DEPARTMENT OF THE INTERIOR
UNITED STATES GEOLOGICAL SURVEY

Prepared in cooperation with
DEPARTMENT of HOUSING and URBAN DEVELOPMENT
AND
ASSOCIATION of BAY AREA GOVERNMENTS

U.S. GEOLOGICAL SURVEY
OPEN FILE MAP
71-246

DESCRIPTION OF MAP UNITS

1-MUD

Mud deposited during the past 10,000 years in San Francisco Bay and in marshlands surrounding San Francisco Bay and the delta area of the Sacramento-San Joaquin Rivers. Location of landward border approximate. In places covered with man-made fill. Mud is mostly clay- and silt-size particles, but locally contains up to 15 percent medium- to fine-grained sand. Contains layers of sand and gravel 1/8 inch to 5 feet thick, especially common near mouths of streams. Thickness of mud generally varies from about 5 feet at landward edge to about 60 feet at bay edge; maximum thickness offshore about 140 feet. Where used for foundation purposes mud may subside, settle differentially, fail by shearing, shrink and crack when dried, and expand and become weak and plastic when wet. Amplitude, duration, and period of earthquake shaking is greater in this map unit than in firm soil or rocks. Such shaking may cause liquefaction of sand layers in the mud and give rise to lurching, subsidence, and landsliding. It is necessary to pay special attention to the design of highrise structures on this unit because their natural period of vibration can or may be similar to the natural period of earthquake vibrations in the thick soft mud. Top 2 to 4 feet in diked-off, drained areas becomes dessicated and stronger than underlying mud.

2-UNCONSOLIDATED SEDIMENTS

Unconsolidated sediments--gravel, sand, silt, clay, and peat that underlie broad valleys and other flatlands; include deposits of marine beaches and adjoining dunes, alluvial plains, terraces, fans, river flood plains, channels, levees, mudflows, and lake bottoms. Thickness is more than 1,000 feet in Santa Clara Valley near San Jose, in Livermore Valley, and in the Great Valley; 500 to 1,000 feet in Santa Rosa-Cotati-Petaluma Valley and in Sonoma and Napa Valleys; a few feet to about 600 feet underlying and landward of unconsolidated mud east and west of San Francisco Bay; a few feet to about 300 feet in the modern and raised beach and dune deposits along the Pacific Coast. Sand and gravel are generally excellent for fill, road metal, and concrete and bituminous aggregate. Principal source of concrete aggregate and sand for the map area is in the Livermore Valley where deposits are several hundred feet thick. Engineering properties vary with sediment type and water content. Silt and clay deposits may subside, settle differentially, fail by shearing, shrink and crack when dry, and expand and become plastic and weak when wet. During strong earthquakes shaking may be severe where deposits are more than several hundred feet thick and the water table is near the surface. 0 to 10,000 years (Holocene) to as great as about 5 million years old (Pliocene).

In San Francisco, include beach and dune sand of Holocene age (past 10,000 years) and older marine sand, clayey sand, and silt of late Quaternary age (Colma Formation--approximate range 10,000 to 500,000 years). Thickness ranges from a few feet to 300 feet.

3-MODERATELY CONSOLIDATED TO WELL-CONSOLIDATED SEDIMENTARY ROCKS

Sandstone, shale, siltstone, conglomerate, chert, porcellanite, coal, limestone, agglomerate, and tuff, moderately to well-consolidated. Total thickness approximately 20,000 feet, local thickness generally more than 100 feet. Map unit includes a wide variety of rocks with a wide range of physical characteristics and uses. Rocks older than Pliocene are generally well compacted, have a high bearing capacity, and make fair to good fill. Shale and claystone and poorly cemented sandstone may slump badly on slopes steeper than about 2 to 1. Some contain bentonitic beds that swell greatly and become plastic and weak when wet and shrink and crack severely when dry. Shearing and chemical alteration not as common as in Franciscan assemblage. Some beds are or have been commercial sources of coal, foundry, refractory, and glass sand, ceramic and fire clay, diatomite, natural gas (leading producers in the State), and oil. Beds may be future sources of bentonite, pozzolan, and expansible shale for lightweight concrete. Age ranges from about 5 to 55 million years (early Pliocene to Eocene).

4-VOLCANIC ROCKS

Volcanic rocks and minor interbedded gravels, sands, and clays. Unit includes lava flows and associated dikes and pyroclastics (volcanic fragments ejected from a vent) of basalt, andesite, and rhyolite composition. Maximum thickness approximately 3,000 feet. Generally fresh rock of high strength and hardness, consequently is important source of concrete aggregate, fill, riprap and flagstone, and makes good foundations. Interbedded sediments and rhyolitic pyroclastics may contain clay and present foundation problems. Age ranges from about 3 to 40 million years (Pliocene to Oligocene).

5-FRANCISCAN ASSEMBLAGE

Franciscan assemblage. A complex of sedimentary, volcanic, and metamorphic rocks 70 to 180 million years old (Jurassic to Cretaceous). The basement (oldest) rock in the area east of the San Andreas fault, and on San Francisco Peninsula east of the Pilarcitos fault.

KJf, Mostly graywacke-type sandstone and shale; interbedded with small amounts of conglomerate, radiolarian chert, and limestone; includes small amount of metamorphic rock. Sandstone and shale is firm rock where fresh, but generally highly fractured. In places weathered to depth of 60 feet. Weathered shale may contain large amounts of swelling clay; weathered sandstone also contains swelling clay. Source of good-quality fill; riprap more than 2 feet in diameter is scarce. Fresh rock may require blasting to excavate. Crushed rock generally unsatisfactory for concrete aggregate because of presence of shale and chemically altered rock, but stream gravel derived from Franciscan assemblage makes good-quality concrete aggregate and is the main source in the San Francisco Bay area. Expansible shale is made by heating the shale at several plants in the area.

Radiolarian chert is generally firm, somewhat brittle, well-bedded rock with little or no soil. Beds are 1 to 4 inches thick and alternate with shale beds generally 1/4 inch thick. Source of good-quality fill. Altered to clay along faults. Chert sections are generally sparse and occur in lenses less than 100 feet thick; however, they are thicker and especially abundant in the Sunset Heights and Mt. Sutro areas of San Francisco, in southern Marin Peninsula, in the hills of San Mateo, Belmont, and San Carlos, and in northeastern Santa Clara County and adjoining parts of Alameda County. Small deposits of manganese may occur in chert. Manganese ore has been mined in Santa Clara, Alameda, Sonoma, and Napa Counties.

Metamorphic rocks are widely scattered and occur within the other Franciscan rocks generally as isolated rounded masses, up to 100 feet in diameter, or in larger, tabular or irregular shaped bodies. Metamorphic rocks are generally tough and sparsely fractured. Excellent source of fill and riprap where sufficiently abundant.

Limestone occurs on San Francisco Peninsula as isolated deposits or as small lenses. It is a firm rock that is good for fill, and is a raw material for cement. A large deposit in Santa Clara County supplies one of the largest cement plants in the world.

Zones of intensely sheared rock are common in the Franciscan assemblage. They appear to be more or less tabular, a few inches to several hundred feet in thickness, extend over many square miles, and are generally, but not everywhere, nearly flat-lying or gently dipping. The zones (mélange) consist of a soft, clayey, highly sheared matrix containing minor hard spheroidal rock masses, rounded by shearing. The hard rock pieces are of all sizes up to hundreds of feet, but are generally less than 20 feet in diameter, and include sandstone, volcanic rock, radiolarian chert, metamorphic rock, limestone, and ultramafic rocks. The matrix is generally shale altered to swelling clay containing large amounts of chlorite and montmorillonite. The matrix is weak and plastic when wet and strongly influences the physical properties of the entire mass. Consequently landsliding is common on slopes of this material, and the erratic distribution of hard coherent rock masses within the shear zones gives rise to considerable local variation in physical characteristics and may lead to erroneous appraisal of foundation conditions unless the nature of the shear zones is understood.

KJv, Volcanic rocks, mostly basaltic and spilitic pillow lavas and pyroclastics (fragmental material ejected from a volcanic vent). Pillows are roughly ellipsoidal or spheroidal, 6 inches to 4 feet in maximum dimension and are separated by 1 to 12 inches of pyroclastic material. Where fresh the pillows are hard, but the surrounding matrix is generally softer. The pillows and enclosing material both weather to a swelling clay, thus are crumbly and friable when dry and plastic and weak when wet. Pyroclastic materials, in beds as much as 100 feet thick, are interbedded with pillow lavas. They generally are not as coherent as pillow lava. The weathered mantle on Franciscan volcanic rock may reach a thickness of 60 feet, and commonly is the locale of numerous small landslides.

6- SANDSTONE, SHALE, AND CONGLOMERATE

Mostly graywacke sandstone, shale, and conglomerate; unit includes a few thin limestone beds, and locally in lowest oldest part basaltic pillow lavas and agglomerates, and chert. Of same age and with approximately the same physical properties as Franciscan assemblage, but differs in the absence of small-scale pervasive crumpling, fracturing, and shearing (though shear zones do occur in these rocks), the greater persistence of individual beds, and the occurrence of broad open folds. In many places this unit overlies the Franciscan assemblage, but is separated from it by a zone of strongly sheared rock. As in the Franciscan assemblage weathered shales contain large amounts of swelling clays. Source of good-quality fill, riprap, and impervious zone material for earth dams. Fresh rock may require blasting to excavate. Shales can be used to make expansible lightweight aggregate. Great Valley sequence, 70 to 180 million years old (Jurassic to Cretaceous).

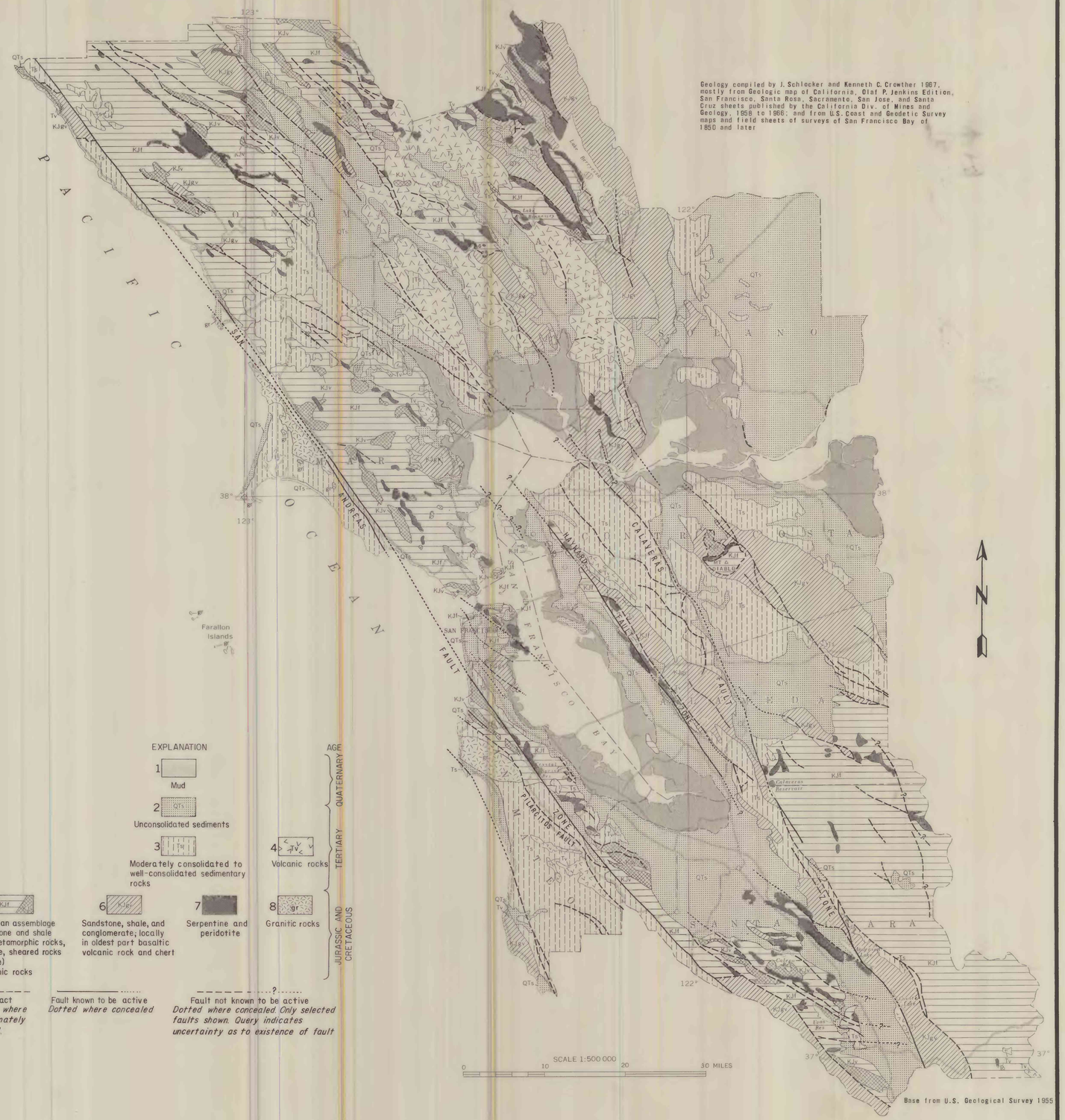
7-SERPENTINE AND PERIDOTITE

Ultramafic rocks, mostly serpentine derived from peridotite, rarely peridotite. Serpentine bodies consist of firm to moderately firm rounded pieces encased in a soft waxy weak matrix of throughly sheared and partly altered serpentine. Serpentine also contains sparse inclusions up to 40 feet in size of hard calcsilicate and other metamorphic rocks, and fresh and hard to altered crumbly gabbro and diabase. The volume proportion of hard and moderately hard pieces of serpentine and other rocks to soft matrix varies considerably, but averages about 3:1. In places the serpentine is almost entirely sheared for horizontal distances of as much as 100 feet; in rare places the serpentine is moderately firm and contains less than 10 percent soft material. Some serpentine border zones consist of severely sheared and altered rock that may be more than 100 feet wide and consists of large amounts of highly swelling clay. Some serpentine is altered to silica-carbonate rock, which is an exceedingly hard, dense to spongy, rusty-weathering rock. Excavation of this rock may require blasting. A variety of commercial mineral commodities occur within or at the borders of serpentine bodies. They include mercury, short-fiber asbestos, magnesite, and chromite.

Peridotite bodies are rare. The main bodies in the area are The Cedars ridge about 4 miles north of Cazadero, Sonoma County, and Red Mountain in Santa Clara County. They are largely unserpentinized olivine-rich rock and are usually harder and less sheared than the more thoroughly serpentinized rock.

8-GRANITIC ROCKS

Granitic rocks. Mostly coarse-grained, crudely foliated biotite-hornblende quartz diorite and granodiorite. In a few places includes small bodies of marble, biotite schist, amphibolite, and quartzite up to 100 feet in greatest dimension. Granitic rocks occur only west of the San Andreas fault in Marin and Sonoma Counties and west of the Pilarcitos fault in San Mateo County. They probably extend in depth thousands of feet. Locally severely fractured, sheared, and altered to clay. Pervasively altered, but only to a minor or moderate degree; where freshest they are firm to moderately firm rock and make good foundations and good fill and small-size riprap (less than 2 feet in diameter), but they are not fresh enough for use as aggregate for concrete. Weathering, generally to a coarse clayey sand, is common to depths of 10 feet, and in places to as much as 70 feet. Approximately 80 to 90 million years old.



Geology compiled by J. Schlocker and Kenneth C. Crowther 1967, mostly from Geologic map of California, Olaf P. Jenkins Edition, San Francisco, Santa Rosa, Sacramento, San Jose, and Santa Cruz sheets published by the California Div. of Mines and Geology, 1958 to 1966; and from U.S. Coast and Geodetic Survey maps and field sheets of surveys of San Francisco Bay of 1850 and later

Base from U.S. Geological Survey 1955

EXPLANATION

1 Mud

2 QTs — Unconsolidated sediments

3 Ts — Moderately consolidated to well-consolidated sedimentary rocks

4 Tv — Volcanic rocks

5 KJf — Franciscan assemblage
KJf - sandstone and shale
chert, metamorphic rocks,
limestone, sheared rocks
(melange)
KJv - volcanic rocks

6 Kgr — Sandstone, shale, and conglomerate; locally in oldest part basaltic volcanic rock and chert

7 Serpentine and peridotite

8 gr — Granitic rocks

AGE: QUATERNARY; TERTIARY; JURASSIC AND CRETACEOUS

Contact — *Dashed where approximately located*

Fault known to be active — *Dotted where concealed*

Fault not known to be active — *Dotted where concealed. Only selected faults shown. Query indicates uncertainty as to existence of fault*

GENERALIZED GEOLOGIC MAP OF THE SAN FRANCISCO BAY REGION, CALIFORNIA

by J. Schlocker

1970

This map is preliminary and has not been reviewed for conformity with U.S. Geological Survey standards and nomenclature.