan deposits are being folded and faulted by a strand of the fault. Estimated slip rates for the fault vary from a maximum of 3.6 mm per year in the central portion of the fault to a minimum of 0.66 mm per year toward the the western terminus. These rates are compatible as displacement per earthquake event as well as total displacement should die out toward the end points of the fault.

Soils in the study area show a great range of variability in profile characteristics and in apparent age. Nevertheless, the older surfaces show stronger profile development and thus a soil chronosequence exists. The soils range in age from Holocene (Q_1) to late Pleistocene (Q_7). Two radiocarbon used in conjunction with known deformation of geomorphic surfaces facilitate the assignment of tentative ages to the seven members of the chronosequence, providing a tool to estimate deformation rates associated with folding and faulting.

Based on soils correlation it is provisionally concluded that the multiple terrace surfaces at different elevations in the Oak View area are all tectonically segmented portions of the Oak View terrace.

Palexeralfs (soils) in the study area, provided the radiocarbon date for the Oak View terrace is correct, form in as short a period as 20 to 30 thousand years, considerably faster than rates estimated for similar soils in the California interior. Fast rates of pedogenesis reflect texture and composition of the parent material, increased weathering, acidic conditions, erosional stability of the geomorphic surface, annual precipitation pattern, downward flow of soil water, and eolian inputs of salts and dust.

INTRODUCTION

The Ventura basin is within the western Transverse Ranges geologic province, an anomalous east-west trending topographic and structural feature overprinted on the dominant, northwest-trending structural grain of California. The basin has been extensively studied by geologists in connection with exploration for petroleum. More recently it has aroused interest in connection with neotectonics and earthquake hazard analysis. Studies by La Joie and others (1979), Yeats (1977 and 1979) and this study indicate that tectonic uplift in the area varies from about 1 to 10 mm per year. Growing human development in the area warrants a detailed study of the recent geologic history of active and potentially active faults in the basin. This preliminary report addresses this need through a tectonic geomorphology study along the north side of the Ventura basin, extending from the Ventura River at Oak View east to Sespe Creek at Fillmore (Fig. 1). This area is characterized by many geomorphic surfaces such as alluvial fans and stream terraces that have been faulted and/or tilted (Fig. 2).

This report will first present a summary statement concerning the earthquake hazard associated with the active and potentially active faults that were investigated, as this is the major objective of this study. Results will then be presented from two specific field studies: 1) the Oak View area extending along the Ventura River from Casitas Springs just south of Oak

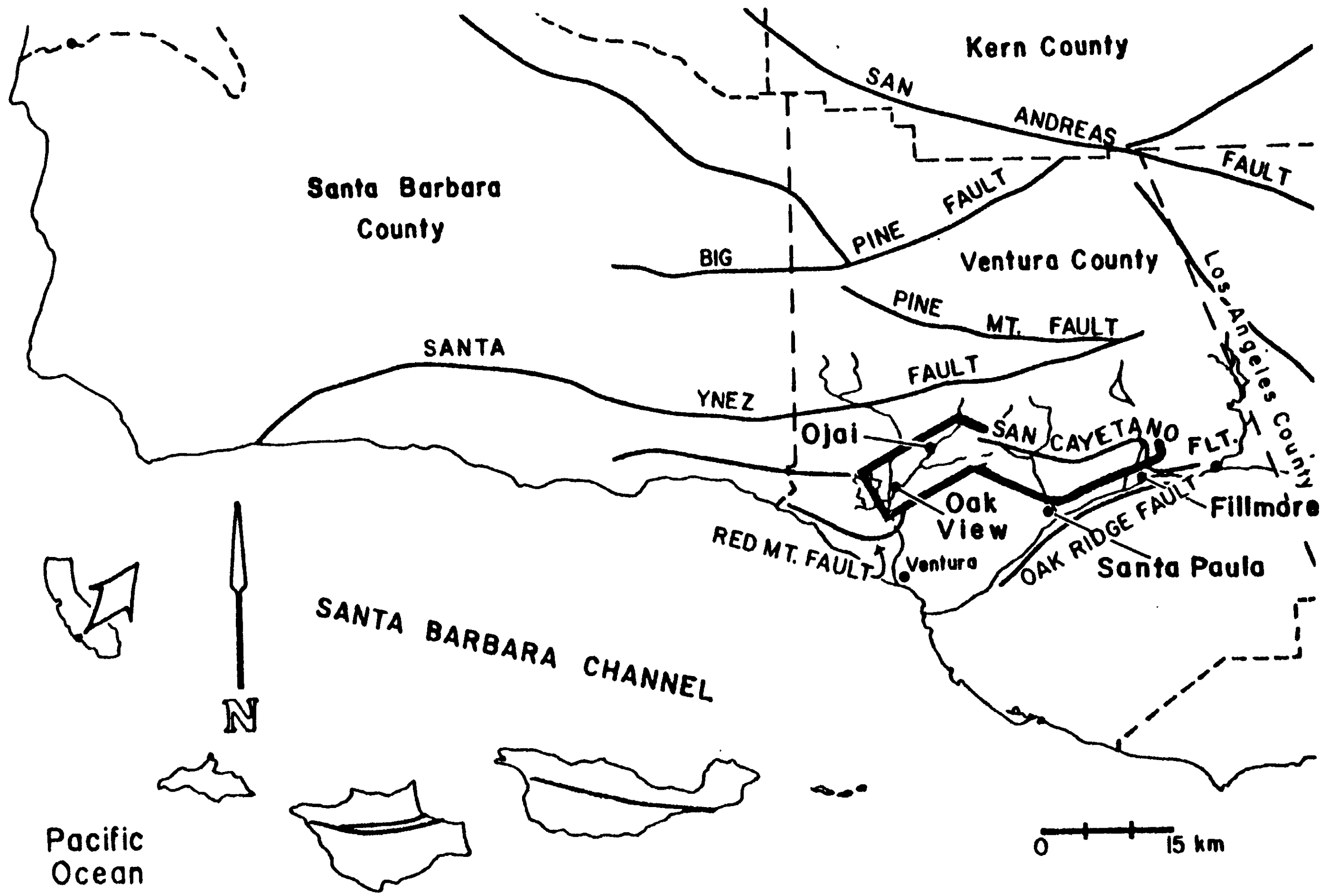

Figure 1. Index map of the study area.

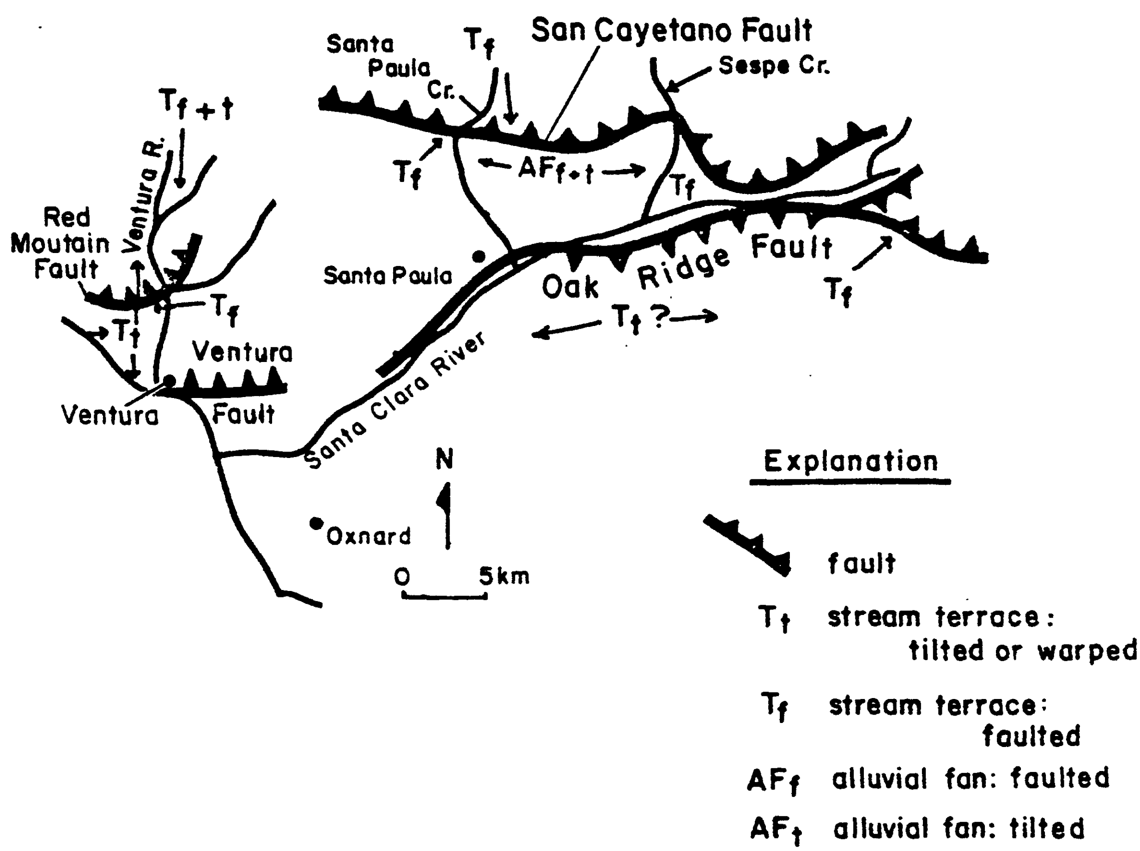

Figure 2. Tilted and/or faulted geomorphic surfaces in the Central Ventura basin.

View to Ojai; and 2) the San Cayetano fault from the Upper Ojai Valley east to Sespe Creek at Fillmore. In addition, the preliminary soils geomorphology that allowed for much of the interpretation and chronology of deformation is presented.

A major purpose of this report is to present maps and a detailed description of the two structurally complex field areas. Particular attention is focused on geomorphic and structural characteristics of two zones of active and/or potentially active flexural-slip faulting: 1) a newly identified zone of faulting that begins at the Ventura River near Oak View and extends east-northeast toward the trace of the San Cayetano fault in the Upper Ojai Valley (Fig. 3); and 2) a zone of faulting located just south of the San Cayetano fault (Fig. 4).

EARTHQUAKE HAZARD: SUMMARY STATEMENT

This summary statement of the potential earthquake hazard was developed with Robert Yeats and a paper, "Active Fault Hazard: Ground Rupture vs. Seismic Shaking," by Yeats, Clark, Keller and Rockwell is in preparation.

In an assessment of fault hazard, faults are presently classified according to the recency of their movement with the implicit assumption that the younger the earth materials offset by the fault, the more hazardous the fault is likely to be. This assumption is challenged based on the hypothesis that there exist three basic types of active faults that may be defined in terms of the type of hazard presented: 1) faults with both

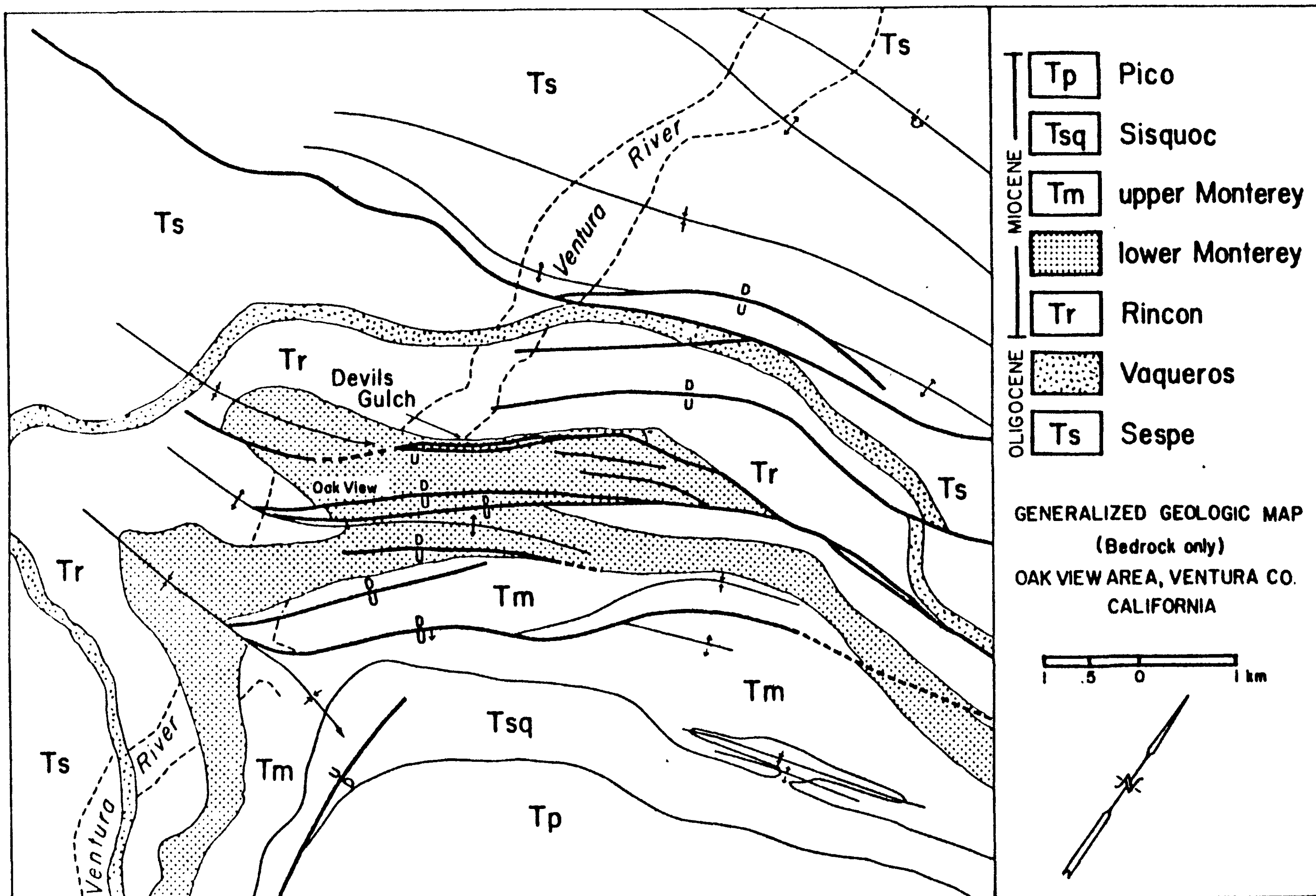

Figure 3. Generalized geologic map (bedrock only) of the Oak View showing synclinorium and zone of active potentially active south-dipping and south-side-up reverse faulting.

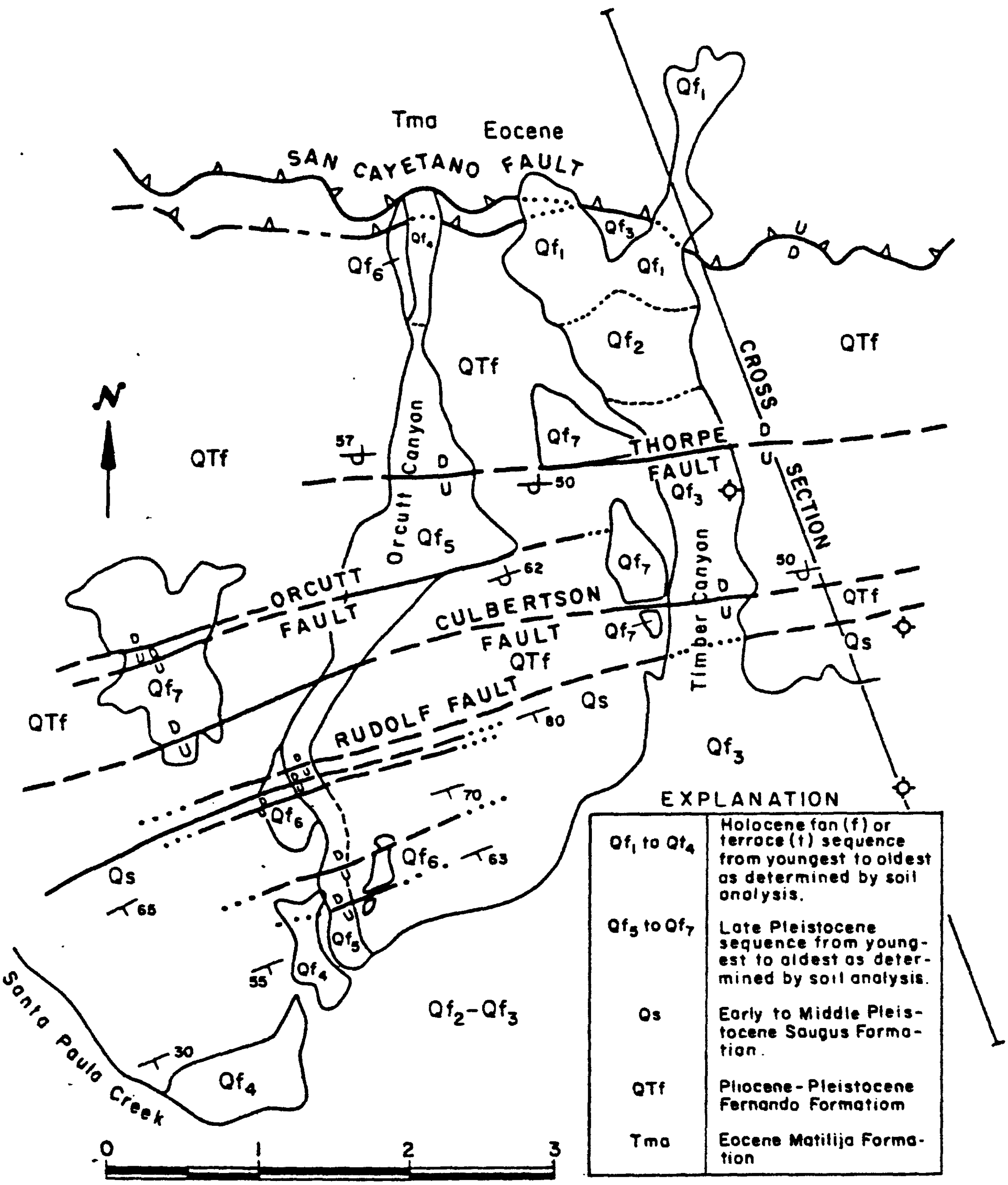

Figure 4. Map of Orcutt and Timber Canyons on the north flank of the Santa Clara syncline. Cross-section is shown on Figure 5.

ground rupture and seismic shaking hazard; 2) faults with seismic shaking but slight or no ground rupture; and 3) faults with ground rupture but minor, if any, seismic shaking hazard.

FAULTS WITH GROUND RUPTURE AND SEISMIC SHAKING POTENTIAL

Faults of this type in the study area include the San Cayetano and Red Mountain thrust faults. The San Cayetano fault is a north-dipping thrust with up to 9,000 meters of apparent vertical (north side up) stratigraphic separation. Fault scarps and fault outcrops in alluvial fan and stream terrace gravels suggest at least late Pleistocene activity. The fault should be considered potentially active with both a seismic shaking and ground rupture hazard; probably capable of producing a San Fernando (1971) type earthquake of M6 to M7.

The Red Mountain fault is a north-dipping thrust that faults Eocene to Miocene rocks southward over Pliocene and Pleistocene rocks. The fault cuts Pleistocene and Holocene marine terraces (La Joie and others, 1979) and has apparently produced nearly 4 mm/year differential movement from 1934 to 1968 (Buchanan-Banks and others, 1975). The fault also has a known history of microseismicity in the period 1970-1975 (Yerkes and Lee, 1979 and Yeats and others, in press), and thus is a candidate for at least a San Fernando-type earthquake of M6 to M7. Therefore the Red Mountain fault clearly presents both a seismic and ground rupture hazard.

FAULTS WITH GROUND RUPTURE BUT MINOR, IF ANY, SEISMIC SHAKING POTENTIAL

Faults of Orcutt and Timber Canyons

East of Santa Paula Creek, a thick Pliocene-Pleistocene sequence is folded into the asymmetric Santa Clara syncline, the north flank of which is exposed in the low hills north of the Santa Clara River (see Plate VIII). Long, narrow alluvial fans of late Pleistocene to Holocene age unconformably overlie these steeply dipping strata.

The fans are cut by at least eight nearly parallel faults (Fig. 4 and Plate VIII), all of which have the south side up, a sense of displacement opposite to that of the active San Cayetano fault to the north (Rockwell and Keller, 1980). The strike of these faults is parallel to that of the underlying steeply dipping strata so that displacement of these strata cannot be measured in the bedrock at the surface except where overlain by alluvial deposits. The faults have normal displacement where bedding is overturned and reverse displacement where right side up, indicating intrinsic control by the bedding dip. Data from petroleum exploratory wells drilled in this area show that these faults do not offset bedding at depth (Fig. 5). In addition to the faulting of the fan surfaces, which show greater separation for older surfaces, they are tilted basinward, indicating decreasing dip of the fault plane with depth in the same sense as the bedding of the underlying strata. The amount of tilting deformation, like amount of separation, is dependent

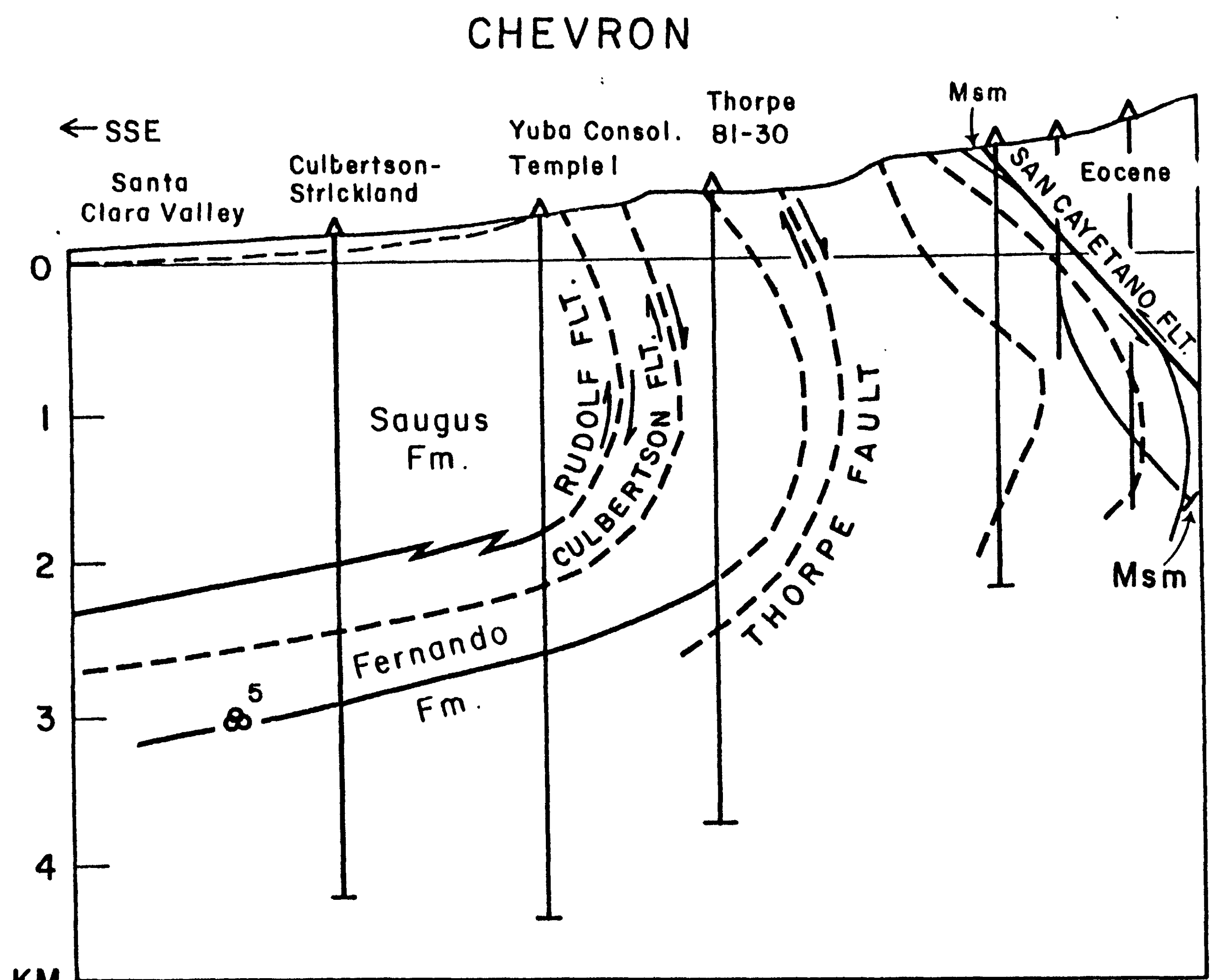

Figure 5. Cross-section showing Culbertson, Thorpe and Rudolf faults. Location is shown on Figure 4. After Yeats, Clark, Keller, and Rockwell (in review).

upon the age of the surface (Fig. 6). These faults are interpreted as bedding-plane faults which undergo displacement during flexural-slip folding of the Santa Clara syncline.

We conclude that the faults of Orcutt and Timber Canyons do not extend downward to rocks of such high shear strength that they could store enough elastic strain energy to produce a damaging earthquake when the strain energy is released instantaneously. Continued north-south compression will accentuate the Santa Clara syncline, resulting in additional bedding slip on these faults and additional ground rupture. Accordingly, these faults constitute a ground-rupture hazard but not a seismic shaking hazard.

Faults of Oak View-Ojai Area

At least seven recently identified faults cut Miocene strata (Monterey and Rincon formations) and overlying Pleistocene terraces gravels and younger material in the Ventura River valley between the towns of Oak View and Ojai (Clark and Keller, 1979, 1980; M. Clark, in progress) (Fig. 7; Plates I and II). These faults strike northeast to east, parallel or nearly parallel to bedding in the underlying Miocene formations on the complex north limb of a large syncline (Fig. 3 and Plate VII). The faults are located on a homoclinal sequence with older strata cropping out to the north. The faults dip southeast to south toward the axis of the syncline, show reversed displacement, and are delineated by abrupt linear scarps that are several kilometers long and locally 50 meters high.

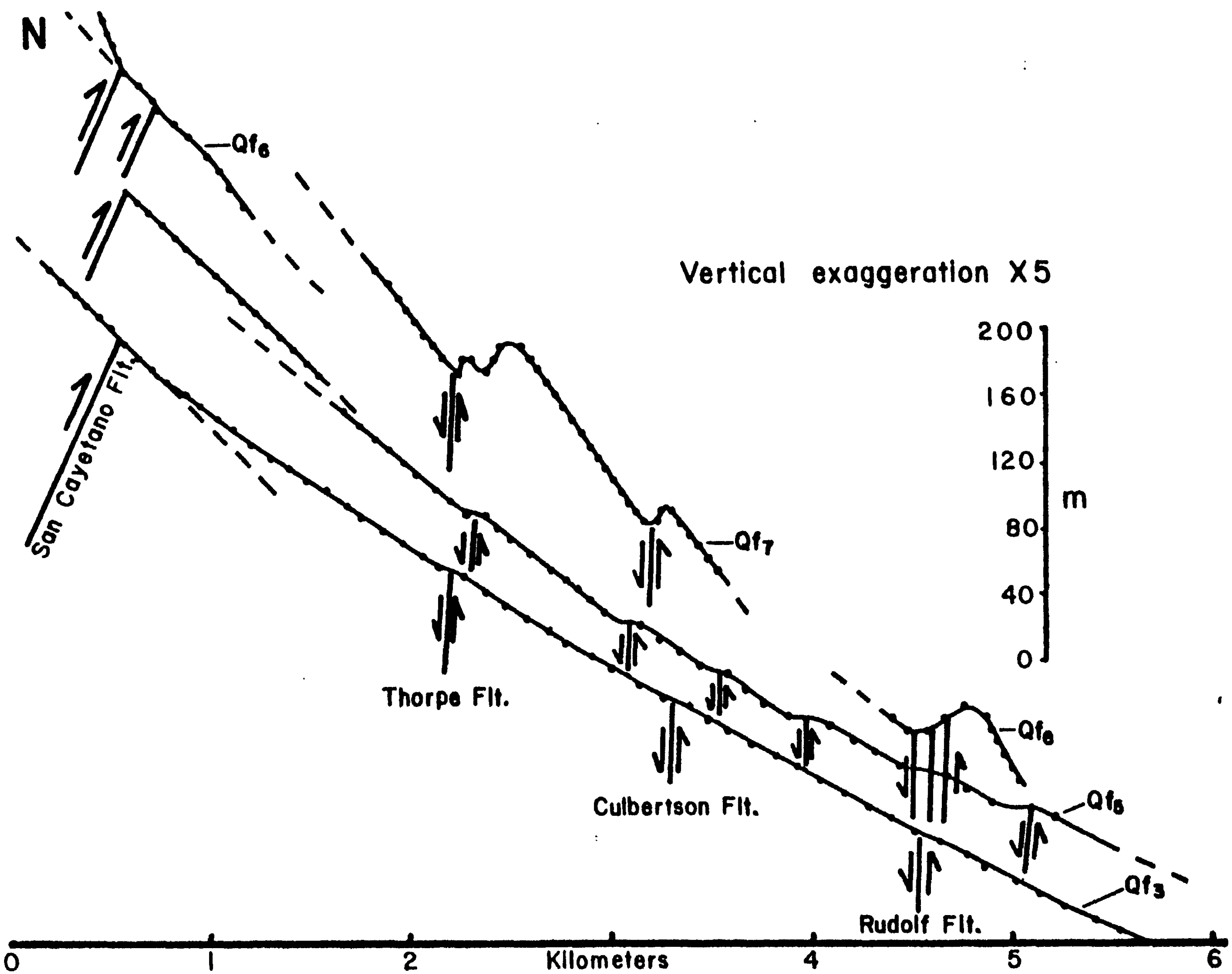

Figure 6. Profiles of faulted alluvial fan segments on the north flank of the Santa Clara syncline, Orcutt and Timber Canyons.

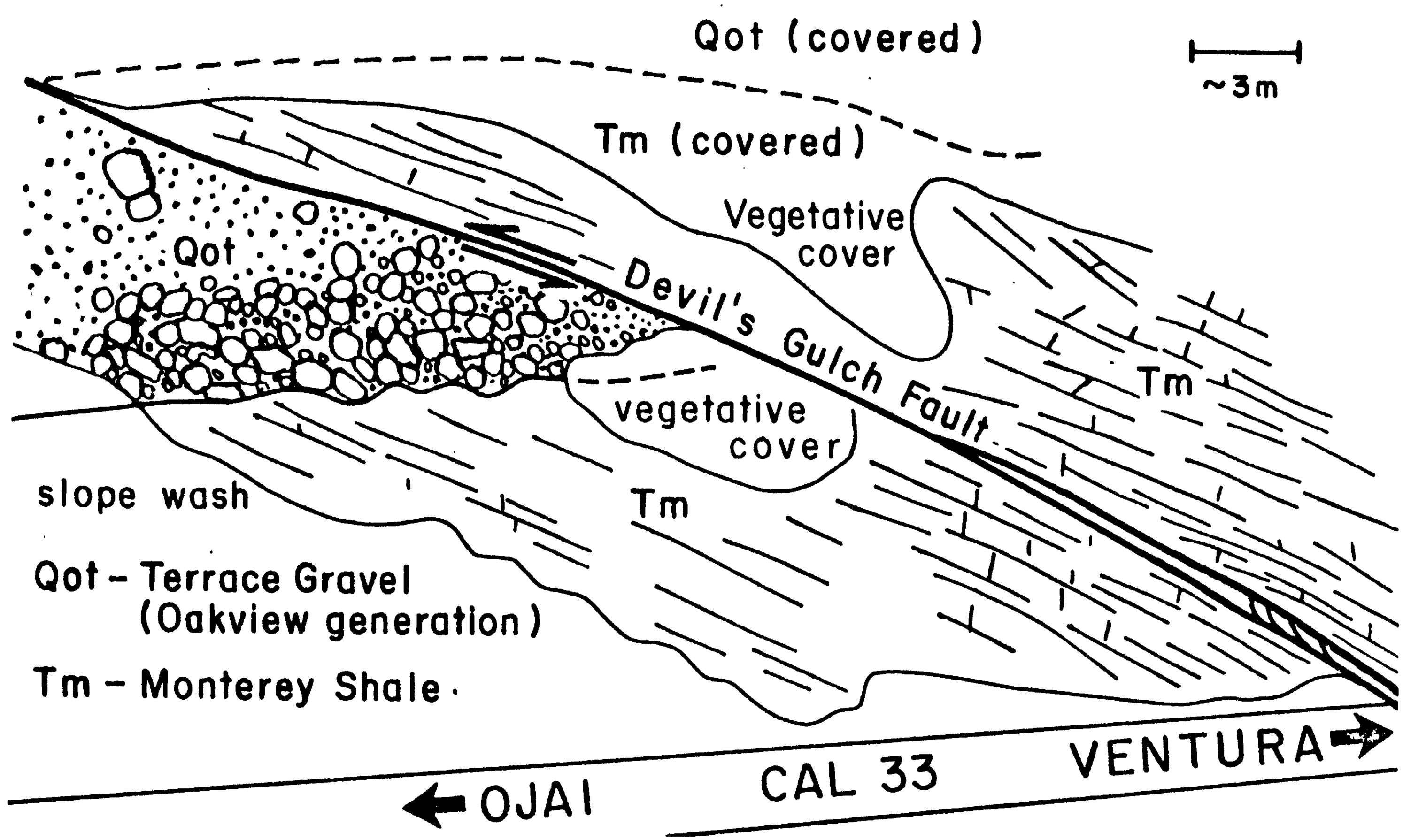

Figure 7. Sketch map of the lower Devil's Gulch fault.

Pleistocene gravels of the Oak View surface cap much of the area but are not shown on Figure 3 and Plate VII in order to emphasize the bedrock structure. These gravels were previously known as the Oak View and older terraces (Putnam, 1942) and have tentatively been correlated by soil profile development. That is, the flight of terraces mapped by Putnam are reinterpreted to be essentially the same surface with multiple offsets produced by faulting. Plate V shows the probable extent of the Oak View strath terrace as interpreted in this study. A radiocarbon date at one site suggests the Oak View surface is approximately 40,000 years old (Clark and Keller, 1979 and 1980; M. Clark, in progress).

Multiple vertical offsets as indicated by the large amounts of displacement of the gravel have produced fault blocks that are tilted southeast away from the Ventura River toward the synclinal axis (Fig. 8), producing linear ponds, internal drainage and drainage reversal (Clark and Keller, 1979). Tilting of the terrace surface that overlies the fault blocks indicates that the faults dip more gently with increasing depth, and that faulting is the result of flexural-slip during folding.

Holocene soil and colluvium are offset by at least one of the south-dipping thrusts near Devil's Gulch (Fig. 9), suggesting that the faults associated with flexural-slip folding are very young and should be considered active. Accordingly, these faults have ground rupture potential, and in fact have produced at least 150 meters of vertical displacement in the last 40,000 years.

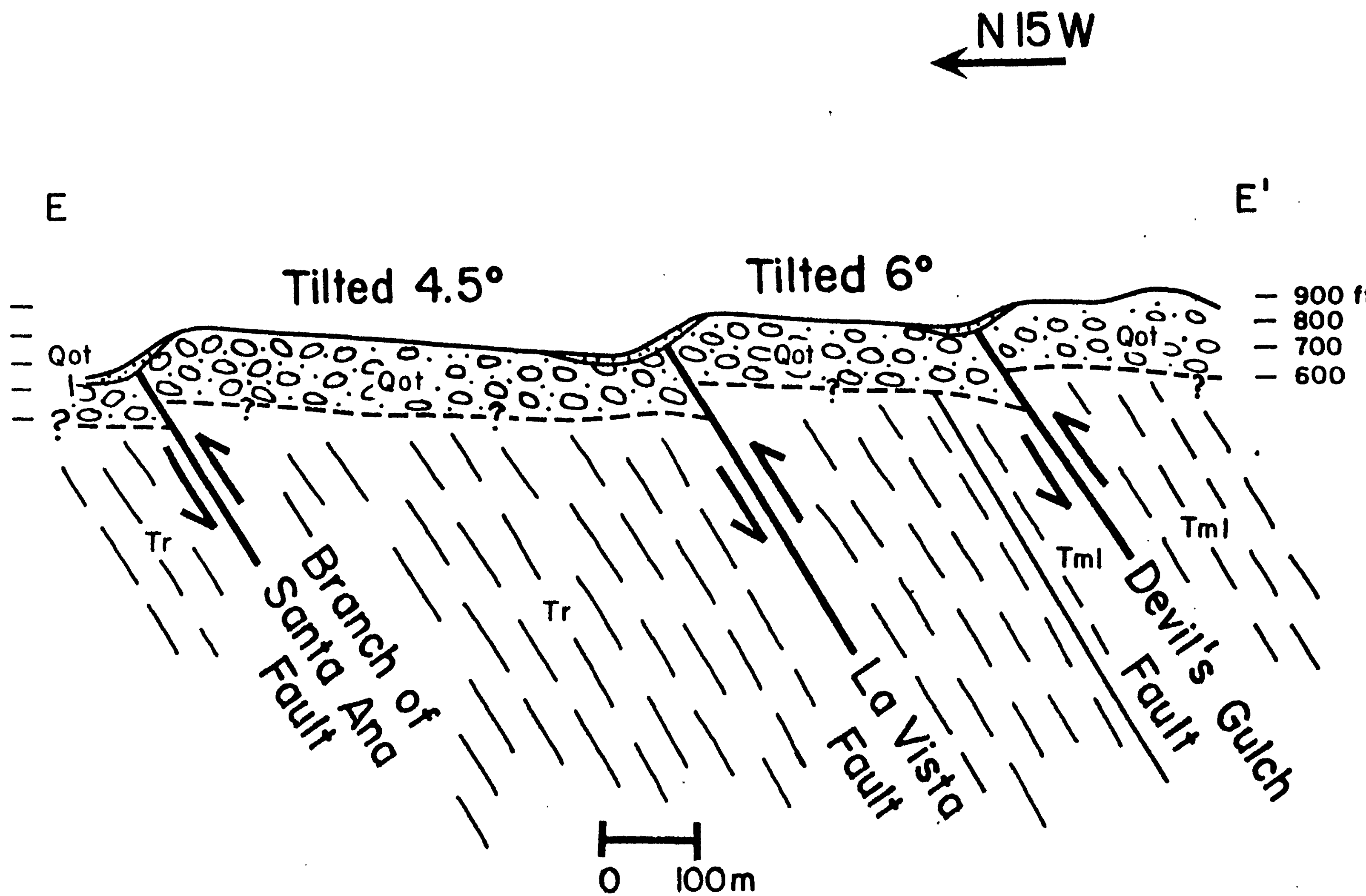

Figure 8. Idealized cross-section showing the faulted Oak View terrace. Thickness of the terrace deposits are exaggerated for illustrative purposes.

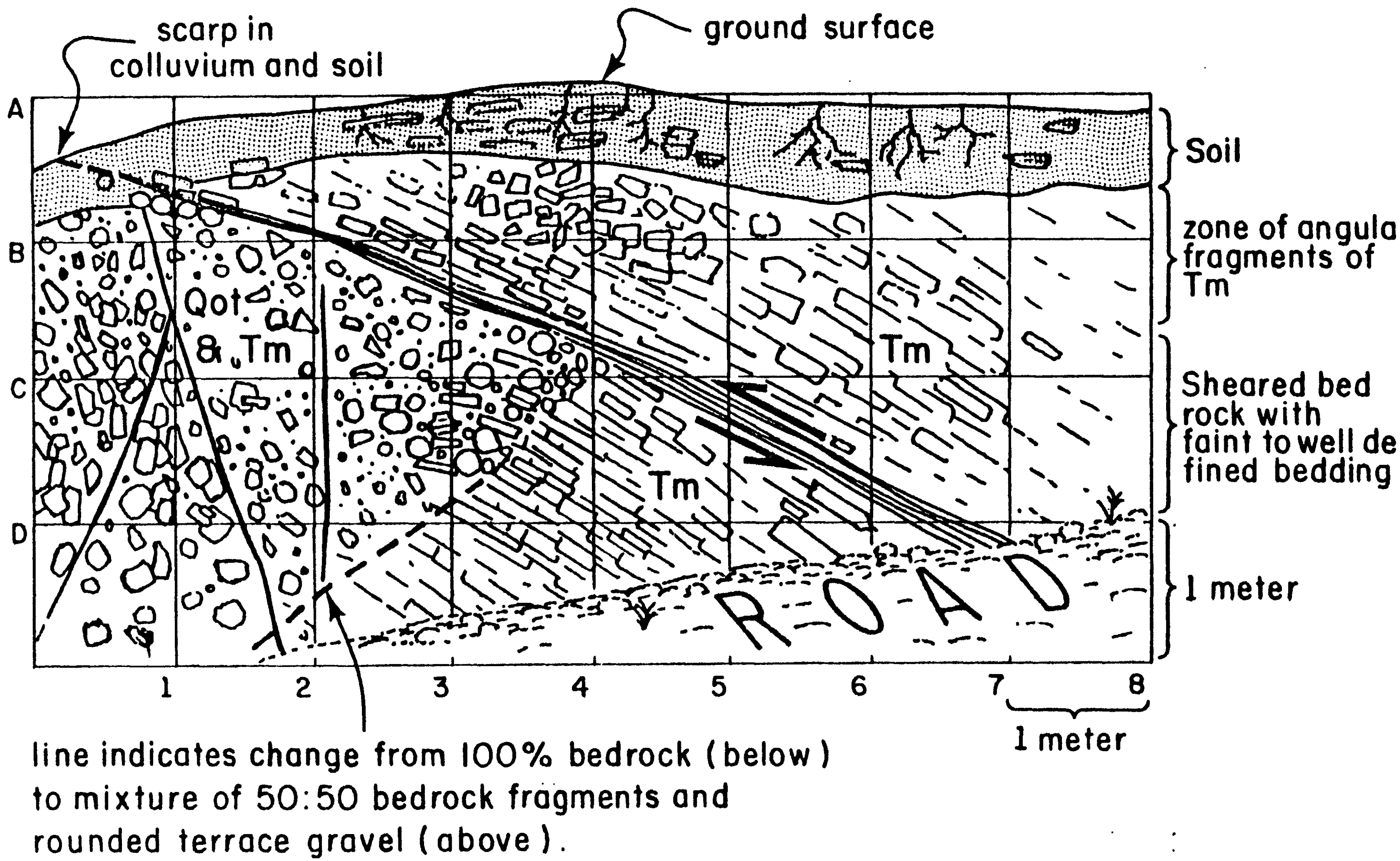

Figure 9. Sketch map of the upper Devil's Gulch fault.

However, because the faults are produced by flexural-slip during folding and the fault planes apparently do not penetrate downward to rocks of high strength, they have low potential for significantly hazardous seismic shaking. Figure 10 contrasts deep straight faults which may produce earthquakes with seismic shaking and ground rupture hazard to faults with flexural-slip and associated ground rupture.

It has been demonstrated that fault movement associated with flexural-slip during folding can produce a good deal of ground rupture. Unfortunately, we have no data concerning when the rupture occurs. It seems reasonable to infer that surface rupture may take place during a large magnitude earthquake along a nearby master fault. Therefore, the hazard associated with the ground rupture is a function of the earthquake activity of nearby master faults and extrinsic seismic shaking will accompany the surface rupture. It also seems reasonable that flexural-slip faulting and ground rupture may be aseismic or accompanied by only low-magnitude earthquakes. In this case, the surface rupture would be an intrinsic consequence of local folding and uplift. In areas characterized by lower rates of uplift and folding flexural-slip might still occur, but surface expression would be more difficult to recognize. Thus, in evaluating the seismic hazard of an area characterized by faulting associated with flexural-slip it may be necessary to plan for occasional intrinsic slip with ground rupture but no seismic shaking as well as extrinsic seismic shaking and sympathetic ground rupture. We

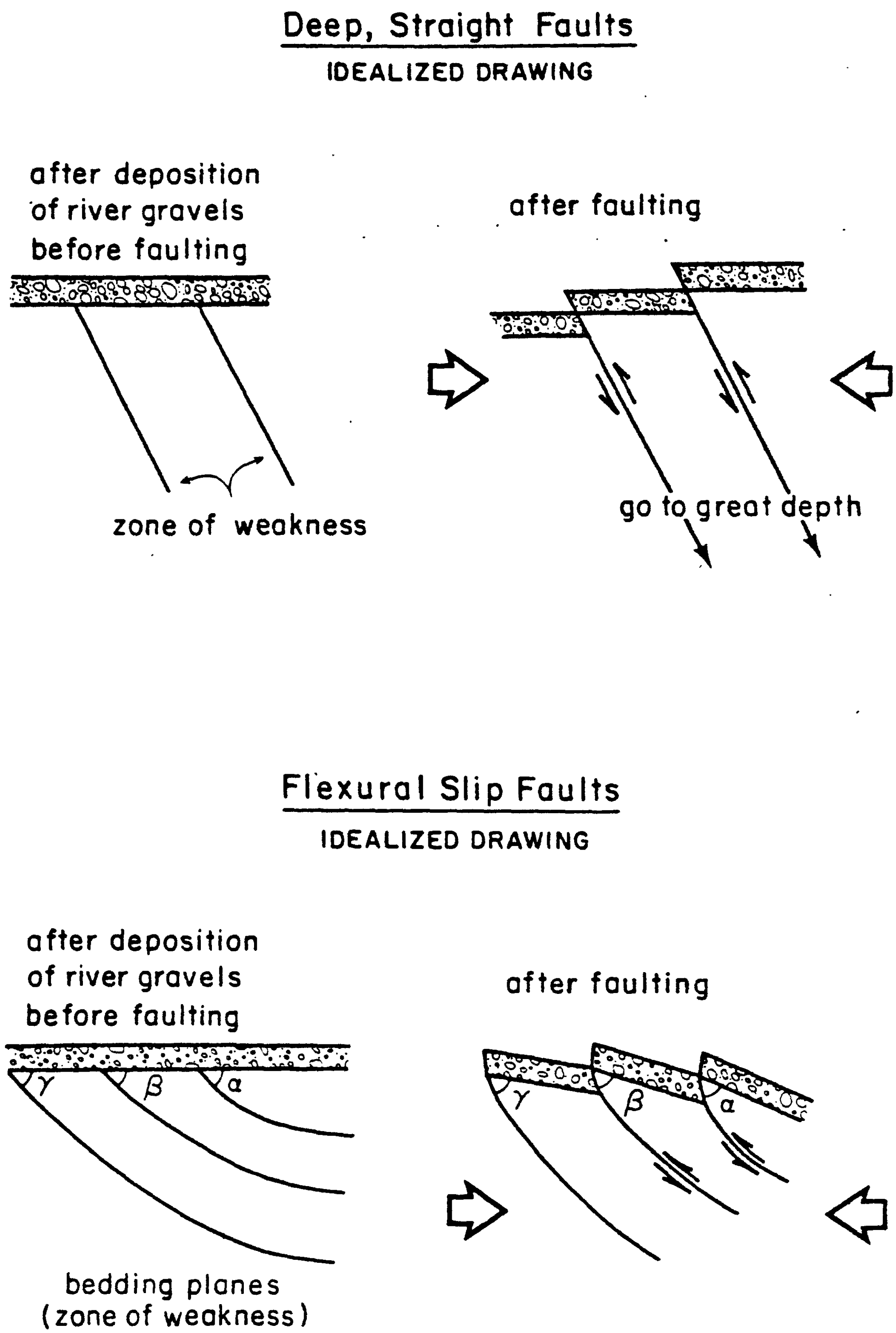

Figure 10. Idealized drawing showing the comparison of deep, straight faults with flexural slip faults.

conclude that the potential hazard produced by shaking may be no greater or less at a particular site with or without the flexural-slip faulting. However, the recognition of the additional surface rupture hazard is important and should be considered in land use planning.

OAK VIEW - OJAI AREA

The Ojai Valley is an intramountain basin within the Santa Ynez Mountains and lies northeast and southwest, respectively, of the terminations of the north-dipping, seismically active Red Mountain and San Cayetano faults. Most of the geologic work done in the area has been devoted to problems of geologic structure, stratigraphy and oil accumulations. One significant exception is W. C. Putnam's 1942 paper which describes the physiography of various river and marine terraces (as he interpreted them) and discusses the geomorphic development of the Ojai Valley. California Division of Mines and Geology Preliminary Report No. 14 contains a geologic map of the Ventura area that is a compilation from several sources (Weber and others, 1973).

High altitude black and white photographs at a scale of 1:20,000 were studied as a preliminary step to fieldwork. The principal method of study employed was field mapping. Other field methods of investigation included: logging of trenches and road cuts, describing and sampling soils in trenches, road cuts and natural exposures. A total of eleven weeks was spent in the field investigation phase, which was conducted in the summer of 1979.

STRATIGRAPHY

Pre-Quaternary stratigraphy of the area was not studied for this report because it is adequately described by earlier workers. It is summarized because pre-Quaternary formations are depicted on the accompanying maps and field recognition was essential to mapping. Also, many of the pre-Quaternary formations are important source rocks for the Quaternary units that are described in this report. Plates III and IV present the compiled stratigraphic columns of the Cenozoic and Quaternary units encountered in the Ojai basin.

The Santa Ynez-Topatopa Mountains and adjacent lowlands around Ojai are composed entirely of sedimentary rocks ranging in age from Eocene to Recent (see Plate I). The Eocene is represented by a great thickness of clastic marine sediments. This is overlain by a terrestrial and marine transgressional Oligocene rock assemblage. The Miocene and Early Pliocene(?) are represented largely by siliceous organic marine sediments. Late Pliocene and Pleistocene strata consist of shallow marine and terrestrial clastic sediments. The exposed stratigraphic succession is nearly continuous from the crest of the mountains north of Ojai to the ocean. This succession is overlain unconformably by upper Pleistocene river gravel and fanglomerate throughout the Ojai Valley and adjacent to the Ventura River.

TERTIARY STRATIGRAPHY

Eocene

A continuously deposited sequence of marine sandstone and shales of Eocene age, about 230 meters thick, makes up most of the eastern part of the Santa Ynez Range. Three formations have been formally established in the sequence; they are, in chronologic order: Matilija sandstone, Cozy Dell shale and Cold Water sandstone (Kerr and Scheck, 1928; Vedder, 1973). Combined, these three formations are responsible for the character of the southern slope of the Santa Ynez Mountains. The lowermost Tertiary formation in the area is the Juncal Formation, which apparently is not represented in the terrace gravels in the Ojai Valley.

Matilija Sandstone (Tma) (Marine): The Matilija Formation conformably overlies the Juncal Formation. It consists of sandstone that is buff, dark gray, greenish gray-white and white, thin-bedded to massive, locally cross-bedded, well indurated and fine to medium grained. It is composed predominantly of well-sorted, subangular to subrounded quartz and feldspar grains with silica cement; calcareous cement occurs locally where fossils are abundant. There are minor siltstone, mudstone and shale interbeds within the formation. In the Ventura region the Matilija sandstone is characteristically mottled pale green with gray-white spots. This characteristic color pattern is retained (although the colors fade) during the weathering process so that

Matilija sandstone clasts are easily recognizable in the Quaternary deposits.

Cozy Dell Shale (Tcd) (Marine): The Cozy Dell shale conformably overlies the Matilija Formation, strikes east-west and is overturned in the eastern Santa Ynez Range. It consists of shale, predominantly argillaceous to silty and highly micaceous, with lesser amounts of siltstone and mudstone. It is dark gray and weathers brownish gray to olive gray. It is massive to laminated, well indurated, locally fissile and readily disintegrates into small sub-ellipsoidal to sub-platy fragments. Locally, occasional beds of well indurated, gray-green sandstone occurs. The rock of the Cozy Dell weathers rapidly and does not transport far before it disintegrates. Consequently it is not found in the old terrace gravel and is usually found in the modern riverbed only as a pile of disintegrated spheroidal fragments.

Coldwater Sandstone (Tc) (Marine): The Coldwater formation lies conformably above the Cozy Dell and forms the final unit in the Eocene sequence of the Matilija overturn. It consists of arkosic sandstone, gray to white, that weathers white or red-brown. It is thin to thick bedded, locally cross-bedded, well indurated, fine to coarse-grained with grains that are sub-angular to angular and unsorted to sorted, cemented by calcareous and clay cement. Varicolored siltstone and mudstone interbeds are common. Oyster biostromes are common locally.

Oligocene

Sespe Formation (TS) (Non-marine): The Sespe is the oldest formation to crop out in the area mapped in the Ojai study area. It probably underlies the Ojai Valley in a syncline (Putnam, 1937). The anticlinal structure of Red and Black Mountains exposes Sespe redbeds.

The formation consists of interbedded argillaceous to silty shale, fine- to coarse-grained sandstone and conglomerate. The rocks are red, maroon, brown-gray and green continental redbeds, and are friable to well indurated. Most of the conglomerate is poorly indurated, with well rounded clasts of volcanic granitic and metamorphic rock and shale. On transport, the interstitial material dissolves, leaving behind characteristic igneous or metamorphic clasts. The red color, imparted by impregnated iron oxides, is retained in Sespe clasts in river gravel that makes up Quaternary terrace deposits.

Vaqueros Sandstone (Tv) (Marine-transitional): The Vaqueros sandstone is a distinctive ridge former that is conformably overlain by the less resistant Rincon shale. The Vaqueros crops out along an east-west trend in Lion Canyon, at Camp Comfort and west of the Ventura River, then curves to the south to define the composite syncline that underlies the Ojai study area. It has been dated as Oligocene by Kleinpell and Weaver (1968). The marine Vaqueros is made up predominantly of fine to coarse, generally medium-grained sandstone with some claystone and siltstone. It is brown, green-brown, gray, white, and buff in color and is composed of well-sorted quartz and a subordinate amount of feldspar and scattered mafics cemented by abundant calcium carbonate. It ranges from massive to locally cross-bedded, poorly to well indurated. Silty shale, limestone nodules and fossiliferous beds are commonly interbedded.

Miocene

Rincon Shale (Tr) (Marine): The north escarpment of Sulphur Mountain is made up of Rincon shale. The formation strikes about east-west through the study area and underlies much of the Pleistocene terrace deposits between Ojai and Oak View.

The formation is predominantly mudstone with some siltstone and shale. Rocks are blue-gray to brown, usually finely laminated, argillaceous to silty with local and common light tan to orange dolomitic limestone interbeds and concretions.

Joints are closely spaces (1-10 cm apart) and cut bedding planes at nearly right angles. This unit is characterized by close ellipsoidal or spheroidal fracturing. The clay-shale contains fish scales, foraminifera, radiolaria and sponge spearles. Minor sandstone intercalations occur throughout the section. Within 5 meters of the contact with the overlying Monterey are beds of weak bentonite that mark the contact (Kerr, 1931).

Monterey Shale (Tm) (Marine): This distinctive siliceous shale is referred to as Modelo in the Ventura basin, by many workers. However, it is indistinguishable from the Monterey formation in the Santa Barbara area and is therefore called Monterey in this report, after the usage of Dibblee (1966). The Monterey shale forms the crest of Sulphur Mountain from its western extent, to the Santa Paula Creek to the east, and underlies terrace gravels in the wedge that is formed by the Ventura River and San Antonio Creek.

The formation consists predominantly of shale with some siltstone and sandstone. It is gray, white and brown, thin-bedded to finely laminated, siliceous, diatomaceous, cherty, clayey, porcelaneous, generally fissile and compact to pinky. The formation is split into two members based on a mappable change in lithologic character. The lower Monterey shale is composed predominantly of soft, fissle, pinky, organic shale, and a lesser amount of interbedded compact siliceous shale, calcareous shale, and thin limestone layers. Where fresh, the lower shale member is finely laminated and dark brown. Where weathered, it is bleached light buff to cream white. The pinky shale contains an abundance of fish scales, test of foraminifera, diatoms and other microscopic marine organisms.

The upper Monterey shale consists of hard, brittle, porcelaneous, siliceous shale that grades upward into less brittle, semi-pinky, sometwhat silty siliceous shale. It is finely laminated and fractures along bedding planes into platy slabs from 1 cm or less to 10 cm thick. Where fresh, the shale is dark brown; but it bleaches light gray to white on the surface.

Sisquoc Formation (Tsq) (Marine): The Sisquoc is the offshore equivalent, for the most part, of the Santa Margarite formation of the Sespe Creek area. Some of the literature, therefore, refers to sections of the Sisquoc in the study area as "Santa Margarita." However, the Santa Margarita is lithologically different, it is sandier and contains evaporate beds. Equivalent rocks in the study area are lithologically identical to the Sisquoc of the Santa Maria and Santa Barbara areas. Use of the name Sisquoc follows the usage of Dibblee (1966).

The Sisquoc consists of mudstone, shale and siltstone, it is chocolate brown to black, massive to laminated, moderately to poorly indurated. Locally, minor sandstone interbeds are gray, fine to medium grained, and range from several centimeters to meters in thickness. Sandstone beds increase in thickness and frequency upward in the formation.

Pliocene

Pico Formation (Tp) (Marine): The Pico formation crops out along the gentle north escarpment of Sulphur Mountain.

The formation consists of interbedded siltstone, sandstone, shale, mudstone and conglomerate. It is gray, blue-gray, tan and brown. Fine-grained rocks are lamellar to thick-bedded, fossiliferous, and commonly contain large amounts of expansive clay. Sandstone and conglomerate units are generally poorly sorted and are composed, in part, of reworked clasts of the Sespe formation.

QUATERNARY

Criteria for recognizing Quaternary units varies from criteria for older lithologic units. Where indurated rock has formed, as in the Saugus formation, standard lithologic criteria apply. However, the distinctions between, for example, older alluvium and conglomerate or landslide may involve the present landform proximity to canyons, rivers or scarps, shape in map view, or presence or absence of bedding. In the case of Qot (Old Terrace) and Qoa (Old Alluvium) described below, the units grade imperceptibly into one another over several hundreds of meters.

Pleistocene

Saugus Formation (Qs) (Non-marine): The Saugus formation reportedly is exposed in the upper Ojai Valley (Bush, 1956) but apparently does not crop out in the Ojai study area. It underlies the alluvium in the upper Ojai Valley, where it lies against the Lion Fault (Bush, 1956).

The Saugus consists of pebbly, coarse sandstone and conglomerate, and is poorly to well consolidated. The conglomerate is composed of clasts of varying source terrain and includes a large percentage of metamorphic and igneous rocks with a gray to black sandy matrix. Lithology of clasts and matrix distinguishes the Saugus from younger alluvium and terrace gravel in the Ojai vicinity.

Fanglomerate (Qf) (Subaerial): Alluvial fan material along the northern border of the map area lies with sangular discordance on the Sespe formation in the synclinal Ojai Valley. The fanglomerate is several tens of meters in maximum thickness, perhaps as much as 100 meters, although the depth is not known exactly in most places. It is brownish buff in color and is composed of unsorted boulders, cobbles, pebbles of sandstone and pebbles of shale, derived from the Eocene formations in the mountains to the north. The clasts are embedded in a comminuted sandy matrix of the same detritus. Some of the sandstone boulders are as much as 2 meters in largest dimension.

The fans emerge from the mouths of Cozy Dell, McDonald, Stewart, Gridley, Señor, Horn and Wilsie Canyons and appear to be progressively younger, in that order. Relative age is inferred from oxidation and weathering of clasts and degree of dissection of the fans (Putnam, 1942). The fans are apparently undeformed, but dissected to varying degrees as they are now above the base level of the Ventura River. The fan between Stewart and McDonald Canyons has been incised 170 meters so that the Sespe is exposed beneath the gravel. Adjacent to the mountain, the fanglomerate has very little if any bedding, but downslope it gradually becomes less coarse, somewhat sorted and crudely bedded.

Old Terrace (Qot) (Fluvial): The terrace gravel in the Ventura River covers 10 to 15 square kilometers. The most complete preservation of the Ojai terraces or surface is in the wedge south of Ojai between San Antonio Creek and the Ventura River (see Plate 1). Putnam called the large terrace that underlies the town of Oak View the "Oakview Terrace" and mapped it from the mouth of the Ventura River at the Pacific Ocean discontinuously to the Ojai Valley, where it merges with the valley alluvium. There are, however, several preserved and isolated terrace patches at various elevations (see Plate V) that, based on preliminary soils work, are here inferred to be contemporaneous with the "Oakview Terrace" of Putnam (1942). That is, the flight of terraces that Putnam mapped north of the city of Oak View are herein mapped as one terrace (separated by faults) and referred to as the Oak View terrace. Additional soils work will undoubtedly show that still other isolated erosion surfaces shown on Plate V are also part of the Oak View terrace.

The gravel that makes up the terrace material forms a mantle ranging in thickness from a veneer to several meters on the beveled surface of underlying Tertiary formations and is derived from the Oligocene and Eocene rocks to the north. The Oak View surface is thus a strath terrace. The detritus is poorly to moderately stratified, poorly sorted, unconsolidated to poorly consolidated, well-rounder gravel, boulders, sand and silt. Terrace gravel is distinguished from fanglomerate on the basis of parent source material; the fanglomerates are locally derived whereas terrace gravel is derived from a mixture of sources.

An age of 39,360$\pm$2610 B.P. was obtained on charcoal fragments found 9 meters below the surface of the Oak View surface in the road cut of Highway 33 between the town of Oak View and where the highway crosses San Antonio Creek. The soil developed on the Oak View terrace apparently correlates with Q_6 on the preliminary soil chronosequence being developed for the research area, but to date only applied to geomorphic surfaces in the Santa Paula to Fillmore area (see Figure 4 and Plate VIII).

Older Alluvium (Qoa) (Fluvial): The Oak View terrace as mapped by Putnam (1942) merges in the Ojai Valley with valley alluvium. The contact between the older alluvium and terrace deposit in the valleys and abandoned river channels is vague, yet over a distance, sometimes of several hundreds of meters, a distinct change can be observed. The older alluvium as mapped in this report usually consists of a layer of finer sediment.

Younger Terraces (Qt) (Fluvial): In the mapped area, younger terraces are found along San Antonio Creek from Camp Comfort to the Ventura River. They also occur along the Ventura River from the narrows of Oak View southward and extend discontinuously to the Pacific Ocean.

Younger terrace material is distinguished from the Old Terrace deposit on the basis of (1) lesser degree of soil development, (2) closer elevation and map distance relationship with the modern streams, (3) lesser degree of surface erosion and (4) absence of deformation and tilting. Younger terraces slope gently (2-6°) toward the thalweg of their respective streams.

Younger terraces are made up predominantly of reworked gravels and, like the old terraces, are composed of Eocene and Oligocene clasts. Soil development of younger terrace material was briefly examined at location N2 (Plate V) and was evaluated as younger than that of the Oak View terrace material. Soils on the younger terraces were not evaluated in detail and some may be of Holocene age.

Holocene

Alluvium (Qal, Qa) (Fluvial): Undissected alluvium of Recent age covers the present flood plains of the Ventura River, San Antonio Creek, and their tributaries. The Qa deposits are only slightly older than Qal deposits and form abandoned meanders along San Antonio Creek. The surficial deposits that fill these flood plains consist of several meters of unconsolidated boulders, gravel, sand and silt derived from the same sources (Eocene and Oligocene strata) as the terraces. In some cases, clasts are reworked from the terraces. Alluvium is distinguished from older material by its presence in stream channels, and proximity of streams. At one location the alluvium of the Ventura River floodplain is dated by the presence of an automobile that is no more than 20 years old.

Landslides (Qls): Landslide material consists of varied debris; disrupted, fragmented and mixed bedrock and soil lacking bedding. The bedrock in the deposits may be jumbled fragments, brecciated masses or relatively intact units. Landslide masses are distinguished in the field in part by hummocky slopes generally of lower gradient than adjacent slopes. The landslides generally are semicircular or elliptical in map view. Disrupted and cracked ground is commonly visible on more recent landslide masses. A scarp in the bedrock above the mass is often associated with a landslide.

Landslides occur on moderately steep to steep slopes usually in unconsolidated material or weak bedrock. Some landslides seem to be associated with faulting.

STRUCTURE

Folding and faulting of the bedrock in the Ojai region are largely the result of Quaternary tectonics. Analysis of bedrock deformation is therefore pertinent to the study of tectonic geomorphology, Quaternary history and hazard analysis.

Plates II and VII show the interpretation of the structure that underlies the study area compiled from data gathered during field mapping and from previously published maps. Plate II is a series of geologic cross-sections; Plate VII is a geologic map from which the Quaternary deposits have been removed to better display the bedrock structure.

Major folds within the mapped area are: 1) Red Mountain dome; 2) Ayers Creek syncline; 3) Coyote Creek anticline; 4) Santa Ana syncline; 5) Long Valley syncline; 6) Wills Canyon anticline; 7) Ojai syncline; and 8) Black Mountain anticline. The Red Mountain dome of Putnam (1942) is located in the southernmost part of the mapped area. North of this major feature is an east plunging composite syncline (5 km wide measured at the Ventura River; see tectonic and bedrock map, Plate VII) that is composed of three smaller folds, notably the Ayers Creek syncline, Coyote Creek anticline and the Santa Ana syncline. The Coyote Creek and Santa Ana folds apparently die out into faults as they cross under the Ventura River from the west. The Ayers Creek syncline, however, gradually becomes wider east of the Ventura River and becomes a homocline west of the trace of the Red Mountain fault along the western end of Sulphur Mountain. North of the Santa Ana fault, the Ojai basin is underlain by 3 folds: the Long Valley syncline; the Wills Canyon anticline; and the Ojai syncline (see Plates I and II). Based on interpretations of effective base of the ground water reservoir (top of bed rock; Turner, pers. commun., 1969) (Plate VI), the Ojai syncline is truncated by the Santa Ana fault west of Denison Grade. The other folds are inferred to merge with the Ojai syncline in the valley (see Plate I). Black Mountain (or Lion Mountain, as it used to be called), is the surface expression of the Lion anticline. This anticline underlies the alluvium of the upper Ojai Valley in the eastern part of the mapped area, plunges about 20° to the east and extends the length of the valley at least as far as Santa Paula Creek. Rocks exposed in the crest of the anticline are red beds of the Sespe formation. The north limb of the fold is overturned along the Santa Ana fault, and the fold is cut at the west end of Black Mountain by the Pirie fault (Mitchell, 1964).

REGIONAL FAULTS

San Andreas Fault

Although the San Andreas fault does not cross the study area, it obviously influences neotectonics of the entire region. Late Cenozoic crustal deformation and faulting in coastal California are directly or indirectly related to motion along the plate boundary between the North American and Pacific plates (Atwater, 1970; Allen, 1975). Seismicity and faulting are dominated by the right-slip tectonics of the San Andreas fault system.

In contrast to the right-slip of the San Andreas, displacements along the east-west trending faults in the Transverse Ranges have been predominantly left-slip and reverse dip-slip (Albee and Smith, 1966; and Jahns, 1973). This contrast in deformation may be caused by compressional forces within the earth's crust where the San Andreas fault makes a large left bend or step about 55 km north of the study area. The left step or "Big Bend" section of the San Andreas fault is probably the structural and tectonic feature that has produced many of the anomalous trends within the Transverse Ranges. Faults in the Ojai Valley region dominantly display reverse dip-slip displacement consistent with the compressional regime observed throughout the Transverse Ranges.

San Cayetano Fault

The San Cayetano fault as mapped by Schleuter (1976) terminates in the Matilija overturn in the eastern part of the lower Ojai Valley under the fan deposits of Wilsie and Horn Canyons. This fault is a major zone of north-south crustal shortening, with demonstrable stratigraphic displacement of as much as 9,000 meters or more dip-slip near Fillmore, 15 kilometers east of Ojai Valley. The expression of this crustal shortening has been problematical in the Ojai Valley area since no single large fault has been found. The present study concludes that crustal shortening is taken up by folding and newly identified flexural-slip faulting in the Ojai Valley west of the termination of the San Cayetano fault.

The Sulphur Mountain Fault

The Sulphur Mountain fault is mapped in Preliminary Report 14 (Calif. Div. of Mines and Geology, 1973) along the southern side of Sulphur Mountain from near Santa Paula Creek westward almost to the Ventura River. However, no stratigraphic separation in the Monterey and Sisquoc formations was observed during the field work for this study. Therefore, it is concluded that the Sulphur Mountain fault does not extend into the Oak View-Ojai mapped area but dies out to the east. Anomalous attitudes in the Monterey and Sisquoc near the crest of Sulphur Mountain may have been previously interpreted as evidence for the presence of the fault. In this report these attitudes are attributed to tight recumbent folds (compressional features) along the projected trend of the Sulphur Mountain fault, not an uncommon expression of the termination of a reverse fault.

The Red Mountain Fault

The Red Mountain fault has been mapped previously as terminating on the south rim of Fresno Canyon, under the terrace called South Mesa, by local ranchers. Evidence that the fault terminates at this location is that south of the mesa, the Pico formation strikes into the Sisquoc, while north of the mesa the Pico-Sisquoc contact is concordant (see Geologic Map, Plate I). However, considering that it is a strike fault (parallel to the strike of the Sisquoc, and Sisquoc-Pico strata), it is possible that the fault could continue into either formation with very little expression.

Neither South Mesa nor the terrace deposits north of Fresno Canyon (North Mesa) show any compelling evidence of offset along the projected Red Mountain fault trace. Data from wells located east of the fault trace on North Mesa indicate that the fault does not follow the contact between the Pico and Sisquoc.

However, in the course of this study a small inconspicuous fault was discovered in a roadcut along Sulphur Mountain Road about 0.5 km north of North Mesa (location F-1, Plate 1). This fault lies along the projected trace of the Red Mountain fault at South Mesa. It dips about 45° to the west and has a west-side-up sense of displacement (inferred from drag folds) as does the Red Mountain fault at South Mesa. The anomalous thickness of the Sisquoc, north of Fresno Canyon, also suggests that fault displacement of that formation has taken place. Therefore, the inferred trace of the Red Mountain fault is extended north to location F-1 and terminates within the Sisquoc formation.

Like the San Cayetano fault to the east, the Red Mountain fault (west of the Ventura River), and the related Ventura anticline account for a considerable amount of north-south crustal shortening in the Ventura basin. Where the trace of the Red Mountain fault turns north at the eastern end of the Red Mountain dome, crustal shortening decreases rapidly and seems to cease at Fresno Canyon. The north-south reach of the Red Mountain fault appears to be a tear fault along the edge of the large thrust plate.

In the Oak View-Ojai area, crustal shortening east of the Red Mountain fault and west of the San Cayetano fault is explained by active folding of the underlying composite syncline with accompanying flexural-slip faulting along a series of south-dipping faults.

LOCAL FAULTS: OAK VIEW-OJAI AREA

Aerial photographs reveal distinct, anomalous, linear features delineated by slope, elevation and vegetation changes. Seven lineaments extend northeast from the east bank of the Ventura River south of Ojai to San Antonio Creek (see Figure 11). Field work demonstrated that many of the lineaments have fault outcrops along some portion of their extent that offset Pleistocene or Holocene deposits. Furthermore the lineaments (or faults) merge to the northeast with faults previously mapped (Bush, 1956; Mitchell, 1964; Turner, 1971). Some of these faults are more clearly defined by outcrops than others, but taken as a zone of faulting they are consistent with the strong, active compression of the Ojai area.

Lion Fault

The Lion fault, described by Bush (1956) extends from "beneath the faults of the San Cayetano System" in the eastern extremity of the upper Ojai Valley where it is "traced largely by inferrence along the foot of Sulphur Mountain, beneath the alluvium" (Bush, 1956). In the present study, the trace of the fault is inferred continuing westward under a large composite landslide in the western part of the upper Ojai Valley, and trending west for about 5 km in a sinuous line marked by the juxtaposition of Miocene Rincon shale and late Pleistocene terrace gravels possibly correlative to the terrace deposits

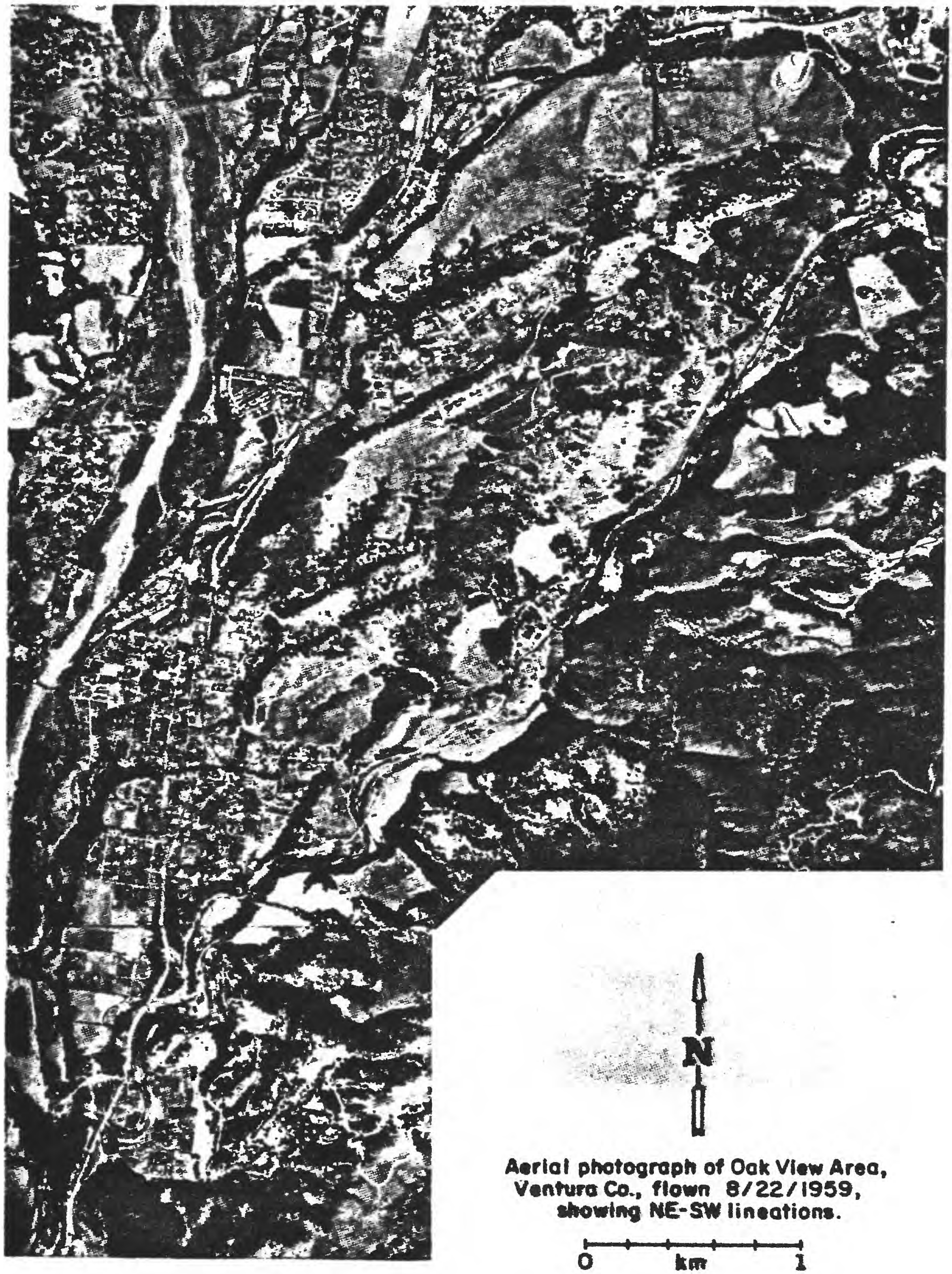

Figure 11. Lineations in the Oak View area.

of the Oak View strath terrace.

Outcrops: At fault location F-17 (Plate 1) the Lion fault is exposed where Rincon shale can be seen overlying Pleistocene river gravels (the gravels are identified and distinguished from Saugus formation by pebble counts). An alternative hypothesis, that the contact represents a buttress unconformity or old river bank, is ruled out by the low strength of the Rincon shale which could not rest at its observed slope in an unsupported bank, and by the occurrence of apparent drag folds (warping) in the terrace bedding near the fault contact.

Some gouge along the fault trace was observed in the Monterey shale exposed by erosion in the landslide mass located in the eastern portion of the mapped area. It is possible that the fault cuts the landslide, but evidence for this is inconclusive.

Physiographic Features: The Lion fault is defined by eroded and discontinuous scarps on the south side of Lion Canyon from the upper Ojai Valley to San Antonio Creek. The trace of the fault in this rugged terrain is sinuous, yet relatively consistent in overall bearing, suggesting a shallow dip to the south. Along most of its trace through the Canyon, cut by Lion Creek, low resistant Rincon mudstone and shale is brought into contact with comparatively resistant terrace deposit which, because of differential weathering, delineates the fault as a sharp break in slope.

About 50 meters north of the main fault trace at F-17 another trace of the fault can be detected completely within the terrace gravels (Plate I). The fault is expressed as about 5 meters of apparent right lateral displacement of a ridge carved in the terrace gravel by a meander loop of Lion Creek. This suggests that, to the east of this point, the fault splays. West of F-17 the north and south traces of the Lion fault apparently separate more and become the Devil's Gulch and Oak View faults respectively.

Devil's Gulch Fault Zone

Some of the best evidence for active faulting in the Ojai area is associated with a zone of faults that crop out about 0.5 km north of the town of Oak View. This narrow zone of faults is named after an area of chaotic topography known locally as "Devil's Gulch", along the east bank of the Ventura River. The contact between the Rincon and Monterey formations trends about N45-50°E through the gulch.

The Devil's Gulch fault zone extends from the Ventura River along a northeast trend and appears to merge with the Lion fault in the canyon of Lion Creek. The Devil's Gulch fault zone is composed of complex, anastomosing strands at Devil's Gulch that appear to coalesce about 0.5 km northeast of Highway 33 forming one strand or at least a more compact series of traces at the base of a 20-30 meter, undissected scarp.

The traces of the faults in the Devil's Gulch zone appear to die out under the gravels of the Ventura River to the east. However, directly in line with the trend of the faults and on the west side of the river, Dibblee (1979) shows a fault on the south limb of the Santa Ana syncline. Since it has the same sense of displacement as the Devil's Gulch faults (i.e., up on the south), it is tempting to infer that it is a continuation of the Devil's Gulch fault zone. Turner (1971), however, does not show any evidence to suggest that the fault has any significant effect on the effective base of groundwater in the river channel at Devil's Gulch.

Outcrops: Two outcrops within the fault zone are observed in the Devil's Gulch area. These faults are referred to in this report as lower Devil's Gulch fault and upper Devil's Gulch fault.

The lower Devil's Gulch fault, exposed in a roadcut on the west side of Highway 33 (Fig. 7), strikes N50E and dips 45°S. It offsets the contact between the Miocene Monterey formation and the late Pleistocene Oak View terrace by about 7 meters and is south side up, so that rocks of Miocene age are thrust over late Pleistocene river gravel. The fault surface is parallel to bedding in the Monterey formation and slippage is probably related to the presence of bentonite layers, common in the lower Monterey formation.

At about 1 meter above the Highway 33 roadbed, the fault is expresssed as a 20 cm thick gouge zone. The gouge material displays an "S"-shaped structure that may indicate recurrent movement.

The upper Devil's Gulch fault is exposed in a new access roadcut on private property about 100 meters southeast of the exposure of lower Devil's Gulch fault in the roadcut (Figs. 9 and 12). This fault strikes N50°E and has a variable dip.

This strand of the Devil's Gulch fault also thrusts Miocene Monterey formation over late Pleistocene terrace gravel, colluvium, and Holocene soil, and is therefore considered to be "active." Near the surface the dip is shallow (about 10°S), but becomes steeper in deeper and more consolidated rock exposed in the cut. This change in dip with depth suggests that either the unconsolidated colluvial material has moved downhill (via soil and/or bedrock creep) after the last fault movement, "bending" the fault surface into its observed configuration, or that in propagating through the surface material, the fault encountered less resistance at shallow depths and was able to displace this material further, resulting in a fault surface that becomes more horizontal as it approaches the ground surface. Quaternary history of the faulted sequence at Devil's Gulch is interpreted as follows: (1) deposition of river gravel (Oak View terrace) unconformably on Tertiary formations; (2) uplift and/or lowering of the Ventura River base level, exposing the Devil's Gulch area; (3) south side up reverse displacement along the Devil's Gulch fault zone, creating a gravity differential allowing (4) the downhill movement of a mixture of gravel and angular fragments of Monterey shale (landslide or colluvium); (5) development of a soil on the landslide/colluvium mass,

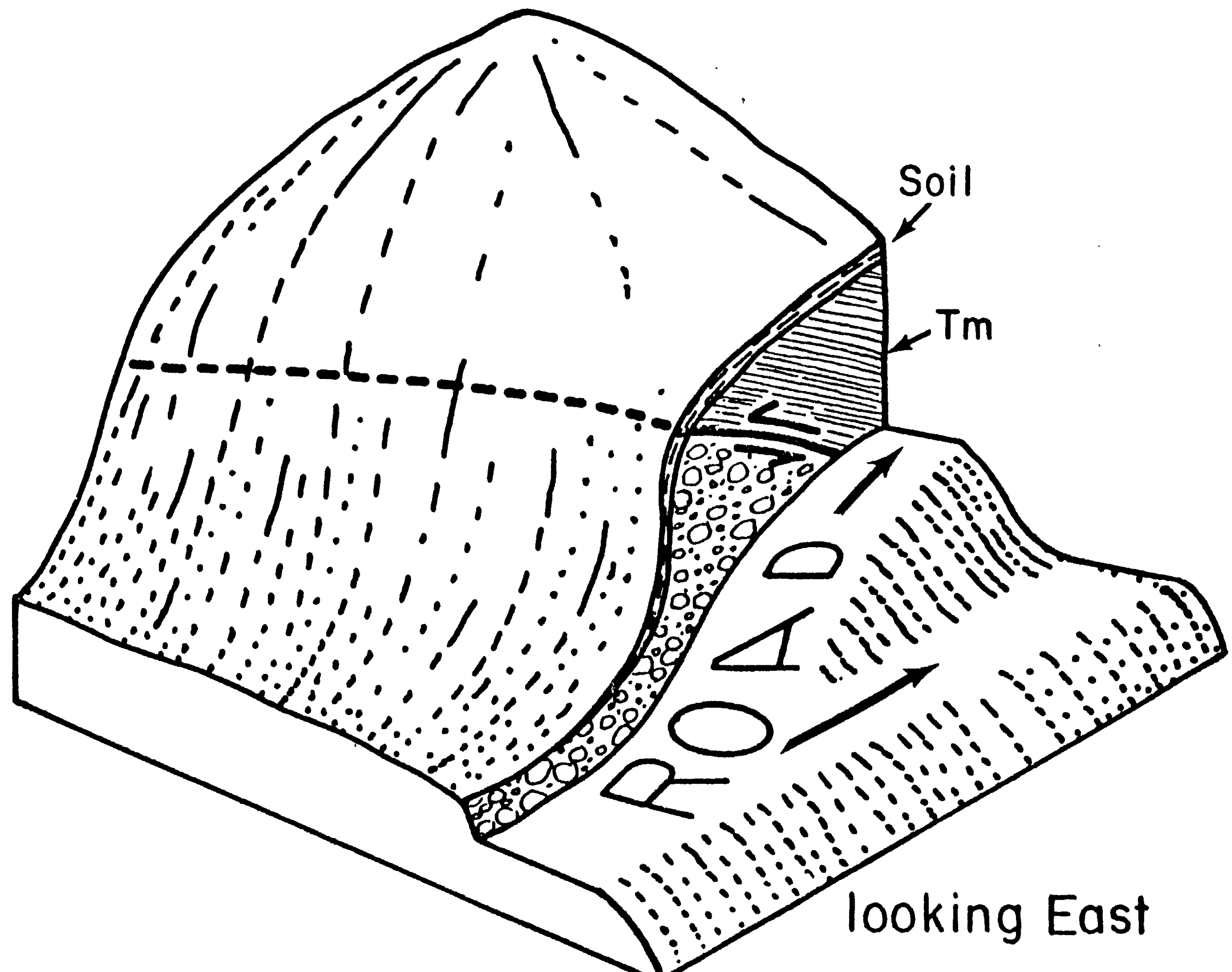

Figure 12. Block diagram of the upper Devil's Gulch fault.

Monterey formation and terrace deposit; (6) renewed movement on the fault offsetting colluvium and soil; and (7) possible continued downslope movement of the colluvium, folding the fault surface.

At fault location F-16 (Plate I) the Devil's Gulch fault is located in a saddle with Monterey rock higher on the knoll to the south of the fault knoll to the north, suggesting south side up displacement. In the roadcut at fault location F-16 bentonite beds are exposed in the Monterey rock, indicating that this exposure is near the base of the Monterey formation. Thus, stratigraphic relationships at F-16 are similar to those at Devil's Gulch where the bentonite beds facilitate displacement along bedding surfaces.

Physiographic Features: The Devil's Gulch fault extends to the Ventura River near Live Oak Acres, where the uplifted southern block has formed a bank along which the river may have been eroded or been diverted to the west (Fig. 13). Although the thalweg is deflected in a right sense, right lateral movement of the fault is not implied. Dip-slip and uplift of the southern block into the path of the river is adequate to explain this possible diversion; however, some component of strike-slip may be present.

East of fault location F-14 (Plate I) the upper and lower Devil's Gulch faults are apparently buried by a young landslide. The landslide does not appear to be cut by the fault. It may, however, have originated because of movement on the fault or instability of the fault scarp.

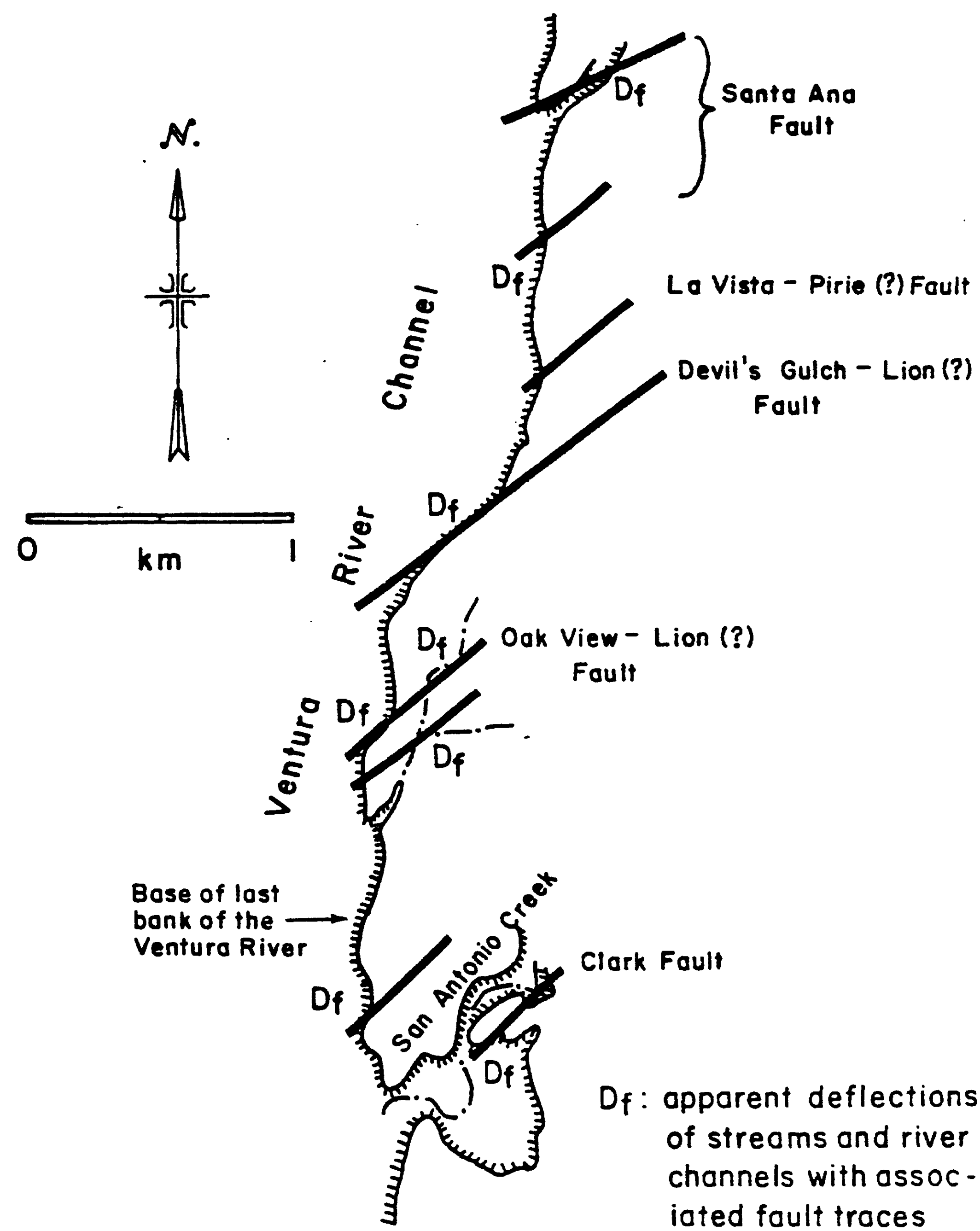

Figure 13. Apparent deflections or erosion of the east bank of the Ventura River associated with recent faulting.

East of the landslide, the fault trace is marked by a prominent linear scarp parallel to and between Feliz Drive and Alto Drive. The scarp, wholly within Pleistocene terrace gravel, trends about N45°E. The scarp has 20-30 meters of relief and is aligned with the fault outcrop at Devil's Gulch. Freshness of the scarp, especially in light of the unconsolidated material exposed in the uplifted terrace, suggests recency of fault activity.

The terrace south of the Devil's Gulch fault is uplifted and tilted to the southeast (slopes about 6° southeast) away from the Ventura River.

Oak View Fault

The north and south branches of the Oak View fault are so named because of their proximity to the town of Oak View. They can be discerned as two parallel linear features northeast of Oak View that stand out clearly on aerial photographs (Fig. 11) because of the concentration of heavy vegetation and distinct changes in relief. The two branches merge to the east to form one fault trace which is defined by the inverted sequence of north-dipping Monterey formation on the north and Rincon formation on the south. Farther to the east the single fault trace is inferred to connect with the Lion fault on the east side of San Antonio Creek near the mouth of Lion Creek.

Outcrops: The south branch of the Oak View fault crops out in a cut bank at location F-8 (Plate I), where Monterey shale is in fault contact with gravel of the Oak View terrace. The fault plane is indistinct at this location but is inferred to follow bedding in the Monterey that strikes N75E and dips 35°S to overturned 70°N.

At fault location F-6 (near the Ventura River), a repeat in section of Rincon and Monterey formations is encountered which is inferred to represent the south branch of the Oak View fault. The north branch of the Oak View fault is inferred on the basis of physiographic evidence.

Physiographic Features: The north branch of the Oak View fault apparently has caused differential erosion or deflected the east bank of the Ventura River in a right sense, in a manner similar to the Devil's Gulch fault at Devil's Gulch. At fault location F-7 (Plate I) just west of Oak View, the stream that flows through the town is deflected due to uplift along both branches of the Oak View fault.

Fault scarps of the north and south branches of the Oak View faults are distinct in aerial view between fault location F-9 on the east and the town of Oak View on the west. Scarps have a relief of several meters and are undissected in spite of the unconsolidated nature of the slope material. However, topographic evidence of faulting is absent in downtown Oak View. Apparently the fault scarps in the downtown area were "abraded" or eroded away by the Ventura River during its adjustment and westward migration as a result of local uplift in the late Quaternary.

Flat surfaces of the Oak View terrace east of the town of Oak View that are offset by the branches of the Oak View fault tilt to the south, so that drainage is directed from the uplifted edge of the surface toward the base of the scarp to the south. This concentration of drainage favors plant growth along the scarps and helps delineate them.

La Vista-Pirie Fault

The La Vista fault, named for the La Vista Rancho through which it passes, extends from the Ventura River on the west along an east-northeast trend until it apparently becomes the Pirie fault to the east. The fault makes a smooth bend to the southeast near the west bank of the San Antonio Creek between F-21 and F-22 (Plate I) and another bend to the north at the west escarpment of Black Mountain (F-23, Plate I). It terminates at or is overridden by the Santa Ana fault along the southern margin of Ojai Valley. The La Vista fault is connected to the Pirie fault in this study on the basis of the alignment of the two traces as they disappear under young deposits near San Antonio Creek.

Outcrops: At location F-18 (Plate I) the La Vista fault is inferred in a cut along a private road leading down an old cut bank in the terrace to the Ventura River bed. At this location the fault is obscured by heavy vegetation; however, over a distance of about 10 meters the stratigraphic relationship is evident; Miocene Rincon formation is faulted above and against the Oak View terrace gravel. Other evidence at this location for existence of the fault is: (1) the re-entrant carved by the river along the fault trace as it intersects the river channel, (2) the alignment with the scarp of the La Vista fault to the east, and (3) the series of ridges and rises lying along the fault trace that are uniformly high on the south.

The La Vista fault is exposed in the road cut of Creek Road at F-22 (Plate I) where the fault trends southeast. Here the fault repeats section so that Vaqueros rock is brought up and into fault contact with the Rincon shale. The thickness of rock unit repeated is small (about 10 m); therefore, the fault has only minor stratigraphic separation.

Physiographic Features: The north escarpment of the small linear ridge at F-19 (Plate I) lies along the projection of the La Vista fault. This feature within the Oak View terrace suggests that the fault is up on the south. East of this ridge at F-20 (Plate I) is a linear and virtually undissected escarpment again within Oak View terrace material. This escarpment is about 30-40 meters high and over 2 km long. The fault lies near the base of the escarpment and thrusts the Oak View terrace surface on the south of the fault up and tilts it to the southeast (Fig. 8). The terrace surface north of the fault is uplifted and tilted to the southeast between the La Vista fault and the next parallel fault to the north (possible branch of the Santa Ana fault). This step-and-tilt faulting results in a sawtooth profile. Five "sag ponds" lie along the inferred trace of the fault at location F-21 (Plate I). Prior to the damming of these ponds, partial internal drainage made a marshy area along the fault valley.

The eastern extension of the La Vista fault, the Pirie fault, apparently cuts the terrace deposit (interpreted to be Oak View terrace) south of Camp Comfort. The apparent displacement on the fault with respect to the terrace surface is again up on the south. However, the Pirie fault curves to the north and trends N20E at F-23 (Plate I). The 200 meters of relief between the terrace deposit and the crest of the mountain was presumably caused by displacement on the Pirie fault.

Santa Ana Fault

The Santa Ana fault is mapped along the base of the north escarpment of Black Mountain (Preliminary Report 14, 1973) and may cause the physiographic (vertical) separation of the upper Ojai Valley from the lower Ojai Valley. The fault is inferred to be south dipping and extends from under the San Cayetano fault in the eastern part of the lower Ojai Valley along a predominantly east-west trend marked by topographic highs on the south. The Santa Ana fault is inferred to splay into two branches south of Krotona Hill; the southern splay dies out along the south-dipping strata under the gravel of the Ventura River and the northern splay continues west and possibly becomes the Arroyo Parido fault that extends westward as far as the city of Santa Barbara.

Attempts to accurately locate the Santa Ana fault have not been completely successful. Minor faults, thought to be associated with the Santa Ana, have been exposed during trenching at the honor farm south of Highway 150 at the east bank of the Ventura River (Cilwick, 1976).

Sespe red beds along the north flank of the Lion Mountain anticline are apparently overturned as a result of drag folding along the Santa Ana fault during uplift. No outcrops of the Santa Ana fault were observed in this study so that there is, so far, insufficient evidence to accurately locate the main trace of this tectonic feature.

Physiographic Features: The approximately 150 meters of relief between the upper and lower Ojai Valleys is marked by a linear scarp that is inferred to be parallel to the Santa Ana fault. Turner (1971) locates the fault under the alluvial and fan material of the lower Ojai Valley by analysis of depth to ground water (Plate VI).

The location of the fault trace south of Krotona Hill is based primarily on the presence of the conspicuous linear ridge between fault locations F-26 and F-27 (Plate I) and the N35E lineament seen on the aerial photograph (Fig. 11).

The Oak View terrace surface west of Krotona Hill between this fault and the next fault to the south is displaced upward and tilted to the southeast. The configuration of the faults with respect to the Quaternary terrace deposits (Oak View terrace) is shown on Figure 8 which demonstrates the relief and back-tilting away from the Ventura River.

Clark Fault

The Clark fault, so named because it crosses the Clark Ranch on Sulphur Mountain, shows up as a photographic and topographic lineament extending from the junction of San Antonio Creek and the Ventura River eastward. It may become the Big Canyon or Sisar fault along the northern flank of the Sulphur Mountain in the upper Ojai Valley. Its westernmost expression is the offset meander loop in San Antonio Creek at fault location F-2 (Plate I) where it produces an apparent right deflection of the creek.

No clear outcrops of the fault were found in the area, although the trace of the fault is apparent in the mapped strata. Miocene Monterey formation is juxtaposed against three terrace deposits of the Oak View strath about 2.5 km northeast from F-2 (Plate I). At its western end the fault dies out in Monterey bedding of the Ayres Creek syncline. Where the fault is inferred to cross section line B-B' (Plate II), it cuts the axis of an anticline mapped in the Monterey formation (Dibblee, unpublished map, 1979). The Clark fault is inferred to extend east along the northern flank of Sulphur Mountain under the large landslide near cross section C-C' (Plate II). It then remains approximately parallel to the Monterey/Rincon contact and trends toward the Big Canyon fault of Bush (1956) in the upper Ojai Valley.

TECTONIC GEOMORPHOLOGY

Correlation of Terraces

In 1942, W. C. Putnam, produced a comprehensive interpretation of the evolution of the Ojai Valley. Putnam noted that the area southwest of Ojai and along the east bank of the Ventura River south to Casitas Springs ". . .is complicated by warping and faulting, both of which are still active" (Putnam, 1942, p. 716). However, even with faulting noted he still maintained that ". . .seven well-defined terraces are recognized, four above the Oakview strath and two small ones below" (p. 731). Soils work and mapping of active and potentially active faults has assisted in the development of a model to explain the physiographic evolution and recent tectonic activity which suggests that Putnam's seven terraces are in actuality two, mapped at Qot (Oak View terrace) and Qt (younger terraces) on Plate I. The distribution of the Oak View terrace, based on limited soils work, is shown on Plate V. The surface probably is much more extensive in both the lower and upper Ojai Valleys, but determination of its extent will require additional soils work.

Drainage Adjustments

Discovery of the role of faulting in shaping the physiography of the Ojai Valley suggests refinements of the interpretation of drainage evolution proposed by Putnam (1942). His history of the development of the basin primarily involves the lowering of base level and episodes of stream incision and/or capture by headward erosion. For example, the capture of Santa Paula and Sisar Creeks by a tributary of the Santa Clara River and the capture of the lower Ojai Valley by San Antonio Creek. We suggest that drainage has also been affected by uplift, folding and displacement along the south-dipping reverse faults that trend through the area.

Many of the streams in the Oak View-Ojai area have a complex history that is intimately related to recent tectonics. Our discussion here is brief and primarily concerned with the Ventura River, as the drainage history adds little to the understanding and evaluation of the earthquake hazard.

When the Oak View terrace was being deposited (about 40,000 years ago) the watershed of the Ventura River included the Santa Paula Creek and Sisar Creek drainages, along with the upper Ojai Valley, which was continuous with the lower Ojai Valley. Santa Paula and Sisar Creeks were eventually captured by headward erosion of a tributary of the Santa Clara River. However, in view of activity of the faults in the area, it seems reasonable to speculate that tectonics probably were a significant factor in the drainage history. For example, after uplift along the Santa Ana fault, separating the upper and lower Ojai Valleys, and after capture of Santa Paula and Sisar Creeks by a tributary of the Santa Clara River, the drainage of the lower Ojai Valley was directed along the scarp of the Santa Ana fault.

Analysis of fault history in this study suggests that following deposition of the Oak View terrace, uplift occurred along east-west trending, south-dipping faults in the Ojai area. The uplift probably resulted in the westward migration of the Ventura River in response to the upthrown fault blocks. Abandoned shallow channels and/or overbank deposits possibly associated with the migration of the Ventura River are shown on Plate V (mapped as AC) and are recognized by their channel-like physiographic features (i.e., shallow channels parallel to the modern river, bordered and underlain by deposits of the Oak View terrace and fine silty sand channel fill which are probably overbank deposits). Soils developed on the channel-fill deposits are younger than the soils on the Oak View terrace. The age difference seems to indicate that the Oak View terrace surface was exposed for some time before the channels were cut, abandoned, and later filled with finer (overbank) sediment. Thus folding and faulting have clearly influenced the recent history of the Ventura River.

Interpretation of the Newly-Mapped Fault Zone Near Oak View

Plate VII, prepared by excluding Quaternary deposits, shows the inferred bedrock geology that underlies the Oak View terrace. The map shows a large composite, east-plunging syncline that is well defined by the Vaqueros formation. The south-dipping, south-side-up, reverse faults discussed earlier in this report lie along the north limb of the syncline. Although there are exposures where lithologic units are repeated across a fault, the stratigraphic separation is minor. Most of the movement is along bedding planes. Stratigraphic separation apparently increases to the east, suggesting that the faults there extend deeper, probably merging with the Lion and Big Canyon faults. The cross section shown on Figure 8 depicts two levels of the Oak View terrace separated by the southern branch of the Santa Ana, the La Vista and Devil's Gulch faults. The faults are parallel to bedding and dip toward the axis of the syncline. As the syncline undergoes compression, the fault blocks slide up, parallel to the axial trace of the fold, by flexual slip.

Tilted Terrace Segments

The Oak View terrace surface of the Ojai Valley supports the "flexual slip" hypothesis. If the terrace surfaces of the Ojai Valley were "flights" of terraces of different ages, as suggested by Putnam (1942), they should slope gently toward the Ventura River. If they were the fragments of one terrace, separated by deeply penetrating faults, it is expected that they would not be tilted, but would remain nearly level, as depicted in Figure 10. In fact, the terrace surfaces tilt measurably to the southeast, away from the river toward the fault scarps (lineaments) that separate successive levels. Runoff accumulates in ponds as a result of internal drainage on some surfaces against the scarp that separates the next higher level. Figure 8 shows two levels of the Oak View terrace tilted to the southeast, separated by about 50 meters along the La Vista fault.

The faults separating the terrace levels are parallel to bedding surfaces of a large syncline and displacement is by flexural slip. Terrace surfaces tilt toward the axis of the fold (see Fig. 10)., and the tilt is geomorphic evidence that the dip of the faults decreases with depth. That is, the faults die out into the trough of the syncline.

Hazard Analysis

The south-side-up reverse faults in the Oak View-Ojai area die out in a syncline and do not penetrate rocks of sufficient strength to store enough strain energy to cause moderate to large earthquakes. Therefore, the hazard of seismic shaking intrinsic to these faults is minimal. On the other hand, fault movement associated with flexural-slip folding has produced 150 meters or more of vertical surface displacement (an average rate of 3.5 mm per year over the last 40,000 years). It seems reasonable however, that surface rupture may take place on these shallow faults as a consequence of an earthquake along a nearby master fault and extrinsic seismic shaking will accompany the surface rupture. It also seems reasonable that flexural-slip faulting and ground rupture along these kinds of faults may occur independent of the extrinsic seismic activity. In this case, the surface rupture would be an intrinsic consequence of local folding and uplift. Thus, in evaluating the seismic hazard of an area characterized by flexural slip or other shallow faulting, it may be necessary to plan for occasional flexural slip with ground rupture, but little or no seismic shaking, as well as extrinsic seismic shaking and sympathetic ground rupture.

In the Ojai-Oak View area geomorphic evidence indicates that the south branch of the Santa Ana, La Vista, upper and lower Devil's Gulch, north and south Oak View and other more minor faults are probably not capable themselves of producing a moderate to large magnitude earthquake, but are fully capable of producing significant ground rupture. Displacement along these faults may be intrinsically induced by compression of the syncline or sympathetically triggered by an earthquake along the Lion, Big Canyon, Sisar, San Cayetano, Red Mountain or other major fault. Thus, Ojai and nearby cities and towns are located in a seismically active area that will remain subject to potentially damaging seismic shaking. In addition, continued vertical displacement along the flexural-slip faults may cause a potential landslide hazard associated with unconsolidated terrace material along the fault scarps; and a potential ground rupture hazard which may damage any structure or road build across these faults. Therefore, before conclusions regarding the potential earthquake hazard are reached, consideration of depth to which a fault penetrates should be made from a structural and geomorphic analysis of the region. The recognition of a faulting and surface rupture hazard not intrinsically associated with large magnitude seismic activity may be important and should be considered in land use planning.

UPPER OJAI VALLEY - FILLMORE AREA

The study area is located in Ventura County, California between Ojai and Fillmore and encompasses about 350 km^2 (Fig. 1). This report will discuss the fault activity and the late Pleistocene and Holocene deformation of geomorphic surfaces in the study area. A general synopsis of the stratigraphy provides the composition, relative ages and thicknesses of the units associated with the primary structural features studied in the area; the north dipping San Cayetano reverse fault and the Santa Clara syncline. Other faults such as the Thorpe, Culbertson, and Rudolf, although of primary importance in the interpretation of the deformational history, are considered secondary features as they are the result of folding of the Santa Clara syncline.

High altitude black and white photographs at a scale of 1:20,000 were studied before and during the fieldwork. A total of eighteen weeks was spent in the field developing a soil chronosequence, mapping and correlating geomorphic surfaces based upon their soil profile development, and mapping faults and faulted Quaternary deposits.

STRATIGRAPHY

Over 10,500 meters of sedimentary rocks of Eocene through Pleistocene age have been penetrated by wells or are exposed at the surface (Schulter, 1976). The Eocene section consists of the Matilija, Cozy Dell, and Coldwater formations with thicknesses of 0-425 m, 760-1100 m, and 390-760 m respectively.

The Matilija and Coldwater and thick-bedded to massive, marine arkosic sandstones separated by the Cozy Dell shale and siltstone.

The Oligocene is represented by the Sespe and Vaqueros formations with thicknesses of 1350 m and 275 m respectively. The Sespe consists of non-marine reddish brown sandstones, claystones and conglomerates (minor). The Vaqueros contains fossiliferous marine sandstone, shale, and limestone.

The Miocene section is composed of the Rincon, Monterey, and Santa Margarita formations. The Rincon is dark gray to brown, massive, hard, brittle, and fractured shale about 450 m thick in undeformed areas. The Monterey, with a total thickness of 780 m, is a hard, brittle, fractured, gray-black to dark-brown, well laminated, siliceous shale (Schleuter, 1976) with some interbeds of chert, diatomite, limestone, bentonite, and sandstone. The Santa Margarita, correlative with the Sisquoc shale to the west, consists of 450 m of chocolate-brown shale.

The Pliocene section consists of 2750 to 3400 m of Fernando formation which is subdivided into the Repetto and Pico members. The lower member is the Repetto, a conglomeritic and sandstone unit approximately 300 m thick. The Pico member consists of a monotonous series of blue to greenish-gray, soft, well laminated, massive clay and siltstone (Schleuter, 1976).

The Pleistocene section consists of 300 to at least 1480 m of non-marine Saugus formation. The Saugus primarily consists of rounded Eocene sandstone and shale clasts as well as older igneous clasts.

Geomorphic surfaces (alluvial fans and river terraces that always lie with angular discordance on the underlying units) have been classified by relative age as determined from soil profiles developed on the surfaces (see Plate VIII and Table 2 in discussion of the soils geomorphology). Two radiocarbon dates assist in calibrating an estimation of absolute chronology for the surfaces.

DEFORMED GEOMORPHIC SURFACES

Interpretation of late Quaternary history is based on estimating the age and rates of deformation on geomorphic surfaces. A soil chronosequence (discussed in the last part of this report and in the appendix) was developed in Orcutt and Timber Canyons where seven récognizably different ages of soils are present (Plates VIII and IX).

Orcutt and Timber Canyon Faults

Eight mappable faults all with south side up cut the alluvial fan deposits of Orcutt and Timber Canyons south of the San Cayetano fault (Fig. 4 and Plate VIII). The faults show normal displacement where the bedding is overturned and reverse displacement where right side up, indicating an intrinsic relationship between dip orientation and sense of displacement. Older fan surfaces have been measurably tilted basinward with the amount of tilting consistent with the degree of soil formation on their surfaces (Table 1) indicating progressive tilting with time. Subsurface control from water and oil wells drilled near Timber Canyon (Fig. 5) show no offset of bedding along these faults suggesting that they are coicident with bedding at depth. The sense of displacement on the faults as a function of bed dip,

TABLE 1: Fault displacements and tilting of geomorphic surfaces in Orcutt and Timber Canyons.

Geomorphic Surface	Displacement on Faults(Δd)			Tilting		Estimated Age(t) y.b.p.
	Thorpe	Culbertson	Rudolf	Present Slope(s)	Degrees Tilted(Δs)	
Qf_3	4.5m	2m	6m	6.0°	0.5°	4,500-5,000
Qf_5	14m	4.5m	24-27m	8.2°	2.0°	15,000-18,000
Qf_6			61m	11.1°	4.9°	37,000-42,000
Qf_7	98m	37m		17.0°	11.5°	112,000-126,000

the tilting of the overlying fan surfaces between faults indicative of a curved fault plane becoming gentler towards the axis of the syncline, and the subsurface control showing no disruption in bedding are strongly suggestive of a flexural slip origin for these faults. As the tilting and faulting has continued into the Holocene and presumably to the present, it is apparent that the Santa Clara syncline is being actively folded in response to north-south regional convergence. As the faults themselves do not extend downward to rocks of high shear strength, they are not expected to produce large magnitude earthquakes. They do, however, represent a potential ground rupture hazard.

Three faults, the Culbertson , Thorpe and Rudolf faults, all displace three fan surfaces of four ages (Fig. 6) with the amount of displacement consistent with the degree of soil profile development on the surfaces. In order to assign reasonable ages to these surfaces, an assumption is made that the rate of folding of the Santa Clara syncline and hence the rate of faulting of the bedding are faults, has been relatively constant through the late Pleistocene. This assumption is based on the relationship between the amounts of displacement and the ages of two radiometrically dated surfaces. The Rudolf fault cuts Timber Canyon-1 (Qf_3), Orcutt-2 (Qf_5), Orcutt-3 (Qf_6) with amounts of displacement of 6 meters, 24 to 27 meters, and 61 meters respectively. The fan surfaces were profiled from USGS topographic sheets and by hand level and tape to determine the amount of displacement. The Orcutt-3 (Qf_6) soil is nearly identical in soil profile development to the Oakview terrace soil a few miles to the west along the Ventura River which is radiometrically dated at 39,360 ± 2,610 B.P. (See Table 2 in discussion of soils geomorphology and the appendix). The Orcutt-3 soil is therefore inferred to be the same age. Timber Canyon-1 (Qf_3) has a composite soil profile with a radio carbon date of 9-10,000 B.P. on charcoal from a buried soil. The two soils (surface and buried) are of very similar development, therefore the surface soil is estimated to be roughly half the age of the buried soil. Plotting the amount of displacement versus the ages of the surface (Fig. 14), a linear relationship between Qf_3, Qf_6, and the origin is attained. This is suggestive of fairly constant deformation rates for the past 40,000 years. Plotting the displacement of Orcutt-2 (Qf_5) on the curve, an age of 15,000-18,000 years is inferred.

Using the assigned ages of Qf_3 and Qf_5 and plotting the displacement of the surfaces from the Thorpe fault, an estimated age of 112,000 to 126,000 years is attained for the oldest soil, Qf_7 (Fig. 15). The primary assumption here is the extention of constant deformation rates from 40,000 ybp to about 130,000 ybp. To cross check this assumption, displacement on a third fault, the Culbertson fault, which cuts Qf_3, Qf_5, and Qf_7, was plotted against the inferred ages of the deposits (Fig. 16). A very good linear fit passing through the origin is produced. If the assigned relative ages of these surfaces are significantly wrong, such a consistent relationship would be unlikely. Therefore,

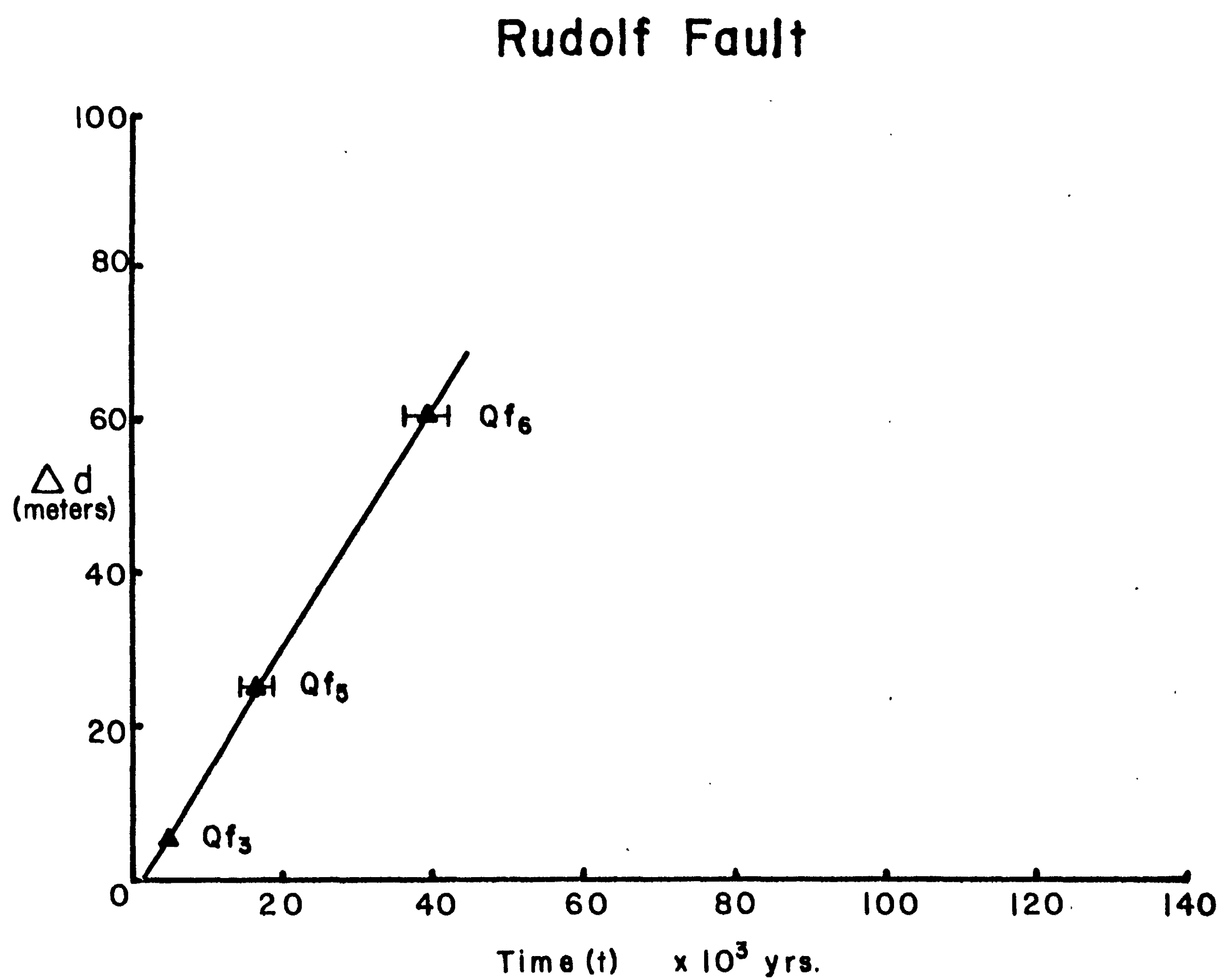

Figure 14. Relationship between fault displacement and age of alluvial fan surfaces on the Rudolf fault in Orcutt and Timber Canyons.

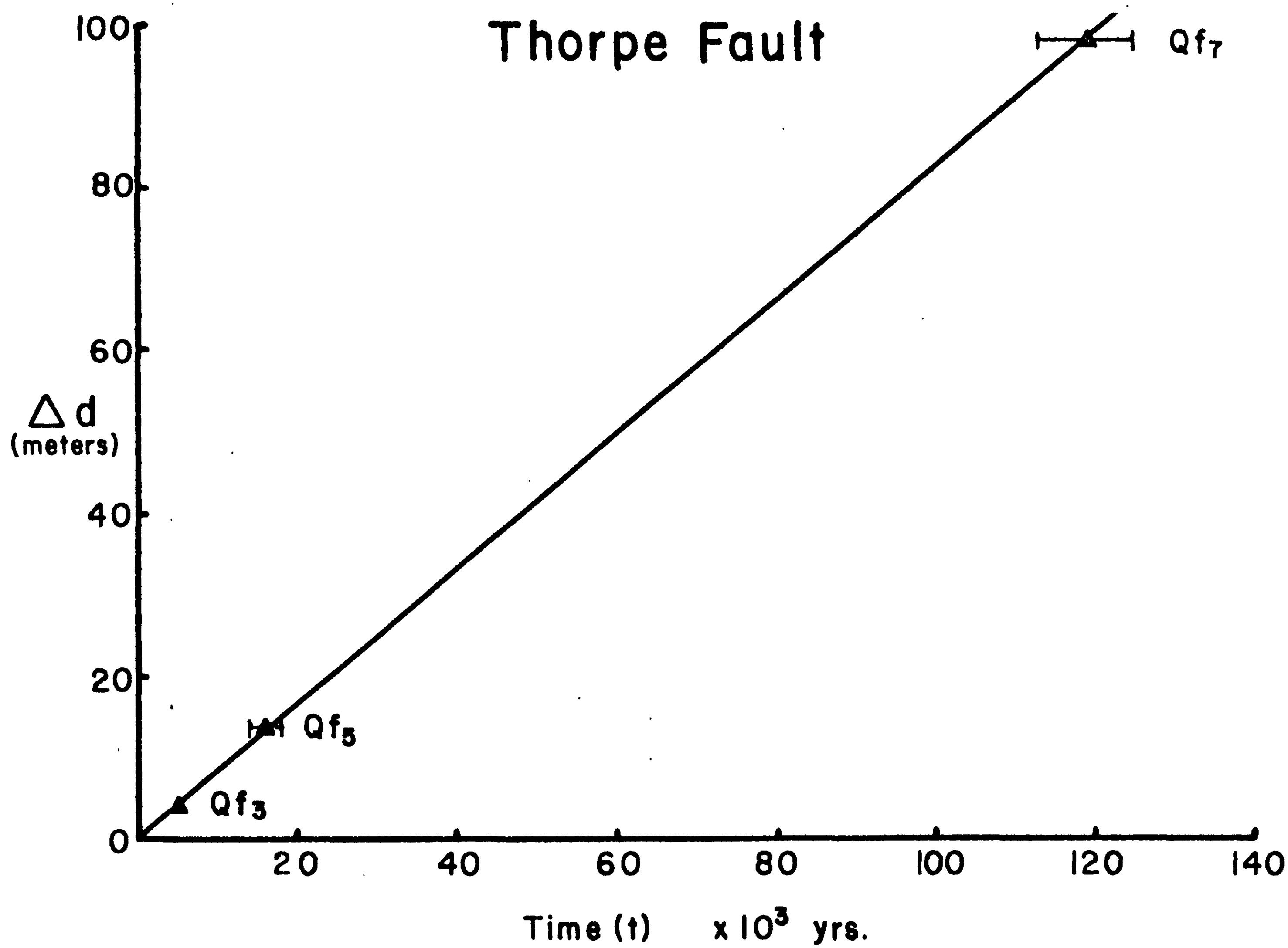

Figure 15. Relationship between fault displacement and age of alluvial fan surface on the Thorpe fault in Orcutt and Timber Canyons.

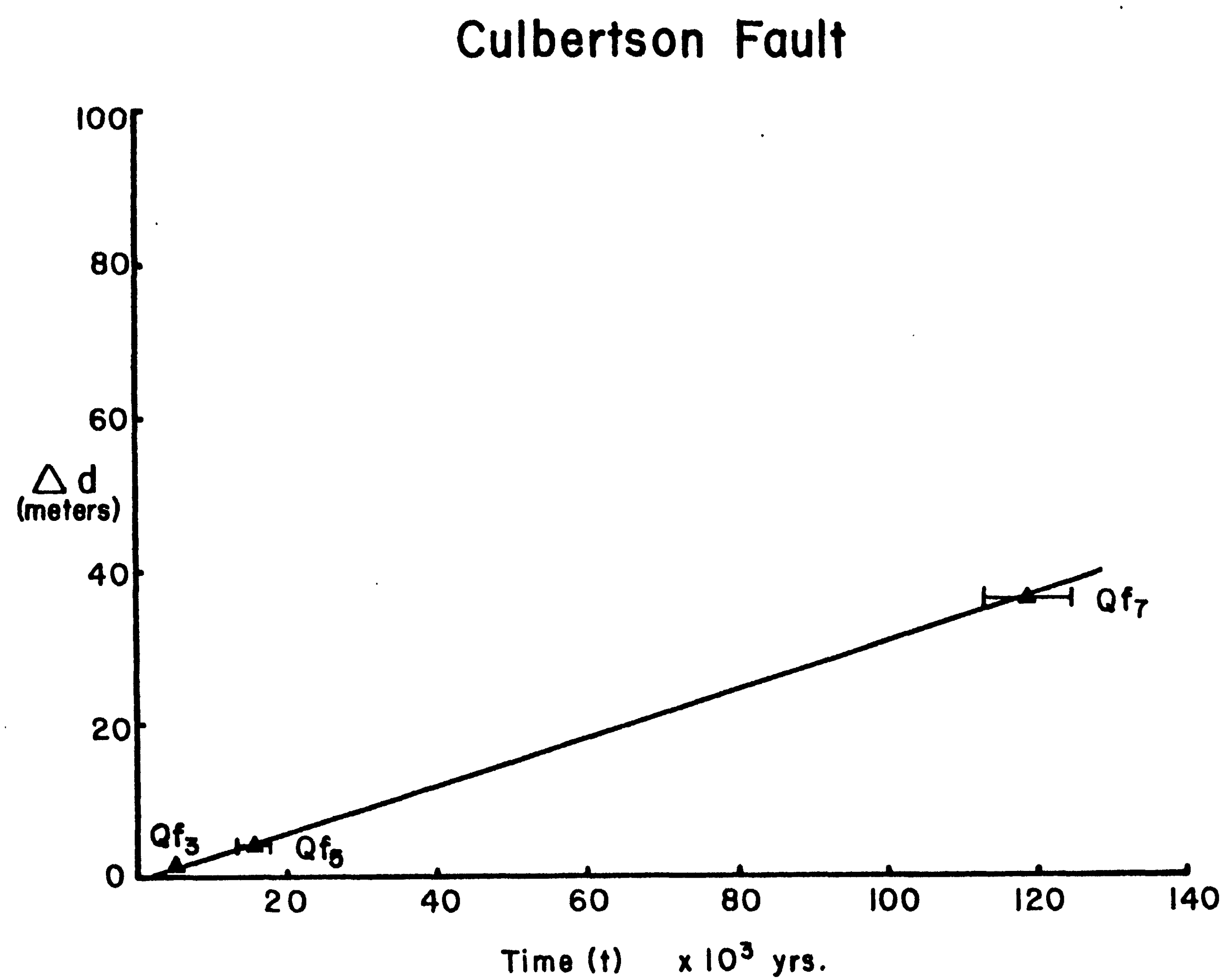

Figure 16. Relationship between fault displacement and age of alluvial fan surface on the Culbertson fault in Orcutt and Timber Canyons.

it is presumed that the assumption of relatively constant rates of deformation on these faults, and hence the folding of the Santa Clara syncline, is justified and that the age assignments are at least internally consistent.

Alluvial fan surfaces should be tilted at a constant rate if the folding and faulting rates have been fairly constant through the late Pleistocene. To estimated amounts of tilting, though, the original slope must first be known. Estimation of the original slope was obtained by plotting the slope of the surfaces against their respective ages and extrapolating to the present (Fig. 17). Initial slopes of 6.2° for Orcutt Canyon and 5.5° for Timber Canyon were thus obtained. The amount of tilting, (ΔS) then, is 0.5° for Timber Canyon-1 (Qf_3), 2.0° for Orcutt-2 (Qf_5), 4.9° for Orcutt-3 (Qf_6), and 11.5° for Timber Canyon-4 (Qf_7). Plotting ΔS against their ages (Fig. 18), a slightly convex curve is obtained. Possible hypotheses for the convexity are: 1) the original slope may not have been at a critical threshold when downcutting began but was triggered by climatic change; 2) the original slope has decreased due to change in drainage basin size or elevation; or 3) the rates of tilting have fluctuated through time. All three hypotheses are related to the existence of a geomorphic threshold (slope of the alluvial fan surface) which if exceeded initiates isolation of the surface by entrenchment and development of a new fan segment at a lower elevation. Thus when a geomorphic threshold is crossed, a change in process occurs (Bull, 1979).

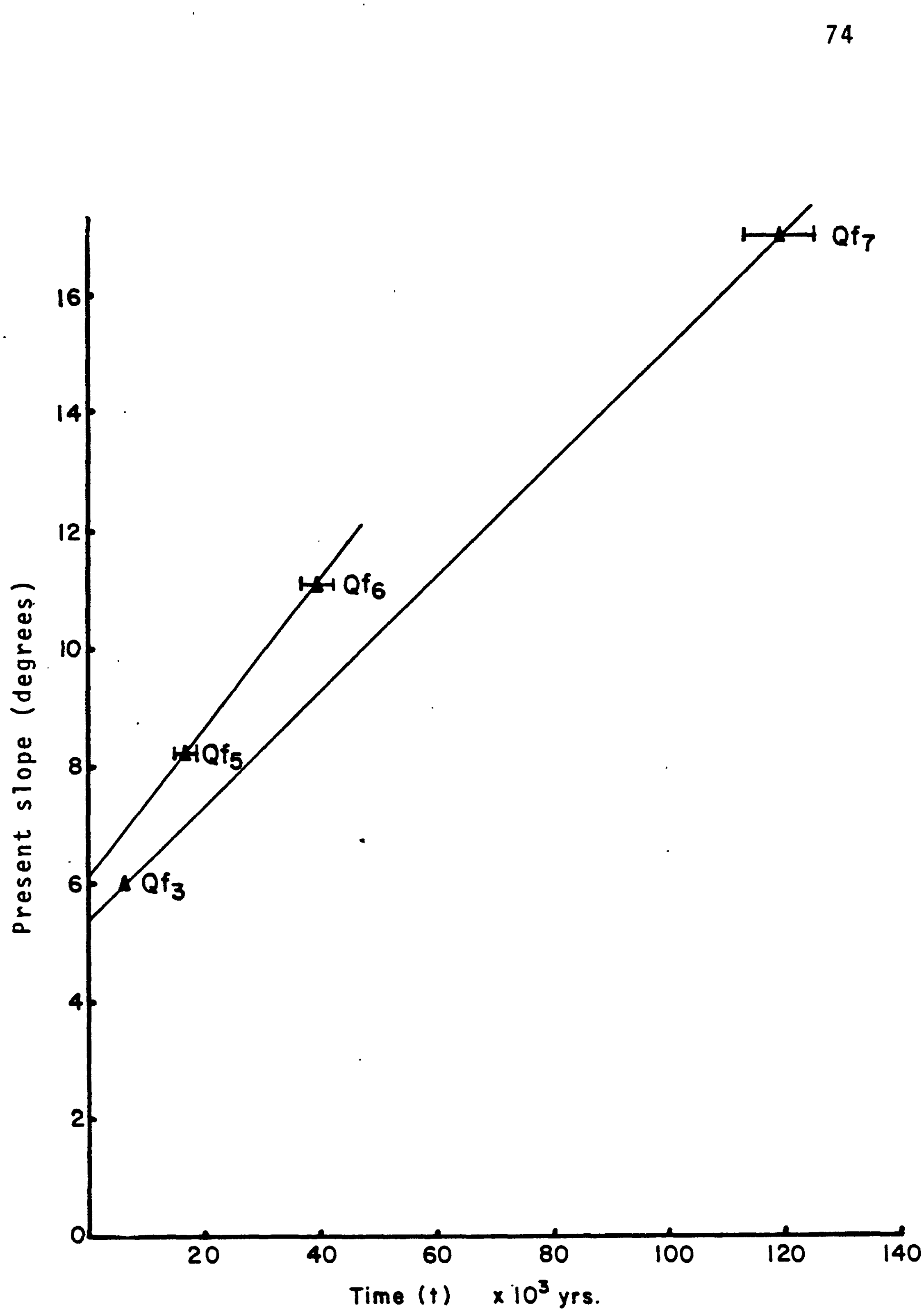

Figure 17. Relationship between present slope and age of alluvial fan surfaces in Orcutt and Timber Canyons. Initial slope is estimated by extrapolation for each drainage basin.

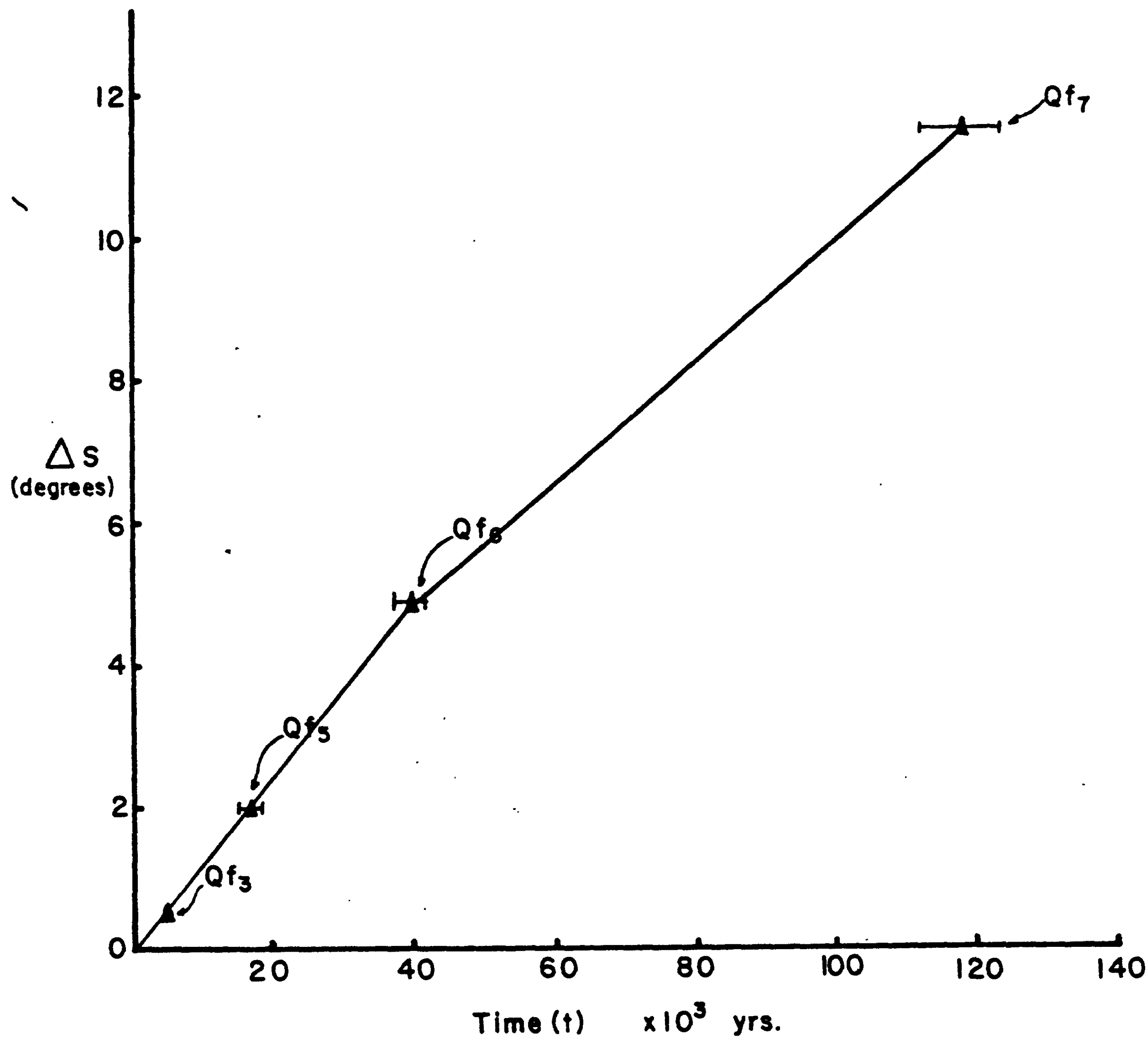

Figure 18. Relationship between tilting (ΔS) and age of alluvial fan surfaces in Orcutt and Timber Canyons.

The first hypothesis to explain the slight convexity of the tilting of geomorphic surfaces versus estimated ages relation in terms of a climatic change (Fig. 18) is possible since both the Orcutt-3 (Qf_6) and Timber Canyon-4 (Qf_7) surfaces have estimated ages corresponding to oxygen isotope stages 3 and 5E respectively (Shackleton, and other, 1973, and Bloom, and others, 1974) subsequent to which major climatic changes took place. If the change in climate had induced the entrenchment and hence the isolation of the surface for soil formation, before a critical slope angle necessary to initiate entrenchment had been reached, the initial slope estimated for these two surfaces could be slightly high. This would move Qf_6 towards the line in the right direction on Figures 17 and 18, but would have the opposite effect on Qf_7. If Qf_6 was half a degree below the critical slope, whereas Qf_7 was almost at it, a linear relationship would result.

The hypothesis to explain the convexity in terms of a drainage basin change is also possible, but, since the drainage basin is small, less than 1 km^2 above the San Cayetano fault, very little enlargement could take place once the basin had initially formed. A general downwasting of the system is also a possible mechanism for decreasing the initial slope through time. However tectonic uplift is occurring along the San Cayetano fault and is probably at least keeping pace with erosion.

The third hypothesis, that the rates of tilting have fluctuated through time, is problematic since the age assignments of two of the surfaces are estimated by assuming constant deformation rates. If the rates had not been constant, then the fault displacement versus time curves should not be so consistent. Also, without assuming constant tilt rates, an estimate of the initial slope could not be made accurately. It would not be expected, then, to have the observed fit unless fluctuations in the rate of tilt were minor.

Alluvial Fan Evolution

Alluvial fans in the study area evolve through a hypothetical cycle starting with fan deposition then tilting to a critical threshold followed by deep entrenchment and isolation of the fan surface. Further tilting of the dissected fan and continued aggradation produces a new fan segment which is again tilted to the critical threshold initiating new entrenchment and development of another younger fan segment. Various stages of the cycle are present in Orcutt and Timber Canyons. The present Timber Canyon fan closely approximates the threshold condition of initial entrenchment of a fully developed fan segment, whereas Orcutt Canyon has a deeply entrenched (40 meters) fan. Canyon filling would now be expected in Orcutt Canyon as a new fan segment is deposited whereas deep entrenchment will probably ensue in Timber Canyon.

Evidence for several cycles of fan deposition and erosion exist from Orcutt-3 (Qf_6) and Orcutt-4 (Qf_7) in Orcutt Canyon and Timber Canyon-4 (Qf_7) in Timber Canyon. Orcutt-4 (Qf_7), cannot be confidently attributed to the Orcutt Canyon drainage as it is located between the divide between the Orcutt drainage and the Mud Creek drainage. Other fan segments are probably buried beneath the Timber Canyon fan or totally eroded away. Orcutt and Timber Canyons both have narrow canyon fill deposits extending down from the San Cayetano fault. In defining the neck portion of these deposits as alluvial fans, criteria such as a convex cross profile, a concave radial profile, and composition of the deposits were used; the confining valley walls are older fan deposits and Pico mudstone. The mudstone contributes little to the fan as the fine particles once eroded are carried away by streams. As such, the entire area south of the San Cayetano fault where all the fans originate is a large fan complex which is being uplifted and tilted. The drainage basins for these fans were considered to be only that portion above the San Cayetano fault as all the material in the fans appears to have originated from the hanging wall of the fault.

SAN CAYETANO AND RELATED FAULTS

The San Cayetano fault is mapped 40 km between Ojai and Piru. Only the section from Ojai to Fillmore (Plate VIII) was included in this study since the hanging wall of the fault from Fillmore to Piru consists almost entirely of Monterey shale with resulting complications in correlation of soils. Discussion of the fault is broken into six sections from west to east: Reeves Canyon to Sisar Canyon; Bear Canyon to Santa Paula Creek; Santa Paula Creek to Orcutt Canyon; Timber Canyon; Boulder Creek to Snow Creek; and Sespe Creek.

San Cayetano Fault: Reeves Canyon to Sisar Canyon

The western terminus of the main trace of the San Cayetano is in the Reeves Canyon area near Ojai. Careful study of the Reeves Canyon fan, which crosses and buries the apparent terminus of the fault trace, shows no noticeable displacement due to faulting (Plate VIII, F-1). The soil on the fan surface is strongly developed, in the range of Qf_6 to Qf_7. However, no soil pit was excavated, exposures are poor, and only an incomplete section of the soil profile was observed. Therefore, only a rough age estimate can be made.

Three kilometers to the east in upper Ojai Valley at Sisar Creek, an impressive scarp in an alluvial fan marks the main trace of the fault (Plate VIII, F-2). The soil at the surface strongly resembles Timber Canyon-4 (Qf_7) but no soil pit was excavated and the exposure is poor. Therefore, the age assignment is tentative. The scarp height is 65 meters representing about 80 meters of displacement on a fault dipping 40 degrees to the north (well control). If the correlation to Qf_7 is valid, a slip rate on the San Cayetano at the Sisar Fan would be approximately 0.66 mm/yr. Further soils analysis is necessary for positive correlation.

A higher fan surface at Sisar Creek on the east side of the drainage has a scarp about 100 meters high (Plate VIII, F-3). The surface is somewhat eroded and no soil exposures were found but it is likely that the soil has stronger development then Qf_7, if any of the profile remains. A terrace surface 12.2 meters above the stream level in Sisar Canyon on the hanging wall of the fault has a soil correlative to Qf_5. There is no exposed correlative surface on the footwall block suggesting that the terrace was isolated due to uplift on the fault. The average slip rate, if the 12.2 meters can be used as an estimate, is 0.70 mm/yr; very close to that estimated for the entire scarp height. These rates of slip are well within the age control estimates of the soils.

San Cayetano Fault: Bear Creek to Santa Paula Creek

Bear Creek drains the area between Sisar Creek and Santa Paula Creek. The Bear Creek fan is entrenched and has a 6.1 meter fault scarp on it (Plate VIII, F-4). The soil is correlative with Qf_4 and is estimated to be about 10,000 years old. A slip rate of about 0.6 mm/yr., is attained for this point along the fault. A fan surface roughly 120 meters higher is present on the hanging wall above the upper Ojai Valley. The soil strongly resembles Qf_6 in age but may be slightly older judging by the brighter chromas in the clay films. The surface is called the Bear Canyon surface as it is extensive and important in the overall interpretation of this area.

East of Bear Creek the San Cayetano fault bifurcates; the frontal strand wrapping around the front of the hills through the Silver Thread oil field to Santa Paula Creek. The San Cayetano fault again bifurcates along this frontal section with a sliver of Monterey between Eocene and Pliocene rocks (Plate VIII, F-5). The fault becomes, then, a single trace at Santa Paula Creek. There are no alluvial deposits crossing the fault along the frontal lobe east of Bear Creek fan so there is no data to indicate recency of movement. The northern strand outcrops in two locations juxtaposing Eocene Cozy Dell shale over fan gravels of unknown age. At one location (Plate VIII, F-6) in a road cut, Eocene shale is thrust over fan gravels but a small stream has recently stripped off and leveled the surface removing all traces of a scarp or soil. The other exposure (Plate VIII, F-7) is a road cut exposing a fault plane thrusting Cozy Dell shale over alluvial fan gravels. The total displacement, as seen in the road cut is estimated to be 8 to 10 meters, but this is tentative since brush covers all stratigraphic markers higher in the section. A topographic scarp is associated with the surface trace but the faulted gravel surface is nearly eroded away. No soil profile is exposed due to brush and colluvial cover. The deposit is topographically higher than the Bear Canyon surface and other remnants of old surfaces with soils above this surface correlate well with Qf_7. Since there is no lower confining age to the movement, the slip rate estimated from such an exposure will be a minimum value. It is possible that this is a young strand breaking through to the surface and faulting older alluvium. Deformation along this section is also represented by folding of the Bear Canyon surface into a shallow syncline. If the folding is associated with the San Cayetano fault then the deformation is younger than the Qf_7 sediments it faults since the Bear Canyon surface is probably of Qf_6 or slightly older age. The folded sediments reach a maximum dip to the north of 10 degrees next to the surface trace of the fault indicating an intrinsic relationship. The sediments are nearly level until a few hundred (300-400) meters from the fault where they steepen rapidly. The fault is definitely not a bedding plane fault as observed in the road cut (Plate VIII, F-8). The fault trace was mapped to Santa Paula Creek primarily by the deformation of the alluvial fan deposits. The gravels were originally dipping a few degrees to the south and now dip up to 10 degrees north next to the fault. This deformation could be easily traced even though the fault trace could not be due to heavy brush and colluvial cover.

San Cayetano Fault: Santa Paula to Orcutt Canyon

The main frontal trace of the San Cayetano fault crosses Santa Paula Creek about 0.75 km north of Ferndale ranch near the junction of Santa Paula and Sisar Creeks (Plate VIII, F-9). Heavy brush cover obscures the fault in this area. To the east, the fault traces across the head of Anlauf Canyon toward the Mud Creek fanhead area where the northern branch rejoins the main fault forming a single trace.

The northern trace is well exposed in Santa Paula Creek (Plate VIII, F-10) in the Cozy Dell formation. The fault zone consists of several meters of brecciated shale and a 0.5 meter gauge zone. The fault crosses Santa Paula ridge and the head of Anlauf Canyon where an abrupt change in slope occurs (Plate VIII, F-11).

The San Cayetano fault then strikes eastward across the Mud Creek fanhead to Orcutt Canyon. The Mud Creek fanhead is correlative with Qf_5 by soil development. Remnants of the fan appear to be present on the hanging wall, but about 35 meters higher. Although more work needs to be done here, a slip rate as high as 1.9 mm/yr., may be demonstrable. The problem is that the relief is very steep in the area and the oil industry has altered the landscape enough to make correlation difficult.

The Orcutt Canyon fanhead section of the fault is buried by recent landslide debris and colluvium. The fan begins at the fault trace and does not appear cut by it.

San Cayetano Fault: Timber Canyon

The Timber Canyon section of the San Cayetano fault is totally buried by very recent alluvial fan material (Plate VIII, F-12). A paved road constructed at an unknown time in the past for use by the oil industry is being actively buried. Radial profiles from the east and west fanhead sections (Fig. 19) show three distinct sequents; The oldest corresponding to Qf_3 (approximately

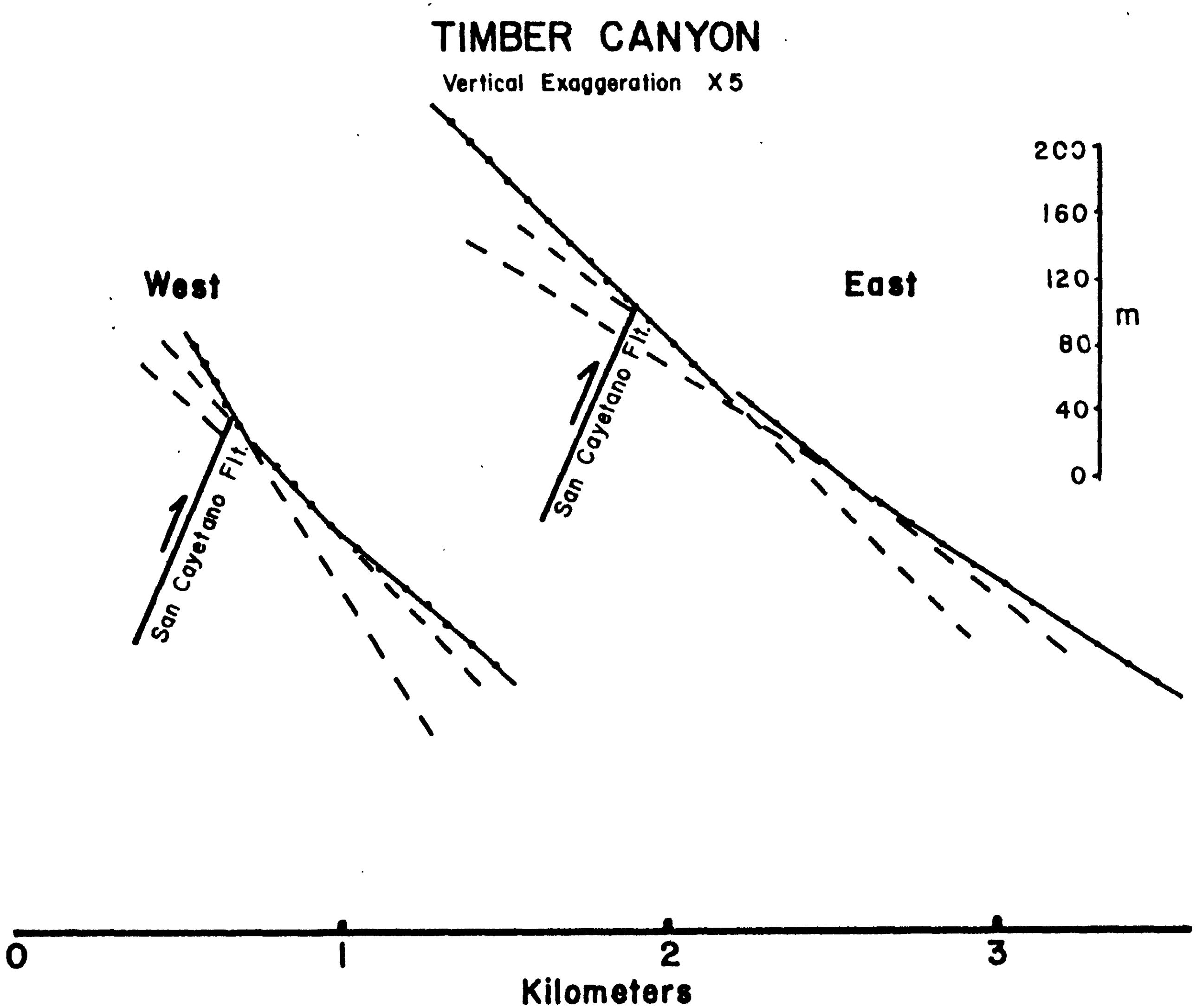

Figure 19. Radial profile of the east and west Timber Canyon fanheads showing fan segments. Dashed lines are extensions of segment slopes.

5,000 ybp), the intermediate with Qf_2 (A/Cox soil), and the youngest with Qf_1). Segmentation of alluvial fans and fanhead deposition are a result of tectonic uplift, climatic change, or vegetational change. The two most probable causes in the last 5,000 years are tectonic uplift and vegetational change.

Vegetational change is a viable alternative because as the vegetation changed from evergreen forest to chaparral (Heusser, 1978), sediment production probably increased initiating deposition at the fanhead. A few false Hemlock still remain attesting to the previous vegetation prevalent during the late Pleistocene.

Tectonic uplift is also a prime factor in fanhead deposition. Previous work by Bull (1979) suggests fanhead deposition is associated with high rates of uplift. As the faulting takes place, the uplifted hanging wall erodes quickly facilitating deposition just below the fault. The fan material regrades quickly and buries the fault and scarp completely. Credence is given to this alternative since the segmentation and fanhead deposition are spatially associated with the main fault trace. If all the segmentation and deposition were due to uplift along the San Cayetano fault, projection along the 5,000 year old surface indicates 18 meters of uplift and a maximum slip rate of 3.6 mm/yr. for this segment of the fault.

San Cayetano Fault: Boulder Creek

The fault trace at Boulder Creek is marked by a small scarp

2.5 to 3.0 meters high in alluvium of Qf_3 or younger age (Plate VIII, F-13). The scarp is in alluvial fan (debris flow) deposits and is spatially associated with the bedrock trace but heavy brush makes absolute correlation difficult. The age is indeterminant since the matrix has a considerable amount of fine material and, although indistinguishable from Qf_3, may be younger. One-half kilometer west of Boulder Creek, a thick section of fanhead material (Qf_5) remains perched on the hanging wall of the fault (Plate VIII, F-14). The fault can be seen in outcrop below the fan material in places. A part of the Qf_5 fan also is present on the footwall just south of the fault. Although the fan on the footwall appears to be in place resting on Pico mudstone, it could just as well have been transported from the hanging wall by landsliding. The next closest section of Qf_5 fan material is over 1 km down the valley from this location.

San Cayetano Fault: Sespe Creek

At Sespe Creek, Oligocene Sespe formation is thrust over Pleistocene Saugus formation (Plate VIII, F-15). Although the actual fault trace in the river cut is obscured by a bulldozed road, a small scarp about 3 meters high trends into the known fault trace area. The escarpment was suggested by Schleuter (1976) to be a fault scarp because of its spatial relationships with the fault and because of a soil color change across the scarp. Augering for orchard planting by a local rancher turned up Sespe bedrock consistently on the high side of the escarpment. Saugus is clearly exposed within a few meters from the escarpment on the low side. This evidence tends to support Schleuter's hypothesis.

The soil developed on the hanging wall is of Qf_2 age, estimated to be on the order of a few hundred to a couple thousand years old. The soil has only an A horizon developed with no B. Trenching at this locality might clearly establish the origin of the escarpment. Since it is parallel to Sespe Creek, it is possibly an eroded stream terrace scarp but the main trace is known to trend parallel to Sespe Creek at this location and must, based on the bedrock outcrops, be very close to this escarpment.

San Cayetano Fault: Summary Statement

Evidence has been presented demonstrating faulting on the San Cayetano fault through the Pleistocene. A few localities suggest possible Holocene movement with associated scarps, but absolute demonstration of this would necessitate trenching. Possible slip rates near the central portion of the fault suggest a maximum slip rate of 3.6 mm/yr. Minimum slip rates toward the western terminus are about 0.66 mm/yr. These two numbers are not incompatible, though, as displacement per event as well as total displacement should and does die out towards the end points.

SOIL GEOMORPHOLOGY

INTRODUCTION

Soil Geomorphology: A Background

Soil is the thin, unconsolidated layer of minerals and organic matter which above sea level covers much of the earth's surface. Most soils are organized into horizontal layers or horizons which lie approximately parallel to the surface, and differ from one another in physical and/or chemical properties. A cross-section of the horizons from the ground down to the parent material or bedrock below the soil is called the soil profile. The characteristics of the profile determine how the soil will be classified.

Soil development consists of two general steps - the accumulation of parent material and the differentiation of horizons in the profile. The horizon formation process occurs when materials are added to or removed from the soil, when soil constituents are moved from one depth to another, or when substances in the soil are chemically transformed (Simonson, 1959). For example, in many soils, clay, suspended in water, is moved from the upper soil ('A' horizon) and deposited at some depth ('B' horizon), creating a profile with a textural difference between the A and B horizons.

The most widely accepted model of soil formation was proposed by Russian pedologists and translated into English by Marbut via German by Glinka, with amplification by Jenny (1941). It states that soil formation reflects joint but independent local influences of five factors--climate, parent material, organisms, slope and time:

$$S = f\ (c,p.o,s,t) \qquad (1)$$

In utilizing this model in soil-geomorphic work, the time factor is critical, for it is widely assumed that the degree of horizon formation and soil development increases over time until a steady state is reached, if all other factors are constant (Birkeland, 1974).

Another model, essentially a simplified version of Jenny's model, is one less known and was developed by Runge (1973). It states that the most important elements of soil development, at least in mid-latitudes, are the amount of organic matter added (the retarding vector), the amount of water infiltrating the soil and effecting horizonation (the organizing vector), and time:

$$S = f\ (o,w,t) \qquad (2)$$

where o = organic matter, w = water, and t = time

In simplest terms, this model states that soils high in organic matter (other things equal) will be minimally developed, and soils with abundant water passing through them (other things equal) will be maximally developed (minimal development = indistinct and thin horizons, dull colors, little illuvial clay; maximal development = distinct and thick horizons, bright colors, much illuvial clay). Organic matter is thought to be the retarding vector because it acts as paint on mineral grains to limit weathering of the grains and, hence, clay formation. Water is the organizing vector because it moves clay from the A to B horizon, and promotes weathering, and, hence, clay formation. This model is referred to as an energy model, where the soil may be thought of as a chromatographic column. Although this model is new, and has drawn criticism (Yaalon, 1975), it has recently been positively tested and shown to have valuable utility under some circumstances (Watson-Stegner, 1979, 1980).

The significance of both Jenny's and Runge's models is that strongly expressed and well developed profiles (i.e., those that appear to be old) may be due indeed to age (the factor "t" in equations 1 and 2), or to energy (the factor "w" in equation 2), or to both age and energy ("t" and "w"). However, while recognizing that the energy model has great utility in some instances, unless energy relations are suspected it is otherwise generally assumed in soil geomorphological work that a reddish, well ordered and developed profile with strong and distinctive horizons is chiefly a reflection of time.

The degree of soil profile development is indicated by various properties observable in the field:

soil depth
horizon distinctness, abruptness and thickness
soil color
quantity and thickness of clay skins

and by laboratory analytical techniques, procedures and measures:

soil thin section (micromorphologic) analysis
binocular microscopic examination of soil peds
soil pH and acidity
free iron oxides
bulk density
clay mineral analysis (x-ray and microscope)

cation exchange capacity

base saturation

calcimetric analysis

organic matter

particle size analysis

elemental analysis

soluble salts

Figure 20 shows the mean value of some of these field and laboratory properties as time indices plotted against soil age (after Hardin and Marchand, 1977). These mean values were determined for soils formed in alluvial deposits in the Modesto-Merced area of California under a present Mediterranean climate by holding the factors *c,p,o* and *s* in (1) relatively constant (it is possible that climate may have varied in the early Pleistocene). Even though the factors of equation (1) vary spatially, the mean values of Figure 20 can possibly be applied with discretion in other regions, such as Ventura County.[1] As indicated in Figure 20, some properties are useful for relative age dating of young soils, whereas others are more useful for dating old soils, while some, like soil color and pH are useful for dating soil of any age. For example, on well drained sites soil color hues redden and chromas brighten with increasing soil age, other things being equal.

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[1]However, at this stage in our research, there are strong indications that soils along the coast, including the study area, may be experiencing more rapid development than the soils in the Central Valley, and on which Figure 20 is based.

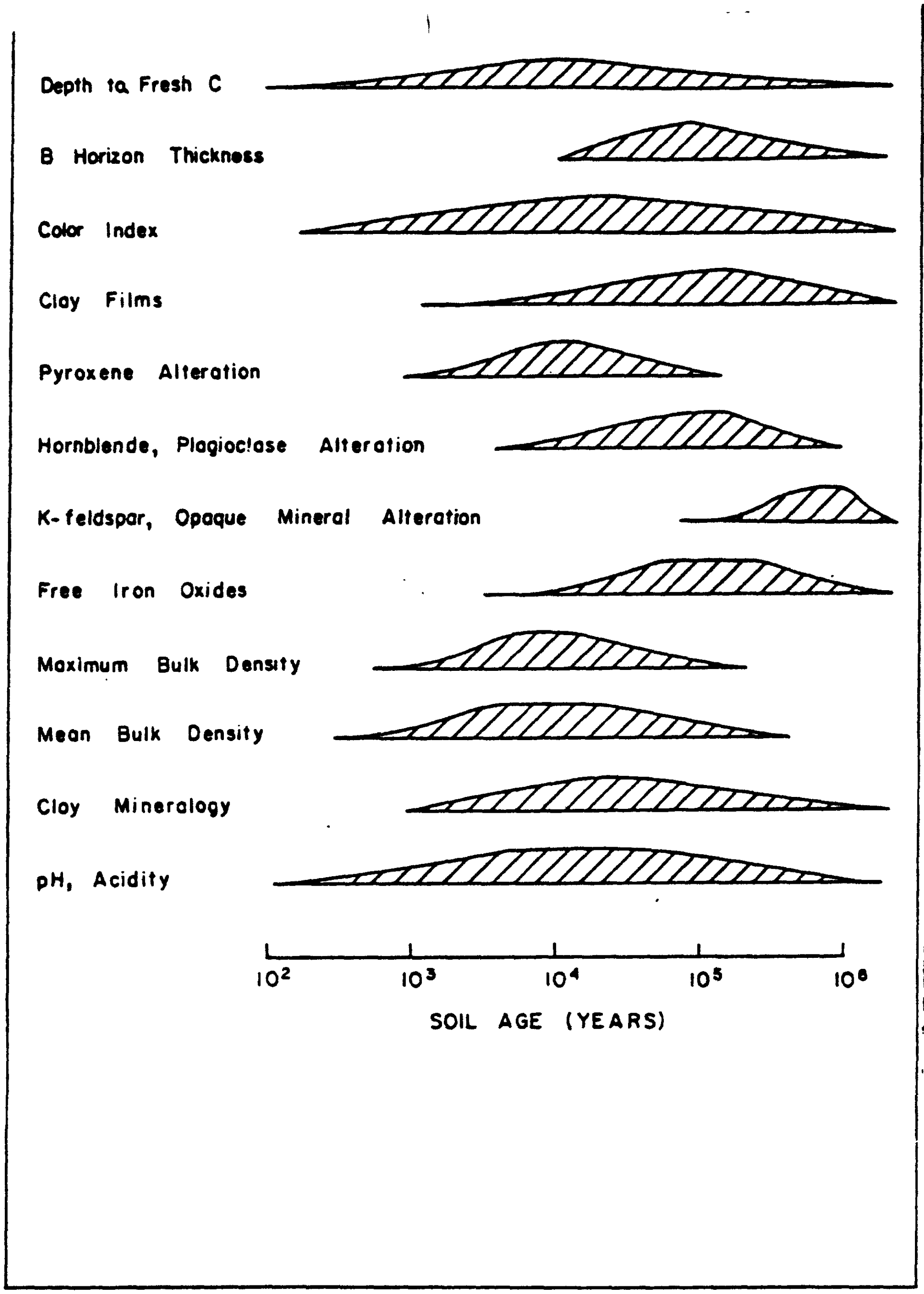

Figure 20. Value of soil properties as time indices plotted against soil age. Length of base line gives approximate age range of applicability. Height of curve reflects value as an age index relative to its optimal value (after Hardin and Marchand, 1977).

Preliminary Work Done in the Study Area

Using the above body of assumptions, concepts, and information, soil geomorphologic work was carried out in conjunction with tectonic geomorphologic studies conducted in the Central Ventura basin. The principal purpose of the soils-geomorphological work is to develop a soil chronology to assist in relative dating of alluvial terraces and, where possible, tectonic events. To this end, soils field work was carried out in selected portions of the Ventura and Santa Clara River basins, Ventura County, California during the summer of 1979. This work consisted initially of a reconnaissance to identify desirable sites where backhoe trenches could be dug, and where soil profiles were already exposed in road cuts, stream cuts or eroded cliffs. Following this, a number of backhoe trenches were dug, and roadcuts and natural exposures cleaned off to the extent that soil profiles could be examined, formally described and sampled for subsequent laboratory analysis. Laboratory analyses were begun towards the end of the 1979 summer field season and were terminated in mid-January, 1980. This report summarizes the field and laboratory work, presents the results followed by a discussion, and presents conclusions.

It should be stressed that the soil geomorphological work is, necessarily, incomplete. More specifically, funding was insufficient to complete the field work and to carry out the laboratory analyses on all the profiles described.

METHODS

Field Work

Location: Soil profiles on stream and river terraces were examined, formally described, and systematically sampled at a number of localities in the following three general areas: the Middle Santa Clara Basin (on the south slopes of the Topa-Topa Mountains), the Ojai Basin of the upper Ventura River, and at the mouth of the Ventura River (Plates V and VIII). Backhoe pits, road-cuts, stream banks and eroded cliff faces were utilized for this purpose. A total of 17 profiles were described and samples, and are identified as follows: La Vista 1,2,3, Apricot 1, Olíva 1, Nye 1, Car Body 1, Orcutt 0,1,2,3, Timber Canyon 1,4, and Taylor Ranch 1,2,3 and 4 (another profile, Nye 2, was sampled in a road-cut, but not described). With one exception (Taylor Ranch 1) the alluvium which forms the parent material of the soils was otherwise found to consist of boulders, cobbles and pebbles with sand, silt and clay as interclast soil material.

Soil Descriptions: Soils were described as recommended in the Soil Survey Manual where the following were noted: color, texture, structure, consistence, clay (and silt and manganese) coatings, reactions, special features (e.g., fecal pellets, mottles, etc.), pores, roots, plus numbers and thickness of horizons. Moist soil colors were determined by wetting and hand homogenizing the <2 mm fine fraction, using the Munsell notation. Unless otherwise indicated, dry colors were noted from homogenized air-dried samples. Texture was initially estimated by hand in the field, and later changed where necessary when particle size data became available from laboratory analyses.

Sampling Procedures: Soil sampling was done at 20 cm (channel) depth intervals (except for Car Body 1, which was sampled at 10 cm intervals), as opposed to horizon sampling, in order to gain an unbiased and objective assessment of comparative vertical particle size and chemical distributions. Fortunately, due to the thickness of the horizons, at least one sampling interval fell within each horizon in almost all cases, so that inter-horizon mixing proved not to be a problem.

Because of the boulder-cobble-pebble framework of the parent materials, sampling was found to be unavoidably very awkward, difficult, and less than satisfying. Matrix fines (<2 mm) had to be dug out from between large clasts by hand, and fine fraction textures appeared to vary noticeably over short horizontal distances. Hence, laboratory analyses were expected to produce variable results to some extent. Samples collected consisted of fine fraction together with some cobbles and many pebbles. Samples were placed in labelled bags and shipped to the laboratory.

Laboratory Work

Sample Preparation Procedures: Once in the laboratory, the fine fractions (<2 mm) that were still adhering to the pebbles and cobbles were removed by hand. A penknife was used to carefully scrape the clasts free of fines which were then passed through a 2 mm sieve.

Laboratory Methods: As originally planned, most of the analytical methods, procedures and measures outlined earlier were to have been employed. However, because of budgetary constraints, limitations were placed on laboratory methods. Hence, of the physical methods, only particle size analysis was done. Particle size analysis of the fine fraction (<2 mm) was carried out by the pipet method (Kilmer and Alexander, 1949; SCS, 1967). Pretreatment of samples involved removal of carbonates, if present, with a buffered (pH 5) sodium acetate-acetic acid solution, and oxidation of organic matter with hydrogen peroxide. The sand fraction (2.0-0.05 mm) was separated from the total soil sample by wet-sieving. Percentages of sand, silt (0.05 - 0.002 mm) and clay (<0.002 mm) in the total soil were calculated from the weights of the total sample, the sand fraction, and the pipetted clay. Particle size data were graphed as percentages against depth.

For clay mineral analysis, glass slides were sedimented with the less than two micron size fraction for all samples that were pipetted. These are stored and are to be x-rayed in the future using our diffractometer as time and funds permit.

Bulk density analysis was originally planned for this study, but intact clods of fine fractions were very difficult to find within the interstices of the coarse-clasts of the parent material, and when found the clods were usually disrupted or destroyed during sampling extraction.

Chemical analyses included pH (1 part soil, 2 parts H_2O), cation exchange capacity (titration method), calculated percent base saturation, organic analysis (Walkley Black method), phosphorus (weak and strong Bray), and soluble salts (Bouyoucos bridge). These analyses were done by A and L Great Lakes Agricultural Laboratories at Fort Wayne, Indiana. Two other determinations, extractable iron and calcimetric analyses, will be carried out as future funding becomes available. The iron measure is anticipated to be maximally useful as an "age" (maturity) discriminator for the soils in the study area.

RESULTS

Formal descriptions of 14 of the 17 profiles described are given in the Appendix. (Three of the Taylor Ranch profiles are not included.) The 14 profiles are identified as Orcutt 0,1,2,3, Timber Canyon 1,4, Car Body 1, La Vista 1,2,3, Apricot 1, Oliva 1, Nye 1, and Taylor Ranch 2. Due to funding limitations only ten of the 14 soil descriptions are accompanied by graphs of basic physical properties (percent sand, silt and clay). For the same reason, graphs of basic chemical properties (pH, CEC, base saturation, percent and parts per million of dominant exchangeable bases, organic matter content, soluble salts and phosphorus) accompany only six of the descriptions (Orcutt 0,1,3 and La Vista 1,2 and 3). These also are in the Appendix.

DISCUSSION

Measures of Age and Age Assignments

The soils in the study area show a great range of variability in profile characteristics, and in apparent age. Nevertheless, while being far from perfect, and with exceptions that need explaining, a pattern has emerged that clearly indicates that the older the surface the more developed is its soil profile. To illustrate, the surfaces and profiles in Table 2 are arranged in the order of increasing age (youngest at top) as hypothesized initially in the field by the writer and co-workers. Tree ring dates (of Orcutt 0) and C-14 dates on charcoal at the base of the Oak View terrace near Oliva 1 and in a buried soil at Timber Canyon provide support to this chronology. Beyond this, with careful study Table 2 is self-explanatory.

Here are one or more attributes of several of the correlative profiles in Table 2 that make them appear problematical (La Vista 3, Oliva 1, Taylor Ranch 2 and Apricot 1). These problematic profiles are, in fact, all correlative to the Qt (Oak View) geomorphic surface. Because the Oak View terrace is (and historically has been) the most important geomorphic surface in the region, particular attention is given to these problematic profiles in the following section. The Oak View terrace soil has been mapped as the Ojai series (Edwards and others, 1970).

Problematic Profiles

La Vista 3: La Vista 3 is problematic in that the profile is bisequal; that is, the modern soil overlies a buried soil. This is clearly evident in the field, and in the profile description, texture, and chemistry (Appendix). The buried soil shows a similar degree of development to La Vista 1 and 2 and other Qt_6 profiles, and is therefore age-correlated with them. However, with the exception of the $IIB_{22}tb$ horizon (7.5YR 5/7 m , where m =

TABLE 2

Measures and Indices of Relative Age of Fifteen Soil Profiles								
Geomorphic Surface	Profile Identifier	Brightest Moist Mixed Color in B Horizon: Hue	Chroma	Color Index[1]		clay $\bar{x}_B/\bar{x}_A$[2]	Clayfilm Index[3]	Estimated Maximum Age
Qt_1	Car Body	AC profile, no B horizon				no B	0.0	10-20 years
Qt_2	Sespe Creek	ND		ND		no B	0.0	250 years
Qt_3	Timber Canyon 1	10YR	3	(4)		ND	0.0	mid to late Holocene[4]
Qt_3	Orcutt 0	10YR	3	(4)		0.6	0.0	mid to late Holocene[4]
Qf_4	Orcutt 1	10YR	4	(5)		1.3	3.0	~10,000-15,000 years[5]
Qf_5	Orcutt 2	10YR	4	(5)		1.1	6.0	~17,000 years[5]
Qf_6	Orcutt 3	7.5YR	4	(6)		1.6	7.5	~39,000 years[6]
Qt_6	Apricot 1	7.5YR	6	(8)		1.5	5.5	~39,000 years[6]
Qt_6	Oliva 1[7]	7.5YR	4	(6)		1.6	7.5	~39,000 years[6]
Qt_6	Nye 1	7.5YR	6	(8)		1.2	7.0	~39,000 years[6]
Qt_6	Taylor Ranch 2	7.5YR	4	(6)		ND	7.0	~39,000 years[6]
Qt_6	La Vista 1	7.5YR	6	(8)		1.4	6.5	~39,000 years[6]
Qt_6	La Vista 2	7.5YR	7	(9)		1.8	7.0	~39,000 years[6]
Qt_6	La Vista 3[7]	7.5YR	7	(9)		1.6	7.5	~39,000 years[6]
Qf_7	Timber Canyon 4	5YR	6	(10)		ND	8.0	~120,000 years[5]

1. Color index is computed by adding chroma number to hue (of moist mixed sample), where 10YR = 1, 7.5YR = 2, 5YR = 3. To determine color, a large air-dried bulk sample was passed through a 2mm sieve, then fractionated in a soiltest mechanical splitter, moistened, hand homogenized to a putty consistency and rolled to a sphere; the latter was then pulled into halves, and color noted from one freshly broken surface.
2. Ratio of the mean percent of clay in B horizon to that in the A horizon (computed from particle size graphs, Appendix).
3. This index is based on clay film information contained in the profile descriptions in the Appendix, and is computed by adding the percent frequency of clay film occurrence to their thickness, as follows: Percent frequency, very few = 1, few = 2, common = 3, many = 4, continuous = 5; Thickness, thin = 1, moderately thick = 2, thick = 3. For example, in the B_{22t} of La Vista 2 there are ". . .many to continuous (4.5) moderately thick to thick (2.5) clay films. . ." The index would be 7.0.
4. This age estimate is collectively based upon tree rings of a number of mature oaks growing upon the Orcutt 0 surface, the degree of soil profile development, and a C-14 date [see Timber Canyon 1 profile description] on charcoal collected from a presumed buried soil in the lower part of the Timber Canyon profile.
5. Age estimate based upon relative amount of displacement on flexural-slip faults between older surfaces in Orcutt and Timber Canyons (see text for further discussion).
6. Based upon a C-14 date on charcoal collected at the base of the Oakview Terrace below Oliva 1.
7. These measures were taken from the buried soil portion of the profile; only the buried profiles of Oliva 1 and La Vista 3 are correlated to the Qt_6 geomorphic surface.

moist color), most of the colors in the buried soil (the portion of the profile being correlated) are more subdued and less red (10YR 4.5/4m, for example) than in La Vista 1 or 2, or Orcutt 3. Probably this is due to fault-caused burial under 2 m of loamy slopewash sediments, and a consequent shift from a highly oxidizing pedogenic environment (well-drained coarse clast parent material with good aeration) to a less well aerated and oxidizing one upon burial. Downfaulting apparently changed the site to a low-lying area that began receiving surface water run-on and slopewash sediments from higher surrounding ground. The presence of manganese films and low chromas in the B_2 horizon of the superposed soil are indicative of imperfect drainage and reflect these events.

The other measures of relative age (color index, percent of clay in B horizon, ratio of mean percent of clay in B to clay in A horizon, and the clayfilm index) all show that the buried soil of La Vista 3 is approximately equivalent in development to La Vista 1, 2 and other Qt_6 profiles. This suggests that the buried soil had probably reached an advanced level of development prior to burial. The fact that the superposed soil also shows indications of strong development (i.e., strong albic (A_2) and argillic horizons, a clayfilm index of 5.0, a ratio of B to A horizon clay of 1.6) suggests either that the upper soil is fairly old itself (<u>time</u> factor of Equations 1 and 2), is a relatively high energy profile (<u>water</u> or energy factor of Equation 2), or reflects the influence of both factors. The run-on, low-lying topographic character of La Vista 3 indicates that excessive amounts of surface water do indeed flow to the site. Further, the character of the profile indicates that fairly good through-flow of soil water occurs there (i.e., while low chromas and subsoil manganese films indicate that less than well drained conditions exist at times, the subsoil is not gleyed nor is it poorly drained). These conditions are interpreted as indicating that the upper soil at La Vista 3 exhibits a relatively high energy profile which could have formed far more quickly than would normally be expected. Therefore if the assumption is correct that the buried soil of La Visat 3 achieved a level of development equivalent to Qt_6 profiles (T a b l e 2) prior to its burial, and if the assumption that Qt_6 profiles (Table) began forming approximately 39,000 years ago or so is correct, then faulting of the Oak View terrace probably occurred in late Pleistocene or early Holocene time. It is our judgement that 12,000 years or less (but probably not less than 5,000 years) would allow sufficient time for slopewash sediments to accumulate above the downfaulted Qt_6 surface, and to be pedogeneticized to their present expression in a relatively high energy run-on site.

Oliva 1: Another buried soil occurs at this locality, and its developmental history is considered to be almost a parallel of La Vista 3.

A profile began developing upon the Oak View surface shortly after about 40,000 years ago and reached a strong Qt_6-type pedologic expression within about 30,000 years (some 10,000 or so years ago). Faulting, or activity associated with faulting, caused the surface at this locality to become elevationally depressed, probably in the early Holocene, creating a relatively high energy run-on type local environment. Loam-textured slope-wash sediments began accumulating, and a high energy profile subsequently developed. Thile the chromas and values are a bit lower here than at La Vista 3, the hues are more red, indicating that subsurface drainage conditions here are probably about the same as at La Vista 3. Moderately good drainage would enhance soil water throughflow and attendant profile-ordering processes (Runge, 1973). However, the markedly less local relief around Oliva 1 compared to La Vista 3, and the thinner sediment fill (1.5m versus 2.2m) suggest that run-on probably is less here, thereby somewhat offestting the enhancing effects of moderately good subsurface drainage on profile ordering.

Nye 1: The soil profile developed at Nye 1 is also problematical in that the ratio of mean percent of B to A horizon clay (Table 2) is lower than expected for Qt_6 surface (Oak View) soils. Also, even though the color index is high (8) most of the profile has 10YR hues and low chromas (2-4). There are two probable reasons for this profile appearing less developed than its correlatives. First, the locally calcium carbonate-bearing Monterey Formation outcrops upslope from Nye 1, which contributes calcium ions to the overland surface water flow and to the soil water solution downslope. Calcium and other divalent cations, when abundant in the soil water solution, tend to flocculate clays, which inhibits their translocation to subsoil (textural, or argillic) B horizons. Other things equal, fine clays (0.2 μ) tend to be translocated more easily than coarse clays, and flocculated clays (aggregates of silt size) are translocated least easily of all. Hence, in the presence of abundant calcium, other things equal, less clay is translocated, argillic B horizons are less well developed, and clay films are thinner and less abundant.

Secondly, the presence of abundant divalent cations such as calcium and magnesium tends to promote greater organic matter production in the topsoil. Organic-rich mollic epipedons, such as in Nye 1, commonly result. Organic matter is though to act as "paint" on otherwise weatherable mineral grains (recall that in Equation (2) organic matter functions as the retarding vector in soil formation). This "paint" is believed to limit weathering of minerals (and therefore clay formation) much like the way paint on the exterior of dwellings protects wood and metal from weathering. Divalent cations also keep the soil pH high, which further tends to retard clay formation (weathering and clay formation are enhanced under acid soil conditions and conversely retarded under alkaline soil conditions, other things equal). In soil profiles the result is limited clay generation through slowed weathering, thereby limiting the total quantity of clays available for translocation and argillic B horizon formation. The process also suppresses A_2 horizon development, where weathering of clays is presumably most intense and from which clay is normally removed and translocated downward.

Organic matter "paint" is also believed to supress soil colors in that dark-colored, humus-clay complexes form and when they are translocated to B horizons the latter tend to have more subdued yellowish hues, lower values and lower chromas.

These relationships and conditions were understood before the backhoe trench at Nye 1 was put in, but at the time it was hoped that the trench would be far enough away from the Monterey clasts that their influence would not be present. As it turned out, it was not. While the Nye 1 profile reflects these pedogenetically retarding relationships, the surface on which it occurs is at the same elevation as the Oak View surface immediately across (east) of the Ventura River, and is therefore correlated with it.

Taylor Ranch 2: While particle size data are, at this writing, not yet available for this profile, the low color index makes Taylor Ranch 2 problematic. However, considering the fact that this profile has a thick mollic epipedon, the low chromas and values and the yellowish hue are not surprising in light of the above discussion about organic matter and its role in color brightness suppression. Additionally, the Taylor Ranch was used for many years as a stockyard for cattle. The effect of large quantities of organic feces and urine leaching through the soil must surely have had consequences for the physical and chemical properties and it is possible that suppressed subsoil colors were one. Otherwise the profile properties as expressed in the description strongly suggest that Taylor Ranch 2 is developmentally related to the Oak View terrace near the town of Oak View, which supports Putnam's original hypothesis (Putnam, 1942).

Apricot 1: The profile expression of Apricot 1 is problematic in that it has a low clayfilm index, and a slightly less

B to A horizon clay ratio than would be expected for a Qt_6 (Oak View) correlative. Thus in terms of clay abundance in the B horizon and clay film thickness, the profile appears less developed than its correlatives. Yet is has no mollic epipedon and no indication of being affected by divalent cations from an extraneous source that might retard development. Consequently there are two possible ways to explain this weakly expressed Qt_6-correlated profile. One is that it is a low energy profile and simply shows less development on the Qt_6 surface because less water has passed through it than elsewhere on this polypedon. Secondly, is that it is a soil developed on a younger surface, perhaps a Qt_5 equivalent surface. Our preferred interpretation is the former, that it is a relatively low energy profile developed on the Qt_6 surface.

Rates of Pedogenesis

There are several factors which affect the rates of pedogenesis on the terraces of streams and rivers of Ventura County. Those that tend to retard pedogenetic rates are organic matter and the presence of abundant divalent cations (the principal source is calcium carbonate) and lateral and upward flow of soil moisture. Factors that tend to speed pedogenesis include: coarse textured parent material, erosionally stable geomorphic surfaces, seasonally concentrated precipitation, downward flow of soil moisture, and eolian inputs of sodium ion (from the ocean) and dust (from the desert).

Parent Material: With the exception of the Taylor Ranch 1 profile, which has not been discussed, all of the terraces under study thus far have been comprised of coarse clasts (bounders, cobbles, pebbles, sand). Coarse clast parent materials, if they are predominantly non-carbonate, by their very nature present conditions that lead to maximal pedogenesis. Because of their coarse texture, wetting fronts tend to vertically move much more deeply into them than in fine textured sediments because they have much less surface area and, therefore, much less moisture "holding" capacity. Also, coarse clast sediments are much better aerated and, in the absence of organic matter, provide maximum opportunities for weathering and the production of clay, and for oxidation and the production of extractable iron compounds. Hence, other things being equal, argillic horizons tend to form rapidly, and the clays tend to complex with iron to produce reddish hues and bright chromas.

Easily weatherable rocks also contribute both color and clay to the alluvial terraces of Ventura County. "Rotten" clasts derived from the Sespe and other formations were observed in the parent materials in La Vista 1,2,3, Apricot 1, and Oliva 1. These clasts were highly weathered to the extent that they could almost be broken by hand. They often had cracks, fractures and joints within which secondary clay had accumulated in almost continuous sheets. Moreover, it is believed that the Sespe clasts in particular weather exceedingly fast, and that in addition to clay, the products of weathering contribute reddish colors to the profile as a whole. The writer and co-workers are of the opinion that reddish hues and high chromas develop more rapidly in coarse clast parent materials where Sespe clasts are present. Thus the bright reddish colors that are thought to develop in "normal" Palexeralfs over many tens of thousands of years can possibly develop much quicker in the study area, perhaps on the order of 20,000 to 30,000 years.

Stability of Geomorphic Surfaces: Because of the coarse clast character of the terrace sediments, they tend to be mimally affected by the normal processes of mass movement that so effectively move fine textured sediments. Also, the clay-iron complexes in the B horizon tend to serve as induration agents which still further stabilize the surfaces and allow the sediments to stand as vertical cliffs. Stable surfaces retain their profiles as intact entities over long periods of time, whereas fine-textured sediments result in unstable surfaces that downwaste and lower their profiles through time. The latter process tends to continually "renew" the profile, whereas profiles on stable surfaces keep getting deeper and more weathered.

Seasonally Concentrated Precipitation and Downward Flow of Soil Moisture: While Ventura County is considered to be a climatically semi-arid area, the precipitation comes, with rare exceptions, almost entirely concentrated over a three or four month period so that wetting fronts and their pedogenetic effects are far more effective than if the precipitation were scattered throughout the year.

Downward flow of soil water, as opposed to lateral or upward flow, is believed to be a major factor in rapid pedogenesis (Runge, 1973 and various personal communications). The energy model expressed in Equation (2) was tested recently by Wagner-Stegner (1980) and found to be generally valid. For example, she found that the quantity and quality of water and its directional flow plays an important role in the strength of soil profile development. Other things being equal, the greater the amount of water flowing downward through the soil, the greater the strength of profile development. In the Ojai area terrace soils, all evidence in the profiles studied suggests that seasonally abundant soil water that moves downward is very significant in the soil-forming process.

Eolian Inputs: Sodium and Dust? Fog is a common spring and summer phenomenon in Ventura County. Every fog droplet carries at its center a hygroscopic nucleus of dust, salt or other substance (smoke, for example). Over very long periods of time, appreciable accumulations of these particles can occur. Rainfall also tends to bring in these constituents. The terrace soils of Ventura County have appreciable soluble salts and absorbed sodium (see Appendix, Orcutt 0,1,3, La Vista 2,3). Sodium tends to disperse clays (as opposed to divalent cations that flocculate them) which makes them much more susceptible to translocation and illuviation. Hence, other things equal, abundant sodium in soils would tend to speed pedogenesis, at least as it is measured by the thickness and strength of the argillic B horizon. Shlemon (1978, p. 98-100) concluded the rates of pedogenesis in coastal California are ". . . .an order of magnitude more rapid than that for comparably-developed, dated profiles in the interior of California." (For such comparably-developed interior California soils see Arkley, 1962; Janda and Croft, 1967; Shlemon, 1967, 1972; Marchand and Hardin, 1976; see also footnote 1 of this report).

The Ventura County region also receives annual inputs of dust brought by Santa Ana winds. Such dust blows, literally, in plumes from playas and other fine-sediment surfaces in the Mojave Desert (see Muhs, 1979). One such dust plume, not visible on the ground, is clearly seen advancing over Ventura and Santa Barbara Counties on a Landsat image taken June 23, 1976 (Muhs, personal communication, January 1980; aeolian dust is probably produced in greater quantity now than prior to recent historic disturbance in the Mojave Desert). During the course of 10 or 20 Santa Ana wind conditions per year in Southern California a surprising quantity of dust can accumulate in a few hundred years (as much as 24 to 31 $gm/m^2/yr$, on San Clemente Island 50 miles (80 km) off the coast; see Muhs, 1979). This is dominantly (50-80%) of silt size (0.05-0.002 mm diameters).

Regular eolian contributions of fine textured weatherable minerals to the highly oxidizing environments of the terrace gravels in Ventura County, in addition to weatherable minerals released by weathering of the coarse clasts themselves, could produce clay for translocation by winter rains relatively rapidly.

CONCLUSIONS (SOILS WORK)

It is concluded that a pattern exists on the stream and river terraces of Ventura County that clearly indicates that the older the surface the more developed is its soil profile. It is further provisionally concluded that the multiple terrace surfaces at different elevations in the Oak View-Ojai area are all tectonically segmented portions of the Oak View terrace. Assuming the radiocarbon date for the Oak View terrace is correct (we have no reason to reject it), then palexeralfs in the study area appear to form in as short a period as 20,000 to 30,000 years, considerably quicker than rates estimated for similar soils in the California interior. Slow rates of pedogenesis in the study area reflect the retarding effects of: 1) organic matter production; 2) presence of abundant divalent cations in the profile; 3) alkaline or less acidic pH conditions; and 4) low energy geomorphic conditions. Fast rates of pedogenesis reflect the enhancing effects of: 1) coarse textured parent material; 2) increased weathering; 3) acidic pH conditions; 4) erosional stability of the geomorphic surface; 5) strong annual precipitation pattern; 6) downward flow of soil water; and 7) eolian input of salt and dust.

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APPENDIX: SOIL DESCRIPTIONS

SOIL DESCRIPTION

Classification: Typic Xeropsamment
Identifier: Car body surface
Location: First "terrace" (floodplain?) of Ventura River at Live Oak Acres, Ventura County, California
Geographic Coordinates: 34° 27' 12" N, 119° 17' 53" W
Geomorphic Surface: Qt_1
Landform: First terrace, or modern floodplain of Ventura River
Parent Material: Coarse textured (boulders, cobbles, pebbles, sand) river alluvium
Slope: 2-4° (4-7%)
Elevation: Approximately 420 feet (128 m)
Vegetation: Sparse riverine scrub-chaparral
Collected by: D. L. Johnson and D. N. Johnson
Described by: D. L. Johnson and D. N. Johnson
Exposure: Natural vertical river-cut bank

Horizon	Depth (cm)	Description
A_1	0- 58	Dark grayish brown (10YR 4/2m; 6/3d) to dark brown (10YR 3/3m; 6/3d) very gravelly loamy sand; massive; soft; very weak cementation by $CaCO_3$, strong effervescence; many very fine to medium pores, continuous, random, tubular with some vesicles, common fine roots, gradual wavy boundary to:
C_1	58-125	Dark brown (10YR 3.5/3m; 6/3d) very gravelly loamy sand to very weak, very fine sub-angular blocky; soft; strong effervescence; many fine to medium pores, continuous, random tubular; many fine to medium roots; clear, wavy boundary to:
C_2	125-300+	Dark brown (10YR 3/3m; 5/3d) very gravelly loamy sand; single grain; loose; strong effervescence; common intergrain pores.

Sespe Creek profile description and data not available. Relationships and age estimates determined on the basis of field observations.

Classification: Typic Xeropsamment
Identifier: Timber Canyon 1
Location: Lower Timber Canyon, near Santa Paula, Ventura County, California
Geographic Coordinates: 34° 23' 35" N, 119° 0' 41" W
Geomorphic Surface: Qf_3
Landform: late Holocene stream terrace
Parent Material: Stream gravels
Slope: 4-6° (7-10%)
Elevation: Approximately 1320 feet (403 m)
Vegetation: Scrub oak, chaparral, scrub
Collected by: D. L. Johnson and T. K. Rockwell
Described by: D. L. Johnson and T. K. Rockwell
Exposure: Stream cut, relatively fresh

Horizon	Depth (cm)	Description
A_1	0- 14	Very dark brown (10YR 2/2m; 4/2d) gravelly silt; medium subangular blocky; soft; many very fine pores between grains; many fine to medium roots along ped-stone interfaces, abrupt wavy boundary to:
IIC_1	14- 65	Dark brown (10YR 3/3m; 5/4d) very gravelly loamy sand; weak medium subangular blocky; very soft; many very fine to medium pores between grains and as biological channelways, continuous random tubular (simple); many fine to medium roots in pores and along ped-pebble interfaces; gradual wavy boundary to:
$IIIC_2$	65-108	Dark brown (10YR 3/3m; 5/4d) very gravelly loamy sand; weak medium subangular blocky; soft; many very fine to medium pores between grains and along biological channelways; common fine to medium roots mainly along ped-stone interfaces; clear wavy boundary to:
IVC_3	108-185	Dark brown (10YR 3/3m; 5/4d) very gravelly silt loam; to weak medium subangular blocky; soft; many very fine to medium pores between grains and along biological channelways; common fine to medium roots in pores; slightly oxidized zone (strong brown 7.5YR 5/6m) between 130-150 cm; charcoal flecks present; cleary wavy boundary to:

$IIIC_1$	185+	Dark brown (10YR 3/3m; 5/4d) sand; massive breaking to single grain; soft; many very fine to fine pores between grain; few fine roots.

Comment: A C-14 date on charcoal in the $IIIB_{2b}$ horizon has yielded a provisional date in the range of 9,000-10,000 years BP, with an uncertainty in the area of ±2,000 years. A final date on this sample will be obtained soon. This horizon, which is interpreted as a probable buried soil, is provisionally age correlated with Orcutt 1, on the Qt_4 geomorphic surface.

SOIL DESCRIPTION

Classification: Pachic Xerumbrept
Identifier: Orcutt O
Location: Orcutt Canyon, Ventura County, California
Geographic Coordinates: 34° 24' 06" N, 119° 01' 53" W
Geomorphic Surface: Qt_3
Landform: Very late Holocene stream terrace
Elevation: Approximately 1360 feet (415 m)
Slope: 3-6° (5-10%)
Parent Material: Coarse textured stream alluvium
Vegetation: Oak grass woodland with a partially shaded oak canopy
Collected by: D. L. Johnson and T. K. Rockwell
Described by: D. L. Johnson and T. K. Rockwell
Exposure: Stream-cut bank (relatively fresh)

Horizon	Depth (cm)	Description
O_1	6- 4	Litter layer (oak leaves, grass thatch, twigs)
O_2	4- 0	Partially decomposed litter
A_1	0-23	Black (10YR 2/1m; 3/1d) very gravelly sandy loam; moderate medium to coarse crumb; soft to slightly hard; few medium to coarse pores; many very fine to very coarse roots; clear smooth boundary to:
A_3	23-35	Very dark brown (10YR 2/2m; 4/2d) very gravelly sandy loam; weak medium subangular blocky; soft; many fine to coarse pores; many very fine to very coarse roots; clear smooth boundary to:
IIC_1	35-48	Dark brown (10YR 3/3m; 5/4d) very gravelly loamy sand; structureless single grain; loose; many fine to coarse interstitial "pores"; many fine to coarse roots; clear smooth boundary to:
IIC_2	48-60	Brown (10YR 4/3m; 5/4d) very gravelly loamy sand; weak medium subangular blocky; soft to slightly hard; many fine to coarse pores; common fine to coarse roots; clear smooth boundary to:
IIC_3	60-69	Brown (10YR 4/3.5m; 5/4d) very gravelly loamy sand; structureless single grain; loose; few to common to medium roots; abrupt smooth boundary to:
$IIIC_4$	69-?	Dark brown (10YR 3/3m) very gravelly loamy sand; structureless single grain; loose; many coarse pores; few fine to coarse roots.

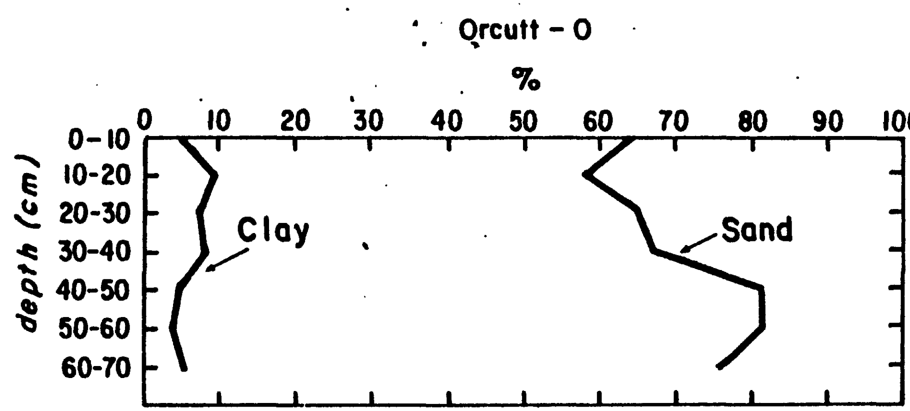

Fig. 21. Orcutt-O (Qt_3): Clay and sand content.

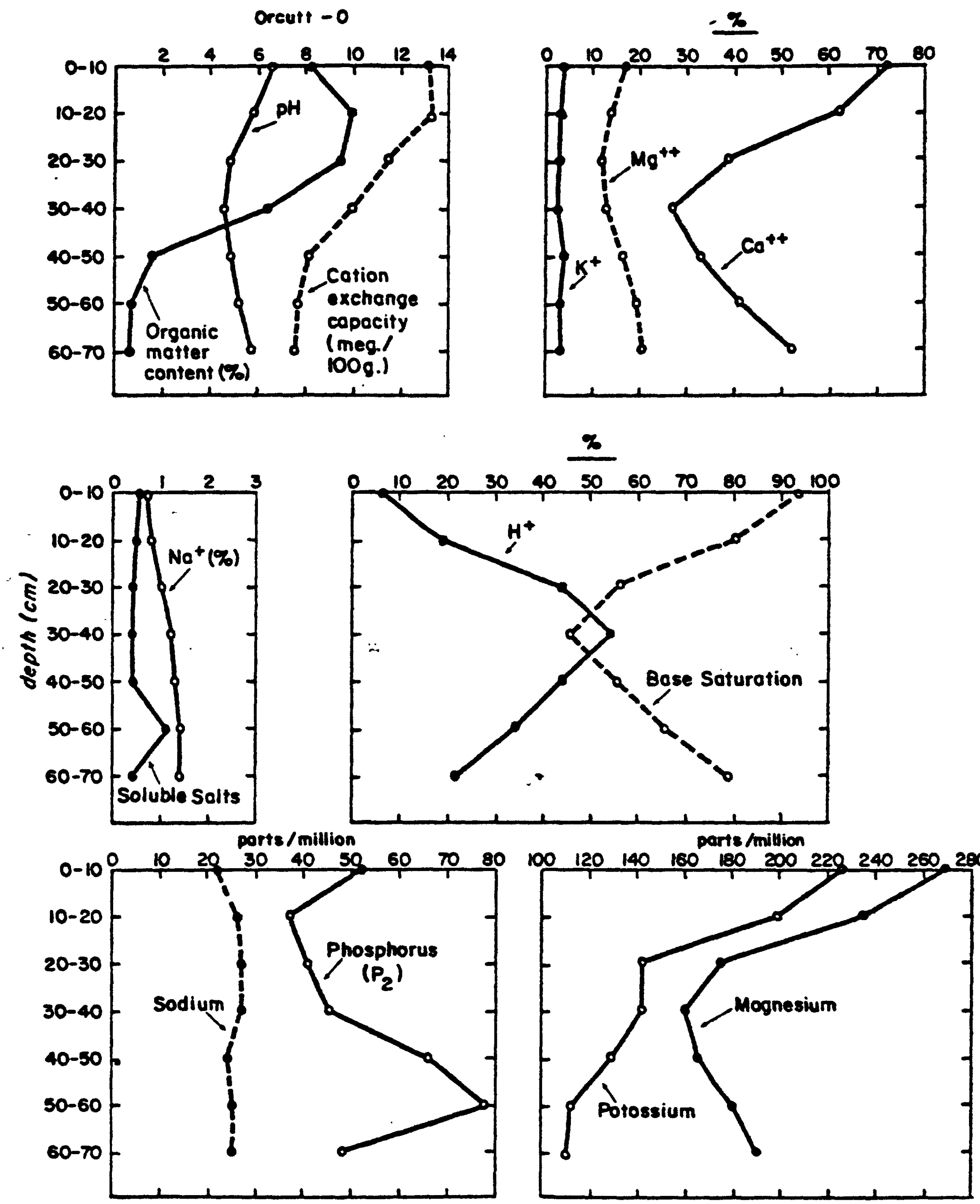

Fig. 22. Orcutt-O (Qt_3): Organic matter, pH, cation exchange capacity, base saturation, soluble salts, and Mg^{++}, Ca^{++}, Na^{+}, H^{+}, P_2 and K^{+} content.

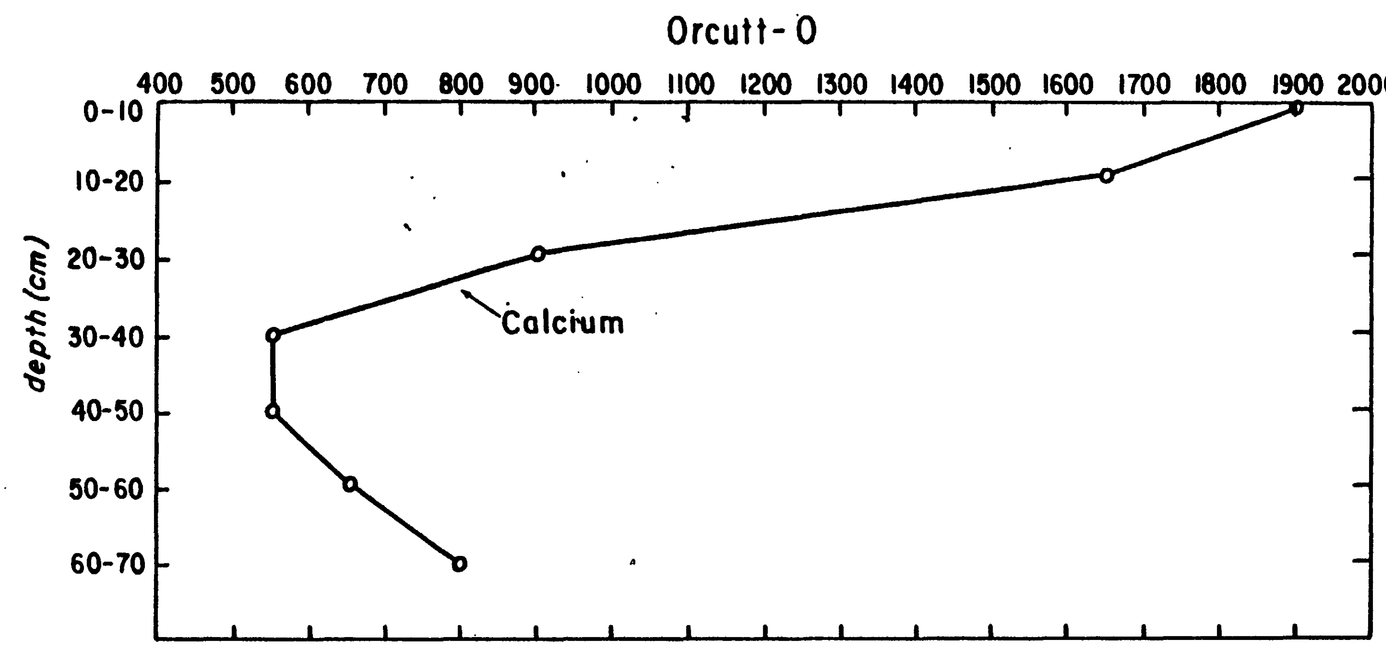

Fig. 23. Orcutt-O (Qt_3): Calcium content.

SOIL DESCRIPTION

Classification: Mollic Haploxeralf
Identifier: Orcutt 1
Location: Lower Orcutt Canyon (east side next to road) near Santa Paula, Ventura County, California
Geographic Coordinates: 34° 22' 52.5" N, 119° 02' 15" W
Geomorphic Surface: Qf_4
Landform: Dissected middle to late Holocene stream terrace
Parent Material: Stream gravels
Slope: 5-8° (8-14%)
Elevation: Approximately 560 feet (171 m)
Vegetation: Oak-grass and chaparral
Collected by: D. L. Johnson and T. K. Rockwell
Described by: D. L. Johnson and T. K. Rockwell
Exposure: Road cut

Horizon	Depth (cm)	Description
A_1	0- 23	Very dark grayish brown (10YR 3/2m: 5/3d) very gravelly sandy loam; moderate coarse subangular blocky; soft; very many fecal pellets (they comprise almost entire horizon); many medium pores between fecal pellets, continuous random tubular (simple); many fine roots in pores; clear smooth boundary to:
B_1	23- 68	Dark brown (10YR 3.5/3m; 5/4d) very gravelly loam; moderate coarse subangular blocky; slightly hard; very many medium pores between fecal pellets (most of this horizon is of fecal pellets), continuous random tubular (simple), many fine roots in pores; clear smooth boundary to:
B_{2t}	68-180	Dark brown (10YR 4/3m; 5/4d) very gravelly loam to sandy loam; moderate coarse; subangular blocky; slightly hard; few thin clay films that envelope clasts and ped interfaces; many fine pores, continuous random tubular (simple); common fine to coarse roots; clear smooth boundary to:
B_3	180-224	Yellowish brown (10YR 5/4m; 6/6d) very gravelly sandy loam; weak medium subangular blocky; soft; very few thin clay films that envelope clasts; many fine to medium pores, continuous random tubular (simple); common fine to medium roots; clear gradual boundary to:
C_1	224+	Yellowish brown (10YR 5/4m; 6/6d) very gravelly sandy loam; weak medium subangular blocky; soft; many very fine to fine pores, continuous random tubular (simple); common fine to medium roots along clast-fine matrix interfaces.

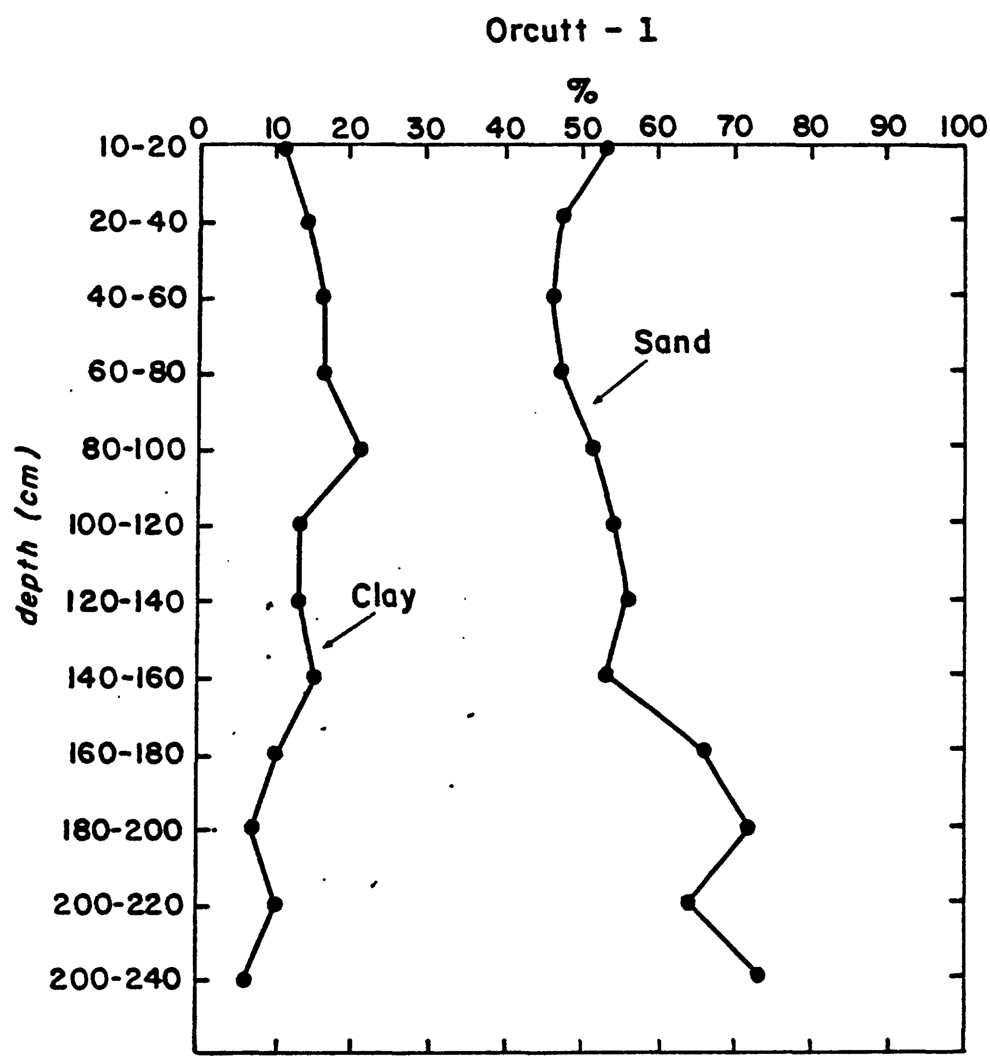

Fig. 24. Orcutt-1 (Qf_4): Clay and sand content.

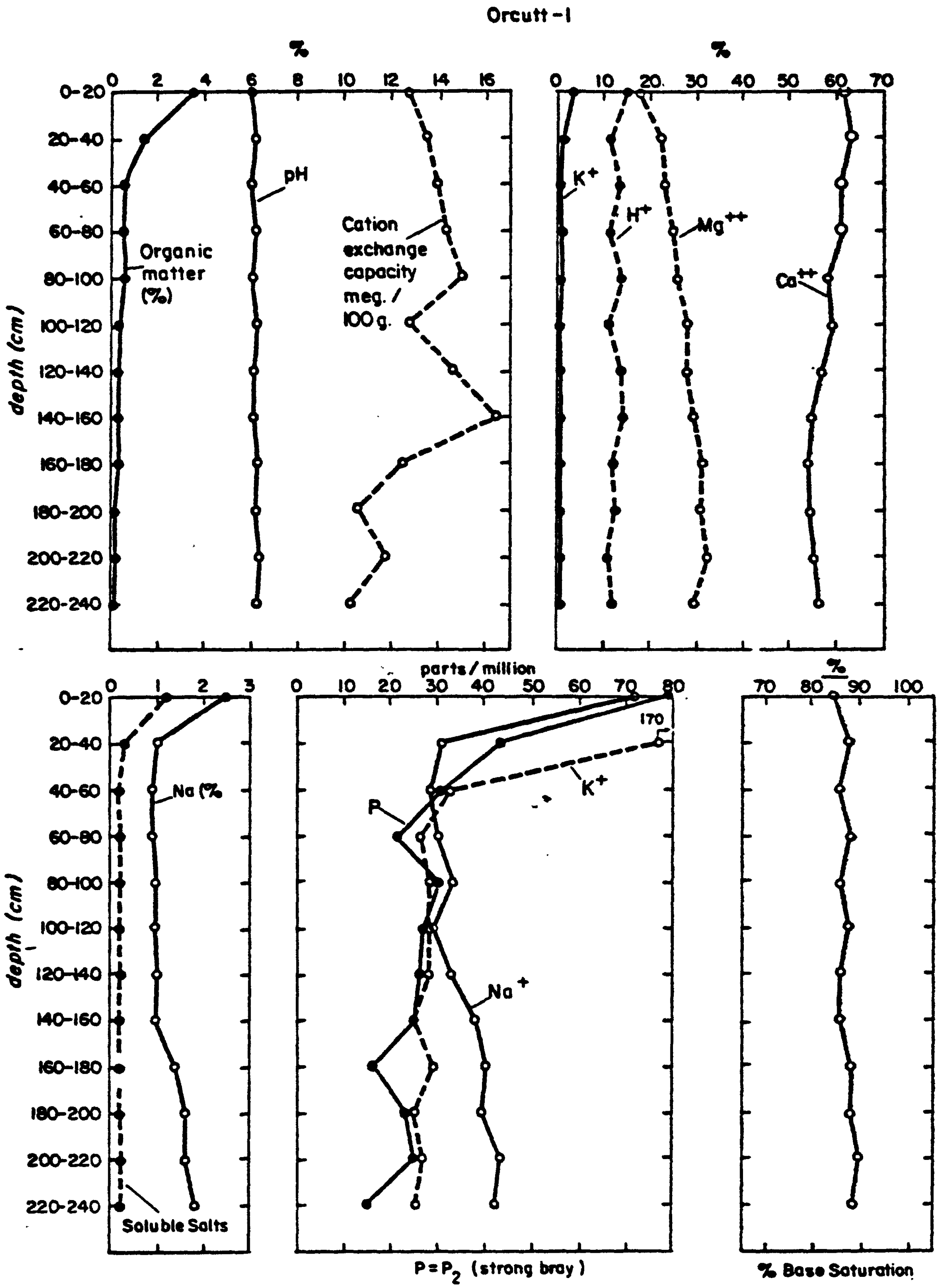

Fig. 25. Orcutt-1 (Qf_4): Organic matter, pH, cation exchange capacity, soluble salts, base saturation and K^+, H^+, Mg^{++}, Ca^{++}, Na^+, P_2 content.

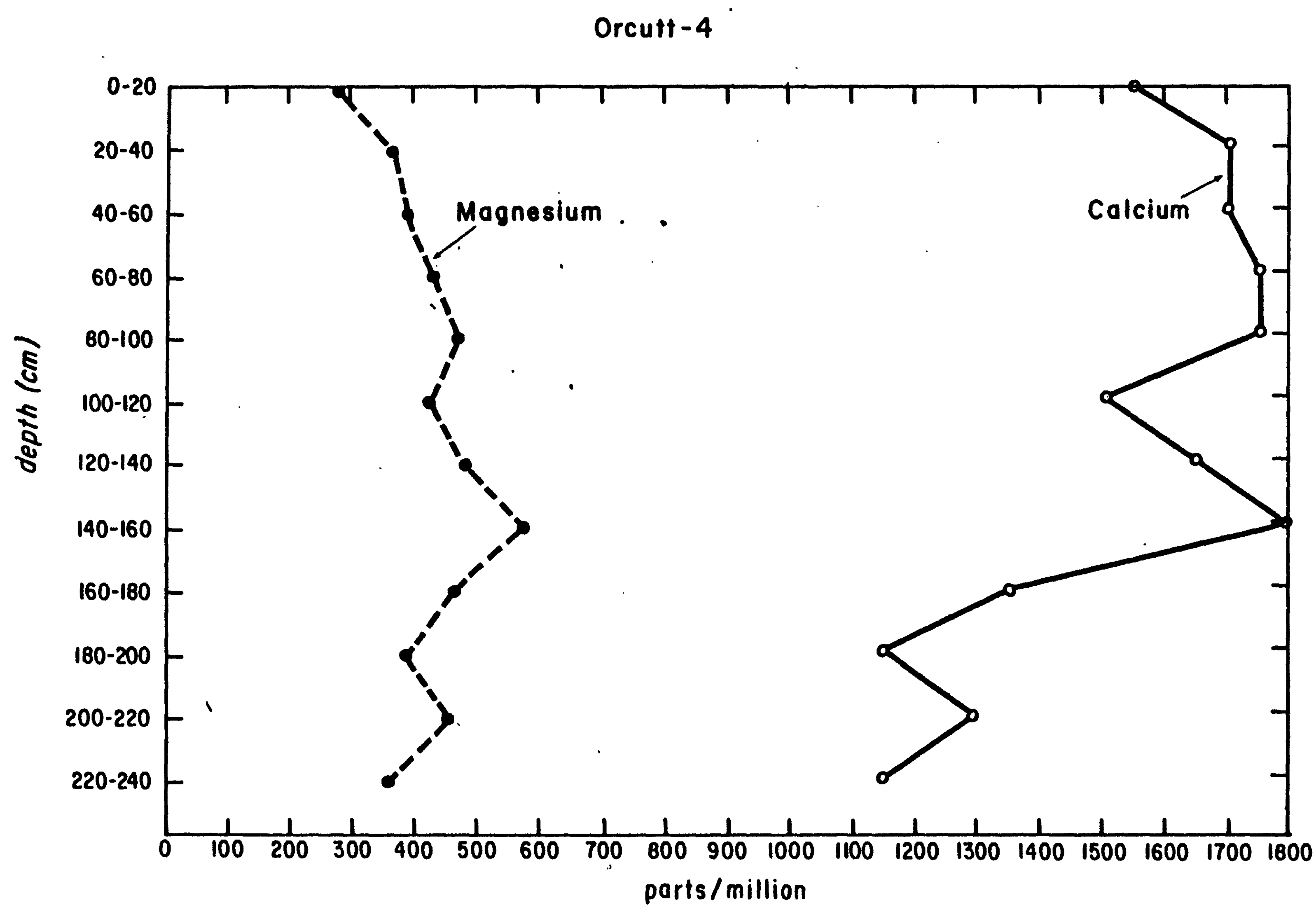

Fig. 26. Orcutt-1 (Qf_4): Magnesium and calcium content.

SOIL DESCRIPTION

Classification: Mollic Haploxeralf
Identifier: Orcutt 2
Location: Middle Orcutt Canyon, south slopes of Topa-Topa Mountains, near Santa Paula, Ventura County, California
Geographic Coordinates: 34° 02' 02" N, 119° 01' 56" W
Geomorphic Surface: Qf_5
Landform: Greatly dissected late Pleistocene stream terrace
Parent Material: Coarse textured stream and/or fan gravels (pebbles, cobbles, boulders)
Slope: 8-9° (14-16%)
Elevation: Approximately 1400 feet (427 m)
Vegetation: Grass with scattered oaks, some scrub-chaparral
Collected by: D. L. Johnson and T. K. Rockwell, July 27, 1979
Described by: D. L. Johnson and T. K. Rockwell, July 27, 1979
Exposure: Almost vertical road cut

Horizon	Depth (cm)	Description
A_{11}	0- 20	Very dark grayish brown (10YR 3/2m; 5/3d) very gravelly loam; weak medium to coarse subangular blocky, to moderate fine-to-medium subangular blocky; slightly hard; many fine to medium pores, continuous random tubular (simple); common very fine roots in pores; clear smooth boundary to:
A_{12}	20- 40	Dark brown (10YR 4/3m; 5/4d) very gravelly loam; weak medium to coarse subangular blocky, to moderate fine-to-medium subangular blocky; very hard; many fine to medium pores, continuous random tubular (simple); common very fine to fine roots in pores; clear smooth boundary to:
B_1	40- 60	Dark yellowish brown (10YR 4/4m; 5.5/4d) very gravelly loam; moderate fine to medium subangular blocky; very hard; incipient illuvial surfaces along ped interfaces and in pores; common very fine pores; very fine to fine roots; very many fecal pellets; clear smooth boundary to:
IIB_{21tb}	60-180	Dark yellowish brown (10YR 4/4m; 5.5/4d) very gravelly sandy loam to moderate to strong, medium to coarse subangular blocky; hard to very hard; common thin clay films (5YR 3/3m) along ped interfaces and in pores; many fine pores, continuous random tubular (simple); few fine roots in pores and along ped interfaces; very many fecal pellets; gradual smooth boundary to:

B_{22t}	180-320	Dark yellowish brown (10YR 4/4m; 6/4d) very gravelly loam; moderate to strong medium subangular blocky; hard; many moderately thick clay films (7.5 YR 3/4m) along ped interfaces and in pores; common fine to medium pores, continuous random tubular; few fine roots along ped interfaces and in pores; gradual smooth boundary to:
IIB_{3b}	320-420	Dark yellowish brown (10YR 4.5/4m;6/4d) very gravelly loam; moderate to strong, medium to coarse subangular blocky; hard; few thin clay films along ped interfaces and in pores; few fine roots; gradual smooth boundary to:
IIC_1	420-540	Yellowish brown (10YR 5/4m;6/4d) very gravelly sandy loam; moderate medium subangular blocky; hard to very hard; very few thin clay films along ped interfaces and in pores; common fine pores, continuous random tubular (simple); few fine roots in pores; gradual smooth boundary:
$IIIC_2$	540-580	Dark yellowish brown (10YR 4/4m; 5/4d) very gravelly loamy sand; moderate medium subangular blocky; moderately hard to hard; very few thin clay flims on matrix fines, and common very thin clay films and MnO_2 coatings on pebble-cobble surfaces; gradual smooth boundary to:
IVC_3	580-700	Brown to dark brown (10YR 4/3.5m; 6/4d) very gravelly loam; moderate medium subangular blocky; hard; very few clay films and MnO_2 coatings on pebble surfaces.
	<u>Comments</u>:	Incipient glossic eluvial tongues of A_2-like material occur beginning about 3 meters depth (they may, as we suspect, occur higher in the profile, but were not seen there).

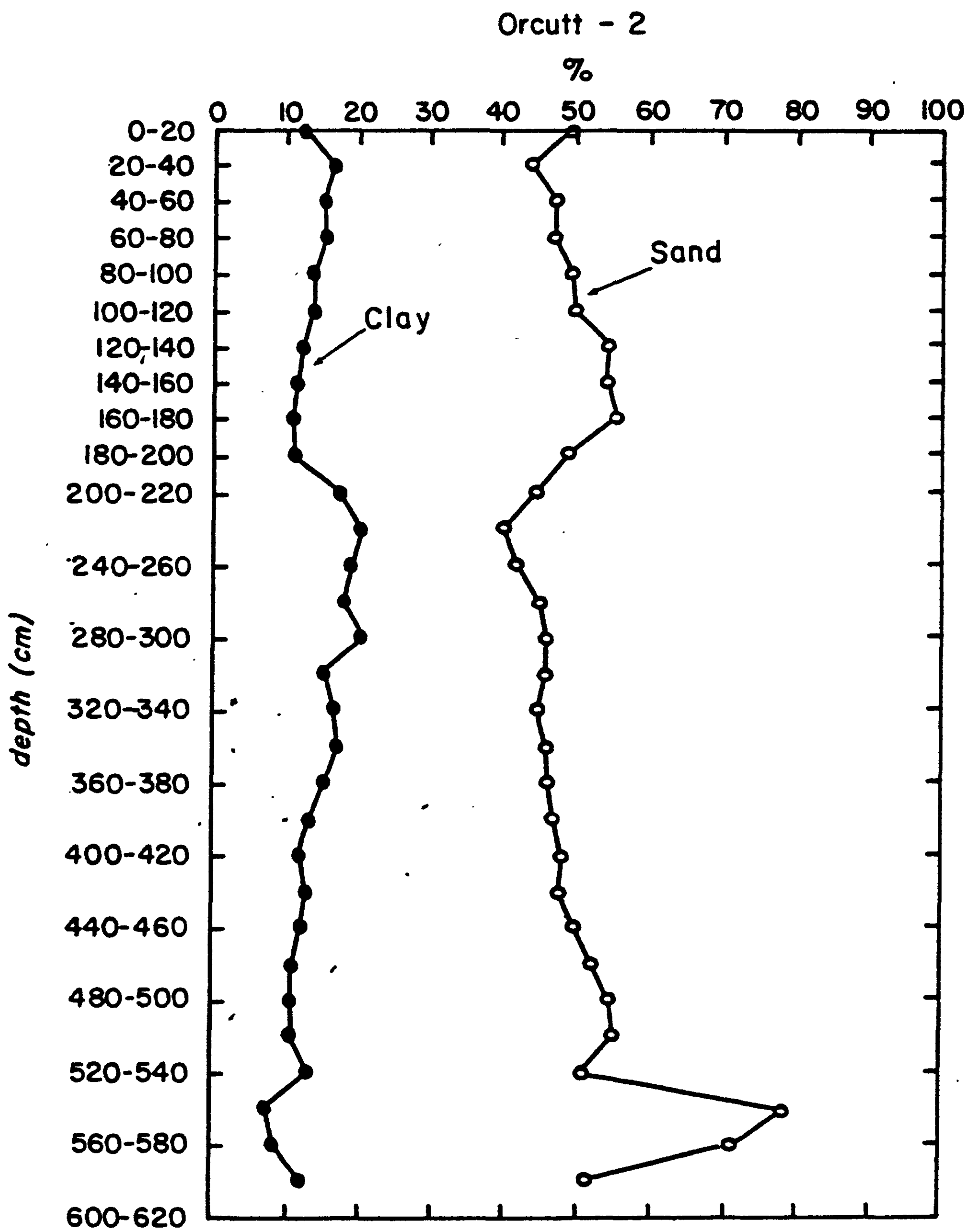

Fig. 27. Orcutt-2 (Qf_2): Clay and sand content.

Classification: Typic Palexeralf
Identifier: Orcutt 3
Location: Lower Orcutt Canyon, south slopes of Topa-Topa Mountains, near Santa Paula, Ventura County, California
Geographic Coordinates: 34° 23' 12" N, 119° 02' 25" W
Geomorphic Surface: Qf_6
Landform: Earlier than late Pleistocene stream terrace, greatly dissected
Slope: 6-10° (10-18%)
Elevation: Approximately 1040 feet (317 m)
Parent Material: Stream gravels (fines, pebbles, cobbles, boulders)
Vegatation: Oak-grass woodland bounded by chaparral
Collected by: D. L. Johnson and T. K. Rockwell
Described by: D. L. Johnson and T. K. Rockwell
Exposure: Natural-steep face formed by recent landslide

Horizon	Depth (cm)	Description
A_{11}	0- 20	Dark brown (10YR 3.5/3m; 5/3d) gravelly loam; weak to moderate medium subangular blocky; soft; many very fine to fine pores, continuous random tubular (simple); many very fine roots in pores and along ped interfaces; clear smooth boundary to:
A_{12}	20- 40	Dark brown (10YR 4/3m; 6/4d) very gravelly sandy clay loam; very weak medium coarse subangular blocky; soft; many very fine to coarse pores, continuous random tubular (simple); common fine to medium roots in pores and along ped interfaces; abrupt clear boundary to:
B_{21t}	40-130	Dark yellowish brown (10YR 4/4m; 5/4d) to dark brown 7.5YR 4/4m; 5/4d) very gravelly sandy clay loam; strong medium subangular blocky; hard; many to continuous thick clay skins along ped interfaces, within peds, and in pores; many very fine pores, continuous random tubular (simple); common very fine roots; diffuse irregular boundary to:
B_{22t}-A_2	130-380+?	Dark yellowish brown (10YR 4/4m; 5.5/4d) very gravelly clay loam to sandy clay loam; massive; hard; common moderately thick to thick clay films; few very fine pores in finer matrix material; few very fine roots in pores and along boulder-cobble-matrix interfaces. Common A_2 horizon material is present (5/4m; 6/4d) as eluvial tongues of yellowish brown (10YR 5/4m) very gravelly loamy fine sand; massive; very soft; many very fine to medium pores, random vesicular and tubular; many very fine to fine roots along pores.
	<u>Comment</u>:	These soils, developed in old dissected Pleistocene stream-fanglomerates, are very deep and well developed and are marked by eluvial tongues of A_2 horizon material that extend well into the B horizon. These eluvial tongues appear to be entirely within the B horizon and not vertically connected with an A_2.

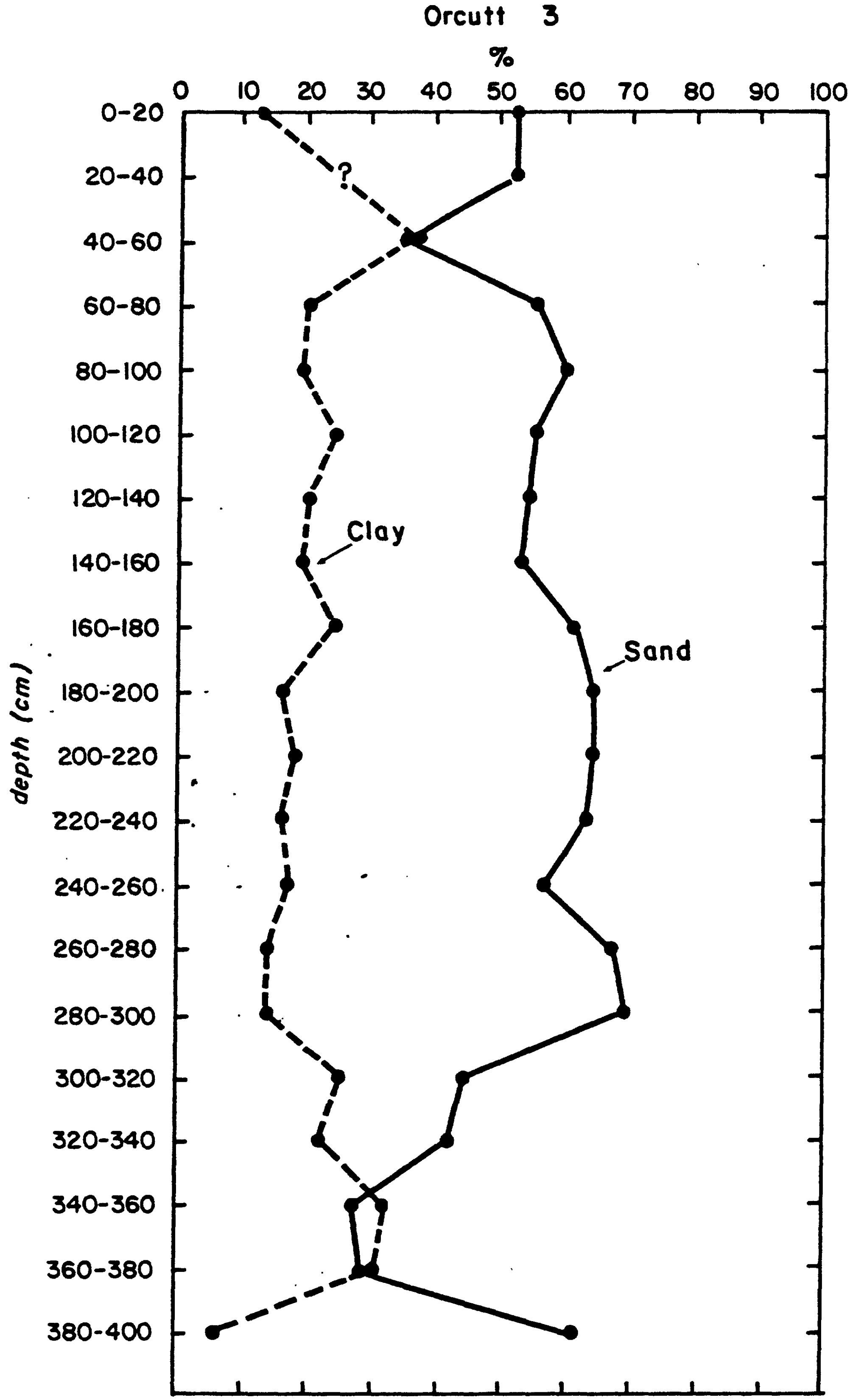

Fig. 28. Orcutt-3 (Qf_6): Clay and sand content.

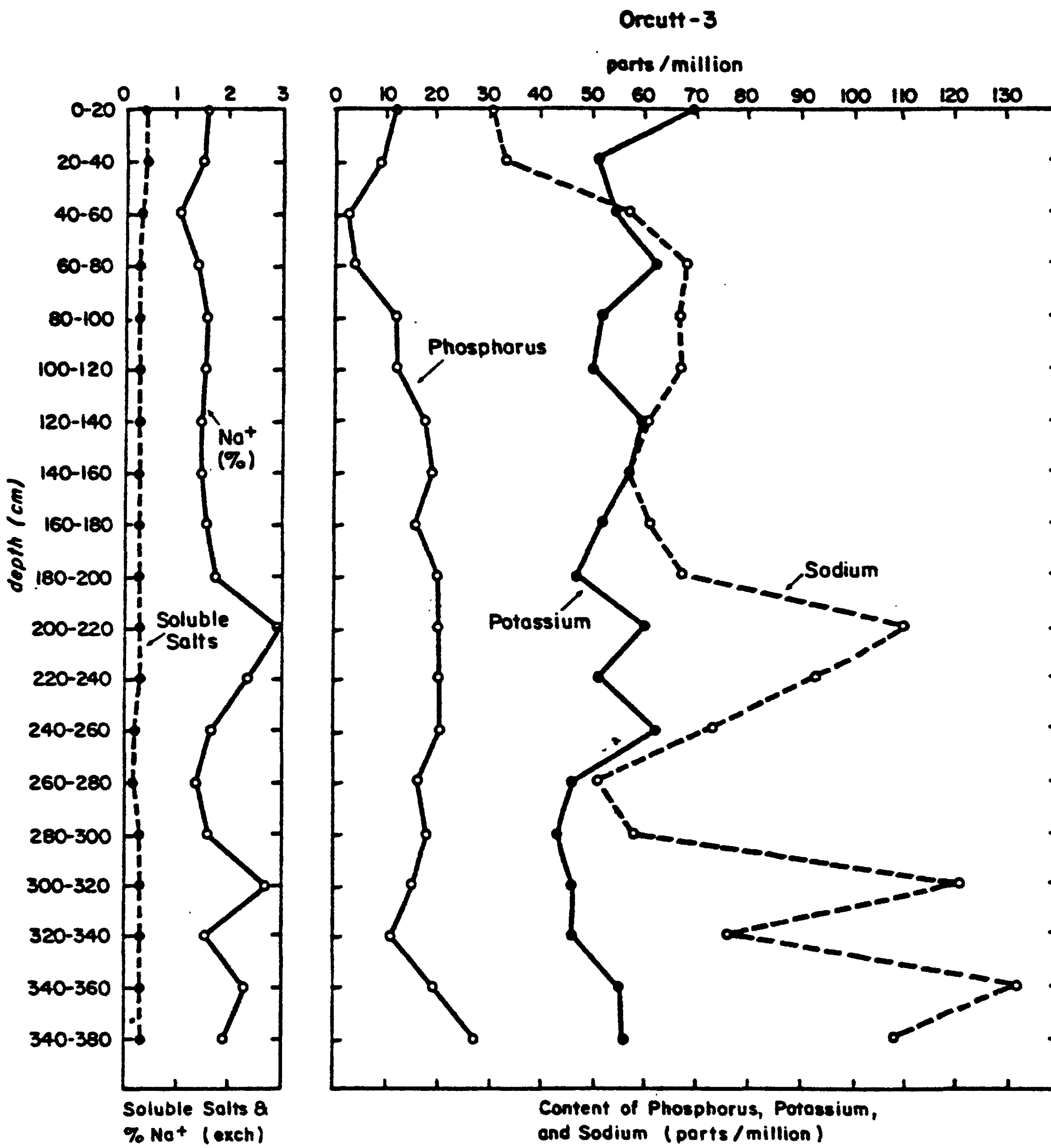

Fig. 29. Orcutt-3 (Qf_6): Soluble salts, Na^+, phosphorus, potassium and sodium content.

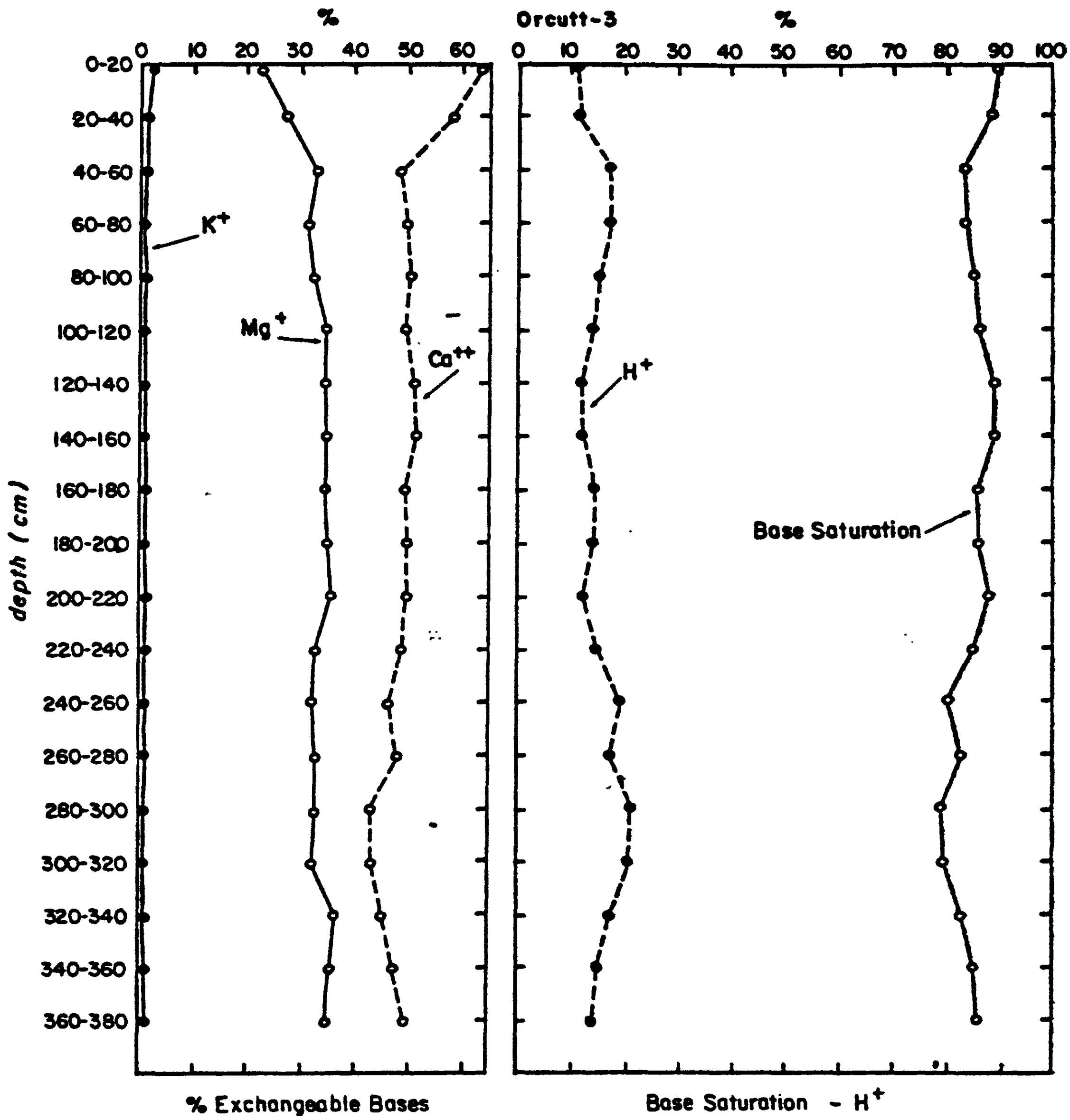

Fig. 30. Orcutt-3 (Qf_6): Base saturation, H^+, Ca^{++}, Mg^+ and K^+ content.

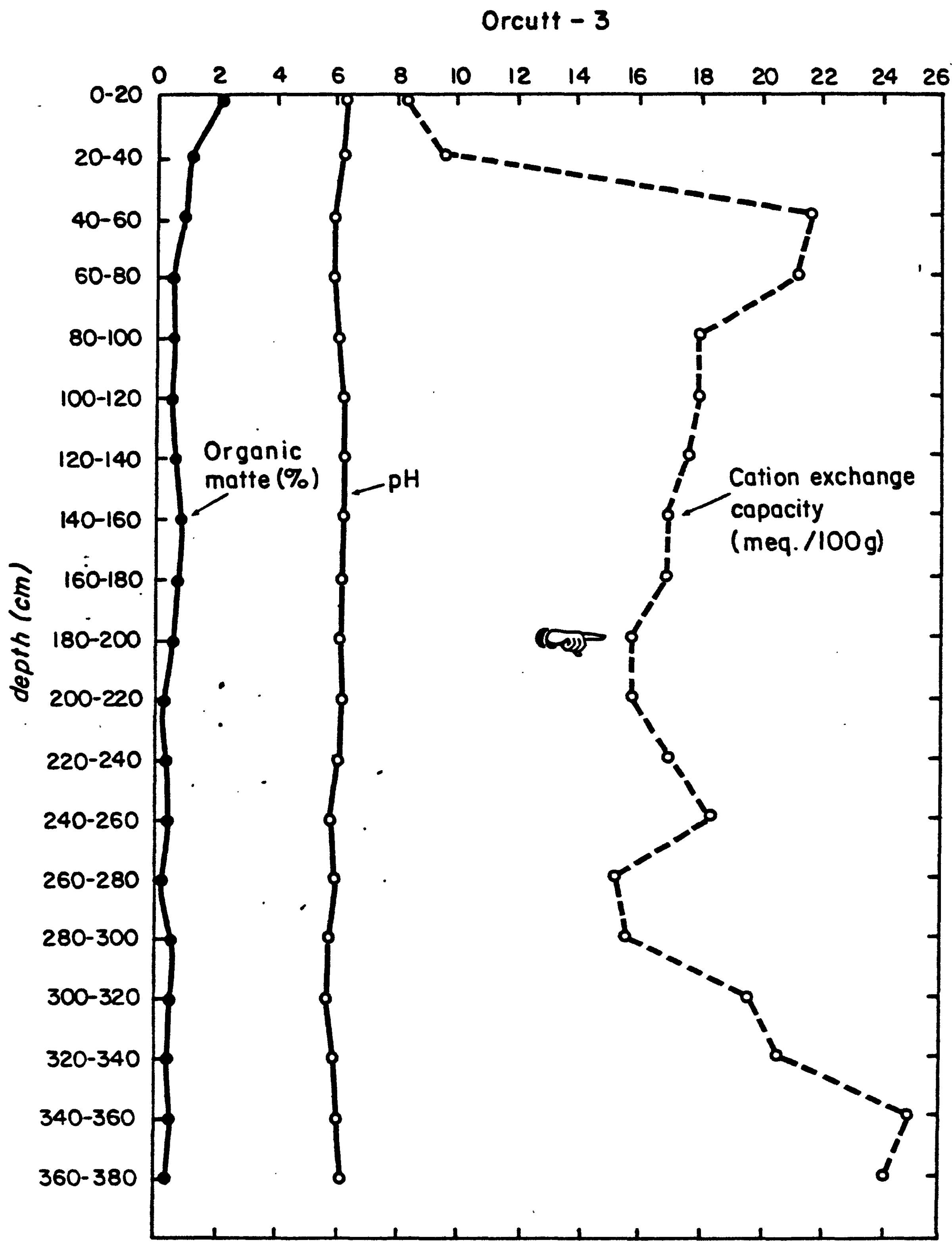

Fig. 31. Orcutt-3 (Qf_6): Cation exchange capacity, pH and organic matter content.

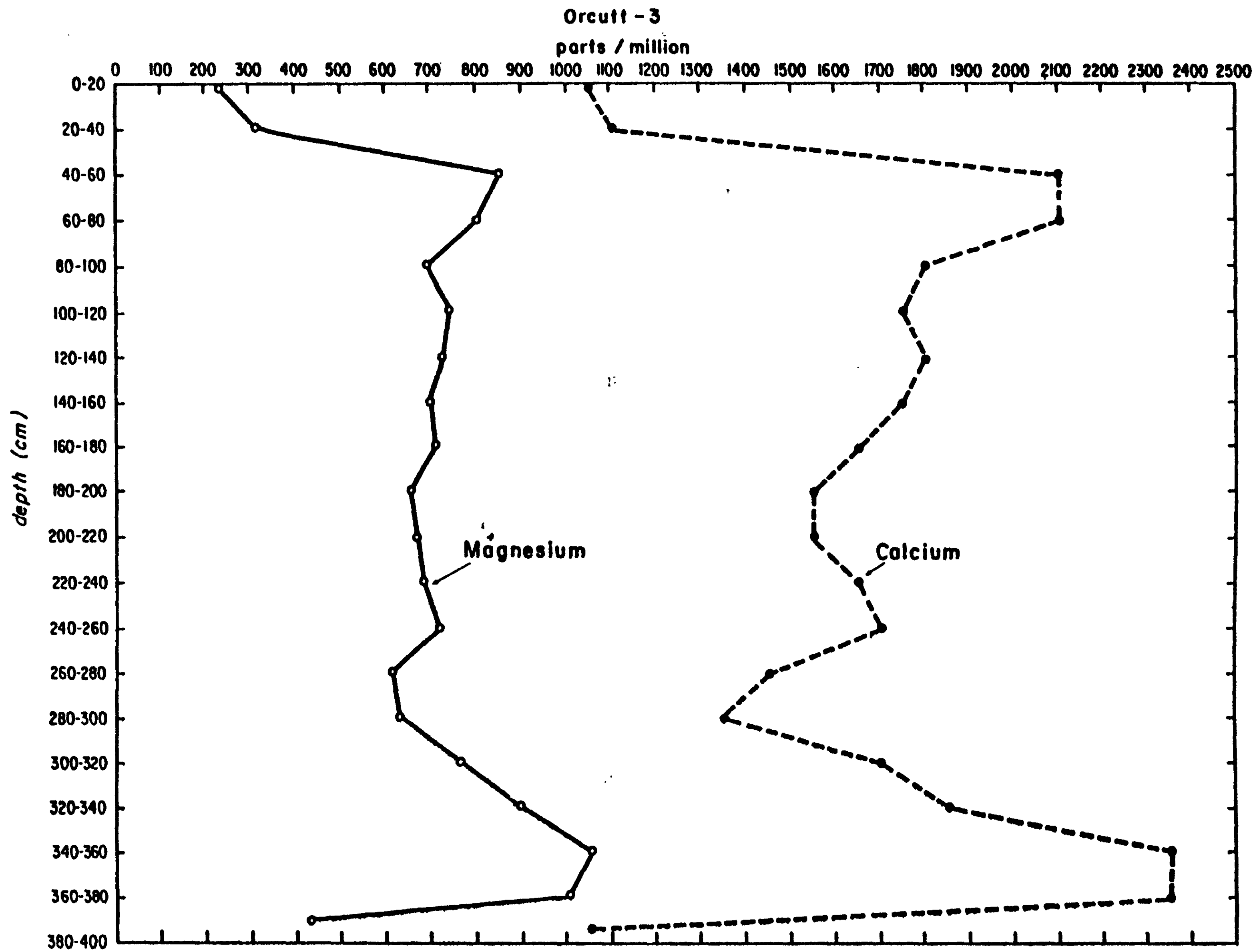

Fig. 32. Orcutt-3 (Qf_6): Magnesium and calcium content.

Classification: Mollic Palexeralf
Identifier: Apricot 1
Location: Oakview, Ventura County, California
Geographic Coordinates: 34° 23' 44" N, 119° 17' 47" W
Geomorphic Surface: Qt_6
Landform: Tectonically tilted late Pleistocene terrace (Oakview) of the Ventura River
Parent Material: River alluvium; fine textured to 40 cm depth, fine textured with pebbles, cobbles and boulders to 1 m depth; pebbles, cobbles and boulders for 100 to 400+ cm
Slope: 1-2° (2-3%)
Elevation: Approximately 540 feet (165 m)
Vegetation: Oak-grass woodland and scrub
Collected by: D. L. Johnson and D. N. Johnson, July 13, 1979
Described by: D. L. Johnson and D. N. Johnson, July 13, 1979
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_1	0- 60	Dark brown (10YR 3/3m; 5/4d) sandy loam, massive; slightly hard to hard; few fine to medium pores, continuous random tubular; common very fine to coarse roots; many fecal pellets; clear wavy boundary to:
A_2	60- 98	Dark brown (7.5YR 4/4m; 6.5/6d) gravelly sandy loam; massive; soft, many fine to coarse pores, continuous random tubular; common fine and medium roots; many fecal pellets; clear wavy boundary to:
B_{21t}	98-200	Strong brown (7.5 YR 5/6m; 6/6d) very gravelly sandy loam; massive; slightly hard; common to many moderately thick clay films, as bridges between grains and as envelopes around pebbles and other clasts (some areas have more clay accumulations than others); few fine to coarse pores in interstitial material; gradual irregular boundary to:
B_{22t}	200-318	Strong brown (7.5 YR 5/6m; 6/6d) very gravelly sandy loam; massive; soft; few to common moderately thick films as bridges between grains and as envelopes around stones; few fine pores in interstitial material; gradual irregular boundary to:
C_1	318-400+	Strong brown (7.5YR 5/6m; 6/6d) to dark yellowish brown (10YR 4/4m; 5/4d) very gravelly sandy loam; single grain; generally loose; few thin clay films that occur few fine pores in interstitial positions.
	<u>Comment:</u>	MnO_2 coatings appear at 120 cm depth and are common from 180 to 270 cm depth.

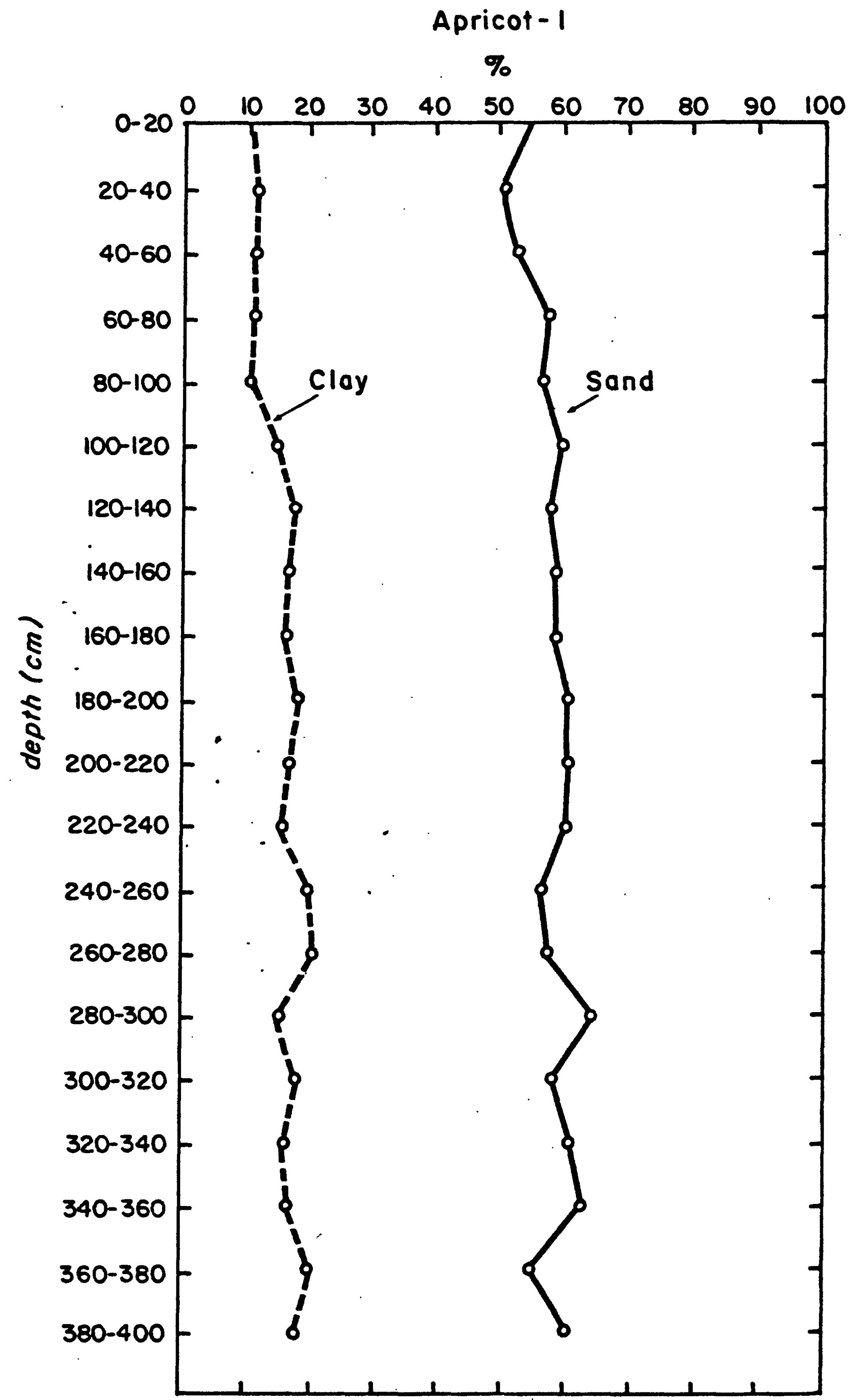

Fig. 33. Apricot-1 (Qt_6): Clay and sand content.

Classification: Mollic Haploxeralf above a Typic Palexeralf
Identifier: Oliva 1
Location: Oliva Ranch, Oakview, Ventura County, California
Geographic Coordinates: 34° 23' 08" N, 119° 18' 12" W
Geomorphic Surface: Qt_6
Landform: Late Pleistocene terrace of the Ventura River
Parent Material: Fine-textured slopewash infill over coarse-textured (cobbles-boulders) river alluvium
Slope: 1-2° (2-3%)
Elevation: Approximately 540 feet (165 m)
Vegetation: Oak-grass woodland bordered by chaparral
Collected by: D. L. Johnson and D. N. Johnson, July 13, 1979
Described by: D. L. Johnson and D. N. Johnson, July 13, 1979
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_{11}	0- 23	Dark brown (10YR 3/3m; 5/4d) loam; massive; soft to slightly hard; many very fine to fine pores, discontinuous-continuous random tubular; common very fine to fine roots in pores; many fecal pellets; clear smooth boundary to:
A_{12}	23- 70	Dark yellowish brown (10YR 3/4m; 7.5YR 5/4d) silt loam; massive; soft to slightly hard, and slightly brittle; many fine to coarse pores, continuous random tubular; common very fine to fine roots concentrated in pores, many fecal pellets; clear irregular boundary to:
B_1	70- 80	Dark brown (7.5YR 3/4m: 5/4d) loam; weak coarse subangular blocky; hard; silans common as horizontal and concentric bands; common fine pores within peds, discontinuous-continuous random, vesicular-tubular; common very fine roots within peds; clear smooth boundary to:
B_{21tx}	80-120	Dark brown (7.5YR 3/4m; 5/4d) slightly gravelly loam; moderate medium to coarse subangular blocky to moderate medium prismatic; soft to slightly hard, and slightly brittle; common moderately thick clay films along ped interfaces and within pores; few silans along ped horizon; common very fine to medium pores, continuous random vesicular-tubular; few roots in pores and along ped interfaces; clear smooth boundary to:
B_{22tx}	120-150	Dark brown (7.5YR 3/4m; 5/4d) slightly gravelly loam; moderate medium to coarse subangular blocky to moderate medium prismatic; soft to slightly hard, and brittle; common thin clay films along ped interfaces, and within peds; common very fine to fine pores within peds and silan islands, continuous random tubular; few fine roots along vertical ped interfaces and within silan islands; abrupt smooth boundary to:

IIA_{bx}	150-163	Dark brown (7.5YR 3/4m; 5/4d) slightly gravelly loam; moderate medium prismatic, massive in places; slightly hard, and brittle; common thin to moderately thick clay films within peds along pores and at ped interfaces; common to many silans along ped interfaces; many fine to medium pores within peds and concentrated where structure is massive, continuous random tubular; few very fine to fine roots along ped interfaces, in pores, and in silans; abrupt smooth boundary to:
IIB_{21tb}	163-275	Dark brown (7.5YR 4/4m; 6/4d) very gravelly loam; strong very coarse prismatic; friable, and slightly brittle; continuous moderately thick to thick clay films along ped interfaces, around stones, and in pores within peds; common fine to medium pores within peds, continuous random tubular; few to common very fine roots along ped interfaces; clear to gradual smooth boundary to:
$IIIB_{22tb}$	275-340	Yellowish brown (7.5YR 4/4m; 6/4d) very gravelly sandy loam; structureless, massive to single grain; loose; many moderately thick to thick clay films in pockets, as bridges between grains, and as envelopes around grains and stones; many fine to medium pores, continuous random tubular in soil matrix between large clasts; few fine roots between clasts; clear smooth boundary to:
$IIIC_1$	340-420+?	Yellowish brown (7.5YR 3/4m; 6/4d) very gravelly sandy loam; structureless, massive to single grain; generally loose; common thin clay films as bridges between grains, in pores, and as envelopes around stones; few fine pores, continuous random tubular; few fine roots in soil matrix between stones.
	Comment:	Fine textures to 80 cm depth, with occasional pebbles and cobbles to 170 cm depth; common pebbles, cobbles and boulders to 270 cm depth; very many pebbles and cobbles to 380 cm; very many cobbles and boulders from 380 cm to 420+. In another nearby pedon at deep road cut (1/3 mile S of Portal Road-Highway 33 intersection on west side of Highway 33), the base of this weathering profile is seen to extend 8.5 m deep to a contact of river gravels and Monterey Formation shale, marked by a 2-10 cm thick weathering zone that appears reduced and gleyed. Clay skins up to 2 cm thick occur along preferred vertical soil water channelways at and above the contact.

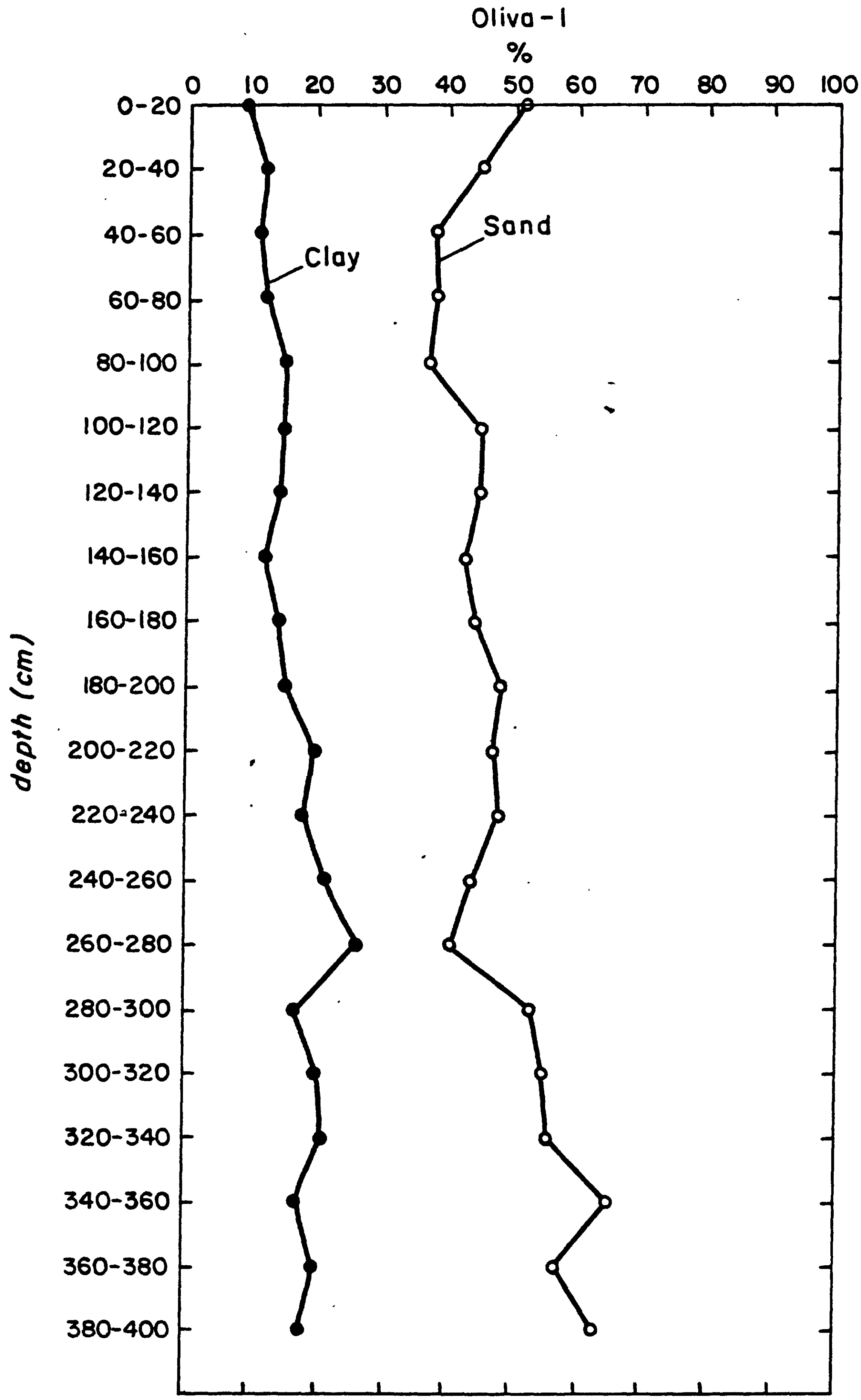

Fig. 34. Oliva-1 (Qt_6): Clay and sand content.

Classification: Typic Argixeroll
Identifier: Nye 1
Location: Nye Ranch, Santa Ana Road, Oakview, Ventura County, California
Geographic Coordinates: 34° 22' 49" N, 119° 18' 35" W
Geomorphic Surface: Qt_6
Landform: Late Pleistocene terrace of Ventura River
Slope: 2-3° (3-5%)
Elevation: Approximately 540 feet (165 m)
Parent Material: Principally coarse textured (pebbles, cobbles, boulders) river gravels
Vegetation: Chaparral-scrub oak
Collected by: D. L. Johnson and D. N. Johnson, July 14, 1979
Described by: D. L. Johnson and D. N. Johnson, July 14, 1979
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_1	0- 30	Very dark grayish brown (10YR 3/2m; 5/3d) gravelly loam; moderate medium to coarse crumb; very friable; many very fine to fine roots, few medium to coarse roots; clear smooth boundary to:
B_1	30- 48	Very dark grayish brown (10YR 3/2m; 5/3d) very gravelly loam; weak medium subangular blocky; very friable; common thin clay films as bridges between grains, and as envelopes around stones; common very fine pores in interstitial material between large clasts; few fine roots; gradual irregular boundary to:
B_{21t}	48- 55	Dark yellowish brown (10YR 4/4m; 4/4d) very gravelly sandy clay loam; moderate medium to coarse prismatic; friable to firm; many thin clay films as bridges between grains, and as envelopes around stones; common very fine pores in interstitial material between large clasts; few very fine roots in interstitial material; abrupt smooth boundary to:
B_{22t}	55-320+	Dark yellowish brown (10YR 4/4m; 4/4d) to strong brown (7.5YR 4/6m; 5/4d) very gravelly sandy clay loam; massive; friable; many to continuous moderately thick to thick clay films as bridges between grains, and as envelopes around stones and grains; common fine pores, continuous random tubular; few very fine to fine roots along stone-matrix interfaces and in stone cracks.
	<u>Comment</u>:	A thin A_2 horizon is discontinuously present in this polypedon, as one was present in an adjacent pedon that was not described. Also, the probable downslope additions of calcium carbonate bearing slopewash sediments (from Monterey Formation rocks) has locally tended to somewhat retard pedogenesis of the soils in this polypedon (see text for explanation).

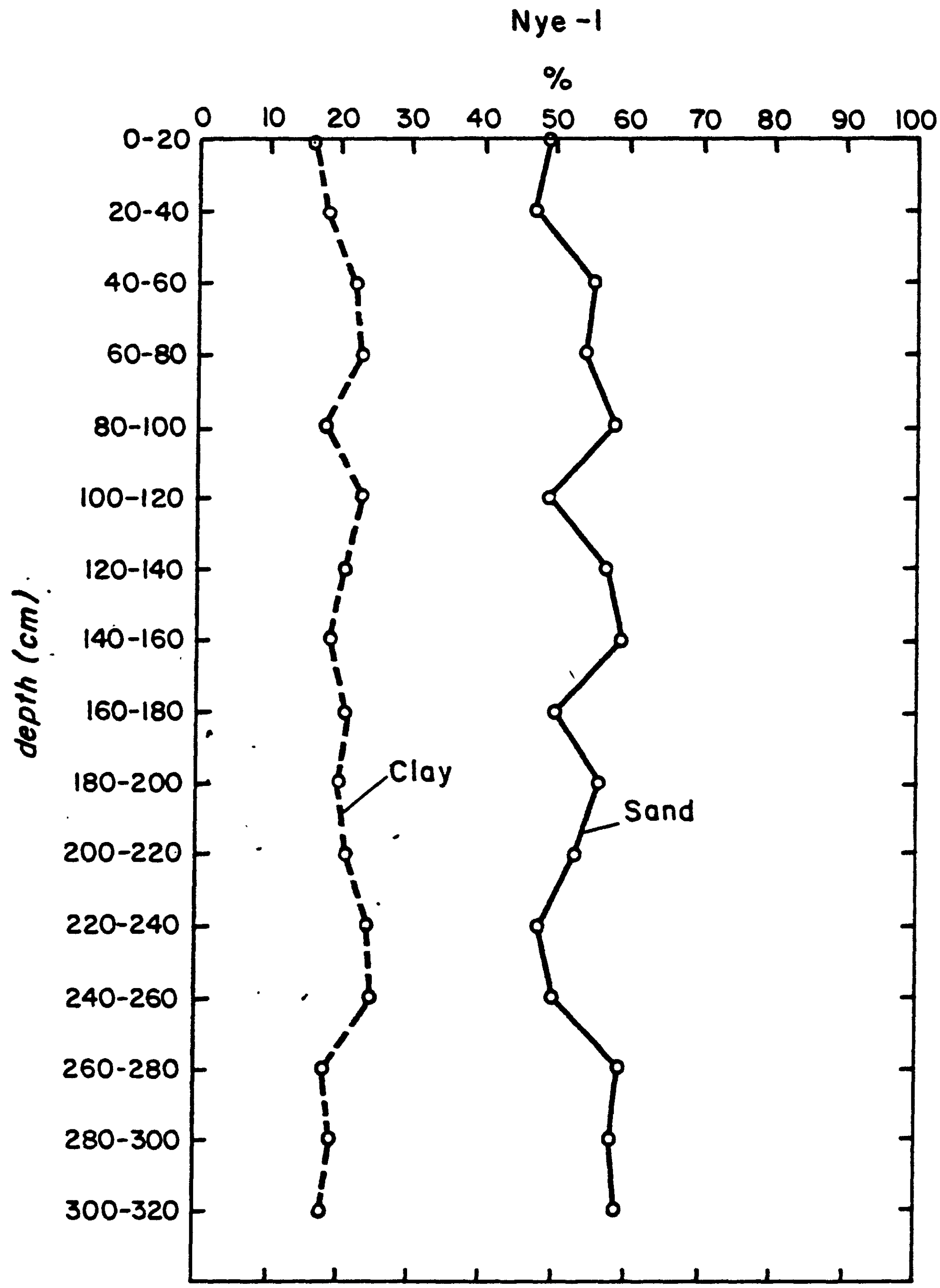

Fig. 35. Nye-1 (Qt_6): Clay and sand content.

SOIL DESCRIPTION

Classification: Typic Argixeroll
Identifier: Taylor Ranch 2
Location: Promontory overlooking Interstate Highway 101, west side of the mouth of the Ventura River
Geographic Coordinates: 34° 17' 02" N, 119° 18' 51" W
Geomorphic Surface: Qt_6
Landform: Oakview terrace of the Ventura River
Parent Material: Ventura River alluvium (pebbles, cobbles, boulders)
Slope: 1-2° (2-3%)
Elevation: Approximately 125 feet (38 m)
Vegetation: Bean crop
Collected by: D. L. Johnson, T. Rockwell, and M. N. Clark
Described by: D. L. Johnson, T. Rockwell, and M. N. Clark
Exposure: Backhoe trench

Horizon	Depth (cm)	Description
Ap	0- 14	Very dark brown (10YR 2/2m; 4/2d) slightly gravelly loam; structureless to weak medium subangular blocky; soft; many fine to medium roots; abrupt clear boundary to:
A_{12}	14- 48	Very dark brown (10YR 2/2m; 4/2d) very gravelly sandy loam; moderate, coarse subangular blocky; soft to slightly hard; many fine to medium pores, continuous, random, tubular (simple); many fine to medium roots in pores; clear smooth boundary to:
A_2	48- 71	Dark brown (10YR 3/3m; 5/4d) very gravelly sandy loam; massive; extremely hard; many fine pores, continuous, random, tubular (simple); few to common fine roots in pores; abrupt smooth boundary to:
B_{21t}	71-111	Dark brown (10YR 3/3m; 4.5/3d) very gravelly sandy loam; moderate very coarse prismatic; extremely hard; slightly to strongly reactive; few thin clay films; many fine pores, continuous, random, tubular (simple); few fine roots along pores, smooth clear boundary to:
B_{22t}	111-220	Dark brown (10YR 3/3.5m; 4/3d) to brown (10YR 4/3m; 4.5/3d) very gravelly sandy clay loam; moderate, medium to coarse, prismatic; hard; slightly to strongly reactive; many moderately thick to thick clay films on peds; many fine to very fine pores, continuous, random, tubular (simple); few very fine roots in pores; clear, irregular boundary to:

IIB_{23t}	220-315	Dispersed argillic horizon, where colors range from dark brown (7.5YR 3.5/4m; 4/4d) to dark yellowish brown (10YR 3/4m; 4/4d) loamy sand to sand clay loam; single grain; soft to loose (clay-rich bands are hard); intermittently slightly to strongly reactive; in clay-rich bands clay occurs as continuous bridges thin to moderately thick; many fine to medium interstitial pores; few to common very fine roots; abrupt wavy boundary to:
$IIIB_{24t}$	315-400+?	Dark yellowish brown (10YR 3/4m; 4/3d) very gravelly sandy loam; massive; slightly hard; intermittently slightly to strongly reactive; intermittent common to many moderately thick manganese films at top of horizon (with increasing depth there is evidence of increasing reducing conditions); many to continuous moderately thick to thick clay films; many medium interstitial pores; common very fine roots.
	<u>Comment</u>:	The Oakview Terrace here at the mouth of the Ventura River was, for many years, the site of a stock (cattle) feeding operation, What effect the abundant cattle feces may have had in modifying the soil through leaching can only be guessed at. Surely some effect was felt and is imprinted in the soil.

SOIL DESCRIPTION

Classification: Typic Palexeralf
Identifier: La Vista 1
Location: La Vista Ranch, Ojai, Ventura County, California
Geographic Coordinates: 34° 25' 12" N, 119° 16' 44" W
Geomorphic Surface: Qt_6
Landform: Tectonically segmented late Pleistocene terrace (Oakview) of the Ventura River
Parent Materia; River alluvium comprised principally of pebbles, cobbles and boulders
Slope: 2-4° (4-7%)
Elevation: Approximately 1010 feet (308 m)
Vegetation: Oak, grass, chaparral (currently under avocados)
Collected by: D. L. Johnson and M. N. Clark
Described by: D. L. Johnson and M. N. Clark
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_1	0- 90	Dark brown (10YR 3/3m; 5/4d) gravelly sandy loam; structureless massive; hard; common very fine to fine pores; common fine roots along cracks and vertical separations; clear broken boundary to:
A_2	90-104	Dark yellowish brown (10YR 4/4m; 6/4d) very gravelly sandy loam; structureless, massive; slightly hard; common fine to medium pores, random vesicular; common fine roots; abrupt wavy to irregular boundary to:
B_{21t}	104-250	Strong brown (7.5YR 4/6m; 6/6d) very gravelly sandy loam; structureless, massive; slightly hard; many moderately thick to thick clay films, as bridges between grains and as envelopes around stones; few fine roots along cracks and stone-matrix interfaces; few fine roots along and at cobble-matrix interfaces; diffuse broken boundary to:
B_{22t}	250-340+	Dark yellowish brown (10YR 4/6m; 7/4d) very gravelly sandy loam; structureless, massive; slightly hard; many moderately thick to thick clay films as bridges between grains and as envelopes around stones.
	Comment:	The A_2 is a discontinuous horizon; narrow tongues (5-10 cm diameter) of eluvial A_2 horizon material (vesicular) extend at least to a depth of 2 m where exposed. The coarse clasts (cobbles, boulders) are in general highly weathered, with clay films in rock cracks and fractures. Several large whitish sandstone clasts appeared relatively unweathered throughout the profile.

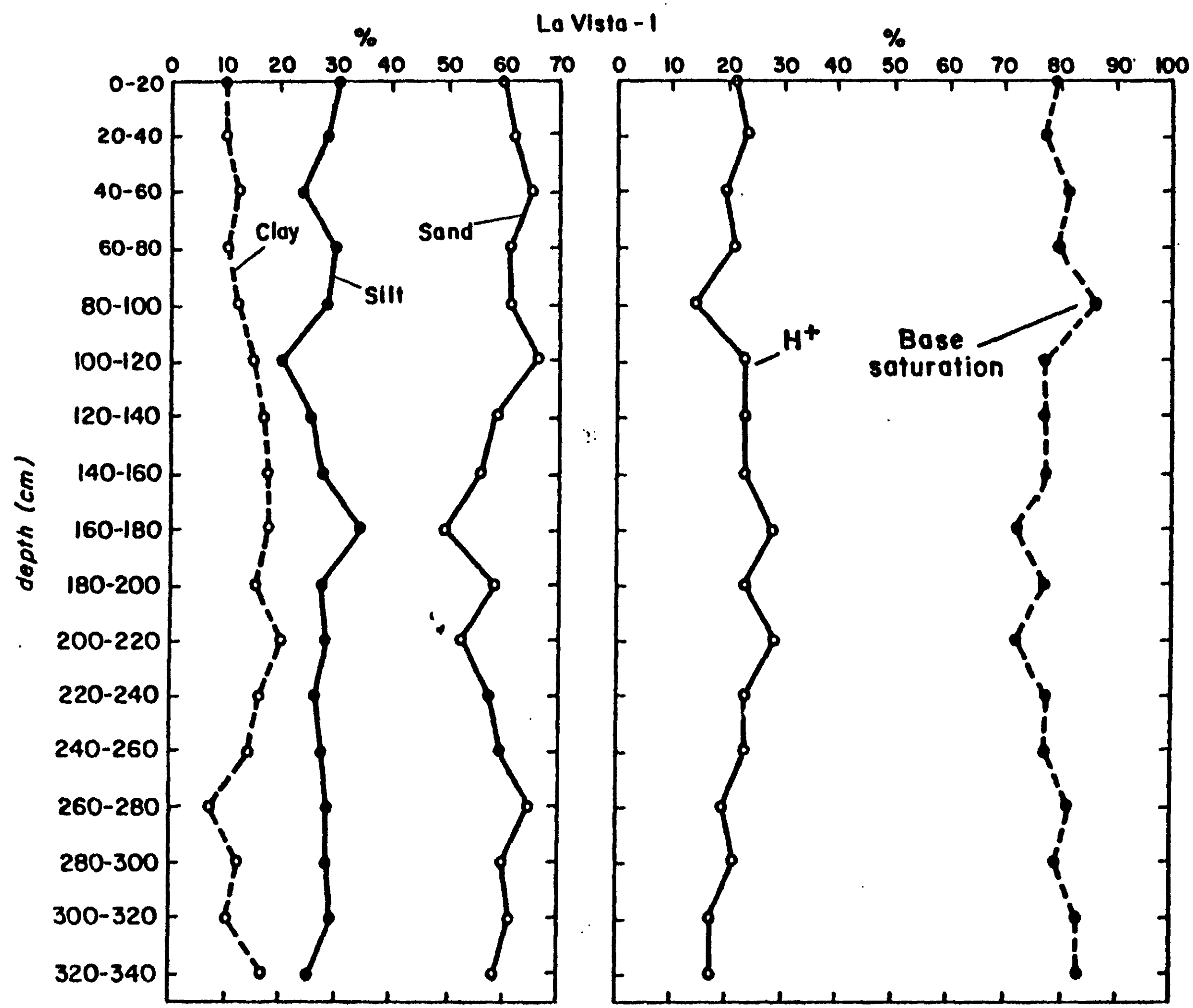

Fig. 36. La Vista-1 (Qt_6): Clay, silt and sand content: H^+ and Base saturation

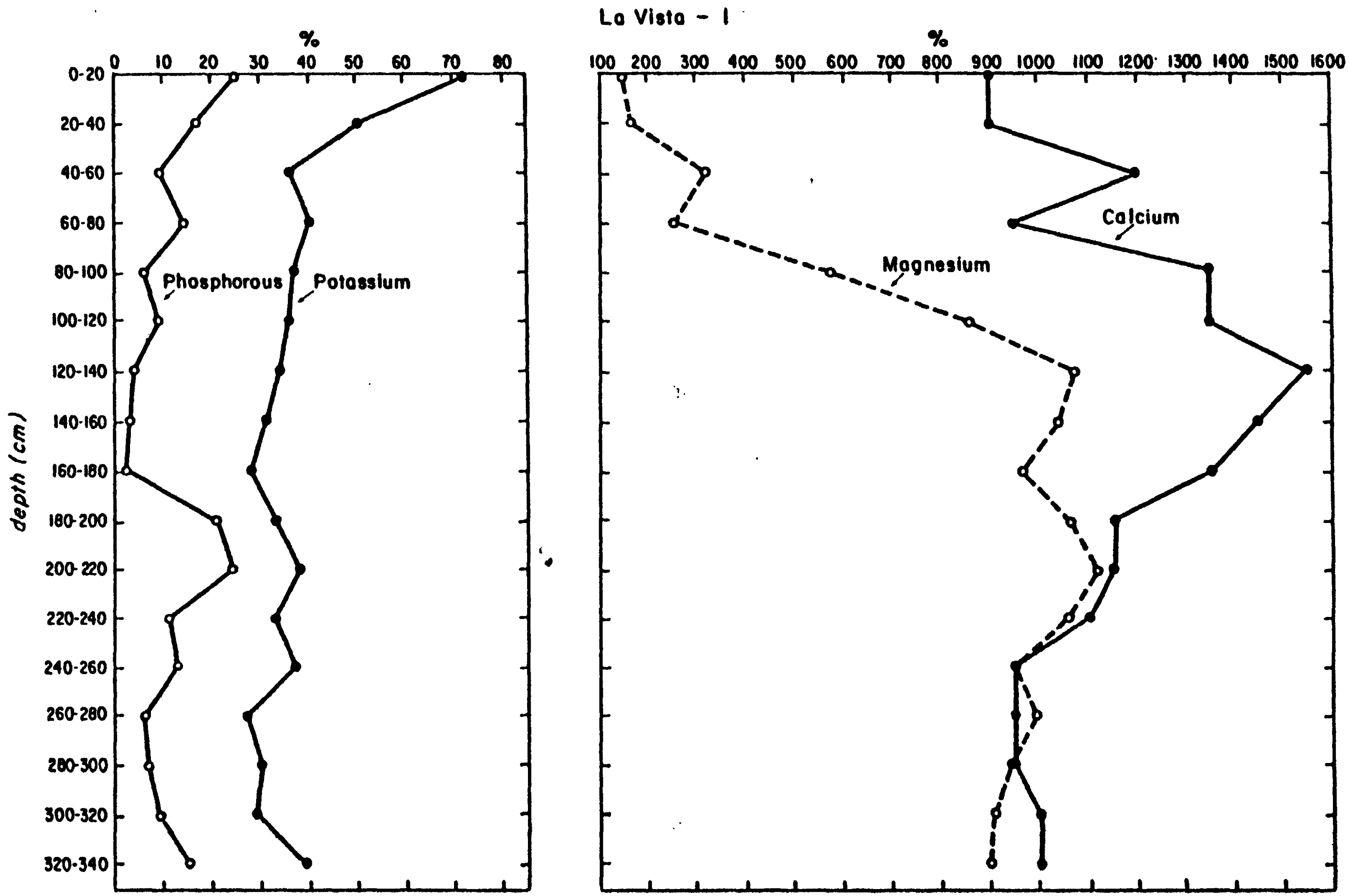

Fig. 37. La Vista-1 (Qt_6): Phosphorus, potassium, magnesium and calcium content.

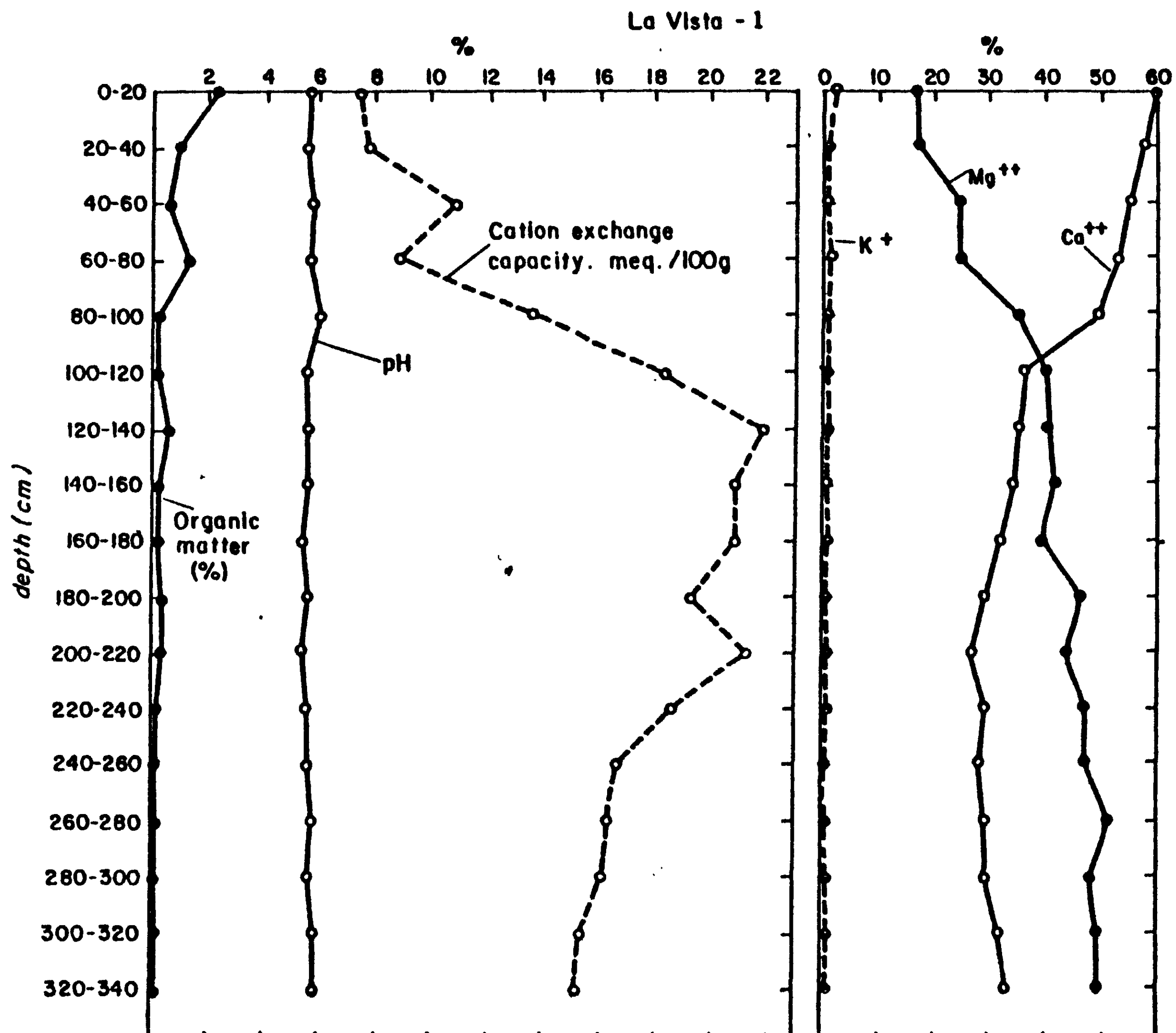

Fig. 38. La Vista-1 (Qt_6): Organic matter, pH, cation exchange capacity, K^+, Mg^{++} and Ca^{++} content.

Classification: Typic Palexeralf
Identifier: La Vista 2
Location: La Vista Ranch, Ojai, Ventura County, California
Geographic Coordinates: 34° 25' 38" N, 119° 16' 42" W
Geomorphic Surface: Qt_6
Landform: Late Pleistocene terrace of the Ventura River
Parent Material: River alluvium (boulders and cobbles)
Slope: 2-4° (4-7%)
Elevation: Approximately 880 feet (268 m)
Vegetation: Oak-grass woodland, chaparral (now in avocados)
Collected by: D. L. Johnson and T. K. Rockwell, July 11, 1979
Described by: D. L. Johnson and T. K. Rockwell, July 11, 1979
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_1	0- 50	Brown to dark brown (7.5YR 4/4m; 6/6d) gravelly loam; massive; slightly hard; many very fine to fine pores, random vesicular; many very fine roots; common medium fecal pellets; clear irregular boundary to:
A_2	50- 63	Brown to dark brown (7.5YR 4/4m; 6/6d) very gravelly sandy loam; strong medium subangular blocky; slightly hard; few thin clay films; many very fine to medium pores, random vesicular; few to common very fine to fine roots along cracks and ped interfaces; clear, irregular boundary to:
B_{21t}	63- 90	Strong brown (7.5YR 5/7m; 7/6d) very gravelly loam or sandy loam; strong medium to coarse prismatic; very hard; continuous moderately thick clay films, with common slickensides; many very fine pores within peds; few very fine roots along ped interfaces and joints and cracks; clear irregular boundary to:
B_{22t}	90-380+	Strong brown (7.5YR 5/6m; 6/6d) sandy clay loam; massive; hard to very hard when dry, plastic when wet; many to continuous moderately thick to thick clay films, with few to common slickensides; few very fine to fine roots along ped and crack interfaces.
	Comment:	Glossic tongues of A_2 material extend deeply into B_{22t}; alluvial cobbles and boulders are well to extremely well weathered and consist principally of sandstone; many clay films evident along joints and cracks within cobbles and boulders; clay films in lower B_{22t} obtain a thickness of up to 2 cm and exhibit slickensides.

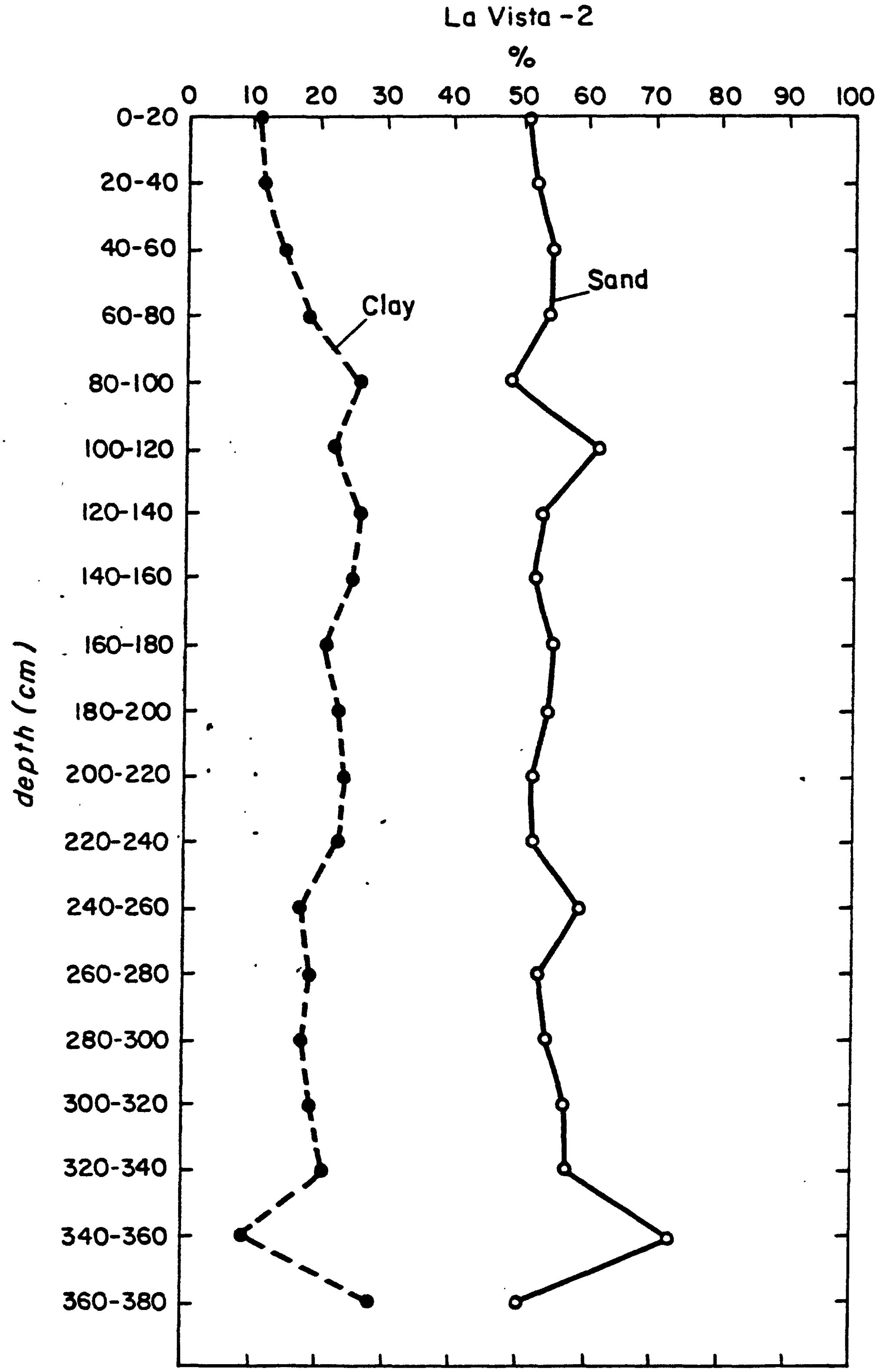

Fig. 39. La Vista-2 (Qt_6): Clay and sand content.

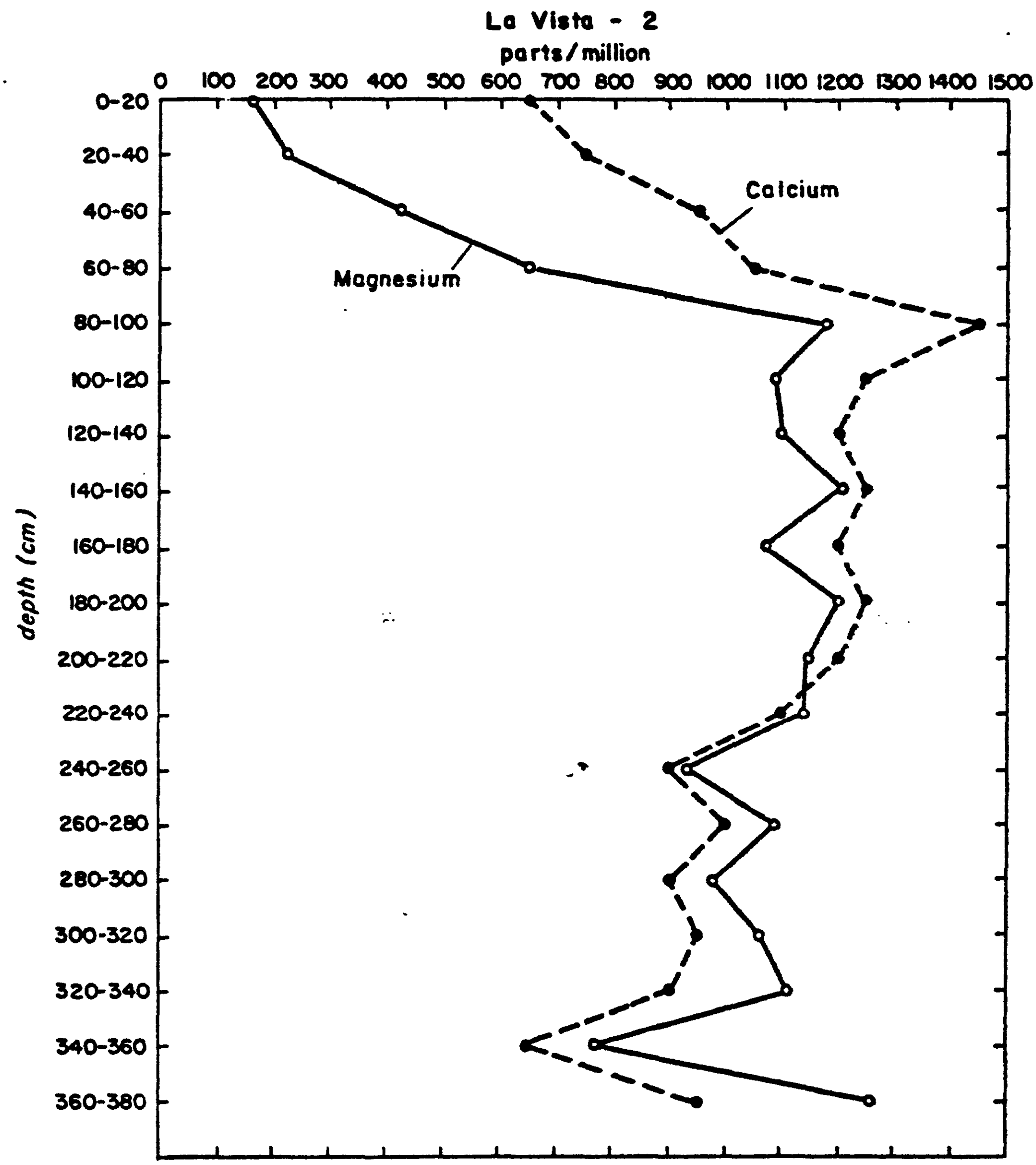

Fig. 40. La Vista-2 (Qt_6): Magnesium and calcium content.

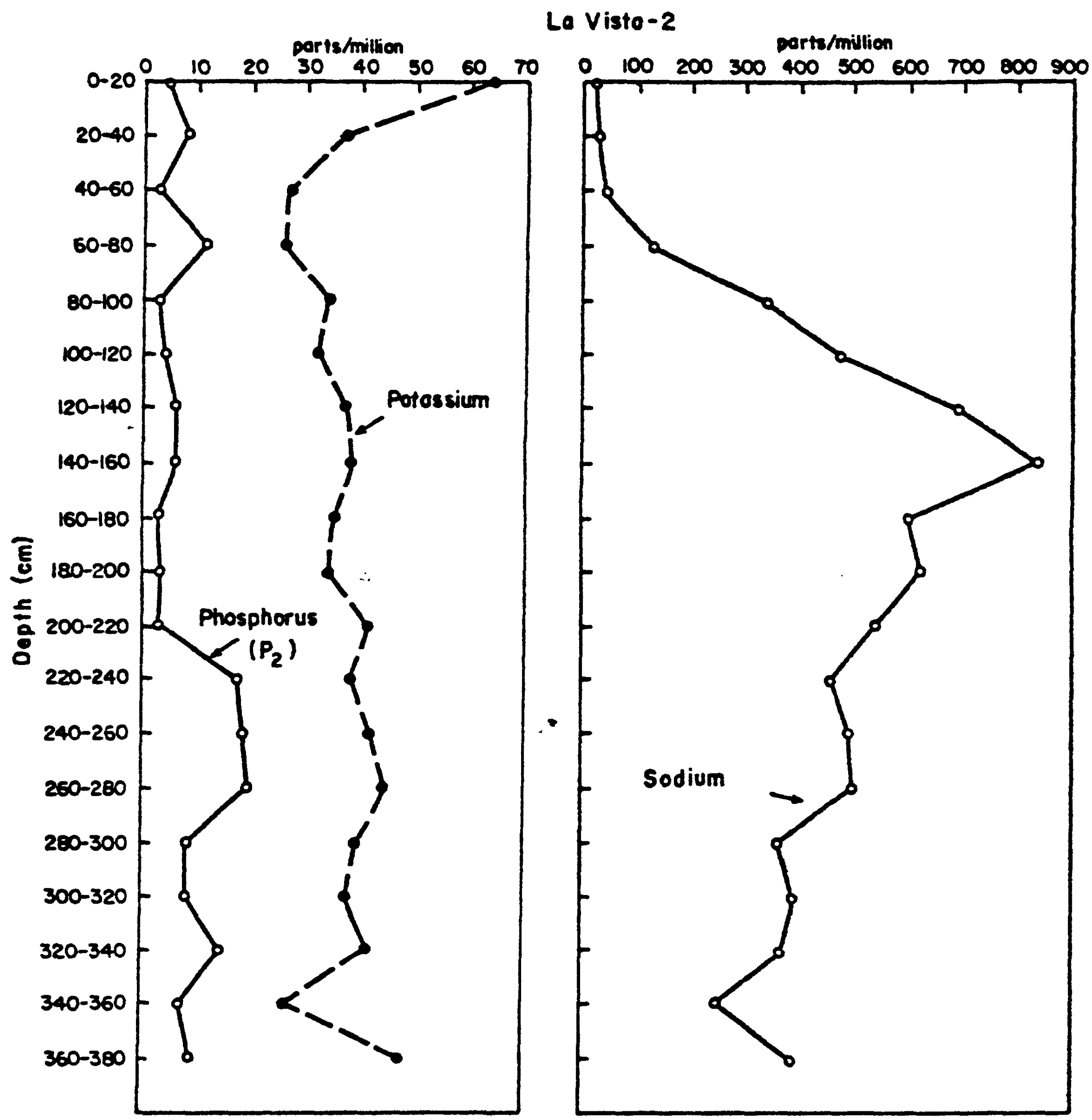

Fig. 41. La Vista-2 (Qt_6): Phosphorus, potassium and sodium content.

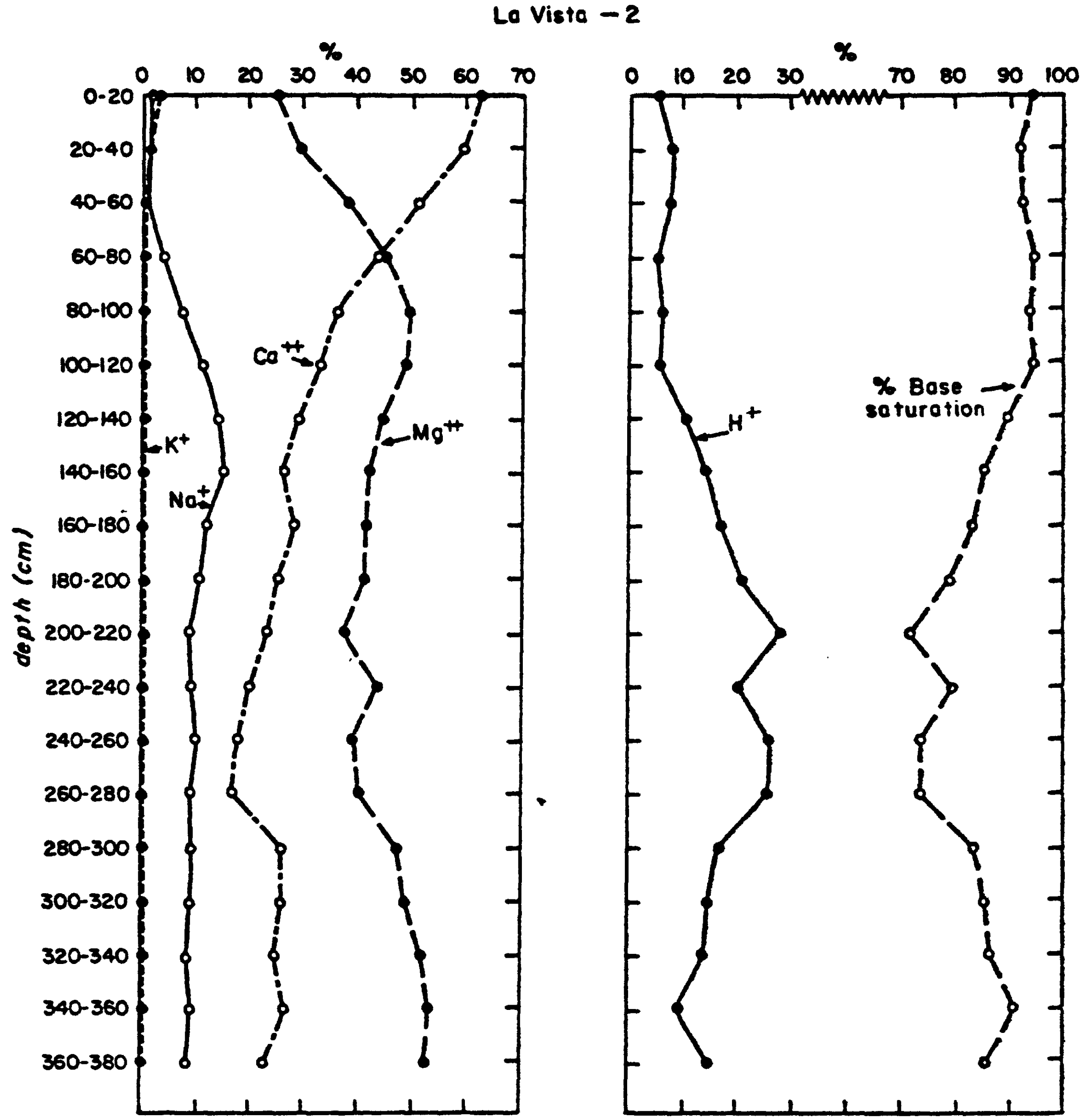

Fig. 42. La Vista-2 (Qt_6): Base saturation, H^+ Mg^{++}, Ca^{++}, Na^+ and K^+ content.

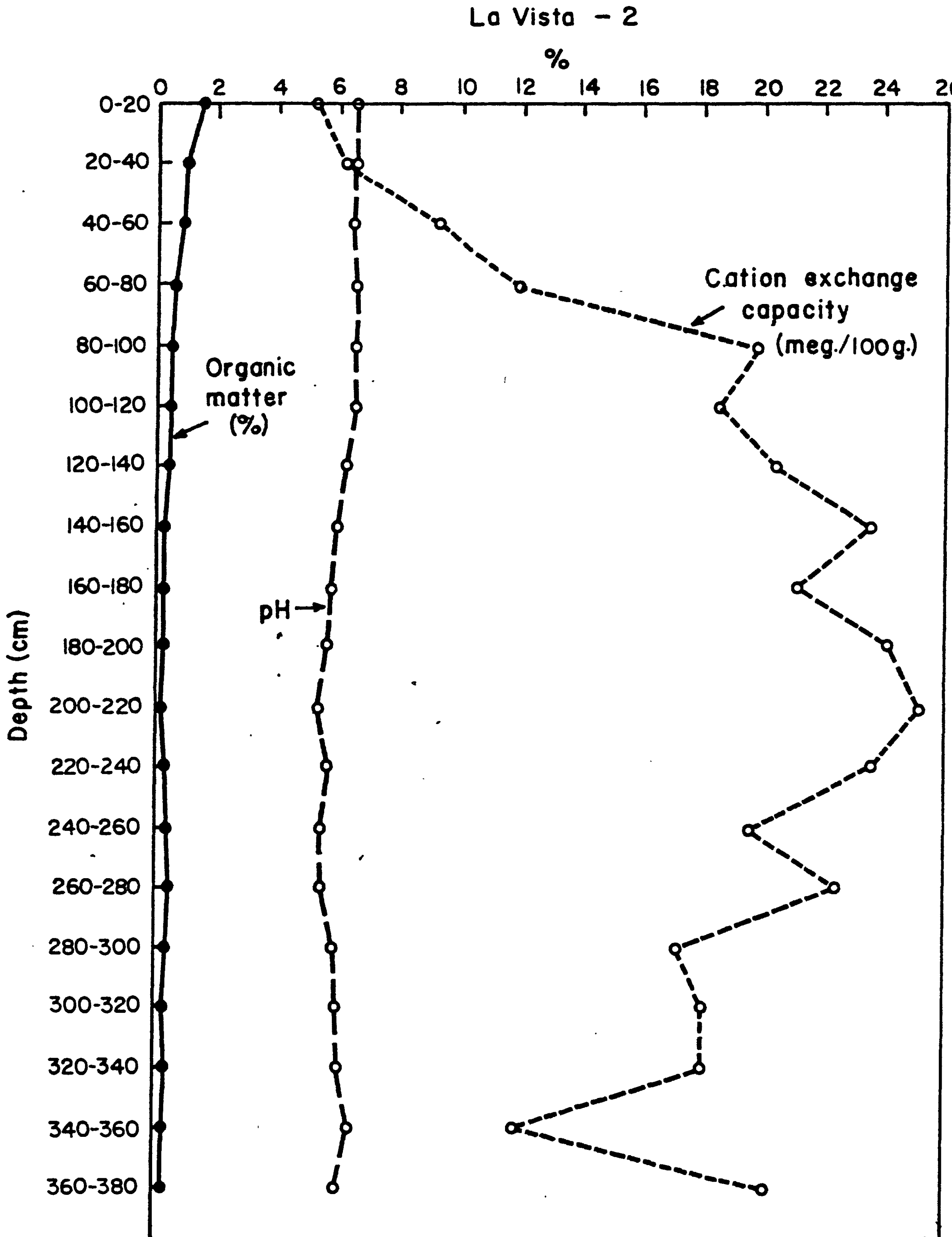

Fig. 43. La Vista-2 (Qt_6): Organic matter, pH, and cation exchange capacity.

Classification: Pachic Argixeroll above a buried Typic Palexeralf
Identifier: La Vista 3
Location: La Vista Ranch, Ojai, Ventura County, California
Geographic Coordinates: 34° 25' 28" N, 119° 16' 10" W
Geomorphic Surface: Qt_6
Landform: Slopewash-colluvial fill overlying a tectonically tilted late Pleistocene terrace (Oakview) of the Ventura River
Parent Material: Slopewash sediments over river alluvium comprised principally of pebbles, cobbles and boulders
Slope: 1-3° (1-5%)
Elevation: Approximately 830 feet (253 m)
Vegetation: Oak, grass
Collected by: D.L. Johnson and M.N. Clark
Described by: D.L. Johnson and M.N. Clark
Exposure: Back-hoe trench

Horizon	Depth (cm)	Description
A_{11}	0-35	Dark brown (10YR 3/3m; 5/4d) sandy loam; weak medium to coarse platy structure; slightly hard; many fine to medium pores, continuous random tubular; many very fine to fine roots in pores and occasionally in matrix material; extremely abundant fecal pellets; clear smooth boundary to:
A_{12}	35-75	Very dark grayish brown (10YR 3/2m; 5/3d) loam; structureless, massive; slightly hard; many fine to medium pores, continuous random tubular; common fine to very fine roots in pores and along cracks; abundant fecal pellets; clear smooth boundary to:
A_2	75-108	Dark brown (10YR 3/3m; 6/3d) sandy loam; weak medium subangular blocky to massive structure; soft (brittle); many silans throughout; many fine medium pores, semi-continuous random tubular, some vesicles; few fine roots along cracks and along pores; clear smooth boundary to:
B_1	108-120	Brown to dark brown (10YR 4/3m; 6/3d) loam; weak coarse prismatic; hard to very hard; few moderately thick clay films along tubular pores; common silans; many fine to medium pores continuous vertical and random tubular (simple) vesicles; few fine roots in vertical pores and along cracks; clear smooth boundary to:
B_{21t}	120-160	Very dark grayish brown (10YR 3/2m; 5/2d) loam; moderate coarse prismatic; hard to very hard; common thin to moderately thick clay films along ped interfaces and in pores; mangans complexed to clay films; many fine to medium pores, continuous vertical random tubular to slightly vesicular; few fine roots in pores and along ped interfaces; clear smooth boundary to:

B_{22t}	160-216	Very dark grayish brown (10YR 3/2m; 5/3d) sandy loam; structureless to weak coarse prismatic; hard to very hard; common moderately thick clay films along ped interfaces; abundant mangans complexed with clay; many fine pores, continuous random vertical tubular (dendritic), with some vesicles; few fine roots along pores, cracks and ped interfaces; gradual smooth boundary to:
$B_3(A_{2b})$	216-258	Dark brown (10YR 3.5/3m; 5/3d) very gravelly sandy loam; massive; hard to very hard; common thin clay films along pores and cracks or joint; common mangans complexed to clay films; many fine pores, continuous vertical random tubular; abrupt clear boundary to:
IIB_{21tb}	258-295	Yellowish brown (10YR 4.5/4m; 5/4d) very gravelly sandy clay loam; moderate to strong, medium to coarse primsatic; firm; common thin to moderately thick clay films along ped interfaces and in pores and within peds; mangans complexed to clay films along pores only; few fine pores, continuous random vertical tubular (simple) clear, wavy boundary to:
IIB_{22tb}	295-385+?	Strong brown (7.5YR 5/7m: 5/7d) very gravelly sandy clay/loam; structureless; friable; continuous moderately thick to thick clay films enveloping grains, pebbles, cobbles and boulders.
	<u>Comments</u>:	The upper 2m or so of this profile consists of pedogenesized fine textured slopewash sediments which overlie a buried soil developed in coarse clast (boulder, cobble, pebble) river gravels.

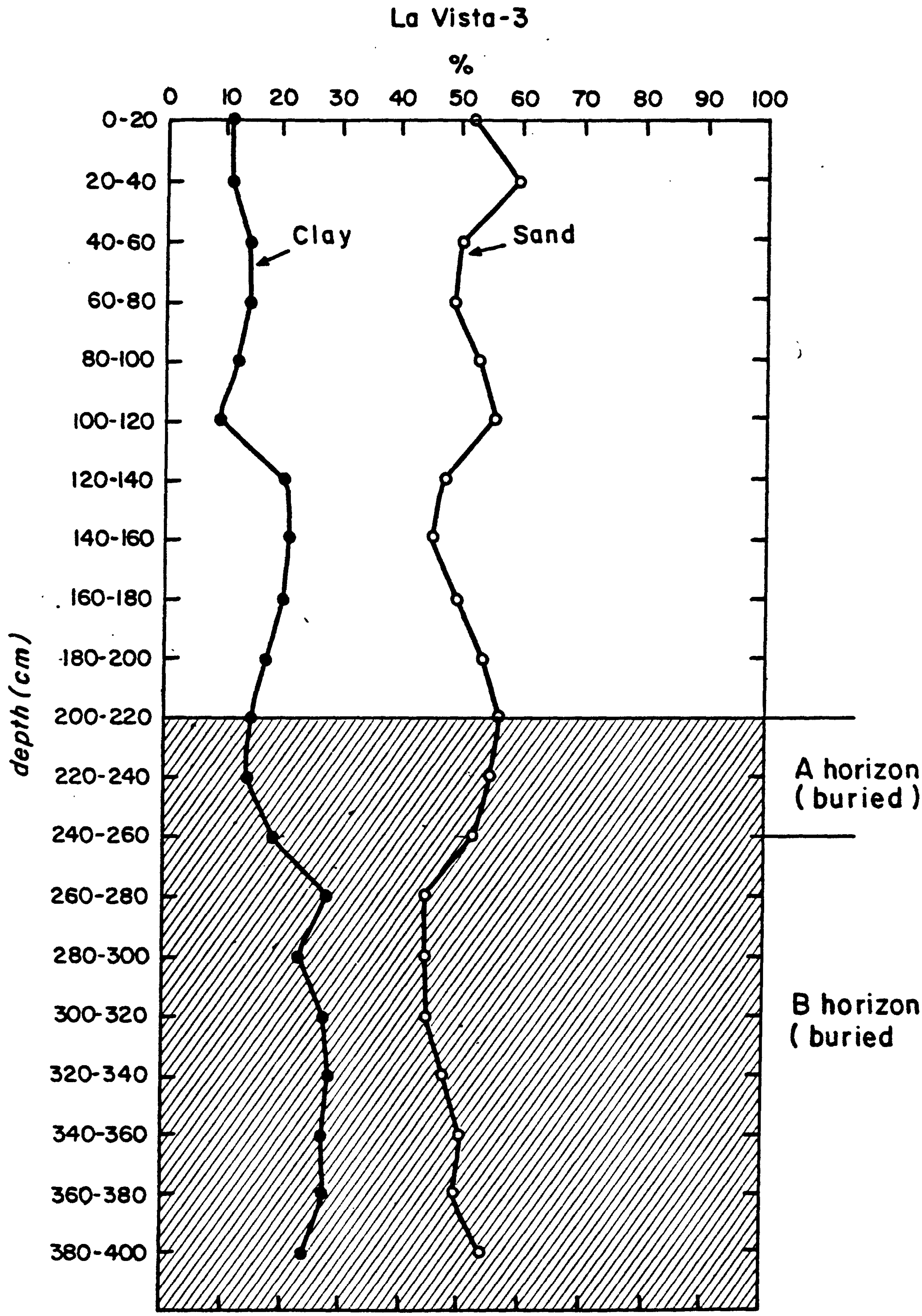

Fig. 44. La Vista-3 (Qt_6): Clay and sand content.

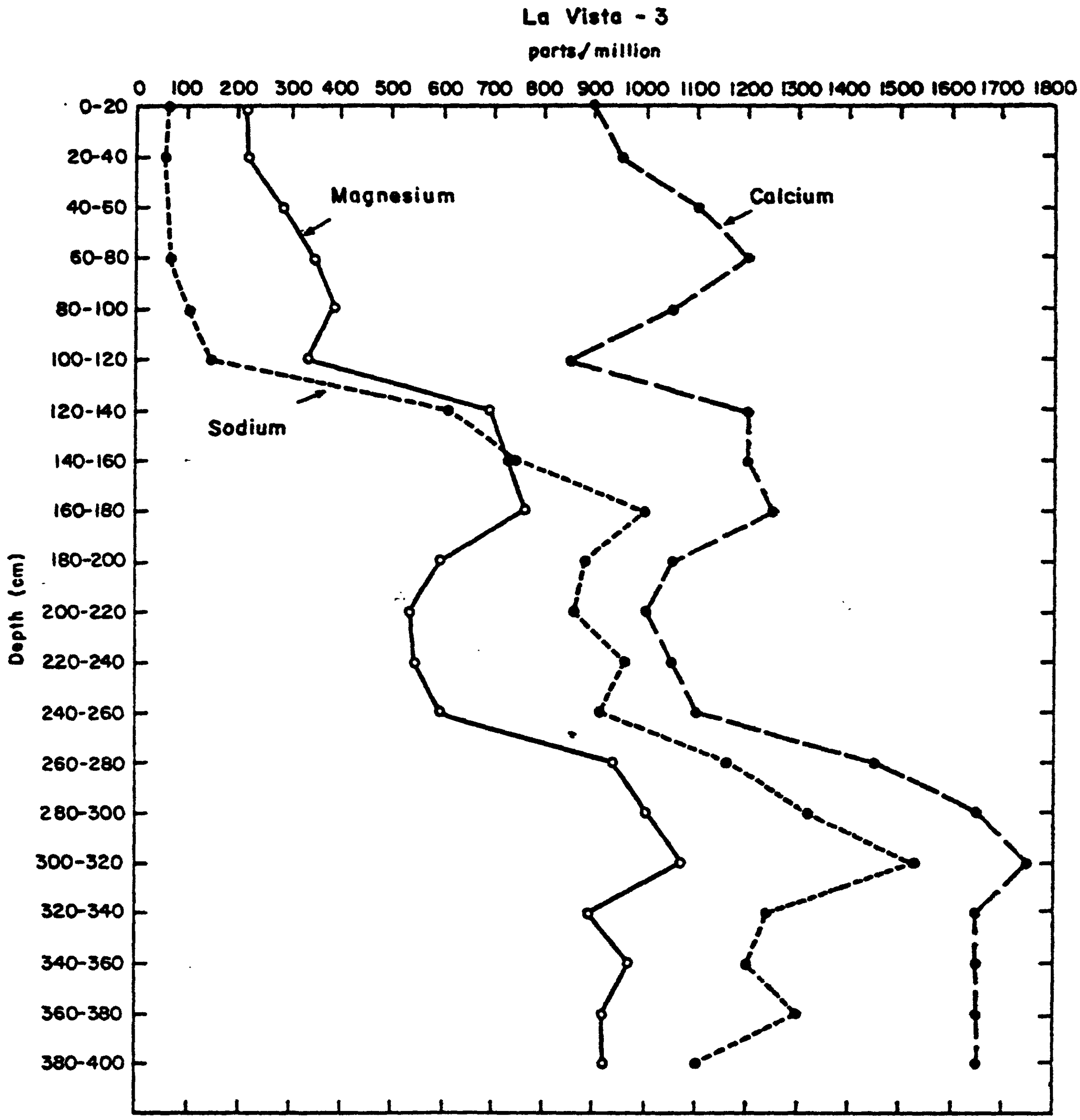

Fig. 45. La Vista-3 (Qt_6): Calcium, magnesium and sodium content.

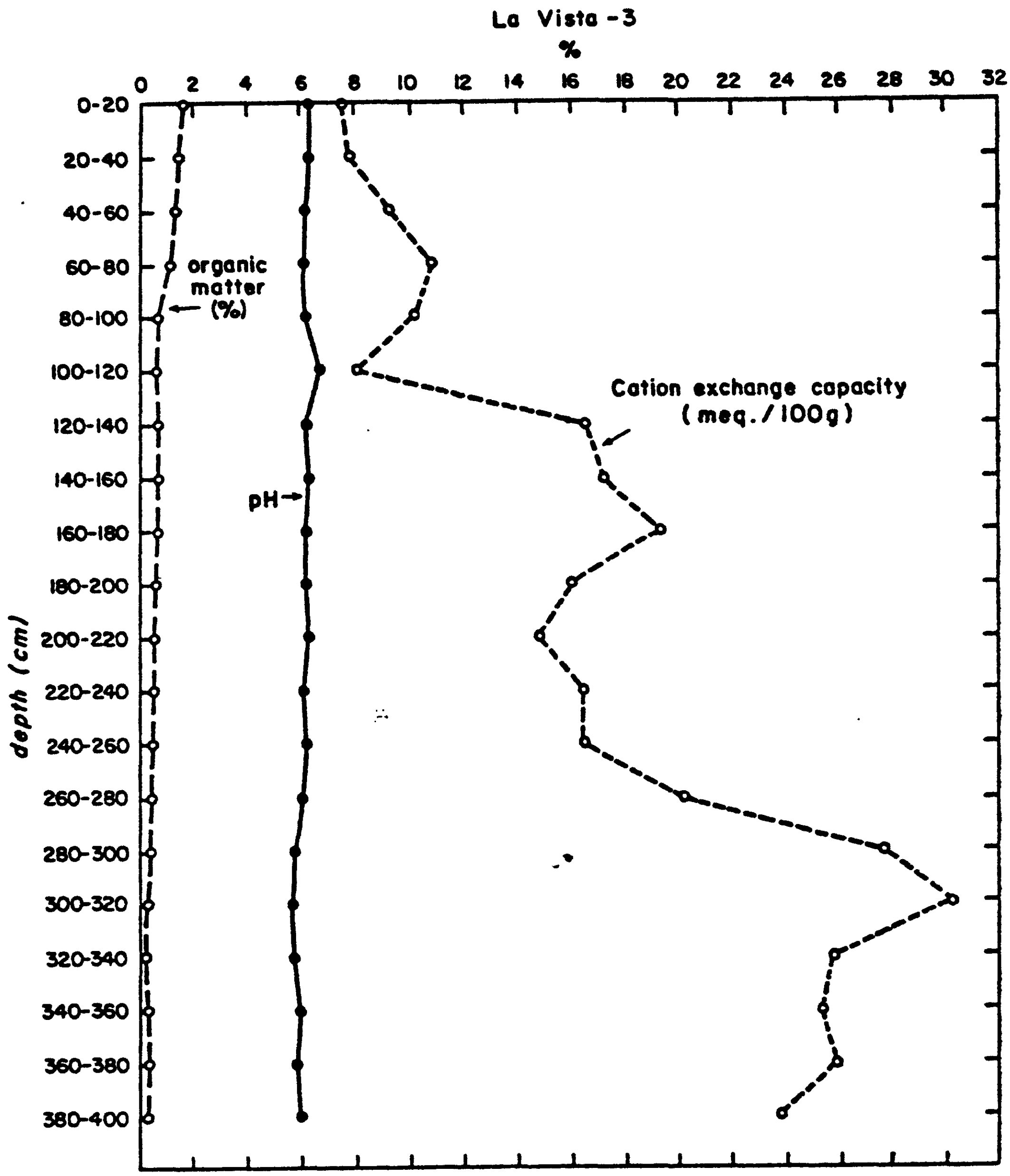

Fig. 46. La Vista-3 (Qt_6): Organic matter, pH and cation exchange capacity.

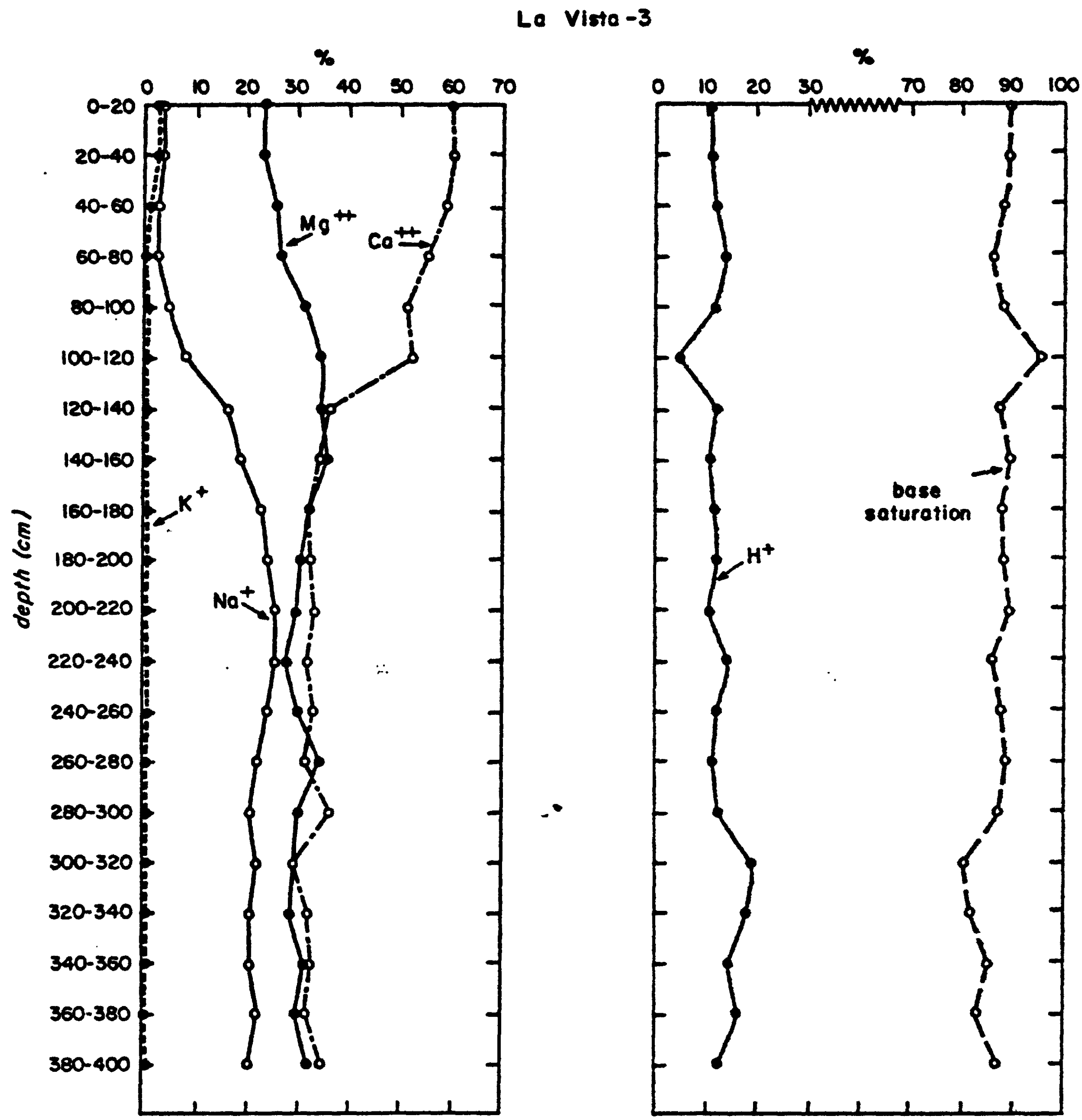

Fig. 47. La Vista-3 (Qt_6): Base saturation, H^+, Ca^{++}, Mg^{++}, Na^+ and K^+ content.

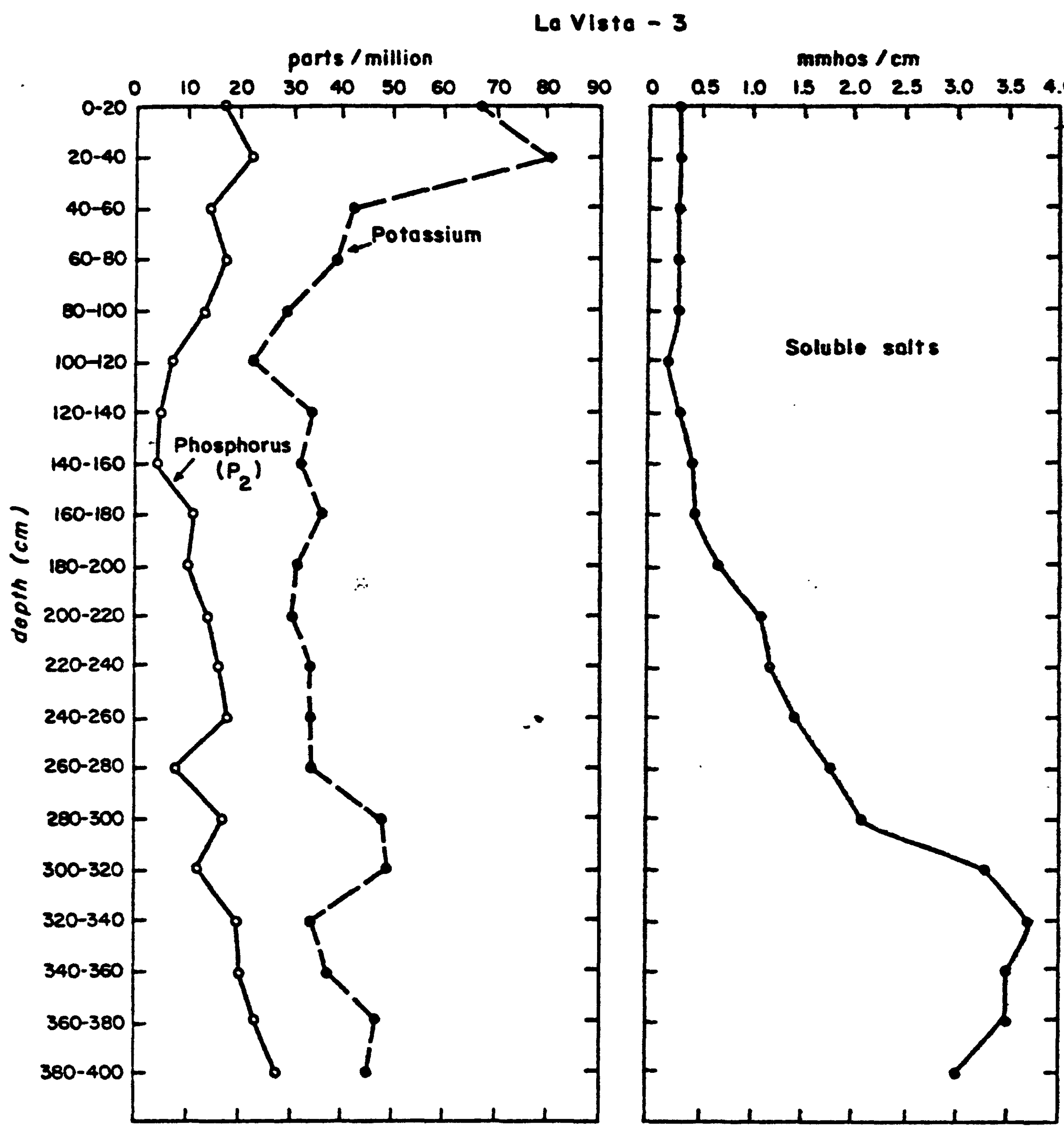

Fig. 48. La Vista-3 (Qt_6): Soluble salts, phosphorus and potassium content.

SOIL DESCRIPTION

Classification: Typic Palexeralf
Identifier: Timber Canyon 4
Location: Interfluve between Timber and Orcutt Canyons on footslopes of Topa-Topa Mountains near Santa Paula, Ventura County, California
Geographic Coordinates: 34° 24' 09" N, 119° 00' 59" W
Geomorphic Surface: Qt_7
Landform: Highly dissected and tectonically tilted ancient stream terrace
Parent Material: Stream gravels (pebbles, cobbles, boulders)
Slope: 17° (30%)
Elevation: Approximately 1640 feet (500 m)
Vegetation: Chaparral
Collected by: D. L. Johnson and T. K. Rockwell
Described by: D. L. Johnson and T. K. Rockwell
Exposure: Natural near-vertical cliff face

Horizon	Depth (cm)	Description
A_1	0- 23	Dark brown (7.5YR 4/4m) gravelly silt loam; very weak, very coarse subangular blocky; soft to slightly hard; many fine to medium pores, continuous random tubular (simple); many very fine to fine roots in pores; abrupt irregular boundary to:
A_2	23- 48	Pink (7.5YR 7/4m) to dark brown (7.5YR 4/4m) very gravelly silt loam; moderate medium to coarse subangular blocky; slightly hard; many fine to medium pores, continuous random vesicular and tubular (simple); many fine to medium roots in pores and along ped-stone interfaces; abrupt irregular boundary to:
B_{21t}	48- 82	Strong brown (7.5YR 4/6m) very gravelly clay loam; strong coarse prismatic where large clasts are absent, otherwise strong medium to coarse subangular blocky; very to extremely hard; continuous thick clay films (reddish brown) (2.5YR 4/4m) (5YR 4/4d) along ped interfaces, as bridges, and in pores; many very fine to fine pores, continuous random tubular (simple); common fine roots; diffuse irregular boundary to:
B_{22t}	82-185	Dark brown (7.5YR 4/4m) very gravelly silt loam; strong coarse subangular blocky; very to extremely hard; many moderately thick reddish brown (5YR 4/4m) clay films along ped interfaces and in pores; many fine pores continuous random tubular (simple); few fine roots along ped interfaces and in pores; gradual irregular boundary to: