UNITED STATES DEPARTMENT OF THE INTERIOR

GEOLOGICAL SURVEY

GEOLOGIC MAP OF O'NEILL FOREBAY, WESTERN MERCED COUNTY, CALIFORNIA

by

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Open-File Report

79-359

INTRODUCTION

The east flank of the Diablo Range in north-central California is shown as an eastward-dipping monocline by Jennings (1977). The edge of the San Joaquin Valley, which closely parallels the strike of this monocline, is also coincident with the San Joaquin fault zone of Herd (1979). Late Pliocene- and Pleistocene-age Tulare Formation gravels and late Pleistocene stream terraces locally end abruptly in a line of east-facing normal fault scarps alined with the escarpment at the valley edge.

Near O'Neill Forebay in western Merced County, Tulare Formation gravels and the intercalated Corcoran Clay Member are offset and tilted eastward along east-dipping reverse faults in the San Joaquin fault zone. The faults nearly parallel bedding in the underlying Great Valley sequence. A groundwater barrier in late Pleistocene (and possibly Holocene) sediments along San Luis Creek is alined with the northern prolongation of one of the faults at O'Neill Forebay.

REGIONAL GEOLOGY

Previous Work

The geology of the O'Neill Forebay area was first mapped by Anderson and Pack (1915) during a geologic reconnaissance of the west side of the San Joaquin Valley. Much later, the Great Valley sequence in the encompassing Pacheco Pass 15' Quadrangle was explored and described by Schilling (1962). For the construction of O'Neill and San Luis Dams and the California Aqueduct, detailed geologic site investigations were conducted in the O'Neill Forebay area (Carpenter, 1965; Hall, 1965a, 1965b; U.S. Bureau of Reclamation, 1971, 1974). Most recently, Dibblee (1975) synthesized recent work on the geology of the Pacheco Pass Quadrangle. None of the investigators recognized late Quaternary faulting in the O'Neill Forebay area.

Geologic Setting

O'Neill Forebay lies at the foot of the Diablo Range, on the west side of the San Joaquin Valley. The Forebay is underlain by northeast-dipping Cretaceous Great Valley sequence rocks (marine sandstone, shale, and conglomerate) which crop out in the hills west of the Forebay. The Great Valley sequence is conformably overlain by a poorly exposed, fine-grained marine sandstone of Paleocene-age, the Laguna Seca Formation of Briggs (1953). Both are obscured locally by shallow-dipping, terrestrial sands, gravels, and clays of the Tulare Formation (Pliocene and Pleistocene), which rest with angular unconformity on the older rocks. Pleistocene- and Holocene-age alluvial fans spread eastward across the Forebay area into the San Joaquin Valley.

Three faults strike southeastward from O'Neill Forebay, closely paralleling bedding in the underlying Great Valley sequence. Two offset the overlying Tulare Formation in southwest-facing scarps; one impounds groundwater in late Pleistocene (and possibly Holocene) alluvium south of San Luis Creek.

Stratigraphy

Great Valley Sequence

A bedded sequence of marine sandstone, shale, and conglomerate underlies the west part of the map area. The rocks, part of the Cretaceous Great Valley sequence (Schilling, 1962; Dibblee, 1975), dip northeastward (generally 40-60°) beneath the west side of the San Joaquin Valley. The stratigraphic sequence locally fines eastward, grading up-section from interbedded sandstones and micaceous shales with conglomerate lenses to clayey shales. The sandstones are largely medium- to fine-grained; several contain cobble- to boulder-size spheroidal limy concretions. The conglomerate lenses are quite coarse, with well-rounded pebbles and cobbles. The shales appear finely laminated.

Laguna Seca Formation of Briggs (1953)

A white, fine-grained, quartzose sandstone conformably overlies the Great Valley sequence in sec. 26, T. 10 S., R. 9 E. Poorly exposed, the sandstone has been previously identified (Diblee, 1975) as part of the marine Laguna Seca Formation (Paleocene) of Briggs (1953). The sandstone dips to the northeast, beneath the Tulare Formation.

Tulare Formation

In the O'Neill Forebay area, a dark gray to light-gray-colored diatomaceous clay and an overlying channel sand and gravel assemblage rest unconformably atop the Great Valley sequence and the Laguna Seca Formation of Briggs (1953). These non-marine sediments, which were included within the Tulare Formation by Anderson and Pack (1915), dip shallowly to the east.

The clay, which is exposed in many outcrops of the Tulare Formation in the O'Neill Forebay area, has been previously identified (Carpenter, 1965; Hall, 1965a, 1965b) as the Corcoran Clay Member (Frink and Kues, 1954). The clay is locally more than 10 m thick, and is crudely bedded in outcrop along the Delta-Mendota Canal near Volta. A basal quartz-rich sand about 1 m thick is present beneath the clay along Interstate Highway 5 in sec. 26, T. 10 S., R. 9 E., but it is unclear whether the sand is everywhere extensive. The overlying sand and gravel assemblage is deeply oxidized and is set into the surface of the clay. The sand and gravel complex reaches a maximum thickness of more than 20 m in the Los Banos Creek area.

The Tulare Formation is of both Pliocene and Pleistocene age. A 2.2 m.y.-old volcanic ash (Obradovich and others, 1978) occurs near the base of the type Tulare (Woodring and others, 1940) in the Kettleman Hills of California. Vertebrate remains of either Irvington (middle Pleistocene) age or of Rancholabrean (late Pleistocene) age (Croft, 1972, p. H19) were recovered by Hall (1965a) from the Corcoran Clay Member in excavations for the San Luis Canal (now California Aqueduct) southeast of O'Neill Forebay. Near Friant, California, the clay lies conformably beneath pumiceous alluvium dated at approximately 600,000 years (Janda, 1965).

Older Alluvium

Three older alluvial units are identifiable in the O'Neill Forebay area based on the relative topographic position, morphology, and soil-profile development on the deposits. The three (Qoa_1, Qoa_2, and Qoa_3) occur as successively higher terrace levels along streams draining the east flank of the Diablo Range (all three are preserved above Los Banos Creek), or as isolated terrace remnants and dissected alluvial fans (Qoa_3 fans south of San Luis Creek are partially buried by younger Qoa_2 alluvium). The alluvial units are locally set into or occur topographically below the Tulare Formation (fig. 1), and are clearly younger than the similar-appearing (in cross-section) channel sand and gravel assemblage in the uppermost Tulare.

The older alluvial units have been mapped and correlated regionally in the O'Neill Forebay area by the tracing of terrace levels downstream, and by characteristic soil development (Cole and others, 1952). Older alluvial unit 1, the first terrace above the Holocene flood plain, is typically undissected. Youthful, light brown to grayish brown soils without, or with only incipient development of clay-rich (argillic) B horizons, such as the Sorrento Series soils, are present on first-terrace deposits. More developed soils, such as the Pleasanton, Rincon, and Herdlyn Series, occur on older alluvial unit 2, the second terrace level. These soils have well-developed argillic B horizons, and are brown to light reddish-brown in color. Although moderately dissected, older alluvial unit 2 is the most extensive alluvium in the map area. Older alluvial unit 3 is deeply eroded and is scarcely preserved in the O'Neill Forebay area. Dark brown to dark reddish-brown soils -- usually the Denverton Series, with strongly developed argillic B horizons are found

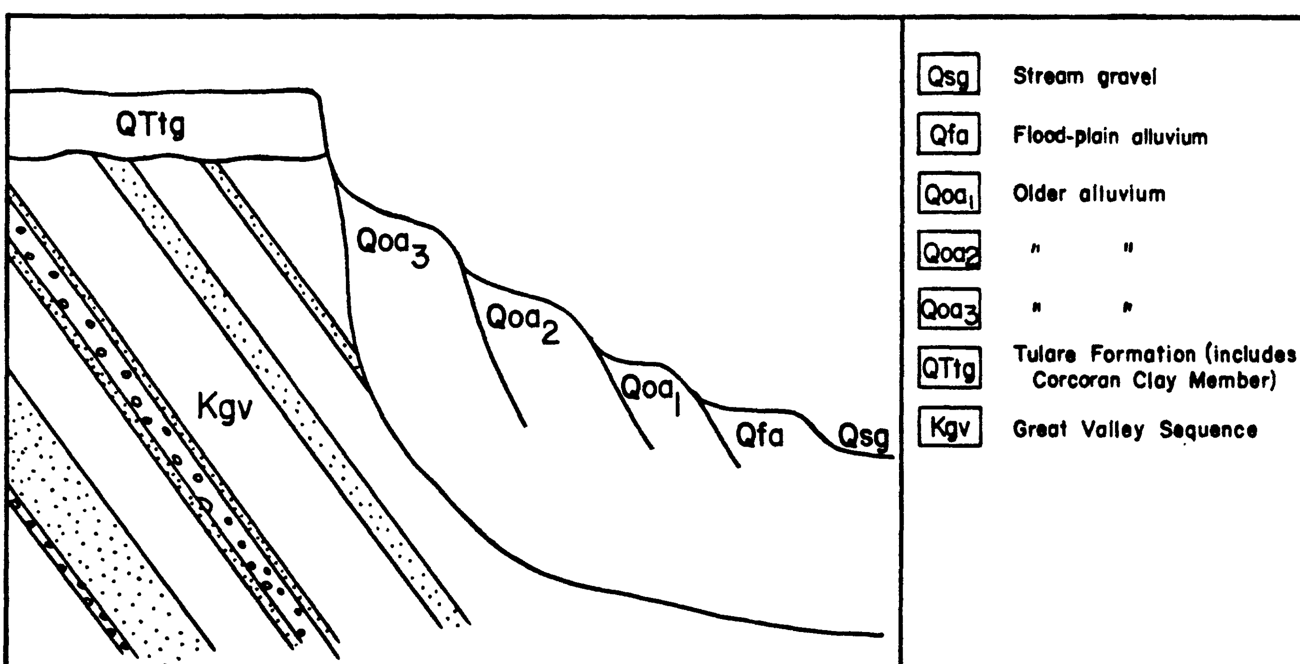

Figure 1. Topographic position and stratigraphic relationship of Quaternary deposits in the O'Neill Forebay area.

on these deposits. These soils are also found on the much older Tulare Formation. All three older alluvial units, especially units 2 and 3, have hummocky, patterned surfaces. Low, flattened, rudely circular or elliptical domes -- "pimple mounds," of unknown origin blanket the deposits.

All of the older alluvial units, except unit 1, are demonstrably Pleistocene in age. Birkeland (1974, p. 162-180) found that in California, some 40,000 years of soil formation appears to be required to form a minimal B horizon. Older alluvial units 2 and 3 have well-developed B horizons; unit 1 has little or no B horizon development. Sorrento Series soils, which occur on older alluvial unit 1, are also mapped on Holocene flood-plain alluvium. It is not clear whether older alluvial unit 1 is an early Holocene deposit, or whether sufficiently detailed soil identification criteria have been used that allows separation of a very late Pleistocene-age alluvium from a Holocene-age deposit.

Flood-plain Alluvium

Areas of flood-plain alluvium -- sediments deposited on the surface adjacent to the active stream channels when the streams overflow their banks at times of high water, occur especially near Romero and San Luis Creeks. The alluvium is undissected (but preserves original surface channel morphology), has no "pimple mound" topography, and displays little or no soil development (Sorrento Series soils).

Stream Gravels

Cobbly, pebbly gravel and sand floor active stream channels in the O'Neill Forebay area. The sediments display no evidence of soil development.

Structure

Late Quaternary Faulting near O'Neill Forebay

Three northwest-trending faults strike toward O'Neill Forebay. The faults closely parallel bedding in the underlying Great Valley sequence, locally displacing the overlying Tulare Formation in southwest-facing scarps. The faults continue to the southeast beyond the map area, ending near Ortigalita Creek (fig. 4).

The westernmost of the three faults south of the Forebay is disclosed by the oblique truncation of north-striking beds in the Great Valley sequence west of the fault against northwest-trending beds (sec. 29, T. 10 S., R. 9 E.). The fault follows a linear swale northwest toward O'Neill Forebay, disappearing beneath the apparently unbroken Tulare Formation south of the substation in sec. 19, T. 10 S., R. 9 E. To the southeast the fault is covered locally by unit 2 older alluvium. Although there is no vertical component of movement along the fault in the map area, just south of Los Banos Reservoir (fig. 4) Tulare Formation gravels are downthrown more than 40 m in a prominent southwest-facing escarpment along this fault.

The second fault of the three strikes northwest into O'Neill Forebay, passing directly beneath the axis of the north limb of O'Neill Dam. The fault is largely confined between bedding in the Great Valley sequence, except where the fault splays

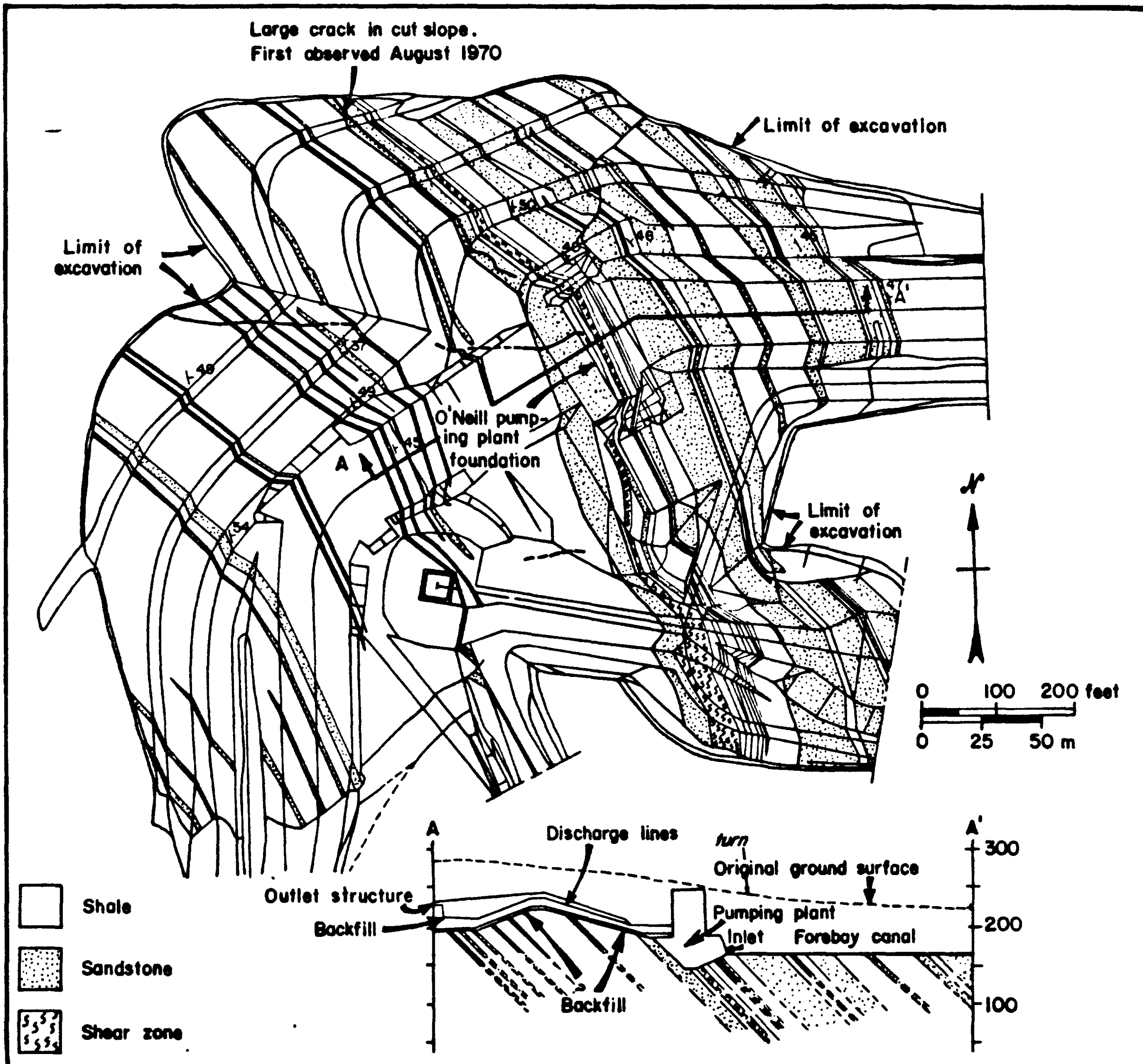

Figure 2. Excavation geology (after U.S. Bureau of Reclamation, 1974, p. 52) of O'Neill Pumping Plant, at the north end of O'Neill Dam. Northeast-dipping Cretaceous Great Valley sequence rocks are sheared along a near bedding-plane fault that strikes through the pumping plant foundation.

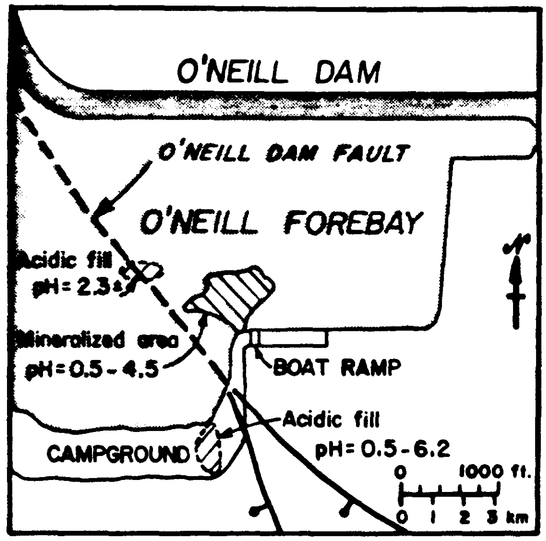

Figure 3. Altered, highly acidic areas in the Corcoran Clay south of O'Neill Forebay (after Prokopovich and others, 1971, p. 828). The alteration is associated with the O'Neill fault.

southeast of the Forebay. The fault is delineated southeast of O'Neill Forebay by a southwest-facing escarpment in Tulare Formation sediments, and by a vertically offset (west side down) stream channel just south of the substation in sec. 19. At California Highway 152 the Corcoran Clay Member and overlying channel sands and gravels of the Tulare stand more than 4 m above unit 2 older alluvium, which is deposited against the escarpment and rests on the Tulare. The throw along the escarpment diminishes southeast of the substation in sec. 19, becoming unrecognizable south of sec. 20. Northwest of Highway 152 the vertical displacement along the fault dies toward the Campground, where the fault splays. Immediately to the east, the throw on the fault splay increases northward toward O'Neill Forebay. The relationship suggests that the fault may actually be two breaks: one which strikes southeast through the substation; a second that lies beneath O'Neill Dam, bending to the southeast near its point of intersection with the O'Neill fault. Before its removal and grading during construction of O'Neill Dam and O'Neill Forebay, the fault scarp continued northwest through sec. 18 to sec. 12 (T. 10 S., R. 8 E.). There the scarp was apparently truncated by the Qoa_2 terrace south of San Luis Creek. Although there was no evident associated scarp, the fault clearly broke the unit 2 alluvium south of San Luis Creek: in pre-construction aerial photographs groundwater was visibly impounded west of a linear northwest-trending barrier alined with the fault scarp to the south. The fault may also have cut the Holocene flood plain south of San Luis Creek. The Holocene alluvium was noticeably darkened by groundwater immediately north of the fault-created groundwater barrier in the Qoa_2 terrace. It is not clear, however, if the groundwater in the Holocene alluvium was fault-impounded, or if it was spilling into the flood plain from the higher, faulted Qoa_2 terrace. At O'Neill Pumping Plant, at the north end of O'Neill Dam, the fault is exposed in the north wall of the plant excavation (fig. 2). The fault dips 45° to the northeast, nearly parallel to bedding. North of the pumping plant the fault locally juxtaposes sandstone beds against siltstone units. The O'Neill fault is the apparent structural control for the alteration of the Corcoran Clay Member near the Boat Ramp in sec. 18, T. 10 S., R. 9 E. (fig. 3). The altered clay is highly acidic, with native sulfur, gypsum, alunite, and related minerals (Prokopovich and others, 1971). The alteration and mineralization was produced by escaping natural gas, evidently trapped by the fault.

The easternmost of the three faults displaces the Tulare Formation in a southwest-facing scarp north of Highway 152 near the east end of O'Neill Forebay. Southeast of Highway 152, where the Tulare is eroded well back from the scarp's edge, the fault offsets the erosional surface atop the Great Valley sequence, on which the Tulare Formation was deposited. The erosional surface is downthrown at least 7 m just north of Billie Wright Road in sec. 28, T. 10 S., R. 9 E. Locally, the fault is covered by unit 2 older alluvium.

Recency of faulting. Movement along the three faults began after the deposition of the Tulare Formation. This displacement, adjudged from the offset of the Corcoran Clay Member, must have occurred in the last approximate 600,000 years (the age of the Corcoran Clay). The deposition of unit 2 older alluvium against the O'Neill fault scarp south of O'Neill Forebay, and the impoundment of groundwater behind the fault in the Qoa_2 terrace south of San Luis Creek records at least 2 episodes of movement along the fault. One displacement occurred before and a second after the deposition of the unit 2 older alluvium. If the groundwater in the Holocene alluvium south of San Luis Creek was fault-dammed, a post-10,000 year age is indicated for the latest displacement on the O'Neill fault.

SEISMICITY

No large earthquakes ($M \geq 4$) have been instrumentally located near the faults at O'Neill Forebay (Real and others, 1978; J. Eaton, written commun., 1978). Moreover, no significant microseismic activity was detected in the Forebay area during the first 5 years of operation (1969-1974) of the U.S. Geological Survey central California seismic network (fig. 4). A number of small earthquakes were instrumentally located near or beneath San Luis Reservoir. These earthquakes appear spatially associated with the Tesla-Ortigalita fault zone, along which Quaternary displacement has been documented at San Luis Reservoir (U.S. Bureau of Reclamation, 1974, p. 17-18). Some of the shocks may be mislocated too far west, and several could be related to the three faults in the O'Neill Forebay area. The reservoirs lie at the eastern limit of the U.S. Geological Survey seismic network; an absence of stations in the San Joaquin Valley results in the westward weighting of epicentral locations. Complexities in wave propagation at the boundary of the Diablo Range and the San Joaquin Valley add additional, indeterminate location errors, making it difficult to determine which epicenters are associated with specific faults.

ACKNOWLEDGMENTS

Catherine R. McMasters ably assisted in the mapping and drafting of this report. I thank the U.S. Bureau of Reclamation and California Department of Water Resources for their cooperation. Conversations with Earl E. Brabb aided significantly in the preparation of the manuscript.

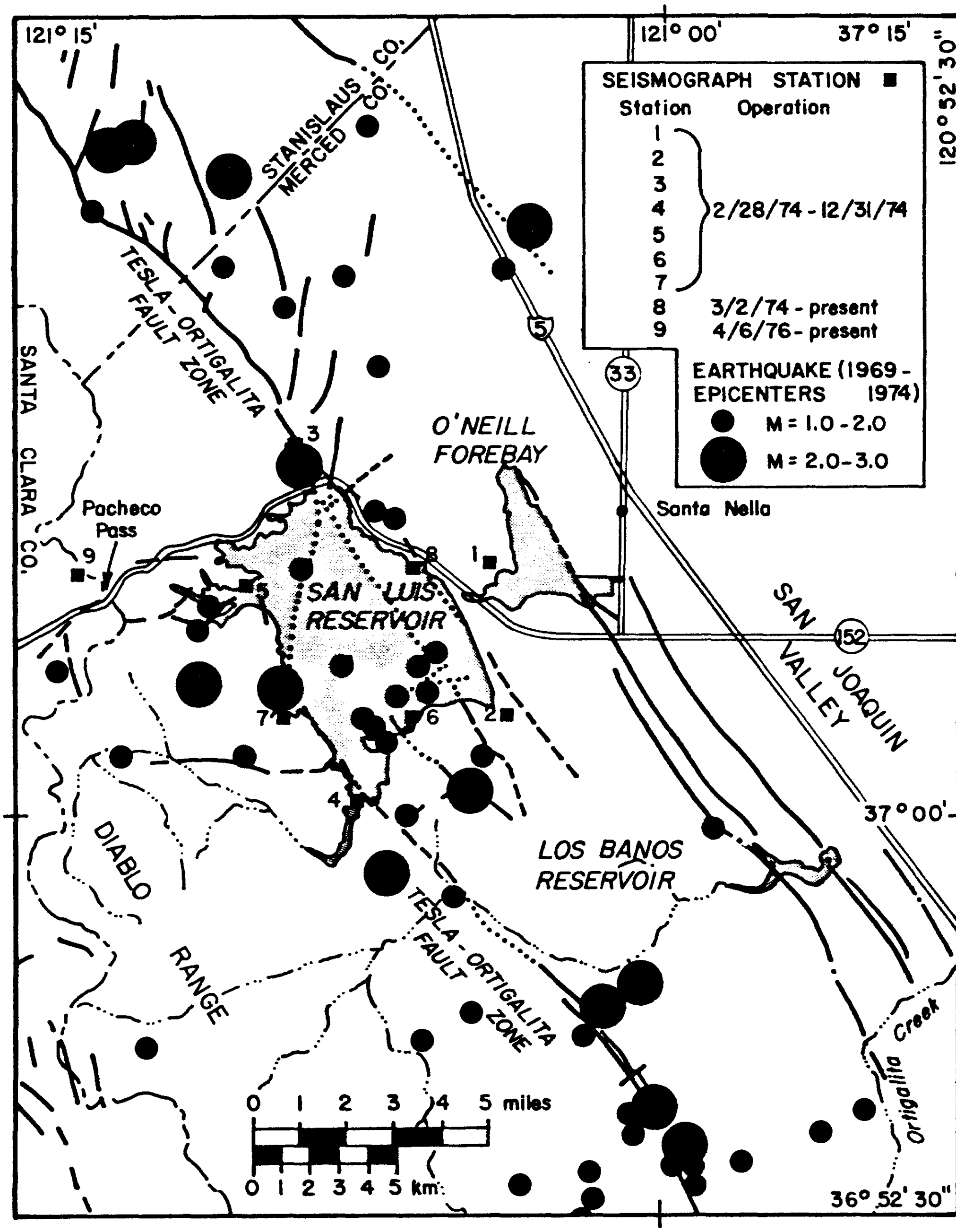

Figure 4. Seismicity (1969-1974) and faulting near O'Neill Forebay and San Luis Reservoir. Epicenters from Bufe and others (1975); Lee and others (1972a, 1972b, 1972c, 1972d); Lester and others (1976a, 1976b, 1978); and Wesson and others (1972a, 1972b, 1973, 1974a, 1974b). Faults after Dibblee (1975), Jennings (1977), and this report.

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