Field Trip No. 4

GEOLOGY OF THE NORTHERN PENINSULAR RANGES, SOUTHERN CALIFORNIA: GEOLOGIC GUIDE AND ROAD LOG

by

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CONTENTS

INTRODUCTION AND ACKNOWLEDGMENTS

This guide covers the north-central part of the Peninsular Ranges, principally in western Riverside County, southern California. Commencing and terminating at the University of California, Riverside campus, the route of travel is a loop of 124 miles, with one short side trip (Fig. 1). The route affords ready access to a variety of geologic features: prebatholithic rocks, rocks of the southern California batholith, Upper Cretaceous to Pleistocene sedimentary rocks, Holocene alluvial deposits, recent fault features, and various geomorphic features. A considerably longer guide, overlapping part of this guide, has been prepared by Jahns (1954a).

The entire Peninsular Range province has been best described in some detail by Jahns (1954b, pp. 29-52) who included a map, and all but the Los Angeles basin part, more briefly by Gray *et al.*, (1971). In 1948 Larsen described the southern California batholith and included a map at a scale of 1:125,000. A number of workers have mapped and described parts of the northern Peninsular Ranges. Published regional reports include the Perris block (Dudley, 1935, 1936), Corona-Elsinore-Murrieta area along the Elsinore fault (Gray, 1954), the Temecula region of the Elsinore fault zone (Mann, 1955) and the Los Angeles basin (Yerkes *et al.*, 1965). For a synthesis of general distribution of major rock units and faults, the reader is referred to Dibblee (1968).

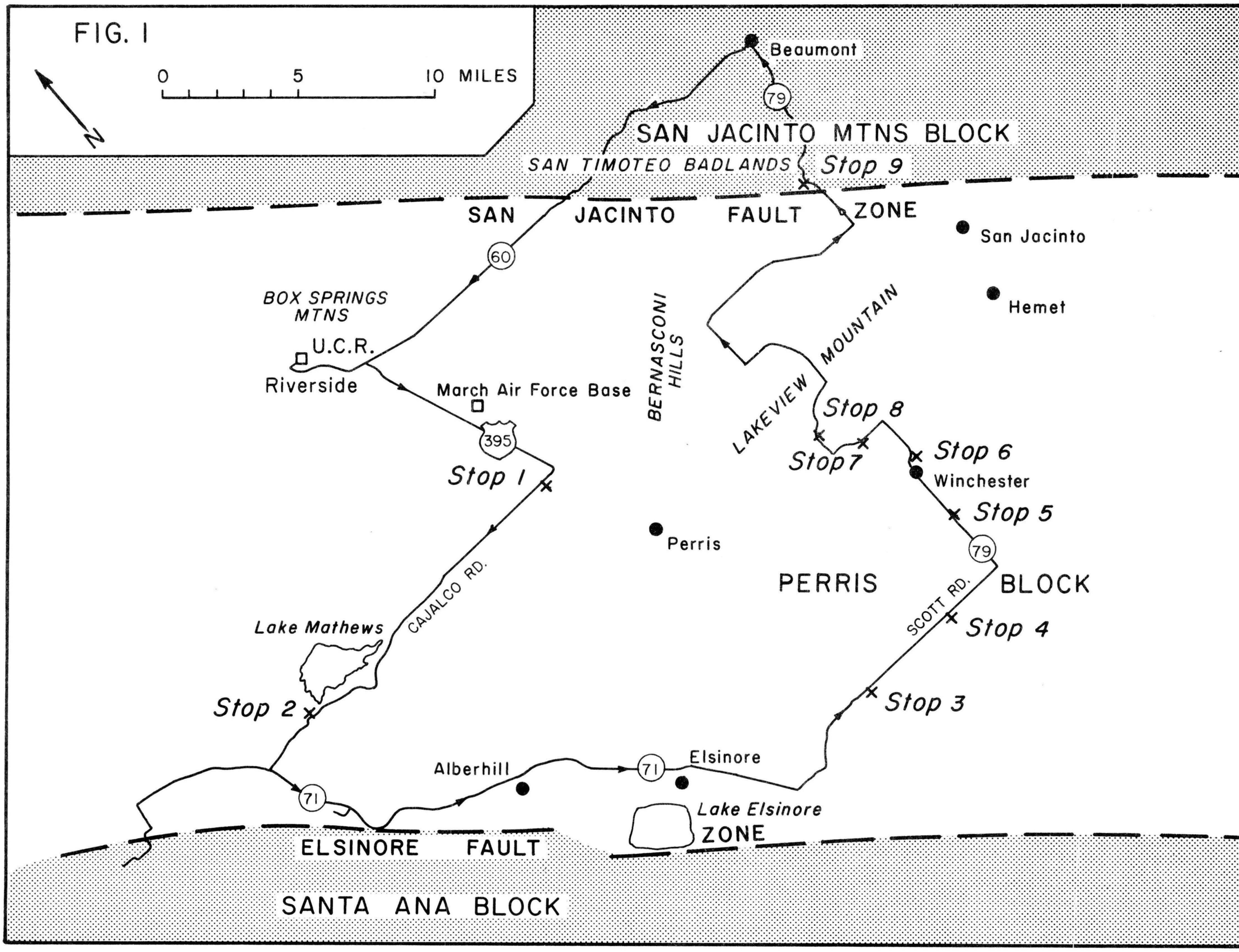
The accompanying generalized geologic map, Figure 2, is after Rogers (1966); modified by the authors. Additional data, mainly structural, were obtained from Engel (1959), English (1953), Gray (1961 and unpublished mapping), Jahns (1954b), Jenney (1968), Larsen, Norman (1962), Menzie (1962), Morton (1969, 1971, and unpublished mapping), and Schwarcz (1969).

A.O. Woodford, Pomona College, kindly made available an unpublished manuscript. Professor Woodford and R.F. Yerkes, U.S. Geological Survey, critically read the geologic synopsis of this guide.

GEOLOGIC SYNOPSIS OF THE NORTHERN PENINSULAR RANGES

An elongate, physiographic domain, the Peninsular Range province extends south-southeast from the latitude of Los Angeles-San Bernardino to the southern tip of Baja California. The western part of the province is submerged, and is part of the area termed the continental borderland (Shepard and Emery, 1941). High prominences of the Peninsular Ranges contintental borderland form the islands of Santa Catalina, Santa Barbara, San Nicolas, and San Clemente off the southern California coast.

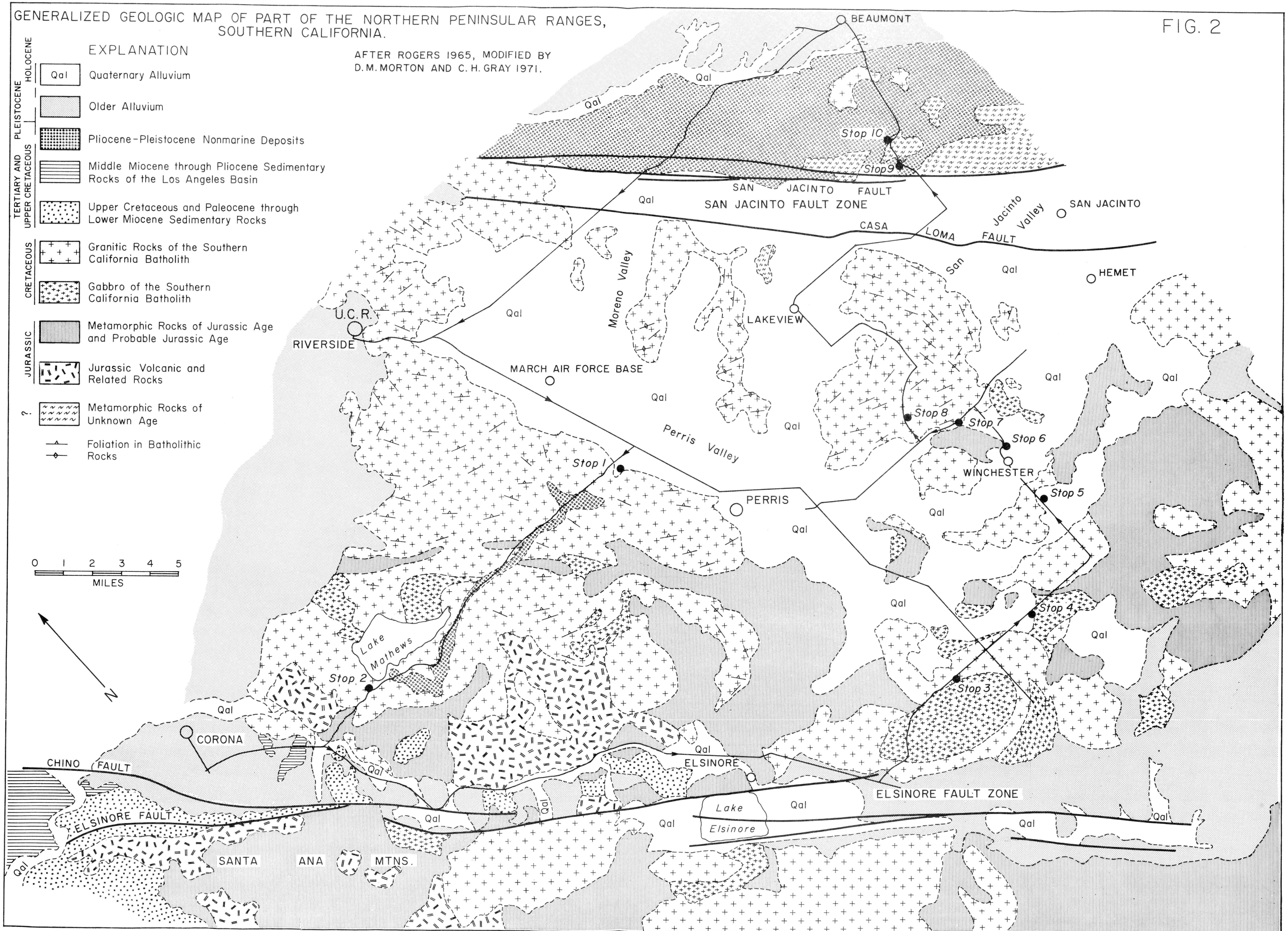
Within the province is a general coincidence of both structural and physiographic features—all having a northwest trend (Jahns, 1954b; Larsen, 1948, pp. 119-127). This trend predates the emplacement of the southern California batholith (≃ 110 m.y.) and has been repeatedly reinforced. Topographically, the province tilts gently westward to depths of about 5,000 feet below sea level over the United States part of the continental borderland. The San Jacinto Mountains along the eastern margin reach elevations in excess of 10,000 feet and drop precipitously to the Salton trough on the east.



INDEX MAP SHOWING MAJOR GEOMORPHIC FEATURES AND ROUTE OF TRAVEL.

GENERALIZED GEOLOGIC MAP OF PART OF THE NORTHERN PENINSULAR RANGES, SOUTHERN CALIFORNIA.

FIG. 2



The landward northern Peninsular Ranges are 60 to 80 miles in width, and divided into three elongate structural blocks separated by major northwest-striking fault zones. From west to east: the Newport-Inglewood zone forms the boundary between the largely submerged continental borderland block to the west and the Santa Ana block to the east; the Elsinore zone and associated Elsinore-Temecula graben separate the Santa Ana block from the Perris block. Eastward, the San Jacinto zone separates the Perris block and San Jacinto Mountains block.

Basement Rocks

The northern Peninsular Ranges consist of pre-Turonian basement rocks separated by a profound unconformity from a superjacent sedimentary sequence of Turonian and younger age. The basement rocks can be divided into two distinctly different complexes: a western complex west of the Newport-Inglewood zone and an eastern complex east of this zone (Woodford, 1960; Yerkes *et al., 1965).*

Western Basement Complex: The western basement complex belongs to the blueschist metamorphic facies characterized by lawsonite and glaucophane. The dominant rock is the Catalina Schist (Catalina metamorphic facies of Woodford, 1924), made up of metamorphosed clastic and volcanic rocks, and serpentinite, which is, in part, intruded by Miocene dacite porphyry and quartz diorite (Forman, 1970; Schoellhamer and Woodford, 1951; Woodford, 1960). Conspicuous by their absence are the granitic rocks that are elsewhere widespread in the Peninsular and Transverse Ranges.

Although the Catalina Schist is of low metamorphic grade, no fossils have been reported. Woodford (1924), on the basis of lithology, correlated this schist with the Franciscan Formation to the north, which is Late Jurassic to early Late Cretaceous in age (Bailey *et al.,* 1964; Irwin, 1967). Forman (1970) reports a K-Ar age of about 100 m.y. for the Catalina Schist.

Eastern Basement Complex: East of the Newport-Inglewood zone the basement consists of granitic rocks, incipiently metamorphosed clastic and volcanic rocks, and locally, marble. Metamorphic grade of the clastic rocks increases progressively eastward, noticeably in the Perris block. Granitic rocks of the southern California batholith have invaded all of these rocks. The eastward increase in regional metamorphic grade is independent of the distribution of individual plutons of the batholith. Local contact metamorphism, however, accompanied the emplacement of the batholith and gave rise to several well-known complex mineral assemblages (e.g., Crestmore—see Burnham, 1959; Murdoch, 1961). Foliation in the metamorphic rocks, which generally strikes northwest, predates emplacement of the batholith (Schwarcz, 1969). Local deviation in the foliation has been produced by the emplacement of some plutons (e.g., Morton, 1969).

In the Santa Ana block the oldest dated rock is a sequence of incipiently metamorphosed, thin-bedded argillite, graywacke, and quartzite, with local pods of marble, termed the Bedford Canyon Formation (Gray, 1961; Larsen, 1948). The

TABLE 1

GENERALIZED GEOLOGIC COLUMN NORTHERN PENINSULAR RANGES (EXCLUDING THE LOS ANGELES BASIN)

Age	*Formation*	*Description*	*Distribution*	*Max. Estimated Thickness in Feet*
Quaternary	Holocene alluvium; Pleistocene nonmarine; Bautista Beds and Temecula Arkose; Pleistocene marine deposits.	Continental sands, gravels, lake beds. Marine fossiliferous terrace deposits.	Marine terrace deposits along coast. Alluvial fan deposits, lake beds, and valley fill in interior areas.	8,000 (?) in San Jacinto Valley.
Continental Pliocene	San Timoteo and Mt. Eden.	Continental sandstones, silt stones and conglomerate; redbeds. Upper part of San Timoteo is Pleistocene.	West of San Jacinto Mts. along San Jacinto fault.	7,000
Marine Pliocene	Repetto (?)	Thick-bedded white sandstone, conglomerate, silt, and shale. Marine.	Northwest end of Elsinore Trough at Corona on margin of Los Angeles Basin.	2,000 near Corona
Pliocene	Santa Rosa Basalt	Basalt, andesite, and pyroclastics.	Mesa-capping basalt near Murrieta.	Several hundred
Upper Miocene	Puente	Sandy siltstone and shale; minor sandstone, conglomerate and diatomite. Marine.	Northwest end of Elsinore Trough at Corona on margin of Los Angeles Basin.	1,000 (?)
Middle Miocene	San Onofre Breccia	Blocks of glaucophane and similar schists.	Oceanside north on coastal margin of region.	2,500
	Topanga	Buff sandstone, conglomerate, and sandy siltstone. Marine.	Northwest end of Elsinore Trough near Corona.	800
Lower Miocene to Upper Eocene	Vaqueros (Lower Miocene) and Sespe (Upper Eocene-Lower Miocene).	White, buff, red and green sandstone, conglomerate, sandy clay, and siltstone. Interfingering marine and nonmarine.	Northwest end of Elsinore Trough near Corona. West flank of Santa Ana Mts. at Trabuco Canyon.	3,000 combined
Eocene	Santiago	Buff sandstone, siltstone, and conglomerate. Marine.	North and northeastern margins of Santa Ana Mts. near Corona.	600 near Corona
Paleocene	Silverado	Upper part marine sandstone, conglomerate, siltstone, and shale; lower part nonmarine or brackish water sandstone, conglomerate, clay, lignite.	Elsinore Trough from Elsinore to Santa Ana River at northwest tip of Santa Ana Mts.	2,000 (?) at Corona
Upper Cretaceous	Williams and Ladd	Sandy shale or siltstone, arkosic sandstone, boulder conglomerate, Well stratified, fossiliferous. Marine.	Along northern part of coastal strip and around northwest tip of Santa Ana Mts. Underlies younger formations.	5,500
Cretaceous	Trabuco	Red and gray-green boulder conglomerate and sandstone. Nonmarine (?).	In Santa Ana Mts. northerly from Plano Trabuco to Black Star Canyon; southwest of Corona.	1,000; 600 near Corona
	Unconformity			
Cretaceous	Plutonic intrusive rocks of southern California batholith.	Granite, adamellite, granodiorite, quartz diorite, tonalite, diorite, and gabbro.	Basement rocks throughout the region.	
Jurassic	Santiago Peak	Volcanics, metavolcanics and hypabyssal intrusive rocks.	Part of basement rocks along western margin of plutonic basement rocks.	Several thousand
	Bedford Canyon	Argillite, slate, schist, quartzite, and minor marbles.	Roof pendants widely distributed in western part of batholith.	Several thousand
Jurassic (?)	French Valley [may overlie Bedford Canyon Fm.].	Quartzite, schist, and amphibolite.	Central part of Perris block.	13,000
Paleozoic (?)	Unnamed	Schist, gneiss, phyllite, quartzite, and marble.	Roof pendants widely distributed in eastern part of batholith; chiefly in San Jacinto and Santa Rosa Mts.	Several thousand

orientation of sedimentary structures indicates that the Bedford Canyon is highly deformed. Owing to the structural complexity and monotonous nature of this sequence, the overall structure and original thickness are unknown (Gray, 1961). Larsen (1948, p. 22) considered the unit to have a stratigraphic thickness of 20,000 feet; Gray (1961, p. 12) believes this thickness to be excessive.

Prior to 1960 the Bedford Canyon Formation was generally considered to be Triassic (Gray, 1961, pp. 12-13), but Fairbanks (1893, p. 116) originally regarded these rocks as Carboniferous. The Triassic age was based upon a sparse collection of the pelecypod *Daonella sanctaeanae* Smith, the Upper Triassic ammonite genera *Discotropites* and *Juvavites,* and rhynchonellid brachiopods of the Triassic genus *Halorella* (Engel, 1959, p. 20, 23, and 24). Subsequent collections, however, indicate an early Late Jurassic (Callovian) (Imlay, 1963; Silberling *et al.,* 1961) and lower Middle Jurassic (Bajocian) (Imlay, 1964) age for the Bedford Canyon. Brachiopods formerly considered to be *Halorella* are now thought to be a new genus, perhaps transitional between *Halorella* of the Upper Triassic and *Peregrinella* of the Lower Cretaceous (Silberling *et al.,* 1961).

Unconformably overlying the Bedford Canyon Formation is the Santiago Peak Volcanics (Larsen, 1948). Most of the rock is of dacitic to andesitic composition. In the northern Santa Ana Mountains this unit has an apparent maximum thickness of 2,300 feet (Gray, 1961, p. 15). The age of the Santiago Peak Volcanics is considered to be Jurassic (Fife *et al.,* 1967). Shallow, intrusive rocks related to the Santiago Peak Volcanics occur in the Bedford Canyon Formation.

Metamorphic rocks in the western and central parts of the Perris block have been correlated, on the basis of lithology, with the Bedford Canyon Formation and Santiago Peak Volcanics (Gray, 1961; Larsen, 1948; Schwarcz, 1969). They are, however, in general more intensely metamorphosed than the Bedford Canyon in the Santa Ana Mountains. Also widespread in the northwestern part of the block is the Temescal Wash Quartz Latite Porphyry (Dudley, 1935, p. 497). Supposedly of Jurassic age, this porphyry may be related to the Santiago Peak Volcanics.

In the Winchester area (north-central part of the Perris block) rocks correlated with the Bedford Canyon Formation are considered by Schwarcz (1969) to be conformably overlain by a 13,000 foot thick sequence of quartzite, schist, and amphibolite. Schwarcz (1969, p. 19) considered the original sediment of this sequence, which he named the French Valley Formation, "to have been deposited in a marginal basin (Krumbein and Sloss, 1963, p. 418), flanking a cratonic highland and possibly transitional on the west into a eugeosyncline." These rocks earlier were considered to be of Paleozoic age (Larsen, 1948; Webb, 1939), as based on a fossil later believed to have been imported (letter to A.O. Woodford from R.W. Webb, November 20, 1959; ref. in Woodford, 1960). Schwarcz's work clearly shows the incompatibility of the fossil with the rocks in the area of its reported occurrence. Just west of the Winchester area, in rocks apparently equivalent to the French Valley Formation, M.A. Murphy (pers. comm., 1968) collected pelecypods of uncertain age. These pelecypods have been considered to be either Late Triassic or Jurassic in age (Schwarcz, 1969).

The metamorphic grade of French Valley Formation rocks increases abruptly eastward in the Winchester area, passing in map distance of less than two miles from a muscovite zone, through andalusite, sillimanite, and garnet isograds. Based on mineral assemblages (Morton, 1969; Schwarcz, 1969) metamorphism was of the Abukuma (andalusite-sillimanite) type (Winkler, 1965).

At the northern end of the Perris block (e.g., Crestmore, Jurupa Hills, Slover Hill) and southeast of Hemet (Bautista Canyon), the metamorphic rocks commonly contain marble, on the basis of which they may be possibly Paleozoic in age (see Woodford, 1960).

The western San Jacinto Mountains block includes banded gneiss, marble, amphibolite schist, quartzite, and metaconglomerate of the almandine amphibolite facies (Sharp, 1967, p. 717). On the east side of the San Jacinto Mountains and passing southward through the Santa Rosa Mountains is a thick zone of cataclastic rocks as well as abundant marble and dolomite (Sharp, 1967, 1968; Theodore, 1966, 1970). These rocks are of unknown age.

Southern California Batholith

Larsen (1941) gave the name Southern California batholith to a sequence of plutonic rocks that makes up much of the eastern basement complex. Rocks of this composite batholith range in composition from olivine gabbro to granite and form myriad bodies of differing shapes and sizes. The general sequence of emplacement has been basic to silicic (gabbro to granite). Although Dudley (1935) first mapped the northern Perris block, the batholith is best known through the works of Larsen, especially his 1948 Memoir.

In the Santa Ana Mountains batholithic rocks intrude the Jurassic Bedford Canyon Formation and are overlain by the Upper Cretaceous Trabuco Formation, a nonmarine conglomerate that contains clasts of granitic rocks resembling those of the batholith. In northern Baja California, early Upper Cretaceous rocks (upper Cenomanian and Turonian) are intruded by rocks of the batholith and are in turn overlain by late Upper Cretaceous (Senonian) sedimentary rocks (see Woodford and Harris, 1938) which there indicates that the batholith is of middle Late Cretaceous age. Geochronological data from U-Pb isotopes in zircon have yielded dates in the interval 100 to 120 m.y. (e.g., Banks and Silver, 1961). K-Ar dates for batholith rocks give consistently younger ages, clustering in the low 90 m.y. range (Evernden and Kistler, 1970; Morton, 1969).

Lithologically, the batholith is composed of essentially three rock types: gabbro, quartz diorite (tonalite), and granodiorite. In its northwestern part, Larsen (1948, 1951, 1954) found the batholith to consist of 7% gabbro, 63% quartz diorite, and 28% granodiorite, with granite constituting only 2%. Gabbro, generally called San Marcos Gabbro (Larsen, 1948; Miller, 1937, 1938), is typically a hornblende or hornblende-bearing gabbro, but is extremely variable in mineralogy. Rocks called San Marcos Gabbro include allivalite, troctolite, norite, quartz norite, and anorthosite. Quartz diorite (tonalite) is the most abundant rock type and Bonsall Tonalite (Hurlbut, 1935) the most common unit. Typically the quartz diorites are medium- to coarse-grained biotite-hornblende quartz diorites. Most are foliated and commonly contain flattened, discoidal, dark inclusions; some exposures exhibit abundant schlieren. Granodiorite, most of which is termed the Woodson Mountain Granodiorite, is generally a relatively uniform, medium-grained rock, either massive or foliated (Larsen, 1948). Some exposures are essentially inclusion free; others are choked with inclusions. Locally a porphyritic or sub-porphyritic texture is prominent.

A number of discrete plutonic bodies or complexes have been studied in detail. These studies indicate the batholith was emplaced by a variety of processes including magmatic, both forceful (Menzie, 1962; Morton, 1969) and passive (Jenney, 1968; Morton and Baird, 1971), and by replacement (Jahns, 1948). Complex internal structures have been demonstrated for some granitic rocks (Morton, 1969; Osborn, 1939).

An exhaustive chemical investigation of the batholithic rocks has been conducted in the northern Peninsular Ranges. Preliminary results of this study show a marked systematic chemical variation parallel to the structural grain (Baird *et al.,* 1965, 1966, 1970). Two individual plutons have been studied chemically. Both bodies show a chemical variation essentially parallel to their structural configuration. In the Box Springs Mountains complex, Joshi (1969) found the core to be more silicic than the margin and considered the variation to be a function of elevation differences. The Lakeview Mountains pluton has a more basic core than margin, reflecting original magma differences (Baird *et al.,* 1967; Morton *et al.,* 1969).

Superjacent Series Sedimentary rocks and unconsolidated sediments range in age from Upper Cretaceous to Holocene and recent. The northern Santa Ana Mountains and adjacent Elsinore fault zone contain the greatest variety of these units. On the Perris and San Jacinto Mountains blocks the superjacent series is essentially limited to late Tertiary and Quaternary nonmarine deposits.

Santa Ana Block and Elsinore Fault Zone

The northern Santa Ana Mountains and the adjacent Elsinore fault zone are part of the Los Angeles basin, which developed during Miocene time. Thus, the later history of this part of the Peninsular Ranges differs considerably from that to the east. Prior to the inception of the Los Angeles basin, this part of the Peninsular Ranges was the site of discontinuous deposition beginning in Late Cretaceous time. For a summary of the history of the Los Angeles basin, the reader is referred to Yerkes *et al.* (1965).

Upper Cretaceous rocks in the northern Santa Ana Mountains attain a thickness of 5,500 feet (Woodford *et al.,* 1954). Resting unconformably upon basement is the Trabuco Formation (Packard, 1916), a 400- to 700-foot sequence of unfossiliferous conglomerate (Gray, 1961, p. 18-19). Clasts in the conglomerate are primarily Santiago Peak Volcanics and related rocks, with minor, but strikingly ubiquitous, clasts of biotite granodiorite.

Above the Trabuco Formation is an Upper Cretaceous marine sequence of conglomerate, sandstone, siltstone, and shale. Termed the Ladd Formation, it has a stratigraphic thickness of 1,700 feet. In places this formation has been divided into two members: the Baker Canyon Conglomerate Member (with fauna of Turonian age) and overlying Holz Shale Member (Turonian to Campanian) (Gray, 1961; Woodring and Popenoe, 1942). Unconformably overlying the Ladd Formation is the Williams Formation. The lower part (Schulz Ranch Sandstone Member) is an unfossiliferous arkosic sandstone and the upper part (Pleasants Sandstone Member) is a fossiliferous (Campanian), shaly sandstone with intercalated lenses of sandstone (Popenoe, 1937; p. 380).

Paleocene rocks, about 1,400 feet thick in the Santa Ana Mountains (Woodford *et al.*, 1954, p. 69), are called the Silverado Formation (Woodring and Popenoe, 1945). They rest unconformably upon Upper Cretaceous and basement rocks in the Santa Ana Mountains and in the Elsinore fault zone (Gray, 1961). Basal Silverado consists of nonmarine conglomerate and feldspathic sandstone. Locally, the sandstone is extremely rich in biotite and resembles biotite schist (Woodford *et al.*, 1954, p. 69). The upper part of the Silverado is a fossiliferous marine sandstone and siltstone.

The basal part of the formation contains large amounts of high-alumina clay. This clay includes both residual and sedimentary clay, some of which is bauxitic (Gray, 1961, p. 25). The residual clay was derived from *in situ* weathering of a variety of basement rocks (Gray, 1961, p. 63). The clay and local silica sand deposits of the Silverado support a number of mining operations which date back over 80 years, among which are the most productive clay operations in southern California.

The Eocene Santiago Formation apparently conformably overlies the Silverado Formation (Woodring and Popenoe, 1945). Predominantly sandstone, the lower part of the Santiago contains a middle Eocene molluscan fauna; the Santiago has a maximum thickness of approximately 2,700 feet. The upper part of the Santiago at least locally contains nonmarine conglomerate and sandstone and is gradational with the Sespe Formation. Late Eocene to earliest Miocene nonmarine Sespe Formation and the early Miocene marine Vaqueros Formation have been mapped as an undifferentiated unit as much as 3,000 feet thick. They consist of vari-colored (maroon, gray, red, and greenish) sandstone and conglomerate (Gray, 1961). These rocks apparently rest conformably upon the Santiago Formation in the Santa Ana Mountains (Woodford *et al.*, 1954, p. 69) and unconformably upon the Santiago west of Corona (Gray, 1961, p. 30).

Following the deposition of lower Miocene sediments was a period of general emergence and erosion which produced a widespread unconformity throughout much of the Los Angeles basin. During middle Miocene time, a northwest-trending embayment covered the site of the basin, with highlands rising both to the northeast and southwest (Yerkes *et al.*, 1965). During part of this time, the western basement (Catalina Schist) emerged and rapidly shed debris which entered the southwest side of the marine embayment to form the San Onofre Breccia (Woodford, 1925).

Marine middle Miocene rocks crop out in the northwestern Santa Ana Mountains and in limited exposures in the Corona area where they have been assigned to the Topanga Formation. In the Corona area these rocks consist of sandstone and conglomerate which have yielded middle Miocene megafossils and microfossils (Gray, 1961, p. 31).

During upper Miocene to lower Pliocene time, with the main phase of basin development there was essentially continuous subsidence and deposition in the Los Angeles basin (Yerkes *et al.*, 1965, p. 17).

Upper Miocene marine sedimentary rocks, the Puente Formation as much as 13,400 feet thick in the Los Angeles basin, occur in the northernmost Santa Ana Mountains and underlie the Puente-Chino Hills to the north. In the Corona area a few patches of siltstone, sandstone, and conglomerate contain upper Miocene foraminifera and are assigned to the Puente Formation (Gray, 1961, p. 31-35). Immediately east of Corona the apparent eastward limit of deposition of this unit is marked by a cliff-like, buttressed unconformity between granitic rock and fossiliferous sandstone and conglomerate tentatively correlated with the Puente Formation (Gray, unpublished map, 1969).

Lower Pliocene sandstone and siltstone with interbedded conglomerate conformably overlie the upper Miocene rocks in the northeasternmost Santa Ana Mountains and along the margins of the Puente Hills. East of there, these strata have not been named. At the end of the Pliocene, the Puente-Chino Hills and Santa Ana Mountains emerged, which have subsequently not been submerged. During late Pleistocene through Holocene, the Los Angeles basin gradually ceased to be a site of major deposition with a continual westward withdrawal of the sea (Yerkes *et al.,* 1965, p. 19-20).

Alluvial deposits of Pleistocene to Recent age are similar over most of the northern Peninsular Ranges. Stream terrace deposits are widespread along major drainages; most consist of unconsolidated gravels in a poorly sorted, sandy matrix, reddish-brown to tan or buff in color. Clasts are of differing composition, depending upon source area. Older terrace deposits are commonly dissected and have nearly flat upper surfaces. They range in thickness from less than one foot to over 100 feet.

Older alluvium is widespread and occurs generally as dissected alluvial fan deposits. Characteristically, the older alluvium is red-brown and well-indurated. It contains considerable clay, with subangular to rounded small clasts.

Tertiary and Quaternary deposits on the Perris and San Jacinto Mountains Blocks

Nonmarine Pliocene to Pleistocene deposits, other than "older alluvium," are very restricted in the northern Perris block. Two east-trending, largely obscured stream channels cross the northwestern part of the block. During recent construction, a Pliocene mammalian fauna was discovered near Lake Mathews (Proctor and Downs, 1963) in poorly sorted, arkosic sandstone that fills a channel cut in basement rock on the Perris surface, an erosion surface at the 1,700 foot elevation.

A much smaller, somewhat sinuous stream channel occurs on the Lakeview-Gavilan surface, a 2,100-foot erosion surface south of Lake Mathews. Mantled by cobbles, it stands in base relief above a largely bedrock surface (Dudley, 1953). Small patches of gray, poorly bedded sediment of unknown age occur on the Lakeview-Gavilan surface in the Lakeview Mountains (Morton, 1971).

Unconsolidated, buff colored, decomposed arkosic sediment underlies older alluvium in the Canyon Lake area (formerly Railroad Canyon) east of Elsinore. This sediment apparently fills an east-trending depression in the basement.

Nonmarine Pliocene and Pleistocene deposits are widespread in the northern San Jacinto Mountains block; the northern 25 miles of the block is underlain by sedimentary deposits comprising the "San Timoteo Badlands." Sediments overlying basement are generally coarse, arkosic sandstone and conglomerate red beds. Overlying the red beds are buff- to gray- and greenish-gray sandstone, conglomerate beds and lenses, and siltstone. Some conglomerate lenses are monolithologic, composed of quartz diorite clasts as much as 20 feet in diameter (Morton, 1971). The lower part of the sequence is generally termed the Mt. Eden Formation, or Beds, and the higher part, the San Timoteo Formation. The Mt. Eden Formation is probably mainly middle Pliocene in age and the San Timoteo is upper Pliocene in age.

These and similar sediments, east and southeast of Hemet have yielded a mid-Pliocene (Hemphillian), early Pleistocene (Blancan) and later Pleistocene (Irvingtonian) fauna (Frick, 1921; Savage *et al.,* 1954). They have also yielded a mid-Pliocene to early Pleistocene flora (Axelrod, 1937, 1945, 1966).

Faults

The Peninsular Ranges abruptly terminate to the north against the east-trending Transverse Ranges. The Malibu Coast-Santa Monica-Raymond Hill-Sierra Madre-Cucamonga fault complex marks their northern terminus, extending from the Pacific Ocean to the Devore area near Cajon Pass. East of Devore this boundary is apparently offset on the San Jacinto fault approximately 15 miles right laterally to the Redlands area. From this point the boundary is termed the Banning fault, which continues eastward into the San Gorgonio Pass area.

The several blocks of the Peninsular Ranges are separated by northwest-striking faults belonging to the San Andreas fault system (Crowell, 1962). The major fault zones are, from west to east: the Newport-Inglewood, the Elsinore-Whittier, and San Jacinto. The Newport-Inglewood zone is poorly exposed; the other zones consist of a complex of subparallel, en échelon, or anastomosing faults. Individual faults within each zone show evidence of recent displacement as indicated by ephemeral features such as closed depressions and scarps.

The presence of unlike metamorphic rocks on opposite sides of the Newport-Inglewood fault zone suggests considerable displacement and recently it has been considered the "proto-San Andreas" fault in southern California (Suppe, 1970). Pre-late middle Miocene displacement of undetermined amount and sense juxtaposed the Eastern and Western basement complexes and exposed Western basement to erosion. Lower Pliocene strata are separated as much as 5,000 feet in a right lateral sense along faults of the zone. Vertical separation at the basement surface locally attains 4,000 feet across the zone, but that of Pliocene strata commonly does not exceed 1,000 feet and that at the base of the Pleistocene 200 feet. Late movement on the fault has resulted in arching of young sediments to form low hills along the zone (Yerkes *et al.,* 1965, p. 48) and seismic activity (i.e., Long Beach earthquake of 1933) indicates continued movement (Barrows, in press, 1971).

The Elsinore-Whittier fault zone, with a known length of about 135 miles, extends from the Whittier Narrows area, east of Los Angeles, southeast to at least within a few miles of the International Border. Bifurcating at the north end of the Santa Ana Mountains, its west branch is termed the Whittier fault. The east branch, the Chino fault, passes along the east side of the Chino (Puente) Hills northwest of Corona. From the Corona area southward the zone is designated Elsinore.

Along the Whittier fault, local structural data indicate an oblique net slip (right-lateral reverse) of about 15,000 feet since Miocene time; this part of the fault zone may have been active since middle Miocene time (Yerkes *et al.,* 1965, p. 50).

Displacement on the Elsinore fault zone has been considered essentially normal, reverse, as well as lateral by various workers (Gray, 1961, p. 46). Distribution of basement rocks across the faults suggests possible lateral displacement on the order of a few miles. Sag ponds and scarps along faults of this zone indicate recent movement (e.g., Glen Ivy, Willard, and Wildomar).

The San Jacinto is the only fault of the San Andreas system, including the San Andreas, to cross the southern Transverse Ranges without deviating from its general strike or being terminated. On the contrary, the San Jacinto fault appears to offset the southern, east-striking faults of the Transverse Ranges (Allen, 1957, p. 339; Sharp, 1967, p. 726). Based on its straightness, continuity, and seismic history, it appears to be the most active fault of the San Andreas system in southern California (Sharp, 1967). Based on a number of offset basement contacts southeast of Hemet, Sharp (1967) determined a 15-mile right-lateral displacement across the San Jacinto. He also found Pleistocene deposits offset right laterally at least 3.2 miles and stream courses offset half a mile.

In the San Jacinto Valley, a remarkably deep, narrow graben has developed between the San Jacinto and adjacent Casa Loma faults. North of San Jacinto the depth to basement in this alluvial-filled graben is some 8,000 feet beneath the present valley floor (Fett, 1968). It is thought this graben developed and filled since the early Pleistocene. Currently, parts of the graben are undergoing rapid subsidence. Surface expression of this subsidence is widespread (Fett *et al.,* 1966) and includes major surface fissures (Morton, 1971). This active subsidence, which in part may be of tectonic origin, appears to be mainly the result of ground-water withdrawal. A large number of recent surface expressions of faulting occur on the San Jacinto fault (Sharp, 1970).

Seismically, the San Jacinto fault zone has been the most active member of the San Andreas system; many destructive earthquakes having occurred along the zone since the turn of the century (e.g., 1899, 1918, 1923, 1937, and 1954) (Allen *et al.,* 1967).

Geomorphology

A number of low-relief, erosional surfaces occur throughout much of the northern Penisnular Ranges at different elevations. They are best developed, and exposed, on the Perris block. Erosional surfaces are present there at elevations of 1,700; 2,100; and 2,500 feet (Dudley, 1936; Larsen, 1948). There is also a largely buried canyon system. Dudley (1936, pp. 358-387) believed that the Perris block, which is bounded on the southwest by the Temecula-Elsinore trough, had a geomorphic history briefly summarized as follows:

1. A mature surface was developed in the area of the Perris block. Drainage was at that time toward the east.

2. This old topography was partly buried by sediments, and the Perris surface was developed. This surface, cut on crystalline rocks and interrupted here and there by monadnocks, lies at an altitude of about 1,700 feet.
3. Sediments accumulated over a large area, and the Lakeview-Gavilan surface at an altitude of about 2,100 feet was formed.
4. Erosion exhumed the Perris surface, and the San Jacinto River then flowed across this surface and through the Santa Ana Mountains to the sea. The river thus is superimposed where it crosses monadnocks on the Perris surface.
5. The San Jacinto River was captured by Temescal Creek, a tributary of the Santa Ana River. Elsinore Lake is a temporary feature, incidental to recent faulting.

A revised interpretation of the development of these features, and their relations to contemporary tectonism has been proposed by Woodford *et al.* (in press, 1971).

Of particular interest is the San Jacinto River course, which may once have flowed across the present area of the Santa Ana Mountains. Apparently movement of the Elsinore fault zone uplifted the Santa Ana Mountains across its path, disrupting the earlier westward course of the drainage and causing the present northward drainage along the Elsinore fault zone toward present-day Santa Ana Canyon. The canyon itself is probably antecedent, as uplift of the Santa Ana Mountains continued after the initial disruption of the San Jacinto River course. Currently except for periods of extraordinary runoff, such as during 1916-1917, the San Jacinto River runoff terminates at Lake Elsinore, a closed depression marking the northern end of the Temecula-Elsinore graben.

FIELD TRIP ROAD LOG

The starting point of the trip is located on the west flank of a funnel-shaped granitic complex (see Fig. 2). This complex, part of the southern California batholith, and termed the Box Springs body (Menzie, 1962), is elliptical in plan (5 x 8 miles) with its long dimension oriented N.40°W. It consists principally of two parts: an outer zone composed of foliated quartz diorite (tonalite) and granodiorite, with minor quartz monzonite and granite; and an interior or center (2 x 3 miles), of massive quartz diorite. Quartz diorite (Bonsall Tonalite), the most abundant rock in the outer zone, is strongly foliated with common to abundant inclusions most of which are disc-like in shape. The long dimensions of the inclusions, as well as the long dimensions of tabular and platy minerals, define the foliation. Quartz diorite comprising the center contains sparse unoriented inclusions. Menzie considers the complex resulted from mobilization of largely crystallized quartz diorite (which forms the outer zone) and was later intruded by magma which formed the central part of the complex. Movements in the largely crystallized quartz diorite resulted in formation of the foliation and "flattening" of the inclusions (after Menzie, 1962).

0.0 Start trip. Parking Lot, Ramada Inn, Riverside. Proceed east from parking lot to University Avenue and hence onto southbound US 395. Highway proceeds up Box Springs grade passing through exposures of typical Bonsall Tonalite. Note the foliated nature of the rock and the common pancake shaped dark inclusions.

3.6 Highway grade decreases on entering the 1,700+ foot Perris erosional surface.

4.1 Overpass across Santa Fe tracks. Here a thin veneer of gray Pleistocene (?) sediments covers the Bonsall Tonalite.

4.3 Highway branches. Bear to the right on US 395.

4.6 To left (northeast) is the east-striking, north-dipping southern part of the Box Springs complex.

5.5 The valley floor, termed the Paloma surface (Woodford *et al.,* 1971), subtly reaches elevation 100-200 feet below the Perris surface.

6.5 Highway crosses Allesandro Road (traffic light).

7.6 March Air Force Base Depot. Strategic Air Command (SAC) headquarters to left.

8.6 Highway crosses Van Buren Boulevard (traffic light).

8.8 Ahead to the right the low relief hills silhouette the Perris surface rising above the alluviated valley.

11.0 Four miles east are the Bernasconi Hills. These hills are upper parts of a buried stream system which drained towards the highway, where at this point the valley fill is over 800 feet deep (Bean, 1955). The former drainage direction abruptly reversed at the west edge of the Bernasconi Hills and flowed eastward towards the San Jacinto Mountains and emptied into a graben along the San Jacinto fault zone (Woodford *et al.,* 1971).

12.5 Right turn off US 395 onto Cajalco Road.

12.6 Low dump 200 yards south of Cajalco Road is spoilage from the Metropolitan Water District's (MWD) Val Verde Tunnel. This tunnel is part of the elaborate aqueduct that brings water from the Colorado River to the metropolitan areas of southern California. Our route follows the aqueduct for the next ten miles to Lake Mathews, an MWD reservoir.

12.9 Near horizontal skyline to south is the Perris surface developed on Bonsall Tonalite.

13.5 Contact between alluvium and Bonsall Tonalite.

13.8 **Stop 1:** Turn left (south) onto dirt road. Proceed for 0.2 mile to dump from MWD tunnel to view abundant fresh boulders of quartz diorite. This quartz diorite is from the Riverside-Perris pluton (Jenney, 1968), a large elongated (4.9 x 13 miles) body of Bonsall Tonalite of predominantly a biotite-hornblende quartz diorite. To the northeast it merges with the Box Springs Mountain body. Like the outer quartz diorite in the Box Springs Mountains, this rock is strongly foliated with abundant inclusions oriented north-northwest and dipping moderately to the northeast. In general the dip flattens from west to east across the pluton. Jenney (1968) considers the quartz diorite to have been intruded into a tensional environment which allowed permissive entry of the quartz diorite magma (after Jenney, 1968). Return to Cajalco Road.

14.1 Cajalco Road reaches top of the Perris surface.

14.8 Intersection of Cajalco Road and Clark Street. A few hundred feet to the left is a buried Pliocene-Pleistocene stream channel marked by the low rounded hills. Note the lack of rounded boulders which would indicate the presence of granitic rocks.

15.4 Cajalco Road crosses north-trending arm of the channel.

16.3 Exposure of Bonsall Tonalite.

16.5 To the left is dump from MWD Val Verde tunnel. To right is an exposure of hybrid rocks. Folded inclusion-like layers in migmatite are oriented with fold axes striking northwest and plunging to southeast. (Note: As of 12/30/70 road was in process of being straightened. In the future the road will pass through the migmatitic rocks.)

17.5 Intersection with Wood Road. To the north is brown-weathered quartz diorite within typical gray-weathered Bonsall Tonalite.

17.6 Road cut in red older alluvium covering buried Pliocene channel. The buried channel is essentially parallel to, and to the left of, the road.

18.1 Smooth hills to the north and south of road are underlain predominantly by pre-batholithic schist.

18.5 Lazy MC Ranch. To the southwest the upper surface of the flat topped hills is the Lakeview-Gavilan surface (2,100 feet of elevation).

18.7 Riverside County fire station.

19.5 On left are dissected Pleistocene fan deposits of red-brown alluvium overlying the buried channel.

20.9 For next several miles the road continues through dissected Pleistocene alluvium. View to the northeast of the Perris surface.

22.2 Water to north and northwest is MWD reservoir Lake Mathews (Cajalco Reservoir). San Gabriel Mountains on skyline to north.

23.2 Straight ahead on skyline is Santiago Peak, the highest point in the Santa Ana Mountains (5,687 feet) on the west side of the Elsinore fault zone.

23.8 Road veers to northwest leaving the Pliocene channel.

24.5 Altered quartz monzonite. This is the start of an extensive area of rock which has been silicified and tourmalinized.

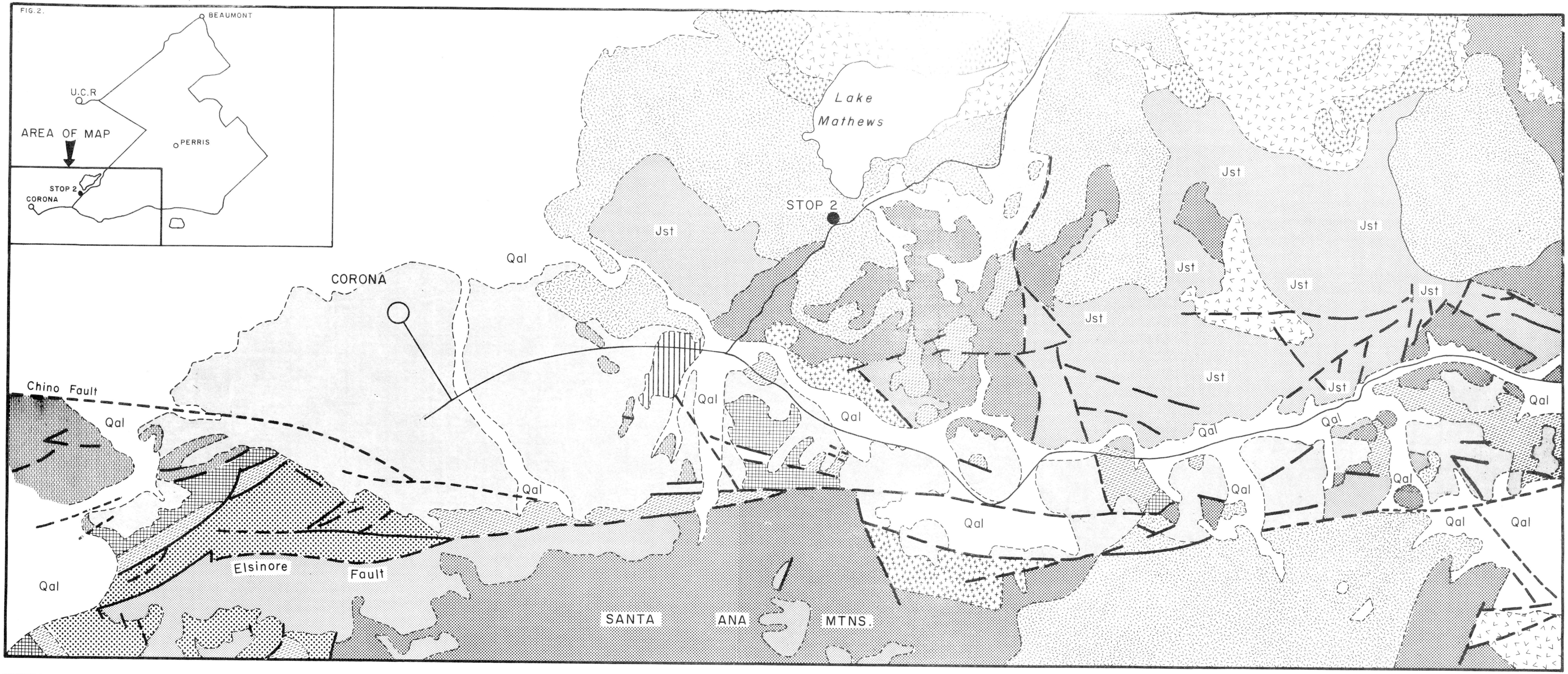
24.8 Small dark outcrops half a mile to the south (left) consist of quartz monzonite completely altered to silica-tourmaline rock termed tourmaline "blowouts." This tourmaline-silica rock is locally tin-bearing.

25.2 To right behind fence is prosptec for tin.

25.4 Dirt road to left leads to site of excavation just south of Cajalco Road that yielded Pliocene mammalian fauna (Proctor and Downs, 1963). At this point the channel turns to the north and extends to the reservoir.

26.0 Intersection of La Sierra Avenue and Cajalco Road; take left branch (Cajalco Road).

26.7 **Stop 2:** Park on shoulder and walk or take dirt road to right to low ridge just north of Cajalco Road (see Fig. 3). Rock is subporphyritic quartz monzonite which contains local "veins" of tourmalinized rock. Lake Mathews dam is to northeast at head of Cajalco Canyon. Numerous prospects to north and northeast explore tourmalinized rock for tin. Low, dark hill to north is Cajalco Hill, site of Cajalco (Temescal) tin mine. Tin was discovered in the area around 1853. The main mining activity was between 1869 and 1892, 1928-29, and 1942. The Cajalco mine, the only producer, had a total production of about 130 long tons of tin (Gray, 1957).



Qal — Alluvium

Older Alluvium (includes terrace deposits)

Undifferentiated marine Pliocene and Puente Formation

Topanga Formation

Undifferentiated Vaqueros, Sespe and Santiago Formations

Silverado Formation

Ladd and Trabuco Formation

Undifferentiated granitic rocks

Quartz diorite (primarily Bonsall tonalite, quartz diorite of the Lakeview Mtns. pluton

Gabbro and diorite

Santiago Peak volcanics

Jst — Temescal Wash quartz latite porphyry

Bedford Canyon Formation

0 1 2 3 4 5

MILES

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Fig. 3. GEOLOGY OF PART OF THE ELSINORE FAULT ZONE.

by

D. M. MORTON and G. H. GRAY

1971

27.5 Dark colored tourmalinized rock on left in the road cut is in mixed granitic rock and Bedford Canyon Formation (?).

27.8 Road cut on left is in Bedford Canyon (?) rock. Here it is predominantly siliceous with some phyllite.

28.2 Elsinore trough (fault zone) straight ahead. From here to the trough the predominant rock type is Bedford Canyon Formation (?).

28.6 Quarry in red rock to left is mostly weathered Bedford Canyon Formation (?) with some sediments of the Silverado Formation.

29.0 Road cut in Pleistocene (?) older alluvium.

29.3 Road crosses Santa Fe tracks. Railroad cut to right is in Bedford Canyon Formation (?) overlain by terrace deposit.

29.6 Intersection Cajalco Road and Temescal Canyon Road. Turn right onto Temescal Canyon Road for Corona Skyline Drive side trip. Turn left on Temescal Canyon Road for continuation of trip.

CORONA SKYLINE DRIVE SIDE TRIP

(0.5) International Pipe & Ceramics Corporation, Corona Plant (Interpace) (formerly Gladding, McBean & Company). Produces red-burning heavy clay products (e.g. sewer pipe, drain tile, and conduit). Plant uses local clays and filler clays, mostly from Paleocene Silverado Formation.

(0.6) Brown- to dark-gray, sandy, older alluvium containing angular cobble clasts.

(0.8) El Cerrito Hills. Exposed on both sides of highway is white to buff and brown sandstone of the middle Miocene Topanga Formation. Some of the Topanga is buff and brown siltstone and shale; in places Topanga strata are diatomaceous.

(1.3) Temescal Canyon Road changes to Ontario Avenue. Ahead to right is operation of Minnesota Mining & Manufacturing Company. Large quarry is developed in Temescal Wash Quartz Latite Porphyry of probable Jurassic age. Rock is crushed, screened, and colored with a sub-vitreous, bonded, ceramic-type glaze and used as granules for roofing materials. This operation produces most of the granules used for processed roofing materials on the west coast; shipments are made as far north as Vancouver, British Columbia. This operation has been active since 1948, although the quarry, Temescal Rock Quarry, was opened and produced rock for macadamizing streets in Los Angeles and area in 1888. Quarry operation in the early 1920s was by tunnel or coyote system which brought down 600,000 to 1,500,000 tons of rock in each blast which used 45 to 125 tons of powder (Gray, 1961). Some of these large blasts in more recent years have been used by seismologists for refining seismic travel times (Richter, 1958).

(1.6) On north side of road are outcrops of granitic rocks (quartz monzonite and hornblende granodiorite porphyry).

(2.0) Is small road cut and along north side of highway is undifferentiated Puente Formation of upper Miocene age. In this area the Puente is mostly white to greenish-gray, thin-bedded, diatomaceous siltstone; some buff to gray siltstone and shale, and brown to buff sandstone, with local conglomerate lenses.

(2.2) Road crosses north end of short stretch of the Corona Freeway (State Highway 71) and joins Highway 71 (Ontario Avenue).

(4.4) Intersection with Main Street. Proceed ahead on Ontario Avenue. The nearby citrus acreage and the town of Corona are developed on a surface of Quaternary older alluvium, the Corona compound alluvial fan.

(5.4) Intersection of Ontario Avenue and Lincoln Avenue; turn left onto Lincoln Avenue.

(6.4) Turn right onto Chase Drive. To the west and south the break in slope in Quaternary older alluvium may be the surface expression of the Chino fault. Further southeast anomalous scarplets and benches in the older alluvium, as well as a definite scarp at the contact between Quaternary terrace deposits and older alluvium, apparently mark the trace of the Chino fault.

(6.8) Oak Avenue. Road cut at left in Quaternary older alluvium.

(7.0) Intersection Chase Drive and Skyline Drive; turn left (south) onto Skyline Drive.

(7.2) Cleveland National Forest Boundary sign and end of pavement. To left (east) is Paleocene Silverado Formation capped by flat-topped Quaternary terrace deposits. Terrace deposits here are at two different elevations that are attributed to erosion, rather than faulting.

(7.4) To left (east) Silverado sandstone and conglomerate capped by brown Quaternary terrace deposits along lower Hagador Canyon.

(7.6) Junction of Hagador and Tin Mine Canyons; keep right along Tin Mine Canyon.

(7.8) To right (north) is white to buff sandstone and conglomerate of the Silverado Formation.

(8.0) Northwest-striking fault along bare cliff faces juxtaposes upper Cretaceous Ladd Formation (Baker Canyon Conglomerate Member) and Paleocene Silverado Formation. Just to west is reef-type deposit in the Baker Canyon containing abundant oyster debris. Channel to left (Tin Mine Canyon bottom) contains boulders derived from the Ladd Formation (Baker Canyon Conglomerate Member) a short distance to the northwest on the brush-covered slope. These boulders contain numerous *Actaeonella oviformis* Gabb and are from a highly fossiliferous, generally hard, sandstone layer that crops out discontinuously over about one and a half miles from Tin Mine Canyon northwest to Mabey Canyon. In places this sandstone contains abundant *Trigonarca californica* Packard and other material that indicates a *Glycymeris pacificus* fauna.

(8.1) Draw on skyline to northwest (right) is contact between the Cretaceous Trabuco Formation (red, buff, and grayish-green massive conglomerate, minor sandstone, probably nonmarine) and Ladd Formation (Baker Canyon Conglomerate member).

(8.3) Road leaves canyon bottom and starts upgrade. Cars can be left here and the remaining trip (0.8 mile) made on foot, or there is a more narrow parking area 0.7 mile further on. Rock exposed in road cut is Jurassic Santiago Peak Volcanics—just west of the Elsinore fault.

(8.4) Road crosses the northwest-striking and steeply south-dipping Elsinore fault and passes back from Santiago Peak Volcanics into Trabuco Formation.

(9.1) Switchback. Turn around here (if driving). The switchback is essentially on the Elsinore fault which again separates Santiago Peak Volcanics on the west from Trabuco conglomerate (note clasts of weathered biotite granodiorite). The switchback is in Santiago Peak Volcanics and immediately below and above the switchback, the contact between the Santiago Peak Volcanics and Trabuco conglomerate can be seen. Up the road 0.1 mile, the fault zone is well exposed in the road cut. The switchback turn out provides a vantage point for a sweeping view of the general area to the south and east.

South across Tin Mine Canyon the bare scar high on the brush-covered slope is an old gypsum working (active in the 1920s) in altered Santiago Peak Volcanics. To the southeast (south side of Tin Mine Canyon) the Elsinore fault crosses the low, rounded, brush-covered landslide debris. Here the fault is at the break in slope between nearby flat-topped areas, which developed through landsliding, and Santiago Peak volcanics. The scars along this trace also are old gypsum prospects. Fault crosses the far ridge, with the line of eucalyptus trees, at the break in slope between this flat-topped ridge (Silverado Formation capped by Quaternary terrace deposit) and the abruptly rising, steep, brush-covered hills to the south (Santiago Peak Volcanics and Bedford Canyon Formation). Continuing to the southeast the Elsinore fault is essentially at the break in slope and separates the Silverado Formation from Santiago Peak Volcanics and Bedford Canyon Formation.

Below, in lower Tin Mine Canyon, the bare hill at left is sandstone of the Baker Canyon Conglomerate Member in fault contact with Silverado sandstone and siltstone. Brushy hills north of Skyline Drive and toward the observer are Cretaceous sandstone and conglomerate (Trabuco Formation and Baker Canyon Conglomerate Member).

Retrace route to intersection Cajalco Road and Temescal Road.

29.6 Proceed southeastward on Temescal Canyon Road.

30.0 Butterfield Stage Station Historical marker. Ahead is spoil bank from Owens-Illinois glass sand operation.

30.3 At left, under the two tanks, terrace deposits overlie Silverado Formation. To right is the glass sand pit of Owens-Illinois in essentially flat-lying Silverado. Farther to the right the freeway traffic is essentially along the contact between the Silverado and the overlying undifferentiated Sespe and Vaqueros Formations (upper Eocene to lower Miocene) which is also essentially flat lying. The Elsinore fault is located along the base of the high hills (Santa Ana Mountains) which are underlain predominantly by Jurassic Bedford Canyon Formation.

30.5 Owens-Illinois glass sand plant. This is the oldest continuously operating and principal source of silica sand in southern California. The sand is obtained from a quartz-rich facies of the Silverado. In the quarry some 120 feet of usable sandstone is exposed; well data, however, indicates locally the sandstone is nearly 300 feet thick. Yearly production exceeds 100,000 tons of finished sand, of both flint and amber, with some monthly production more than 20,000 tons. To left are silt-clay waste ponds from Owens-Illinois operations. This material has been used by several companies in the manufacture of clay products.

32.0 At left San Marcos Gabbro and Bedford Canyon Formation form the low part of the hills. Overlying the basement rocks are both residual clay deposits and Silverado Formation.

33.1 Temescal (Harrington and Atlas) clay pits are to the left (east). Both residual and sedimentary clays of the Silverado Formation are mined.

33.5 Stop Sign. Proceed southeastward on Highway 71.

33.7 To right is Mission Clay Products which produces sewer pipe. Hills to left are Quaternary terrace deposits capping clay deposits of residual clay derived from the Bedford Canyon and Silverado Formations.

33.9 Turn right onto Lawson-Hunt Road.

34.1 Terrace deposits on right. Sag pond to left developed on north branch of Glen Ivy fault, part of the Elsinore fault zone. The road follows along the trace of this fault with a southwest facing scarp.

34.6 Light colored sediments in road cut are probably part of the Silverado Formation brought up along the Glen Ivy fault.

34.7 Lawson Road-Hunt Road intersection. To the northwest the trace of the fault is marked by saddles and aligned gullies in several ridges. Retrace route along trace of Glen Ivy fault to Highway 71.

35.5 Rejoin Highway 71 and turn right.

35.7 Dense vegetation at right marks the position of the Glen Ivy fault.

36.0 Entrance to Glen Ivy Resort. The south branch of the Glen Ivy fault goes through the resort but its trace is masked by recent alluvial deposits.

36.5 To the left are Holocene terrace deposits.

37.0 Santa Fe Railroad underpass. Hill straight ahead (Estelle Mountain) underlain by intermediate composition batholith rock and Temescal Wash Quartz Latite Porphyry.

37.3 Steep walled gorge ahead is superposed meander of Temescal Wash. The stream is believed to have cut a cover of sedimentary rocks which formerly filled the valley (Dudley, 1936).

38.0 Highway 71 ascends terrace deposits which cover fossiliferous Silverado Formation. The obvious break in slope paralleling and just to the left of the road is a modified fault scarp. Rock on the east side of fault is the Temescal Wash Quartz Latite Porphyry.

38.6 Highway 71 crosses fault separating Silverado Formation from Temescal Wash Quartz Latite Porphyry.

38.9 Upper end of the superposed drainage.

39.0 South end of Lee Lake, a reservoir for Temescal Water Company. This is a good vantage point from which to view the steep walled gorge. To the southwest terrace deposits cap Silverado Formation beyond the railroad tracks.

39.4 Dissected alluvial fan deposits capping Silverado Formation.

41.0 Alberhill turnoff.

41.7 Santiago Peak volcanics (Jurassic age) are exposed in road cut on left. To the right is the operation of Pacific Clay Products and the community of Alberhill which developed around the clay mining industry. The clay deposits in the Alberhill area are of both residual and sedimentary origin and are restricted to a zone within (or just below) the Paleocene Silverado Formation. Residual clay deposits, which attain a thickness of 130 feet, have been developed from the Bedford Canyon Formation, Santiago Peak Volcanics, Temescal Wash Quartz Latite Porphyry and dioritic-gabbroic rocks. The sedimentary clay is the product of local erosion of the clay which developed on the weathered basement. Sedimentary clay averages 80 feet in thickness with a maximum of about 150 feet. Two main types of clay products are produced: red burning clay is used to make heavy clay products (e.g., brick, sewer pipe and tile); white burning clay is used to produce refractory clay products (e.g., firebrick and flue lining material). In the early 1880s both coal and clay were mined at Alberhill. Mining at the time was by underground methods. The coal, lignite, was of low grade and soon constituted only a nuisance to clay mining. Between 1895 and 1955 almost six million tons of clay had been mined in the Alberhill area. By 1955 as much as 800 tons of clay was being mined each day (Engel *et al.*, 1959, pp. 77-97).

42.7 Hill to right is Bedford Canyon Formation overlain by Silverado Formation which is in turn covered by Quaternary terrace deposits and dumps from the clay mining. The road follows Walker Canyon which is apparently a superposed drainage.

45.2 Elsinore City limits.

45.3 Exposures of Bedford Canyon Formation.

45.8 Closed depression to right of highway. At this site earlier (1926) was a fissure at least an eighth of a mile in length which later formed a trench in places more than ten feet deep and averaging two or three feet in width. According to local residents this feature developed at the time of the 1918 San Jacinto earthquake (Engel, 1959, p. 52).

46.1 State Park turnoff. The broad valley to the right is underlain by Silverado Formation.

46.9 Junction with Highway 74. Low hills ahead and to left are underlain mostly by rocks presumed to be equivalent to Bedford Canyon Formation. To the right on the west side of the low hills is trace of the Glen Ivy fault.

48.1 Turnoff to downtown Elsinore and San Juan Capistrano.

48.4 Boulders of dioritic rock to left.

48.8 Hills straight ahead on skyline are at the northern end of the Paloma Valley ring-complex.

50.0 Railroad Canyon Road. At this point the San Jacinto River enters the Elsinore

Valley (trough) from the Perris block. The Elsinore trough here constitutes a closed depression and is filled by ephemeral Lake Elsinore. In historic times only during a few prolonged periods of wet years, the last being 1916-17, has the lake overflowed entering Temescal Wash which drains northward to Santa Ana Canyon and ultimately the Pacific Ocean. A recent gravity investigation indicates the valley to be underlain by four to 8,000 feet of sediments (Ghaeni, 1967).

51.0 Road cuts in old dissected alluvial fan.

51.8 To the right in the Elsinore trough is a low hill, Rome Hill, which is bounded on both sides by faults of the Elsinore fault zone. The fault on the north is generally termed the Wildomar fault, the fault to the west, the Willard fault, the frontal fault of the Santa Ana Range in this area.

53.1 Turn left onto Bundy Canyon Road. On the skyline to the northeast is a contact between San Marcos Gabbro to the right, which constitutes the interior rock of the Paloma Valley ring-complex, and granodiorite to the left, which is the outer part of the Paloma Valley ring-complex. Immediate hills on both sides of the road are granodiorite of the Paloma Valley ring-complex which contain blocks of gabbro. This composite ring-complex consists of an older, singular ring-dike, with two subsidiary shorter-arc inner dikes; and a younger set of thin, shorter-arced dikes, largely inside the older ring-dike. The older ring-dike is granodiorite (Woodson Mountain Granodiorite of Larsen, 1948), has nearly vertical walls, and is elliptical in plan with its long axis (nine miles) oriented west-northwest. This dike was emplaced in, and contains numerous inclusions of, gabbro. Largely within the older ring-dike are more than 200 younger, shorter-arced dikes, half a foot to three feet thick. These dikes, of granitic composition, define a ring-structure which cuts older-dike rock as well as gabbro. The structure is of a classical form with moderately- to steeply-dipping margins and a horizontal center. Spatially associated with the younger dikes are a number of bodies of fine-grained granophyre. The older ring-dike appears to have resulted from vertical ring-fracturing and emplacement by magmatic stopping. Granitic magma was emplaced along a younger set of domal ring-fractures. Granophyre resulted from "pressure quenching" of part of the magma which formed the younger ring-dike (after Morton and Baird, 1971).

53.7 Decomposed granite quarry with gabbro blocks within granodiorite.

54.0 Contact of the inner side of the ring-dike (granodiorite to gabbro).

54.5 Hills ahead and to right are underlain by gabbro which is intruded by granitic dikes which form an annular pattern.

55.0 Bundy Canyon Road reaches the Perris surface. The red-brown soil is characteristic of decomposed gabbro.

55.5 Granitic dikes of the ring-dike in gabbro.

55.8 To the north is the contact between gabbro and older ring-dike rock.

56.0 To the north (left) is an exposure of a finger of metamorphic rock which interrupts the otherwise continuous outer ring-dike. Note that the metamorphic rock weathers similarly to the gabbro giving rise to smooth slopes devoid of prominent outcrops.

56.6 Road cut in San Marcos Gabbro.

57.3 At this point contact between gabbro and outer ring-dike rock is just north of the road.

57.5 Intersection with Murietta Road. Exposed in road cut to left is migmatitic rock consisting of gabbro partly digested by ring-dike rock. This is essentially at the contact of the gabbro and ring-dike.

57.8 Bundy Canyon Road crosses back into the ring-dike (granodiorite) which here strikes northwest. Hill on skyline to the south (right) is at the structural center of the ring-dike complex. Top of hill is a body of granophyre.

58.1 **Stop 3:** Road cut in weathered San Marcos Gabbro with kernels of fresh rock.

59.8 Intersection with US 395. Continue straight across and continue east on Scott Road.

59.9 Boulders of ring-dike rock protrude above valley floor (Paloma surface of Woodford *et al.*, 1971).

60.6 Northeast end of Paloma ring-dike complex.

61.8 **Stop 4:** Intersection of Scott Road and Briggs Road. The road cut is in phyllitic quartz-rich metamorphic rock correlated with Bedford Canyon Formation. Hills to the left, underlain by phyllite and slate, contain a few gold-bearing quartz veins. Small building at the base of the hill is the Leon gold mine.

62.3 Hills to right are underlain by San Marcos Gabbro.

63.0 Road crosses contact between San Marcos Gabbro and granodiorite of the Domenigoni Valley pluton. The discontinuously exposed Domenigoni Valley pluton is elliptical in plan (4 x 8 miles) and oriented slightly west of north; similar rock occurs west of the pluton. The pluton invades country rock of the Bedford Canyon and French Valley Formations. The pluton, partly discordant and partly concordant, is composed of homogeneous appearing granodiorite-quartz diorite. In all but its southernmost part the plutonic rock is massive,and contains abundant unoriented inclusions. In its southernmost part the pluton is faintly foliated and contains inclusions parallel to the margin of the pluton. Two relatively consistent, steeply-dipping joint sets are present; one strikes northeast, the other northwest. A dike swarm, principally of quartz latite composition, occurs in the northwest-striking joint set. Most of the dike rock is porphyritic with a foliated structure and with a lineation produced by micaceous streaks and oriented hornblende and plagioclase crystals, on S-surfaces of the foliated rock. This lineation is strikingly consistent in orientation; it trends southeast and plunges at moderate angles to the southeast. Field evidence suggests most of the pluton was passively emplaced. Movement within quartz latite dikes after they were largely crystallized produced cataclastic texture (after Morton, unpublished mapping, 1970).

64.4 To the left is outcrop of resistant foliated quartz latite dike rock in granodiorite.

64.8 Hills on skyline to east are underlain by metasedimentary rocks of the French Valley Formation (Schwarcz, 1969).

65.0 Intersection with Winchester Road. Turn left.

65.8 Skyline to west and north is underlain by Domenigoni Valley pluton rock cut by abundant foliated quartz latite dikes.

67.0 Ahead and to left are wall-like masses of resistant quartz latite.

67.6 **Stop 5:** Road cut affords excellent exposure of granodiorite cut by foliated quartz latite dikes.

67.8 To right at base of low hills is seen the contact between the pluton and the French Valley Formation.

68.4 Road cut shows typical rock of the pluton with abundant unoriented equidimensional dark inclusions.

68.6 To the east on the far hillside is the open pit working of the old Winchester magnesite mine developed in a metaserpentine body.

68.8 Hills on skyline ahead are underlain by French Valley Formation and cut by granitic dikes. To the northwest is the contact between the Domenigoni pluton to the west, and French Valley Formation rocks to the east.

69.6 Downtown Winchester.

70.3 **Stop 6:** Cordierite-bearing biotite schist of the French Valley Formation.

71.1 Hills to right are underlain by San Marcos Gabbro which is here primarily olivine gabbro. Bouldery hills straight ahead are part of the Lakeview Mountains pluton.

71.8 Low hills to right are quartz diorite and migmatitic quartz dioritic rock that surround the Lakeview Mountains pluton.

72.2 Intersection with Highway 74. Turn left.

72.6 Workings on hill to right are feldspar-quartz prospects in pegmatite dikes in the Lakeview Mountains pluton.

73.0 Road cuts in foliated quartz dioritic rock.

73.5 **Stop 7:** Exposures of foliated quartz dioritic and migmatitic rock.

74.5 Turn right onto Juniper Flats Road.

75.1 Cross contact between foliated quartz dioritic rock and Lakeview Mountains pluton.

75.6 **Stop 8:** Outcrops to left contain abundant schlieren which are characteristic of rock of the Lakeview Mountains pluton. This pluton is a steep-walled body tear-shaped in ground plan, exposed discontinuously over an area of 60-80 square miles. Located at an abrupt local deflection of the northwest-striking regional grain, it is concordant with the enclosing rocks, which consist of varied granitic and mixed granitic-metamorphic rocks. The pluton is almost entirely coarse-grained hornblende-biotite-quartz diorite that lacks potassium feldspar. Schlieren are ubiquitous, as are lenticular inclusions, which parallel the schlieren. Schlieren, which impart to the rock an extreme small-scale mineralogic heterogeneity, geometrically fall into three orientation groups with the most pronounced concordant to the outline of the body. The other two groups, which are discordant, strike northwest and northeast. Granitic pegmatite dikes, hypersthene gabbro masses, and both mafic and leucocratic quartz diorite are concentrated in the geometrically and structurally deduced center of the pluton. It is believed the pluton was emplaced forcefully producing the deflection in the regional grain. The pegmatite dikes represent the fugitive constituents of the pluton-forming magma and their concentation in the center of the pluton marks the last part of the pluton to crystallize. An extensive chemical study shows the pluton is highly homogeneous on a large scale and extremely heterogeneous on a small scale. However, a weak, but consistent, zonational chemical pattern parallels the walls of the pluton. This zonation shows the pluton has a relatively basic and dense core and implies the last rock to crystallize was more basic than rock formed earlier (after Morton, 1969; Morton *et al.,* 1969).

75.9 Quarry in partly decomposed quartz diorite. Note the numerous schlieren.

76.5 Road reaches the 2,100 ft. Lakeview-Gavilan surface.

76.9 Thin veneer of gray bedded sediments on Lakeview-Gavilan surface.

77.8 Turn left.

78.0 Flat skyline to west and east are remnants of a 2,500 foot surface (Magee surface of Woodford *et al.,* 1971). To the north is seen a continuation of the Lakeview-Gavilan surface.

78.2 Road cut in typical rock of the pluton with abundant schlieren. Northward towards the center of the pluton granitic pegmatite dikes become common to abundant.

79.3 To the northeast is a good view of the Lakeview-Gavilan surface.

80.1 Road cut in old red alluvium.

81.4 Low hills on skyline straight ahead are the northwest part of the Lakeview Mountains pluton. Higher hills, Bernasconi Hills, are underlain by a variety of granitic rock and schist.

81.9 Turn right onto Hansen Avenue.

84.0 Community of Lakeview. Turn right onto Ramona Expressway.

84.2 Hill to the left is schist of unknown age intruded by quartz diorite. Straight ahead the higher hills are mostly metamorphic rock and the lower hills, the San Timoteo Badlands, Pliocene-Pleistocene sediments. The San Jacinto fault bounds these hills on the southwest.

86.7 In the small canyon to the south is located the contact between the Lakeview Mountains pluton to the west and foliated granitic rocks to the east.

88.0 Line of cottonwood trees to the left marks the Casa Loma fault. An 8,000-foot deep sediment-filled graben is located between the Casa Loma fault and the San Jacinto fault (Fett, 1968).

89.0 Low hill to the left, Casa Loma Hill, is a tectonically produced feature along the Casa Loma fault (Proctor, 1962).

89.5 Road crosses Casa Loma fault scarp.

89.8 West side of the high hills ahead is the modified fault scarp of the San Jacinto fault. These hills are covered by extensive landslide deposits.

91.2 Turn left onto Sanderson Avenue.

92.1 San Jacinto River.

92.9 Road crosses San Jacinto fault. Note fault scarp which produced southwest-facing break-in-slope in alluvium to northwest.

93.1 The road crosses the Gilman Springs Road. Continue straight ahead on Highway 79 (Lamb Canyon Road) entering the Badlands.

93.2 Road cut in coarse clastic red beds of Pliocene age.

93.9 **Stop 9:** Road cut affords excellent view of a minor reverse fault. Here schist of unknown age has been thrust over Pliocene red beds.

94.0 Depositional contact of red beds over gneiss. The road for a short distance to the north skirts this depositional contact.

94.3 Road cut in schist.

94.7 **Stop 10:** To the right is schist and marble of unknown age. Just north of the road is a depositional contact between these rocks and Pliocene sediments. The Pliocene sediments contain lenticular beds of monolithologic conglomerate with clasts of quartz diorite as much as 20 feet in diameter.

95.1 To left are beds of boulder conglomerate.

95.4 Prominent red bed to the left is the approximate top of the red beds in this sequence. Above this marker unit gray to tan, finer grained clastic rocks predominate.

97.0 Bouldery hill to the north is quartz diorite. Lithologically it is the same as the clasts in the conglomerate to the south and may have been the source for the clasts.

97.7 Contact between sediments and quartz diorite.

97.9 Contact between quartz diorite and sediments.

98.4 Contact between Pliocene-Pleistocene sediments and Pleistocene red alluvium.

98.8 Road cut in red alluvium. Straight ahead on the skyline is San Gorgonio Peak—high point of the San Bernardino Mountains, 11,502 feet.

99.7 Southern Pacific Railroad and the town of Beaumont.

99.9 Left turn onto Interstate Highway 10 towards Los Angeles. Enter left lanes to take Highway 60 to Riverside.

100.7 Take Highway 60 west towards Riverside.

102.3 Road cuts in red alluvium.

103.1 Road crosses contact back into Pleistocene sediments.

103.4 Jack Rabbit Trail turnoff.

103.8 Terrace deposits to the right are of old red alluvium.

104.5 Recent terraces to the right have been cut by San Timoteo stream.

105.2 Re-enter San Timoteo Badlands. Highway is essentially normal to the length of the Badlands and predominant structure which, in a gross form, is a northwest-trending anticline.

106.2 Eastward-dipping coarse clastic Pliocene-Pleistocene sediments.

107.7 Westward-dipping Pliocene-Pleistocene sediments on the south flank of the anticline.

109.4 Hemet—San Jacinto turnoff.

110.1 Highway crosses San Jacinto fault.

110.4 Smooth-topped hills to the northwest are underlain by quartz diorite and separated from the Badlands to the east by the San Jacinto fault.

115.0 To the northeast is Pigeon Pass Valley. Exposed on both sides are rocks of the Box Springs complex. Note the eastward dip of the rocks on the west side of the valley and the westward dip of the rocks on the east side.

119.2 San Diego turnoff onto US 395.

119.5 Junction with US 395.

122.6 University Avenue turnoff. Bear to the right to return to Ramada Inn.

123.8 Parking Lot, Ramada Inn, Riverside. End of trip.

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