FIELD TRIP TO THE IONE CLAY AREA[1] HELD IN CONJUNCTION WITH THE SIXTH NATIONAL CLAY CONFERENCE AUGUST 21, 1957

by

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ROAD LOG: BERKELEY TO IONE

VIA VALLEJO, FAIRFIELD, BIRDS LANDING, RIO VISTA AND WOODBRIDGE

MILES

Meeting time: 7 : 00 A.M.

0.0 Load busses on Telegraph Avenue at Sather Gate. Turn left around block and right (west) on Bancroft Way. Turn right (north) on Fulton and Oxford to University Avenue.

0.4 Turn left (west) on UNIVERSITY AVE. Proceed west through Berkeley to U.S. Highway 40. (Fig. 1.)

2.5 Turn right (north) on Highway 40 (Eastshore Freeway) toward Vallejo.

3.8 The isolated, tree-covered hill ahead is El Cerrito ("Little Hill"), or Albany Hill. Now covered with eucalyptus trees on this side, in old pictures it was seen to be strikingly bare. These trees were introduced from Australia and were planted widely in western California.
The hill is made of weathered sandstones of the Jurassic Franciscan formation, a complex of sandstone, shale, radiolarian chert, ultrabasic igneous rocks (in part serpentinized), and associated metamorphic rocks. This knob remains as an erosional remnant surrounded by the softer alluvium. The sandstone may be observed in old quarry workings on the west side of the hill (Jenkins, 1951, p. 339).

4.7 RICHMOND CITY LIMITS, CONTRA COSTA COUNTY LINE. Northward, Highway 40 traverses low bay-margin land through Richmond and San Pablo. In pre-Spanish days this area was thickly populated by Indians. Many shell mounds mark their ancient camp grounds and have yielded numerous artifacts.
The region was first settled by the Spanish in 1826, and became part of a Spanish grant, Rancho San Pablo. Remains of two adobes from the early Spanish period still stand.

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4.9 Cross Central Ave. (Stop light). For the next mile sandstones, shales and basalts of the Franciscan formation are exposed in road cuts, but the exposures are not representative owing to deep weathering.

7.3 McDonald Ave. turnoff. One block east is a good exposure of Franciscan chert. Farther east the hills are made up of serpentine and schist.

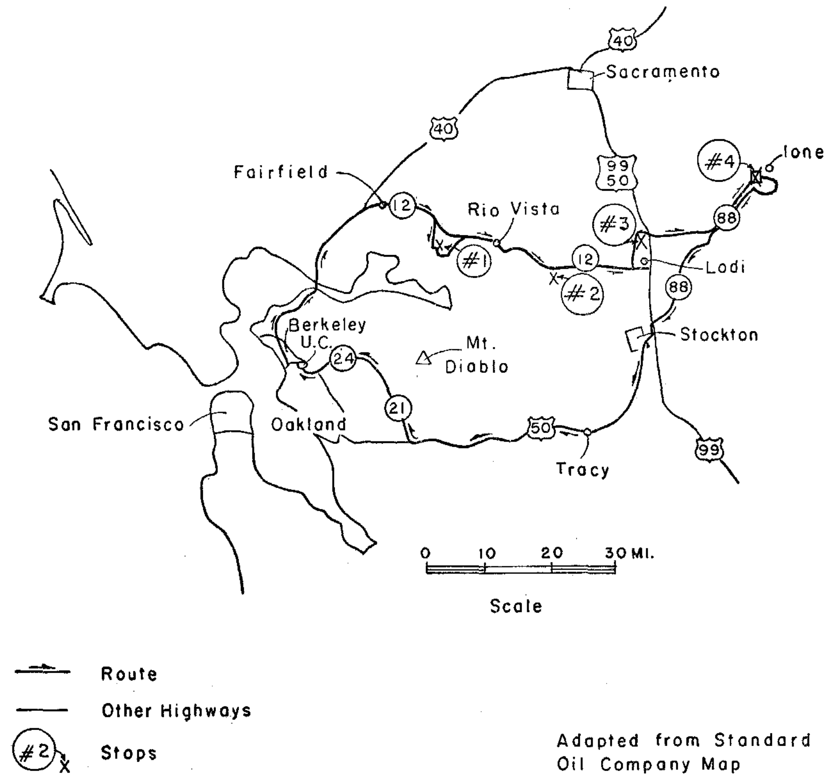

Figure 1.—Field trip route, Berkeley to Ione and return.

7.4 Turn Right Off Freeway to San Pablo Ave. At stop light 0.1 mile farther, turn left on San Pablo Ave. toward Vallejo. Pass through town of San Pablo.

10.3 Road starts upward over north end of San Pablo Ridge. The low road cuts expose sediments of the Mio-Pliocene Orinda formation. These are poorly consolidated light-colored silt, clay, and conglomerate, which are widely distributed in the Berkeley Hills. They are river flood-plain deposits that contain shells of fresh-water ostracods and mollusks, together with remains of horses, camels, and other vertebrates.

11.1 to 11.8 Passing through San Pablo Tank Farm, a facility of Standard Oil's big Richmond refinery, which provides storage for incoming crude oil and refined products.

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12.1 Long road cut exposes continental strata of the Orinda formation. These are soft, light-colored sediments which contain debris from the Franciscan and Monterey formations. They are strongly folded, striking northwest and dipping steeply northeast.

12.8 Hayward fault which trends southeast along the west side of the small hill to the right of the highway. The fault brings the Orinda formation against crushed shale beds of a member of the Monterey " group " (Miocene) exposed in the road cut. These are white, diatomaceous shales interbedded with silt-stone, and containing marine mollusks. Shale of this type occurs over wide areas in western California, but differs in age at various localities.
The Hayward fault is a large structural break traceable from San Pablo Bay to the vicinity of Gilroy, 100 miles southeast.

13.8 to 14.1 Road cuts give good exposures of the Miocene shales. Ahead, the highway descends into Pinole, in a narrow valley bounded by faults on both sides. The bedrock here is Pliocene tuff and is not well exposed.

14.2 Town of PINOLE (stop light), named from Rancho El Pinole, a Spanish grant dating from 1829. Beyond Pinole the road passes over the Santa Fe railroad tracks, and a side road on the left leads to the plant of the Hercules Powder Company. In the next two miles various sandstones and shales of the Monterey (middle Miocene) and San Pablo (upper Miocene) groups are exposed in the road and railroad cuts.

15.2 JUNCTION, HIGHWAYS U.S. 40 AND CALIF. 4. Turn left on Highway 40. Road cuts visible in hillsides along new freeway route expose shale of the San Pablo group.

16.4 ENTER RODEO. This locality at the mouth of the Rodeo Creek was a camp site of the Pedro Fages expedition, which explored much of this area in 1776.
Miocene and Pliocene beds in the vicinity contain abundant fossils. The railroad cuts along the bay from Rodeo to Oleum are favorite collecting localities.

17.4 The small promontory, projecting into the bay on the left, is made up of Pinole tuff (Pliocene) a white, soft rhyolitic tuff composed mainly of pumice fragments. It lies near the axis of a northwest-trending syncline.

17.8 The road passes through the Union Oil Company's Oleum Refinery. The bay front area is attractive for large industrial establishments because it affords deep-water dock facilities, and service by both the Southern Pacific and Santa Fe railroads.

18.2 Along the bay, north of the highway, may be seen the great Selby Smelter of American Smelting and Refining Co. It processes ore brought from all over the world. Many metals are produced, and much of the slag is used by insulation manufacturers in making rock wool. The smelter was first established here in 1885 by an earlier company. Its 605 ft smokestack is a landmark that can be seen for a considerable distance.

18.7 Road starts uphill; cuts show exposures of Monterey group sandstones and shales. At top of hill is a narrow belt of Martinez formation (Paleocene) ; beyond this are " Chico " sandstones (Upper Cretaceous) separated from the Martinez by the Franklin thrust fault.

19.3 View of Carquinez Strait and Bridge, also mouth of Vallejo Harbor to the north. The great Mare Island Navy Yard, established in 1853 and one of the oldest in the west, lies west of Vallejo. The rocks in this vicinity are strongly distorted and crushed along the Franklin fault ; because of this condition some of the road cuts have been faced with concrete to prevent slides.

20.1 TURN LEFT ACROSS BRIDGE. Carquinez Strait, joining San Pablo and Suisun Bays, is crossed here by the high, narrow Carquinez Bridge. The strait is the

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outlet for the Sacramento-San Joaquin river system draining California's Central Valley. About 25 miles east of here is the " delta " area, which our route will traverse.

This was the first of the high bridges in the San Francisco area, being privately built in the '20s. It remained a toll bridge for 25 years. It is being supplemented by a parallel bridge, now under construction, as part of a major freeway link. Below the bridge may be seen the C. & H. Sugar Refinery. Besides it and the two refineries, dynamite plant, and smelter already seen, several other large plants are located in the continuation of this strip to the east. Included is the Gladding, McBean refractory brick plant.

20.9 North end of bridge. Fossiliferous Cretaceous rocks make up the north bank of Carquinez Strait. These well-bedded brown sandstones and clay shales extend northward beyond Vallejo and are deformed into broad folds that trend northwestward.

23.0 to 24.3 Passing through eastern edge of VALLEJO (Cross Tennessee St. at 24.0). Town founded in 1850 by General Mariano Vallejo.

26.2 Road cut, bluish shales (Cretaceous). Ahead, the highway passes over Sulphur Springs Mountain. Faulted Franciscan rocks make up the higher portion of the hills. Some quicksilver has been mined from these rocks to the southeast.

27.1 Summit of ridge. Past the shale and sandstone outcrops is an exposure of serpentine in the cut bank on the left. Still farther, the serpentine is in fault contact with brown sandstones and shales (mapped as Lower Cretaceous by Weaver, 1949, Pl. 15).

28.4 NAPA-SOLANO COUNTY LINE. The highway continues northeast down American Canyon, through poorly exposed Cretaceous and Eocene sandstones.

32.4 Highway passes under the Southern Pacific tracks and is joined by Highway 12 at the junction of American and Jameson Canyons. From here the highway passes over an alluvial plain toward Fairfield. North of the junction is a small quarry exposing rocks of the Sonoma volcanic series (Pliocene). There are several buttes of Sonoma lavas and tuffs on the plain to the east. At 34.2 a road cut affords a good exposure of the light-colored tuffs.

37.2 TURN RIGHT on Highway 12 toward FAIRFIELD, leaving Highway 40.

38.9 FAIRFIELD. TURN RIGHT opposite Solano County Courthouse. This is the center of a rich agricultural area of fruit orchards and livestock grazing. The town dates from 1859.

39.1 TURN LEFT at south edge of town and cross railroad (39.2) taking road eastward toward Rio Vista. The Potrero Hills are seen two miles to the southeast. They trend eastward for six miles in an anticlinal structure exposing Paleocene and younger formations, although a small outcrop of Cretaceous is present on one side. Gas was discovered here in 1938 but the well was later abandoned.

43.2 Road to left enters Travis Air Force Base, a major installation of the Strategic Air Command's long range bomber force.

46.3 Quarry left (east) of road is in Markeley (Eocene) sandstone.

47.6 Road cut exposures of Wolfskill formation (Pliocene), continental sandstone, conglomerate, and tuff dipping gently to the northeast.

48.0 TURN RIGHT (south) on road toward Birds Landing, leaving Highway 12. Road goes southward over Wolfskill sands and gravels (exposed in cut at 49.5). At 51.4, off to the southwest is Kirby Hill, site of a small gas field. View of Mt. Diablo, straight ahead, about 17 miles distant.

52.8 TURN LEFT and cross track of Sacramento Northern Railroad 0.1 mile farther.

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53.7 STOP 1. Road cut. *Denverton Soil Series.* (See profile description and laboratory data in Appendix B.) The section exposed at this point was identified as loess by F. F. Riecken, E. P. Whiteside and J. Thorp. Loess of this type has not been identified previously in California.

54.9 TURN LEFT AT BIRDS LANDING. Continue eastward through the Montezuma Hills, over the dissected surface of Pleistocene terrace deposits (Montezuma formation, poorly bedded clay, sand, and gravel).

58.8 Old olive orchard, growing without irrigation.

60.8 REJOIN HIGHWAY 12. TURN RIGHT (east). At 62.0, view of California's great "Central Valley." The valley is covered with Pleistocene and Recent alluvial sediments and soils. The subsurface structure is broadly synclinal (Fig. 2); much subsurface information has been obtained from the drilling of gas wells.

66.9 ENTER RIO VISTA. Follow Highway 12 to left and cross SACRAMENTO RIVER at 67.7. Moderate-sized ships can navigate up this river to Sacramento. They still carry some of the freight traffic in spite of rail and truck competition. The waterways of the delta are an important recreation area. Two miles southwest is the important Rio Vista gas field, a major supplier of natural gas fuel to the Bay area.

68.1 JUNCTION HIGHWAYS 12 and 24, east side of Sacramento River. TURN LEFT (northeast) toward Isleton. Road runs on top of levee, paralleling river. Some farm land back of levee is 10 ft or more below river level. Pear orchards parallel part of the route.

72.5 ISLETON. TURN RIGHT on Highway 12, leaving Highway 24, which leads to Sacramento (40 miles north). The river route to Sacramento carried much of the heavy traffic during the days of the gold rush. Sacramento was founded as New Helvetia in 1839 by John Sutter and became a major supply point for the transcontinental wagon traffic and the mining country.

As Highway 12 leaves Isleton, note gas wells a short distance to the left of the road at 73.0 and at the sharp left turn at 73.7. A mile farther the road, several feet below river level, runs beside the levee.

76.3 CROSS MOKELUMNE RIVER. The highway travels eastward over peat lands for several miles. The peat soil supports a rich agriculture, and huge tonnages of rice and other cereals are grown. In some places the peat is thick and pure enough for horticultural use, and peat mining in this area is a growing industry. Peat land has caught fire and smoldered undetected for long periods, fire breaking forth suddenly and causing extensive damage.

80.2 STOP 2. Pit beside road. *Staten Peaty Muck.* (See profile description and laboratory data in Appendix B.)

80.8 CROSS POTATO SLOUGH, ENTER TERMINOUS.

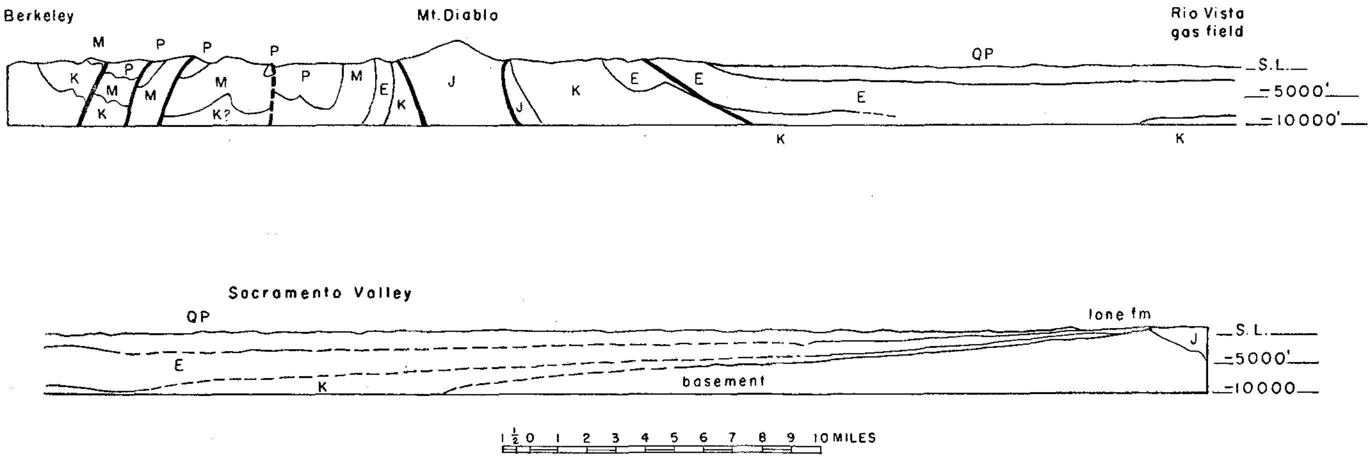
86.3 CROSS THORNTON ROAD. (Boulevard stop.) One-half mile farther is the margin of the granitic alluvial fan material that covers much of the eastern side of the Central Valley. This is the Victor formation whose Pleistocene sands, silts and gravels make up the Victor alluvial plain and form soils that favor the growing of grapes and a wide variety of other crops.

88.2 CROSS WESTERN PACIFIC RAILROAD TRACK.

90.9 Boulevard stop. TURN LEFT on Sacramento Road toward WOODBRIDGE, leaving Highway 12.

93.5 WOODBRIDGE. Cross S. P. railroad (3 tracks), jog right two streets and continue north, crossing Mokelumne River.

97.3 STOP 3, just past JAHANT SLOUGH. Cut on right side of road. *San Joaquin Sandy Loam.* (See profile description and laboratory data in Appendix B.)



EXPLANATION

QP Pliocene and Pleistocene
P Pliocene
M Miocene
E Paleocene and Eocene
K Cretaceous
J Jurassic

Modified after N. L. Taliaferro
California Division of Mines Bull. 154

FIGURE 2.—Generalized geologic cross section between Berkeley and Ione.

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97.9 UNDERPASS, Southern Pacific tracks. Continue 0.2 miles farther north and make sharp RIGHT TURN, doubling back to the southeast.

99.9 CROSS JAHANT OVERHEAD over U.S. Highway 99 FREEWAY. Continue eastward on Jahant Road, directly toward the Sierran foothills and the belt of clay-bearing Eocene rocks of the Ione formation which lies along these hills a few miles west of the Mother Lode.

100.9 CROSS KENEFICK ROAD and railroad tracks of California Traction Co.; continue eastward.

109.2 JOIN HIGHWAY 88, coming from the south across the Mokelumne River, and continue NORTHEAST. The gravel mounds in the river bed were left by gold-dredging operations.
The road continues through rolling country mapped as Laguna formation by Piper and others (1939, Pl. 1). These are Pliocene (?) alluvial deposits. The Laguna lacks the andesitic material found in the underlying Mehrten.

112.7 Junction Liberty Road, from left, about 0.2 mile past contact of Laguna with Mehrten formation (Mio-Pliocene).

113.5 In the next four miles are many typical exposures of the Mehrten formation, especially on the ridges and in road cuts and ditches. These beds are characterized by andesitic detritus and agglomerates and are associated with the Miocene (?) andesitic eruptions in the Sierra Nevada.

116.1 SAN JOAQUIN-AMADOR COUNTY LINE.

118.0 Light-colored, tuffaceous sandstones and clays in road cut, just past a conspicuous exposure of Mehrten agglomerate. These beds contain no andesitic material and have been mapped as Valley Springs formation (Miocene) by Piper, Gale and Thomas. They are derived largely from the rocks of the earlier or rhyolitic period of Sierran eruptions.

119.2 CROSS JACKSON CREEK. Side road to Buena Vista turns right at 119.6; continue straight ahead. Road climbs over the "Greenstone Ridge" (120.1–120.4), a partially buried ridge of Jurassic metamorphic rocks lying parallel to and about three miles in front of the main outcrop belt of these metamorphic rocks along the foothill front (Bates, 1945, p. 5). This ridge seems to have acted as a threshold, behind which troughlike depressions impounded much of the Ione formation sediment.

121.1 Ione sandstone (Eocene) exposed in road cuts. The Ione is characterized by white quartzose sandstones and clays, with some associated lignitic beds (Allen, 1929; Dietrich, 1928).

121.7 TURN LEFT towards Ione, leaving Highway 88.

122.8 TURN LEFT INTO GATE of Owens-Illinois Ione Sand Plant and Gladding, McBean Ione Plant; STOP 4, in front of Ione Sand Plant. Tour of open pit operations of Gladding, McBean & Co. and sand and clay processing plants of Owens-Illinois and Gladding, McBean. See Appendix A for geologic summary of Ione Area.

ROAD LOG: IONE TO BERKELEY

VIA BUENA VISTA, STOCKTON, TRACY AND WALNUT CREEK

0.0 GATE of Gladding, McBean and Owens-Illinois plants. TURN RIGHT on to main road. One-half mile east is the brick plant of the Western Refractories Co.

1.0 JUNCTION HIGHWAY 88. TURN LEFT toward Jackson. Ione exposed in new cuts along this road. The low, brushy hills are the characteristic topographic expression of these soft, flat-lying Ione beds.

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2.8 TURN RIGHT on Buena Vista road, leaving Highway 88.

4.1 Side road on right leads to clay pit operated by Gladding Bros of San Jose. A mile farther, the buttes visible ahead are Buena Vista Peaks capped by a resistant rhyolite tuff bed of the Valley Springs formation. At their base may be seen the plant of the American Lignite Products Co., which extracts Montan wax from the lignites of the Ione formation (Pask and Turner, 1952).

5.9 BUENA VISTA. Continue straight ahead. Much placer mining was done in this vicinity and at Lancha Plana on the river a few miles south. Water is diverted from the Mokelumne at Pardee Dam nearby as municipal supply for Berkeley and other East Bay cities.

6.7 Road on left to Camanche, location of a Pacific Clay Products Co. plant.

7.2 Road parallels a portion of the " Greenstone Ridge " for a short distance.

9.3 INTERSECTION with Highway 88. TURN LEFT toward Stockton. Road traverses section seen on morning trip ; Valley Springs, Mehrten and Laguna formations.

12.8 AMADOR-SAN JOAQUIN COUNTY LINE.

19.9 CROSS MOKELUMNE RIVER. One mile farther is junction of Highway 88 with 12, from Valley Springs, another locality where the Ione clays are mined.

TURN RIGHT, passing through CLEMENTS, as highway parallels Southern Pacific tracks.

25.0 Center of LOCKEFORD. Continue, crossing railroad at 25.4. At 26.8, Highway 12 turns right ; continue ahead on Highway 88 toward Stockton.

38.8 JUNCTION Highway 88 with U.S. Routes 99 and 50 (stop light).

TURN LEFT on Highways 99 and 50. Cross tracks of Stockton Terminal and Eastern at 39.4 and Southern Pacific at 40.3.

41.3 TURN RIGHT following Highway 50 through edge of Stockton, center for a rich agricultural area and inland port city accessible to deep water navigation. Underpasses at Santa Fe and S.P.–W.P. tracks.

44.3 TURN LEFT following Highway 50 route to Tracy. At 45.9, near south city limits of Stockton, Laurel Potteries, manufacturers of dinner ware from California and Tennessee clays ; also California Clay Products Company, makers of brick and hollow tile from local clays.

At 51.4, U.S. Army Sharpe General Depot, visible east of highway.

56.0 UNDERPASS and JUNCTION with HIGHWAY 120 ; follow Highway 50 to RIGHT. At 56.2 cross SAN JOAQUIN RIVER. In 1846 twenty Mormon pioneers came up the river in a sail launch and landed near this point to start a new community. The first ferry across the river was established here in 1848.

64.0 OVERPASS. Southern Pacific tracks at east edge of TRACY. Pass through town and cross S.P. tracks again at 65.7.

66.1 One-half mile west of Tracy, road to Corral Hollow turns off to south, leading 14 miles to Tesla, site of coal and clay mining and refractory brick making in the early 1900's (Huey, 1948). The clay occurs with white sand and coal in the Eocene Tesla formation, similar in many ways to the Ione. However, the steep dip of the beds makes underground mining necessary and costs are too high to be competitive, although some of the clay is of very good quality.

Ahead is the Diablo Range, which extends southeastward for 130 miles. Most of the core of the range is made up of Franciscan rocks, flanked on the east by Cretaceous, with a thin Tertiary sequence in some places.

An important manganese mine is located in Franciscan rocks 13 miles south of Tracy.

71.6 CROSS DELTA-MENDOTA CANAL, major aqueduct carrying water from delta for

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irrigation of northwestern San Joaquin Valley. SAN JOAQUIN-ALAMEDA COUNTY LINE 0.1 mile farther. At 72.2, first Tertiary exposures in road cuts ; for next 1.3 miles, lenticular sandstones and conglomerates of Neroly formation.

73.5 Unconformity between Miocene (Neroly formation) and Cretaceous (Panoche formation) 100 ft from west end of road cut north of highway at road junction. Basal conglomerate of Neroly overlies steeper-dipping Cretaceous shales. In next 2.4 miles are good exposures of the Cretaceous sandstones and shales in the road and railroad cuts.

75.9 OVERPASS SOUTHERN PACIFIC ; UNDERPASS WESTERN PACIFIC TRACKS. Beyond, the dips become flatter as the axial area of a broadly arched anticline is approached ; some distance farther the beds dip westward. Large cuts show the character of the shales and massive, concretionary sandstones as the road descends into the Livermore Valley.

79.9 CROSS OVER S.P. and W.P. TRACKS. At 82.5, road turns off to Livermore ; continue west on Route 50.

90.0 Alameda County Prison Farm to right of road. Beyond may be seen buildings of Parks Air Force Base.

93.3 DUBLIN. TURN RIGHT on Highway 21, leaving Highway 50, and heading northward. Mt Diablo (elevation 3849 ft), guiding landmark since early Spanish days, dominates the skyline to the right. Since 1851 it has been the point of origin for land surveys of a vast part of California and Nevada. On its south flank are steep-dipping Tertiary and Cretaceous beds while its core is a jumbled mass of Franciscan rocks punched up through the younger sediments. On the opposite (northeast) side a similar Cretaceous and Tertiary sequence is repeated, with coal beds and white sands of some economic interest in the Eocene portion.

Our route continues northwest along the San Ramon syncline, between Mt Diablo and the Berkeley hills.

95.3 CROSS ALAMEDA–CONTRA COSTA COUNTY LINE. At 102.5 cross Southern Pacific tracks and enter Danville. About 4.5 miles farther, Sugarloaf Hill on right of road is made up of San Pablo sandstone. Cross S.P. tracks at 107.7.

109.1 JUNCTION OF HIGHWAYS 21 and 24 in WALNUT CREEK (settled in 1850). TURN LEFT on 24, across west limb of San Ramon syncline, crossing poorly exposed Pliocene, Miocene, and Eocene beds. Below, the Eocene is in contact with Miocene strata at a large thrust fault, and the road approaches another synclinal structure with Pliocene beds appearing at 111.3.

112.9 LAFAYETTE, site of a large Indian village. Settled by Spanish Californians before 1834. Highway passing over folded and faulted Pliocene beds.

116.5 ORINDA CROSSROADS, turnoff for residential community of Orinda to north and St Marys College at Moraga to the south.

At 117.1 a major landslide blocked the road on December 9, 1950 when soft Pliocene rocks of the high road cut failed. Ahead, the road crosses another syncline in Pliocene volcanics and continental beds, with axis at 117.7.

118.5 ENTER BROADWAY TUNNEL. Orinda nonmarine beds (Pliocene) near portal, with tunnel passing into a near-vertical section of Claremont (Monterey " group ") cherts and shales, riddled by diabase dikes. The dikes are altered and structurally very weak, causing great unforeseen difficulty in construction of the tunnel.

119.2 WEST END OF BROADWAY TUNNEL. Road passes from Miocene shales into dark Cretaceous shales and sandstones.

120.2 JUNCTION BROADWAY and MOUNTAIN BLVD.–TUNNEL ROAD. TURN RIGHT toward Berkeley. Road crosses Hayward fault here with Cretaceous in contact with Franciscan, which is found only on west side of fault. Fault extends along base of Berkeley Hills, through University of California campus.

The road parallels the hill front, where large quarry faces show the weathered, rust-colored Leona rhyolite (Pliocene ?), used as fill during the construction of the Oakland Army Base in 1943–1944.

121.4 TURN RIGHT, off Ashby Avenue onto Claremont ; at 121.7, left from Claremont onto Derby ; at 122.1, right from Derby onto College ; at 122.6, left from College on to Bancroft ; at 122.9, right from Bancroft on to Telegraph.

123.0 Arrive University of California Campus.

STRATIGRAPHIC NAMES MENTIONED IN LOGS

AGE	WEST AREA		EAST AREA
Pleistocene	Montezuma		Victor
Pliocene	Wolfskill Sonoma, Pinole, Leona (volcanics)		Laguna
Mio-Pliocene	Orinda		Mehrten
Miocene	San Pablo (group) Neroly Monterey (group)		Valley Springs
Eocene	Markeley	Tesla	Ione
Paleocene	Martinez		
Cretaceous (U.)	" Chico "	Panoche	
Jurassic	Franciscan		Mariposa-Amador

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APPENDIX A

IONE AREA

The middle Eocene Ione formation crops out in a discontinuous belt bordering the western foothills of the Sierra Nevada, from approximately the Feather River in the north to the San Joaquin River in the south. The Ione formation consists mostly of sand and clay–sand mixtures, with local beds of clay, shale, siliceous gravel, conglomerate and lignite. The formation was deposited in a lagoonal environment and therefore shows a wide range in thickness and lithology within a given basin and from one basin to another. The clay-rich bodies occur as beds and lenses and commonly consist of clay–sand mixtures with a sand content that ranges from a few percent to 60 percent or more. Other beds within the Ione formation are composed essentially of sand and a small proportion of anauxite. Although most of the clay is of sedimentary origin and was derived from the crystalline rocks of the Sierra Nevada, minor residual deposits are developed on Jurassic metamorphic rocks adjacent to the Ione deposits. The Ione formation in the Ione area consists of two members and has a total thickness of about 400 ft. The lower member consists principally of clayey sand, clay and lignite. The upper member is characterized by sand, clayey sand, some clay, and minor amounts of conglomerate. Most of the commercial clays are in the lower member and they are either kaolinite or anauxite, mixed with iron oxide and quartz impurities. To the west, the Ione formation is buried by younger sedimentary rocks. Along the foothills to the east in many places the formation is capped by younger volcanic rocks.

Near the small town of Ione, in west central Amador County, are 33 clay pits distributed over an area about 12 miles long and 2 miles wide. This

TABLE 1.—TYPICAL CHEMICAL ANALYSES OF CLAYS FROM THE IONE AREA, AMADOR COUNTY, CALIFORNIA

Constituent	Percent				
SiO_2	41.76	49.34	75.46	42.18	52.26
Al_2O_3	38.86	33.07	16.05	38.09	30.60
Fe_2O_3	1.18	1.31	0.31	1.46	1.00
FeO	0.15	0.28	*Nil*	0.14	*Nil*
CaO	0.26	0.10	0.06	0.14	0.16
MgO	*Nil*	0.06	0.01	*Nil*	0.30
Na_2O	0.10	0.22	0.97	0.17	1.03
K_2O	0.09	0.69	0.12	0.11	0.07
TiO_2	2.64	1.43	1.07	2.47	1.57
V_2O_5	0.02	0.01	0.01	0.02	0.01
SO_3	0.11	0.09	0.03	0.04	0.11
CO_2	*Nil*	*Nil*	0.07	*Nil*	0.31
Loss on ignition	15.08	13.27	5.57	14.80	12.23

area has yielded about one-third of the fire clay produced in California since mining began about 1860. The Ione sediments in this area appear to have filled an irregular depression developed in Upper Jurassic metamorphic rocks of the Amador group and Mariposa formation. Near Buena Vista the Ione overlies unnamed pre-Ione sedimentary rocks. The Ione formation crops out irregularly and is overlain largely by pyroclastic rocks of the Miocene Valley Springs formation and by Recent alluvium. The Ione forma-

TABLE 2.—PHYSICAL PROPERTIES OF SELECTED IONE CLAYS[1]

			1	2	3	4	5
	Clay Type		1	2	3	4	5
Unfired Properties	Color		Blue-Gray	Red and Buff	Lt. Buff Tr. Brown	Very Lt. Buff	White
	Water of plasticity (%)		31.1	33.8	37.1	32.0	32.4
	Plasticity		Low	Good	Very good	Good	Poor
	Dry modulus of rupture (p.s.i.)		50	218	252	371	68
	Dry shrinkage (%)		3.5	5.6	4.9	5.2	1.0
Fired Properties[2]	P.C.E.		33	20–23	$32\frac{1}{2}$–33	32–$32\frac{1}{2}$	32–$32\frac{1}{2}$
	Cone 3	Shrinkage (%)	9.0	7.6	9.8	9.5	7.5
	Cone 3	Total shrinkage (%)	12.5	13.2	14.7	14.7	8.5
	Cone 3	Adsorption	9.6	12.9	4.0	7.0	10.1
	Cone 3	Color	Buff	Red	Yellow Buff	Yellow Buff	Grey
	Remarks		At cone 3 bar showed cracking and was soft and friable	At cone 3 bar showed no cracking or warping	At cone 3 bar showed no cracking but slight warping	At cone 3 bar showed no cracking or warping	At cone 3 bar showed no cracking or warping

[1] Test made by the Ceramic Laboratories, University of California, Berkeley, California.

[2] Test bars were made from a stiff mud mix and extruded from a laboratory-size vacuumed auger machine.

tion and the post-Ione rocks are nearly free from structural complexities, being nearly horizontal with a regional westward dip of about 4°.

The clays produced in the Ione area are fire clays and they have been classified into six types based on their ceramic properties. They are the Edwin, Cheney Hill, Bacon, Yosemite, Ione sand (from 25 to 80 percent clay) and Ione Red. These clays were deposited in local depressions on the bedrock or on the underlying Ione sedimentary rocks and therefore the beds are not continuous throughout the area. The clay beds range in thickness from a few feet to 30 ft or more but average about 15 ft. A shallow embayment of the Eocene sea inundated the Ione area and received the clay-rich sediments transported by streams from higher ground to the east. The purer and more refractory clays were deposited on the western side of the basin.

In recent years Gladding, McBean and Company, Pacific Clay Products Company, Western Refractories Company, and the Calaveras Cement Company have been actively mining clay in the Ione area. Most of the fire clay is mined for use in heavy clay products ; however, a significant tonnage of Edwin-type clay is used in refractory products. Open pit methods are used to mine the clay. In the past, certain of the highly refractory clays were selectively mined underground, when contamination was a factor or when it was not economically feasible to strip off the overburden. The amount of overburden that must be removed to reach the clay varies from a few feet to 25 ft and in rare cases to as much as 50 ft or more.

APPENDIX B

SOILS

Denverton Series—Clay Loam

The Denverton series are chernozem-like soils developed on old dissected alluvial terraces of sedimentary and metamorphosed sedimentary origin. The terrace materials are softly consolidated and superimposed on sedimentary bedrock. These soils occur in many parts of the Coast Range valleys of California, where the winters are mild with 15 to 20 inches of rainfall, and the summers are hot and dry.

Associated with the Denverton soils at our observation site in the Montezuma Hills are the Montezuma soils. These soils are dark gray or black in color, and have some of the characteristics of grumosols. Both of these soils produce good yields of dry farmed barley and wheat when they are fallowed for one or two years between plantings. Natural vegetation is grass which affords excellent grazing for beef cattle.

Laboratory data on Denverton soil are shown in Tables 3 and 5.

San Joaquin Loam

The San Joaquin series are mineral secondary soils developed from transported material mainly of granitic rock origin, but more or less mixed in

TABLE 3.—LABORATORY DATA ON DENVERTON SOIL[1]

	Depth (inches)				
	0–8	8–28	28–35	35–56	56–64
Mechanical analysis					
Gravel (plus 2 mm)	—	—	1.1	—	—
Sand (wet sieve)	26.31	21.29	19.35	57.60	76.35
Silt (by difference)	31	31	33	25	9
Clay minus 2μ (hydr.)	43	48	48	17	15
,, ,, 1μ (hydr.)	37	41	41	16	12
pH (Beckman)	7.5	7.6	7.7	7.9	8.0
Calcium carbonate	0.20	6.15	15.25	12.60	6.98
Cation-exchange capacity[2]	36.5	34.2	28.4	14.6	12.1
Exchangeable Ca	22.2	26.2	25.2	—	—
,, Mg	28.3	31.6	31.2	—	—
,, K	0.77	0.30	0.28	—	—
,, Na	0.25	0.17	0.16	—	—
Approximate mineralogical composition of the minus 1μ clay and cation-exchange capacity of observed profiles					
Montmorin(% air dry)	88	—	93	—	92
Mica (% air dry)	2	—	2	—	3
Kaolin (% air dry)	10	—	5	—	5
Quartz (% air dry)	x[3]	—	x	—	x
Feldspar (% air dry)	?	—	?	—	?
Capacity[4]	78	—	73	—	84

[1] Figure 3 gives differential thermal analyses of typical samples.
[2] meq/100 g O.D. soil.
[3] x means this mineral is present.
[4] meq/100 g air dry.

mineralogical character. For the most part, they have been weathered from the Pleistocene sandy sediments that occupy sloping plains on the east side of the Sacramento and San Joaquin Valleys in the Noncalcic Brown soils zone. In these regions the rainfall ranges from 10 to 20 in. with mild winters and hot, dry summer seasons.

The profiles have a hardpan horizon formed by the cementing of a subsoil layer, which is considered to be the direct result of soil weathering processes. Commonly the hardpan surface follows the contour of the characteristic hogwallow surface relief, the depth to hardpan underneath the center of the mounds being about the same as the depth of soil above the hardpan in the hollows.

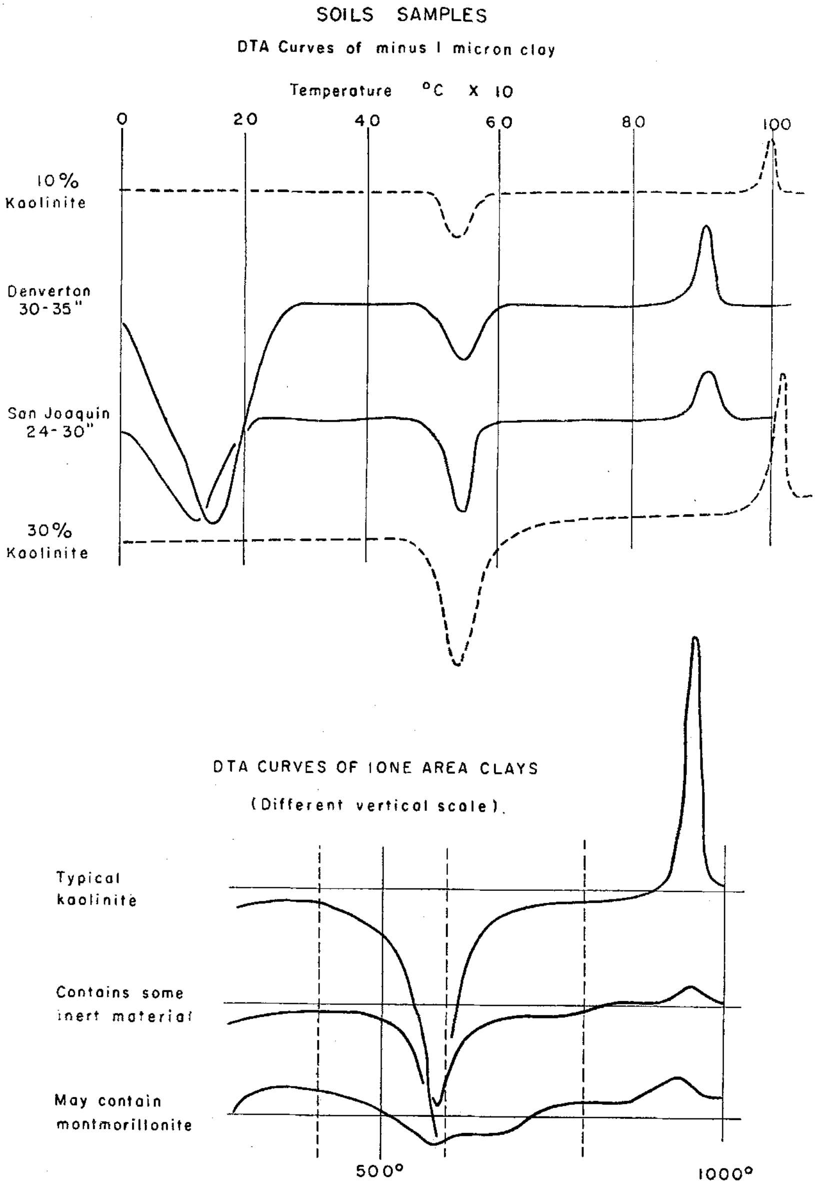

FIGURE 3.—Differential thermal analysis curves of some typical soils from central California and clays from Ione area. (Ione area curves adapted from California Division of Mines Special Report 19.)

About 1,000,000 acres of San Joaquin soils have been mapped; most of this acreage is dry farmed to grain or put into irrigated pasture. These soils are not very fertile; they have been thoroughly leached and many of the available nutrients have been fixed in the process of soil weathering.

Tables 4 and 5 give laboratory data on the San Joaquin loam.

TABLE 4.—LABORATORY DATA, SAN JOAQUIN LOAM

	Depth[1] (inches)					
	0–6	6–15	15–24	24–30	38–84	84–100
Mechanical analysis :						
Gravel (plus 2 mm)	—	—	—	—	—	—
Sand (wet sieve)	46.46	38.02	45.58	34.33	47.50	64.40
Silt (by difference)	40	45	37	33	36	20
Clay minus 2μ (hydr.)	14	17	17	33	17	16
,, ,, 1μ (hydr.)	12	14	14	30	13	15
pH (Beckman)	5.6	5.7	6.1	6.0	6.8	6.4
Calcium carbonate	—	—	—	—	—	—
Cation-exchange capacity[2]	8.3	6.7	7.3	16.5	16.6	—
Exchangeable Ca	3.6	3.3	3.6	4.0	—	—
,, Mg	1.6	1.6	2.4	11.6	—	—
,, K	0.54	0.35	0.16	0.18	—	—
,, Na	0.08	0.36	0.14	0.45	—	—
Approximate minerological composition of the minus 1μ clay and cation-exchange capacity of observed profiles						
Montmorin (% air dry)	60	—	—	70	70	—
Mica (% air dry)	10	—	—	5	5	—
Kaolin (% air dry)	30	—	—	25	25	—
Quartz (% air dry)	x	—	—	x	x	—
Feldspar (% air dry)	x	—	—	x	x	—
Capacity[3]	58	—	—	56	57	—

[1] 30–38 inches : Hardpan.
[2] meq/100 g O.D. soil.
[3] meq/100 g air dry.

Staten Peaty Muck

The soils in the Sacramento–San Joaquin delta basin, comprising 481 square miles, are predominantly organic soils developed on tule-reed peat in various stages of decomposition and oxidation, together with an admixture of mineral alluvial sediments. The climate is characterized by hot, rainless summers and cool, moist winters with frequent fogs. Mean annual rainfall ranges in different parts of the delta from 10 in. in the southern to 18 in. in the central and eastern sections.

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TABLE 5.—X-RAY DIFFRACTION DATA ON MINUS 1μ CLAY

Spacings	Mineral	Depth (inches) Denverton 0–8	28–33	56–64	San Joaquin 0–6	24–30	38–84
		Line Intensity[1]					
15.4	Montmorin	vs	vs	vs	w–m	m–s	m–s
10.0	Mica	vvw	vvw	vw	w–s	vw	vw
7.2	Kaolin	w	vw	vw	m–w	m–w	m–w
3.4	Quartz	m	m	m	w–m	w–m	w–m
3.1	Feldspar	?	?	?	w	w	w

[1] *Line Intensity* vs—very strong; s—strong; m—medium; w—weak; vw—very weak; vvw—very, very weak; ?—doubtful.

Note: Barshad's sodium citrate paste method was used for the x-ray analyses.

Staten peaty muck, the dominant soil type, occupies about 20 percent of the area. It has reached a more advanced stage of decomposition and alteration than has the less acid, partly decomposed Venice peaty muck, which grades into the practically unaltered virgin Correra peat soil. Laboratory data for Staten peaty muck are shown in Table 6.

Most of the organic soils have been reclaimed by protection from overflow, with an extensive system of levees and artificial drainage. An intricate system of natural drainage channels and artificial canals forms many islands, which now constitute a unique agricultural section of the state.

TABLE 6.—LABORATORY DATA, STATEN PEATY MUCK

	Depth (inches) 0–12	12–30	30–60
Percent moisture of field sample	71.2	247.6	365.3
pH (Beckman)	6.4	5.9	5.4
Cation-exchange capacity[1]	94.6	113.8	98.6
Salt Content:			
Conductivity on sat. extract	1.67	1.79	2.50
Total Na	4.1	2.9	5.2
Soluble Na	0.5	0.7	1.2
Exchangeable Na	3.6	2.2	4.0
Percent Na saturation	3.8	1.9	4.1

[1] meq/100 g O.D. soil

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