U.S. DEPARTMENT OF THE INTERIOR
U.S. GEOLOGICAL SURVEY

TO ACCOMPANY MAP I-2371

GEOLOGIC MAP OF THE PALO ALTO AND PART OF THE REDWOOD POINT 7-1/2' QUADRANGLES, SAN MATEO AND SANTA CLARA COUNTIES, CALIFORNIA

By Earl H. Pampeyan

INTRODUCTION

The Palo Alto and southern part of the Redwood Point 7-1/2' quadrangles cover an area on the San Francisco peninsula between San Francisco Bay and the Santa Cruz Mountains. San Francisquito and Los Trancos Creeks, in the southeastern part of the map area, form the boundary between San Mateo and Santa Clara Counties. The area covered by the geologic map extends from tidal and marsh lands at the edge of the bay southward across a gently sloping alluvial plain to the foothills of the northern Santa Cruz Mountains. The foothills are separated from the main mass of the mountains by two northwest-striking faults, the San Andreas and Pilarcitos, that cross the southwest corner of the map area (fig. 1). The map and adjoining areas are here divided into three structural blocks juxtaposed along these faults, adopting the scheme of Nilsen and Brabb (1979): (1) the San Francisco Bay block lying east of the San Andreas Fault Zone; (2) the Pilarcitos block lying between the San Andreas and Pilarcitos Faults; and (3) the La Honda block that includes the main mass of the Santa Cruz Mountains lying west of the Pilarcitos Fault. The west boundary of the La Honda block is the Seal Cove-San Gregorio Fault.

Pre-late Pleistocene Cenozoic rocks of the foothills have been compressed into northwest-striking folds, which have been overridden by Mesozoic rocks along southwest-dipping low-angle faults. Coarse- to fine-grained upper Pleistocene and Holocene alluvial and estuarine deposits, eroded from the foothills and composing the alluvial plain, are essentially undeformed. Most of the alluvial plain, including some parts of the marsh land that borders the bay, has been covered by residential and commercial developments, and virtually all of the remaining marsh land has been diked off and used as salt evaporating ponds. The map area includes parts of the municipalities of San Carlos, Redwood City, Atherton, Woodside, Portola Valley, Menlo Park, and East Palo Alto in San Mateo County; and Palo Alto, Stanford University, Los Altos, and Los Altos Hills in Santa Clara County (fig. 2). Much of the university land remains as undeveloped open space surrounded by densely urbanized lands.

Geologic maps of all or part of the present map area have been prepared previously by Branner and others (1909), Thomas (1949), Dobbs and Forbes (1960), Dibblee (1966), Page and Tabor (1967), Pampeyan (1970a, 1970b), Beaulieu (1970), Helley and others (1979), and by numerous Stanford University students working on topical earth science problems. In addition, numerous engineering geologic studies have been conducted for site investigations relating to residential and commercial developments and, in particular, for construction of the Stanford Linear Accelerator Center (SLAC). The reports pertaining to SLAC are summarized in Skjei and others (1965) and more recently in a report by Earth Sciences Associates (1983). The interested reader is referred to Brabb and Pampeyan (1983), Brabb and others (1982), Wentworth and others (1985), Wieczorek and others (1985), Thomson and Evernden (1986), Brabb and Olson (1986), Youd and Perkins (1987), Perkins (1987), and Mark and Newman (1988) for information pertaining to geology, history, slope stability, seismic shaking, liquifaction potential, and faulting and seismicity in San Mateo County, some of which can be applied directly to northern Santa Clara County.

Field work for the present geologic map was done in 1962-1964 and 1966 when SLAC and Interstate 280 were in early stages of construction. Only minor additions and revisions have been made since this mapping was first released (Pampeyan, 1970a; 1970b) as it was impractical to keep pace with accelerating urban development of the area. Geologic units of the flatlands area are largely adapted from Helley and Lajoie (1979).

STRATIGRAPHY

JURASSIC AND CRETACEOUS ROCKS

The oldest rocks present in the map area are metasedimentary and meta-igneous rocks of the Franciscan Complex in the San Francisco Bay block (fig. 1). They have not been dated in this area but are considered to be Jurassic and Cretaceous in age based on determinations made elsewhere on the San Francisco Peninsula (Bailey and others, 1964). Franciscan rocks are exposed in Jasper Ridge adjacent to Searsville Lake, along the south edge of the map area south of Felt Lake, and along the west edge of the map area in Redwood City. The Jasper Ridge exposure is composed largely of greenstone interlayered with lesser amounts of chert and graywacke, and a narrow body of serpentinite occurs along the northeast side of the ridge. Franciscan rocks exposed along the south edge of the map area also are largely greenstone with interlayered chert, graywacke, and limestone and bodies of serpentinite. At Jasper Ridge and near Felt Lake the Franciscan rocks have been thrust northward over younger rocks—over Eocene rocks along Jasper Ridge and over Pleistocene to Eocene rocks south of Felt Lake. In Redwood City and Woodside the Franciscan rocks exposed are mostly graywacke and serpentinite containing small amounts of other Franciscan Complex rocks. The larger bodies of graywacke oc-

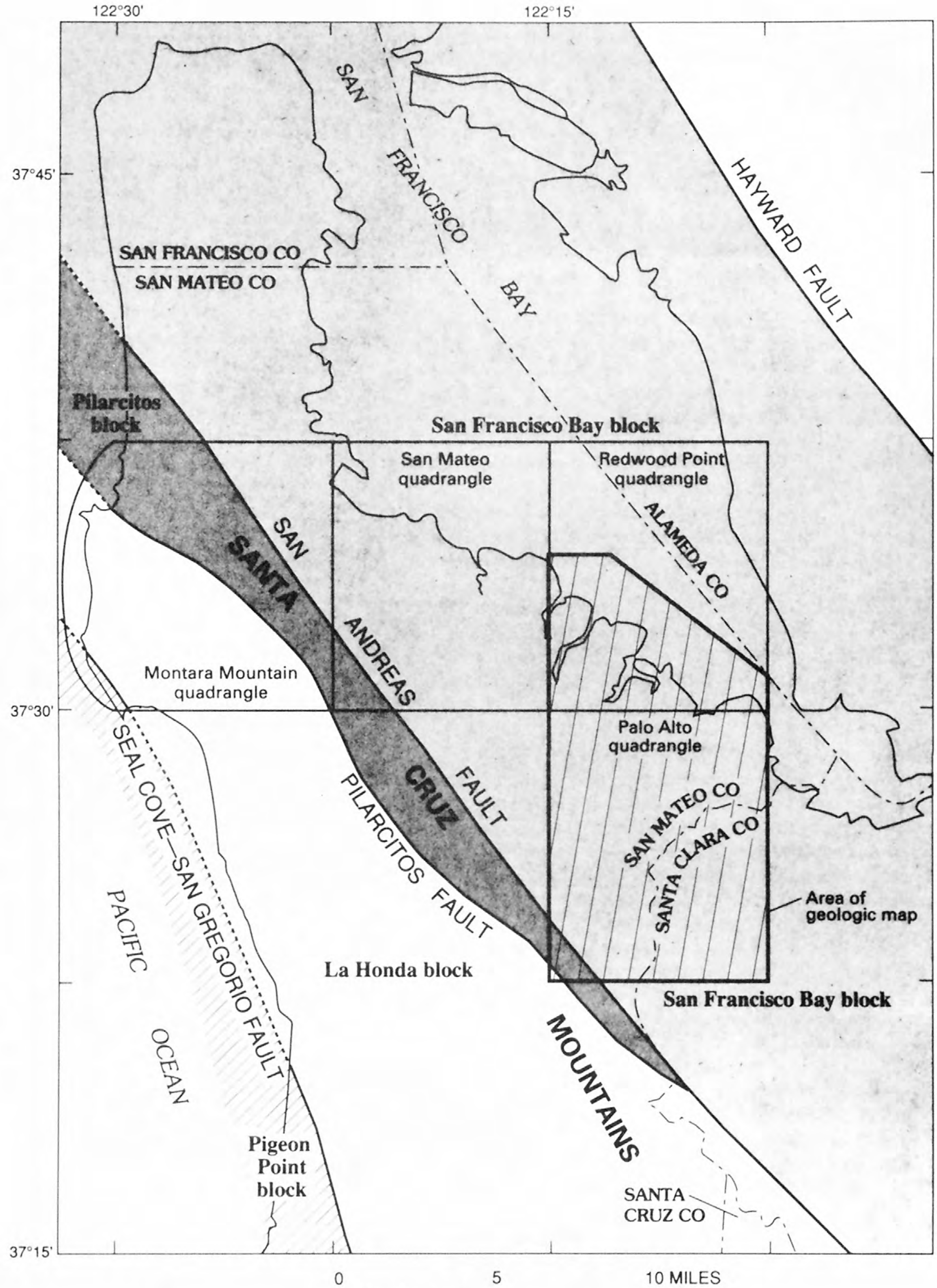


Figure 1. Map showing relation of study area (diagonal lines) to major tectonic boundaries of the northern Santa Cruz Mountains.

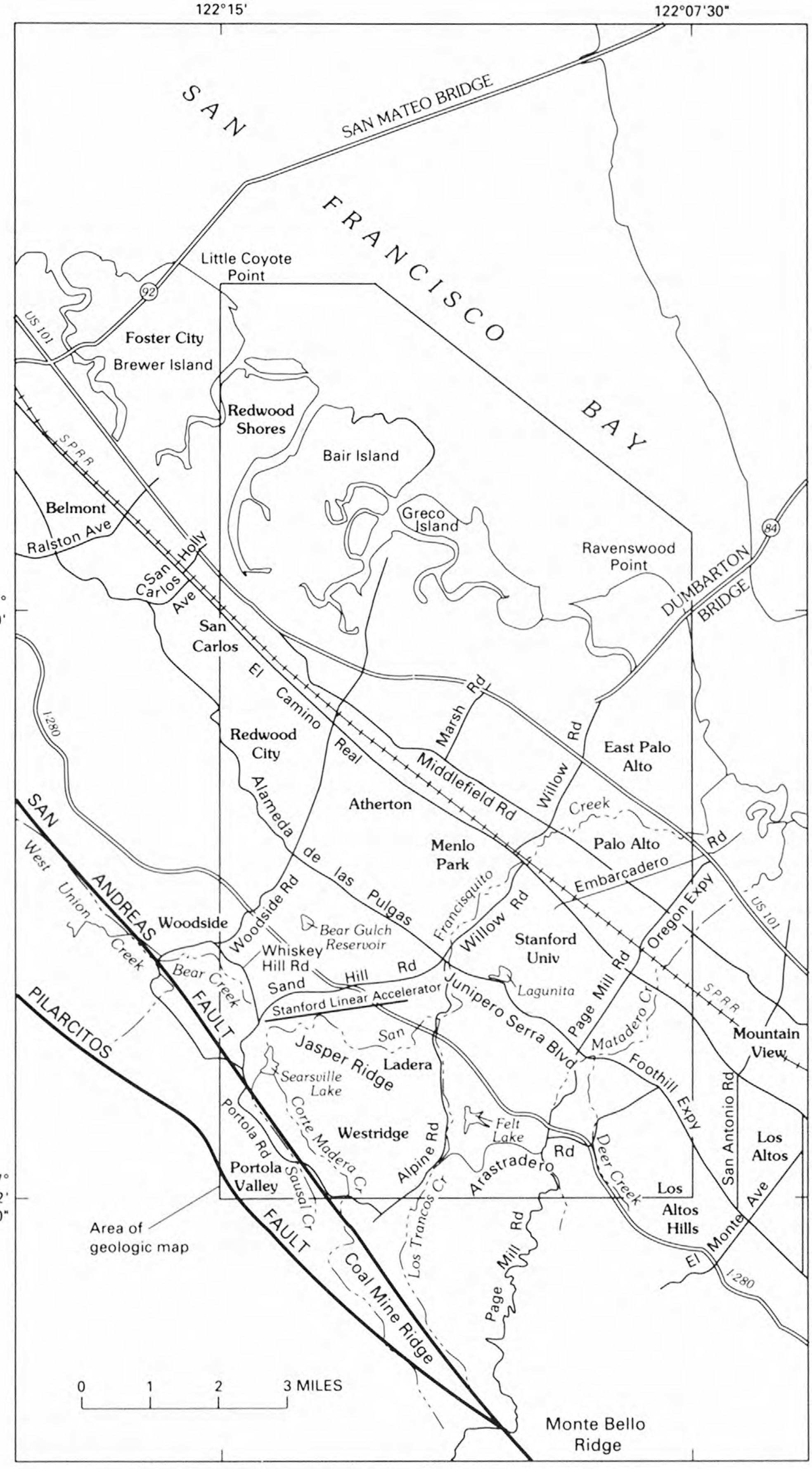


Figure 2. Geographic map of study area and vicinity.

cur as outliers surrounded by alluvial deposits and, locally, are in fault or sedimentary(?) contact with Eocene rocks. Logs of borings indicate that Franciscan rocks are present beneath all of the alluvial plain and baylands. These borings typically extend only a few feet into basement rock, and although several are correctly described as bottoming in graywacke or sheared rocks, many of the basement-rock lithic descriptions are questionable. Basement rock on the cross sections, therefore, is shown as undivided meta-igneous and metasedimentary rocks of the Franciscan Complex and associated rocks (unit fu). The basement-rock surface has been contoured and is shown in maps by Brabb and others (1990) and Hensolt and Brabb (1990).

The large serpentinite body in Woodside rests on Eocene strata, the basal contact dipping gently under the serpentinite, and the serpentinite appears to be a flow extruded onto an erosion surface from a fissure in Eocene sandstone. Thomas (1951) believed the serpentinite was a plug-like intrusion cutting but not distorting homoclinally dipping Eocene strata, but apparently he did not recognize that the basal serpentinite contact followed contour lines or did not have the benefit of roadcuts across the contact. The northernmost serpentinite body may have a similar origin, but natural exposures have been modified by grading so its structural relations with adjacent rocks have been obscured. A small diapir of serpentinite cuts Eocene strata along the axis of an anticline half a mile southeast of Bear Gulch Reservoir, and the crestline of that fold strikes northwest toward the large serpentinite body in Woodside. A linear positive aeromagnetic anomaly (fig. 5) which follows the fold crestline may indicate a serpentinite ribbon in a zone of crustal weakness (Brabb and Hanna, 1981; V.E. Langenheim and R.F. Sikora, unpubl. data, 1991). The presumed fissure under the large serpentinite body may be part of a similar diapir-like structure along the axis of the anticline. Other nearly flat lying sheets of serpentinite are present about 8 mi to the northwest along the San Andreas Fault Zone (Pampeyan, 1981b, in press). All of these serpentinite sheets may have flowed from fissures onto erosion surfaces as described by Carlson (1984) elsewhere in the Coast Ranges.

Silica-carbonate rock (hydrothermally altered serpentinite) occurs in several places, for example, along the northeast edge of the serpentinite diapir near Bear Gulch Reservoir, locally along both long sides of the largest serpentinite body southeast of Felt Lake, and in a few places on Jasper Ridge; it also was present in the northernmost serpentinite body but was removed or concealed by mining and grading operations in the 1950's. Silica-carbonate rock is a common host-rock for mercury (quicksilver) deposits in the Coast Ranges of California. The silica-carbonate rock is included with the serpentinite on this map for convenience of discussion even though it probably represents a late Tertiary episode of hydrothermal alteration.

Small amounts of limestone are present near the south edge of the map area; most of them occur as thin beds and lenses in greenstone. These limestone outcrops are lithologicaly similar to the Calera Limestone on Monte Bello Ridge (south of map area) and at the type locality of the Calera in northern San Mateo County (Lawson, 1914). In the southeast corner of the map area several irregularly shaped bodies of limestone are enclosed by gravels of the Santa Clara Formation and appear to underlie a thrust plate of Franciscan rocks that bears limestone. These limestone outliers may be a lag from the eroded overriding thrust plate. Foraminifers from the type Calera Limestone indicate an Aptian to Cenomanian (mid-Cretaceous) age similar to the Calera Limestone on Monte Bello Ridge (Tarduno and others, 1991). No recognizable microfossils were found in the limestone of this map area.

CRETACEOUS ROCK

One occurrence of Upper Cretaceous shale (unit Ks) is present in the map area. This occurrence, though not always exposed, is in San Francisquito Creek at the Willow Road bridge, west of the Stanford campus (fig. 3, No. 15). Molluscan and foraminiferal fossils from this locality (table 1) indicate a Campanian age (Graham and Church, 1959; 1963). A maximum thickness of 90 ft of section was reported by Graham and Church (1963), but part of that section is now covered by the north bridge abutment, and exposure of the remainder of the section depends upon stream flow and scouring of the creek bottom. The shale is in fault contact on the south with Eocene strata and on the north with gravels of the Santa Clara Formation, but the latter contact is very seldom exposed. The presence of Cretaceous shale here appears to be anomalous, for the closest similar-age rocks are exposed near Pigeon Point, about 20 mi to the southwest across the San Andreas, Pilarcitos, and San Gregorio Faults (fig. 1), where Upper Cretaceous rocks are overlain by Miocene and Pliocene strata (Hall and others, 1959). In the vicinity of Loma Prieta Mountain, however, about 30 mi to the southeast, Campanian-age sandstone, shale, and conglomerate appear to lie unconformably on Franciscan rocks and are unconformably overlain by Eocene mudstone, sandstone, and shale that have been correlated tentatively with Eocene rocks of the Palo Alto quadrangle (McLaughlin and others, 1988). Dibblee (1966, sections A-A'and B- B') shows the Cretaceous shale as unconformably(?) underlying Eocene sandstone northeast of the San Andreas Fault. That stratigraphy may exist here even though nowhere exposed.

Cretaceous foraminifers have been identified from other localities in the map area in siltstone or claystone mapped as the Eocene Whiskey Hill Formation. One locality (Tabor, 1962, sample LLT-95) was in a trench about 500 ft south- southeast from the small serpentinite diapir southeast of Bear Gulch Reservoir (fig. 3, near No. 21) and a second locality was on the west side of Farm Hill Boulevard 350 ft north of McGarvey Avenue in Redwood City (fig 3, No. 6). A reexamination of these fossil collections indicates the diagnostic benthic forms range in age from early to late Eocene, and earlier determinations based on arenaceous forms are invalid (Kristin McDougall, written commun, 1989).

EOCENE ROCKS

Eocene sandstone, siltstone, and claystone are present in the San Francisco Bay block, resting unconformably on Franciscan rocks. These clastic rocks initially were incorrectly correlated with the Cretaceous Chico Formation by Branner and others (1909) and Martin (1937), a correlation not used by Thomas (1949) who applied the name "Searsville Formation" to the unit on his map but did not properly define the name. Langerfeldt and Vigrass (1959) adopted Thomas' unit but they too did not adequately define it. Subsequently its rocks have been variously referred to as the Eocene and Paleocene sandstone and shale (Dobbs and Forbes, 1960), Butano Sandstone (Dibblee, 1966), unnamed Eocene rocks (Page and Tabor, 1967), Butano(?) Sandstone (Pampeyan, 1970a), and the (informal) Whiskey Hill formation (Beaulieu, 1970, 1971). On this map the name Whiskey Hill Formation (unit Tw) is adopted for these lower to upper Eocene rocks, and the unit's type area is designated as Woodside, or the southwest part of the Palo Alto 7-1/2' quadrangle, east of the San Andreas Fault Zone. Beaulieu's (1970) type section is along Whiskey Hill Road, for which the unit is named, where he reports 300 ft of section is exposed—only a small fraction of his total estimated thickness of 4,000 ft for the entire unit. Additional exposures are present in road cuts along Woodside Road near Interstate 280 where chaotic structures, sandstone dikes, and variations in lithology are visible in partial sections. Owing to the sparse natural exposures, faulting, and chaotic structure, a complete stratigraphic sequence could not be constructed.

Interlayered sandstone, siltstone, and claystone make up at least 90 percent of the Whiskey Hill unit, and conglomerate or conglomeratic beds, glauconitic sandstone, and tuffaceous siltstone make up the remainder. The sandstone beds commonly form ridges separated by swales underlain by silty and clayey beds that weather into dark-brown to grayish-black clay-rich ("adobe") soils. The clay-rich beds and related soils are expansive, owing to their sodium-montmorillonite content, and cause distress in pavements, residential and commercial buildings, and related structures, especially where the claystones crop out southwest of Menlo Park. Several samples of Whiskey Hill rocks were tested for Potential Volume Change (PVC) following the procedure of Lambe (1960) and the results are shown in table 2. For more information on expansivity of geologic units in San Mateo County see Wentworth and others (1985).

Included with the interlayered sandstones, siltstones, and claystones are chaotic zones where blocks of sandstone are suspended in a claystone matrix (Skjei and others, 1965; Page and Tabor, 1967; Pampeyan, 1970a; Beaulieu, 1970). The chaotic relations were exposed in cuts made for the linear accelerator but were not recognized in natural exposures or in test borings. Page and Tabor (1967) describe the chaos and believe it resulted from submarine slumping when the sandstone was sufficiently consolidated to be broken into blocks and mixed into the claystone. Although the magnificent exposures at the linear accelerator are no longer visible, they are accurately illustrated in the reports of Skjei and others (1965) and Page and Tabor (1967). The chaotic zones may be 1,700 to 2,700 ft thick, and the orderly parts of the Eocene section are thought to be at least an additional 1,300 ft thick (Beaulieu, 1970).

The lowest part of the Whiskey Hill Formation is a pebble to cobble conglomerate which appears to interfinger with Eocene sandstone beds and rest unconformably on Franciscan rocks along the south side of Jasper Ridge. Exposures are poor and deeply weathered, but the clasts include volcanic and granitic rocks as well as some quartzite, chert, greenstone, and serpentinite. A different and distinctive granule conglomerate is exposed at several localities between Eocene sandstone and Franciscan rocks on and near the north side of Jasper Ridge. This conglomerate is composed almost entirely of sub- to well-rounded granules of greenstone, with only a few chert granules present, and the interstices are filled with calcite. Branner and others (1909) originally described this unit as a basal conglomerate of the Chico Formation made up largely of serpentine and resting unconformably on serpentine in place. Graham (1967) reported that the greenstone conglomerate represented the base of the Eocene sandstone section and was deposited on the adjacent serpentinite body, even though no serpentinite detritus is present in the conglomerate. I suggest that the distinctive granule conglomerate accumulated within the lower part of the Whiskey Hill Formation adjacent to an ancestral Jasper Ridge greenstone source, which ultimately was intruded by serpentinite and thrust over the conglomerate.

The Eocene rocks of the San Francisco Bay block range in age from lower (Penutian) to upper (Narizian) Eocene based on foraminiferal determinations (table 1). Paleocene or older formanifers reported from the greenstone- granule conglomerate bed (Graham, 1967) and other scattered localities in Menlo Park and Redwood City apparently were based on invalid determinations or out-of-date data (Kristin McDougall, oral commun., 1989). In general the older forms were found near exposures of Franciscan rocks, but they were not restricted to the proximity of exposed Franciscan rocks. Samples collected along Farm Hill Boulevard in Redwood City, from exposures of shale and limestone that lithologically resemble neither typical Franciscan, Cretaceous, nor Eocene lithologies, may represent the stratigraphically lowest part of the Eocene section or, possibly, another formation. Some samples contained foraminifers believed by Graham and Classen (1955) to be restricted to the Cretaceous, but all these species are now known to range into the Eocene (Kristin McDougall, oral commun., 1991), and some may be reworked. Age determinations on samples collected during site-investigation studies for SLAC and for other paleontologic projects are summarized in Skjei and others (1965) whose list includes preliminary results from samples collected for this map. In that listing Eocene samples are either designated Eocene

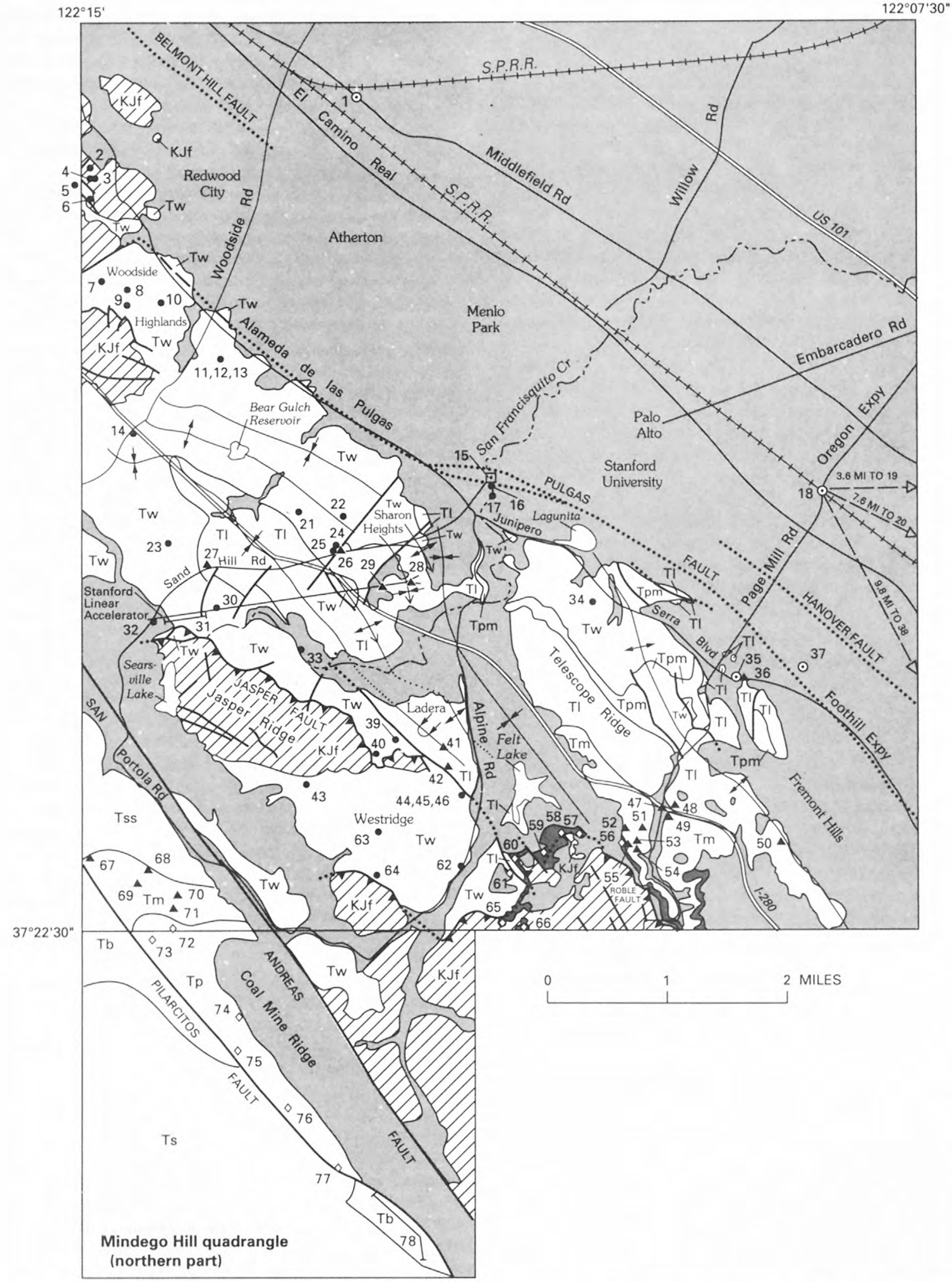


Figure 3. Map showing fossil localities and generalized geology in and near the Palo Alto 7-1/2' quadrangle. See table 1 for information on collections.

EXPLANATION FOR FIGURE 3

Sedimentary deposits and rocks, undivided (Holocene to Pliocene)—Includes Santa Clara Formation

Merced (?) Formation (Pliocene)

Tp — Purisima Formation (Pliocene)

Tm — Monterey Shale (Miocene)

Tl — Ladera Sandstone (Miocene)

Tpm — Page Mill Basalt (Miocene)

Ts — Sedimentary rocks (Miocene to Eocene)

Tb — Butano Sandstone (Eocene)

Tss — Sandstone (Eocene)

Tw — Whiskey Hill Formation (Eocene)

KJf — Franciscan Complex (Cretaceous and Jurassic)

Contact

Fault—Dashed where approximately located; dotted where concealed

Thrust fault—Sawteeth on upper plate. Dotted where concealed

Major folds—Showing crestline and direction of plunge where known. Dotted where concealed

Anticline

Syncline

Overturned syncline

Fossil locality—Numbers refer to table 1

18 Pleistocene

60 Pliocene

53 Miocene

34 Eocene

15 Cretaceous

78 Line of section sampled for coccoliths (Kheradyar, 1987)

or "upper" Eocene. According to Nilsen and Clarke (1975) the Eocene rocks of the San Francisco Bay block had a source to the north in the Sacramento Basin.

Sedimentary rocks with similar lithologies and ages are present in the Pilarcitos and La Honda blocks in the southwest corner of the map area. The type Butano Sandstone (unit Tb) in the La Honda block contains early (Penutian) to late (Narizian) Eocene foraminifers (Nilsen, 1979). The Eocene sandstone (unit Ts) underlying the Monterey Shale (unit Tm) in the Pilarcitos block is lithologically similar to Eocene units across both boundary faults and has been called the Butano Sandstone (Mack, 1959; Dibblee, 1966; Pampeyan, 1970a). Because these Pilarcitos block sandstone beds rest on Franciscan rocks instead of Salinian granitic rocks, they may be more closely related to the Whiskey Hill Formation than to the Butano Sandstone. According to Tieh (1965) these rocks had a Sierran source similar to the Whiskey Hill strata.

A study of the coccolith biostratigraphy of Eocene claystone in the San Francisco Bay and La Honda blocks by Kheradyar (1987) indicates that Whiskey Hill claystones (unit Tw) from the west end of the linear accelerator (fig. 3, No. 31) range from early middle (*Rhabdospaera inflata* subzone) to middle middle (*Discoaster bifax* subzone) Eocene in age, Butano claystones (unit Tb) (fig. 3, No. 78) range in age from late early (Discoaster sublodensis zone) to middle middle (*Nannotetrina quadrata* zone) Eocene, and, so far as the coccolith biostratigraphy is concerned, the rocks are essentially age equivalent. An additional sample from Whiskey Hill rocks on Westridge Road (fig. 3, No. 46), adjacent to the Eocene-Miocene contact west of Felt Lake, was assigned to the *D. bifax* subzone by Bukry and others (1977). The Butano Sandstone appears to be offset about 190 mi from its source area in central California (Nilsen and Simoni, 1973; Graham and others, 1989).

MIOCENE ROCKS

Overlying Eocene rocks in the San Francisco Bay block are middle and upper Miocene sedimentary rocks, which originally were incorrectly called the Purisima Formation (Branner and others, 1909) and, subsequently, the Los Trancos Formation by Thomas (1949) and Langerfeldt and Vigrass (1959), none of whom defined a type section for the unit. Dobbs and Forbes (1960) referred to these rocks as the Miocene sandstone, Dibblee (1966), Page and Tabor (1967), and Pampeyan (1970a) used unnamed sandstone, and Beaulieu (1970, 1971) the (informal) Ladera sandstone. The name "Ladera Sandstone" (unit Tl) is adopted for middle and upper Miocene clastic rocks in this report, and the unit's type area is designated as that part of the map area in the southwestern part of the Palo Alto 7-1/2' quadrangle that lies east of the San Andreas Fault. The unit is named for the Ladera School in the Ladera district of San Mateo County near the center of the type area. Beaulieu (1970) measured sections along Sand Hill Road and in the synclinal fold crossed by the linear accelerator and constructed a composite section 1,000-1,500 ft thick. Natural exposures of the contact between Eocene and Miocene rocks in the map area are rare and typically cannot be located closer than about 50 ft, but the contact was exposed in cuts made during construction of SLAC. In the accelerator trench, I saw the Miocene strata draped over a block of chaotically deformed Whiskey Hill rocks unconformably on the east side of the block and in fault contact on the west side, 1,000 ft away. Farther west in the trench, Eocene and Miocene beds were in contact, both dipping vertically or slightly overturned to the west, and the Miocene strata were well bedded while the Eocene strata near the contact were less well bedded and truncated or chaotic. Elsewhere, the few natural exposures exhibit some shearing along the contact, which Page and Tabor (1967) describe as a surface of decollement.

At or near the base of the Ladera Sandstone is the middle Miocene Page Mill Basalt (unit Tpm) (Dibblee, 1966). South of the Stanford University campus on radio telescope ridge the Page Mill Basalt essentially separates Eocene and Miocene sedimentary rocks, but in places there is a friable white sandstone unit or thin lenses of chert-granule quartzite between the basalt and underlying Eocene beds. The friable white sandstone, which lithologically resembles the Santa Margarita Sandstone of southern San Mateo County, is exposed along Alpine Road under the basalt. The quartzite occurs as lenses both under and in the basalt section and contains middle Miocene mollusks. The Page Mill Basalt is thickest in quarry exposures along old Page Mill Road, just south of Junipero Serra Boulevard, and thins to zero away from there, suggesting that the basalt erupted from a vent in or near that area. No basalt, white friable sandstone, or quartzite was seen along the Eocene-Miocene contact to the west of Interstate 280 or north of SLAC. Potassium-argon analyses of the basalt yielded an age of 14.8 Ma (Turner, 1970, using constants of Steiger and Jager, 1977) and more recently 14.0 Ma (Mark Mason, oral commun., 1989).

Overlying the basalt is a near-shore deposit of well-cemented barnacle-shell sandstone containing a middle Miocene fauna, a distinctive unit seen only adjacent to the basalt and in one excavation near the Eocene-Miocene contact about half a mile from the northernmost basalt exposure. The Page Mill Basalt apparently created a local environment that favored accumulation of the barnacle-shell sandstone.

Sandstones overlying the barnacle-shell sandstone are uniformly well sorted and were used as "select" fill during construction of SLAC, in contrast to the sandstone-claystone mixtures of the Whiskey Hill Formation that were too heterogeneous and expansive to use. Included in the Ladera Sandstone (unit Tl) are thin beds of dolomitic siltstone and porcelaneous shale, most of which are too thin to show on the map. Within its type area the Ladera Sandstone contains poorly preserved micro- and mega-fossils. Foraminifers and fossil fish scales suggest a probable middle Miocene age (P.J. Smith, written commun., 1963; R.L. Pierce, written commun., 1966); molluscan fossils (table 1) indicate a middle to late Miocene age (W.O. Addicott, written commun., 1963, 1965, 1966). Exceptionally well preserved molluscan fossils from a lithologically similar sandstone unit a few miles to the southeast near Monta Vista (table 3, No. 38), establish a middle to late Miocene age for the sandstone, which at that locality is above the Monterey Shale (W.O. Addicott, written commun., 1974; Sorg and McLaughlin, 1975). Vertebrate fossils are present in the Ladera Sandstone in San Francisquito Creek near Alpine Road, in Matadero Creek west of the U.S. Veterans Hospital, and near the east (target) end of the linear accelerator. Fossils from the first two localities are described by Packard (1962) who indicated that they are similar to middle Miocene forms found elsewhere. The third locality, somewhat higher in the section, was uncovered in excavations at the east end of the linear accelerator (fig. 3, No. 28). Seal and whale bones, shark teeth, and a *Paleoparadoxia* skeleton from this locality are equivalent in age to the middle to late Miocene molluscan fauna from nearby localities (Repenning, 1965; Adele Panofsky, oral commun., 1989).

Along Interstate 280, near Page Mill Road, the Ladera Sandstone grades upward into semisiliceous and diatomaceous shales and siltstones, with rare spicularite and sandstone interbeds, all assigned to the Monterey Shale (unit Tm). Branner and others (1909) incorrectly considered these rocks to be part of the Purisima Formation; later they were called the (informal) Pliocene(?) Portola shale unit by Thomas (1949) and the Pliocene siltstone and sandstone by Dobbs and Forbes (1960). Subsequently, these rocks were assigned to the Miocene Monterey Shale (Hogg, 1963; Dibblee, 1966; Pampeyan, 1970a). Some local reversals of the typical shale-on-sandstone sequence, probably the result of interfingering relations with the Ladera Sandstone, cause an apparent thickening southeastward of the Monterey Shale. About 1,200 ft southwest of the intersection of Interstate 280 and Page Mill Road, near the exposed top of the Monterey Shale, a thin vitric tuff bed contains diatoms that indicate a late middle (late Luisian) or possibly early late (early Mohnian) Miocene age (fig. 3, No. 51, K.E. Lohman, written commun., 1964). According to Hogg (1963), who mapped this locality as it was being graded for development, a 15-ft-thick bed of siliceous sponge spicules occurs nearby, and some yellowish- brown sandstone beds also are present amongst the predominant semisiliceous shale beds. Other samples of semisiliceous shale from this locality have yielded somewhat different provincial ages. Fish scales and molds of *Siphogenerina* species foraminifers in samples (fig. 3, Nos. 49, 53, 54) from near the vitric tuff bed were reported to be middle or early Miocene in age (R.L. Pierce, written commun., 1966), and Dibblee (1966) referred to a late Miocene or early Pliocene (Delmontian?) fauna in the Monterey Shale lower in the section than the vitric tuff bed (fig. 3, Nos. 47, 55), the fauna Cummings and others (1962, p. 197) described as being suggestive of Delmontian age. Whale and seacow bones in sandstone and siltstone from below the vitric tuff bed (fig. 3, No. 52) were initially reported to be late Miocene or possibly younger in age (C.A. Repenning, written commun., 1963), but subsequently Repenning (written commun., 1989) suggested that these bones might represent overlying Pliocene strata of the Merced(?) or Santa Clara Formations as seacows (sirenians) are not known from the Miocene. The whale bones I saw were *in situ* while the seacow bones were in boulder-size concretions uncovered and moved around while grading building sites; however Hogg (1963) reported that he saw bone-bearing concretions in this area in the Monterey Shale near the vitric tuff bed 200-300 ft below unconformably overlying upper Pliocene Merced(?) beds. The best paleontologic evidence available here indicates that the Monterey Shale of the San Francisco Bay block is middle and late Miocene in age— an age that corresponds with that of the Ladera Sandstone.

In the Pilarcitos block Miocene rocks consist mostly of mudstone, claystone, and shale assigned to the Monterey Shale (Cummings and others, 1962; Dibblee, 1966; Pampeyan, 1970a). Foraminiferal casts and fish-scale fossils (fig. 3, Nos. 67, 71) indicate a middle or early (early Relizian or late Saucesian) Miocene age and middle bathyal to abyssal paleoecology (R.L. Pierce, written commun., 1966). Dibblee (1966) considered these rocks to be correlative with the Woodhams Shale Member of the Monterey Shale in the La Honda block, and Cummings and others (1962) considered the Woodhams to be correlative with the Monterey Shale of the San Francisco Bay block.

In west Menlo Park, about 1,700 ft southwest of La Entrada School, a wall of resistant rock about 190 ft long and as wide as 55 ft stands above the less resistant Whiskey Hill strata. The wall is a vertical flow-banded rhyolite dike (unit Td). All of the feldspar in the dike has been altered to buddingtonite (ammonium feldspar) so that the rock consists almost wholly of buddingtonite and quartz. The dike is surrounded by a halo of ammonium alteration which has affected the enclosing feldspathic sandstone and claystone. Time of intrusion of the dike is post-late Eocene and probably related to other Miocene volcanic activity in the region, and it may possibly be temporally related to deposition of vitric tuff and the Monterey Shale.

PLIOCENE ROCKS

Overlying the Monterey Shale in the Pilarcitos block is a sandstone of early(?) Pliocene age assigned to the Purisima Formation (unit Tp), only a small part of which is present in this map area. These rocks were correlated with the Tahana Member of the Purisima Formation in the La Honda block by Cummings and others (1962), but a direct correlation of poorly preserved molluscan faunal assemblages from these rocks in the Pilarcitos block cannot be made with those from the type Tahana section 9 mi west in the La Honda block (W.O. Addicott, written commun., 1967). Addicott (1969) also states that none of the taxa from the Purisima of the Pilarcitos block (fig. 3, Nos. 72-77) occur in upper Pliocene (Merced?) strata of the San Francisco Bay block in the map area, and though both faunas represent a shallow inner sublittoral paleoecology, the compositional differences suggest the two faunas were never closely related.

In the San Francisco Bay block, sandstones of the Merced(?) Formation (unit Tme) unconformably overlie the Monterey Shale and older formations at the south edge of the map area. Most of the Merced(?) is a fine-grained poorly cemented marine sandstone and is easily distinguished from the overlying subaerial gravels of the Santa Clara Formation.

Addicott (1969, p. 60) also reports late Pliocene fossils from fine-grained sandstone lenses in the Santa Clara Formation along Arastradero Road south-southeast of Felt Lake, near the axis of a syncline in the Santa Clara as mapped by Dibblee (1966). The poorly exposed fossiliferous beds at this locality are typical Merced(?) sandstone in exposures masked by float from overlying Santa Clara gravels and are neither lenses in the Santa Clara Formation nor significantly higher in the local Merced(?) section than exposures in the east and west limbs of the syncline (fig. 3, Nos. 56-59). Total thickness of Merced(?) here is about 100 ft. Although I believe marine Merced(?) and fluvial Santa Clara strata probably do interfinger on a regional scale, it is unlikely that this particular locality is an example of tongues or lenses of the Merced(?) above the base of the Santa Clara Formation. Addicott's (1969) correlation of the Merced in the Palo Alto quadrangle with Glen's (1959) lower type-Merced strata west of the San Andreas Fault appears to be valid and indicates that shallow late Pliocene embayments were more extensive than previously recognized.

PLIOCENE AND PLEISTOCENE ROCKS AND DEPOSITS

Accumulations of alluvial deposits with clasts ranging from clay- to boulder-size unconformably overlie Pliocene and older rocks in the San Francisco Bay block. These deposits, which extend from west of Belmont (fig. 2) to south of San Jose, were mapped as the Santa Clara Formation by Branner and others (1909), and subsequently divided into eight lithofacies by Cummings (1968, 1972) on the basis of recognizable differences in clast composition. From northwest to southeast the facies are: Crystal Springs I, Crystal Springs II, Woodside, Searsville, Arastadero, Corte Madera, Stevens Creek, and Los Gatos. Parts of the Woodside, Searsville, and Arastradero facies (unit QTss) occur in the San Francisco Bay block but are not shown separately on this map. With the exception of one small patch in the La Honda block, the Corte Madera facies (unit QTsc) is confined to the Pilarcitos block, and the main exposure begins 1 mi southeast of the map area on Coal Mine Ridge (fig. 2). There the basal part of the facies contains fluvial and lacustrine deposits with significant amounts of carbonized wood, some logs as large as 2 ft in diameter, which were prospected for coal sometime in the 1880's (Watts, 1890). The Corte Madera facies contains well-rounded cobbles and boulders of an exotic conglomerate which Cummings (1968) demonstrated had a source near Loma Prieta Mountain, about 18 mi southeast of Coal Mine Ridge in the San Francisco Bay block, across the San Andreas Fault. The Arastadero facies appears to be the oldest of the Santa Clara lithofacies (Vanderhurst and others, 1982; Adam and others, 1983), and it is at least 100 ft thick in Los Altos Hills. Along Arastadero Road it overlies the Merced(?) Formation. Gravels of the Arastadero facies consist mainly of red chert, graywacke and arkosic sandstone, laminated siliceous shale, and siliceous volcanic rocks and are enclosed in a fine sand matrix (Cummings, 1968, 1972). According to Vanderhurst and others (1982) the Searsville facies overlies the Arastadero facies in Los Altos Hills. There, greenstone, graywacke, and arkosic sandstone clasts predominate in the Searsville, and chert clasts are subordinate (Cummings, 1968, 1972). The Woodside facies consists almost entirely of feldspathic to arkosic sandstone detritus with scattered pebbles of black chert and flow-banded rhyolite. The sandstone clasts are angular to subangular and as long as 18 in. Exposures are poor and the unit lithologically resembles a breccia of Whiskey Hill rocks. In Portola Valley the ridge parallel to Portola Road, shown as underlain by the Whiskey Hill Formation, may actually be underlain by the Woodside facies of the Santa Clara Formation. According to Cummings (1972) the clast-size distribution indicates that the Woodside facies had a source area west of the San Andreas Fault, now located somewhere to the southeast.

I saw no lacustrine deposits in the Woodside, Searsville, or Arastradero facies, but a few miles southeast of the map area, plant and animal fossils were found in local accumulations of fresh-water deposits in the Arastradero facies (Dorf, 1933; Sorg and McLaughlin, 1975, Adam and others, 1983) that indicate a late Pliocene (Blancan) age for the lower part of the Santa Clara. An ash bed in the uppermost part of the Woodside facies about 7 mi northwest of Portola Valley, has been correlated with the 400,000 year-old Rockland ash bed (Sarna-Wojcicki and others, 1985). This same ash bed is present in the upper part of the type Merced Formation of Glen (1959) in northern San Mateo County (Sarna-Wojcicki and others, 1985). The Santa Clara Formation, therefore, is time transgressive through the Pliocene-Pleistocene boundary and, as in the type Merced Formation of Glen (1959), the time boundary is not marked by a mappable stratigraphic break.

PLEISTOCENE DEPOSITS

Older coarse-grained fan deposits (unit Qoa) are found mainly along the foothills and appear to form a gently north sloping to northeast-sloping unit containing a basal fine-grained fossiliferous stratum. Widespread extent of the basal stratum has been confirmed near the margin of San Francisco Bay in sparse natural and artificial exposures, for example: in an excavation on Middlefield Road at Dumbarton Avenue in Redwood City (fig. 3, No. 1), where the Oregon Expressway passes under the Southern Pacific railroad in Palo Alto (fig. 3, No. 18), in the Mountain View sanitary landfill 3.5 mi due east of the Oregon Expressway underpass (fig. 3, No. 19), and in Sunnyvale at localities south and southeast of the Mountain View site (fig. 3, No. 20) (C.A. Repenning, written commun., 1989; Helley and others, 1972). Well-preserved leaves, seeds, and wood were found in the fine-grained basal unit at the Mountain View site, and radiocarbon dates of 20,820 yr B.P., 21,960 yr B.P., and 23,000 yr B.P. were determined from the wood (Helley and others, 1972). A nonmarine vertebrate fauna, including camel, mammoth, mastodon, bison, horse, antelope, ground sloth, squirrel, and other small mammal bones from the basal part of the unit, indicates a late Pleistocene age of about 20,000 yr B.P. The fauna and flora indicate a cooler climate than the present at a time when San Francisco Bay was mostly dry land (Helley and others, 1972; C.A Repenning, written commun., 1989). A similar nonmarine silt was exposed in Matadero Creek between the U.S. Veterans Hospital and Foothill Expressway (fig. 3, No. 35) and in nearby building sites (fig. 3, No. 37). Bone fragments from the Matadero Creek site indicate a Rancholabrean age, less than 15,000 yr B.P. (C.A. Repenning, written commun., 1989). In Matadero Creek the contact relations were obscure but the silt appeared to be resting on strata of the Santa Clara Formation. Branner and others (1909, p. 7) report finding an elephant tusk 2 mi southeast of Stanford University, probably from this same area, to which Hay (1927) assigned a Pleistocene age. In this report the older alluvium (unit Qoa) is considered to be late Pleistocene in age.

PLEISTOCENE AND HOLOCENE DEPOSITS

Along the San Francisquito, Los Trancos, Corte Madera, and Sausal Creek drainages, stream terrace deposits (unit Qst) cover the older formations. Composition of these deposits varies from place to place depending on the source areas. Some of the deposits lithologically resemble the Santa Clara Formation but can be distinguished from it by degree of induration and flat instead of inclined bedding planes. Also, terrace deposits of the San Francisco Bay block contain cobbles and boulders of exotic conglomerate eroded from the Corte Madera facies of the Santa Clara Formation in the Pilarcitos block. Along San Francisquito Creek several terrace surfaces are visible, some cut into bedrock and others constructed of terrace deposits. The most prominent surfaces are in the Ladera district, near the intersection of Interstate 280 and Alpine Road. The terrace deposits are considered to be Pleistocene and Holocene in age. A 2-ft-thick layer of organic matter, thought to have an areal extent of at least two acres (F.R. Conwell, oral commun., 1962), was cut in boreholes along San Francisquito Creek under 22 ft of terrace deposits. A piece of wood from this layer yielded a ^{14}C age of 5,840 yr B.P. (Ives and others, 1967, sample W-1579). Typically, the terrace deposits are confined to narrow drainage channels and interfinger or grade into older fan deposits (unit Qoa) where they spread out onto the alluvial plain.

Slope failures are classified as older landslide deposits (unit Qol) and younger landslide deposits (unit Qyl) on the basis of activity, the older deposits showing no evidence of movement in the past several decades—for example, tilted trees or distressed man-made structures. Miocene rocks in the Pilarcitos block are especially susceptible to slope failure as evidenced by large old and young landslides (Brabb and Pampeyan, 1972; Brabb and others, 1972; Ellen and Wieczorek, 1988). In general the Tertiary rocks west of the San Andreas Fault are weaker than their counterparts east of the fault, and eyewitness accounts tell of widespread slope failures in these rocks triggered by the 1906 earthquake (G.F. Morell, oral commun., 1964; Lawson, 1908).

HOLOCENE DEPOSITS

Holocene deposits are widely distributed on the gently sloping alluvial plain, although not everywhere well exposed owing to urban developments. The distribution of coarse- and fine-grained alluvial and basin deposits as shown on the geologic map is based largely on studies by Helley and Lajoie (1979). The Holocene deposits vary considerably in thickness because the underlying bedrock surface is irregular. Using data from logs of wells drilled for water or engineering and scientific purposes, depths to bedrock have been plotted and a bedrock-surface map constructed (Brabb and others, 1990; Hensolt and Brabb, 1990), but most of the water-well logs do not contain sufficient detail to positively identify specific Holocene units. At the time of my study, depth to Franciscan basement rock as shown on this map, was the main interest. The historic landward extent of bay mud (unit Qm) is based on personal observation and old U.S. Coast Survey (1853, 1857 a, b, c) and U.S. Coast and Geodetic Survey (1897a, b) topographic maps of the margins of San Francisco Bay. The methods of study and characteristics and interrelations of these deposits and their importance to comprehensive planning are discussed in detail by Helley and others (1979). The interested reader also is referred to a report by Atwater and others (1977) describing the late Quaternary history of San Francisco Bay.

Excavations for building sites in East Palo Alto, just north of Jack Farrell Park, uncovered several aboriginal burial sites and middens (Gerow with Force, 1968). The site (referred to as the University Village site), on the natural levee of an ancestral San Francisquito Creek, is composed of coarse-grained alluvial fan deposits (unit Qac) that extend northward into the bay marshlands. Carbon-14 analysis of charcoal from the site yielded dates of 2,700 and 3,150 yr B.P. (Broecker and others, 1956, samples L-187A and L-187B, respectively). A human skeleton was found in the same geologic unit about 17 ft below the land surface in the bank of San Francisquito Creek, about 3,000 ft southwest of El Camino Real. Carbon-14 analysis of bones from this site (referred to as the Stanford Man "II" site) gave dates of 4,400 and 4,350 yr B.P. (Wright, 1971, samples UCLA-1425A and UCLA-1425B, respectively). Aboriginal artifacts and skeletal remains have been found in Holocene deposits at other localities in the bay region (Helley and others, 1979). The wood sample noted earlier from under 22 ft of stream terrace deposits in San Francisquito Creek may represent the same period of cultural development. Numerous other middens have been found on the alluvial plain, most of them on the historic land surface and representative of more recent cultures.

STRUCTURE

Tertiary bedrock units exposed in the San Francisco Bay block are folded into a northwest-trending, southeast-plunging synclinorium with Eocene beds in both limbs and Miocene beds in the core. Pliocene to Pleistocene deposits, which unconformably overlie the older units, also have been folded. Rocks of the Franciscan Complex in Jasper Ridge form the core of a northeast-verging anticline thrust over strata of the Whiskey Hill Formation in the southwest limb of a synclinorium. Strata of the Santa Clara Formation also have been folded and dip as steeply as 90° in exposures along Mapache Drive in Portola Valley. The unconformable relations between map units, steeply dipping Santa Clara beds, and overthrust Pleistocene beds indicate ongoing tectonic deformation (not readily measurable across the most recently active traces of the San Andreas Fault).

The San Andreas Fault passes through the Town of Portola Valley and separates the main mass of the Santa Cruz Mountains from the foothills and alluvial plain leading to San Francisco Bay. On a global scale, the San Andreas Fault is the boundary between major segments of the earth's crust, the Pacific Plate on the west and the North American Plate on the east, which are sliding laterally past each other at about 1.38 to 1.97 in. (35 to 50 mm) per year (Argus and Gordon, 1990). Throughout most of central California the San Andreas Fault forms a geologic boundary between granitic basement rocks to the west and Franciscan basement rocks to the east, Salinia and the Northern Franciscan area, respectively, of Reed (1933). In Portola Valley the fault is marked by a northwest-trending valley 800 to 1,000 ft wide believed to be underlain by rocks sheared and broken through repeated shifts over millions of years. Within this zone traces of the most recent surface ruptures are shown, based on historical data and geologic and geomorphic studies (Lawson, 1908; Pampeyan, 1970a; Dickinson, 1970, 1973; Taylor and others, 1980). Surface offsets resulting from the April 18, 1906 earthquake were as great as 8 ft here, the land west of the fault moving north relative to the east side; the amount of displacement was documented by offset fences, pipelines, and roads in Portola Valley and adjacent Woodside (Branner, 1907; Lawson, 1908). According to Taber (1906) and Branner (1907) the manifestation of the surface rupture through Portola Valley, was that of a single plowed furrow in a continuous and nearly straight line, except that the sod was not turned over. Measurements of displacement across the most recently active strand of the fault in Woodside, 2.5 mi northwest of Portola Valley, demonstrate horizontal deformation at varying rates which average out to a tectonic slip rate of 0.09 in. (2.2 mm)/yr (Harsh, 1977). Long-term geodimeter measurements across this part of the Santa Cruz Mountains show no aseismic slip but about 0.4 in. (10 mm)/yr of strain build-up across the San Andreas Fault Zone (Bennett, 1980), suggesting that the total plate motion is distributed over a wider zone of coastal California.

The Pilarcitos Fault cuts the southwest corner of the map area a mile west of the San Andreas Fault, and the block bounded by these two faults is underlain by Franciscan rocks. According to Dibblee (1966) the Franciscan Complex through Monterey Shale sequence in the Pilarcitos block is similar to that of the San Francisco Bay block, and both blocks moved as a unit prior to deposition of the Purisima Formation when the San Andreas Fault branched off along its present path. In the Montara Mountain quadrangle the Pilarcitos Fault was originally considered to be a northeast-dipping, high-angle reverse fault (Lawson, 1914; Darrow, 1963), and that view is reinforced by Wakabayashi and Moores (1988) who believe the northern part of the Pilarcitos Fault is a thrust that extends only as far south as lat. 37°30' where it disappears among a group of younger sub-parallel high-angle normal faults. In the vicinity of the present map area Salinian and Franciscan basement units are juxtaposed along the Pilarcitos Fault, a linear trace that certainly is a strike-slip fault; farther north, where the fault curves west, the Pilarcitos Fault may have a component of dip slip-movement along with the predominant right-lateral strike-slip sense of movement.

In the Town of Woodside the east edge of the San Andreas Fault Zone has been shown bounded by an unnamed fault extending south along Bear Creek to the intersection of Whiskey Hill and Sand Hill Roads (fig. 4; Branner and others, 1909). In reconnaissance studies of active faulting, Dickinson (1970, 1973) showed a fault along the same trend but a few hundred feet west of the earlier location and named it the Cañada trace of the San Andreas Fault. This fault was not visible in Bear Creek, in roadcuts along Sand Hill Road, or in the greenstone shoreline of Searsville Lake but was based on a linear alignment of topographic breaks in slope. Subsequently, three trenches across the Cañada trace, in an area 600 to 2,400 ft northwest of Sand Hill Road, exposed no evidence of faulting, but a gentle monoclinal fold in strata of the Santa Clara Formation was noted at the intersection of the Cañada trace and one trench, which, according to R.H. Wright (written commun., 1983), suggests a possible thrust fault at depth.

More recently Brabb and Olson (1986) have interpreted Dickinson's Cañada trace to be part of the Hermit Fault, a southwest-dipping thrust fault, which abruptly turns east and follows the course of San Francisquito Creek, skirting the northeast edge of Jasper Ridge, and then merges southeastward with the Roble Fault of this map and the Monte Vista Fault Zone of Sorg and McLaughlin (1975). Willis (1924, fig. 2) coined the name Hermit Fault when describing the structural setting of the area near Stanford. He inferred its presence at the north base of Jasper Ridge, once informally known as Hermits Ridge for the hermit Domonico Grosso who lived there from 1878 to 1915 (Repass, 1923), but Willis left no maps showing the fault's actual position or extent. B.M. Page (oral commun., 1989) also believes there is a fault along the north base of Jasper Ridge but that its exact position is unknown. No Hermit Fault is shown on this map owing to the lack of exposures demonstrating displaced strata or sufficient structural data or geomorphic features through which to draw a fault. In the Ladera district, curvilinear breaks in slope along which the Hermit Fault was drawn are stream-cut features and the adjacent benches are stream terraces, several of which exist in that area.

On Jasper Ridge, rocks of the Franciscan Complex are in fault contact with strata of the Whiskey Hill Formation, which typically are overturned to the northeast. The northwest half of this fault, referred to as the Jasper Fault, juxtaposes Whiskey Hill strata and serpentinite and dips steeply southwest; the southeast half of the fault has serpentinite and other Franciscan units in contact with Whiskey Hill strata and the dip is considerably flatter. The north end of the fault is concealed by Santa Clara Formation, and the south end appears to be truncated by a high-angle normal fault which juxtaposes Eocene and Miocene rocks. Page and Tabor (1967) show the fault along Jasper Ridge as part of a southwest-dipping zone of thrusting, which places Franciscan rocks on Eocene rocks. The Jasper Fault is at the north end of McLaughlin's (1974) Sargent-Berrocal Fault Zone.

Along the south edge of the map area another low-angle fault places Franciscan rocks on Pleistocene and older strata. This fault, referred to as the Roble Fault for an excellent exposure on Paseo del Roble, is part of the Monte Vista Fault Zone of Sorg and McLaughlin (1975) which is, in turn, a part of McLaughlin's (1974) Sargent-Berrocal Fault Zone. Fleck (1967) shows a somewhat different configuration of this fault, in part based on the position of several isolated blocks of Franciscan limestone surrounded by gravels of the Santa Clara Formation. As noted earlier, I believe the limestone blocks are erosional or detached remnants of the overriding Roble Thrust Fault incorporated within the Santa Clara deposits. Dibblee (1966) and Rogers and Williams (1974) also have their own interpretations of the low-angle fault pattern in this area and to the south. The thrust fault may well be more complex than shown.

A northeast-facing linear scarp subparallel to Alameda de las Pulgas in west Menlo Park appears to mark the trace of a concealed fault separating buried Eocene rocks on the southwest from buried Pliocene and younger deposits on the northeast side. This fault, here referred to as the Pulgas Fault, is projected southeastward across San Francisquito Creek where it bifurcates and encloses a block of Cretaceous shale exposed between the Whiskey Hill Formation and the Santa Clara Formation. Northwest of the creek the presence of sheared basement rock at shallow depth in water wells confirms the location of one strand of the fault (Brabb and others, 1990). Southeast of the creek the fault traces appear to merge and follow a break in slope across the Stanford campus, separating hills with exposed bedrock units from lower slopes underlain by the Santa Clara Formation. The Pulgas Fault may merge southeastward with the Monte Vista Fault Zone of Sorg and McLaughlin (1975).

According to B.M. Page (oral commun., 1989) the faults exposed in San Francisquito Creek are part of the Stanford Fault of Willis (1924), the northwest continuation of a fault Willis saw in an excavation on campus in 1916. As with the Hermit Fault, however, Willis left no map showing the location of his fault. A gravity study by Taylor (1956) shows a positive anomaly, extending from the vicinity of Eagle Hill in Redwood City southeastward into Mountain View, along which he drew the Stanford Fault. Brabb and Olson (1986) assigned the name "Stanford Fault" to a zone of faulting which coincides with the Pulgas Fault north of San Francisquito Creek then extends southeast through the Stanford campus. Because the name "Stanford" has been applied to more than one real and inferred fault the name was not used on this geologic map.

In San Carlos the Belmont Hill Fault cuts Franciscan units (Pampeyan, 1981b), and it probably extends southeast at least to the vicinity of Woodside Road and possibly farther. In Redwood City, Franciscan rocks on the north side of the fault appear to step down. Where exposed in Belmont and San Carlos, the fault plane is vertical or steeply west dipping suggesting a west-dipping steep reverse fault.

In the southern part of Palo Alto a 20-ft-high northeast-facing scarp subparallel to Hanover Street crosses Page Mill Road and follows the Santa Clara Formation (unit QTss)-older alluvium (unit Qoa) contact. South of this, scarp Miocene sandstone is very near the surface of the low rolling hills, and north of the

EXPLANATION

- Unnamed Fault of Branner and others (1909)
- Stanford Fault of Taylor (1956)
- Palo Alto and San Jose Faults of California Department of Water Resources (1967)
- Cañada and Searsville traces of San Andreas Fault of Dickinson (1970, 1973)
- Stanford Fault Zone, Hermit Fault, and Monta Vista Fault Zone of Brabb and Olson (1986)
- Atherton and San Francisquito Faults of Carle and Langenheim (1990) and V.E. Langenheim and R.F. Sikora (unpub. data, 1991)
- Redwood City Fault Zone of Brabb and others (1990)

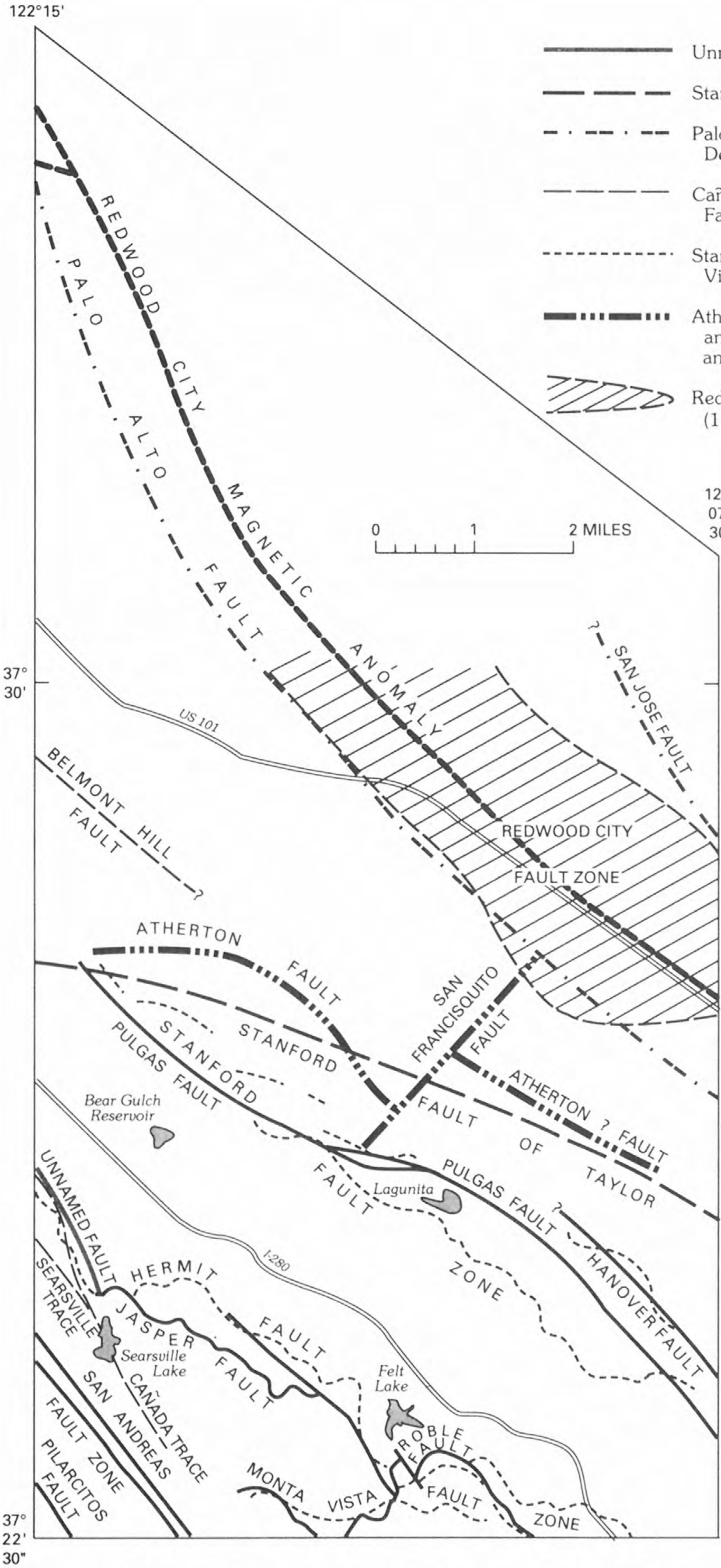


Figure 4. Sketch map of study area showing relation of other fault interpretations to major faults (heavy solid lines) shown on the geologic map

scarp, alluvial deposits are hundreds of feet thick under the flatlands (Pampeyan, 1970a; Brabb and others, 1990). This probable fault-line scarp, here referred to as the Hanover Fault, may be an extension of the Sargent-Berrocal Fault Zone of McLaughlin (1974). Recent groundwater-movement studies near Page Mill Road indicate that the Hanover Fault marks the boundary between two groundwater regimes (Jeanne Wahler, oral commun., 1990).

On a regional scale the Pulgas, Hanover, Jasper, and Roble Faults all appear to be parts of the system of southwest-dipping reverse faults which includes the Sargent-Berrocal Fault Zone to the southeast (McLaughlin, 1974; Sorg and McLaughlin, 1975) and the Serra Fault Zone to the northwest (Bonilla, 1971; Pampeyan, 1981a, 1993), and probably constitute what Willis (1938, fig. 1) envisioned as the Foothill Thrust along the west edge of the flatlands of the San Francisco peninsula.

The San Andreas Fault is known to be tectonically active and, accordingly, has been zoned for Special Studies (California Division of Mines and Geology, 1974; Hart, 1988). No other faults in the immediate vicinity are known to be tectonically active, although some coseismic slip in the Monte Vista Fault zone may have occurred during the Loma Prieta earthquakes of October 1989. The Cañada trace of Dickinson (1970, 1973) has been designated potentially active and zoned for Special Studies (California Division of Mines and Geology, 1974) even though no actual fault break has been exposed along its indicated trend (fig. 4). Within the map area the San Andreas Fault is seismically active, as is the Monte Vista Fault Zone, extending into the map area from the southeast, and the Pulgas (Stanford Fault of Brabb and Olson, 1986) and Pilarcitos Faults are classified as probably seismically active on the basis of clusters of seismic events assigned to their respective fault-plane projections (Brabb and Olson, 1986).

GEOPHYSICAL INTERPRETATIONS

The basement-rock surface beneath the alluvial plain is irregular, and it deepens southeastward across the map. Its depth has been verified in the logs of several water wells (Pampeyan 1970a, b; Brabb and others, 1990), but these logs are not sufficiently detailed to permit positive identification of Cenozoic formations in the subsurface in much of the area. Several data points, however, along with geophysical data, suggest where Tertiary units are present and provide evidence that other faults very likely are present beneath the alluvial plain (Oliver, 1990).

Both gravity and aeromagnetic surveys have been made in this area and subsurface faults inferred from these surveys were published in a report by Pampeyan (1979). Data from more recent surveys (Brabb and Hanna, 1981; Carle and Langenheim, 1990) were used to prepare bedrock-surface maps of the northeastern part of the Palo Alto 7-1/2' quadrangle (Brabb and others, 1990; Carle and others, 1990), and additional aeromagnetic surveys have increased the resolution of the earlier surveys (V.E. Langenheim, oral commun., 1991).

Aeromagnetic surveys show several linear positive magnetic anomalies which are interpreted to represent steeply dipping tabular serpentinite bodies at depth in zones of crustal weakness (Brabb and Hanna, 1981). The most pronounced of these is the Redwood City anomaly which trends northwest across the northern part of the map area (figs. 4, 5). Near the San Mateo bridge this anomaly splits into north and south branches, probably the result of folding or faulting of the serpentinite source (Brabb and Hanna, 1981). The recent gravity study by Carle and Langenheim (1990) shows a broad negative isostatic residual anomaly in the same area, thought to represent a serpentinite body at depth, overlain by graywacke probably in a wide zone of faulting—the Redwood City Fault Zone of Brabb and others (1990) and Carle and others (1990) (fig. 4). The boundaries of the wide residual gravity anomaly coincide approximately with the subsurface Palo Alto and San Jose Faults of Taylor (1956) and California Department of Water Resources (1967, fig 4; Carle and others, 1990). The few wells in this zone which penetrate basement rocks do not cut rocks identified as serpentinite, but those wells effectively stop at the basement-rock surface. Other linear positive magnetic anomalies are present in the southern part of the map area (fig. 5). The Woodside anomaly trends southeast along the broad serpentinite body, and the Searsville Lake anomaly follows the elongate serpentinite body in Jasper Ridge (Brabb and Hanna, 1981). An unnamed anomaly northeast of the Searsville Lake anomally may mark a zone of crustal weakness—or fissure—from which the Woodside serpentinite body originated and along which the small serpentinite diapir was emplaced (V.E. Langenheim and R.F. Sikora, unpubl. data, 1991). This zone of weakness may also be a branch of the zone marked by the Searsville Lake anomaly.

The gravity data (Dibblee, 1966; Robbins and others, 1982; Carle and others, 1990) show a basement- rock ridge extending east-southeast from the northwest corner of the Palo Alto 7-1/2' quadrangle. Carle and others (1990) interpret the ridge to be bounded by a fault along its southwest side, between the Belmont Hill and Pulgas Faults. This fault, referred to as the Atherton Fault (fig. 4; Carle and others, 1990) is thought to juxtapose less dense Tertiary rocks against the basement ridge. The Atherton Fault appears to be truncated at San Francisquito Creek by an inferred northeast-striking fault in the subsurface referred to as the San Francisquito Fault (Carle and others, 1990). The latter fault has the same strike as some northeast-trending faults which cut Eocene and Miocene rocks near SLAC, southwest of the Pulgas Fault, and appears to displace the Atherton Fault in the same sense as the Tertiary rocks and Pulgas Fault appear to be offset (V.E. Langenheim and R.F. Sikora, unpub. data, 1991). The west end of the inferred Atherton Fault is subparallel to Taylor's (1956) Stanford Fault which Taylor extended continuously south- southeast on the basis of his gravity data. The interested reader is referred to the report by Oliver (1990) for a complete description of recent geophysical studies in this map area.

ROCK ALTERATION

Evidence of hydrothermal ammonium alteration was found at several localities in the southern part of the map area. At seven of these localities igneous and sedimentary rocks have been altered by the substitution of ammonium for potassium or other alkali cations in feldspars, micas, smectites, and jarosites (Dennis Krohn and Steve Altmer, unpub. data, 1985), the most common conversion being feldspar to the mineral buddingtonite (Erd and others, 1964). At an eighth locality, glass shards of a vitric tuff bed in the Monterey Shale gave a positive test for ammonia. The alteration product was recognized in 1964 while analyzing samples of a rhyolite dike in west Menlo Park. Subsequent investigation uncovered the other sites where ammonia was present in the rocks.

The dike rock is mostly buff colored to rust-red-stained amorphous clayey material covered by a thin cap of silicified breccia containing sandstone, siltstone, claystone, and rhyolite fragments. X-ray diffraction studies show the dike rock is predominantly buddingtonite and quartz. Small amounts of other minerals identified in the altered dike rock include ammoniojarosite, gypsum, niter, oily hydrocarbons in quartz-lined vugs, alunite, limonite, cinnabar, and ammonium muscovite, with traces of pyrite, anatase, chalcopyrite, and carnotite(?). Small to trace amounts of marcasite, pyrrhotite, covelite, and jarosite also were identified by R.C. Erd, Jr. (oral commun., 1964). Some—perhaps all—of the mineralization is related to the hydrothermal alteration, for many of the sulfide minerals are in seams of ammoniojarosite. The occurrence of buddingtonite and related mineralization is similar to that of the Sulphur Bank Mine in northern California where buddingtonite was discovered (White and Roberson, 1962; Erd and others, 1964). Age of the alteration and mineralization probably is late Tertiary as in other nearby major mineralized districts in the Coast Ranges. The presence of ammonia in vitric tuff of the Monterey Shale suggests a temporal relation between intrusion of the dike, ammonia alteration, and deposition of the ammonia-rich vitric tuff. Source of the ammonia is unknown but it may have been transported by hydrothermal solutions from organic-rich sedimentary rocks at depth. In recent years ammonium minerals have been found in several hot-spring mercury deposits near disseminated gold deposits.

Hydrothermally altered serpentinite commonly known as silica-carbonate rock is present locally on the margins of serpentinite bodies or as pods in Franciscan rocks. Whether or not the silica-carbonate rock represents the same or a separate episode of alteration as the ammonium alteration is unknown, but they may both be part of a larger episode of late Tertiary hydrothermal activity.

Basalt flows exposed in the largest quarry along old Page Mill Road locally appear to be hydrothermally altered. No evidence of metallic mineralization was seen in the bleached, clayey, altered zones, but pyrite and marcasite are disseminated throught the lower fresh-appearing flows.

MINERAL RESOURCES

Metallic minerals have been found in the map area, but only one deposit contained ore-grade material. Silica-carbonate rock in the northernmost serpentinite body was described by Rogers (1911) as containing cinnabar, native mercury, calomel, and eglestonite. Between 1955 and 1959, preceding residential development of the area, more than 1,700 flasks of mercury were produced from ore taken from the Farm Hill (Challenge) Mine, an open-cut operation along the north edge of Stulsaft Park (Pennington and Greenspoon, 1958a, b, c; Davis and others, 1959). In subsequent exploration studies R.J. Weiskal (written commun., 1967) recognized the presence of montroydite, metacinnabar, and terlinguaite(?) and determined that significant mercury deposits remained adjacent to the Farm Hill Mine area.

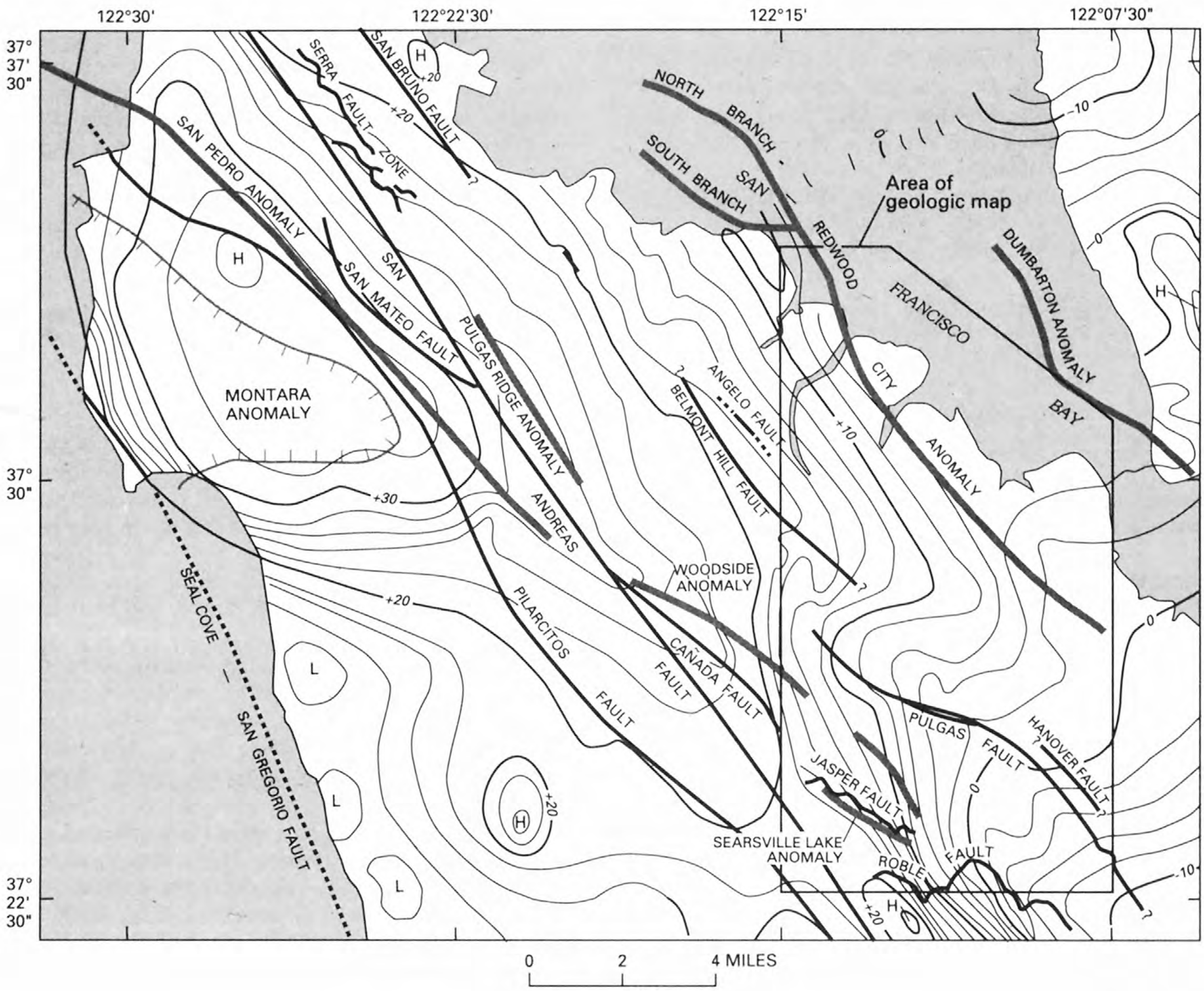
The Franciscan rocks of Jasper Ridge were prospected for gold between 1878–1915 (Repass, 1923). Apparently no ore was found, but in a dump near one shaft I saw traces of galena and sphalerite in greenstone, and in prospect pits on pods of silica-carbonate rock I saw traces of galena, pyrite, and cinnabar.

Along Arastadero Road, half a mile east of Alpine Road, Franciscan chert is banded with hematite and resembles metallic black-and-red-banded iron-rich rocks of the Great Lakes region. The outcrop of chert here is in the upper plate of the Roble Thrust Fault and the iron-rich rock is of possible interest only to mineral collectors.

Salt (NaCl) production in solar evaporation ponds along the edge of San Francisco Bay was a significant industry in Redwood City beginning about 1906 (Ver Planck, 1958). Much of the marshland was diked off for the evaporation ponds, and salt was harvested regularly for at least 60 years until the salt production industry moved on to make way for commercial and residential developments.

Another nonmetallic nonrock commodity of the map area was oyster (*Ostrea lurida*) shells dredged from the bay for use in making Portland cement. In 1924 the Pacific Portland Cement Company began an operation in Redwood City (Bowen, 1957) which continued until the 1970's when the plant became uneconomic to maintain. The oyster shells provided lime, and the accompanying clayey sediment provided alumina, silica, and iron oxide for the cement making process (Bowen and Gray, 1962a, b).

Basalt was produced commercially from quarries along old Page Mill Road for use in runways at Moffett Naval Air Station, U.S. Highway 101, and local roads, rip rap for Felt Lake dam, and aggregate in many post-1919 Stanford University buildings (Atchley and Grose, 1954). Pyrite and marcasite, visible in freshly broken samples from the lower part of the basalt section are reactive and decompose rapidly on exposure, causing much of the basalt to be unsuitable for many uses; the upper part of the basalt section, however, appears to have no deleterious properties. The quarries have been idle since the early 1960's.



EXPLANATION

Crestline of linear positive magnetic anomaly

Boundary of negative magnetic anomaly—Hachures point toward lower value

Complete Bouguer gravity contour—H, gravity high; L, gravity low. Contour interval 2 milligals

Fault—Dotted where concealed; queried where uncertain

Figure 5. Sketch map showing complete Bouguer gravity contours, aeromagnetic anomalies, and principal faults in the study area and vicinity. Gravity data from Robbins and others (1982). Aeromagnetic data from Brabb and Hanna (1981) and V.E. Langenheim and R.F. Sikora (unpub. data, 1991).

REFERENCES CITED

Adam, D.P., McLaughlin, R.J., Sorg, D.H., Adams, D.B., Forester, R.M., and Repenning, C.A., 1983, An animal- and plant-fossil assemblage from the Clara Formation (Pliocene and Pleistocene), Saratoga, California, *in* Andersen, D.W., and Rymer, M.J., eds., Tectonics and sedimentation along faults of the San Andreas system: Los Angeles, Society of Economic Paleontologists and Mineralogists, Pacific Section, p. 105–110.

Addicott, W.O., 1969, Late Pliocene mollusks from northwest Santa Clara County, California, and their paleogeographic significance: Proceedings, California Academy of Sciences 4th Series, v. 37, no. 3, p. 57–93.

Argus, D.F., and Gordon, R.G., 1990, Pacific-North American Plate motion from very long baseline interferometry compared with motion inferred from magnetic anomalies, transform faults, and earthquake slip vectors: Journal of Geophysical Research, v. 95, no. B11, p. 17,315–17,324.

Atchley, F.W., and Grose, L.T., 1954, Geology of the Page Mill Quarry area, Stanford, California: Report prepared for the Utah Construction Company, San Francisco, 12 p., appendices.

Atwater, B.F., Hedel, C.W., and Helley, E.J., 1977, Late Quaternary depositional history, Holocene sea-level changes, and vertical crustal movement, southern San Francisco Bay, California: U.S. Geological Survey Professional Paper 1014, 15 p.

Bailey, E.H., Irwin, W.P., and Jones, D.L., 1964, Franciscan and related rocks, and their significance in the geology of western California: California Division of Mines and Geology Bull. 183, 177 p.

Beaulieu, J.D., 1970, Cenozoic stratigraphy of the Santa Cruz Mountains, California, and inferred displacement along the San Andreas fault: Stanford, California, Stanford University, Ph.D. dissertation, 202 p.

———1971, Cenozoic stratigraphy of the Santa Cruz Mountains, and inferred displacement along the San Andreas fault: Dissertation Abstracts International, Part B., Science and Engineering, v. 32, no. 2, p. 1019-B.

Bennett, J.H., 1980, Geodimeter measurements of strain and slip along the northern San Andreas fault system, *in* Streitz, Robert, and Sherburne, Roger, eds., Studies of the San Andreas fault zone in northern California: California Division of Mines and Geology Special Report 140, p. 99–109.

Bonilla, M.G., 1971, Preliminary geologic map of the San Francisco South quadrangle and part of the Hunters Point quadrangle, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–311, scale 1:24,000.

Bowen, O.E., Jr., 1957, Cement, in Wright, L.A., ed., Mineral commodities of California: California Division of Mines Bull. 176, p. 113–120.

Bowen, O.E., and Gray, C.H., Jr., 1962a, The Portland cement industry in California, 1962—Part I: California Division of Mines and Geology, Mineral Information Service, v. 15, no. 7, p. 1–7.

———1962b, The Portland cement industry in California, 1962—Part II: California Division of Mines and Geology, Mineral Information Service, v. 5, no. 8, p. 1-11.

Brabb, E.E., and Hanna, W.F., 1981, Maps showing aeromagnetic anomalies, faults, earthquake epicenters, and igneous rocks in southern San Francisco Bay region: U.S. Geological Survey Geophysical Map GP–932, scale 1:125,000.

Brabb, E.E., and Olson, J.A., 1986, Map showing faults and earthquake epicenters in San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-F, scale 1:62,500.

Brabb, E.E., and Pampeyan, E.H., 1972, Preliminary map of landslide deposits in San Mateo County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF-344, scale 1:62,500.

———1983, Geologic map of San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-A, scale 1:62,500

Brabb, E.E., Carle, S.F., and Pampeyan, E.H., 1990, Map showing elevation of bedrock surface beneath the flatlands of Menlo Park, Atherton, and adjoining areas, California, in Oliver, H.W., ed., Preliminary ground water quality data and the extent of the ground water basin from drill hole, gravity, and seismic data in the Palo Alto 7-1/2-minute quadrangle, California: U.S. Geological Survey Open-File Report 90-74, pl. 1, map scale 1:24,000.

Brabb, E.E., Pampeyan, E.H., and Bonilla, M.G., 1972, Landslide susceptibility in San Mateo County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–360, scale 1:62,500.

Brabb, E.E., Taylor, F.A., and Miller, G.P., 1982, Geologic, scenic, and historic points of interest in San Mateo county, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-B, scale 1:62,500.

Branner, J.C., 1907, Geology and the earthquake, *in* Jordan, D.S., ed., The California earthquake of 1906: San Francisco, A.M. Robertson, p. 63–78.

Branner, J.C., Newsom, J.F., and Arnold, Ralph, 1909, Description of the Santa Cruz quadrangle, California: U.S. Geological Survey Geologic Atlas 163, Santa Cruz Folio, 11 p., map scale 1:125,000.

Broecker, W.S., Kulp, J.L., and Tucek, C.S., 1956, Lamont natural radiocarbon measurements III: Science, v. 124, no. 3213, p. 154–165.

Bukry, David, Brabb, E.E., and Vedder, J.G., 1977, Correlation of Tertiary nannoplankton assemblages from the Coast and Peninsular Ranges of California: Segundo Congreso Latinoamericano de Geologica, Memoria, t. 3, p. 1461–1483.

California Division of Mines and Geology, 1974, Special Studies Zones, Palo Alto quadrangle: California Division of Mines and Geology, map scale 1:24,000.

California Department of Water Resources, 1967, Evaluation of ground water resources, South Bay: California Department of Water Resources Bulletin 118-1, Appendix A, 153 p., pl. 3, map scale 1:130,000.

Carle, S.F., and Langenheim, V.E., 1990, Isostatic residual gravity anomaly map of the Palo Alto 7-1/2 quadrangle, California, *in* Oliver, H.A., ed., Preliminary ground water quality data and the extent of the ground water basin from drill hole, gravity, and seismic data in the Palo Alto 7-1/2-minute quadrangle, California: U.S. Geological Survey Open-File Report 90- 74, pl. 2, scale 1:24,000.

Carle, S.F., Langenheim, V.E., Brabb, E.E., and Pampeyan, E.H., 1990, Geophysical interpretative map of bedrock surface beneath the flatland areas of Menlo Park, Atherton, and adjoining areas, California, *in* Oliver, H.W., ed., Preliminary ground water quality data and the extent of the ground water basin from drill hole, gravity, and seismic data in the Palo Alto 7-1/2-minute quadrangle, California: U.S. Geological Survey Open-File Report 90–74, pl. 3, scale 1:24,000.

Carlson, Christine, 1984, Introduction, *in* Carlson, Christine, ed., Depositional facies of sedimentary serpentinite; selected examples from the Coast Ranges, California: Society of Economic Paleontologists and Mineralogists, Field Trip Guidebook no. 3, 1984 midyear meeting, San Jose, Calif., p. 73–76.

Cummings, J.C., 1968, The Santa Clara Formation and possible post-Pliocene slip of the San Andreas fault in central California, *in* Dickinson, W.R., and Grantz, Arthur, eds., Proceedings of conference on geologic problems of San Andreas fault system: Stanford University Publications in the Geological Sciences, v. 11, p. 191–207.

———1972, The Santa Clara Formation on the San Francisco Peninsula, *in* Frizzell, Virgil, Helley, E.J., and Adam, D.P., eds., Progress report on the USGS Quaternary studies in the San Francisco Bay area: Friends of the Pleistocene Guidebook, Oct. 6–8, 1972, p. 3–10.

Cummings, J.C., Touring, R.M., and Brabb, E.E., 1962, Geology of the northern Santa Cruz Mountains, California, in Geologic guide to the gas and oil fields of northern California, Pt. II: California Division of Mines and Geology Bulletin 181, p. 179–220.

Darrow, R.K., 1963, Age and structural relationships of the Franciscan Formation of the Montara Mountain quadrangle: California Division of Mines and Geology Special Report 78, 23 p.

Davis, L.E., Branner, G.C., Mull, J.B., and Ashizawa, R.Y., 1959, The mineral industry of California, in Minerals Yearbook 1958: U.S. Bureau of Mines, v. III, p. 143–200.

Dibblee, T.W., Jr., 1966, Geology of the Palo Alto quadrangle, Santa Clara and San Mateo Counties, California: California Division of Mines and Geology Map 8, scale 1:62,500.

Dickinson, W.R., 1970, Commentary and reconnaissance photogeologic map, San Andreas rift belt, Portola Valley (California): Unpubl. report prepared for the Town of Portola Valley, 48 p.

———1973, Reconnaissance of active traces of San Andreas fault in Woodside (California): Unpubl. report prepared for the Town of Woodside, 23 p.

Dobbs, R.O., and Forbes, C.F., 1960, Geologic map of the Stanford foothills, *in* Atchley, F.W., and Dobbs, R.O., Geological investigation of the Stanford Two-Mile Linear Accelerator site: Microwave Lab. Report no. 682, W.W. Hansen Laboratories of Physics, Stanford University, Appendix II-B.

Dorf, Erling, 1933, Study of the Pliocene paleobotany of California: Carnegie Institution of Washington Contributions to Paleontology Publication 412, 12 p.

Earth Sciences Associates, 1983, Stanford Linear Accelerator Center Linear Collider, North and South Arc Tunnels, Title II, Geotechnical report: Earth Sciences Associates, Palo Alto, Calif., report prepared for Tudor Engineering Company, 149 New Montgomery Street, San Francisco, 20 p., appendices, 10 pl., photographs, logs of borings.

Ellen, S.D., and Wieczorek, G.E., eds., 1988, Landslides, floods, and marine effects of the storm of January 3–5, 1982, in the San Francisco Bay Region, California: U.S. Geological Survey Professional Paper 1434, 310 p., 14 pl.

Erd, R.C., Jr., White, D.E., Fahey, J.J., and Lee, D.E., 1964, Buddingtonite, an ammonium feldspar with zeolitic water: American Mineralogist, v. 49, nos. 7 and 8, pp. 831–850.

Fleck, R.J., 1967, Structural significance of the contact between Franciscan and Cenozoic rocks, southern San Francisco peninsula, California: Unpub. student report, Stanford University, 31 p., map scale 1:24,000.

Gerow, B.A., with Force, R.W., 1968, An analysis of the University Village complex with a reappraisal of Central California Archaeology: Leland Stanford Junior University, 209 p.

Glen, William, 1959, Pliocene and lower Pleistocene of the western part of the San Francisco peninsula: University of California Publications in Geological Sciences, v. 36, no. 2, p. 147–198.

Graham, J.J., 1967, Early Tertiary Foraminifera from Jasper Ridge, San Mateo County, California [abs.]: American Association of Petroleum Geologists Bulletin, v. 51, no. 3, pt. 1, p. 466.

Graham, J.J., and Church, C.C., 1959, Upper Cretaceous Foraminifera from Stanford University campus California [abs.]: Geological Society of America Bulletin, v. 70, no. 12, pt. 2, p. 1610.

———1963, Campanian Foraminifera from the Stanford University campus, California: Stanford University Publications in the Geological Sciences, v. 8, no.1, p. 1–85.

Graham, J.J., and Classen, W.J., 1955, A lower Eocene foraminiferal faunule from the Woodside area, San Mateo County, California: Contribution from Cushman Foundation for Foraminiferal Research, v. VI, pt. 1, p. 1–38, map scale 1:156.

Graham, S.A., Stanley, R.G., Bent, J.V., and Carter, J.B., 1989, Oligocene and Miocene paleogeography of central California and displacement along the San Andreas fault: Geological Society of America Bulletin, v. 101, no. 5, p. 711–730.

Hall, C.A., Jones, D.L., and Brooks, S.A., 1959, Pigeon Point Formation of Late Cretaceous age, San Mateo County, California: American Association of Petroleum Geologists Bulletin, v. 43, no. 12, p. 2855–2865 [fig. 2 is geologic map 1"=2.75 mi].

Harsh, P.W., 1977, Alinement array measurements on the San Andreas fault in northern California and their significance [abs.]: Geological Society of America Abstracts with Programs, v. 9, no. 4, p. 431.

Hart, E.W. 1988, Fault-rupture hazard zones in California: California Division of Mines and Geology Special Publication 42, 24 p.

Hay, O.P., 1927, The Pleistocene of the western region of North America and its vertebrated animals: Carnegie Institute of Washington, Publication No. 322B, 346 p., 12 pls.

Helley, E.J., and Lajoie, K.R., 1979, Geology and engineering properties of the flatland deposits, *in* Helley, E.J., Lajoie, K.R., Spangle, W.E., and Blair, M.L., Flatland deposits of the San Francisco Bay Region, California—their geology and engineering properties, and their importance to comprehensive planning: U.S. Geological Survey Professional Paper 943, p. 14–68, pl. 3, map scale 1:125,000.

Helley, E.J., Adam, D.P., and Burke, D.B., 1972, Late Quaternary stratigraphic and paleoecological investigations in the San Francisco Bay area, *in* Frizzell, Virgil, Helley, E.J., and Adam, D.P., eds., Progress report on the USGS Quaternary studies in the San Francisco Bay area: Friends of the Pleistocene Guidebook, Oct. 6-8, 1972, p. 19–29.

Helley, E.J., Lajoie, K.R., Spangle, W.E., and Blair, M.L., 1979, Flatland deposits of the San Francisco Bay Region, California—their geology and engineering properties, and their importance to comprehensive planning: U.S. Geological Survey Professional Paper 943, 87 p., 3 pl., map scale 1:125,000.

Hensolt, W.H., and Brabb, E.E., 1990, Maps showing elevation of bedrock and implications for design of engineered structures to withstand earthquake shaking in San Mateo County, California: U.S. Geological Survey Open-File Report 90-496, scale 1:62,500.

Hogg, S.L., 1963, The geology of the Stanford foothills, Santa Clara County, California: Unpub. student report, Stanford University, 26 p., map scale 1:24,000.

Ives, P.C., Levin, Betsy, Oman, C.L., and Rubin, Meyer, 1967, U.S. Geological Survey radiocarbon dates IX: Radiocarbon, v. 9, p. 515.

Kheradyar, Tara, 1987, Coccolith biostratigraphy of the Eocene Butano Sandstone, San Mateo County, California: M.A. thesis, University of California, Berkeley, 205 p.

Krynine, P.D., and Judd, W.R., 1957, Principles of engineering geology and geomechanics: New York, McGraw-Hill, 730 p.

Lambe, T.W., 1960, The character and identification of expansive soils: Washington, D.C., Federal Housing Administration Technical Studies Report, FHA-701, 51 p.

Langerfeldt, H.C., and Vigrass, L.W., 1959, Engineering geology of the proposed site of Project "M", Stanford, California, in U.S. Congress, Joint Committee on Atomic Energy, Subcommittee on Research and Development, and Subcommittee on Legislation, Stanford Linear Electron Accelerator, Hearings: U.S. 86th Congress, 1st Session, app. D, p. 617– 626.

Lawson, A.C., chm., 1908, The California earthquake of April 18, 1906: Report of the State Earthquake Investigation Commission: Carnegie Institute of Washington Publication 87, v. 1, 451 p., atlas.

Lawson, A.C., 1914, San Francisco folio, California: U.S. Geological Survey, Geologic Atlas of the United States, no. 193, 24 p., 15 maps, scale 1:62,5000.

Mack, J.E., Jr., 1959, Reconnaissance geology of the Woodside quadrangle, San Mateo County, California: Stanford, California, Stanford University, M.S. thesis, 79 p.

Mark, R.K., and Newman, E.B., 1988, Slope map of San Mateo county, California: U.S. Geological Survey Miscellaneous Investigations Series Map 1257-J, scale 1:62,500.

Martin, L.T., 1937, Upper Cretaceous Foraminifera from the Chico formation, San Francisquito Creek, California: Geological Society of America, Proceedings, 1936, p. 394.

McLaughlin, R.J., 1974, the Sargent-Berrocal fault zone and its relation to the San Andreas fault system in the southern San Francisco Bay region and Santa Clara Valley, California: U.S. Geological Survey Journal of Research, v. 2, no. 5, p. 593-598.

McLaughlin, R.J., Clark, J.C., and Brabb, E.E., 1988, Geologic map and structure sections of the Loma Prieta 7-1/2' quadrangle, Santa Clara and Santa Cruz Counties, California: U.S. Geological Survey Open-File Report 88-752, scale 1:24,000.

Nilsen, T.H., 1979, General geology of the Santa Cruz Mountains, California, *in* Nilsen, T.H. and Brabb, E.E., eds., Geology of the Santa Cruz Mountains: Geological Society of America Cordilleran Section Field Trip Guidebook No. 7, p. 6–16, April 9–11, 1979.

Nilsen, T.H., and Brabb, E.E., 1979, Geology of the Santa Cruz Mountains, California: Geological Society of America Cordilleran Section Field Trip Guidebook No. 7, 97 p.

Nilsen, T.H., and Clarke, S.H., 1975, Sedimentation and tectonics in the early Tertiary continental borderland of central California: U.S. Geological Survey Prof. Paper 925, 64 p.

Nilsen, T.H., and Simoni, T.R., 1973, Deep-sea fan paleocurrent patterns of the Eocene Butano Sandstone, Santa Cruz Mountains, California: U.S. Geological Survey Journal of Research, v. 1, no. 4, p. 439–452.

Oliver, H.W., ed., 1990, Preliminary ground water quality data and the extent of the ground water basin from drill hole, gravity, and seismic data in the Palo Alto 7-1/2-minute quadrangle, California: U.S. Geological Survey Open-File Report 90-74, 21 p., 3 pl., map scale 1:24,000.

Packard, E.L., 1962, Fossil mammals from the vicinity of Stanford University: Journal of Paleontology, v. 3, no. 1, p. 29–37.

Page, B.M., and Tabor, L.L., 1967, Chaotic structure and decollement in Cenozoic rocks near Stanford University, California: Geological Society of America Bulletin, v. 78, p. 1–12.

Pampeyan, E.H., 1970a, Geologic map of the Palo Alto 7-1/2-minute quadrangle, San Mateo and Santa Clara Counties, California: U.S. Geological Survey Open-File Map, scale 1:12,000.

———1970b, Geologic map of the southern part of the Redwood Point 7-1/2-minute quadrangle, San Mateo County, California: U.S. Geological Survey Open-File Map, scale 1:12,000.

———1979, Preliminary map showing recency of faulting in coastal north-central California: U.S. Geological Survey Miscellaneous Field Studies Map MF–1070, scale, 1:250,000.

———1981a, Geologic map of the Montara Mountain quadrangle, San Mateo County, California: U.S. Geological Survey Open-File Report 81–451, 14 p., scale 1:12,000.

———1981b, Geology and former shoreline features of the San Mateo 7-1/2' quadrangle, San Mateo County, California: U.S. Geological Survey Open-File Report 81-839, 12 p., map scale 1:24,000.

———1994, Geologic map of the Montara Mountain and San Mateo 7 1/2' quadrangles, San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–2390, 20 p., scale 1:24,000.

Pennington, J.W., and Greenspoon, G.N., 1958a, Mercury, *in* Minerals Yearbook 1955: U.S. Bureau of Mines, v. I, p. 771–791.

———1958b, Mercury, *in* Minerals Yearbook 1956: U.S. Bureau of Mines, v. I, p. 813-830.

———1958c, Mercury, *in* Minerals Yearbook 1957: U.S. Bureau of Mines, v. I, p. 821–839.

Perkins, J.B., 1987, Maps showing cumulative damage potential from earthquake ground shaking, San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-I, scale 1:62,500.

Reed, R.D., 1933, Geology of California: Tulsa, Okla, American Association of Petroleum Geologists, 355 p.

Repass, M.M., 1923, The Hermit mine: Stanford, California, Stanford University, Engineer's Degree thesis, 76 p.

Repenning, C.A., 1965, Stanford fossil—studied by U.S.G.S.: California Division of Mines and Geology, Mineral Information Service, v. 18, no. 6, p. 124–125.

Robbins, S.L., Roberts, C.W., and Chapman, R.H., 1982, Bouguer gravity map of the southern San Francisco Bay region, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–780-C, scale 1:125,000.

Rogers, A.F., 1911, Eglestonite from San Mateo County, California: American Journal of Science, 4th ser., v. 32, p. 48–50.

Rogers, T.H., and Williams, J.W., 1974, Potential seismic hazards in Santa Clara County, California: California Division of Mines and Geology Special Report 107, 39 p.

Sarna-Wojcicki, Meyer, C.E., Bowman, H.R., Hall, N.T., Russell, P.C., Woodward, M.J., and Slate, J.L.,.1985, Correlation of Rockland ash bed, a 400,000-year-old stratigraphic marker in northern California and western Nevada, and implications for middle Pleistocene paleography of central California: Quaternary Research, v. 23, p. 236–257.

Scott, G.R., 1969, General and engineering geology of the northern part of Pueblo, Colorado: U.S. Geological Survey Bulletin 1262, 131 p.

Skjei, R.E., Conwell, F.R., Brittain, J.H., Tabor, L.L., and Danehy, E.A., 1965, Geologic site investigation for Stanford Linear Accelerator Center: Aetron-Blume-Atkinson, Palo Alto, Calif., Report No. ABA-88, U.S. Atomic Energy Commission Contract AT (04-3)-400, 75 p.

Sorg, D.H., and McLaughlin, R.J., 1975, Geologic map of the Sargent-Berrocal fault zone between Los Gatos and Los Altos Hills, Santa Clara County, California: U.S. Geological Survey Miscellaneous Field Studies Map MF–643, scale 1:24,000.

Steiger, R.H., and Jager, E., 1977, Subcommission on geochronology: Convention on the use of decay constants in geo- and cosmochronology: Earth and Planetary Science and Letters, v. 36, p. 359–362.

Taber, Stephen, 1906, Some local effects of the San Francisco earthquake: Journal of Geology, v. 14, p. 303–315.

Tabor, L.L., 1962, Interim geological report on the Stanford Two-Mile Linear Electron Accelerator site, San Mateo County, California: Report to Stanford Linear Accelerator Center, No. ABA-60, Aetron-Blume-Atkinson, Palo Alto, 39 p.

Tarduno, J.A., Blake, M.C., and Sliter, W.V., 1991, Stratigraphy and structure of the Permanente terrane, southern San Franciscio Bay area [abs.]: Geological Society of America Abstracts with Programs, v. 23, no. 2, p.

Taylor, C.L., Cummings, J.C., and Ridley, A.P., 1980, Discontinuous en echelon faulting and ground warping, Portola Valley, California, in Streitz, Robert, and Sherburne, Roger, eds., Studies of the San Andreas fault zone in northern California: California Division of Mines and Geology Special Report 140, p. 59–70.

Taylor, S.G., 1956, Gravity investigations of the southern San Francisco Bay Area: Stanford, California, Stanford University, Ph.D. thesis, 105 p.

Thomas, R.G., 1949, Geology of the northwest part of the Palo Alto (15-minute) quadrangle, California: unpub. map in Branner Library, Stanford University. scale 1:20,000.

———1951, An example of reintrusion of serpentine: Transactions of the American Geophysical Union, v. 32, no. 3, p. 462–465.

Thomson, J.M., and Evernden, J.F., 1986, Map showing predicted shaking intensities of an earthquake in San Mateo County, California, comparable in magnitude to the 1906 earthquake: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-H, scale 1:62,500.

Tieh, T.T., 1965, Heavy mineral assemblages in some Tertiary sediments near Stanford University: Stanford, California, Stanford University Ph.D. dissertation, 148 p.

Turner, D.L., 1970, Potassium-argon dating of Pacific Coast Miocene foraminiferal stages, in Radiometric dating and paleontologic zonation: Geological Society of America Special Paper 124. p. 91–129.

U.S. Coast Survey, 1853, Pulgas base, San Francisco County, California: U.S. Coast Survey, Register No. 432, scale 1:10,000.

———1857a, San Francisco Bay (between Guano Island and Ravenswood): U.S. Coast Survey, Register No. 664, scale 1:10,000.

———1857b, San Francisco Bay, California (between Belmont and Redwood City): U.S. Coast Survey, Register No. 665, scale 1:10,000.

———1857c, San Francisco Bay, California (between Ravenswood and Alviso): U.S. Coast Survey, Register No. 676, scale 1:10,000).

U.S. Coast and Geodetic Survey, 1897a, Pacific Coast, Resurvey of San Francisco Bay, California, San Carlos to Menlo Park: U.S. Coast and Geodetic Survey Register No. 2311, scale 1:10,000.

———1897b Pacific Coast, Resurvey of San Francisco Bay, Menlo Park to near Mountain View: U.S. Coast and Geodetic Survey, Register No. 2312, scale 1:10,000.

Vanderhurst, W.L., Cummings, J.C., and Andersen, D.W., 1982, The Santa Clara Formation as a record of late Cenozoic uplift of the Santa Cruz Mountains, Santa Clara County, California, *in* Ingersoll, R.V., and Woodburne, M.O., eds., Cenozoic Nonmarine Deposits of California and Arizona: Los Angeles, Pacific Section Society of Economic Paleontologists and Mineralogists, p. 23–33, April 16, 1982.

Ver Planck, W.E., 1958, Salt in California: California Division of Mines Bulletin 175, 168 p.

Wakabayashi, John, and Moores, E.M., 1988, Evidence for the collision of the Salinian block with the Franciscan subduction zone: Journal of Geology, v. 96, p. 245–253.

Watts, W.L., 1890, San Mateo County, in Tenth Annual Report of the State Mineralogist: California State Mining Bureau, p. 586–594.

Wentworth, C.M., Ellen, Stephen, Frizzell, V.A., Jr., and Schlocker, Julius, 1985, Map of hillside materials and description of their engineering character, San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-D, scale 1:62,500.

White, D.E., and Roberson, C.E., 1962, Sulphur Bank, California, a major hot- spring quicksilver deposit: Geological Society of America Buddington volume, p. 397–428.

Wieczorek, G.F., Wilson, R.C., and Harp, E.L., 1985, Map showing slope stability during earthquakes in San Mateo county, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-E, scale 1:62,500.

Willis, Bailey, 1924, Earthquake risk in California, pt. 9: Seismological Society of America Bulletin, v. 14, no. 2, p. 150–164.

———1938, San Andreas rift, California: Journal of Geology, v. 46, no. 6, p. 793–827.

Wright, R.H., 1971, Map showing locations of samples dated by radiocarbon methods in the San Francisco Bay region: U.S. Geological Survey Miscellaneous Field Studies Map MF-317, scale 1:500,000.

Youd, T.L., and Perkins, J.B., 1987, Map showing liquefaction susceptibility of San Mateo County, California: U.S. Geological Survey Miscellaneous Investigations Series Map I–1257-G, scale 1:62,500.

Table 1: *Fossil collections from Palo Alto and part of Mindego Hill 7-1/2' quadrangles and adjacent areas, California. See figure 3 for location of sample sites.*

[Samples collected by: a, W.O. Addicott; b, E.E. Brabb; c, J.C. Cummings; k, Kheradyar (1987); p, E.H. Pampeyan; r, C.A. Repenning; and sm, Sorg and McLaughlin (1975). Collections identified by: WOA, W.O. Addicott; NMB, N.M. Bramlette; DB, David Bukry; JEE, James E. Eke; MCI, M.C. Israelsky; TK, Tara Kheradyar; KEL, K.E. Lohman; KM, Kristin McDougall; EHP, E.H. Pampeyan; EP, Emil Pessagno; RLP, R.L. Pierce; CAR, C.A. Repenning; and PJS, P.J. Smith. Dashes indicate no number assigned: Note: the microfauna determinations, except for those by McDougall, were made in the 1960's and may not agree with current interpretations. All samples from San Francisco Bay block unless otherwise specified]

Map No. (fig. 3)	USGS sample No.	Collector and collectors sample No.	Fossil age (map unit)	Determined by	Notes
37	M1001	— — —	Rancholabrean <15,000 yr B.P. (QTu)	CAR	Matadero Creek bank, behind Palo Alto Veterans Administration Hospital. Bone scraps in olive-tan pebbly mudstone.
35	M1202	— — —	do	CAR	Matadero Creek at north edge of Foothill Expy. Bone scraps.
18	M1203	— — —	Rancholabrean ~20,000 yr B.P. (QTu)	CAR	Excavation for Oregon Expy underpass at Alma St., Palo Alto. Mammoth, horse, camel bones in tan silt above conglomeratic aquifer, 10-15 ft below land surface.
20	M1218		do	CAR	"Sunnyvale sewer" locality, drainage ditch between Arques and Taylor Aves., one block west of Fair Oaks Ave. Camel, mammoth, bear, squirrel bones exposed in ditch. Mountain View quadrangle.
19	M1227	— — —	do	CAR	"Mountain View dump" locality, largest exposure of fossiliferous horizon, 25 ft below mean sea level. Mountain View quadrangle. See Helley and others (1972) for description of site, flora and fauna.
1	M1302	— — —	do	CAR	Utility excavation opposite 2895 Middlefield Rd., 40 northwest of Dumbarton Ave., 13 ft below Rd. surface. Camel bones in water-bearing sand and gravel.
56	M1715	p63-416	Late Pliocene (Tme)	WOA	Pebbly sandstone under Santa Clara Formation, Arastradero Rd., 1,200 ft west of Page Mill Rd.
61	— — —	a577	do	WOA	Excavation at site of American Institute for Research, 2,100 ft east of Alpine Rd.-Arastradero Rd. intersection.
65	M1926	p63-681	do	WOA	Yellow-gray fine-grained sandstone exposed in prospect pit, south edge of Palo Alto 7-1/2' quadrangle.
66	M1927	p63-683	do	WOA	Yellow fine-grained fossiliferous sandstone exposed in gopher mounds, south edge of Palo Alto 7-1/2' quadrangle.
60	— — —	p63-356	do	EHP	Yellow to brown, fossiliferous fine-grained sand, pebbly sand and conglomerate in road-cuts along Arastradero Rd. west of Page Mill Rd.
58	— — —	p66-868			
57	— — —	p66-870			
59	— — —	p66-873			
74	M3253	c67-4	Early(?) Pliocene (Tp)	WOA	Hamms Gulch, Mindego Hill quadrangle. Pilarcitos block.
76	M3254	c67-12	do	WOA	Damiani Creek, Mindego Hill quadrangle. Pilarcitos block.
77	M3255	c67-17	do	WOA	Rapley Trail Rd., Mindego Hill quadrangle. Pilarcitos block.

Table 1: *Fossil collections from Palo Alto and part of Mindego Hill 7-1/2' quadrangles and adjacent areas, California. See figure 3 for location of sample sites.—Continued*

Map No. (fig. 3)	USGS sample No.	Collector and collectors sample No.	Fossil age (map unit)	Determined by	Notes
75	M3256	c67-47	do	WOA	Jones Gulch, Mindego Hill quadrangle. Pilarcitos block.
73	M2664	p63-913	do	WOA	Head of Neils Gulch, Mindego Hill quadrangle. Pilarcitos block.
72	M2665	p63-917	do	WOA	Neils Gulch near south edge of Palo Alto 7-1/2' quadrangle. Pilarcitos block.
47	———	b60-544	Probably Delmontian (late Miocene to Pliocene)	JEE	Light-gray, weathered, limy claystone of Monterey Shale along Page Mill Rd. at I-280.
55	———	b60-545	do	JEE	Lithology same as Sample No. b60-544. Along Arastradero Rd. adjacent to Sample No. M1715.
51	D5685	p64-723	Late middle or possibly early late Miocene (Tm)	KEL	Tuffaceous diatomite in clayey siltstone. Southwest of Page Mill Rd. and I-280 crossing, in Page Mill Estates.
36	———	p63-583	Middle Miocene (Tl)	WOA	Barnacle shell sandstone. Aqueduct trench along Foothill Expy. at Matadero Creek.
27	———	SHR	Middle and late Miocene (Tl)	WOA	Sandstone. Sand Hill Rd.
50	M1832	p63-625	Middle or late Miocene (Tl)	WOA	Very fine-grained sandstone with thin calcareous fossiliferous layers. Fremont Hills.
29	M1925	p63-648	Probably middle Miocene (Tl)	WOA	Fine-grained, poorly to well-sorted, poorly to well-cemented sandstone and pebbly sandstone. East end of Stanford Linear Accelerator.
48	M2547	a65-0	Probably middle Miocene (Tl)	WOA	Sandstone. Page Mill Rd. at I-280.
38	M5997	sm-117	Late Miocene (Tl)	WOA	Sandstone in Cupertino quadrangle (Sorg and McLaughlin, 1975).
	M5998	sm-118			
	M5999	sm-120			
	M6000	sm-121			
41	———	p62-269	Saucesian or Relizian (Tl)	PJS	Calcareous layer in siltstone. Ladera district.
42	———	p62-183	Middle Miocene (Tl)	PJS	Tan siltstone. Ladera district.
54	———	p63-417	Possibly middle Miocene (Tm)	RLP	Mudstone, siltstone, and siliceous shale near vertebrate Sample No. M1034 and tuffaceous diatomite Sample No. D5685. Southwest of Page Mill Rd. and I-280 crossing, in Page Mill Estates.
53	———	p63-418			
49	———	p66-829			
71	———	p66-918A	Early Relizian or	RLP	Shale, mudstone, porcelaneous shale, siliceous siltstone, and silty shale. Pilarcitos block, Portola Valley.
	———	p66-918B	ate Saucesian (Tm)		
70	———	p66-919	Early Relizian or late Saucesian (Tm)	RLP	Shale, mudstone, porcelaneous shale, siliceous siltstone, and silty shale. Pilarcitos block, Portola Valley.
69	———	p66-926	do		
68	———	p66-925	do		do
67	———	p66-945	do		do
26	———	p63-658E	Relizian/middle Miocene (Tl)	KM	Clayey siltstone. Sand Hill Rd..

Table 1: *Fossil collections from Palo Alto and part of Mindego Hill 7-1/2' quadrangles and adjacent areas, California. See figure 3 for location of sample sites.—Continued*

Map No. (fig. 3)	USGS sample No.	Collector and collectors sample No.	Fossil age (map unit)	Determined by	Notes
52	M1034	— — —	Clarendonian or Hemphillian late Miocene or possibly younger (Tm)	CAR	Siltstone and clayey siltstone. Southwest of Page Mill Rd. and I-280 crossing, in Page Mill Estates.
28	M1489	— — —	Middle Miocene (Tl)	CAR	Yellow-gray well-sorted medium- to fine-grained sandstone. East end of Stanford Linear Accelerator.
44	Mf707	p62-161	Narizian(?) (Tw)	MCI	Tan mudstone with foraminifera (Sample No. Mf 707), small mud pecten (Sample No. M1492), and coccoliths (Sample No. Mf2053). Westridge district.
45	M1492	p62-161	Late Eocene (Tw)	WOA	
46	Mf2053	b519B	Middle Eocene (Tw)	DB	
33	Mf708	p62-158	Ulatisian (Tw)	MCI	Black shale and mudstone with traces of pyrite. San Francisquito Creek.
39	Mf709	p62-299	do	MCI	Siltstone, shale, and calcareous shale. Westridge district.
17	Mf729	p63-340	do	MCI	Calcareous siltstone. San Francisquito Creek.
63	Mf730	p63-167	do	MCI	Mudstone and shale interlayered with sandstone. Westridge district.
40	Mf731	p63-165	Eocene (Tw)	MCI	Siltstone, Westridge district.
32	Mf732	p62-210	Ulatisian(?) (Tw)	MCI	Calcareous mudstone. Bear Creek at Sand Hill Rd.
62	Mf733	p62-246	Contains a form found in Paleocene rocks of Monterey County, Calif. (Tw)	MCI	Mudstone and siltstone alternating with sandstone. Alpine Rd., Westridge district.
9	Mf735	p63-390	Narizian (Tw)	MCI	Calcareous siltstone. Woodside Highlands.
7	Mf737	p63-409	do	MCI	Calcareous siltstone. Woodside Highlands.
8	Mf738	p63-411	Ulatisian (Tw)	MCI	Calcareous siltstone. Woodside Highlands.
16	Mf739	p63-338	Narizian(?) (Tw)	MCI	Mudstone. San Francisquito Creek.
64	Mf740	p62-172	Ulatisian or Narizian (Tw)	MCI	Thin-bedded argillaceous limestone. Westridge district.
10	Mf751	p63-442	Ulatisian (Tw)	MCI	Calcareous claystone and clayey limestone. Woodside Highlands.
24	Mf752	p63-497	do	MCI	Calcareous claystone. Sharon Heights district.
34	Mf753	p63-535	do	MCI	Calcareous siltstone. "Telescope Ridge," Stanford.
11	Mf754	p63-556A	do	MCI	Calcareous claystone. Woodside High school.
12	Mf755	p63-556B	Ulatisian or Narizian (Tw)	MCI	Micaceous siltstone. Woodside High School.
13	Mf756	p63-556E	Narizian (Tw)	MCI	Calcareous siltstone. Woodside High School.
43	Mf757	p62-74	Penutian to Narizian (Tw)	MCI	Shale and siltstone. Westridge district.
30	Mf748	p24+50	Ulatisian or Narizian Laiming's A-2 Early middle Eocene (Tw)	MCI NMB EP	Calcareous mudstone. West end of Stanford Linear Accelerator.

Table 1: *Fossil collections from Palo Alto and part of Mindego Hill 7-1/2' quadrangles and adjacent areas, California. See figure 3 for location of sample sites.—Continued*

Map No. (fig. 3)	USGS sample No.	Collector and collectors sample No.	Fossil age (map unit)	Determined by	Notes
2	Mf750	p63-363	Cretaceous to Eocene (fs)	MCI	Shale interbeded with (Franciscan? Complex) graywacke. Farm Hill Blvd.
3	Mf744	p63-365	Middle Eocene or older, probably no older than Paleocene Eocene or younger (fs)	RLP	Shale in roadcut at northwest corner of Jefferson Ave. and Farm Hill Blvd.
4	Mf745, Mf1142	p63-365W	Eocene(?) Eocene or older Eocene or younger (Tw)	MCI RLP KM	Shale interlayered with (Franciscan? Complex) graywacke. Farm Hill Blvd., 200 ft west of Sample No. p63-365.
6	Mf736, Mf1143B	p63-383	Eocene or older, possibly Paleocene or Late Cretaceous(?) (Tw)	RLP	Siltstone and shale. Farm Hill Blvd.
25	———	p63-658W	Early Eocene or late Paleocene, possibly the latter Early Eocene (Tw)	RLP KM	Silty claystone. Sand Hill Rd.
21	———	p63-661	Early Eocene or possibly late Paleocene Late Eocene (Tw)	RLP KM	Calcareous claystone. Sharon Heights district.
22	———	p63-662	do	RLP KM	Cretaceous or Eocene silty claystone. Sharon Heights district.
14	———	p63-750	Paleocene, probably late Paleocene (Tw)	RLP	Sandstone-siltstone-claystone sequence. Woodside Rd.
23	———	p63-757	Probably Eocene or Paleocene (Tw?)	RLP	"Porcelaneous" shale. Whiskey Hill Rd.
5	Mf749	p63-397	Foraminifers with Cretaceous to Eocene range (Tw?)	MCI	Yellow-gray limestone. Jefferson Ave., Woodside quadrangle.
31	K1	———	Early middle Eocene(CP 12b) to middle middle Eocene (CP 14a)(Tw)	TK	Samples from claystone-mudstone-shale section at west end of Stanford Linear Accelerator. Coccoliths.
78	K2	———	Late early Eocene (CP 12a) to middle middle Eocene (CP 13) (Tb)	TK	Sample from mudstone and siliceous shale section in La Honda block. Mindego Hill quadrangle. Coccoliths.
15	Mf747	p63-344	Campanian (Ks)	MCI	Mudstone under Willow Rd. bridge. San Francisquito Creek.

Table 2: *Potential volume change data from the Palo Alto 7-1/2' quadrangle, California*

Map No.	Map unit	Sample Description	Swelling Pressure (psf) [1]	Free Swell (%) [2]
1	Qoa	Yellowish-brown pebbly and clayey sand	1530	50
2	Qoa	Grayish-yellow plastic sandy clay, 10 ft below surface	153	65
3	QTss	Black ("adobe") silty clay soil	4170	127
4	Tw	Light-gray claystone, 5 ft below surface	2278	134
5	Tw	Greenish-gray glauconitic sandstone	——	11
6	Tw	Light-gray clayey siltstone and silty claystone	4400	100
7	Tw	Yellowish-gray claystone	——	80
8	Qaf	Black ("adobe") silty clay soil	4030	113
9	Tw	Grayish-orange claystone	2800	100
10	Tw	Yellowish-gray silty claystone	——	130
11	Tw	Grayish-orange gypsiferous claystone	5890	74
12	Tw	Grayish-orange sandstone and calcareous claystone	——	75
13	QTss	Grayish-orange pebbly sand, 12 ft below surface	1753	52
14	QTss	Brownish-black ("adobe") soil	3245	105
15	QTss?	Yellowish-gray "fat" clay from core sample	4150	130
16	QTss	Yellowish-orange clay	——	80
17	QTss	Light-brownish-gray clay, 8 ft below surface	——	145
18	——	Greenish-gray gouge from sp-Tw contact	——	157
19	QTss	Yellowish-orange sandy and silty clay	643	45

[1] Lambe (1960) established the following categories of swelling pressure in pounds per square foot (psf): noncritical, 200–1,750 psf; marginal, 1,750–3,250 psf; critical, 3,250–4,750 psf; and very critical, greater than 4,750 psf. Swelling pressures in the marginal range (about 2,200 psf) are high enough to crack typical residential foundations and pavement and cause recurring trouble (Scott, 1969, p. 11).

[2] Percent increase of original volume. Procedure for determining free-swell described by Krynine and Judd (1957, p. 144).

* U.S. G.P.O.:1993-301-077:80034