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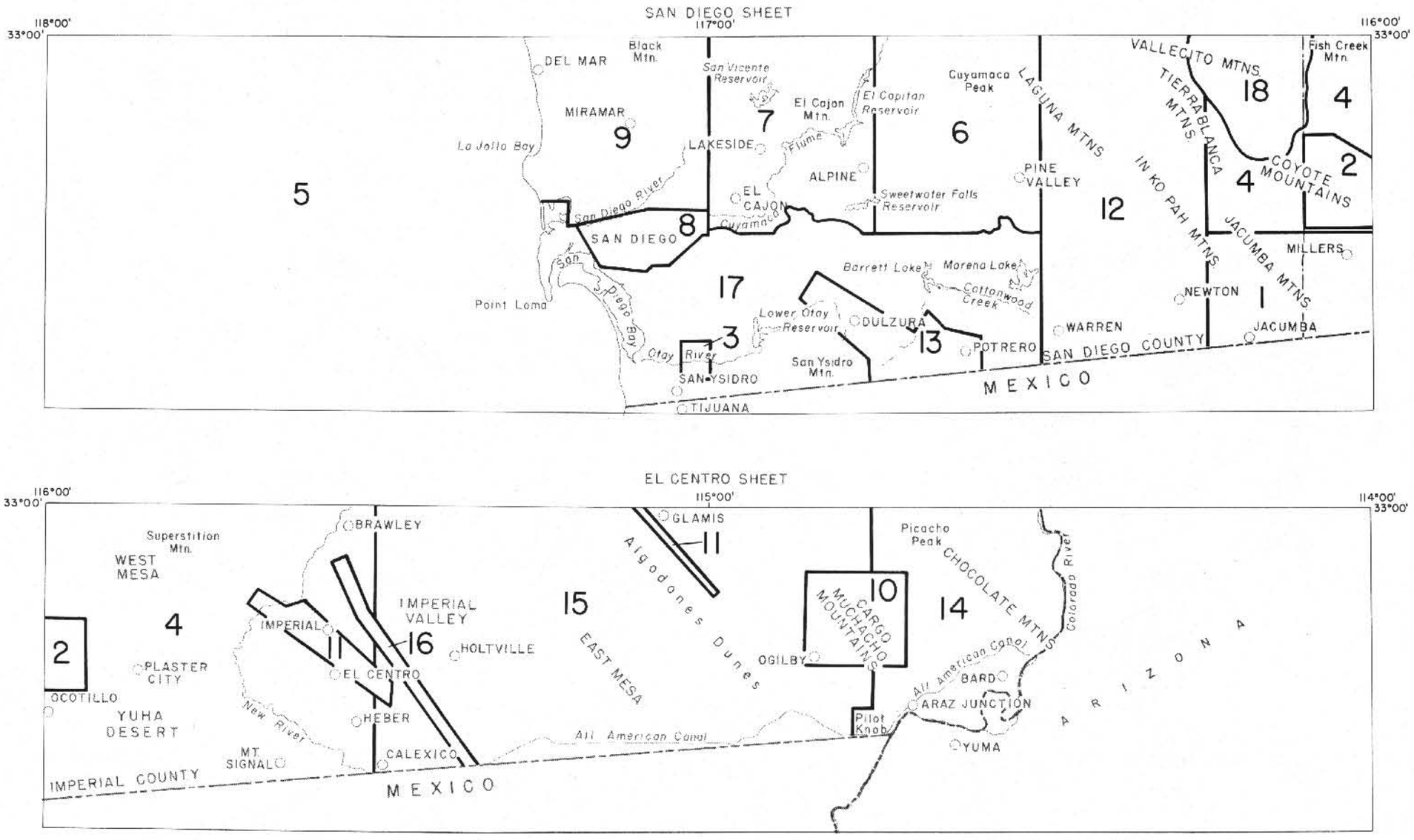
EXPLANATORY DATA
SAN DIEGO—EL CENTRO SHEET
GEOLOGIC MAP OF CALIFORNIA
OLAF P. JENKINS EDITION

Compiled by Rudolph G. Strand 1962

(Second Printing, 1973)

INDEX TO GEOLOGIC MAPPING
USED IN COMPILATION OF THE SAN DIEGO–EL CENTRO SHEET



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(Sand deposits are shown as mapped by the U.S. Geological Survey on the Glamis S.W. quadrangle and by the Army Map Service on this, the El Centro NI 11-12 topographic base map.) (Tentative projection of San Andreas fault zone? by California Div. Mines and Geology, 1962.)

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18. Woodard, G. Davidson, Geology of portion of the west Colorado Desert, Southern California, Vallecito and Carrizo Badlands, scale 1:24,000, University of California, Berkeley, Ph.D. thesis in progress. (This mapping was done in conjunction with Theodore Downs and J. A. White, Los Angeles County Museum studies of the Anza-Borrego State Park, 1958-1961.)

For a complete list of published geologic maps of this area see Division of Mines and Geology Special Reports 52 and 52-A.

View southeastward toward Coyote Mountains (left middleground), and the Elsinore Fault zone marked by the prominent trough at the base of the mountains. The high peak on left skyline is Signal Mountain, located just south of the international border. *Photo by F. Harold Weber, Jr.*

STRATIGRAPHIC NOMENCLATURE—SAN DIEGO SHEET

AGE	STATE MAP SYMBOL	STATE MAP UNIT State Map Units listed here are not necessarily in stratigraphic sequence; the sequence used has been standardized for all sheets of the Geologic Map of California	STRATIGRAPHIC UNITS AND CHARACTERISTIC LITHOLOGIES (The formally named formations grouped within an individual State Map Unit are listed in stratigraphic sequence from youngest to oldest.)
CENOZOIC — QUATERNARY — Recent	Qs	**RECENT DUNE SAND**	Beach sand (sand spits), and coastal dune sand.
CENOZOIC — QUATERNARY — Recent	Qal	**RECENT ALLUVIUM**	Recent river and stream deposits, filled land, salt ponds, and delta deposits.
CENOZOIC — QUATERNARY — Pleistocene	Qt	**QUATERNARY NONMARINE TERRACE DEPOSITS**	Pleistocene and Recent (?) nonmarine terrace deposits.
CENOZOIC — QUATERNARY — Pleistocene	Qm	**PLEISTOCENE MARINE DEPOSITS AND MARINE TERRACE DEPOSITS**[1]	Lindavista Formation—*light-gray, and reddish-tan sandstone, siltstone, and conglomerate* (in part nonmarine); Bay Point Formation—*gray to tan sandstone, coquina, siltstone, and conglomerate;* Sweitzer Formation—*brown, reddish-brown, and red poorly sorted sandstone, and conglomerate* (in large part nonmarine; Pleistocene according to E. D. Milow and D. B. Ennis, 1961, Geol. Soc. Am. Cordilleran Section Guidebook, p. 28). Unnamed marine and estuarine (?) terrace deposits bordering San Diego Bay and extending eastward.
CENOZOIC — QUATERNARY — Pleistocene	Qc	**PLEISTOCENE NONMARINE SEDIMENTARY DEPOSITS**	Pleistocene fan deposits in the Mt. Laguna quadrangle. Unnamed Pleistocene deposits in the Coyote Mountains and Jacumba areas. Granitic breccia-conglomerate in Carrizo Mountains and Mt. Laguna quadrangles.
CENOZOIC — QUATERNARY — Pleistocene	QP	**PLIOCENE-PLEISTOCENE NONMARINE SEDIMENTARY DEPOSITS**	Ancient fanglomerate, composed of angular metavolcanic detritus, that borders the west flank of the San Ysidro Mountains (contains abundant caliche near surface).
CENOZOIC — TERTIARY — Pliocene	Pc	**UNDIVIDED PLIOCENE NONMARINE SEDIMENTARY ROCKS**	Canebrake Conglomerate[2]—*gray conglomerate of granitic and metamorphic clasts* (this unit is interpreted as being the lateral equivalent of the Imperial and Palm Spring Formations as well as overlying the Palm Spring Formation in part); Palm Spring Formation[2]—*interbedded light-gray arkosic sandstones and reddish clays* (upper part considered to be middle Pleistocene by T. Downs and G. D. Woodard, 1961: Geol. Soc. Am. Spec. Paper 68, p. 21).
CENOZOIC — TERTIARY — Pliocene	Pu	**UPPER PLIOCENE MARINE SEDIMENTARY ROCKS**	San Diego Formation—*gray friable sandstone, and conglomerate* (upper Pliocene according to E. D. Milow and D. B. Ennis, 1961, *op. cit.* p. 28; may include some middle Pliocene according to J. W. Durham, 1954, California Div. Mines Bull. 170, Chap. 3, p. 24).
CENOZOIC — TERTIARY — Pliocene	Pml	**MIDDLE AND/OR LOWER PLIOCENE MARINE SEDIMENTARY ROCKS**	Imperial Formation—*light-gray and light-yellow claystone, some interbedded arkosic sandstones, calcareous oyster-shell reefs, and fossiliferous calcareous sandstone* (considered to be early Pliocene *Ibid.*).
CENOZOIC — TERTIARY — Miocene	Muc	**UPPER MIOCENE NONMARINE SEDIMENTARY ROCKS**	Nonmarine part of the upper Split Mountain Formation—*gray conglomerate* (composed of two members, one above, and one below the marine member of the Split Mountain Formation).
CENOZOIC — TERTIARY — Miocene	Mu	**UPPER MIOCENE MARINE SEDIMENTARY ROCKS**	Marine member of the upper Split Mountain Formation[3]—*olive-green and drab sandstone and shale* and Fish Creek Gypsum member of the upper part of the Split Mountain Formation—*white bedded gypsum and anhydrite* (probably marine).[4]
CENOZOIC — TERTIARY — Miocene	Mv^a Mv^p	**MIOCENE VOLCANIC ROCKS:** **ANDESITIC** **PYROCLASTIC**	Alverson Canyon Formation—*dark-brown andesite lava, breccia, and tuff* (overlies the lower part of the Split Mountain Formation shown hereon as "Mc"). Jacumba Pyroclastics—*primarily andesitic, white to red tuffs, gray to red agglomerates, and interbedded gravels* (possibly Pliocene).
CENOZOIC — TERTIARY — Miocene	Mc	**UNDIVIDED MIOCENE NONMARINE SEDIMENTARY ROCKS**	Lower part of the Split Mountain Formation[3]—*reddish-brown arkosic sandstones, conglomerates, and sedimentary breccia.* Table Mountain Gravels[3]—*well-rounded to angular clasts derived from local sources* (Jacumba area), *and clasts of material similar to the Santiago Peak Volcanics.*
CENOZOIC — TERTIARY — Eocene	Ec	**EOCENE NONMARINE SEDIMENTARY ROCKS**	Poway Conglomerate—*light-gray fine-grained sandstone, massive reddish-tan conglomerate, and light green-gray conglomerate.* Unnamed siltstone, mudstone and grit unit in the El Cajon quadrangle, and an unnamed breccia unit in El Cajon quadrangle.
CENOZOIC — TERTIARY — Eocene	E	**EOCENE MARINE SEDIMENTARY ROCKS**	Rose Canyon Fm.——*mudstone, gray shale, light to dark brown fine-grained sandstone, conglomerate and a few thin beds of limestone;* Torrey Ss.——*white to light brown, coarse, poorly consolidated sandstone;* Delmar Formation—*multicolored, fine- to medium-grained sandstone and siltstone, oyster interbeds, green to blue-gray massive mudstone and siltstone, and fine-grained sandstone* (in part Paleocene).
MESOZOIC — CRETACEOUS	Ku	**UPPER CRETACEOUS MARINE SEDIMENTARY ROCKS**	Upper Cretaceous strata which are thought to be correlative with the Rosario Formation of Baja California—*light-gray to tan arkose containing concretions, olive to olive-gray siltstone, silty claystone, light-gray to tan fine-grained sandstone, gray massive mudstone, and local conglomerate lenses* (the Point Loma area contains some overlying units still considered to be Eocene by Leo Hertlein written communication, 1962).
MESOZOIC — CRETACEOUS	gr	**MESOZOIC GRANITIC ROCKS**[5]	gr_8 Rattlesnake Granite—*coarse-grained white granite containing prominent muscovite.* gr_7 Leucogranodiorite in the Cuyamaca Peak quadrangle—fine-grained light-colored granitoid rock. gr_6 Woodson Mountain Granodiorite—*light-colored granodiorite* (weathers along joints to form huge white or pink, rounded knobs). gr_5 Bonsall Tonalite—*light-gray massive quartz diorite characterized by abundant streaked-out dark inclusions* (similar to Green Valley Tonalite). gr_4 Lakeview Mountain Tonalite and/or La Posta Quartz Diorite—*uniform quartz diorite forming nearly white outcrops and huge boulders of disintegration* (similar to Bonsall Tonalite with the exception that schlieren are generally not present). gr_3 Green Valley Tonalite—*light- to dark-gray, medium- to coarse-grained granular rock with prominent euhedral plagioclase crystals* (weathers deeply leaving numerous small boulders of dark fresh rock). gr_2 Stonewall Granodiorite—*white to light-gray, medium- to coarse-grained massive granodiorite which locally possesses a gneissic texture* (generally does not weather to leave residual boulders). gr_1 Tonalite in the Mt. Laguna (Cuyapaipe) quadrangle (thought to be older than the Stonewall Granodiorite). gr Granitic rocks which have not been correlated with a formally named intrusive mass; includes some gneissic rocks.
MESOZOIC — CRETACEOUS	bi	**MESOZOIC BASIC INTRUSIVE ROCKS**	bi_2 Diorite (similar to Green Valley Tonalite but lacks quartz). bi_1 Cuyamaca Gabbro and/or San Marcos Gabbro—*massive gray to black gabbro containing white veinlets of feldspar; weathers to deep reddish-brown residual soil.*
MESOZOIC — JURASSIC	Ju	**UPPER JURASSIC MARINE SEDIMENTARY AND METASEDIMENTARY ROCKS**	Bedford Canyon Formation (?)—*slightly metamorphosed dark-gray to black siliceous siltstone interbedded with dark gray-wackes, gray sandstone, intraformational breccia and conglomerate.* (Small isolated outcrops in Los Peñasquitos Canyon north of San Diego.)
MESOZOIC — JURASSIC	JRv	**JURASSIC AND/OR TRIASSIC METAVOLCANIC ROCKS**	Black Mountain Volcanics—*massive greenstone, metavolcanic breccia, tuff, rhyolite, tuffaceous sandstone, metashale, bluish-gray metaconglomerate and quartz-feldspathic granulite* (considered to be possible Jurassic; mapped as Jurassic Santiago Peak Volcanics immediately to the north, but also thought by some to be a possible correlative of the Cretaceous Alisitos Formation of Baja California).
MESOZOIC	m ls	**PRE-CRETACEOUS METAMORPHIC ROCKS, UNDIFFERENTIATED, ls = LIMESTONE AND/OR DOLOMITE**	Undifferentiated metamorphic rocks of El Cajon quadrangle, in part probably equivalent to the JRv unit, but in part composed of other metasedimentary rocks which are not correlative with the JRv unit. Metamorphic rocks in the Dos Cabezas area. Metamorphosed limestone in the Dos Cabezas area.
MESOZOIC	ms	**PRE-CRETACEOUS METASEDIMENTARY ROCKS**	Julian Schist—*quartz mica schist and quartzite* (weathers to dark reddish-brown platy rock).
MESOZOIC	gr-m	**PRE-CENOZOIC GRANITIC AND METAMORPHIC ROCKS**	A mixed or hybrid rock unit composed of Julian Schist and Stonewall Granodiorite—*migmatite and gradational rocks of schist and granodiorite* (in the Cuyamaca Peak quadrangle). Pre-Cretaceous metasedimentary schists, marble, and quartzite intruded by numerous pegmatite dikes, in the Carrizo Mountain-Jacumba area, (considered to be Triassic and/or Paleozoic).

NOTES

[1] Includes some nonmarine terrace deposits on wave-cut terrace surfaces.
[2] The Canebrake Conglomerate and the Palm Spring Formation are Pliocene according to T. W. Dibblee, Jr., 1954.
[3] Not necessarily in stratigraphic sequence.
[4] The gypsum and anhydrite may have been formed "in desiccated marginal gulf areas with restricted circulation or in saline lakes", J. W. Durham and E. C. Allison, Syst. Zool., vol. 9, no. 2, June 1960, p. 63.
[5] The granitic rocks designated by subscripts are listed from youngest (gr_8) to oldest (gr_1) as determined by Everhart, 1951, and Merriam (ref. 12).

STRATIGRAPHIC NOMENCLATURE—EL CENTRO SHEET

AGE	STATE MAP SYMBOL	STATE MAP UNIT State Map Units listed here are not necessarily in stratigraphic sequence; the sequence used has been standardized for all sheets of the Geologic Map of California	STRATIGRAPHIC UNITS AND CHARACTERISTIC LITHOLOGIES (The formally named formations grouped within an individual State Map Unit, are listed in stratigraphic sequence from youngest to oldest.)
CENOZOIC — QUATERNARY — Recent	Qs	**RECENT DUNE SAND**	Dune sand.
CENOZOIC — QUATERNARY — Recent	Qal	**RECENT ALLUVIUM**	Alluvium.
CENOZOIC — QUATERNARY — Recent	Ql	**QUATERNARY LAKE DEPOSITS**	Lake Coahuila deposits and playa deposits.
CENOZOIC — QUATERNARY — Pleistocene	Qt	**QUATERNARY NONMARINE TERRACE DEPOSITS**	Pleistocene nonmarine terrace deposits.
CENOZOIC — QUATERNARY — Pleistocene	Qc	**PLEISTOCENE NONMARINE SEDIMENTARY DEPOSITS**	Brawley Formation—*light-gray lacustrine clays, buff sandstones and pebble conglomerates;* Ocotillo Conglomerate—*gray granitic-pebble conglomerate* (elsewhere in the Salton Sink area the Ocotillo grades laterally into the Brawley Formation, but in this area the only exposure of the Ocotillo Conglomerate is at the base of the Brawley Formation section and is exposed on Superstition Mountain). Older alluvium in the Cargo Muchacho Mountain and Chocolate Mountain areas.
CENOZOIC — QUATERNARY — Pleistocene	Qpv^b	**PLEISTOCENE VOLCANIC ROCKS:** **BASALTIC**	Dark-gray fine-grained olivine basalt flows which at the Cargo Muchacho Mountain locality are highly vesicular near both the top and bottom.
CENOZOIC — QUATERNARY — Pleistocene	QP	**PLIOCENE-PLEISTOCENE NONMARINE SEDIMENTARY DEPOSITS**	Dissected alluvial deposits, some of which have been tilted. This ancient alluvium is for the most part very waterworn and well sorted, being perhaps deposited along a former course of the Colorado River.
CENOZOIC — TERTIARY — Pliocene	Pc	**UNDIVIDED PLIOCENE NONMARINE SEDIMENTARY ROCKS**	Palm Spring Formation—*interbedded light-gray arkosic sandstones and reddish clays.* (Considered to be Pliocene by T. W. Dibblee, Jr., 1954.)
CENOZOIC — TERTIARY — Pliocene	Pml	**MIDDLE AND/OR LOWER PLIOCENE MARINE SEDIMENTARY ROCKS**	Imperial Formation—*light-gray claystone, containing some interbedded arkosic sandstones, calcareous oyster-shell reefs, and fossiliferous calcareous sandstone.* (Considered to be early Pliocene by J. W. Durham, 1954, The marine Cenozoic of Southern California—California Div. Mines Bull. 170, Chap. 3, Part 4, p. 27.)
CENOZOIC — TERTIARY — Miocene	Muc	**UPPER MIOCENE NONMARINE SEDIMENTARY ROCKS**	Upper part of the Split Mountain Formation—*brown arkosic sandstone and conglomerate.* (May be middle Miocene in part.)
CENOZOIC — TERTIARY — Miocene	Mv^a	**MIOCENE VOLCANIC ROCKS:** **ANDESITIC**	Alverson Canyon Formation—*dark-brown andesite lava, breccia, and tuff.*
CENOZOIC — TERTIARY — Miocene	Mc	**UNDIVIDED MIOCENE NONMARINE SEDIMENTARY ROCKS**	Lower part of the Split Mountain Formation—*reddish-brown arkosic sandstone, conglomerate, and sedimentary breccia.* (Considered to be no older than about middle Miocene by J. W. Durham, *op. cit.* p. 27.)
CENOZOIC — TERTIARY — Undivided	Tl	**TERTIARY LAKE DEPOSITS**	Borrego Formation—*probable upper Pliocene light-gray claystone and buff sandstones* (considered by T. W. Dibblee, Jr., *op. cit.* to be the lacustrine equivalent of the Palm Spring Formation although in part the Borrego Formation rests upon the Palm Spring Formation).
CENOZOIC — TERTIARY — Undivided	Ti^a	**TERTIARY INTRUSIVE (HYPABYSSAL) ROCKS:** **ANDESITIC**	Intrusive greenish-gray fine-grained andesite which locally contains pebble-like fragments of milky white quartz.
CENOZOIC — TERTIARY — Undivided		**TERTIARY VOLCANIC ROCKS:**	
	Tv	**UNDIFFERENTIATED**	Undifferentiated volcanic and hypabyssal rocks.
	Tv^r	**RHYOLITIC**	Rhyolite.
	Tv^a	**ANDESITIC**	Andesite.
	Tv^p	**PYROCLASTIC**	Pyroclastic rocks containing minor interbedded flows.
MESOZOIC	gr	**MESOZOIC GRANITIC ROCKS**[1] gr_4 Leucogranite. gr_3 Biotite granite—light- to dark-colored granite characterized by abundant coarse pink to gray feldspar and biotite. gr_2 Quartz monzonite—characterized by grains and aggregates of dark biotite and hornblende which contrast sharply with light-colored feldspar and quartz; usually granitoid but locally gneissic; elsewhere aplitic and porphyritic textures are present. gr_1 Quartz diorite—dark-colored granitoid rock of gray feldspar and quartz with abundant biotite and hornblende; locally gneissic and locally containing numerous dark sillimanite schist inclusions. gr Other granitic rocks which have not been correlated with a formally named intrusive mass; includes some gneissic rocks, diorite and gabbro.	
MESOZOIC	m	**PRE-CRETACEOUS METAMORPHIC ROCKS**	Tumco Formation—*gray to pinkish-gray highly indurated, massive, fine-grained arkosic quartzite, and green-gray hornblende schist.* Undifferentiated metasedimentary and metavolcanic rocks of the Chocolate Mountains (principally metaconglomerate; thought possibly to be a correlative of the Upper Paleozoic or Triassic McCoy Mountains Formation to the north).
MESOZOIC	ms	**PRE-CRETACEOUS METASEDIMENTARY ROCKS**	Vitrefrax Formation—*quartz-kyanite schists, sericite schists, and white quartzite; fine- to medium-grained except for large matted aggregates and radiating groups of kyanite crystals.* Sericite schist in the Chocolate Mountains (thought possibly to be a correlative of the Orocopia Schist to the north).
MESOZOIC	gr-m	**PRE-CENOZOIC GRANITIC AND METAMORPHIC ROCKS**	Vitrefrax Formation rocks which have been intruded by abundant aplite dikes and plugs. Gneiss and meta-igneous rocks of the Chocolate Mountains (thought perhaps to be correlative with the Chuckwalla Complex to the north). Metasedimentary rocks, (gray mica schist and gray to white marble) that have been intruded by numerous pegmatite and granitoid dikes, in the Coyote Mountains area.

NOTE

[1] The granitic rocks designated by subscripts are listed from youngest (gr_4) to oldest (gr_1) as determined by P. C. Henshaw, 1942.

View toward north showing La Jolla Mesa in lower middleground. The Mesa area consists primarily of dissected Eocene marine deposits and Pleistocene marine terrace deposits. Younger terraces in foreground are much less dissected and provide the site of numerous dwellings of Pacific Beach. Note the smooth coastline in the right half of foreground and the rugged coastline to the left. The contrast is attributed to the difference in the ease of wave erosion between the soft upper Pliocene and Pleistocene marine deposits and the more resistant Upper Cretaceous sedimentary rocks. Black Mountain in the right center background, consists of Jurassic(?) metavolcanic rocks and stands out as a dark form above the Pleistocene Lindavista marine terrace surface.

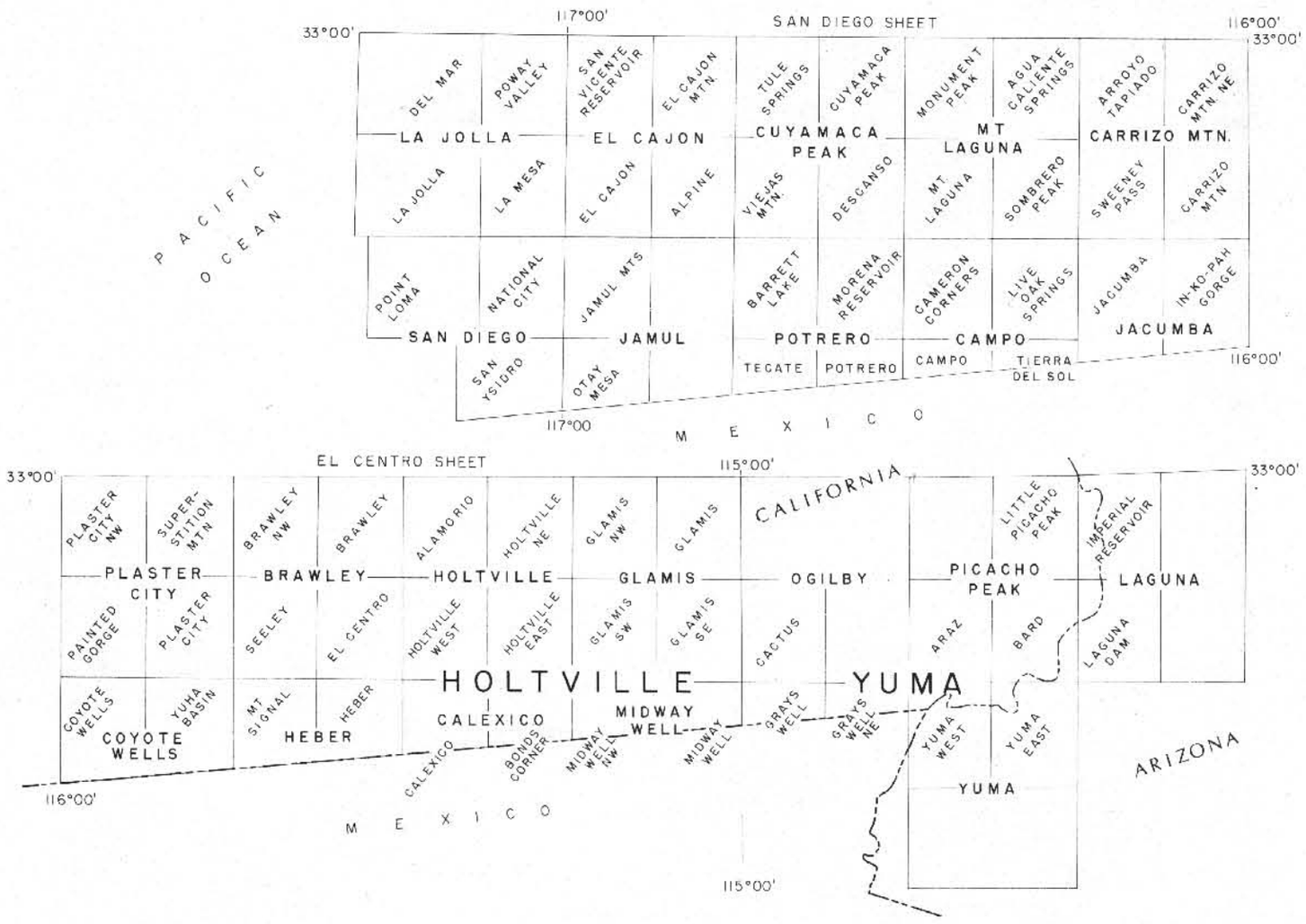
Photo by F. Harold Weber, Jr., 1963.

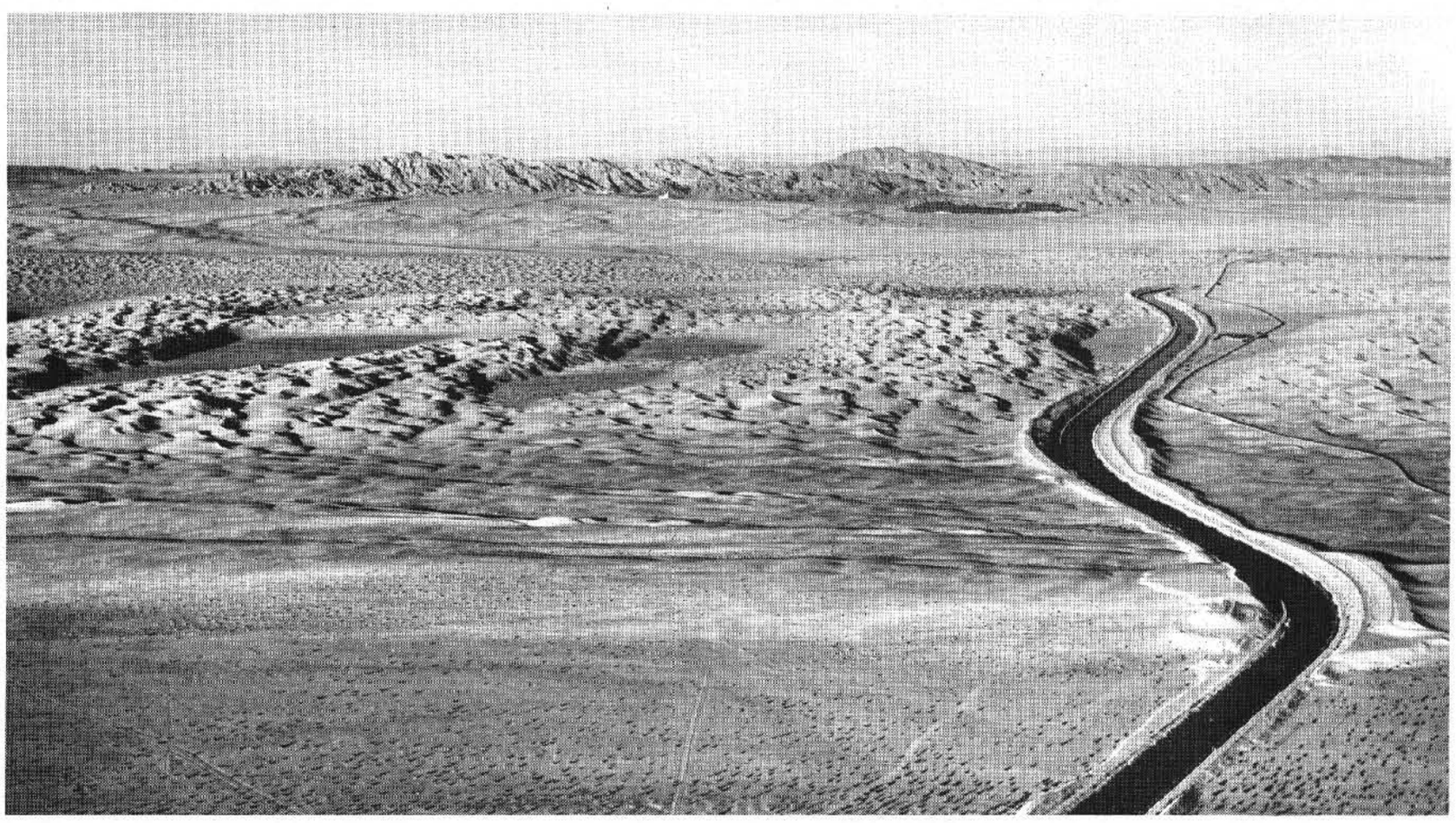
TOPOGRAPHIC QUADRANGLES

WITHIN THE SAN DIEGO–EL CENTRO SHEET

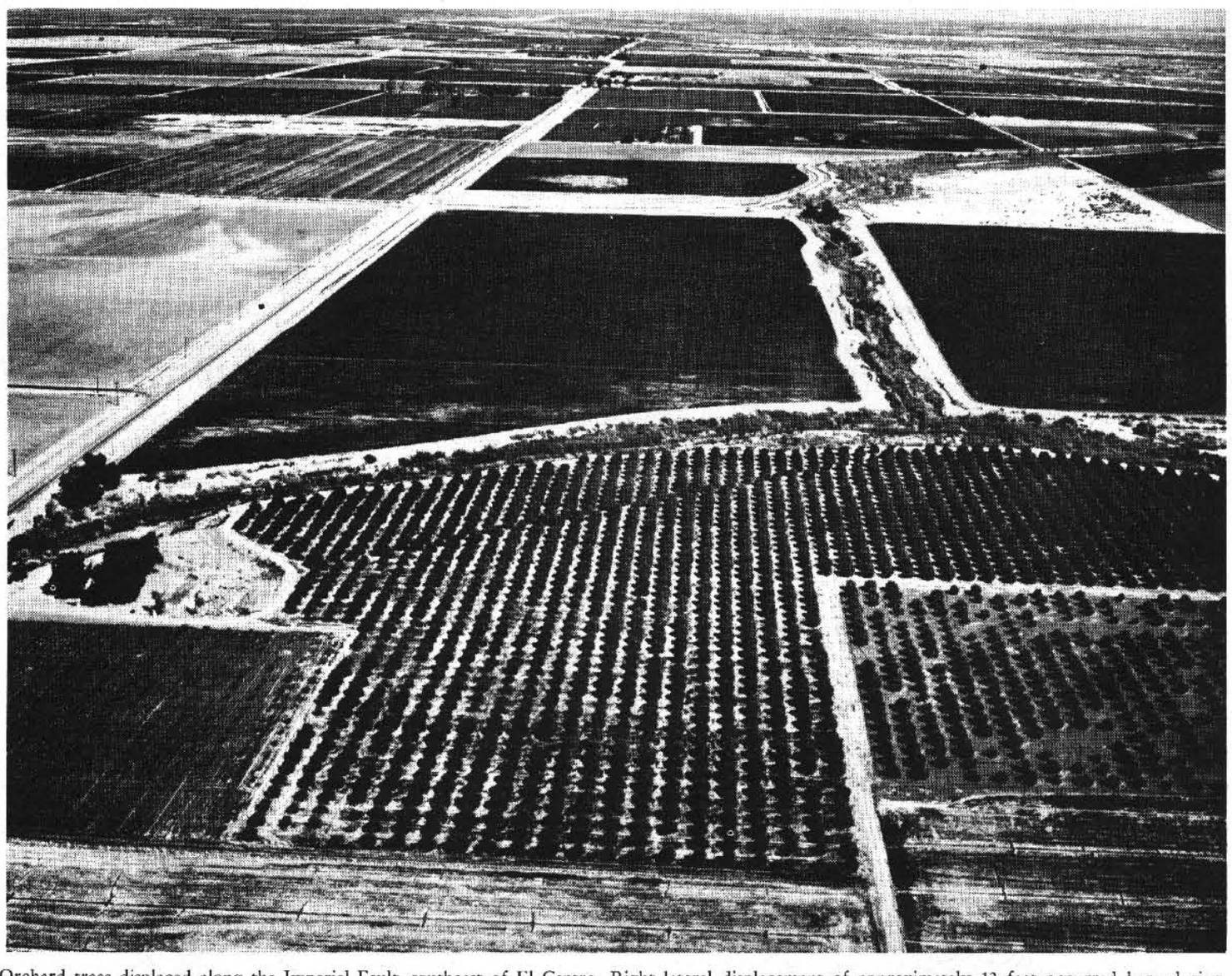
AVAILABLE FROM THE U.S. GEOLOGICAL SURVEY

1962





View toward the northeast in the Salton Sink showing the Algodones Dunes in middleground and the Cargo Muchacho Mountains in the background. The San Andreas Fault possibly parallels the sand ridges in the foreground although evidence is inconclusive. The All American Canal and U.S. Highway 80 at right side of photo transect the dunes in one of the remarkable flat-floored, relatively sand-free depressions that are found within the dune area. *Photo by John S. Shelton*



Orchard trees displaced along the Imperial Fault, southeast of El Centro. Right lateral displacement of approximately 12 feet occurred here during April 1940, greater displacements being observed farther to the south. Note the broad flat topography of Imperial Valley, consisting of Quaternary lake beds of ancient Lake Coahuila. This view is toward the east; Alamo Creek in middleground, and state route 98 on left.
Photo by John S. Shelton, 1959.