CHAPTER 86

SEDIMENT DISTRIBUTION AND ITS RELATIONS TO CIRCULATION PATTERNS IN BOLINAS BAY, CALIFORNIA

P Wilde[1] and T Yancey[2]

ABSTRACT

Grain size and heavy mineral analyses of 6 cliff, 12 beach, and 44 marine sediment and rock samples from Bolinas Bay and its surrounding drainage area were done as part of a long term study of sediment transport on the continental shelf off Central California

Sediments in the bay are predominately very fine sands Some samples, particularly adjacent to Duxbury Reef on the west, have a coarse sand to pebble component The primary mode of the marine samples is in the range 088 to 125 mm, whereas, the primary mode for beach material is from 175 to 25 mm The range of median diameters of the marine samples is from 07 to 14 mm The median diameters show a trend of decreasing grain size seaward parallel to the depth contours except opposite the entrance to Bolinas Lagoon where a tongue of relatively coarser material cuts across the depth contours The range of other statistical parameters are (1) sorting coefficient 1 10 to 1 41, (2) skewness 0 83 to 1 18, and (3) kurtosis 0 15 to 0 32

Our sediment studies indicate

(1) The heavy mineral assemblage is predominantly green hornblende with secondary amounts of hypersthene and augite Glaucophane and jadeite occur in locally high concentrations near shore

(2) The pattern of distribution of the heavy minerals shows (a) a tongue of high concentrations of minerals with a granitic source extending northwest from the San Francisco Bar, (b) flanked on the north and northeast by increasing landward concentrations of Franciscan metamorphic minerals

(3) The major source of heavy minerals is the San Francisco Bar Secondary contributions come from Bolinas Lagoon and the adjacent cliffs

(4) The circulation in the Bay is primarily counterclockwise, produced by a combination of wave refraction around Duxbury Reef and the tidal Coast Eddy Current The tidal influence, however, of Bolinas Lagoon is restricted to about one mile from the lagoon mouth Circulation

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patterns in the Bay greatly influence the sediment distribution

(5) The annual sediment flux in Bolinas Bay is about 300,000 cubic yards The bottom sediments in the Bay are apparently in quasiequilibrium

This report summarizes a comprehensive study of Bolinas Bay sediments given in Isselhardt and others, 1968, 1969, and Wilde and others, 1969 Bolinas Bay is a parabolic shaped embayment of the Pacific Ocean at the southern tip of the Point Reyes Peninsula, ten miles north of the entrance to San Francisco Bay (Fig 1) Bolinas Bay is bounded (1) on the north by the Bolinas Cliffs, (2) on the northeast by Sea Drift Spit, the barrier bar at the entrance to Bolinas Lagoon, (3) on the east by the Marin County Coast Ranges, (4) on the south by the Pacific Ocean, and (5) on the west by the shoals of Duxbury Reef The long axis of the bay points towards Bolinas Lagoon and is oriented about N 40°W along the submarine trace of the San Andreas Fault

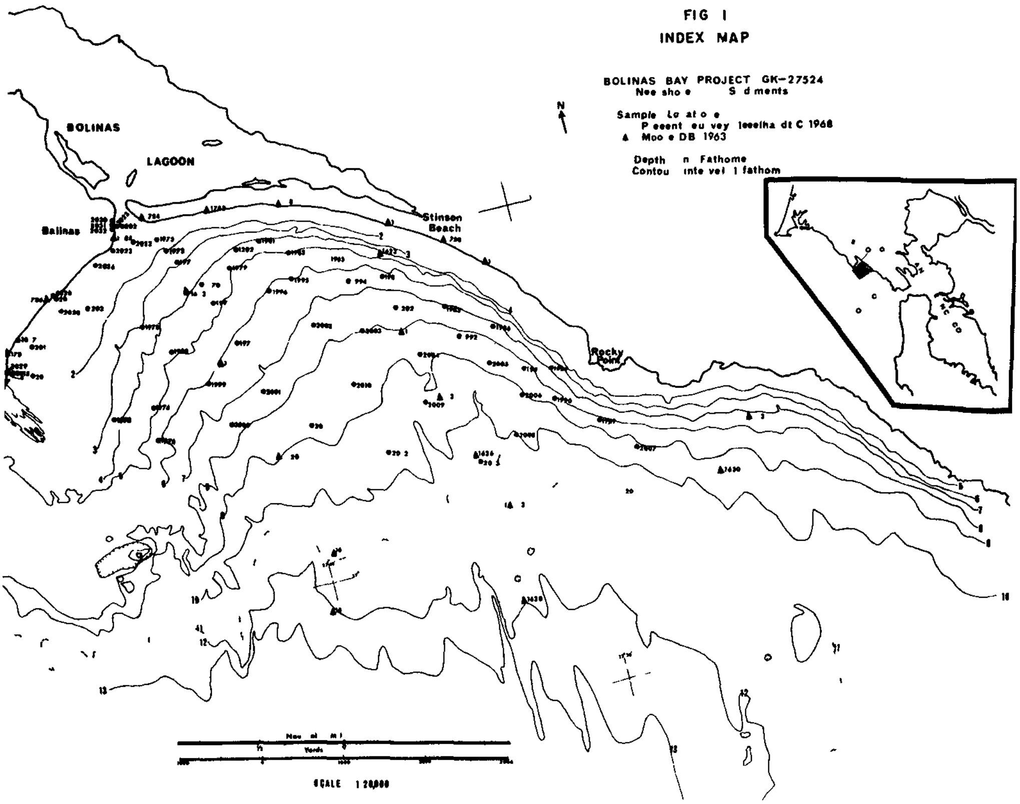


FIG I
INDEX MAP

The land area in the drainage adjacent to Bolinas Bay can be divided, east to west, respectively, into three topographic regions, (1) Bolinas Ridge which extends northeastward from Mount Tamalpais to Tomales Bay, (2) the San Andreas rift zone of rolling hills, sag ponds, and Bolinas Lagoon, and (3) the Bolinas Plateau with Duxbury Reef, a wave cut bench at the base of the western edge of the plateau (U S G S $7\frac{1}{2}$ minute quadrangle Bolinas sheet) The main feature of the Bolinas region is the conspicuous rift valley of the San Andreas Fault, which is prominently expressed by Bolinas Lagoon In Bolinas Bay it can be traced, less conspicuously, in the submarine contours This rift separates structural blocks of greatly different geological composition, as well as acting as a focus for drainage within the region

Depth contours in Bolinas Bay generally are sub-parallel to the shore line (Fig 1) Bay bottom gradients are steepest on the eastern side near Rocky Point where the 10 fathom line lies one-half mile offshore The contours diverge to the west where adjacent to Duxbury Reef the 10 fathom line is one and three-quarters miles offshore

Two submarine channels heading southeast downslope can be traced seaward of 7 fathoms These channels are aligned with the northwest-southeast trend of the San Andreas Fault The channels empty into a depression lying between Bolinas Bay and the north rim of the San Francisco Bar (Potato Patch Shoal)

Changes in bathymetry with tidal fluctuations apparently are limited to a small region with an offshore bar just seaward of the entrance to Bolinas Lagoon (Ritter, 1969) Seasonal depth changes are being studied now by comparison of various precision depth surveys of the bay Preliminary results (Johnson, 1969) indicate that seasonal depth changes also are limited to shallow nearshore regions near the entrance to the lagoon

Tides

The Bolinas area has a mixed tide like San Francisco Bay, with a maximum range of 8 feet from higher high water to lower low water (Ritter, 1969, p 13)

Currents

Open Ocean Currents The major offshore current off the central California coast is the southwesterly flowing California Current which is the eastern return gyre of the clockwise circulation pattern of the North Pacific (Reid and others, 1958, U S Hydro, 1947) During the winter months a coastal northward flowing current called the Davidson Current (Reid and Schwartzlose, 1962) interposes itself between the coast and the California Current The Davidson Current flows during the periods of maximum water runoff and erosion (Hendricks, 1964) on the adjacent land areas Thus, the Davidson current probably carries a significant load of suspended sediment in a northward direction along the coast

Tidal Currents The most apparent water movements in Bolinas Bay are tidal, complicated by the configuration of the coastline and the inputs of the tidal prisms of both Bolinas Lagoon and San Francisco Bay Strong non-surging currents have been encountered by scuba divers near station 1627 (R Zelwer, 1968, personal communication) in about 70 feet of water, which indicates tidal rather than wave produced currents The Coast Eddy Current (U S Coast Pilot, no 7, 1968, p 152), a feature of the San Francisco Bay tide, flows north and counterclockwise north of the San Francisco Bar into Bolinas Bay

Longshore Currents Longshore currents develop in response to the prevailing west northwest swell (Fig 2) Refraction of the waves about Duxbury Reef would produce a northerly drift north of the Golden Gate Northwesterly longshore currents within Bolinas Bay is suggested by the orientation of Sea Drift Spit across the mouth of Bolinas Lagoon Drift measurements by dye drops (rhodamine B) and floating rubber balls by the U S Geological Survey (Ritter, 1969, p 30), and by milk bottle caps (Brown and Caldwell Consulting Eng , 1961) indicate counterclockwise drift in the eastern portion of Bolinas Bay

Geology

The Bolinas Bay drainage area is at the southern edge of the Northern Coast Ranges and is divided by the San Andreas rift zone into two distinct geological provinces (Fig 3) The eastern section noted topographically as Bolinas Ridge consists entirely of Franciscan Formation rocks except for recent alluvium in stream valleys In the Bolinas Bay drainage area the Franciscan consists of undifferentiated sandstones, chert, serpentine, and diabases Feldspathic sandstone is the most abundant rock type (Gluskoter, 1962)

The area to the west of the San Andreas fault is in the Salinian Quartz Diorite province, although no granitic type rocks crop out in the Bolinas Bay drainage, such rocks are found nearby at Point Reyes, Tomales Point, and Bodega, and presumably are the basement rocks in the Bolinas area Two Cenozoic formations, the Monterey and the Merced, form the surface exposures, except for patches of recent alluvium, over the entire Bolinas Peninsula The Merced Formation, found as a thin band parallel to the fault, consists of fine grained, friable sandstones and siltstones with small amounts of fossiliferous sandstone and pebble conglomerates The Monterey Formation is the most extensive unit found on the Bolinas Peninsula and forms the rapidly eroding cliffs extending from Duxbury Reef almost to the Bolinas Lagoon entrance The Monterey rocks are predominately tan to gray mudstones, silty mudstones, and siltstones with occasional lenses of sandstones

The San Andreas rift zone is a jumbled mass of rock composed of slivers from formations on both sides of the zone The fault is active and displacements of one foot vertically and 8-14 feet horizontally were recorded in the Bolinas area from the 1906 earthquake (Lawson, 1908, p 70, 84) In fact, the epicenter of the 1906 earthquake was located near Bolinas Bay on the Pt Reyes Peninsula

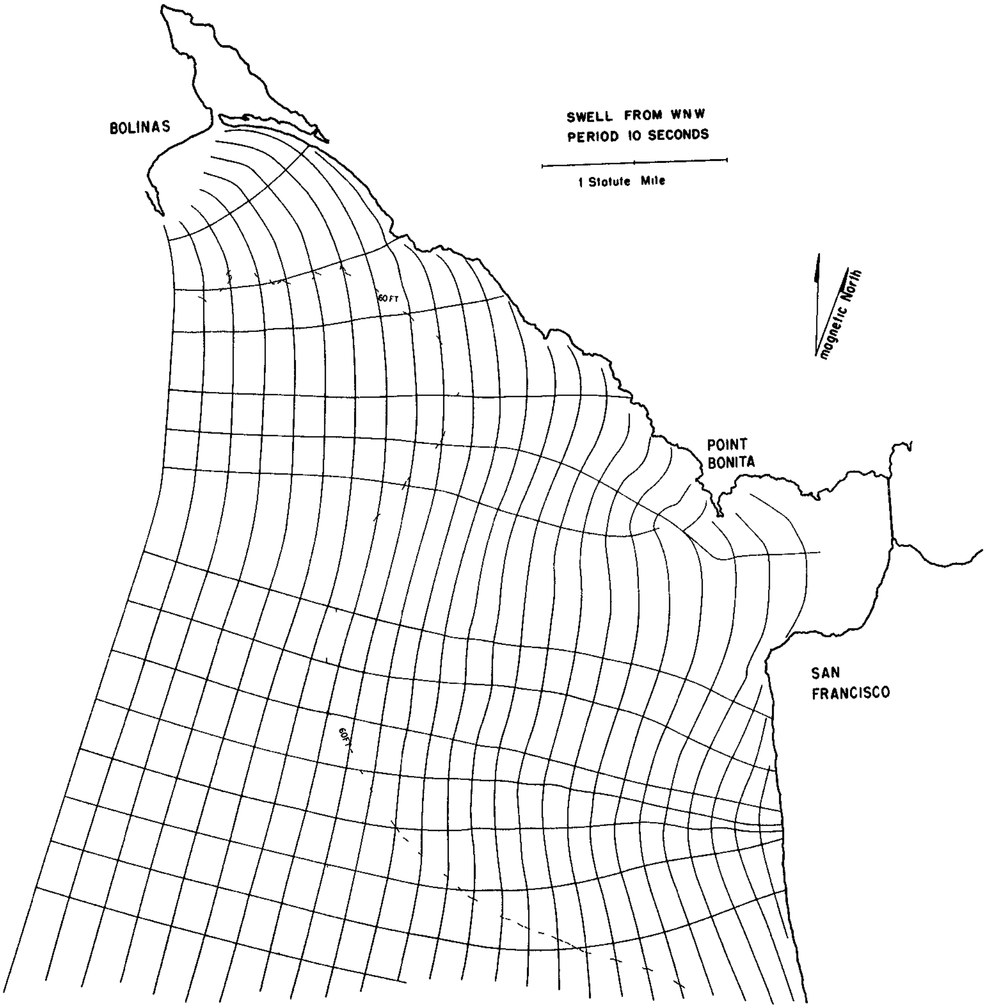
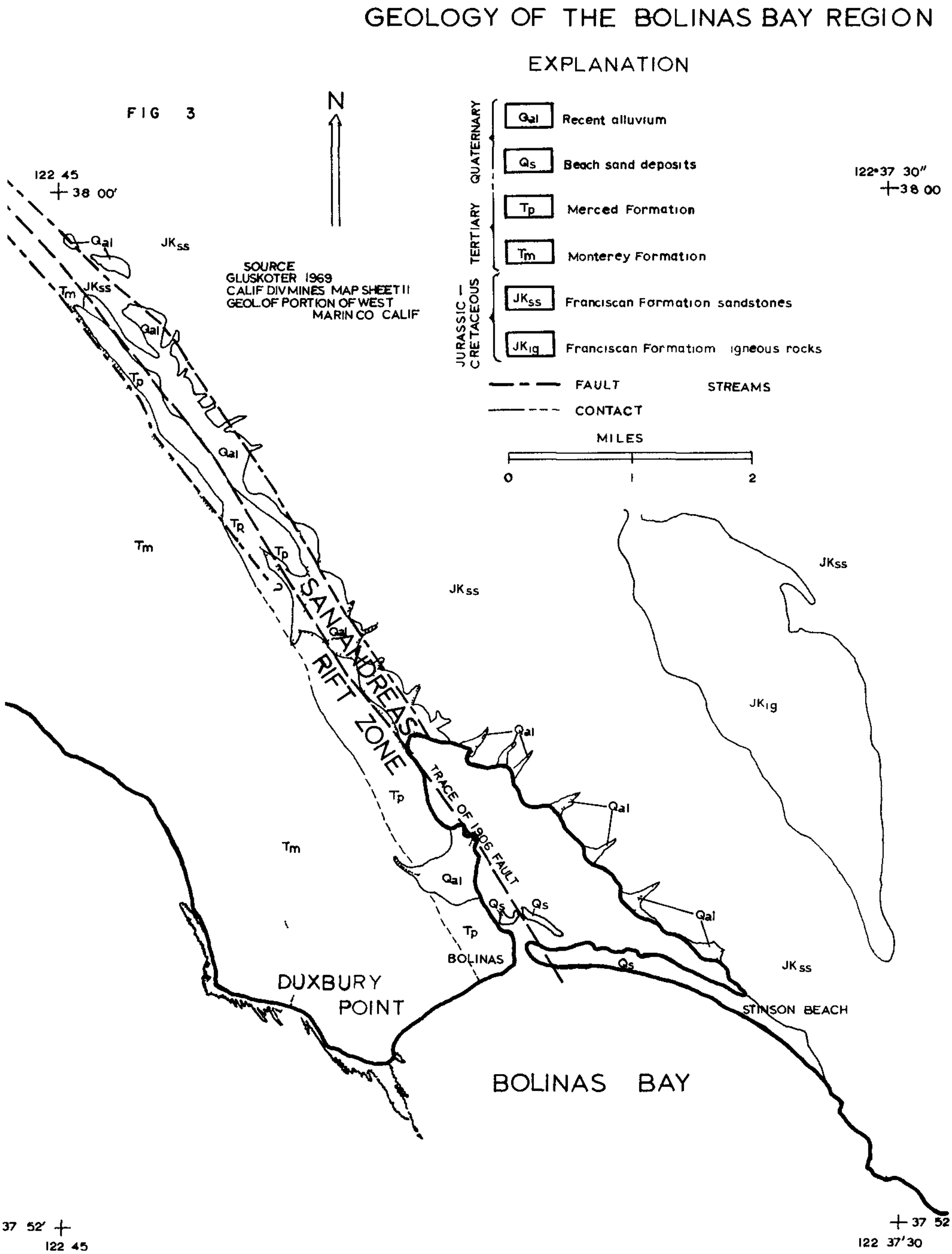


FIG 2 WAVE REFRACTION DIAGRAM (WNW, 10 SEC) FOR MARIN-SAN FRANCISCO AREA

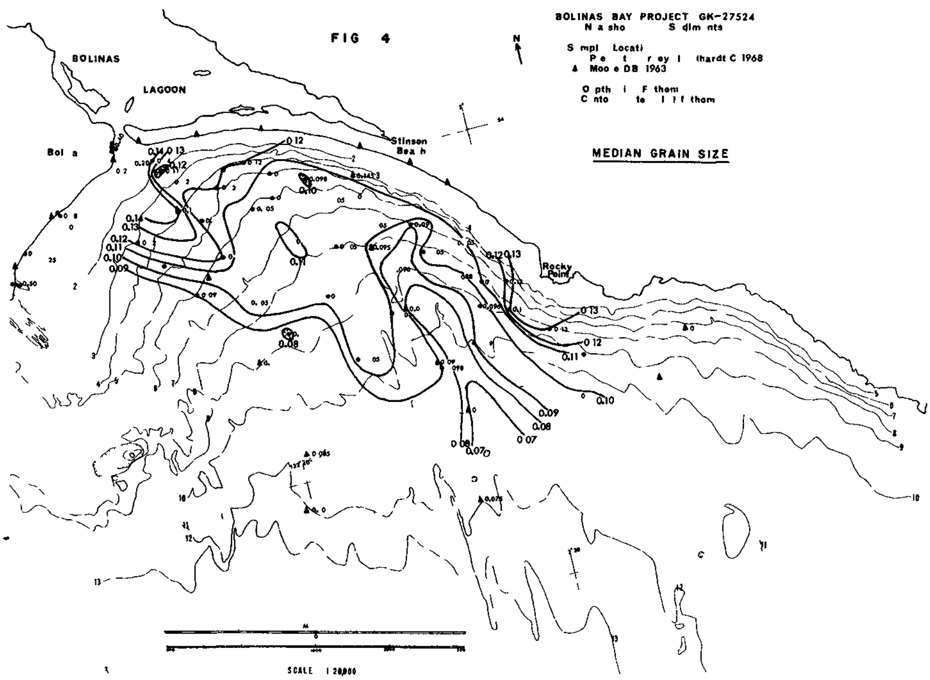
FIG 3


GEOLOGY OF THE BOLINAS BAY REGION
EXPLANATION
QUATERNARY
Qal Recent alluvium
Qs Beach sand deposits
TERTIARY
Tp Merced Formation
Tm Monterey Formation
JURASSIC — CRETACEOUS
JKss Franciscan Formation sandstones
JKig Franciscan Formatiom igneous rocks
FAULT
STREAMS
CONTACT
MILES
0
1
2
N
SOURCE
GLUSKOTER 1969
CALIF DIV MINES MAP SHEET 11
GEOL. OF PORTION OF WEST
MARIN CO CALIF
122 45
38 00'
122°37 30"
38 00
SAN ANDREAS
RIFT ZONE
TRACE OF 1906 FAULT
Qal
Qs
Tp
Tm
JKss
JKig
BOLINAS
DUXBURY
POINT
STINSON BEACH
BOLINAS BAY
37 52'
122 45
37 52
122 37'30

For more detailed information on the geology of the Bolinas area, see Weaver (1949), Gluskoter (1962, 1969), Galloway (1966), and Bailey (1964)

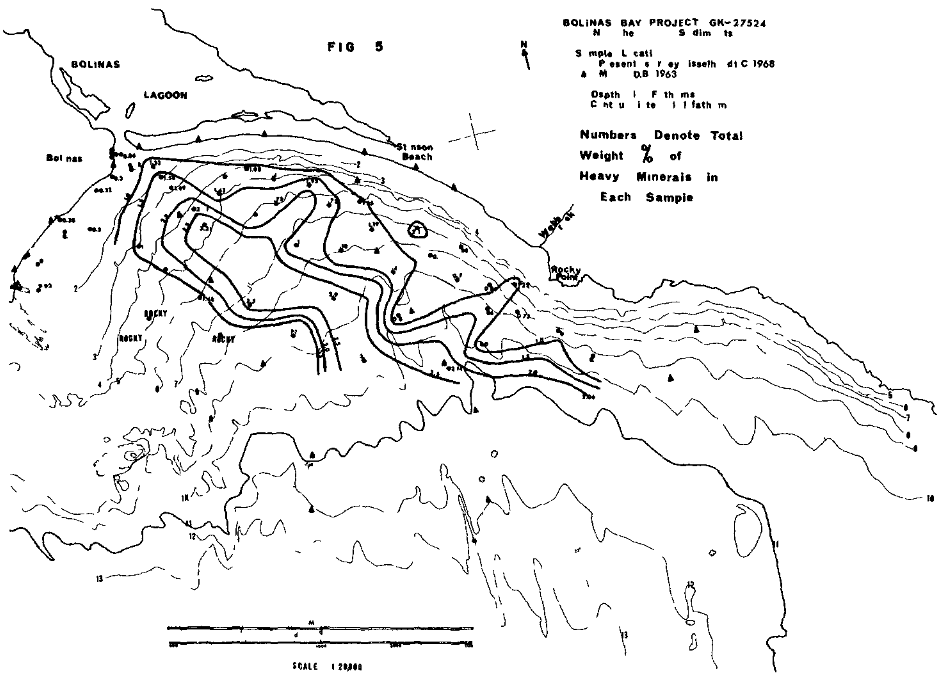
Grain Size Properties

The statistical parameters, median grain size, and sorting coefficient are derived from data presented in Isselhardt and others, 1968 The average of median grain size for the bay sediments is about 0 10 mm or fine sand, with extremes at 0 40 mm medium sand to 0 07 mm very fine sand The median grain size generally decreases seaward paralleling the depth contours Figure 4 shows variations of this trend as two lobes of coarser sediment extending (1) seaward from Rocky Point and (2) from the mouth of Bolinas Lagoon, and a band of finer grained sediment on the western margin of the bay next to Duxbury Reef Topographic and bathymetric irregularities produce the Rocky Point and Duxbury Reef anomalies Wave agitation around Rocky Point prevents fine material from depositing While on the protected lee side of Duxbury Reef, finer particles may settle out The lobe of coarser material near the mouth of Bolinas Lagoon presumably is a product of tidal action Coarser sediment is carried seaward by the strong tidal currents measured by Ritter (1969) exiting the lagoon Winnowing by tidal reversals prevents settling of finer material here



Values of the sorting coefficient indicate all the samples are well sorted, with the expected gradient of poorer sorting seaward The gradient is greatly masked by sample to sample variation, but deep samples have values of 1 20 or greater while shallow samples have values usually less than 1 20 The best sorting in the bay is associated as expected with the entrance to Bolinas Lagoon and with Rocky Point The sorting roughly shows the same pattern as the median grain size, but much less clearly In Bolinas Bay the sorting of the sediments is primarily a function of the grain size of the sediments, in both deep and shallow water

Contours of weight percent heavy minerals (Fig 5) also gives strong indication of bottom currents flowing between the lagoon entrance and deeper water The major trend is a linear concentration of heavy minerals aligned from the entrance to Bolinas Lagoon to the center of the bay It extends between and connects the two tongues of coarse sediment noted on the median grain size chart, and apparently is caused by tidal currents



Mineralogy

The heavy mineral assemblages reveal two discrete suites (1) in a mid-bay tongue typified by green hornblende and hypersthene, and (2) along the shore characterized by glaucophane and jadeite Figure 6 shows the relative proportion of the two mineral suites in each sample plotted as a function of distance from shore These data plotted on a map (Fig 7) describe three zones (1) off shore, for sediments of the hornblende + hypersthene suite, (2) near shore, for samples with a glaucophane + jadeite assemblage, and (3) at intermediate distance from shore where the two suites are mixed

Provenance

Potential sources for the sediments of Bolinas Bay are

(1) Webb Creek drainage, which empties directly into Bolinas Bay,

(2) drainage area of Bolinas Lagoon, with sediment transported from the lagoon into Bolinas Bay by tidal action,

(3) sea cliff erosion of cliffs between Duxbury Reef and the town of Bolinas,

(4) San Francisco Bar, with sediments transported into Bolinas Bay by northward flowing bottom currents,

(5) rocks north and south of Bolinas Bay - sediments brought into the bay by longshore drift

Webb Creek, draining Franciscan terrain, is the only stream that empties directly into Bolinas Bay Sediments in Bolinas Bay adjacent to the mouth of Webb Creek contain high concentrations of glaucophane and jadeite, a typical Franciscan mineralogy, indicating a flow of Webb Creek sediments into the bay

The mineralogy of bottom sediments in the lagoon (Helley, in Ritter, 1969) indicates that Pine Gulch Creek, the largest creek, principally contributes Monterey shale sediments to the lagoon, which is mixed with the contribution from the smaller streams with exclusively Franciscan drainage As a result, Bolinas Lagoon sediments are dominantly of Monterey shale fragments, while containing a heavy mineralogy characteristic of Franciscan Formation sediments

The Bolinas Cliffs are actively eroding and supply large amounts of sediment to Bolinas Bay annually Helley (in Ritter, 1969) cites an annual rate of cliff erosion of 2 3 feet per year (determined by A J Galloway) The sea cliffs fronting on Bolinas Bay are 7000 feet long and are at least 120 feet high, and would give an annual yield of sediment of 72,000 cubic yards The cliffs are composed mostly of Monterey shale, with lesser exposures of Merced Formation near the town of Bolinas

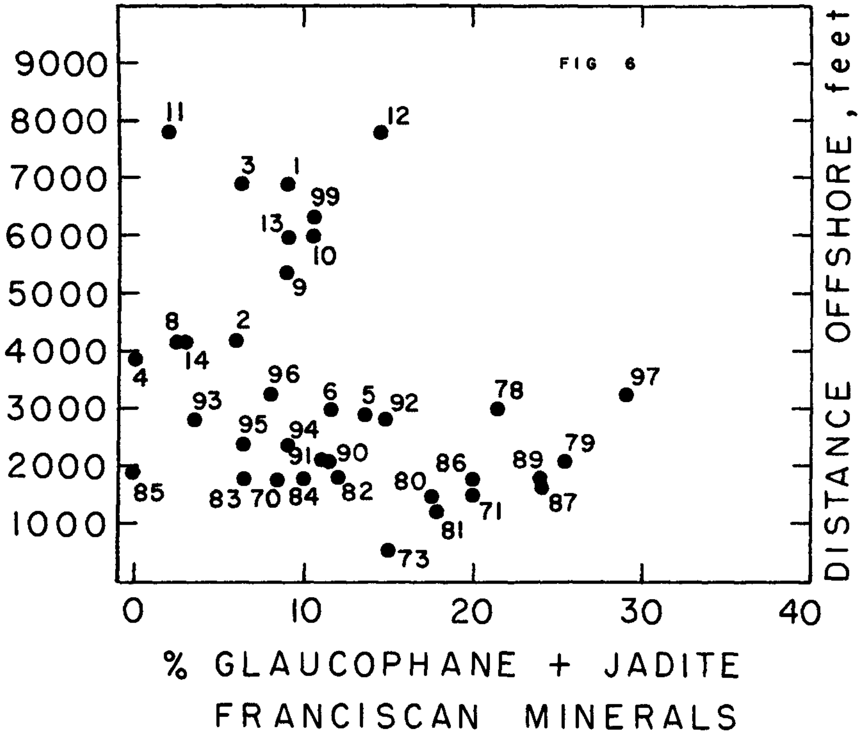


FIG 6
DISTANCE OFFSHORE, feet
% GLAUCOPHANE + JADITE
FRANCISCAN MINERALS
9000
8000
7000
6000
5000
4000
3000
2000
1000
0
10
20
30
40

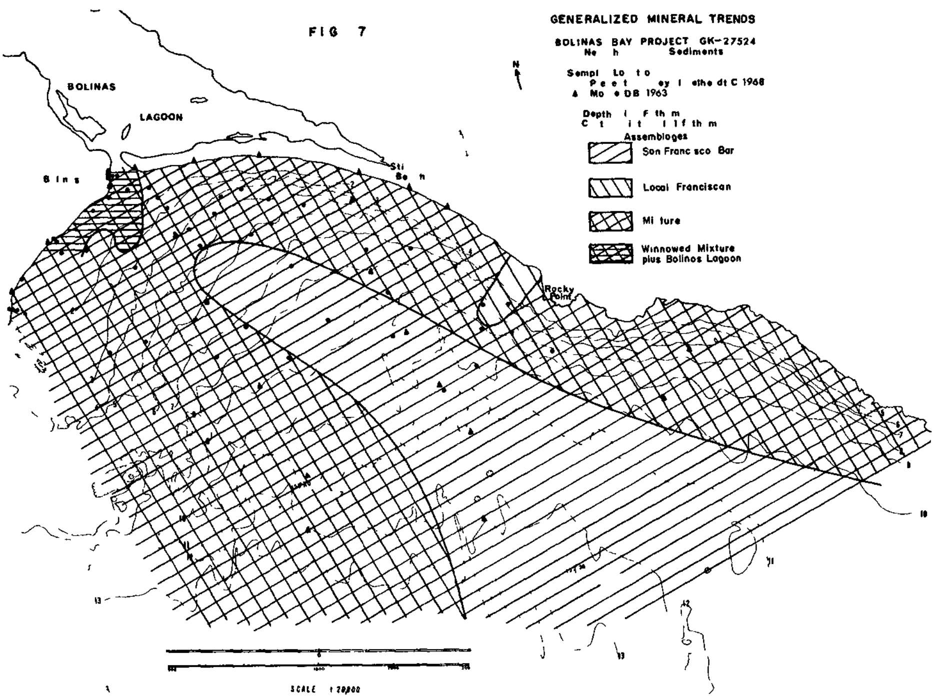


FIG 7
GENERALIZED MINERAL TRENDS
BOLINAS BAY PROJECT GK-27524
Sediments
BOLINAS
LAGOON
Assemblages
San Francisco Bar
Local Franciscan
Winnowed Mixture plus Bolinas Lagoon
Rocky Point

The San Francisco Bar, to the south of Bolinas Bay, contains a very large reservoir of unconsolidated sediment, part of which is brought into Bolinas Bay by tidal currents Sediments of the San Francisco Bar are characterized by higher concentrations of augite and hypersthene than are found in marine sediments to the northwest or south (Moore, 1965) The source of the hypersthene is the volcanic rocks and volcanic sediment of the Central Valley drainage area (Hall, 1965) Part of the sediments in Bolinas Bay are characterized by similar high concentrations of augite and hypersthene and thus are probably derived directly from the San Francisco Bar, carried by the northward flowing Coast Eddy Current (U S Coast Pilot, No 7, 1968, p 152)

The San Francisco Bar is formed of sediment brought to the Pacific through the Golden Gate from the Central Valley drainage area U S Geological Survey estimates (in Homan and Schultz, 1963, p 4) of the sediment entering San Francisco Bay are from 7 2 to 9 6 million cubic yards per year Table 1 shows the rates of sedimentation of San Francisco Bay and Bar for the past 101 years (Homan and Schultz, 1963) With the present rate of sedimentation, 2 9 to 5 3 million cubic yards of sediment per year passes through the bay and off the Bar A portion of this volume must move north into Bolinas Bay by northward flowing currents

The sea cliffs south of Bolinas Bay, between Rocky Point and Point Bonita, are a possible source for sediments in Bolinas Bay However, sediment entering Bolinas Bay from this source would be carried northward by longshore drift,which would be blocked or directed seaward by the irregular shoreline, and its character would be masked by mixing with the San Francisco Bar sediments Duxbury Reef acts as a barrier to sediment movement into the bay from sources north of Bolinas Bay The reef forms a continuous barrier on the sea floor extending about two miles out into the ocean and acts as a baffle which traps sediment, or as a barrier to deflect it to the south The reef completely blocks sediment movement into the shallow part of Bolinas Bay from the coastline to the northwest, and probably keeps it out of the bay entirely Figure 7 shows these mineralogic trends

Sediment Regime

Sediment Sources The data from mineralogical studies presented in this report permit us to distinguish two major and one minor source(s) of sediment for Bolinas Bay A fourth source, of nondiagnostic mineral composition, is known from studies of sea cliff erosion The first source is Bolinas Lagoon, which supplies sediment of a distinctive heavy mineral composition characterized by glaucophane and jadeite Bolinas Bay sediments near the entrance to Bolinas Lagoon are of this composition, and there is a limited eastward dispersal of sediment from this source

The other major source is the unconsolidated sediments of San Francisco Bar, south of Bolinas Bay, characterized by hornblende and hypersthene Sediments derived from this source cover a large area in the southeast and central portions of the bay, in areas of the bay closest to the bar Sediment from the bar enters Bolinas Bay from the southeast, and is mixed with sediment from other sources This sediment is moved into the bay by bottom currents in the deeper parts of the bay, in depths probably of 50-80 feet, where topographic gradients are low This sediment does not enter the bay by longshore drift, and does not enter depths that lie within the regime of the surf zone (approx 0-30 feet)

A third, and minor, source of sediment is Webb Creek near Rocky Point Sediment with a Franciscan glaucophane-jadeite mineral composition enters Bolinas Bay at this place, and is spread a short distance to the north, west, and south of the point The limited and equal distribution of sediment from Webb Creek shows that sediment bypassing around Rocky Point, from either the north or the south, is relatively unimportant As a result, longshore drift on a long term basis is unimportant in sediment movement in the vicinity of Rocky Point This supplies further evidence that sediment transported into Bolinas Bay from the San Francisco Bar enters through the deeper portions of the bay, outside the surf zone

A fourth source of sediment, although indistinguishable by heavy mineral content, is present in the northwest corner of the bay The sea cliffs between the town of Bolinas and Duxbury Reef are rapidly eroding at the present and deliver sediment directly into the bay The relative importance of this source cannot be determined on the basis of heavy mineral data, but estimates of 72,000 cubic yards of erosion per year indicate that this is a major source of sediment

Sediment Transport The sedimentary budget of Bolinas Bay is a function of (1) the volume, size distribution, and entry point of material introduced into the bay, and (2) the volume, size distribution, and exit areas for material leaving the bay Within the bay these sediment fluxes are governed by (3) bottom currents which distribute the sediment, and (4) the bottom configuration which modifies the hydraulic regime causing transportation or deposition of sediment in a given area The above four factors also, at least in part, are time dependent, some seasonal like the volume of stream discharge, or semi-diurnal like tidal fluctuations of the bottom currents However, Johnson (1969) has shown that the changes in bottom configuration are limited to shallow areas near the mouth of the lagoon Therefore, the mineralogic distributions shown in this report probably are valid for the generalized annual picture for the entire bay

Sediment Budget As noted in the section on provenance, the major source of the sedimentary cover is San Francisco Bar Secondary to this is the sediment from Bolinas Lagoon, and of least importance is Webb Creek For the Bolinas Cliffs the rate of retreat of the cliffs is known, and volumes of sediment can be roughly determined

As cited earlier in this report, the Bolinas Cliffs are presently eroding at a rate of 2 3 feet per year Computing the area of cliff face subject to erosion, the resultant sediment yield to the ocean is determined to be approximately 72,000 cubic yards per year

Ritter (1969) made measurements of the amount of sediment transported through the mouth of Bolinas Lagoon for one complete tidal day, a period of 25 hours, on October 24-25, 1967. Most of the sediment was moved during the major ebbtide, and the resultant of all portions of the tidal cycle was a net removal of about 330 tons of sediment from the lagoon for a 25 hour period. Projecting this over a full year, and using a density of 79 pounds per cubic foot, which Ritter (1969) determined to be the average density of sediments in Bolinas Lagoon, the resultant is a sediment yield of about 32,500 cubic yards per year. This figure is used as a minimum value of yearly sediment yield. The measurements were made at the end of the California dry summer season, when sediment yield is low. High sediment yields are associated with periods of high water runoff during the winter, which our calculations do not allow for, although it may be counterbalanced to a small degree by dry summer months with a lower sediment yield. A safe estimate would be an average of about 50,000 cubic yards per year.

No data on the amount of water flow, or suspended sediment content is available for Webb Creek, so an estimate of the sediment yield is made on the basis of the areal distribution of sediments derived from this source in the sediment cover of Bolinas Bay. A rough estimate of between 1,000-10,000 cubic yards per year can be made on this basis. Sediment yield of Webb Creek is augmented by sea cliff erosion of Rocky Point, which may provide as much, or more, sediment as Webb Creek proper. In any event, this source is not a major source of sediment to Bolinas Bay.

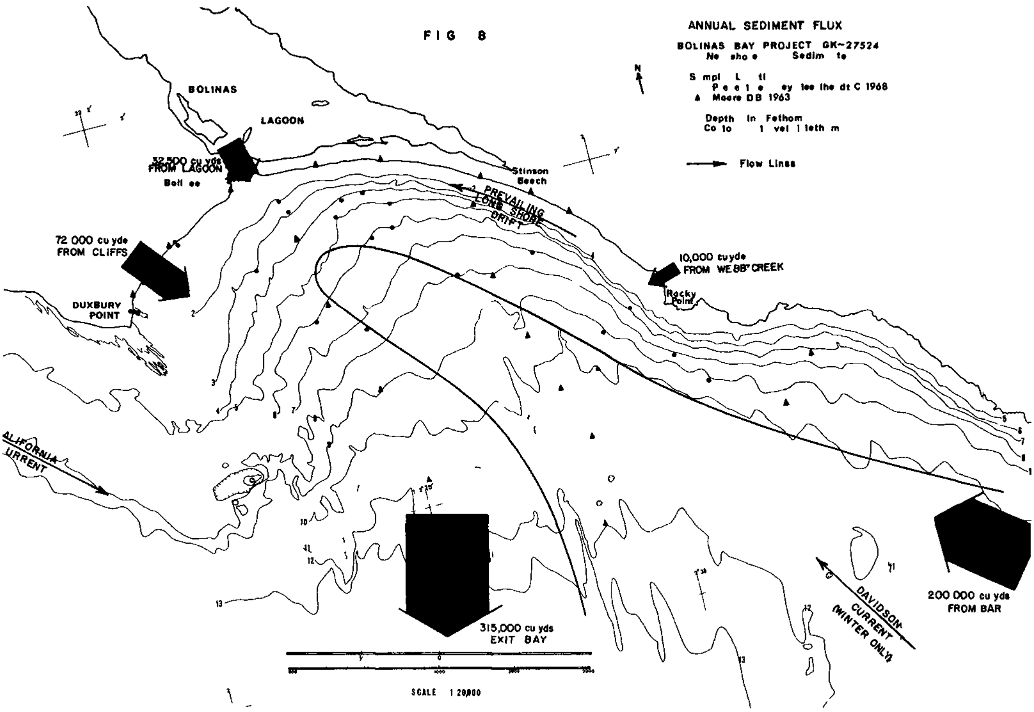
An estimate of the volume of sediment entering Bolinas Bay from San Francisco Bar can be made from the computed volume of sediment passing over San Francisco Bar. Sediment is transported over the bar at a rate of 2.9-5.3 million cubic yards per year. Assuming a fairly even radial dispersal off the bar, about 20% of this total will move towards Bolinas Bay, or about 800,000 cubic yards per year. Assuming that 25% of this amount will actually reach Bolinas Bay, with the remainder moving into deeper water, the resultant total is 200,000 cubic yards of sediment per year. Comparing the relative areal distribution of sediment in Bolinas Bay from each source, with a standard of about 50,000 cubic yards of sediment per year from Bolinas Lagoon, 200,000 cubic yards per year is a reasonable estimate of sediment yield to Bolinas Bay from San Francisco Bar.

Estimates of sedimentary inputs into Bolinas Bay are summarized in Table 1.

Figure 8 shows postulated sediment flux and non-tidal currents for the end of the winter season in Bolinas Bay. As seen in Fig. 7, the orientation of the heavy mineral provinces is not adequately explained by the non-tidal currents in Bolinas Bay. This is particularly true for the lobe of high hornblende-hypersthene emanating from the Potato Patch Shoals of the San Francisco Bar. The influence of the tides in governing the sediment distribution in Bolinas Bay is postulated as a two step process.

Table 1 Estimated Annual Sediment Influx into Bolinas Bay

Source	Volume	Authority
Bolinas Cliffs	72,000 cu yards	rate from Galloway
Bolinas Lagoon	32,500 cu yards	Ritter
Webb Creek	1-10,000 cu yards	this report
San Francisco Bay	200,000 cu yards	estimation Holman & Schutz
TOTAL	314,500	
	315,000 cubic yards/year	



I During flood tide in the lagoon (Fig 9), the flow of water and entrained sediment to the northwest is at a maximum as (a) the Coast Eddy Current, (b) the Davidson Current, (c) longshore drift by wave refraction around Duxbury Reef, all act in consort with the incoming tide in the lagoon Apparently the axis of transport is directed approximately along the 50 foot (8-9 fathom) line as shown by the orientation of the hornblende-hypersthene lobe

II During ebb tide in the lagoon (Fig 10), the outflow from the lagoon combines with or produces the southwest return gyre of the Coast Eddy Current, which is reinforced to the southwest off the tip of Duxbury Reef by the California Current The leading edge of the counterclockwise gyre, (a) entrains material from local sources which mixes with lagoonal material from the ebb tide on the southwest side, but (b) maintains on the inner side of the gyre the compositional integrity of the sediment brought from the San Francisco Bar The gyre thus produces a northwest oriented lobe of San Francisco Bar material surrounded on three sides by sediments from local source areas

The above models are based on an input from various sources of 315,000 cubic yards annually to Bolinas Bay (Table 1) Johnson (1969) has shown that the bottom configuration in deeper water does not change throughout the year Thus, there is no net aggradation-degradation in Bolinas Bay This implies quasi-equilibrium with a balancing outflow of approximately 315,000 cubic yards annually With sediment added along the counterclockwise gyre (a) from the southeast from the San Francisco Bar, (b) from the northeast from Webb Creek, and (c) from the northwest from the lagoon and cliff erosion, the logical exit is to the southwest to deeper water on the shelf This is indicated on the bathymetry map by (1) the steep seaward gradients in the channel adjacent to Duxbury Reef, and (2) two small channels emptying into the embayment which separates the bay from Potato Patch Shoals

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FIG 9

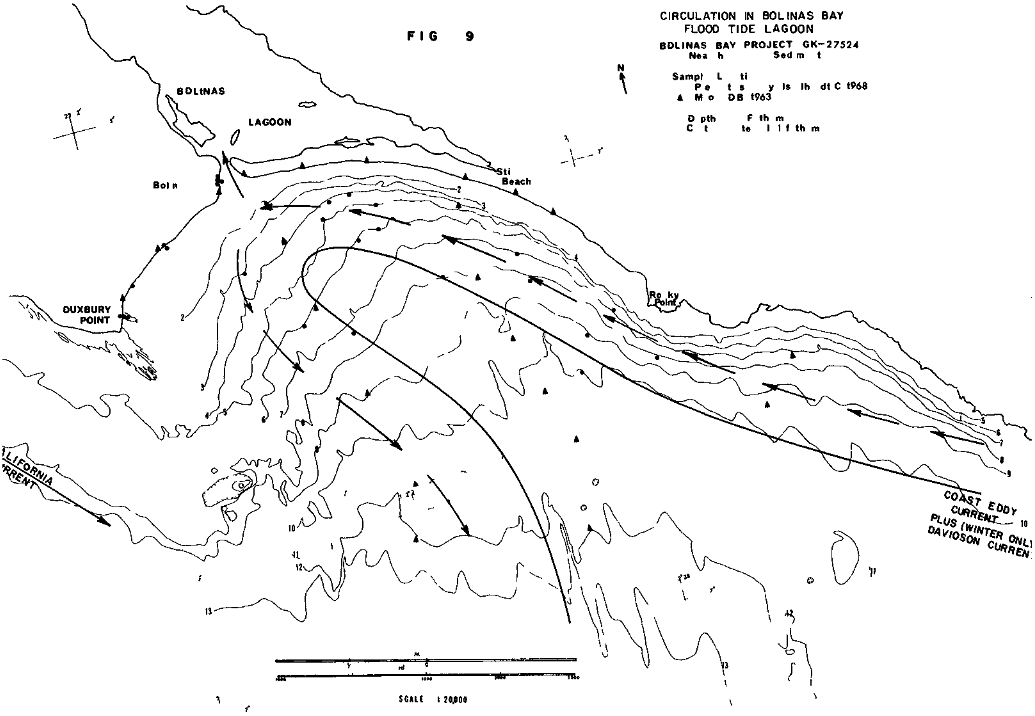
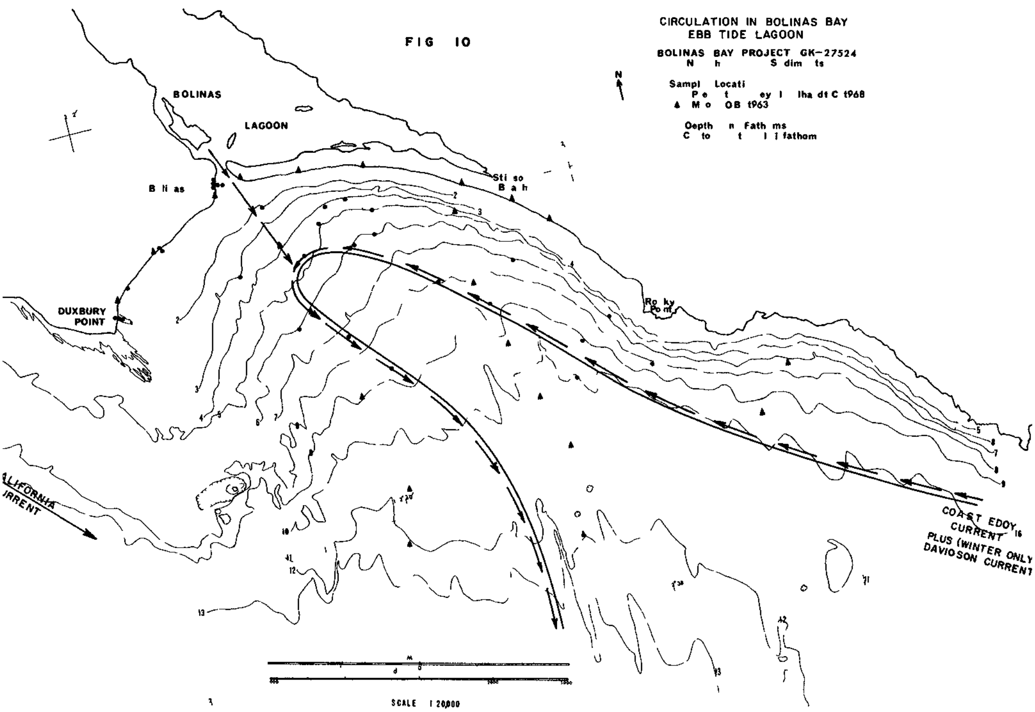

CIRCULATION IN BOLINAS BAY
FLOOD TIDE LAGOON
BDLINAS BAY PROJECT GK-27524
N
BDLtNAS
LAGOON
Beach
DUXBURY
POINT
COAST EDDY
CURRENT
PLUS (WINTER ONLY)
DAVIOSON CURREN
SCALE 1 20,000

FIG 10


CIRCULATION IN BOLINAS BAY
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BOLINAS
LAGOON
DUXBURY
POINT
COAST EDDY
CURRENT
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DAVIOSON CURRENT
SCALE 1 20,000

References

Bailey, E H , Irwin, W P , and Jones, D L , 1964, Franciscan and related rocks, and their significance in the geology of western California Calif Div Mines and Geology Bull 183, 177 p

Brown and Caldwell, 1967, Interim report on the Bolinas watershed Brown and Caldwell Consulting Engineers

Cherry, J A , 1964, Sand movement along a portion of the northern California coast Univ of Calif , Inst of Eng Res Tech Report Series HEL-4-3, 150 p

Cherry, J A , 1966, Sand movement along equilibrium beaches north of San Francisco Jour of Sed Petrology, v 36, no 2, p 341-357

Galloway, A J , 1966, Geology of Northern California Calif Div Mines, Bull 190, p 429-440

Gluskoter, H J , 1962, Geology of a portion of western Marin County, Calif unpub Ph D thesis, Univ of Calif , Berkeley, 184 p

Gluskoter, H J , 1969, Geology of a portion of western Marin County, Calif Calif Div Mines and Geology, Map Sheet 11

Hall, N T , 1965, Petrology of the type Merced Group, San Francisco Peninsula, California Univ of Calif , Berkeley, unpublished M A thesis, Geology, 127 p

Hendricks, H L , ed , Compilation of records of surface waters of the United States, October 1950 to September 1960, part 11, Pacific slope basins in California U S Geol Survey Water-Supply Paper 1735, 715 p

Homan, W J , and Schultz, E A , 1963, Model tests of shoaling and of dredge spoil disposal in San Francisco Bay Jackson, Miss , Federal Interagency Sedimentation Conf , 30 p

Isselhardt, C , Osuch, L , and Wilde, P , 1968, Recent sediments of Bolinas Bay, Calif , Part A Introduction and grain size analysis, Univ of Calif , Hydraulic Engineering Lab , Tech Rept HEL-2-19, 55 p

Isselhardt, C , Osuch, L , Yancey, T , and Wilde, P , 1969, Recent sediments of Bolinas Bay, Calif , Part B Mineralogical data Univ of Calif , Hydraulic Engineering Lab , Tech Rept HEL-2-22, 155 p

Johnson, J W , 1969, Stabilization of the Bolinas Lagoon Inlet Report to Bolinas Harbor District, 40 p

Minard, C R , 1964, The erosional and depositional history of the coast of northern California Univ of Calif , Inst of Engineering Research, Tech Rept HEL-2-10, 63 p

Moore, D B , 1965, Recent coastal sediments Double Point to Point San Pedro, Calif Univ of Calif , Hydraulic Engineering Lab , Tech Rept HEL-2-14, 86 p

Reid, J L , Roden, G I , and Wyllie, J G , 1958, Studies of the California current system Calif Co-op Ocean Fish Invest Progress Reports 1 July 1956 - 1 January 1958, p 27-56

Reid, J L , and Schwartzlose, R A , 1962, Direct measurement of the Davidson Current off central California Jour Geophysical Research, v 67, p 2491-2497

Ritter, J R , 1969, Preliminary studies of sedimentation and hydrology in Bolinas Lagoon, Marin County, Calif , May 1967-June 1968 U S Geol Survey Open File Report, Menlo Park, 68 p

U S Coast and Geodetic Survey, 1947, Tide Chart, San Francisco Bay

U S Coast and Geodetic Survey, 1968, United States Coast Pilot 7, Pacific Coast, Calif , Oregon, Washington, and Hawaii, Fenth-edition, 380 p

U S Hydrographic Office, 1947, Atlas of surface currents, north-eastern Pacific Ocean

Weaver, C E , 1949, Geology of the Coast Ranges immediately north of the San Francisco Bay region, Calif Geol Soc of America Memoir 35, 242 p

Wilde, P , Isselhardt, C , Osuch, L , and Yancey, T , 1969, Recent Sediments of Bolinas Bay, Part C, Interpretation and Summary of Results Univ of Calif , Hydraulic Engineering Research Lab , Tech Rept HEL-2-23, 86 p

Yancey, T E , 1968, Recent sediments of Monterey Bay, Calif Univ of Calif , Hydraulic Engineering Lab , Tech Rept HEL-2-18, 145 p