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MEASURED SECTIONS OF PALEOGENE ROCKS FROM THE CALIFORNIA COAST RANGES

By

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This report is preliminary and has not been edited or reviewed for conformity with Geological Survey standards and nomenclature

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MEASURED SECTIONS OF PALEOGENE ROCKS FROM THE CALIFORNIA COAST RANGES

By E. E. Brabb, J. C. Clark and C. K. Throckmorton

INTRODUCTION

The short-term purpose of this report is to provide the geologic and geographic framework for a series of field trips and a symposium on the California Paleogene to be held in Menlo Park, California, October 23-29, 1977, under the auspices of the International Commission on Paleogene Stratigraphy (ICPS). The long-term purpose is to facilitate the correlation of California Paleogene sequences with those in the classic and type areas of western Europe.

The report was conceived in 1968 during a series of field trips held in France, Italy, Belgium, and England as a part of an Eocene Colloquium organized by Professor Ch. Pomerol of the University of Paris, currently Chairman of the ICPS. The great success of these field trips in facilitating exchanges of ideas about the concepts of stratotypes and in correlating sequences from one region to another (see summary by Brabb, 1969) led to subsequent field trips and meetings on the Oligocene in Germany (1969) and the Caribbean region (1973) and the proposal to meet in California during 1977 and in the Soviet Union in 1978.

Ideally, the Paleogene sections selected for study should record continuous deposition from Late Cretaceous to early Miocene time; they should be reasonably accessible and well exposed; they should contain an association of different fossil groups that are useful for intercontinental correlation, such as planktonic foraminifers and nannoplankton; they should contain some of the fossil groups that have proven useful for local correlation, such as mollusks, echinoids, and benthonic foraminifers; and they should be in an area where the structure is reasonably simple.

Accordingly, the senior author in 1974 began a search for sections in California (fig. 1) that would fulfill most, if not all, of the above-mentioned requirements. This search is still continuing, because no perfect sections have been found, but the sections described in this report provide collectively a first approximation of an ideal California Paleogene sequence. Hopefully, additional work in the years ahead will fill gaps in our knowledge about the evolution of the different fossil groups and about the correlation of provincial chronologies with those in other areas of the world.

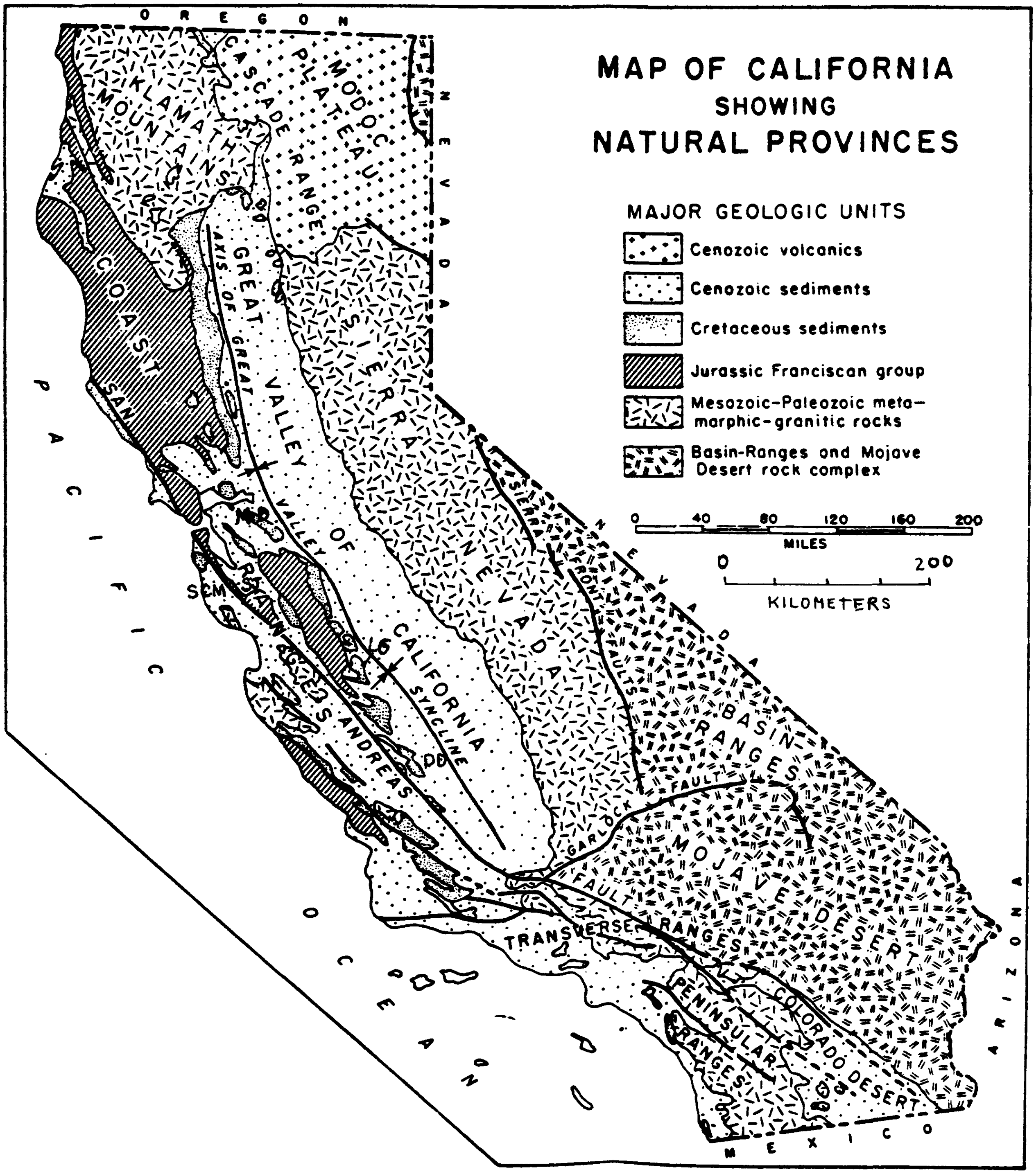
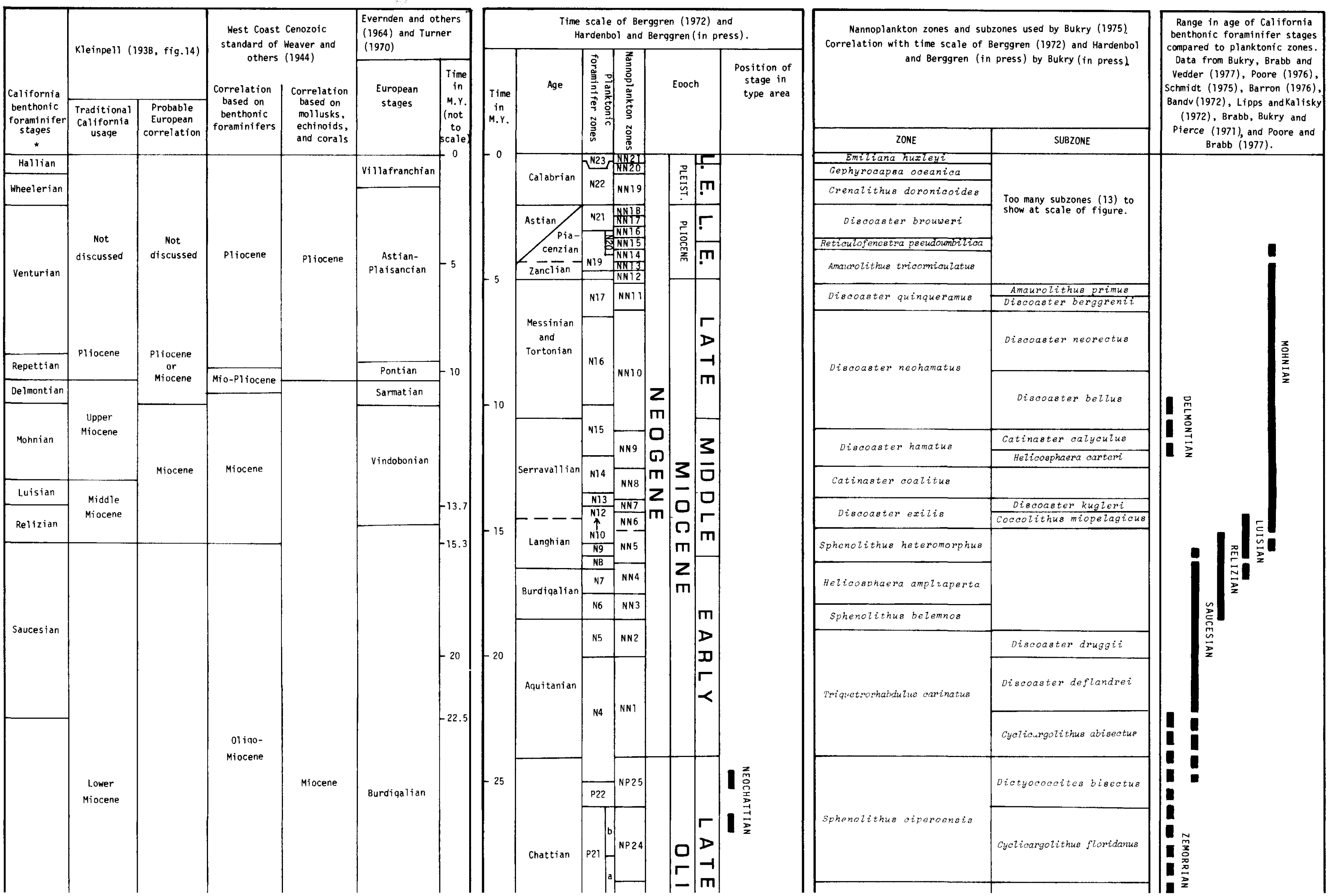


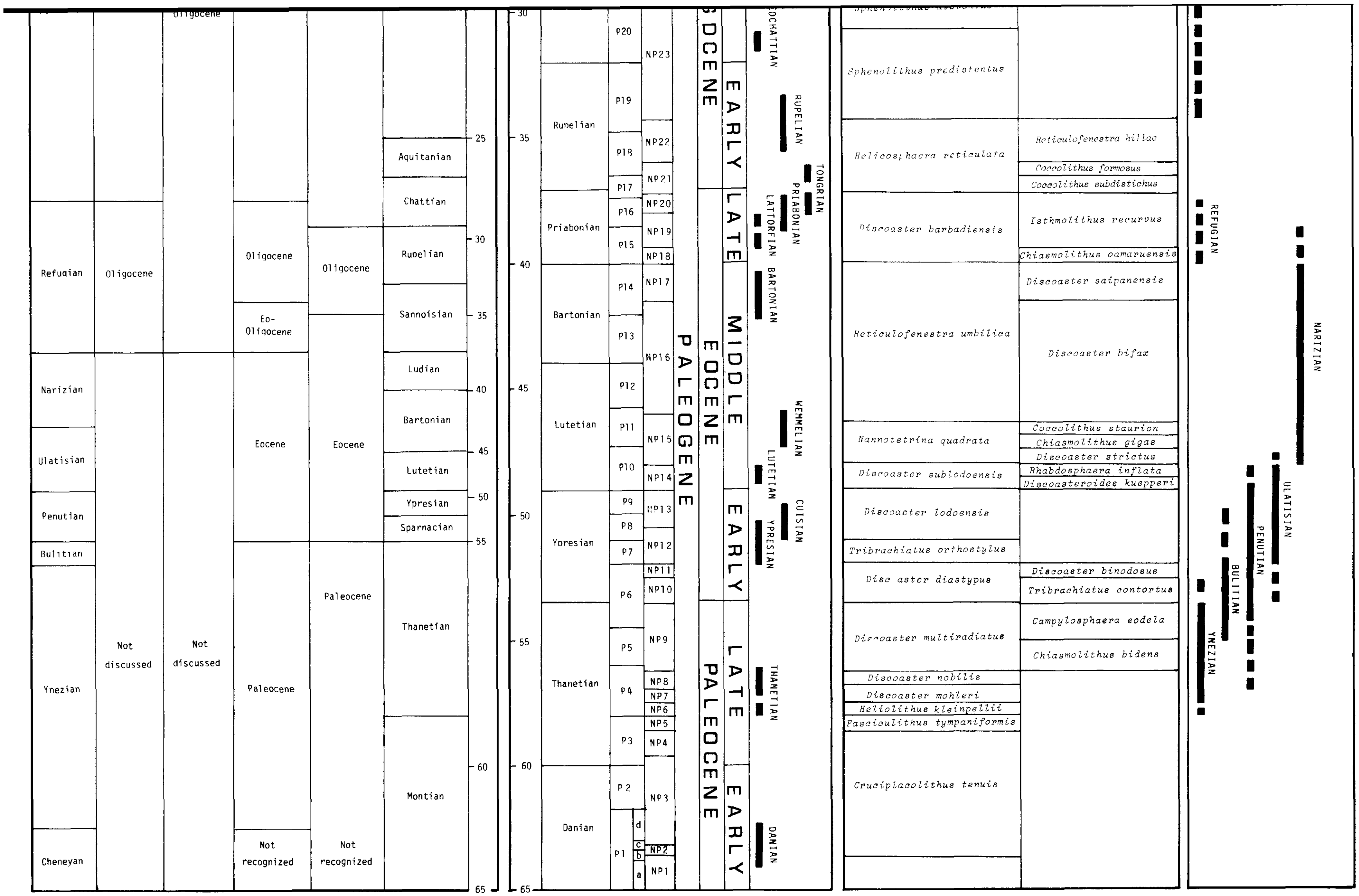
Figure 1.--Natural provinces of California and major geologic units (from Hinds, 1952). MD = Mount Diablo; SJ = San Jose; SCM = Santa Cruz Mountains; LG = Lodo Gulch; DD = Devils Den

Previous Work

The correlation of California rocks of Paleogene age with those in Europe has a long and complex history that can only be highlighted here. Kleinpell (1938, p. 168-181), in his classic work defining the Miocene benthonic foraminiferal stages of California, attempted to correlate the California faunas with those of western European sections and elsewhere. He pointed out that rocks considered traditionally as Lower Miocene in California are probably correlative with those considered Oligocene in Europe ((fig. 2). The correlation of the Refugian Stage with the Oligocene is still practiced by some oil company micropaleontologists; see, for example, the report by the International Oil Scouts Association (1973, p. 32). Schenck and Childs (1942) correlated the Saucesian Stage and the Vaqueros Formation with the Middle and Upper Oligocene of Europe and elsewhere, based on the stratigraphic occurrence of Lepidocyclina. Their correlation was discussed extensively by a number of paleontologists in the same report, some favoring a Miocene age based on similarities of the Vaqueros molluscan fauna with the Burdigalian faunas of Europe, and on the apparent "Miocene" age of vertebrates from beds below the Vaqueros, whereas others argued that some of the Vaqueros mollusks were similar to those of "Oligocene" age in Trinidad, and that the percent of living mollusks in the Vaqueros (1-2%) is most similar to faunas of "Oligocene" age. These differences in opinion proved to be irreconcilable in the attempt by the U.S. Committee on Stratigraphy to provide a standard correlation chart for marine Cenozoic formations of western North America (Weaver, and others, 1944). Two standards had to be provided, one based largely on species of mollusks, echinoids and corals, and the other on benthonic foraminifers. The present correlation of these separate standards with the European series is shown on figure 2. These correlations were modified somewhat by Turner (1970) and were used by Berggren (1972) and Hardenbol and Berggren (in press) to correlate with planktonic foraminifer and nannoplankton zones shown on figure 2.

The validity of some California Tertiary stages based largely on benthonic foraminifers has been questioned in recent years. Pierce (1972) and Barron (1976) believe that the Delmontian Stage of Kleinpell (1938) is coeval with the lower and middle part of the Mohnian Stage. Steineck and Gibson (1971), Gibson and Steineck (1972), Schmidt (1975), Bandy (1972) and Bukry and others (1977) believe that probably all of the California Eocene and Paleocene stages of Mallory (1959) are time-transgressive when compared to nannoplankton and planktonic foraminifer zonations. Hornaday and Philips (1972), on the other hand, challenge most of these opinions.


California benthonic foraminifer stages *
Hallian
Wheelerian
Venturian
Repettian
Delmontian
Mohnian
Luisian
Relizian
Saucesian
Kleinpell (1938, fig.14)
Traditional California usage
Not discussed
Pliocene
Upper Miocene
Middle Miocene
Lower Miocene
Probable European correlation
Not discussed
Pliocene or Miocene
Miocene
West Coast Cenozoic standard of Weaver and others (1944)
Correlation based on benthonic foraminifers
Pliocene
Mio-Pliocene
Miocene
Oligo-Miocene
Correlation based on mollusks, echinoids, and corals
Pliocene
Miocene
Evernden and others (1964) and Turner (1970)
European stages
Villafranchian
Astian-Plaisancian
Pontian
Sarmatian
Vindobonian
Burdigalian
Time in M.Y. (not to scale)
0
5
10
13.7
15.3
20
22.5
Time scale of Berggren (1972) and Hardenbol and Berggren (in press).
Time in M.Y.
0
5
10
15
20
25
Age
Calabrian
Astian
Pia-cenzian
Zanclian
Messinian and Tortonian
Serravallian
Langhian
Burdigalian
Aquitanian
Chattian
Planktonic foraminifer zones
N23
N22
N21
N20
N19
N17
N16
N15
N14
N13
N12
N10
N9
N8
N7
N6
N5
N4
P22
P21
b
a
Nannoplankton zones
NN21
NN20
NN19
NN18
NN17
NN16
NN15
NN14
NN13
NN12
NN11
NN10
NN9
NN8
NN7
NN6
NN5
NN4
NN3
NN2
NN1
NP25
NP24
Epoch
NEOGENE
PLEIST.
PLIOCENE
MIOCENE
OLI
L.
E.
L.
E.
LATE
MIDDLE
EARLY
LATE
Position of stage in type area
NEOCHATTIAN
Nannoplankton zones and subzones used by Bukry (1975). Correlation with time scale of Berggren (1972) and Hardenbol and Berggren (in press) by Bukry (in press).
ZONE
Emiliana huxleyi
Gephyrocapsa oceanica
Crenalithus doronicoides
Discoaster brouweri
Reticulofenestra pseudoumbilica
Amaurolithus tricorniculatus
Discoaster quinqueramus
Discoaster neohamatus
Discoaster hamatus
Catinaster coalitus
Discoaster exilis
Sphenolithus heteromorphus
Helicosphaera ampliaperta
Sphenolithus belemnos
Triquetrorhabdulus carinatus
Sphenolithus ciperoensis
SUBZONE
Too many subzones (13) to show at scale of figure.
Amaurolithus primus
Discoaster berggrenii
Discoaster neorectus
Discoaster bellus
Catinaster calyculus
Helicosphaera carteri
Discoaster kugleri
Coccolithus miopelagicus
Discoaster druggii
Discoaster deflandrei
Cyclicargolithus abisectus
Dictyococcites bisectus
Cyclicargolithus floridanus
Range in age of California benthonic foraminifer stages compared to planktonic zones. Data from Bukry, Brabb and Vedder (1977), Poore (1976), Schmidt (1975), Barron (1976), Bandy (1972), Lipps and Kalisky (1972), Brabb, Bukry and Pierce (1971), and Poore and Brabb (1977).
MOHNIAN
DELMONTIAN
LUISIAN
RELIZIAN
SAUCESIAN
ZEMORRIAN



* As defined by Schenck and Kleinpell (1936); Kleinpell (1938); Goudkoff (1945); Natland (1953); and Mallory (1959). Correlated to planktonic foraminifer and nannoplankton zones by Berggren (1972).

Figure 2.--Correlation chart showing relation between California benthonic foraminifer stages and planktonic zones, and different correlations with European series

Present Investigation

The time is opportune, therefore, for a systematic new look at the validity and correlation of California Tertiary biostratigraphic units. This report and the paleontologic reports that will follow concentrate on the Paleogene. Ideally, the type sections for each of the Paleogene benthonic foraminiferal stages should have been included, but the task proved to be immense and several unanticipated problems were encountered. For instance, there does not seem to be a surface section for the Narizian Stage of Mallory (1959) in its type locality. Instead, several sections representative of deep marine deposition with benthonic foraminifers, planktonic foraminifers, and nannoplankton were measured, and their faunas and floras distributed to paleontologists for study. Their reports will constitute the conference part of the ICPS field meeting in October 1977.

Acknowledgements

Richard Z. Poore has been especially helpful in assembling and reviewing the correlation chart (fig. 2) in determining the abundance of the various microfossil assemblages in several sections, in directing the processing of many of these assemblages, and in offering advice about the most appropriate faunas to collect on the October field trips. Kristin McDougall kindly provided data on the age of some of the benthonic foraminifers. The authors also wish to thank William S. Brabb, James R. LeCompte, Steven W. Moore, Robert L. McCollom, Jr., and Bette R. Hamachi for helping to measure the sections. We are also indebted to Robert M. Kleinpell and A. D. Warren for examining critical Saucesian and Relizian faunas from near Año Nuevo Point. A. D. Warren also provided information on the structure and fossils in the Devils Den area.

REGIONAL SETTING

The Paleogene sections described in this report are in the California Coast Ranges (fig. 1). Most are from areas west of the San Andreas fault in the Santa Cruz Mountains of west-central California--a few are from areas east of the San Andreas fault from Mount Diablo to Devils Den. The Paleogene rocks west of the San Andreas fault rest either directly on crystalline metasedimentary and granitic rocks of the Salinian block or on sedimentary strata of Late Cretaceous age. East of the San Andreas fault, the Paleogene rocks commonly rest on Jurassic and Cretaceous strata of the Great Valley sequence, which in turn are faulted against a complex tectonic assemblage of

Mesozoic sedimentary metamorphic, igneous, and volcanic rocks that is commonly referred to by petroleum geologists as "Franciscan basement." The relation of "Franciscan basement" rocks to the granitic basement rocks along which they are juxtaposed by the San Andreas fault has long been one of the most intriguing and complex problems of California geology. A series of lectures edited by Nilsen (1977) gives a synopsis of the problems and some working hypotheses for the tectonic evolution of California during Mesozoic and Cenozoic time. The most significant concept for the purpose of this report is that the San Andreas and other strike-slip faults have displaced the Paleogene sequences hundreds of kilometers with respect to each other. The Santa Cruz Mountains, for example, are thought by Nilsen and Clarke (1975) to have been opposite the Devils Den area, 250 km to the south, during the early Tertiary.

The paleogeography of central California during the Paleogene is not well established. Most published analyses are not based on a firm biostratigraphic framework, so that rocks of middle Eocene age in one area may be compared with rocks of late Eocene age in another. There is also a problem with displacement of the Paleogene sequences along secondary lateral faults. Although extensive lateral displacement along the San Andreas has been considered since the classic report by Hill and Dibblee (1953), many new lateral faults have been discovered that make paleogeographic reconstructions more complex. Nevertheless, much progress has been made, especially by a few geologists who have atempted to apply modern sedimentary concepts to understanding Paleogene depositional patterns. Nilsen (1977) and Dibblee (1977) provided extensive bibliographies listing many of these studies, and they also provided the synthesis that is summarized below.

A generalized paleogeographic map of early Tertiary California based on about 300 km of late Cenozoic right-lateral slip is shown on figure 3. The area between Devils Den and Mount Diablo was characterized by uplands in the Sierra Nevada, a linear basin in the area of the Great Valley in which a westward-thickening sequence of marine strata was deposited, islands on the continental borderland that contributed sediments in local areas, and a trench and subduction zone in what is now the Pacific Ocean. The La Honda basin, where all the field trips will take place, was on the continental borderland, mostly at lower bathyal and abyssal depths with open connections to the ocean.

The present location of the Garlock fault and the following geographic features are include for orientation purposes: SAC = Sacramento; SF = San Francisco; BAK = Bakerfield; Mon = Monterey; LA = Los Angele SD = San Diego; DD = Devils Den LG = Lodo Gulch; MD = Mount Diablo; SJ = San Jose; SCM = Santa Cruz Mountains.

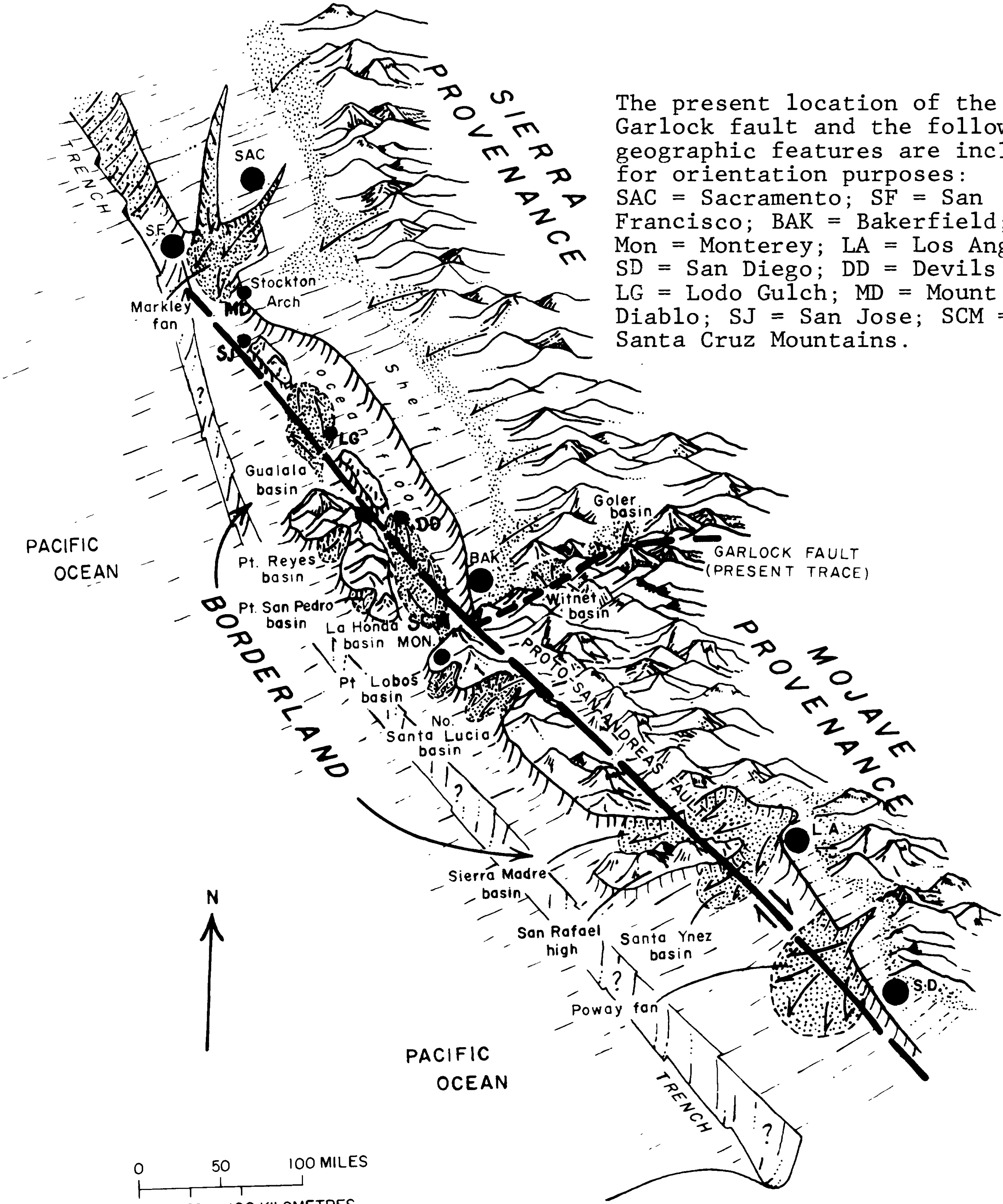


Figure 3.--Generalized paleogeographic map of early Tertiary California, based on reversal of 190 miles (305 km) of late Cenozoic right-lateral slip along the modern San Andreas fault (from Nilsen and Clarke, 1975).

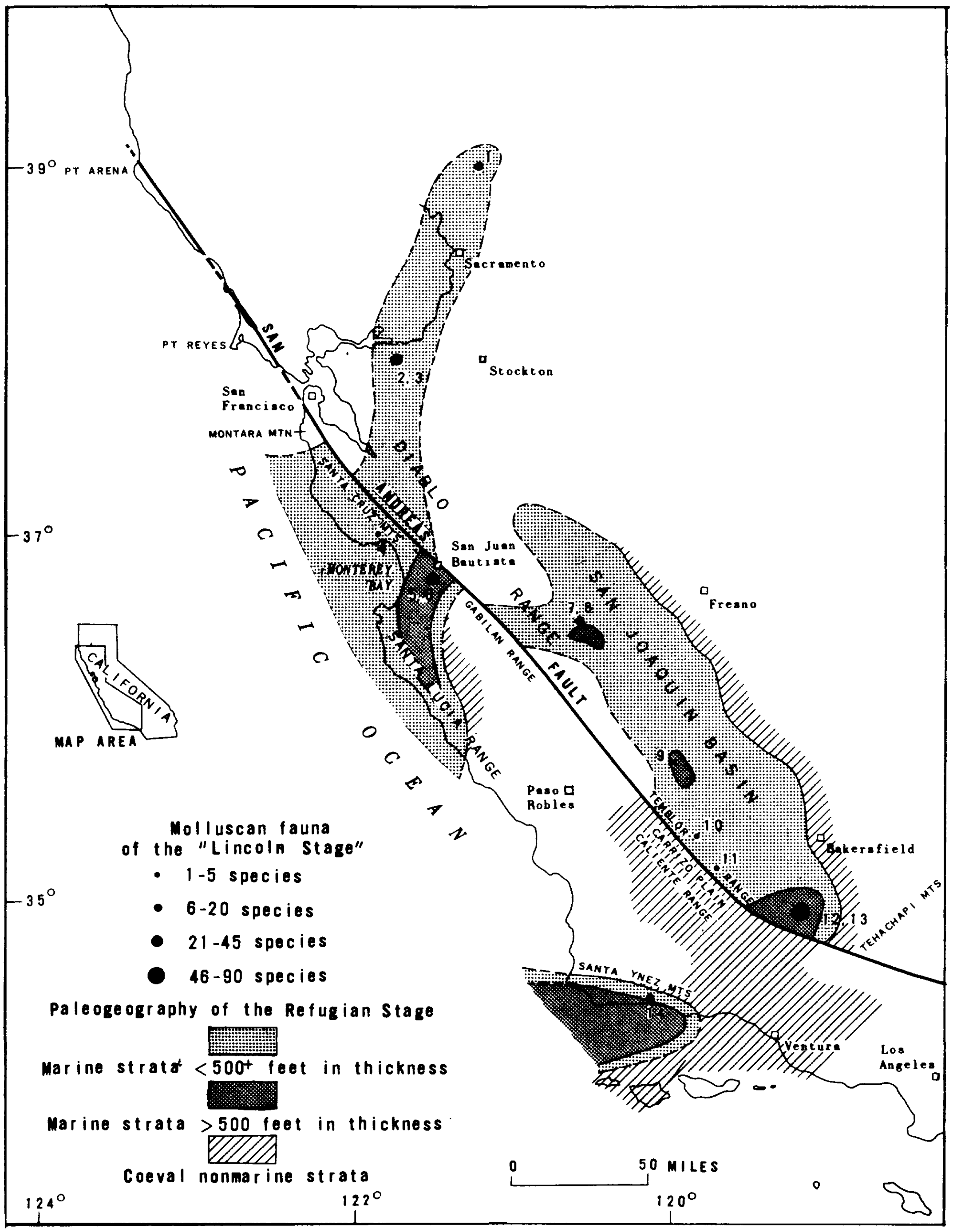


Figure 4.--Index map of California showing generalized Refugian Stage paleogeography and principal occurrences of molluscan assemblages. From Addicott (1968, fig. 2).

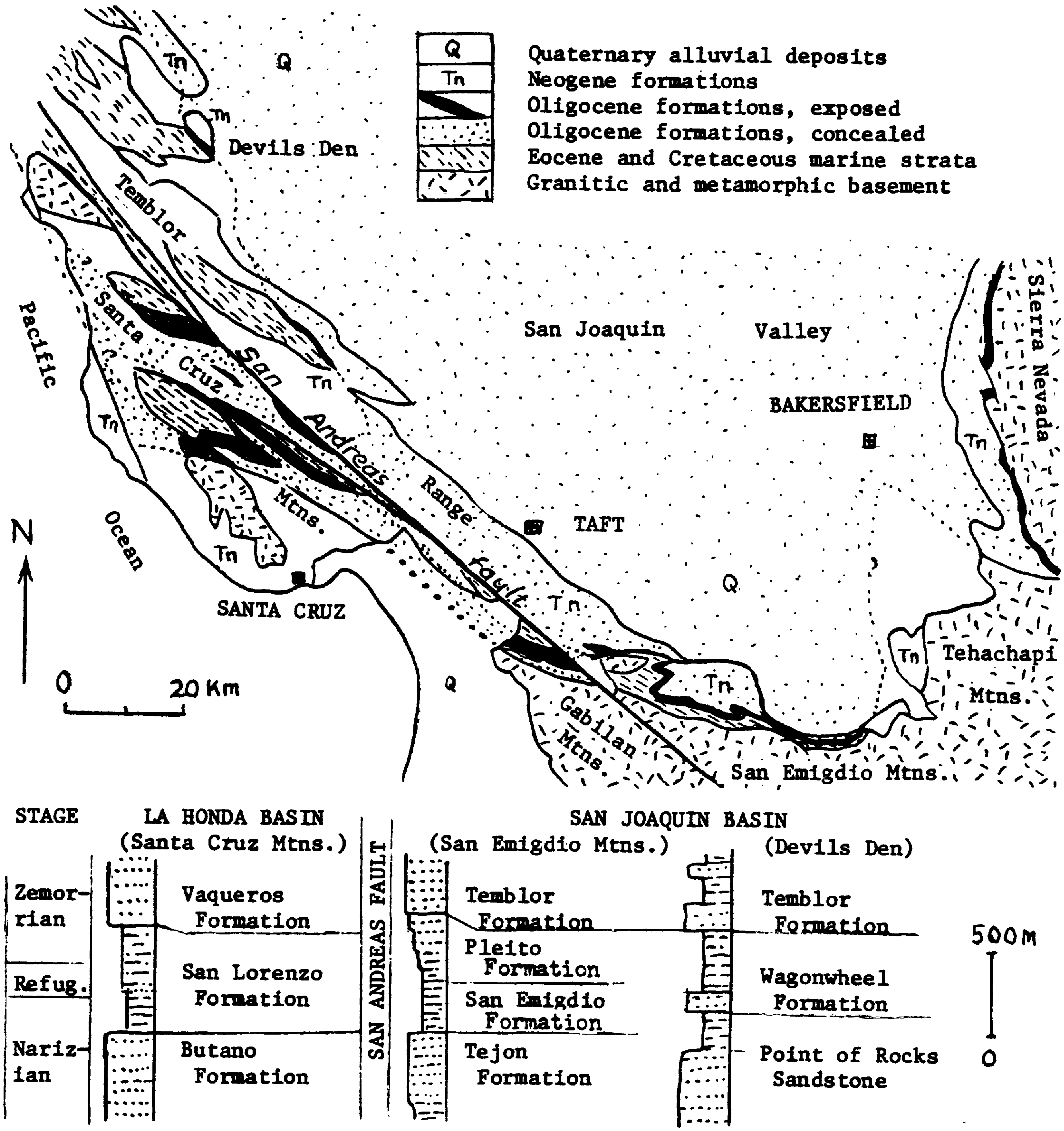


Figure 5.--Palinspastic map showing Oligocene (Refugian-early Zemorrian Stages) and adjacent formations of the La Honda sedimentary basin of Santa Cruz Mountains and of the San Joaquin basin, in inferred original relative positions, prior to about 280 km of post-Oligocene right-slip displacement on the San Andreas fault. Also shown are the nomenclature and stratigraphic positions of the Oligocene units of each area. From Dibblee (1977, fig. 8-6).

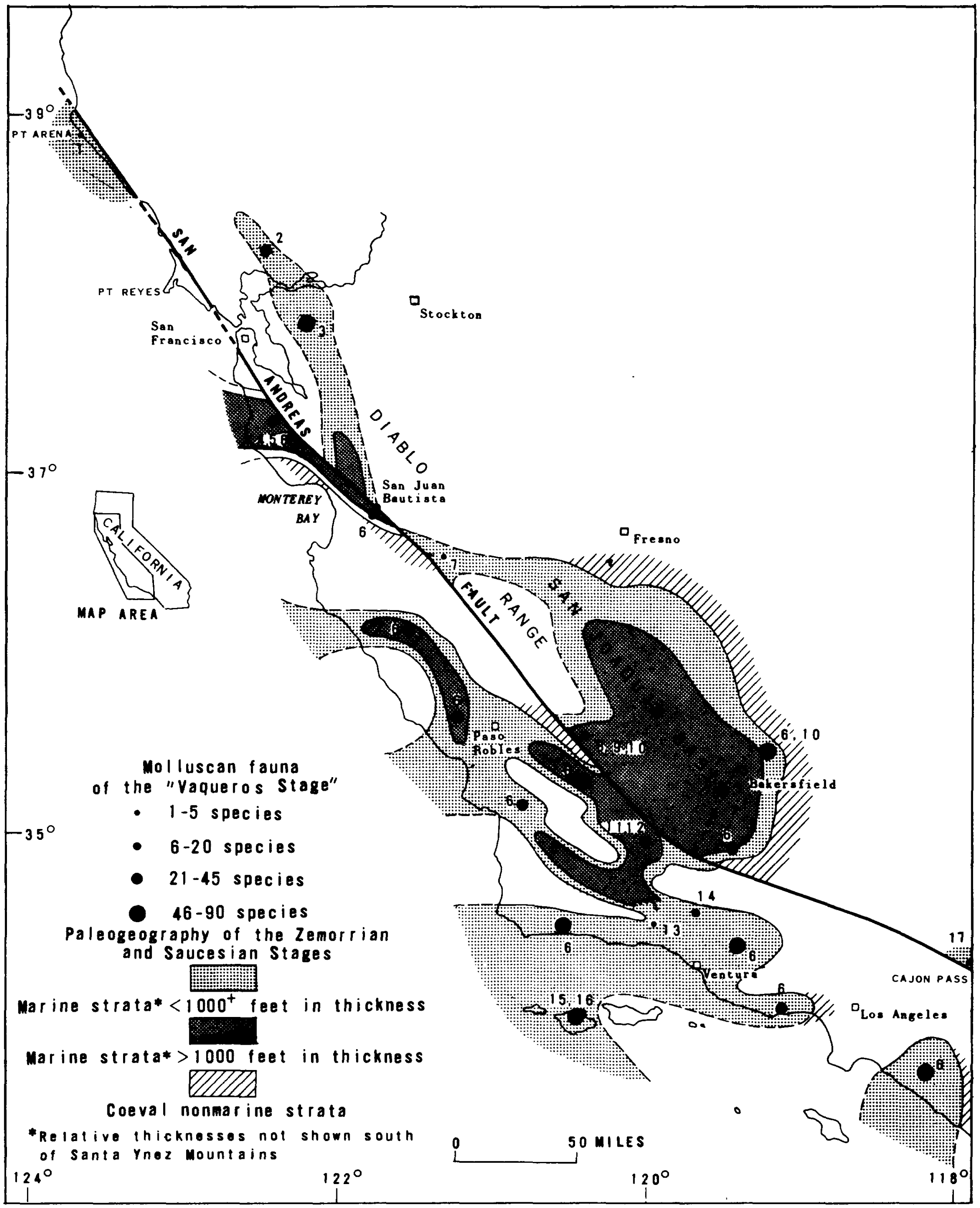


Figure 6.--Index map of California showing generalized Zemorrian and Saucesian Stages paleogeography and principal occurrences of molluscan assemblages. From Addicott (1968, fig. 3).

The Oligocene Epoch was characterized by major changes in California tectonics and paleogeography. Significant dip-slip displacement along several major faults produced widespread emergence of the Salinian block and the deposition in down-dropped blocks of hundreds of meters of nonmarine clastic sediments. Volcanism was extensive. Marine conditions continued in the La Honda basin with the deposition of mud that now forms the San Lorenzo Formation and Lambert Shale, which was interrupted by the local extrusion of as much as 700m of volcanic rocks (Mindego Basalt) and the northerly influx of arkosic sand and conglomerate that now form the Vaqueros Sandstone and Zayante Sandstone. Some paleogeographic reconstructions during the Oligocene are shown on figures 4, 5, and 6.

DESCRIPTION OF THE SECTIONS

Most of the sections described in this report are shown on the geologic map, figure 7. A composite geologic column for the sections in the Santa Cruz Mountains between the San Andreas and San Gregorio faults is shown on figure 8. Additional geologic and geographic maps and other information about the sections are provided in the individual description of each section. The field trip route is not shown on any map because it will likely change according to weather, tide height, and other access problems.

Exposures along the creek and river sections vary considerably from year to year depending primarily on rainfall. Most sections were best exposed after the 1955 flood waters had moved enormous quantities of gravel, sand and silt into the sea. Since then, construction and logging activities upstream and less runoff from the winter rain storms have resulted in the deposition of considerable sediment and the covering of bedrock exposures.

The availability of fresh rock exposures in the river and creek bed beneath the water may determine the relative chances of obtaining calcareous foraminifers. The tests of the calcareous foraminifers seem to be weakened or entirely dissolved by circulating ground water along the river and creek banks, whereas rocks collected beneath the summer water level have yielded well-preserved assemblages.

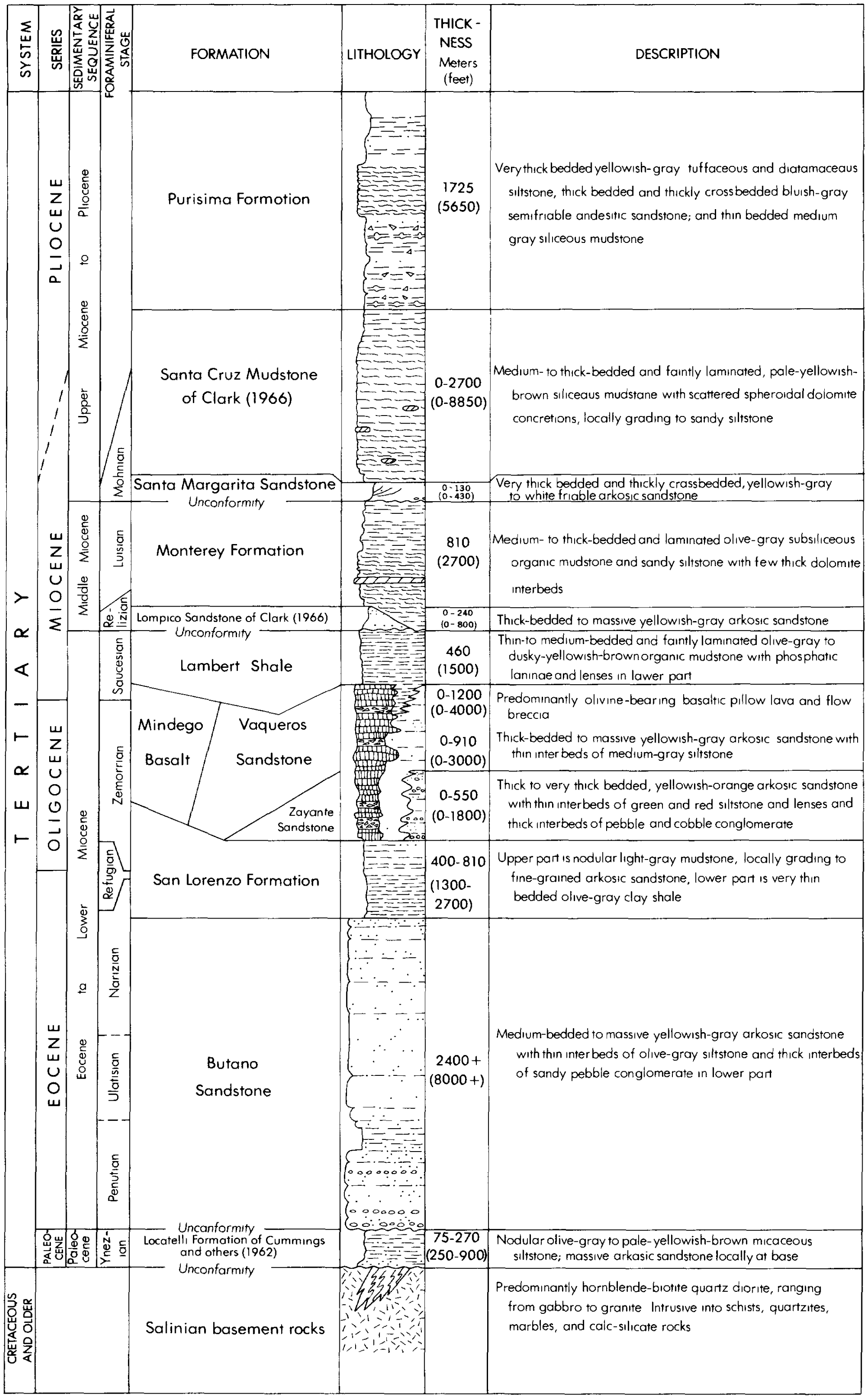


Figure 8.--Composite stratigraphic column for the area between the San Andreas and San Gregorio faults

The distribution of the foraminifers is also uneven. They seem to be concentrated in laminae or thin beds, and sparse or absent in similar rocks nearby. They are generally less abundant in sandstones and siltstones compared to claystones. Several hours of careful searching with a hand lens may be required to find the same foraminifer-bearing bed shown on the various stratigraphic columns. To help geologists find the exact bed, metal tags were put on the rock at many localities. Unfortunately, the tags do not seem to last long in populated areas.

The sections are reasonably accessible, unless otherwise noted. Permission to cross private property can usually be obtained from residents in the area. There are generally no problems taking small samples for microfossil analyses except in State parks and nature preserves, such as in the Año Nuevo area, where no samples can be collected without a permit.

GLAUCONITE

The upper and lower boundaries of the Refugian Stage are marked by glauconitic sandstones. In Little Boulder Creek, the basal 30 cm (1 foot) of the Refugian Stage (the basal 30 cm of the Rices Sandstone Member of the San Lorenzo Formation) is 90 percent glauconite. The glauconite was bright green in outcrop before it was covered by material caved in from the stream bank. The other 10 percent of the rock consists of well-rounded quartz and feldspar grains and abraded fish teeth.

About 2.3 km southeast of Little Boulder Creek, in an unnamed tributary of Pescadero Creek, the glauconite-rich basal bed of the Refugian Stage is about 15 cm (6 inches) thick. Some of the glauconite is in ovoid tubes, presumably worm burrows, that extend several centimeters into the underlying Twobar Shale Member.

At other localities the glauconite is not as abundant in the basal bed, but it generally comprises at least 5 percent of the basal sandstone. The glauconitic sandstone marks not only the base of the Refugian Stage but also the contact between the laminated shales characteristic of the Twobar Shale Member and the more massive and spheroided weathering mudstones and siltstones characteristic of Rices Mudstone Member. It also marks a change from open-sea faunas represented predominantly by the Buliminids, Globigerinids, robust arenaceous foraminifers, and a few thin-shelled mud pectens to assemblages in the Rices Mudstone Member dominated by Lagenids Anomalinids, and more abundant and more robust mollusks like _Bruclarkia_, _Priscofusus_, and _Modiolus_. As mentioned by Brabb (1964, p. 677), these changes suggest significant tectonic adjustments requiring considerable time. The glauconinte, therefore, may indicate a stratigraphic break or disconformity.

The glauconitic sandstone at the base of the Zemorrian Stage contains phosphatic pellets that are 1-2 cm long at most localities. Some of the phosphatic pellets are coated with manganese and are black, whereas others are pale brown and appear to be entirely phosphate.

There are at least two glauconitic sandstone beds within the Vaqueros Sandstone. Burchfiel (1964) and McCollom (1959) used these beds to correlate sections of the Vaqueros from one valley to another. The significance of these glauconites with respect to foraminiferal and nannoplankton zonations has not yet been established.

No glauconite-rich beds have been found in the Butano Sandstone or the Locatelli Formation. Glauconite-rich sandstone and conglomerate beds are common in Neogene sequences in the Santa Cruz Mountains, but few of these have been described or dated by paleontologic methods. The Paleogene glauconites seem to have been too deeply buried for meaningful K-Ar dating, but one of the Neogene glauconites (the basal Purisima of late Miocene or early Pliocene age) has been dated by this method.

LITTLE BOULDER CREEK SECTION

The Little Boulder Creek section (fig. 9) on the north side of Butano Ridge was designated the type section for the upper 518 m (1700 feet) of the Butano Sandstone by Cummings and others (1962, p. 184). The section was also described briefly and designated as a reference section for the Twobar Shale Member of the San Lorenzo Formation by Brabb (1964).

After this section was measured in 1958, landslide debris and sediments deposited in the creek have reduced the amount of section exposed. Trees felled by snow have made access along the creek more difficult. The access road is not suitable for a large bus, and part of the road may be impassable when it rains. Permission to visit the section must be obtained from the Santa Cruz Lumber Company.

The stratigraphic column (fig. 10) provides information on the lithology and texture of the Butano Sandstone and San Lorenzo Formation. Table 1 provides information on the microfaunas of these formations. The planktonic foraminifers have not been examined by specialists, and no attempt has yet been made to find nannoplankton.

Nilsen and Simoni (1973) studied the sedimentary structures in the Butano Sandstone along Butano Ridge and elsewhere. They believe that the Butano Sandstone is a deep-sea fan deposit derived from a southern provenance area adjacent to Monterey Bay.

Table 1.--Check list of Foraminifera from the Little Boulder Creek section

Note: Foraminifera washed and identified by oil company micropaleontologists. Many identifications are provisional.

V = Very abundant (>500)
A = Abundant (101-500)
C = Common (10-100)
R = Rare (1-9)
X = Abundance not estimated
? = Questionable identification

Approximate stratigraphic distance (in feet) from glauconite at Twobar-Rices contact.	-2115	-2090	-1970	-1865	-1760	-1520	-1150	-1100	-1085	-925	-740	-715	-555	-270	-250	-190	-40	-23	0	+25	+35	+40	+41	+57	+100	?
Formation	BUTANO										SAN LORENZO															
Member											Twobar shale								Rices mudstone							
Coset	D						E			F	G					H	J		K				L			
Age	Narizian																		Refugian				Zemorrian			
Locality and sample number	EB 330L	EB 330H	EB 330F	EB 330E	EB 330D	EB 330B	EB 202G	EB 202A	EB 202H	EB 202B	EB 203B	EB 203D	EB 203C	EB 204C	EB 204D	EB 204A	EB 205A	EB 205J	EB 205B	EB 205C	EB 205H	EB 205D	EB 205G	EB 205F	EB 205M	EB 206
Amphimorphina jenkinsi (Church)														R	?		?									
Anomalina californiensis Cushman & Hobson																										R
Anomalina crassisepta Cushman & Siegfus			R					R								R										
Anomalina sp.	R									R			?													
Asterigerina crassaformis Cushman & Siegfus				R																						
Bathysiphon sp.							R				X		R													
Bolivina jacksonensis Cushman & Applin														R												
Bolivina jacksonensis tumeyensis Cush. & Simon.																					R	R				
Bolivina sp.																	X			X		X				
Bulimina corrugata Cushman & Siegfus		R																								X
Bulimina inflata Sequenza																										X
Bulimina cf. B. ovata cowlitzensis Beck									C																	
Bulimina rinconensis Cushman & Laiming																										A
Bulimina schencki Beck															X											
Bulimina cf. B. schwageri Yokoyama																					R					
Bulimina cf. B. semicostata Nuttall						R							C			C	R	R								
Bulimina aff. B. stalacta Cushman & Parker		R																								
Bulimina sp.		R		R	R	R			R	R							X									
Cassidulina crassipunctata Cushman & Hobson																								X		V
Cassidulina globosa Hantken						R				A							R									
Cassidulina aff. C. globosa Hantken	R		R	R																						
Cassidulina sp.									R				R													
Ceratobulimina cf. C. washburnei C. & Schenck									R																	
Chilostomella sp.				R					R																	
Cibicides aff. C. bayleyi Beck		R	C	R	?																					
Cibicides cushmani Nuttall										?			R				X									
Cibicides floridanus cushmani Barbat & Estorff																					V	C				X
Cibicides pseudoungerianus evolutus C. & Hob.																					X	C		X		A
Cibicides sp.				R	R									R		R						X				
Cyclammina incisa (Stache)										C														X	X	
Cyclammina sp.	R					R				C																
Dentalina aff. D. communis (Orbigny)									R																	
Dentalina quadrulata Cushman & Laiming																									X	
Dentalina sp.							R			R		R	C													
Dorothia sp.			R	R						C																
Eponides cf. E. duprei ciervoensis C. & Simon.																		R								
Eponides kleinpelli Cushman & Frizzell																					X			X		
Eponides cf. E. pygmea Hantken						?		?	A				C			?										
Eponides aff. E. tenera H. B. Brady		R	R	R																						
Eponides sp.					R	R				R											R					R
Globigerina sp.	R	C	R	R	R	A	C	A	A	C		V	C	C	V	R		R								
Globobulimina sp.				R		R		X																		R
Guttulina irregularis Orbigny																						X				
Gyroidina condoni rotundiformis Cush. & Simon.													R	R			R									
Gyroidina soldanii Orbigny																					A					C
Gyroidina cf. G. soldani Orbigny		R		R																X		C				
Haplophragmoides sp.	A	C		C	C	A	C	A	A	V	X		R	A			V								X	
Hastigerinella cf. H. eocenica Nuttall							R																			
Lagena sp.																						R				R
Marginulina subbullata Hantken		R																								
Nodosarella sp.									C																	
Nodosaria arundinea Schwager		R	R													R										
Nodosaria sp.			R		R	C				R				R		R					X				X	R
Nonion aff. N. applini Howe & Wallace													R													
Planularia sp.									R																	
Plectina garzaensis Cushman & Siegfus		R																								
Plectofrondicularia garzaensis Cush. & Siegfus																R										X
Plectofrondicularia packardi multilineata																					A	R		X		
Plectofrondicularia packardi packardi C. & Sc.													A				R			A	C	C				
Plectofrondicularia vaughani Cushman																										R
Pullenia lillisi Church								R	?																	
Robulus inornatus Orbigny		R	C					R		R			R	R												
Robulus sp.				R		R			R	R						R					X	X			X	C
Saracenaria sp.													C													
Siphonodosaria sp.		R						C		C			R			R		R								C
Tritaxilina colei Cushman & Siegfus				R																						
Uvigerina churchi Cushman & Siegfus						R																				
Uvigerina cocoaensis Cushman																				?	C	X				
Uvigerina gallowayi Cushman																						X				X
Uvigerina gardnerae Cushman																				X	X	X				
Uvigerina garzaensis Cushman & Siegfus						R				R						?										
Uvigerina cf. U. gesteri Barbat & Estorff																						R				C
Uvigerina cf. U. kernensis Barbat & Estorff																						A				
Uvigerina cf. U. vicksburgensis Cush. & Ellisor																					C					
Uvigerinella obesa impolita Cushman & Laiming																										R
Valvulineria advena Cushman & Siegfus															X											
Valvulineria churchi Cushman																	X									
Verneuilina sp.											X															
Virgulina aff. V. hobsoni Beck									R																	
Virgulina sp.																										X
Diatoms								X			X				X		X								X	
Radiolaria								X			X				X		X									

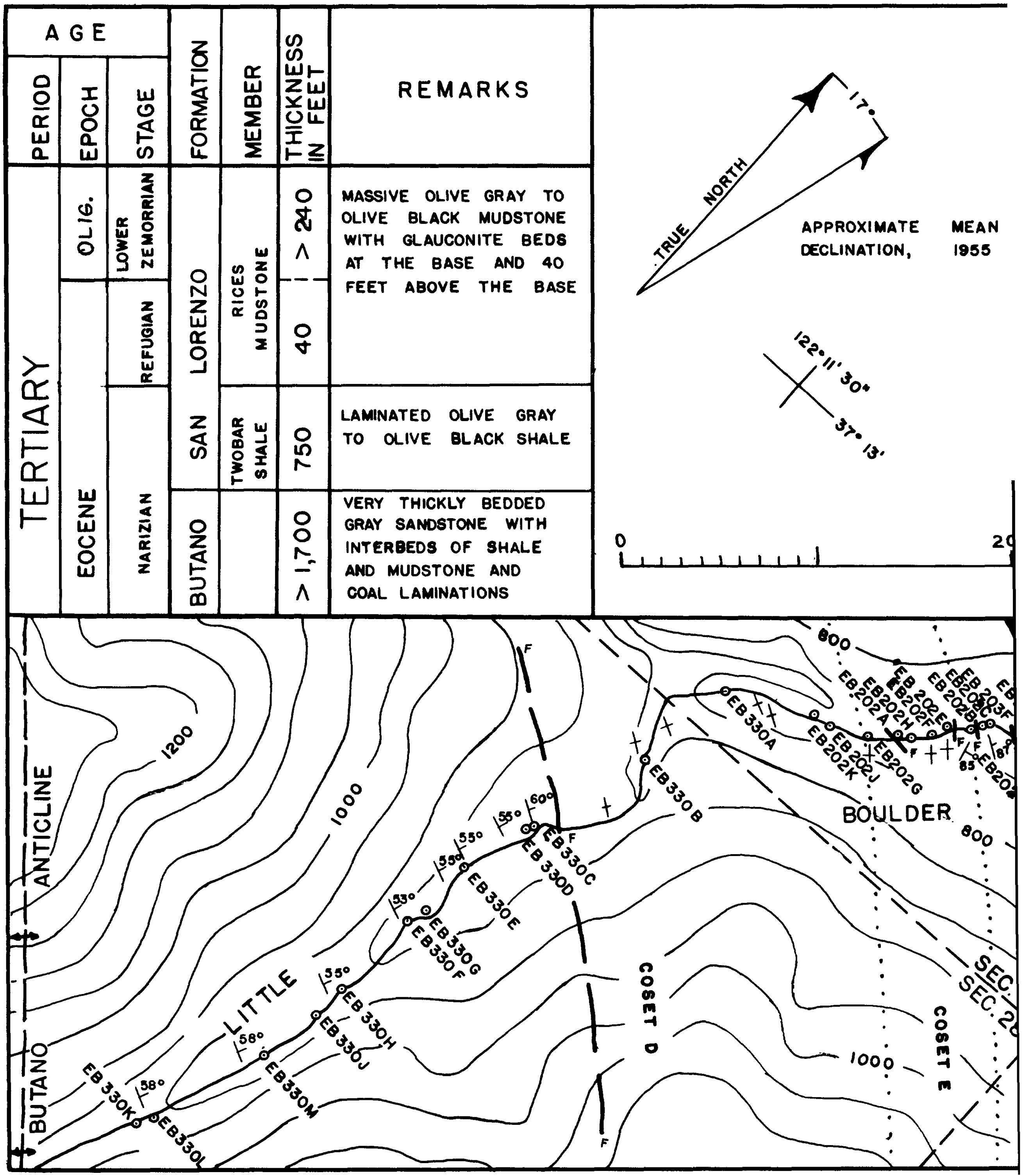


Figure 9.--Collecting localities along Little Boulder Creek

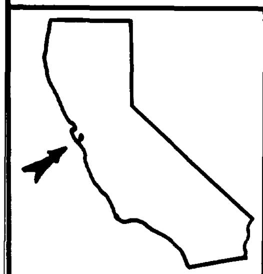
COLLECTING LOCALITIES ALONG LITTLE BOULDER CREEK IN A PART OF THE TYPE LOCALITY OF THE BUTANO SANDSTONE

SECS. 21, 22, 27, AND 28, T. 8 S., R. 3 W. M.D.B.M.

FROM REPORT BY EARL E. BRABB, 1960

"GEOLOGY OF THE BIG BASIN AREA, SANTA CRUZ MOUNTAINS, CALIFORNIA"

BASE MAP ENLARGED FROM U. S. GEOLOGICAL SURVEY BIG BASIN 7.5 QUADRANGLE, 1955 EDITION. COLLECTING LOCALITIES AND DETAILS OF CREEK SURVEYED BY TAPE AND BRUNTON COMPASS



LOCATION MAP

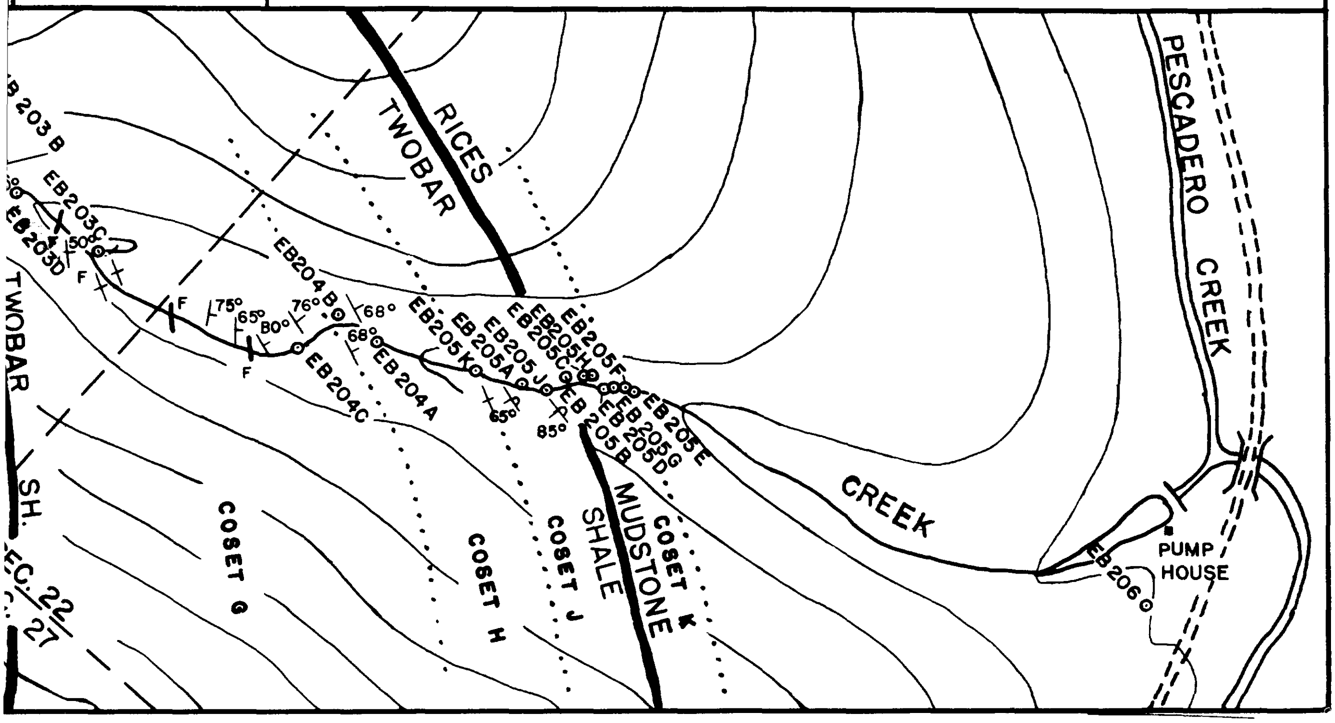
LEGEND

- STRIKE AND DIP OF BEDS
- STRIKE OF VERTICAL BEDS
- STRIKE AND DIP OF OVERTURNED BEDS
- APPROXIMATE AXIS OF ANTICLINE
- COLLECTING LOCALITY
- FORMATION CONTACT
- F FAULT
- COSET CONTACT

SCALE

200 0 200 400 600 800 1,000 FEET

CONTOUR INTERVAL 40 FEET



STRATIGRAPHIC COLUMN

OF THE SAN LORENZO FORMATION AND TYPE BUTANO SANDSTONE EXPOSED IN LITTLE BOULDER CREEK, CALIFORNIA

Secs. 21, 22, and 28, T. 8 S., R. 2 W., Mount Diablo Base and Meridian

From report by Earl E. Brabb, 1960

"Geology of the Big Basin area, Santa Cruz Mountains, California"

LEGEND

PREDOMINANT PARTICLE SIZE

- Fine- to medium-grained sandstone (Median diameter 0.50-0.12 mm.)
- Very fine-grained sandstone (Median diameter 0.12-0.06 mm.)
- Interbedded sandstone and mudstone or shale
- Mudstone (Median diameter<0.06 mm.)
- Shale (Median diameter<0.06 mm)
- Fault - part of section missing
- Covered

PREDOMINANT STRATIFICATION

V = Very thick-bedded (massive of authors) >100 cm.
T = Thick-bedded 30-100
M = Medium-bedded 10-30
H = Thin-bedded 3-10
E = Very thin-bedded 1-3
L = Laminated <1 cm.

OTHER SYMBOLS

- Carbonate concretion
- Glauconite bed
- Collecting locality

1 inch = 200 feet

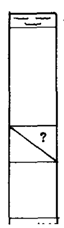
200 feet — 0 — 800 feet

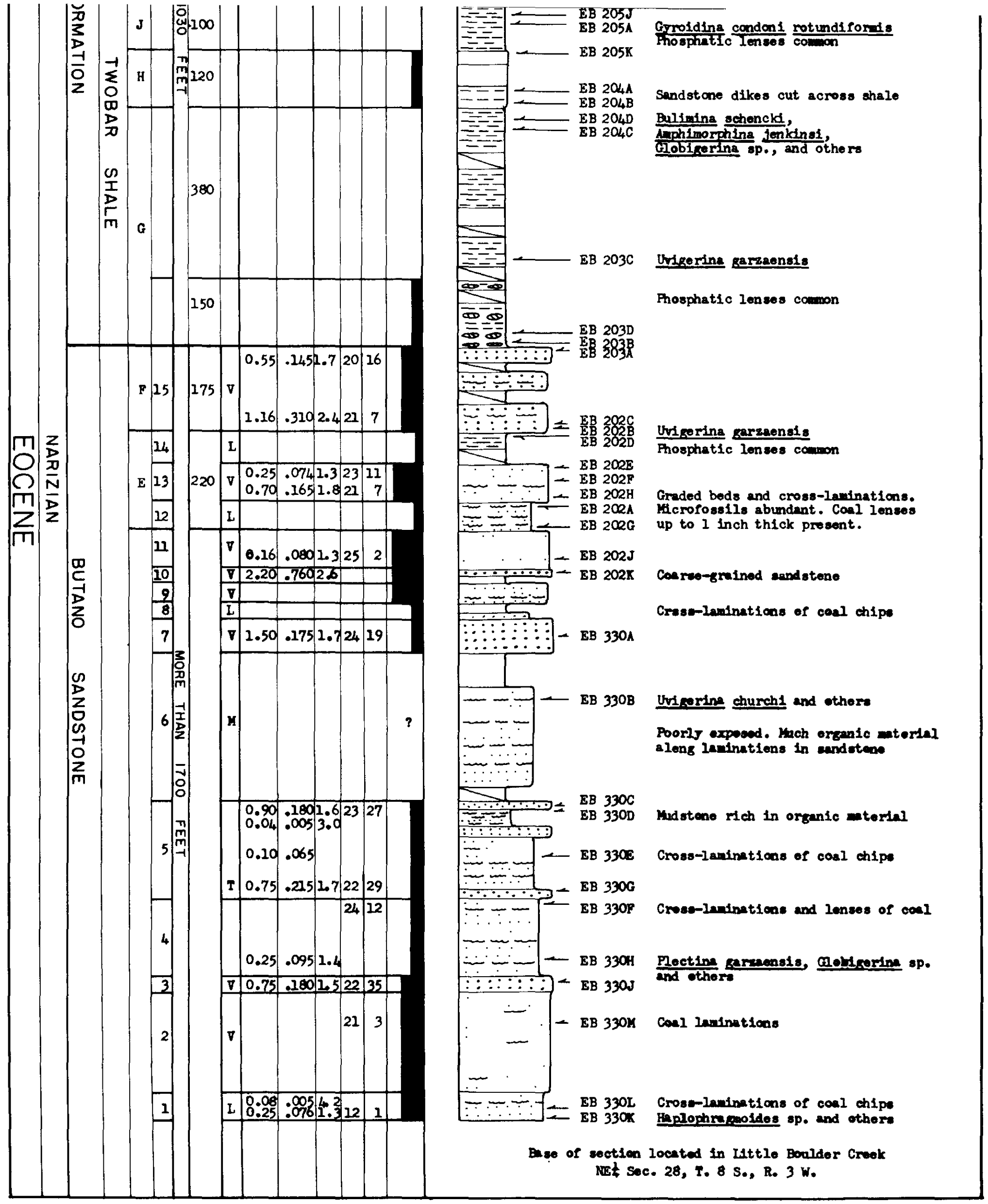
NOTES

(1) Sandstones are light gray (N7) to medium dark gray (N4); mudstones and shales are olive gray (5Y 4/1) to olive black and grayish black, where fresh and wet.

0 — 200 m.

EPOCH	STAGE	FORMATION	MEMBER	COSET	SET	FORMATION THICKNESS	THICKNESS OF COSET IN FEET	STRATIFICATION	ONE PERCENTILE (C) IN MM.	MEDIAN DIAMETER OF SAMPLES, IN MM.	TRASK INDEX (S_o)	MAX. POROSITY, %	MAX. PERM., MDCYS.	PERCENT OF SET CEMENTED BY CARBONATE (0–50–100)
OLIGOCENE	ZEMORRIAN / REFU	SAN LORENZO	RICES MUDSTONE	L		MORE T	? / 240							

GRAPHIC COLUMN (PERCENT OF SANDSTONE IN SET 0–100)	COLLECTING LOCALITIES	REMARKS
	EB 206	Top of section at pumphouse near intersection of Little Boulder Creek and Pescadero Creek *Uvigerina gallowayi* *Plectofrondicularia vaughani* *Acila* sp., and others



15	V	0.55	.145	1.7	20	16	
		1.16	.310	2.4	21	7	
14	L						
13	V	0.25	.074	1.3	23	11	
		0.70	.165	1.8	21	7	
12	L						
11	V	0.16	.080	1.3	25	2	
10	V	2.20	.760	2.6			
9	V						
8	L						
7	V	1.50	.175	1.7	24	19	
6	M						?
5		0.90	.180	1.6	23	27	
		0.04	.005	3.0			
		0.10	.065				
	T	0.75	.215	1.7	22	29	
4					24	12	
		0.25	.095	1.4			
3	V	0.75	.180	1.5	22	35	
2	V				21	3	
1	L	0.08	.005	4.2			
		0.25	.076	1.3	12	1	

Figure 10.--Stratigraphic column, Little Boulder Creek

SAN LORENZO RIVER SECTION

The San Lorenzo River area (fig. 11) includes the lower part of the San Lorenzo Formation in its type section (Arnold, 1906). The upper part of the formation is folded and has few reliable attitudes, so that it is difficult to construct a complete stratigraphic column. The column by Sullivan (1962, fig. 4) includes about 170 m (550 feet) of repeated section, according to Brabb (1964, p. 675).

Benthonic foraminifers and a few planktonic foraminifers from the San Lorenzo River section were described by Sullivan (1962). Poore and Brabb (1977) described the planktonic foraminifers in greater detail.

A stratigraphic column (fig. 12) shows the position of faunas collected by various geologists. Sample B2251, a critical sample in Sullivan's faunal sequence (1962, p. 290), could not be located precisely enough to show on the map.

In the San Lorenzo River and other measured sections, the following symbols are used to indicate abundance of foraminifers and nannoplankton:

A	Abundant
C	Common
F	Few
S	Sparse
X	None

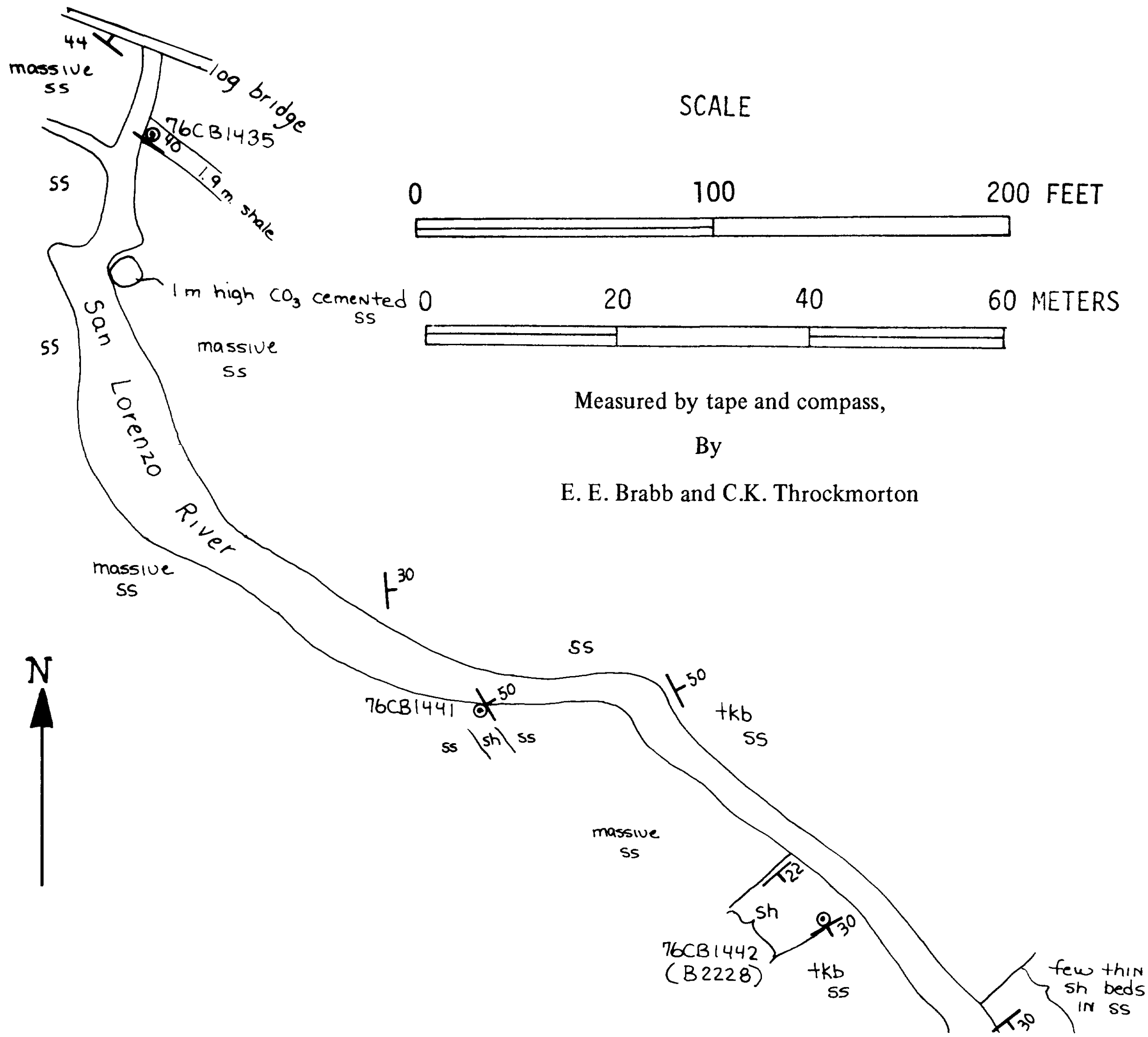


Figure 11.--Geologic sketch map of the San Lorenzo River near Riverside Grove showing formation contacts and localities where fossils and rocks were collected

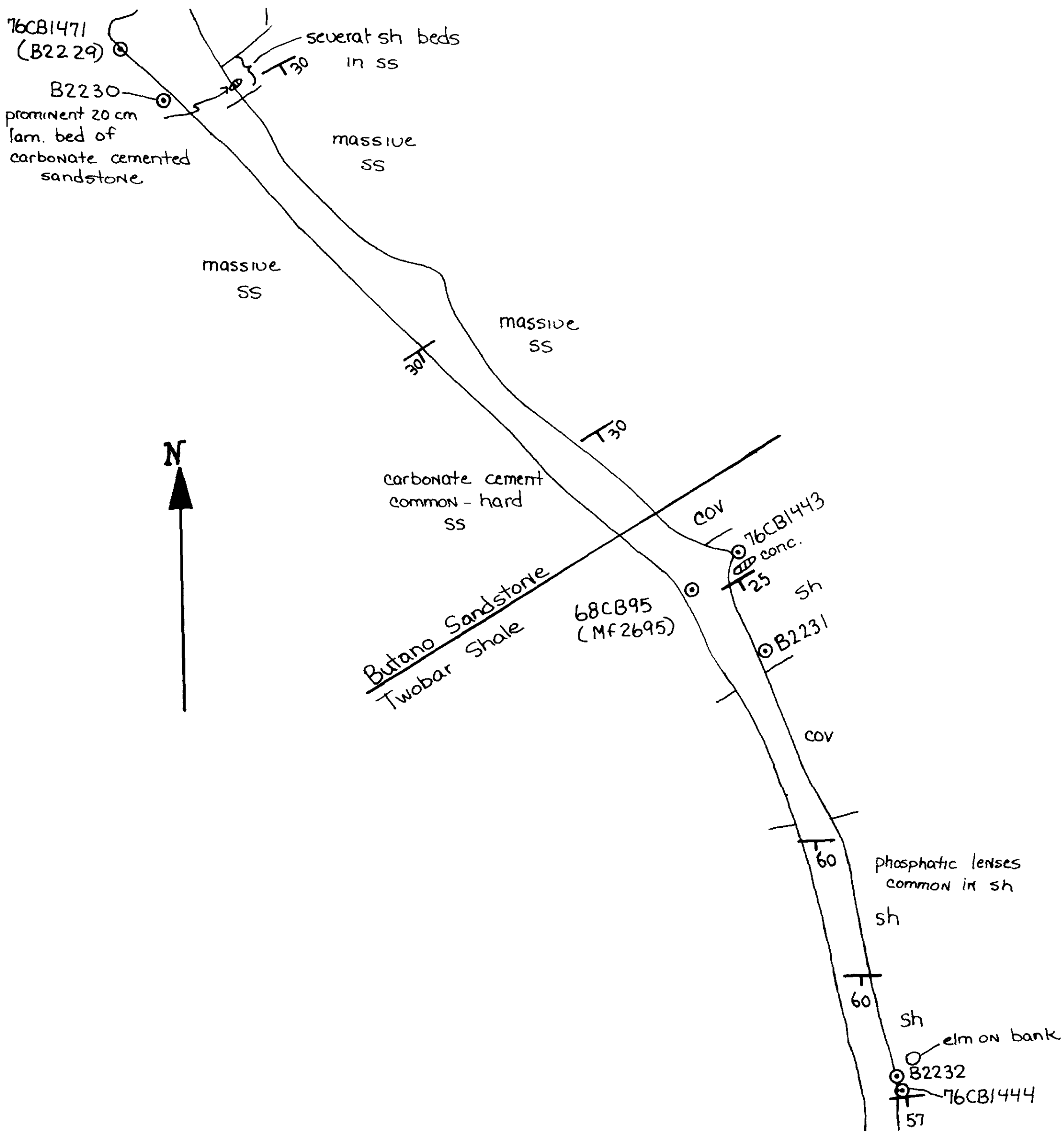
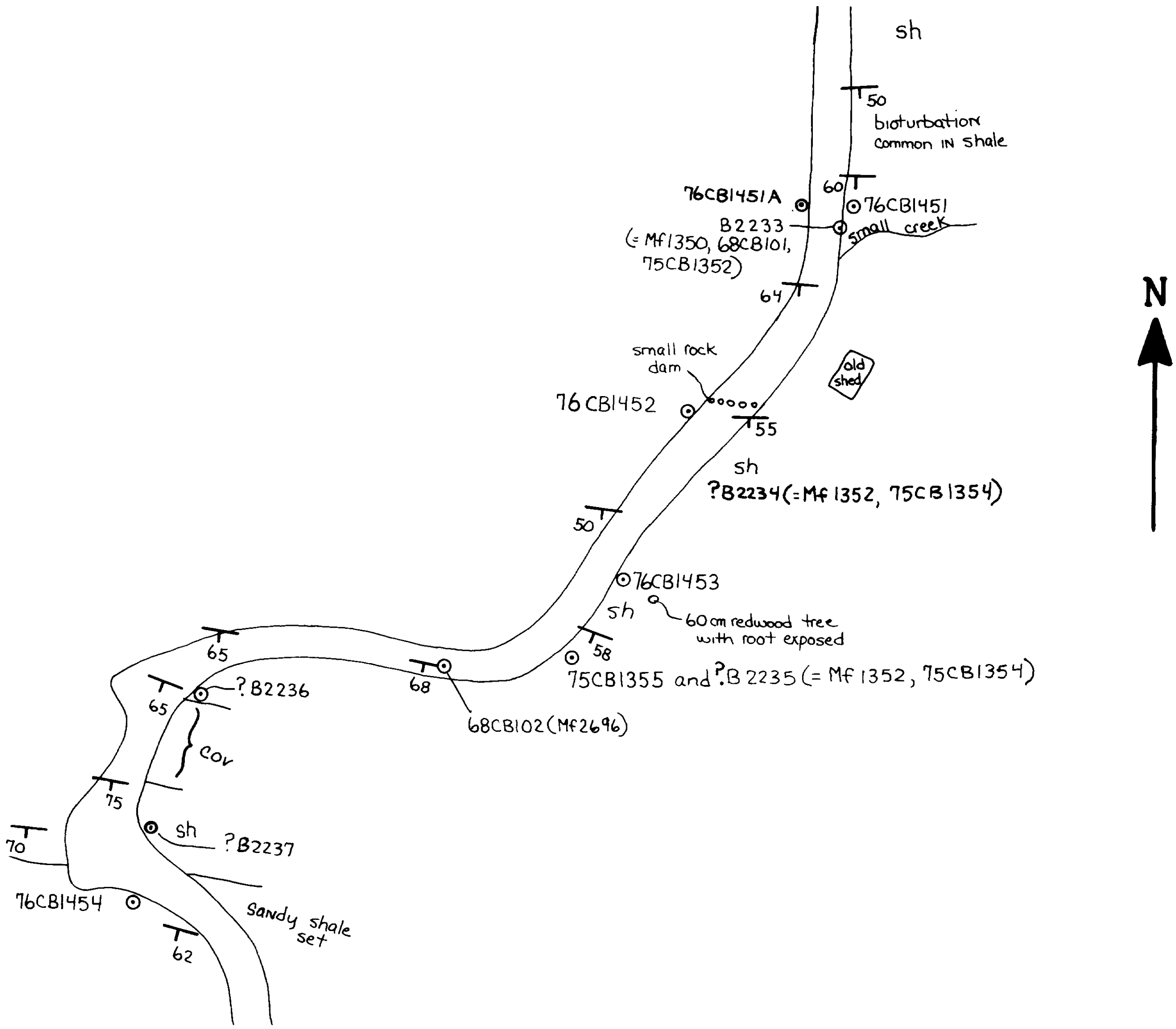
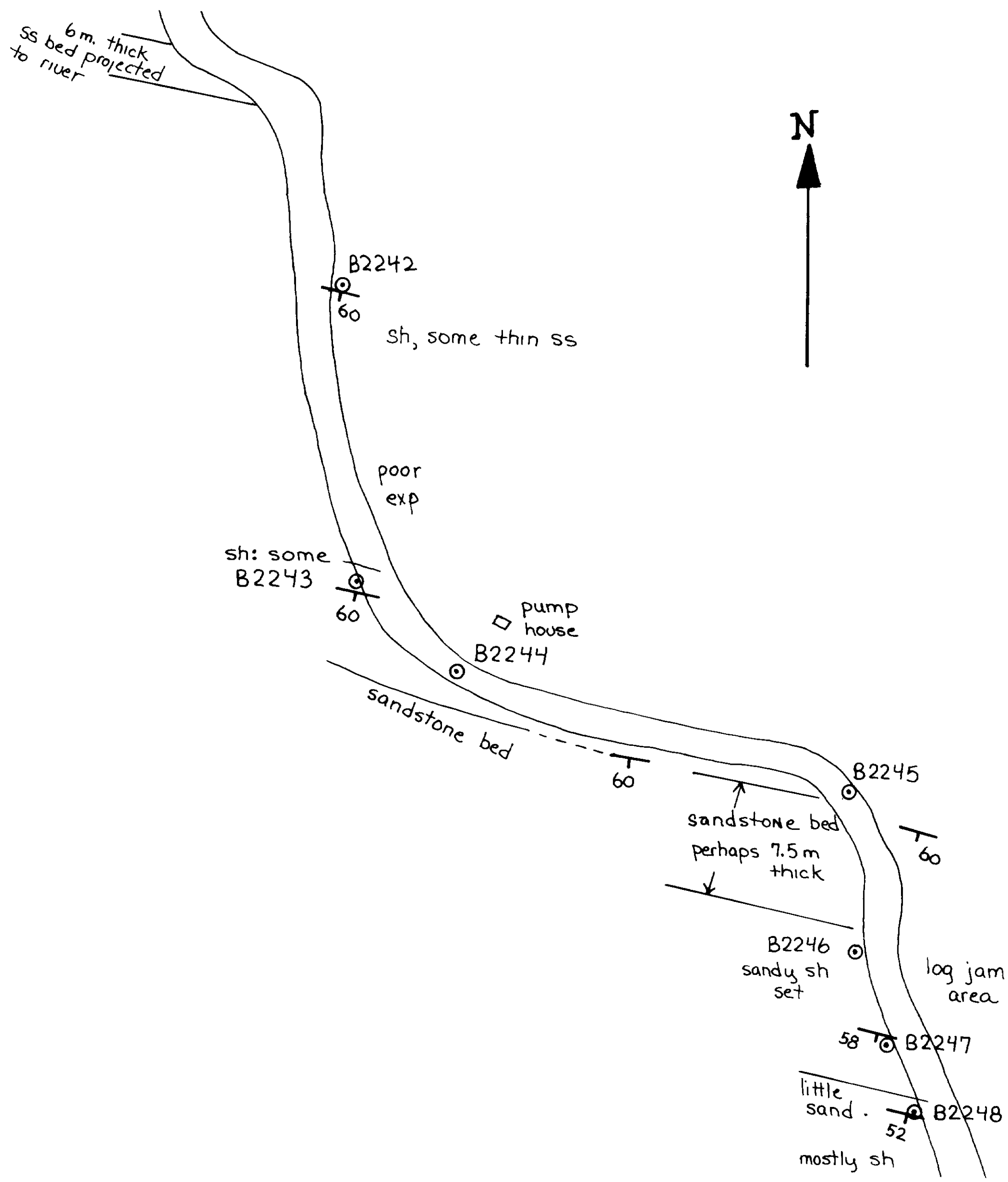

76CB1471
(B2229)
B2230
prominent 20 cm lam. bed of carbonate cemented sandstone
several sh beds in ss
30
massive ss
massive ss
massive ss
30
30
carbonate cement common - hard ss
Butano Sandstone
Twobar Shale
cov
76CB1443
conc.
25
sh
68CB95
(MF2695)
B2231
cov
60
phosphatic lenses common in sh
sh
60
sh
elm on bank
B2232
76CB1444
57
N

Figure 11.--

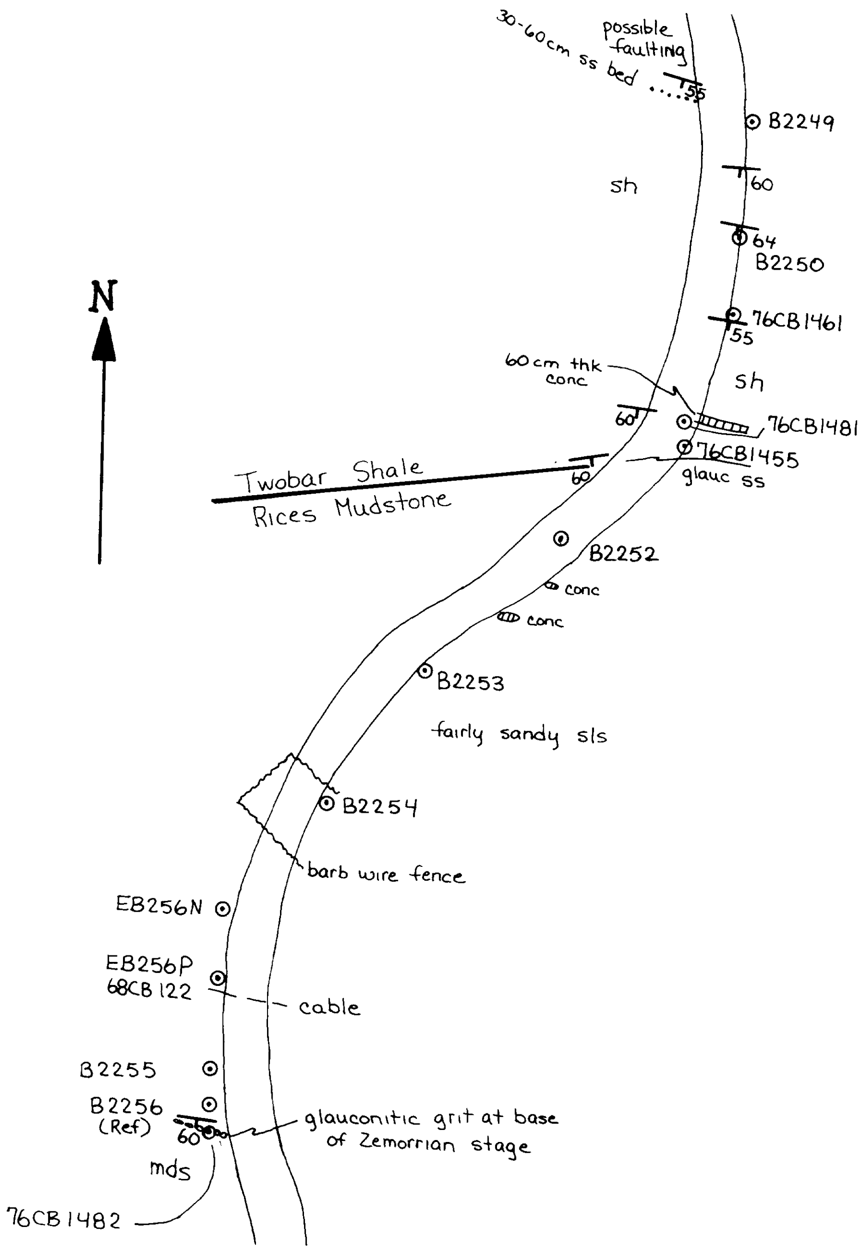

sh
50
bioturbation common in shale
60
76CB1451A
76CB1451
B2233
(= Mf1350, 68CB101, 75CB1352)
small creek
64
small rock dam
old shed
76CB1452
55
sh
?B2234 (= Mf 1352, 75CB1354)
50
76CB1453
sh
60 cm redwood tree with root exposed
58
75CB1355 and ?B2235 (= Mf 1352, 75CB1354)
65
68
68CB102 (Mf2696)
65
?B2236
cov
75
sh
?B2237
70
76CB1454
sandy shale set
62
N

ontinued



6 m. thick
ss bed projected
to river
N
B2242
60
sh, some thin ss
poor
exp
sh: some
B2243
60
pump
house
B2244
sandstone bed
60
B2245
sandstone bed
perhaps 7.5 m
thick
60
B2246
sandy sh
set
log jam
area
58
B2247
little
sand.
B2248
52
mostly sh

Figure 11.-



N
possible faulting
30-60cm ss bed
55
B2249
sh
60
64
B2250
76CB1461
55
60 cm thk conc
sh
60
76CB1481
76CB1455
glauc ss
Twobar Shale
Rices Mudstone
60
B2252
conc
conc
B2253
fairly sandy sls
B2254
barb wire fence
EB256N
EB256P
68CB 122
cable
B2255
B2256
(Ref)
60
glauconitic grit at base of Zemorrian stage
mds
76CB1482

ntinued

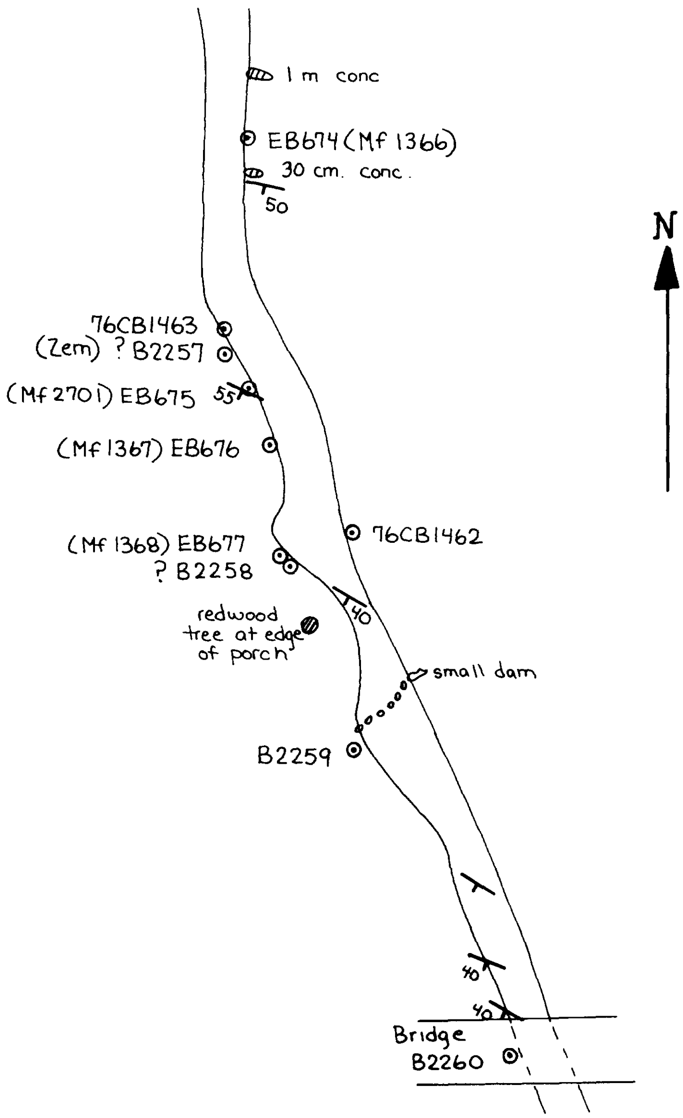


Figure 11.--continued

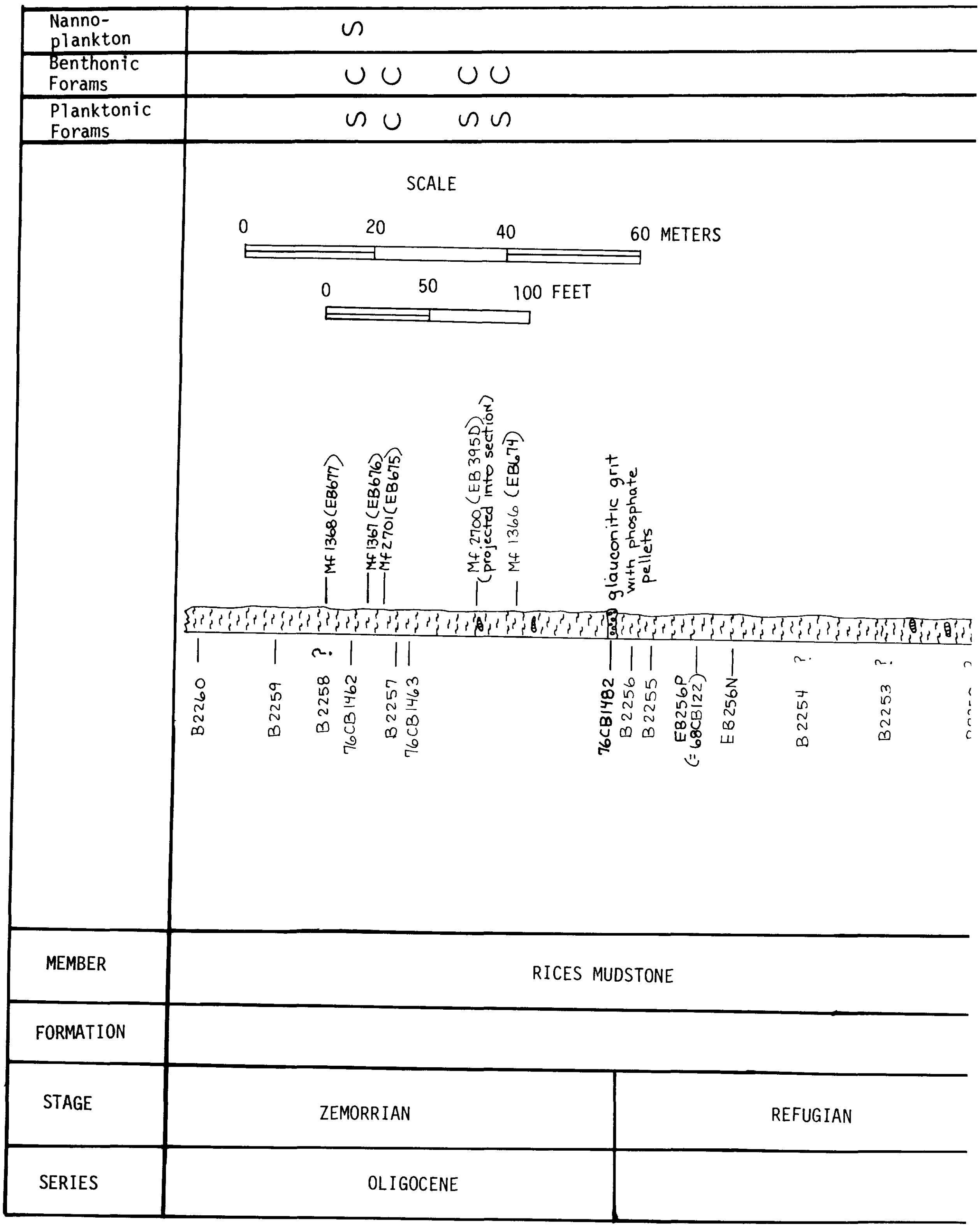


Figure 12.--Stratigraphic column for San Lorenzo River section near Riverside Grove

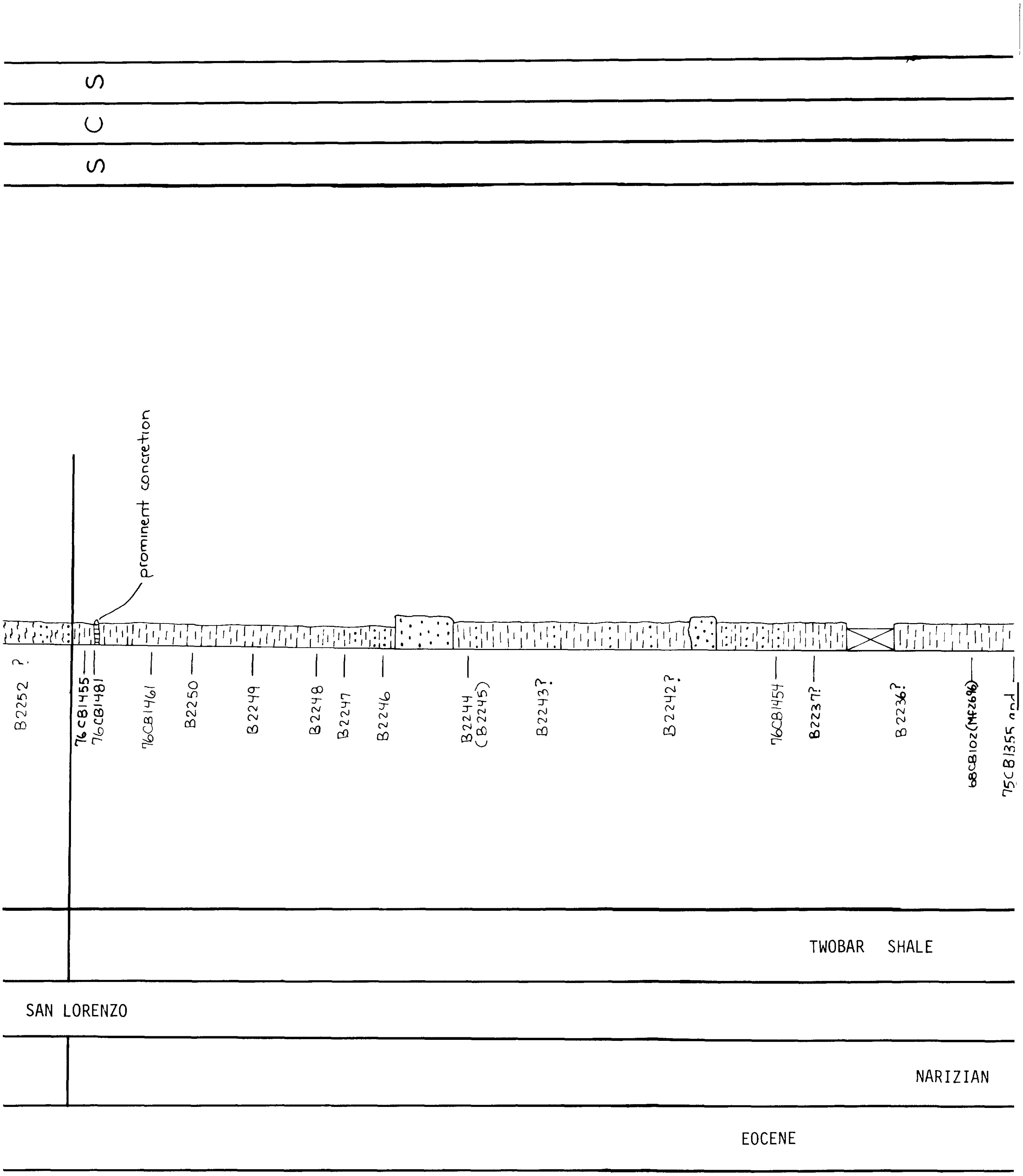
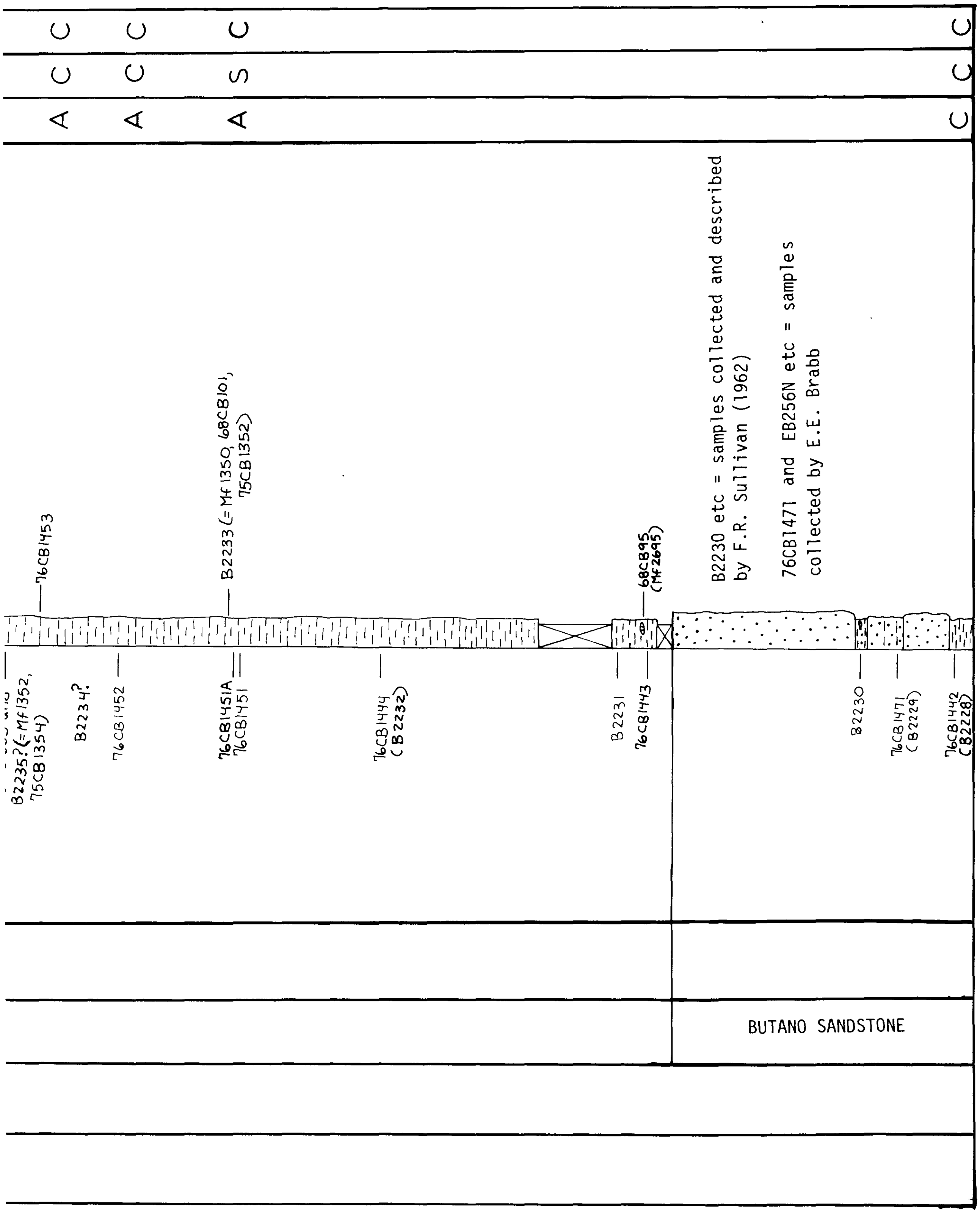

S
C
S
prominent concretion
B2252 ?
76CB1455
76CB1481
76CB1461
B2250
B2249
B2248
B2247
B2246
B2244
(B2245)
B2243?
B2242?
76CB1454
B2237?
B2236?
68CB102
TWOBAR SHALE
SAN LORENZO
NARIZIAN
EOCENE

Figure 1


C
C
C
C
C
S
C
A
A
A
C
B2230 etc = samples collected and described by F.R. Sullivan (1962)
76CB1471 and EB256N etc = samples collected by E.E. Brabb
76CB1453
B2233 (= Mf1350, 68CB101, 75CB1352)
68CB95 (Mf2695)
B2235? (= Mf1352, 75CB1354)
B2234?
76CB1452
76CB1451A
76CB1451
76CB1444 (B2232)
B2231
76CB1443
B2230
76CB1471 (B2229)
76CB1442 (B2228)
BUTANO SANDSTONE

tinued

KINGS CREEK SECTION

The Kings Creek area (fig. 13) was designated by Brabb (1964) as the type section for the Twobar Shale and Rices Mudstone Members of the San Lorenzo Formation. After the section was measured in 1958, sediment from road construction along the upper part of Kings Creek was washed into the creek, covering part of the section that was formerly exposed. Heavy snowfalls in the 1970's felled many trees into the creek, thereby making access difficult in some places. Nevertheless, the section still has excellent exposures of the San Lorenzo, Butano and Vaqueros Formations.

The stratigraphic column for the Kings Creek area is shown on figure 14. Foraminifers from the formations are listed on table 2. Three samples (B4357, B4358, and B4369) collected and described by Fairchild and others (1969) are not shown. The section was recollected by the senior author in 1968 but these samples have not been completely processed. Preliminary examination by R. Z. Poore indicates that planktonic formainifers and nannoplankton are not as abundant or as well preserved as in the San Lorenzo River section.

Table 2.--Check list of Foraminifera from the Kings Creek Section

Kings Creek, California: Sec. 31, T. 8 S., R. 2 W., and Sec. 6, T. 9 S., R. 2 W.

from report by Earl E. Brabb, 1960

"Geology of the Big Basin Area, Santa Cruz Mountains, California"

Note: Foraminifera washed and identified by oil company micropaleontologists.
Many identifications are provisional.

A = Abundant
C = Common
F = Few
R = Rare
X = Abundance not estimated
? = Questionable identification

Locality and sample number	EB 426B	EB 425C	EB 425A	EB 363B	EB 363C	EB 419A	EB 419C	EB 366B	EB 366C	EB 366D	EB 366E	EB 367A	EB 367B	EB 367C	EB 367D	EB 367F	EB 365A	EB 365B	EB 365D	EB 364B	EB 420D	EB 420B	EB 421A	EB 422B	EB 423C	EB 424C	EB 427B	EB 427C	EB 428B	EB 368B
Approximate stratigraphic distance (in feet) from glauconite at Twobar-Rices contact.	-1230	-1040	-965	-465	-435	-320	-240	-155	-130	-90	-60	-13	-4	0	+6	+35	+125	+165	+200	+385	+505	+600	+740	+850	+1100	+1270	+1725	+1730	+1950	+2200
Formation	BUTANO			SAN LORENZO																					VAQUEROS					
Member				Twobar shale (type)										Rices mudstone (type)																
Coset	E	F		G				H		J				K					L						M					
Age				Narizian										Refugian					Zemorrian											
Amphimorphina jenkinsi (Church)												X																		
Anomalina californiensis Cushman & Hobson																					F	R	R	C		R	R	F	F	X
Arenobulimina sp.						C		F																						
Asterigerina crassaformis Cushman & Siegfus			R																											
Bathysiphon sp.					F	R						R	C		R	F	R						R	F	R	R				
Bolivina advena striatella Cushman																														X
Bolivina marginata Cushman																											R	R	R	R
Bulimina cf. B. alsatica Cushman & Parker																		R												
Bulimina carnerosensis Cushman & Kleinpell																														R
Bulimina inflata alligata Cushman & Laiming																				R		R	F	R						
Bulimina microcostata Cushman & Parker						A			C	F																				
Bulimina schencki Beck																		R												
Bulimina sculptilis Cushman									F																					
Bulimina cf. B. socialis Bornemann																							F							
Buliminella curta Cushman																										R	R	F		
Buliminella subfusiformis Cushman																													R	
Cancris cf. C. joaquinensis Smith							F						R																	
Cassidulina crassipunctata Cushman & Hobson																				R	F		A	R			R	R	C	F
Cassidulina globosa Hantken										R																				
Cassidulina pulchella Orbigny																						R								
Cassidulina subglobosa Brady																R														
Chilostomella cylindroides Reuss			R																											
Cibicides cf. C. cushmani Nuttall			R												X															
Cibicides floridanus (Cushman)																							R			F				
Cibicides hodgei Cushman & Schenck															F	R														
Cibicides pseudoungerianus evolutus C. & Hob.																		X		R	R		A	A	C		R	F	C	
Cibicidoides coalingensis (Cushman & Hanna)																F														
Cyclammina incisa (Stache)	C		R										R							F	F		C	C	F	F	C	A	A	R
Cyclammina pacifica Beck															C	C														
Dentalina cf. D. communis Orbigny																					R									
Dentalina consobrina Orbigny															R															
Dentalina quadrulata Cushman & Laiming																					R									
Eggerella elongata (Terquem)	F					R	R	R				?																		
Eponides cf. E. kleinpelli Cushman & Frizzell																										R				
Eponides cf. E. mansfieldi Cushman																														C
Eponides nanus (Reuss)																													R	
Eponides umbonata (Reuss)			R																									R		
Globigerina bulloides Orbigny		E	F	C																										
Globigerina triloculinoides Plummer		A		C					F	R																				
Globigerina sp.												X									R									
Globigerinella micrum (Cole)				F																										
Globorotalia cf. G. crassata aequa C. & Renz				R																										
Gyroidina cf. G. condoni Cushman & Schenck													R																	
Gyroidina orbicularis Orbigny													X																	
Gyroidina cf. G. planulata Cushman & Renz																									R	F				
Gyroidina soldanii Orbigny																				R	C	R		R	F		R	C	A	A
Gyroidina soldanii octocamerata Cush. & Hanna			R																											
Guttulina cf. G. irregularis Orbigny																										R				
Guttulina problema Orbigny																R														
Haplophragmoides cf. H. emaciatum (Brady)								A																	R					
Haplophragmoides excavata Cushman & Waters	X				A																									
Haplophragmoides trullisata (H. B. Brady)	C		A										R			C				R			C	R	C	C	F	F	F	
Haplophragmoides sp.	?						F	?	C	R	X	A																		
Lagena cf. L. strumosa Reuss																				R				R						
Lenticulina cf. L. convergens (Bornemann)																				R	R									
Marginulina cf. M. subbullata Hantken																										R				
Marginulina sp.																							R			F				
Nodosarella cf. N. coccoaensis (Cushman)			R																											
Nodosaria anomala Reuss						R	R		R	R													R							
Nodosaria sp.	X										X												R		R					
Nonion affinis (Reuss)																														R
Planulina cushmani (Barbat & Estorff)																										R				
Planulina haydoni Cushman & Schenck															C	R														
Plectofrondicularia cf. P. barbati Kleinpell																								R						
Plectofrondicularia californica C. & Stewart																					R									
Plectofrondicularia miocenica Cushman																					R	R	R							
Plectofrondicularia packardi multilineata													X																	
Plectofrondicularia packardi packardi C. & Sc.												R	R		C	A		R												
Plectofrondicularia sp.									R	R																				
Pseudoglandulina inflata (Bornemann)															R	R					A	R	C							
Pullenia octoloba Barbat & Estorff																							R							
Quinqueloculina cf. Q. imperialis Hanna & H.																					R									
Reophax cf. R. pilulifera Brady																					R									
Robulus barbati Cushman & Hobson																							R		R	R		R		
Robulus inornatus (Orbigny)			R						R				C		C	C		C												
Robulus cf. R. texanus (Cushman & Applin)							R																							
Robulus wartmani Barbat & Estorff																		R			A		C	R	R	A	C	C	C	F
Robulus welchi Church											?																			
Robulus sp.												F	R								R					R			R	
Trochammina sp.							C	R																						
Trochamminoides sp.					R	A																								
Saracenaria schencki Cushman & Hobson																										R				
Siphonodosaria advena (Cushman & Laiming)																								R						
Siphonodosaria santaecrucis (Kleinpell)																								R						R
Uvigerina auberiana Orbigny																								R		F			R	
Uvigerina gallowayi Cushman																F	R	R					R	F		F				
Uvigerina gardnerae Cushman																		X												
Uvigerina garzaensis Cushman & Siegfus												A																		
Uvigerina garzaensis nudorobusta Mallory			R			F	C																							
Uvigerinella obesa impolita Cush. & Laiming																									F	F				
Valvulineria tumeyensis Cushman & Simonson						A	C	C	A	F																				
Verneuilina sp.	X						X	X																	F	R	F	F	R	R
Virgulina bramlettei Galloway & Morrey																										R			R	
Diatoms	X										X	X																		
Radiolaria	X									R	X	F																		
Ostracode																								X						

GLAUCONITE BED MARKS BASE OF REFUGIAN STAGE

GLAUCONITE AND PHOSPHATIC PEBBLE BED MARKS BASE OF ZEMORRIAN STAGE

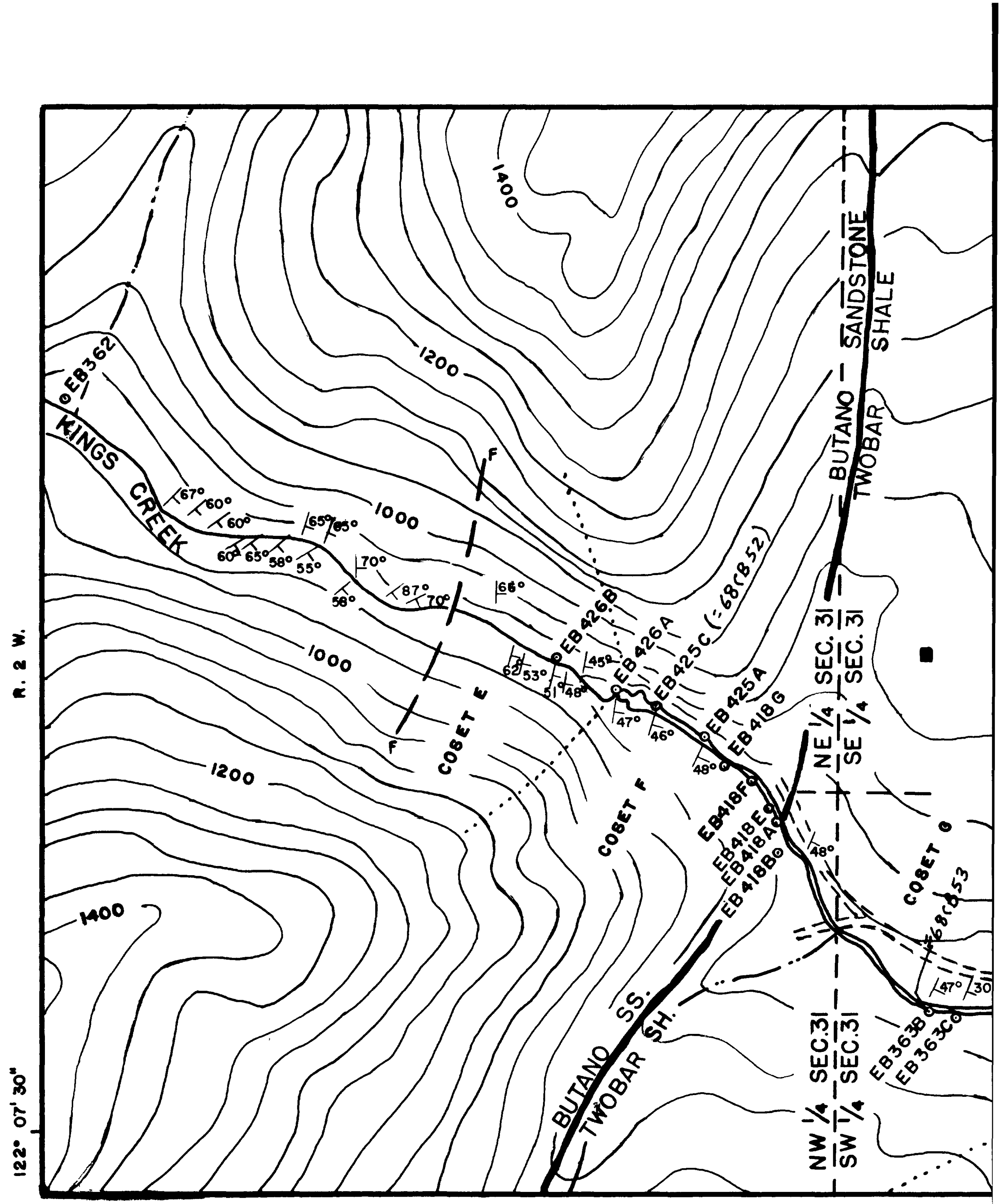
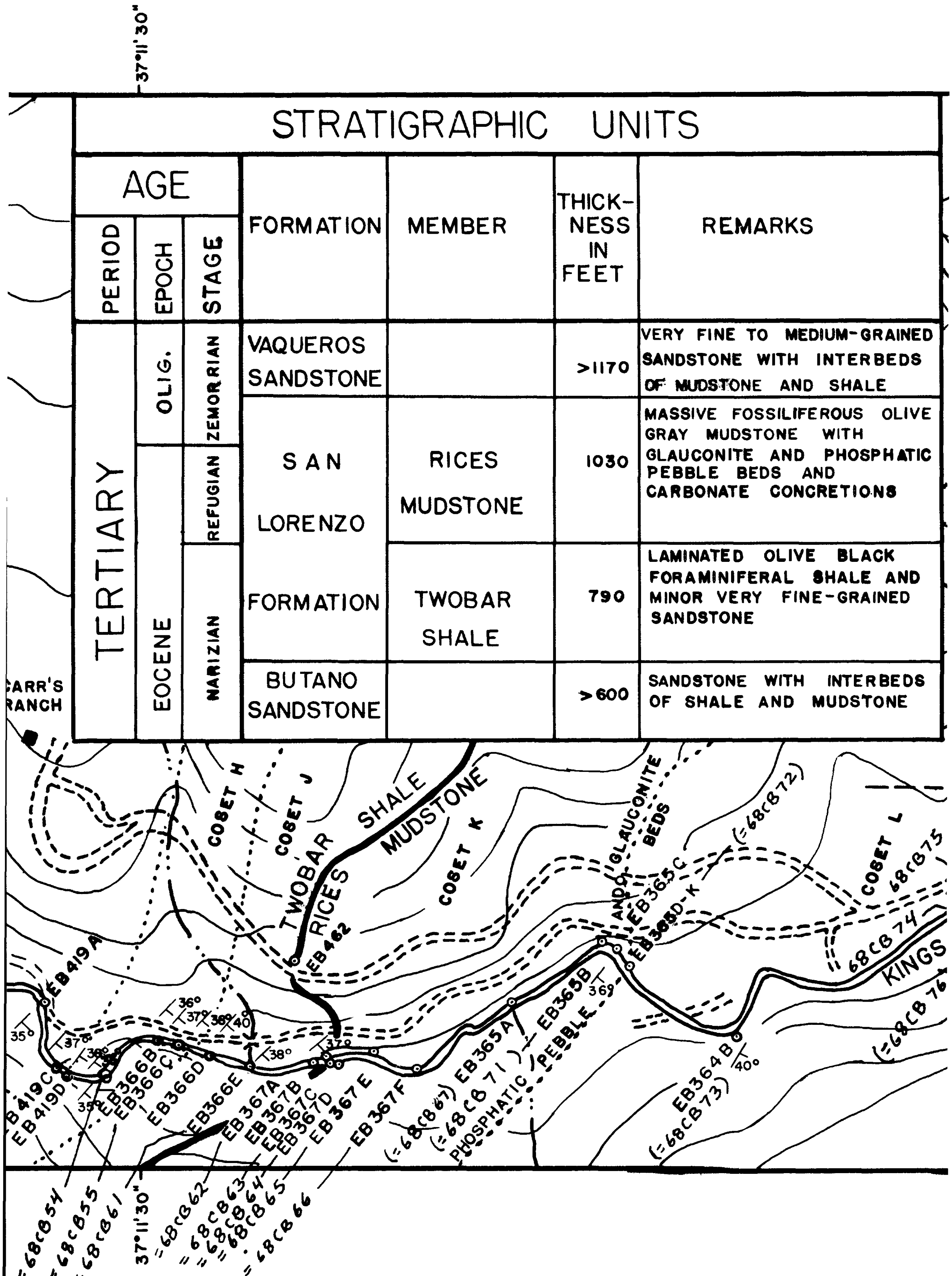


Figure 13.--Type section of the Rices Mudstone and Twoba



STRATIGRAPHIC UNITS

AGE: PERIOD	AGE: EPOCH	AGE: STAGE	FORMATION	MEMBER	THICKNESS IN FEET	REMARKS
TERTIARY	OLIG.	ZEMORRIAN	VAQUEROS SANDSTONE		>1170	VERY FINE TO MEDIUM-GRAINED SANDSTONE WITH INTERBEDS OF MUDSTONE AND SHALE
TERTIARY	OLIG. / EOCENE	ZEMORRIAN / REFUGIAN	SAN LORENZO FORMATION	RICES MUDSTONE	1030	MASSIVE FOSSILIFEROUS OLIVE GRAY MUDSTONE WITH GLAUCONITE AND PHOSPHATIC PEBBLE BEDS AND CARBONATE CONCRETIONS
TERTIARY	EOCENE	NARIZIAN	SAN LORENZO FORMATION	TWOBAR SHALE	790	LAMINATED OLIVE BLACK FORAMINIFERAL SHALE AND MINOR VERY FINE-GRAINED SANDSTONE
TERTIARY	EOCENE	NARIZIAN	BUTANO SANDSTONE		>600	SANDSTONE WITH INTERBEDS OF SHALE AND MUDSTONE

hale Members of the San Lorenzo Formation along Kings Creek

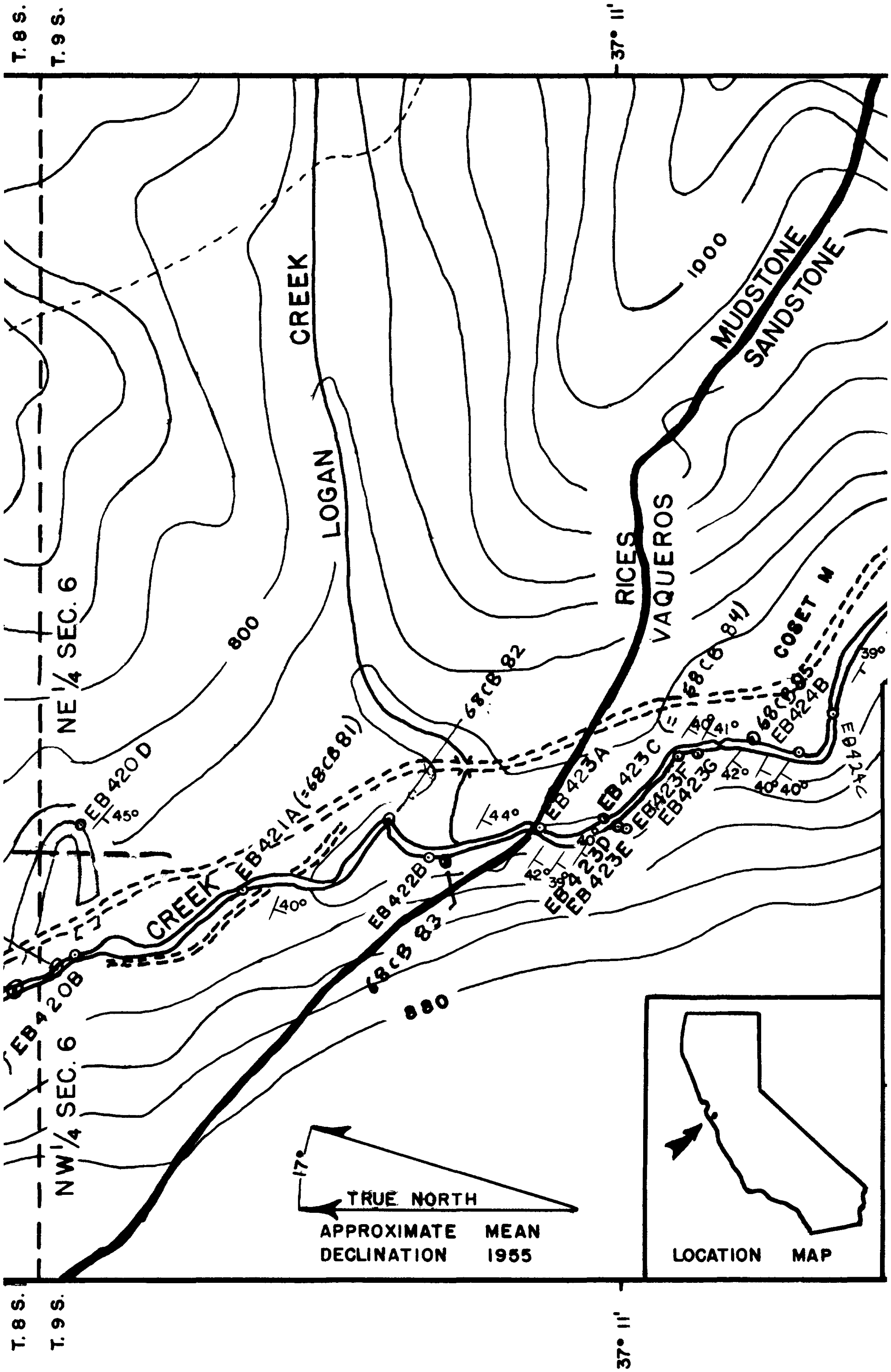
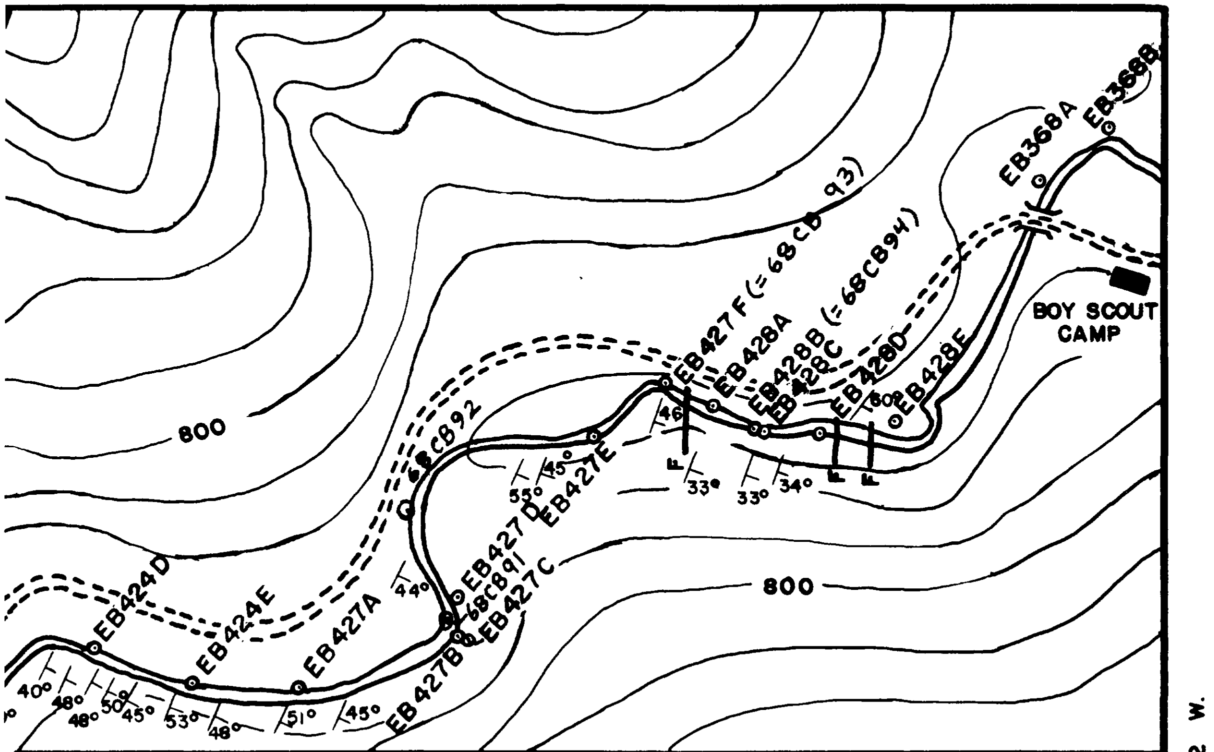

T. 8 S.
T. 9 S.
37° 11'
NE 1/4 SEC. 6
NW 1/4 SEC. 6
LOGAN
CREEK
RICES
VAQUEROS
CREEK
MUDSTONE
SANDSTONE
COSET M
800
880
1000
EB420D
EB420B
EB421A (=68CB81)
EB422B
EB423A
EB423C (=68CB84)
EB423D
EB423E
EB423F
EB423G
EB424B
EB424C
68CB82
68CB83
68CB85
17°
TRUE NORTH
APPROXIMATE MEAN
DECLINATION 1955
LOCATION MAP

Figure 13.



TYPE SECTION OF THE RICES MUDSTONE AND TWOBAR SHALE MEMBERS OF THE SAN LORENZO FORMATION, KINGS CREEK, CALIFORNIA

SECS. 31 AND 6, T. 8 S. AND T. 9 S., R. 2 W., M. D. B. M.

FROM REPORT BY EARL E. BRABB, 1960

"GEOLOGY OF THE BIG BASIN AREA, SANTA CRUZ MOUNTAINS, CALIFORNIA"

BASE MAP ENLARGED FROM U. S. GEOLOGICAL SURVEY BIG BASIN AND CASTLE ROCK RIDGE 7.5 QUADRANGLES, 1955 EDITIONS. COLLECTING LOCALITIES AND DETAILS OF KINGS CREEK SURVEYED WITH BRUNTON COMPASS AND TAPE

LEGEND

30° STRIKE AND DIP OF BEDS — F FAULT ... COSET CONTACT

⊙ COLLECTING LOCALITIES ▬ FORMATION OR MEMBER CONTACT

CONTOUR INTERVAL 40 FEET

SCALE

200 0 200 400 600 800 1000 1200 1400 FEET

0 200 m.

ntinued

STRATIGRAPHIC COLUMN

OF THE TYPE TWOBAR SHALE AND RICES MUDSTONE MEMBERS OF THE SAN LORENZO FORMATION, AND ADJACENT UNITS, KINGS CREEK, CALIFORNIA

Sec. 31, T.8 S., R.2 W. and Sec. 6, T.9 S., R.2 W., Mount Diablo Base and Meridian

From report by Earl E. Brabb, 1960

"Geology of the Big Basin area, Santa Cruz Mountains, California"

PREDOMINANT PARTICLE SIZE

- Medium-grained sandstone (Median diameter 0.25-0.50 mm.)
- Fine- to very fine-grained sandstone (median diameter 0.12-0.25 mm.)
- Interbedded fine- to very fine-grained sandstone and mudstone
- Mudstone (Median dia.<0.06 mm.)
- Shale (Median dia.<0.06 mm.)
- Fault - part of section missing
- Covered

PREDOMINANT STRATIFICATION

V =	Very thick-bedded (massive of authors)	>100 cm.
T =	Thick-bedded	30-100
M =	Medium-bedded	10-30
H =	Thin-bedded	3-10
E =	Very thin-bedded	1-3
L =	Laminated	<1 cm.

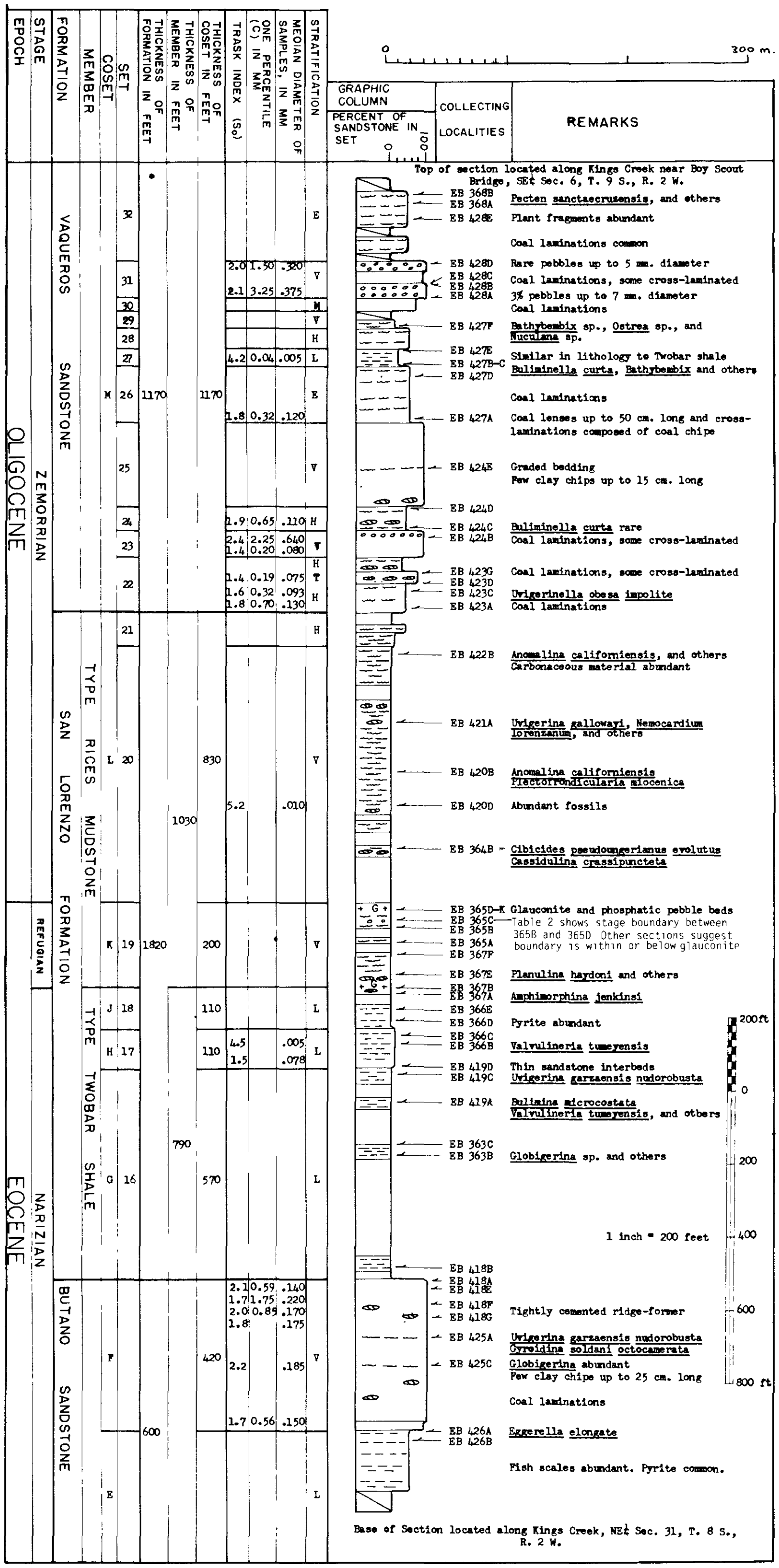
- Carbonate concretion
- + G + Glauconite bed
- Collecting locality

NOTES

(1) Sandstones are light gray (N7) to medium dark gray (N4); mudstones and shales are olive gray (5Y 4/1) to olive black (5Y 2/1), where fresh and wet.

(2) Section measured with tape and Brunton compass.

Figure 14.--Stratigraphic column, Kings Creek area


EPOCH
STAGE
FORMATION
MEMBER
COSET
SET
THICKNESS OF FORMATION IN FEET
THICKNESS OF MEMBER IN FEET
THICKNESS OF COSET IN FEET
TRASK INDEX (So)
ONE PERCENTILE (C) IN MM
MEDIAN DIAMETER OF SAMPLES, IN MM
STRATIFICATION
0 300 m.
GRAPHIC COLUMN
PERCENT OF SANDSTONE IN SET 0 100
COLLECTING LOCALITIES
REMARKS
OLIGOCENE
EOCENE
ZEMORRIAN
REFUGIAN
NARIZIAN
VAQUEROS SANDSTONE
SAN LORENZO FORMATION
TYPE RICES MUDSTONE
TYPE TWOBAR SHALE
BUTANO SANDSTONE
Top of section located along Kings Creek near Boy Scout Bridge, SE¼ Sec. 6, T. 9 S., R. 2 W.
EB 368B
EB 368A Pecten sanctaecruzensis, and others
EB 428E Plant fragments abundant
Coal laminations common
EB 428D Rare pebbles up to 5 mm. diameter
EB 428C Coal laminations, some cross-laminated
EB 428B
EB 428A 3% pebbles up to 7 mm. diameter
Coal laminations
EB 427F Bathybembix sp., Ostrea sp., and Nuculana sp.
EB 427E Similar in lithology to Twobar shale
EB 427B-C Buliminella curta, Bathybembix and others
EB 427D
Coal laminations
EB 427A Coal lenses up to 50 cm. long and cross-laminations composed of coal chips
EB 424E Graded bedding
Few clay chips up to 15 cm. long
EB 424D
EB 424C Buliminella curta rare
EB 424B Coal laminations, some cross-laminated
EB 423G Coal laminations, some cross-laminated
EB 423D
EB 423C Uvigerinella obesa impolite
EB 423A Coal laminations
EB 422B Anomalina californiensis, and others
Carbonaceous material abundant
EB 421A Uvigerina gallowayi, Nemocardium lorenzanum, and others
EB 420B Anomalina californiensis
Plectofrondicularia miocenica
EB 420D Abundant fossils
EB 364B Cibicides pseudoungerianus evolutus
Cassidulina crassipunctata
EB 365D-K Glauconite and phosphatic pebble beds
EB 365C Table 2 shows stage boundary between 365B and 365D Other sections suggest boundary is within or below glauconite
EB 365B
EB 365A
EB 367F
EB 367E Planulina haydoni and others
EB 367B
EB 367A Amphimorphina jenkinsi
EB 366E
EB 366D Pyrite abundant
EB 366C
EB 366B Valvulineria tumeyensis
EB 419D Thin sandstone interbeds
EB 419C Uvigerina garzaensis nudorobusta
EB 419A Bulimina microcostata
Valvulineria tumeyensis, and others
EB 363C
EB 363B Globigerina sp. and others
1 inch = 200 feet
200 ft 0 200 400 600 800 ft
EB 418B
EB 418A
EB 418E
EB 418F Tightly cemented ridge-former
EB 418G
EB 425A Uvigerina garzaensis nudorobusta
Gyroidina soldani octocamerata
EB 425C Globigerina abundant
Few clay chips up to 25 cm. long
Coal laminations
EB 426A Eggerella elongate
EB 426B
Fish scales abundant. Pyrite common.
Base of Section located along Kings Creek, NE¼ Sec. 31, T. 8 S., R. 2 W.
M 26 1170 1170
L 20 830 1030
K 19 1820 200
J 18 110
H 17 110 790
G 16 570
F 420 600
E
32 E
31 2.0 1.50 .320 V
2.1 3.25 .375
30 M
29 V
28 H
27 4.2 0.04 .005 L
1.8 0.32 .120
25 V
24 1.9 0.65 .110 H
23 2.4 2.25 .640 V
1.4 0.20 .080 H
22 1.4 0.19 .075 T
1.6 0.32 .093 H
1.8 0.70 .130
21 H
5.2 .010
4.5 .005
1.5 .078
2.1 0.59 .140
1.7 1.75 .220
2.0 0.89 .170
1.8 .175
2.2 .185 V
1.7 0.56 .150
L

TWO BAR CREEK SECTION

The Two Bar Creek section is interesting because it shows the Vaqueros Sandstone grading upward into very coarse-grained arkosic sandstone and conglomerate with shallow-water mollusks and barnacles. This shoaling in the Vaqueros Sandstone, which is also recorded by a diverse large invertebrate fauna in the Vaqueros along Zayante Creek 10 km to the east (table 3),

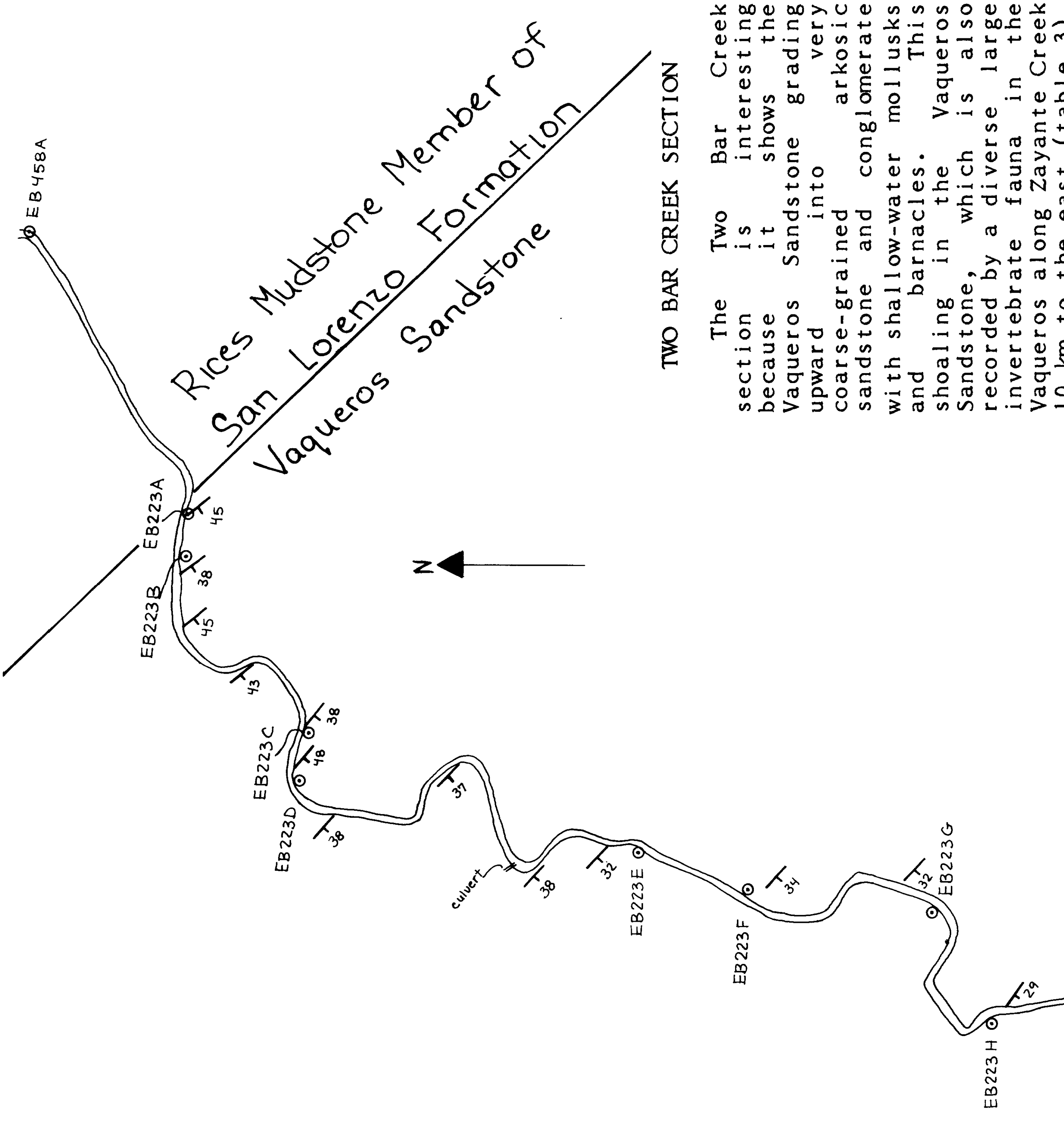
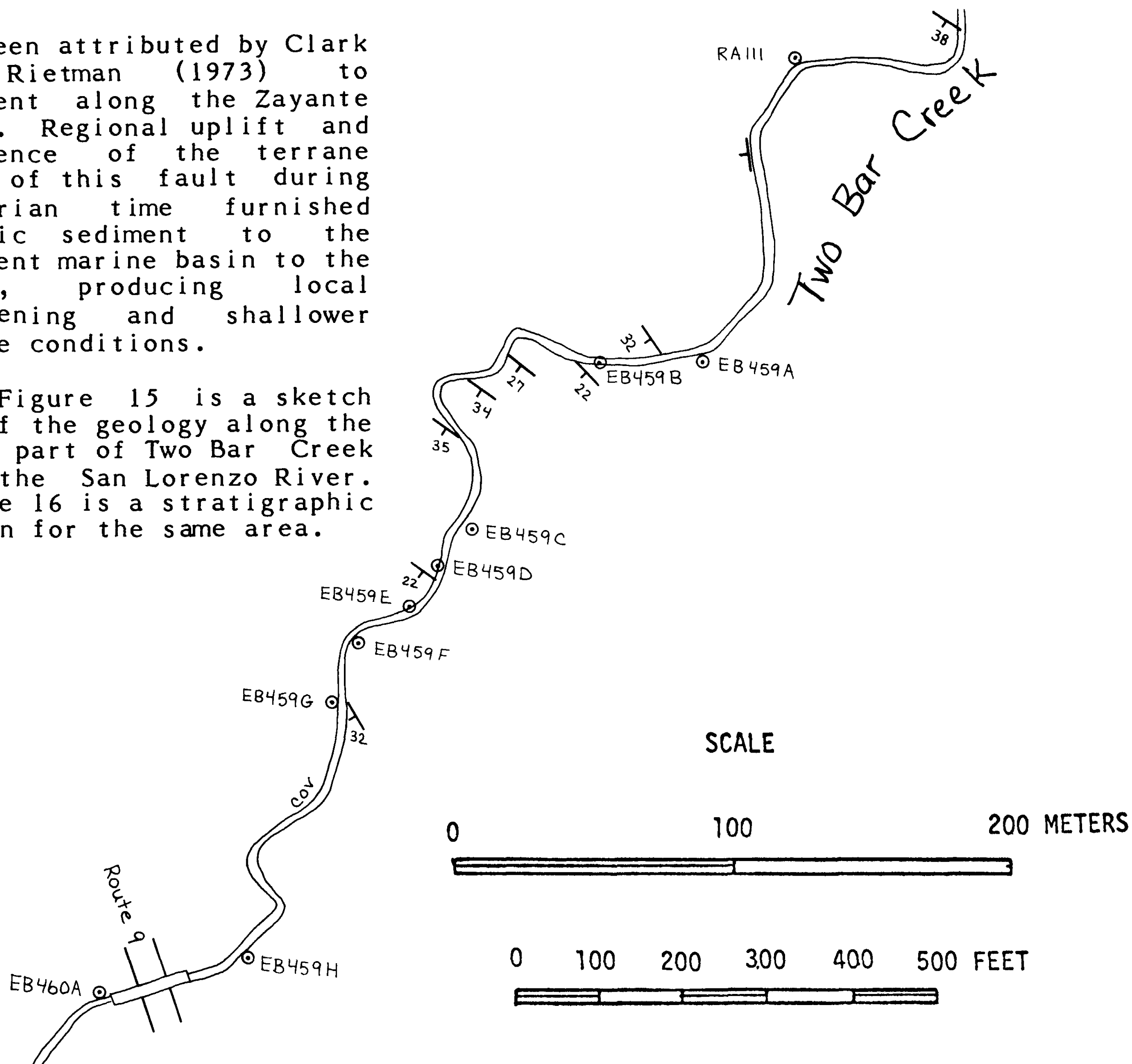


Figure 15.--Geologic sketch map of the lower Two Bar Creek and San Lorenzo River area showing formation contacts and localities where fossils and rocks were collected

has been attributed by Clark and Rietman (1973) to movement along the Zayante fault. Regional uplift and emergence of the terrane south of this fault during Zemorrian time furnished clastic sediment to the adjacent marine basin to the north, producing local coarsening and shallower marine conditions.

Figure 15 is a sketch map of the geology along the lower part of Two Bar Creek and the San Lorenzo River. Figure 16 is a stratigraphic column for the same area.



Measured by tape and compass, 1958 by E.E. Brabb and R.M. McCollom, Jr.

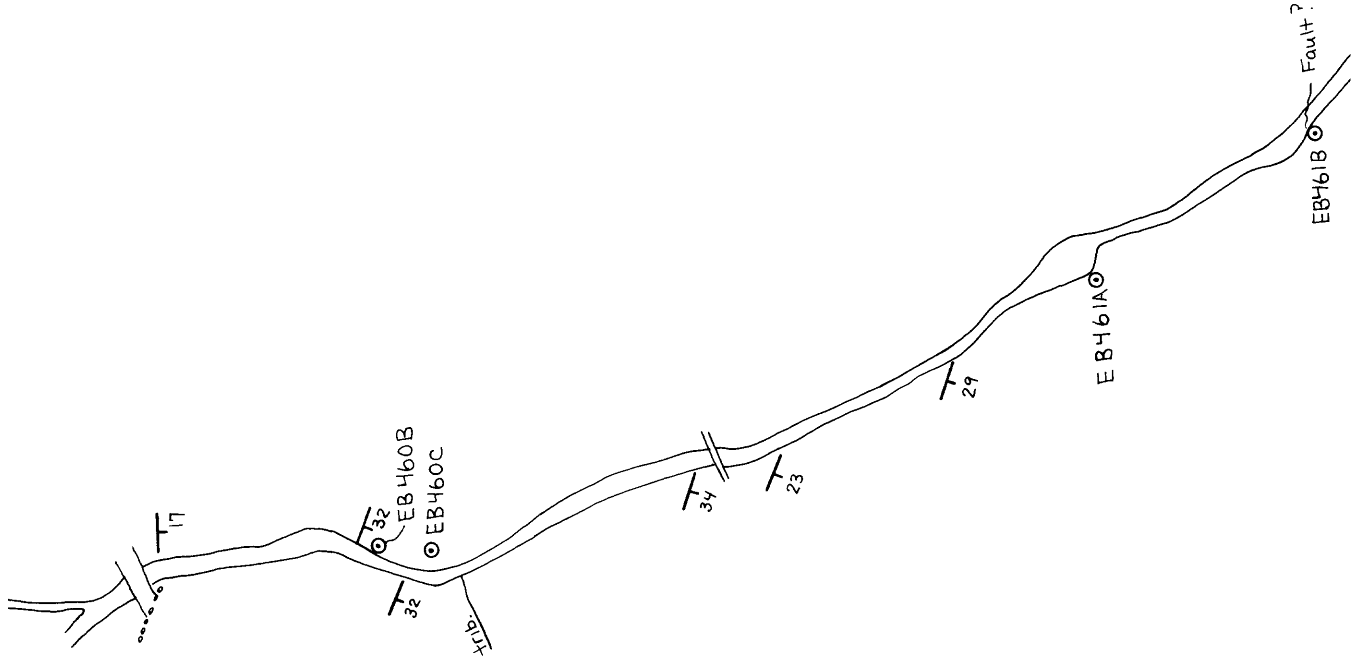
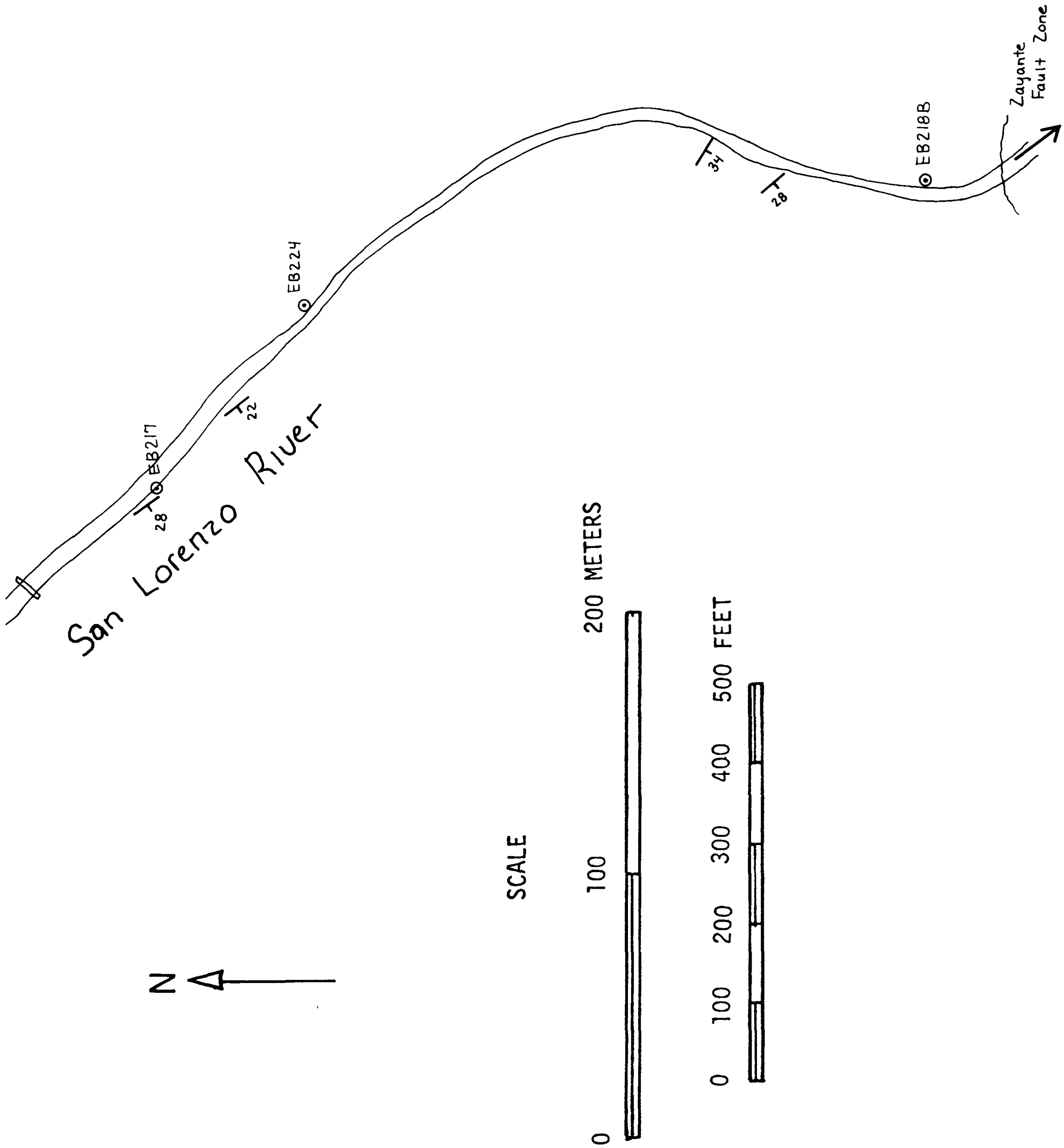


Figure 15.


Zayante Fault Zone
EB218B
34
28
EB224
22
EB217
28
San Lorenzo River
SCALE
0 100 200 METERS
0 100 200 300 400 500 FEET
N

ontinued

STRATIGRAPHIC COLUMN

OF THE VAQUEROS SANDSTONE AND UPPER PART OF THE SAN LORENZO FORMATION, TWO BAR CREEK AND SAN LORENZO RIVER SECTION

Secs. 18 and 19, T. 9 S., R. 2 W., Mount Diablo Base and Meridian

From report by Earl E. Brabb, 1960
"Geology of the Big Basin area, Santa Cruz Mountains, California"

LEGEND

PREDOMINANT PARTICLE SIZE

- Pebbles, cobbles, or boulders in medium- to coarse-grained sandstone
- Medium- to coarse-grained sandstone (Median diameter 0.25–1 mm.)
- Fine- to very fine-grained sandstone (Median diameter 0.12–0.25 mm.)
- Interbedded sandstone and mudstone
- Mudstone (Median dia. <0.06 mm.)
- Fault - part of section missing
- Covered

PREDOMINANT STRATIFICATION

V =	Very thick-bedded (massive of authors)	>100 cm.
T =	Thick-bedded	30–100
M =	Medium-bedded	10–30
H =	Thin-bedded	3–10
E =	Very thin-bedded	1–3
L =	Laminated	<1 cm.

Carbonate concretion

Collecting locality

0 — 200 m.

1 inch = 200 feet

200 ft — 0 — 200 — 400 — 600 — 800 ft

(1) Sandstones are light gray (N7) to medium dark gray (N4); mudstones are olive gray (5Y 4/1) to olive black (5Y 2/1) when fresh and wet.

(2) Section measured with tape and Brunton compass by R. McCollom and E. Brabb, 1958.

REMARKS	The top of the section is in the San Lorenzo River at the Zayante fault, NW¼ Sec. 19, T. 9 S., R. 2 W.	Oyster and barnacle fragments common. Thin mudstone containing pelecypods. Sandstone contains 1% glauconite		Pebbles up to 150 mm. in diameter are 5 to 15% by weight of the total sand in the sample.			Pebbles and cobbles up to 200 mm. dia. Pebbles up to 40 mm. diameter. Rare glauconite	*Ostrea* sp.		Contains a few granodiorite boulders, some 600 mm. in diameter. Pelecypod fragments abundant.		*Anomalina californiensis* and others	
COLLECTING LOCALITIES		EB 217, EB 224		EB 461A	EB 460C	EB 460B	EB 460A	EB 459G		EB 459C		EB 459B	EB 459A
STRATIFICATION		▷		▷	▷	▷	▷	▷	▷	▷	▷	▷	▷
MEDIAN DIAMETER OF SAMPLES, IN MM.				.250	.350	.195	.950			.250			.250
ONE PERCENTILE (C) IN MM.				1.75	1.25	0.49				2.00			1.15
TRASK INDEX (S_o)				2.2	1.7	1.4	2.8			2.5			1.9
THICKNESS OF SET IN FEET		185		220	140	85	110	410	40	95	60	40	40
THICKNESS OF COSET IN FEET		More than 1200											
THICKNESS OF FORMATION IN FEET		More than 2435											
SET		64		63	62	61	60	59	58	57	56	55	54
COSET	N												
MEMBER													
FORMATION	VAQUEROS SANDSTONE												
STAGE	ZEMORRIAN												
EPOCH	OLIGOCENE												

GRAPHIC COLUMN — PERCENT OF SANDSTONE IN SET

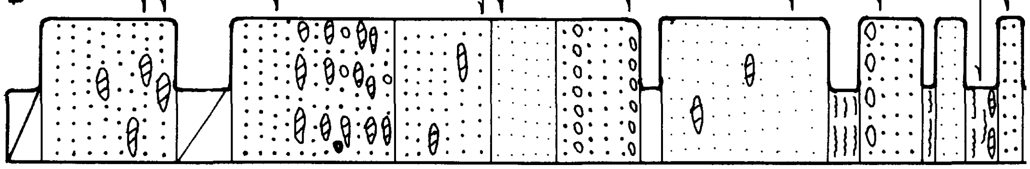


Figure 16.--continued on next page

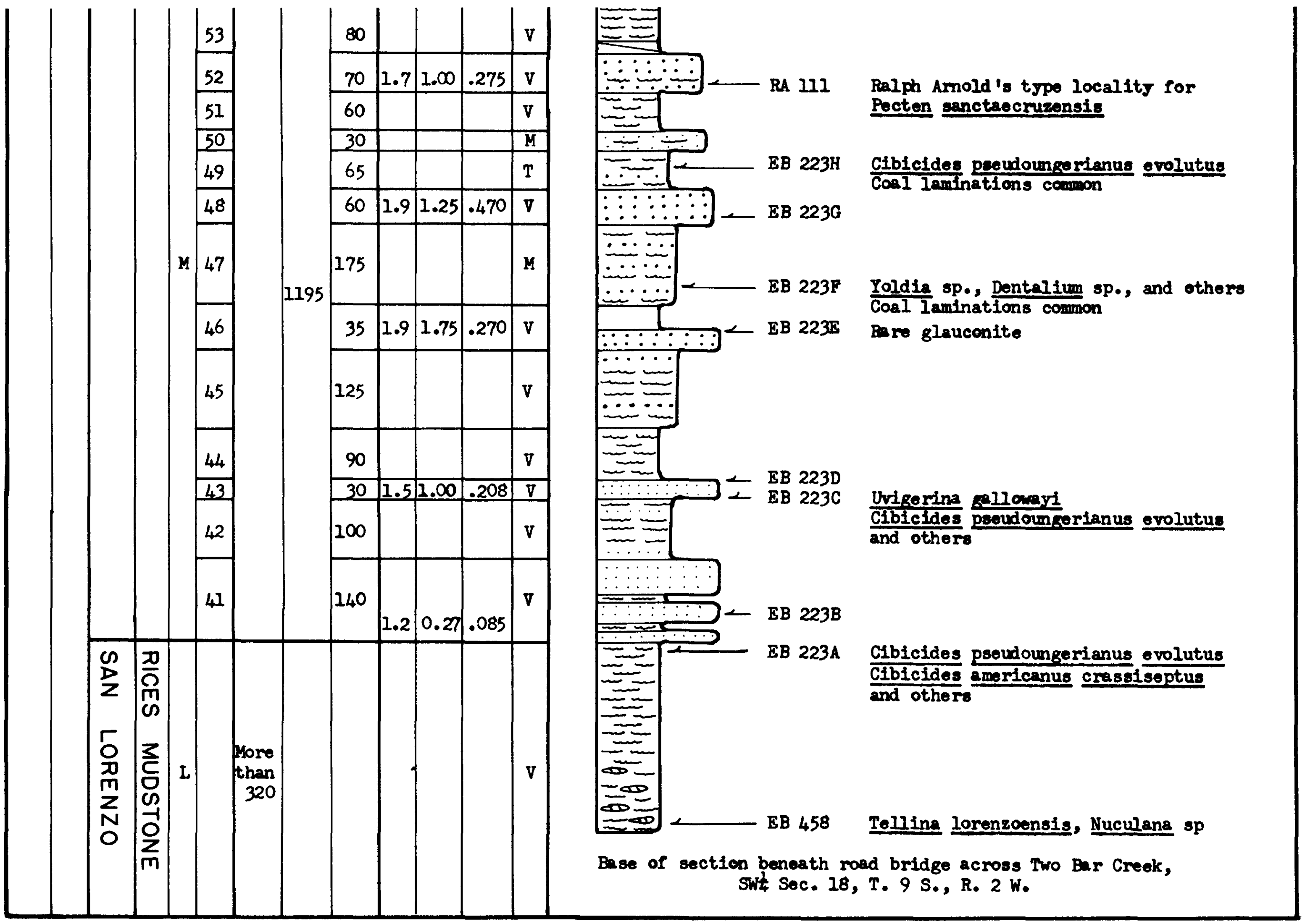


Figure 16.--Stratigraphic column, lower Two Bar Creek and San Lorenzo River area

BEAR CREEK SECTION

The Bear Creek area has been the training ground for a number of notable geology graduates of Stanford University who studied under the late Professor H. G. Schenck, such as R. M. Kleinpell, T. W. Dibblee, Jr., L. C. Forrest, H. D. Hobson, and L. J. Simon. All worked in the Bear Creek area, but no one has published previously a detailed locality map or stratigraphic column. Several paleontologic reports have been published, however. The earliest are by Arnold (1906 and 1908), who described some of the mollusks. Reports by Hobson (1932) and Cushman and Hobson (1935) mentioned collections from the Bear Creek area, including those that have holotypes for *Robulus barbati*, *Cassidulina crassipunctata*, *Anomalina californiensis* and *Cibicides pseudoungerianus evolutus*. Schenck (1936, p. 67-8) collected *Acila dalli* and other fossils from the Bear Creek area--his localities are shown on a map by Brabb (1960, fig. 14). Kleinpell (1938, table 10) lists benthonic foraminifers from the upper part of the San Lorenzo Formation along Bear Creek. Burchfiel (1964) has a generalized geologic map that shows a few of the important fossil localities. In particular, he discusses the Teilzone of *Pecten sanctaecruzensis*, which has been used to correlate rocks in the Santa Cruz Mountains with those in the Santa Lucia Range, 120 km to the south. Fairchild and others (1969, fig. 5) provided a geologic and locality map of the Upper Bear Creek area and a check list of foraminifers. Their discussion of the age and paleoecology of the faunas is very instructive, but their samples along the creek are difficult to locate precisely because of the paucity of cultural features. Their Bear Creek samples, together with their samples from the Brown School area nearby, provide the most extensive documentation yet published of the character of foraminifers from the middle part of the Butano Sandstone.

The geologic sketch map, figure 17, shows the upper part of the Bear Creek area. This section should be continued to the northeast to include the lower part of the Butano Sandstone. A section should also be measured along the lower part of Bear Creek where many of the fossil collections mentioned above were taken. Figure 18 is a stratigraphic column for the part of the section measured for the October conference.

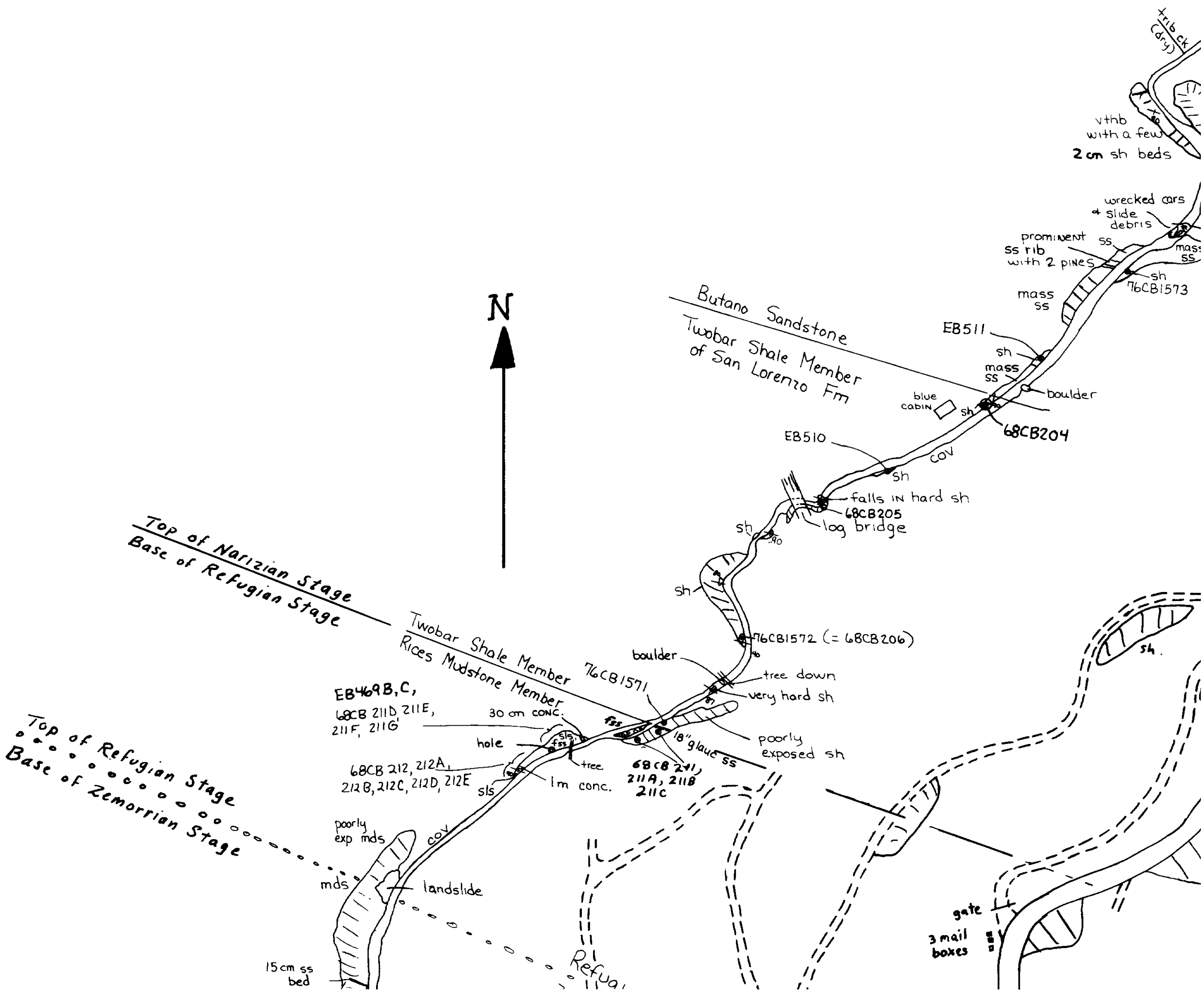
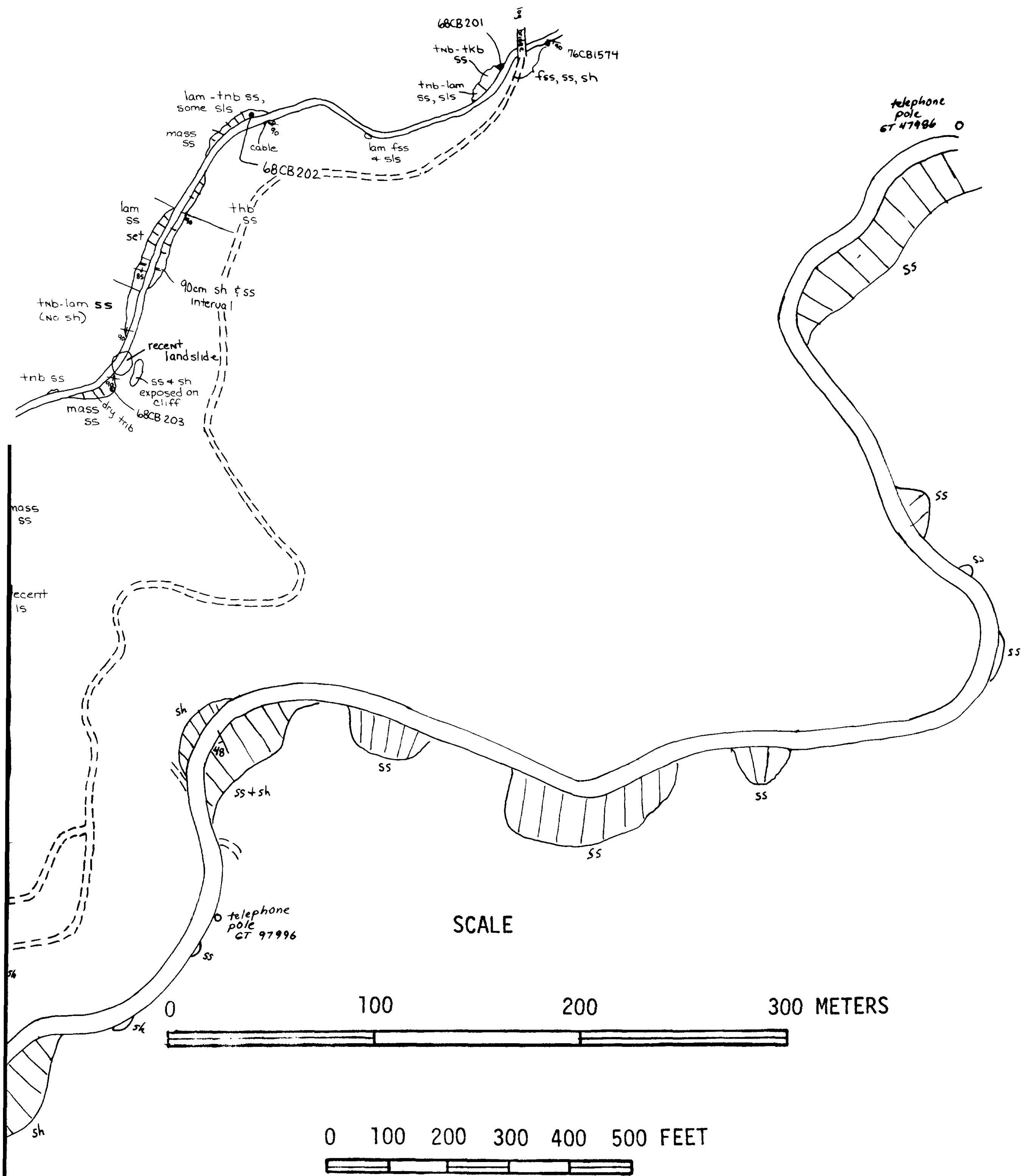


Figure 17.--Geologic sketch map of the upper Bear Creel



Measured by tape and compass, 1976-7 by E.E. Brabb, C.K. Throckmorton, and B.R. Hamachi

area showing formation contacts, stage boundaries and localities

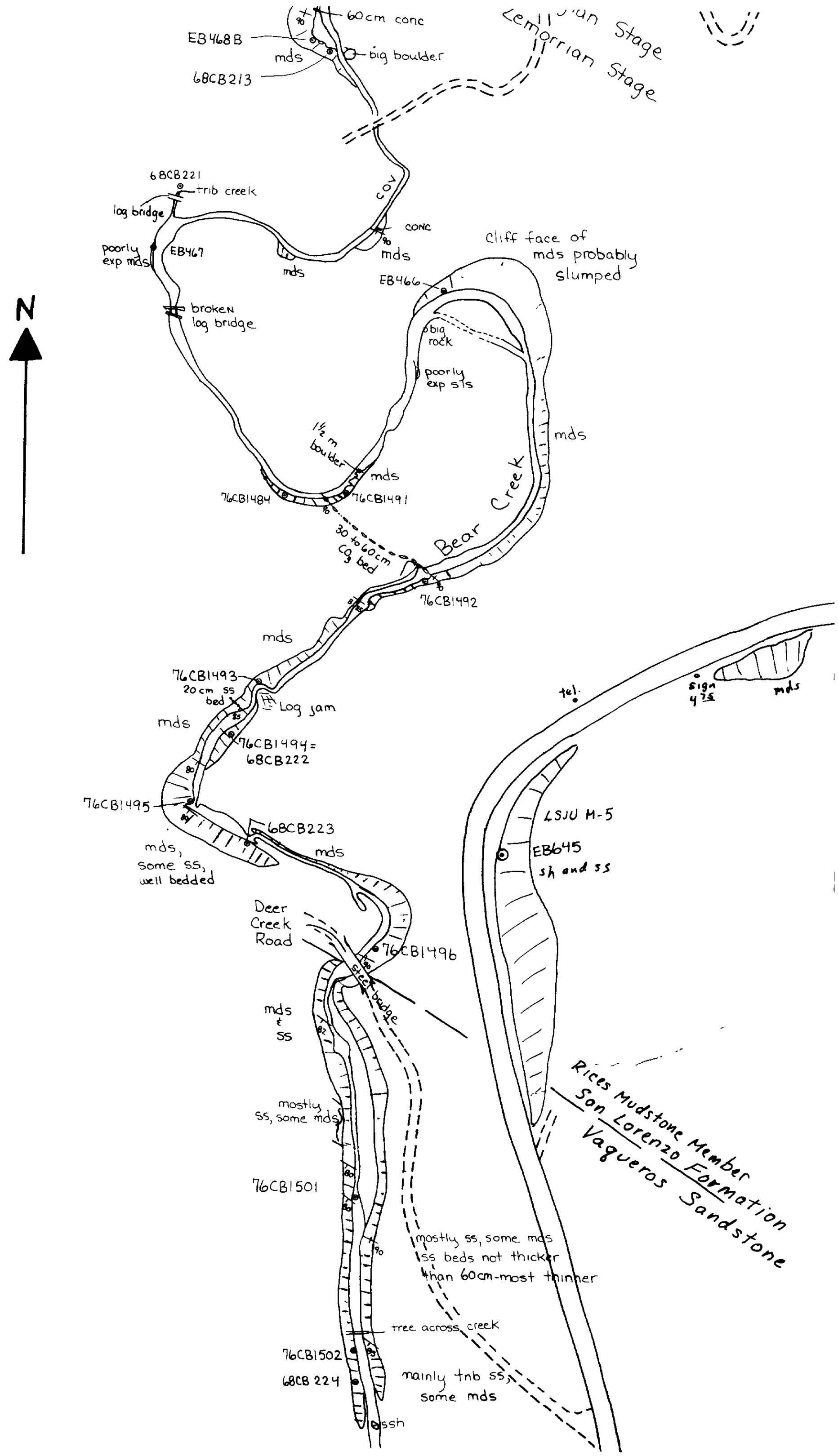
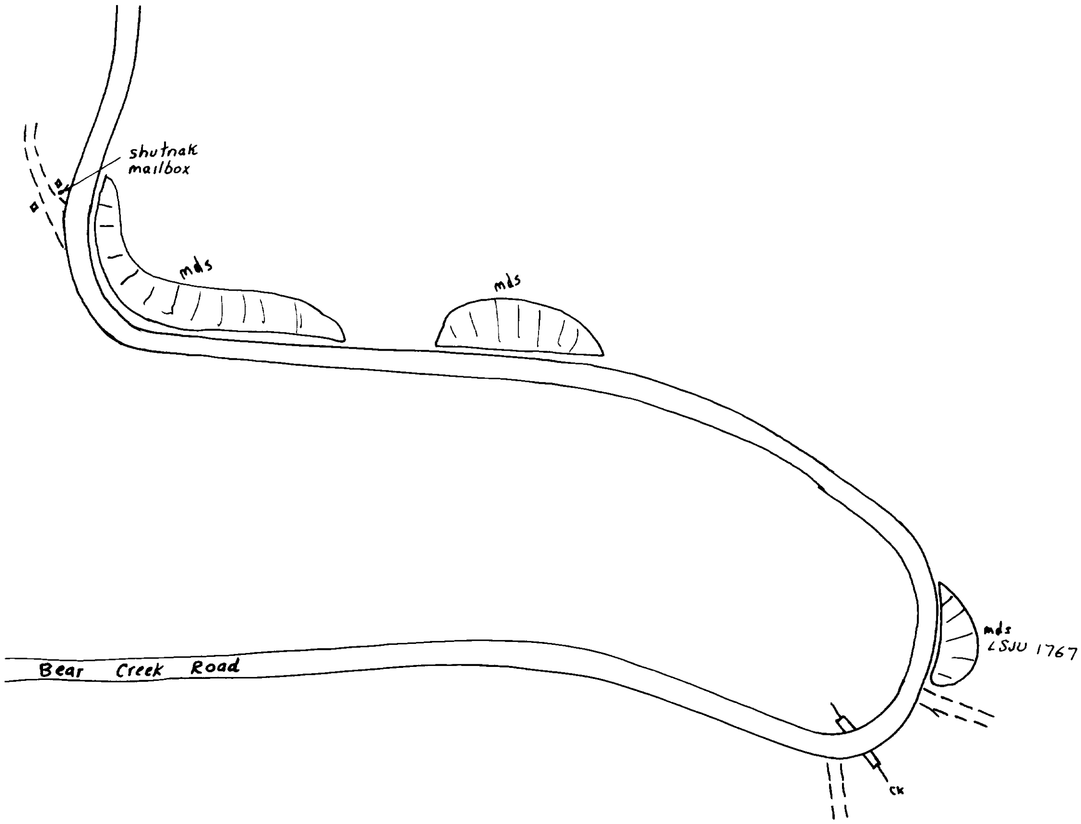

N
60cm conc
EB468B
mds
big boulder
68CB213
Lemorrian Stage
68CB221
trib creek
log bridge
cov
conc
mds
poorly exp mds
EB467
Cliff face of mds probably slumped
EB466
broken log bridge
big rock
poorly exp ss
mds
1½ m boulder
mds
76CB1484
76CB1491
Bear Creek
30 to 60 cm Cg bed
76CB1492
mds
tel.
sign
mds
76CB1493
20 cm ss bed
Log jam
mds
76CB1494=
68CB222
76CB1495
LSJU M-5
68CB223
EB645
sh and ss
mds
mds, some ss, well bedded
Deer Creek Road
76CB1496
steel bridge
mds & ss
mostly ss, some mds
Rices Mudstone Member
San Lorenzo Formation
Vaqueros Sandstone
76CB1501
mostly ss, some mds
ss beds not thicker than 60cm-most thinner
tree across creek
76CB1502
68CB 224
mainly tnb ss, some mds
ssh

Figure 17.



ontinued

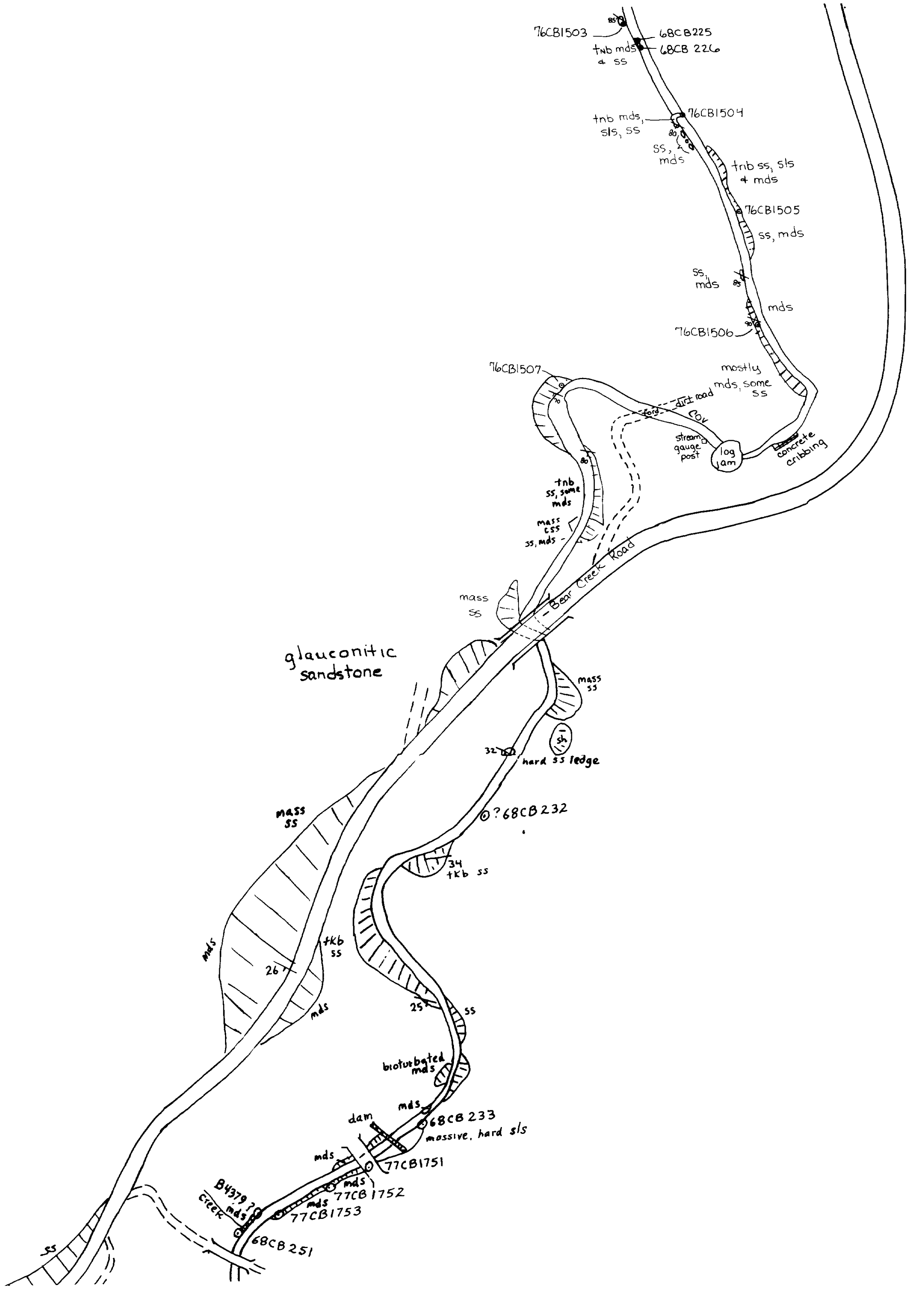
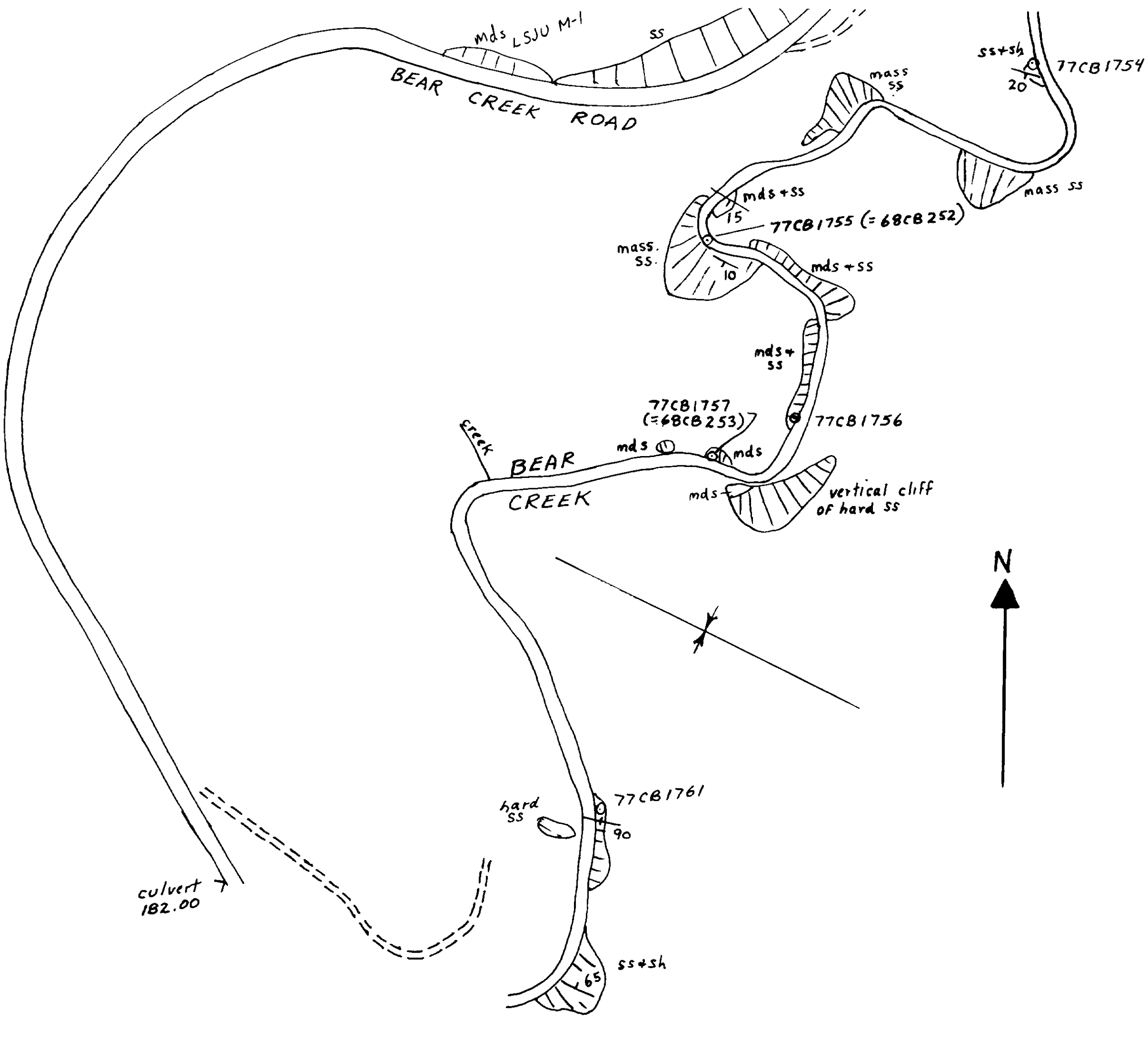

76CB1503
68CB225
tnb mds & ss
68CB 226
tnb mds, sls, ss
76CB1504
ss, & mds
tnb ss, sls & mds
76CB1505
ss, mds
ss, mds
mds
76CB1506
mostly mds, some ss
76CB1507
dirt road
ford
COV
stream gauge post
log jam
concrete cribbing
tnb ss, some mds
mass css
ss, mds
mass ss
Bear Creek Road
glauconitic sandstone
mass ss
32
hard ss ledge
?68CB 232
34
tkb ss
mass ss
mds
tkb ss
26
mds
25
ss
bioturbated mds
mds
dam
68CB 233
massive, hard sls
mds
77CB1751
mds
77CB 1752
mds
77CB1753
B4379 ?
mds
creek
68CB 251
ss

Figure 17.--



mds
LSJU M-1
ss
BEAR CREEK ROAD
ss+sh
77CB1754
20
mass ss
mass ss
mds+ss
15
77CB1755 (=68CB252)
mass. ss.
10
mds+ss
mds+ ss
77CB1757 (=68CB253)
77CB1756
creek
mds
mds
BEAR CREEK
mds
vertical cliff of hard ss
N
hard ss
77CB1761
90
culvert 182.00
ss+sh
65

continued

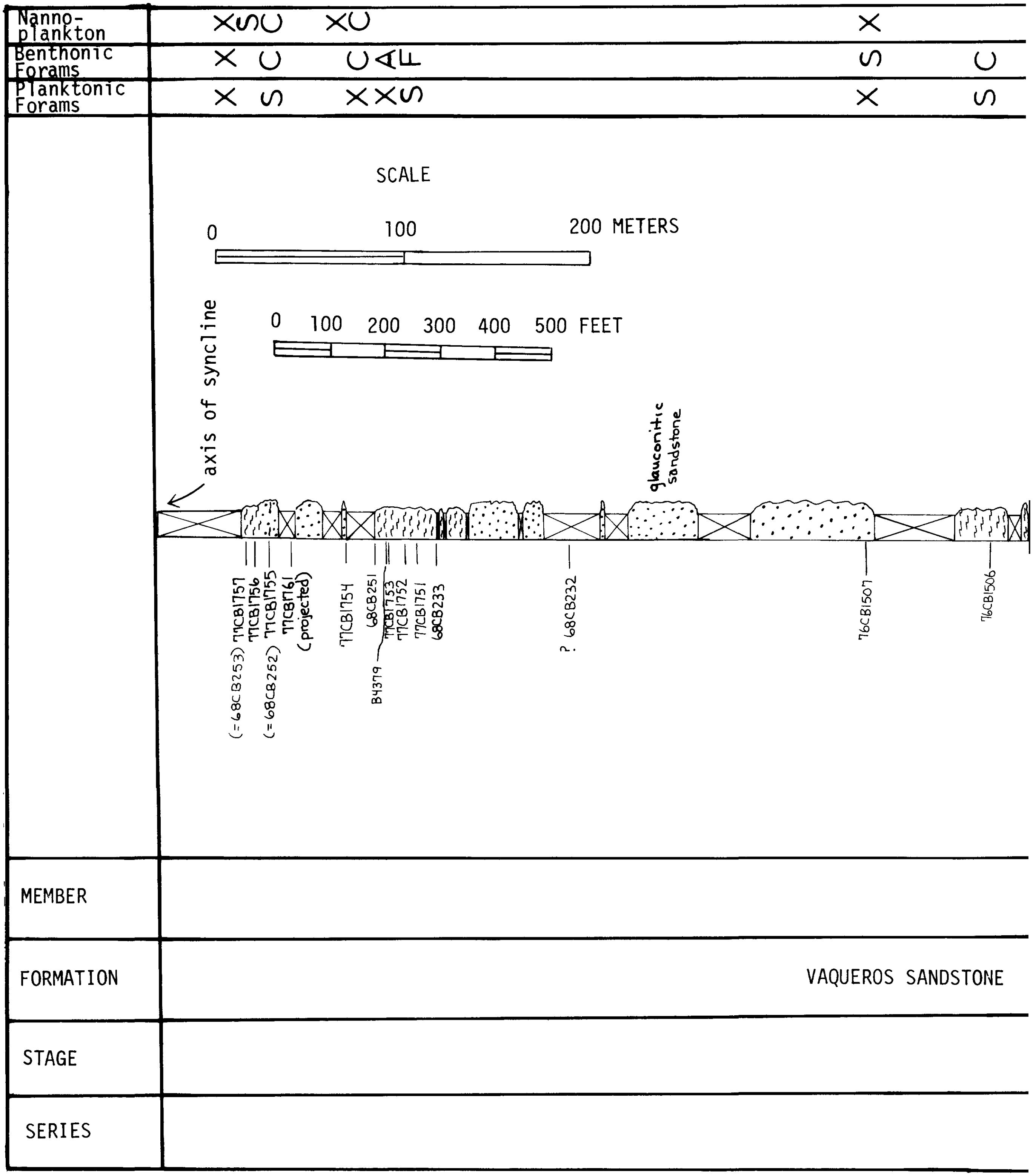
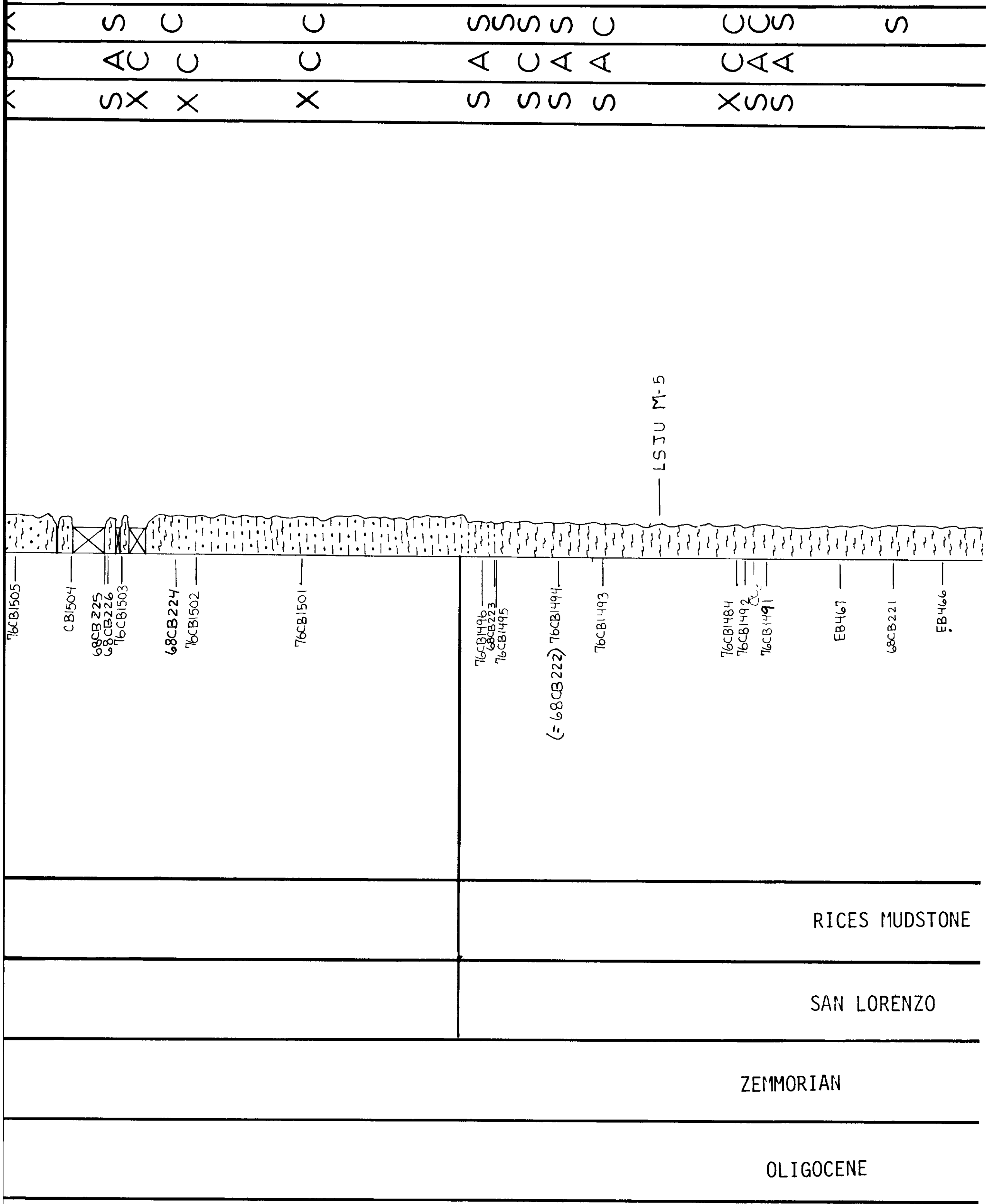
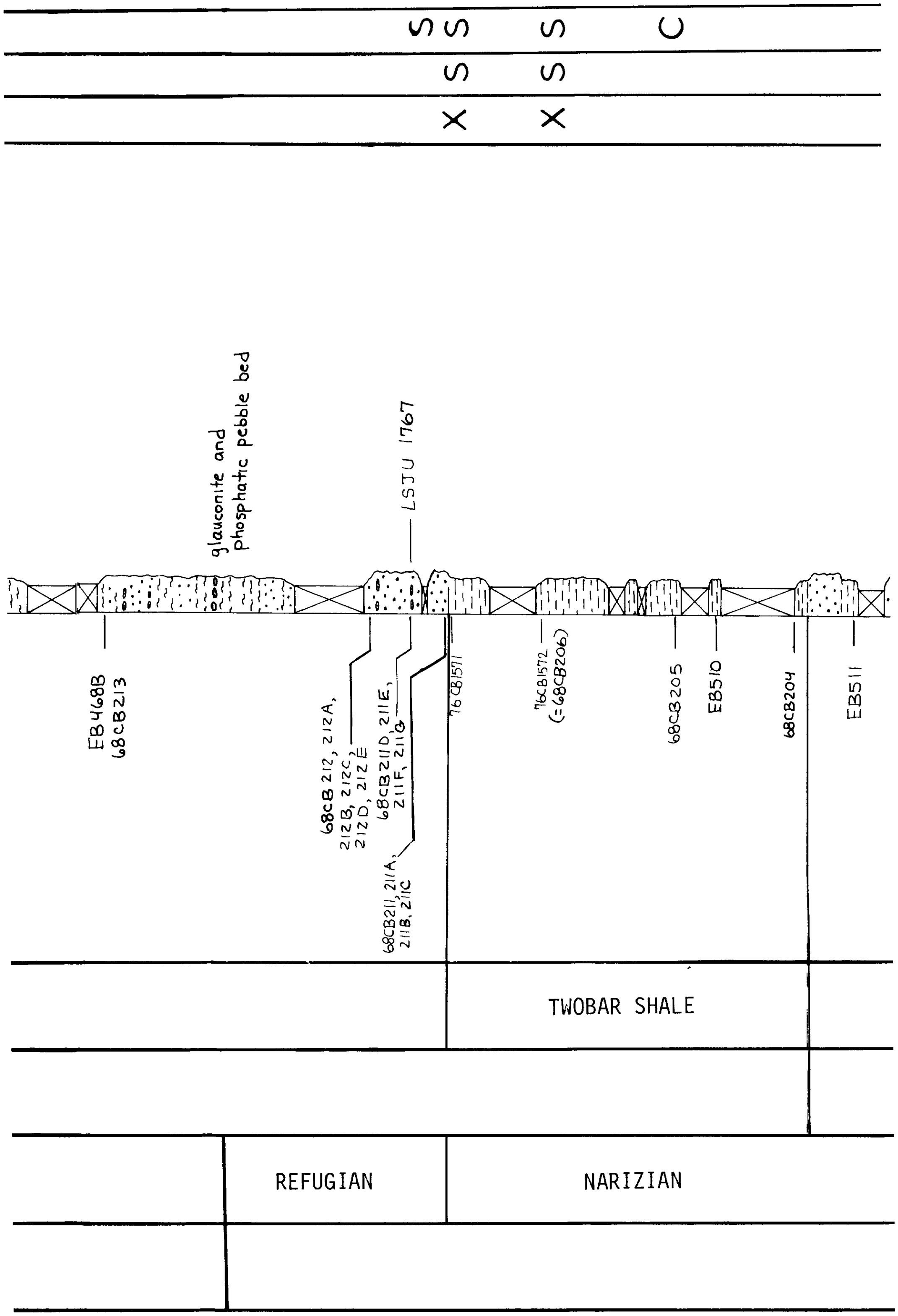


Figure 18.--Stratigraphic

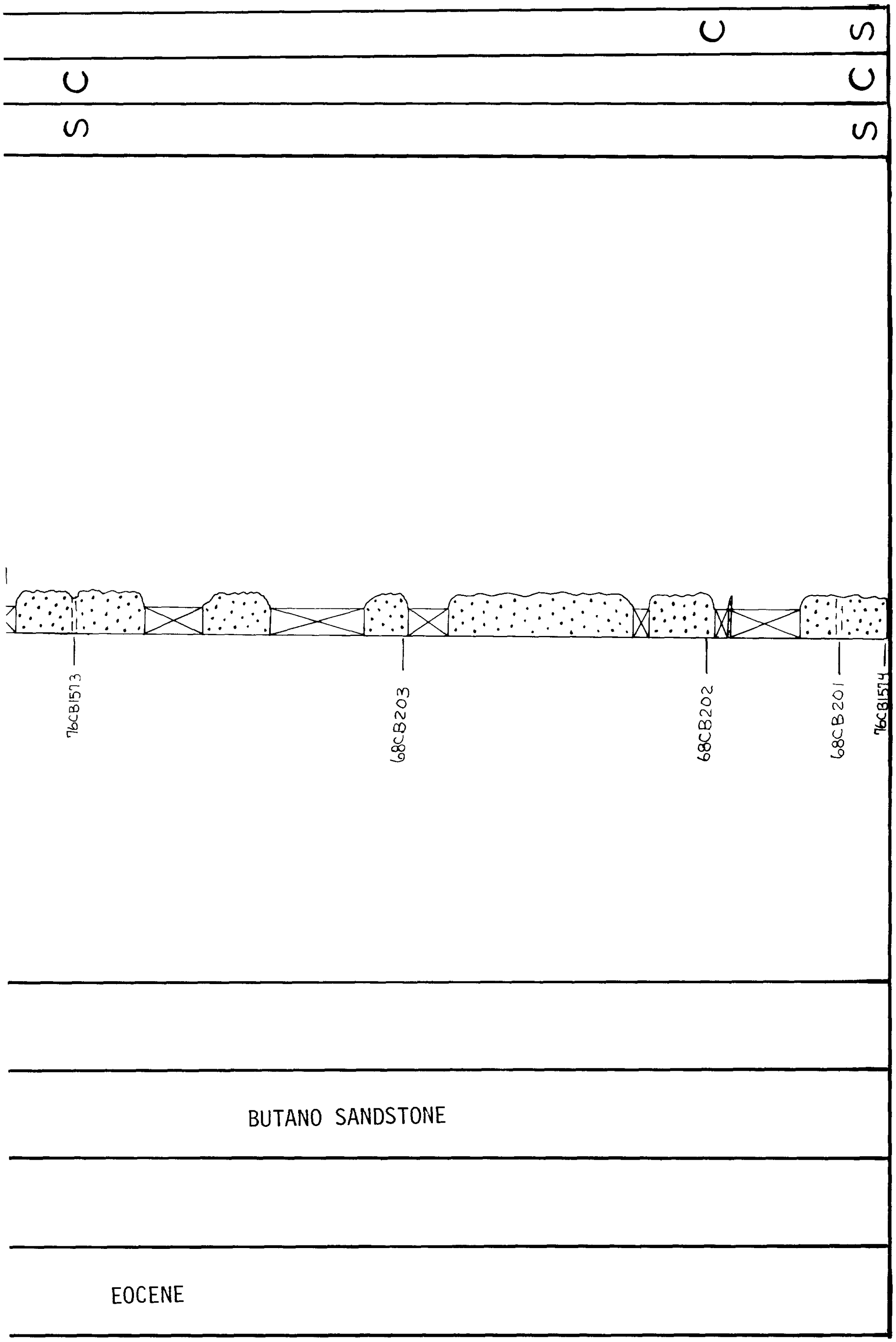


olumn, Bear Creek area

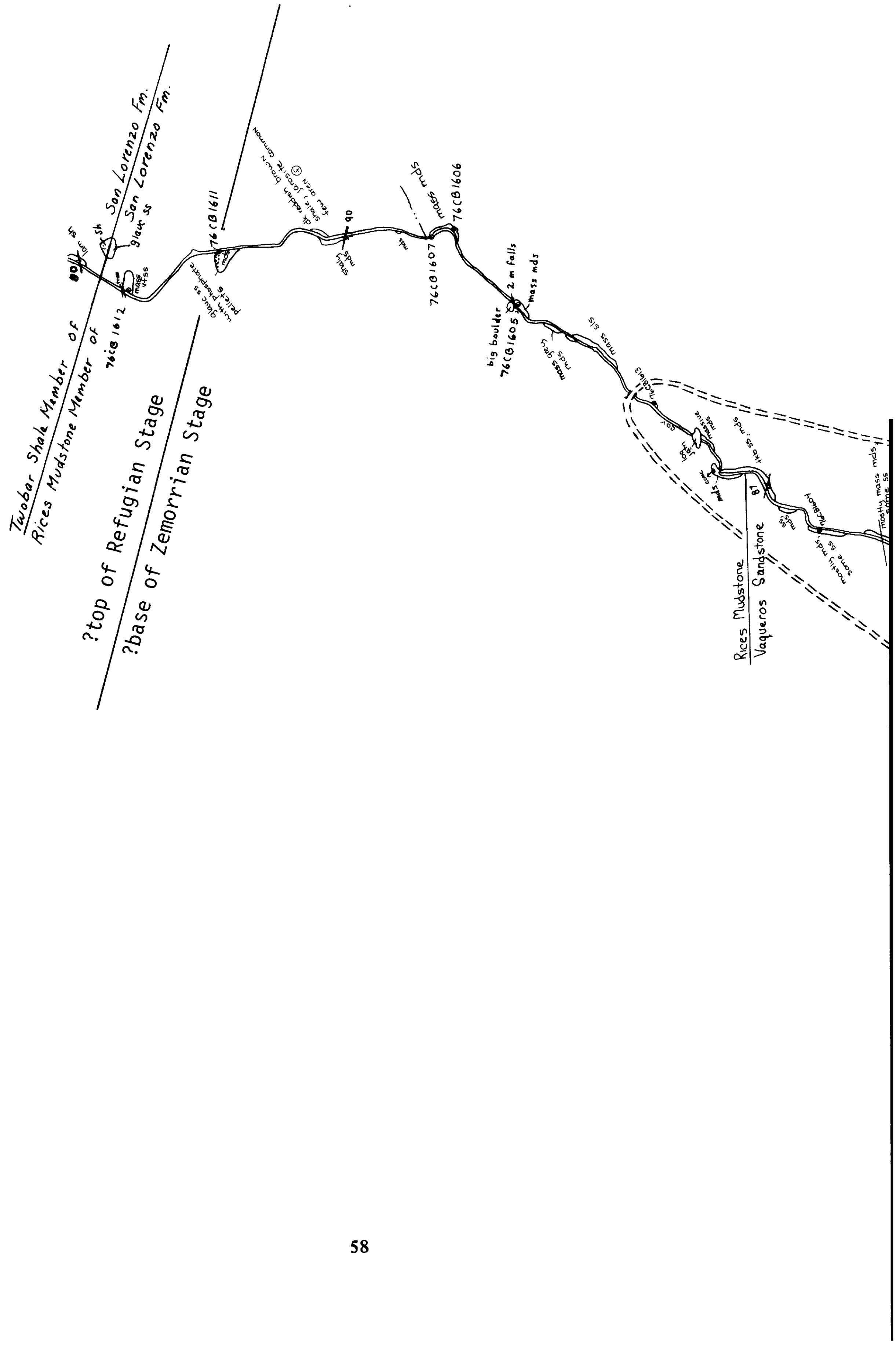


S S S C
S S
X X
glauconite and
phosphatic pebble bed
LSJU 1767
EB468B
68CB213
68CB212, 212A,
212B, 212C,
212D, 212E
68CB211D, 211E,
211F, 211G
68CB211, 211A,
211B, 211C
76CB1571
76CB1572
(=68CB206)
68CB205
EB510
68CB204
EB511
TWOBAR SHALE
REFUGIAN
NARIZIAN

Figure 18.·


C
S
C
C
S
S
76CB1513
68CB203
68CB202
68CB201
76CB1514
BUTANO SANDSTONE
EOCENE

ıtinued


Twobar Shale Member of San Lorenzo Fm.
Rices Mudstone Member of San Lorenzo Fm.
?top of Refugian Stage
?base of Zemorrian Stage
76CB1612
glauc ss
76CB1611
76CB1607
76CB1606
mass mds
2 m falls
big boulder
76CB1605
mass mds
mass gray mds
mass ss
Rices Mudstone
Vaqueros Sandstone
81
90

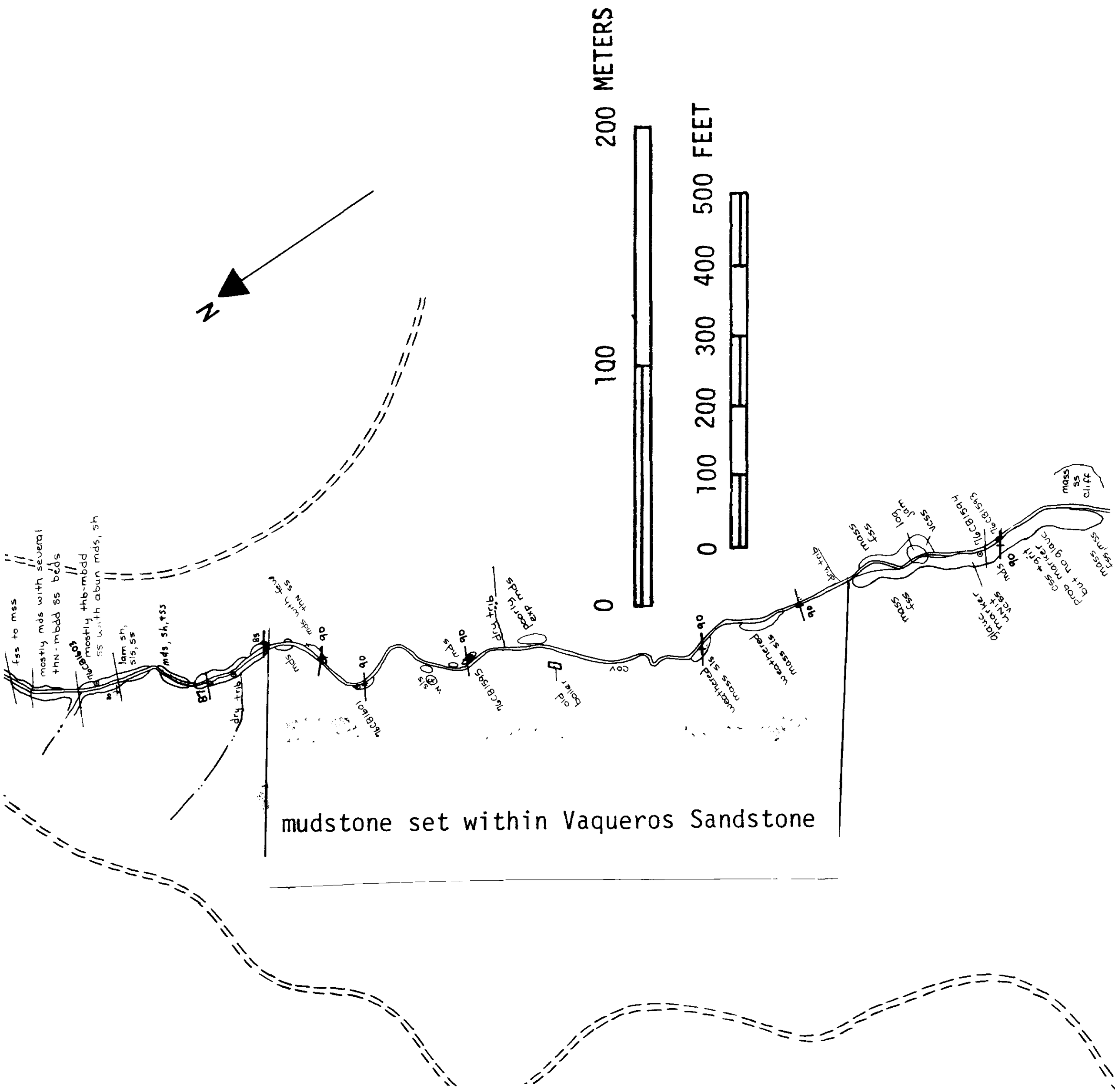
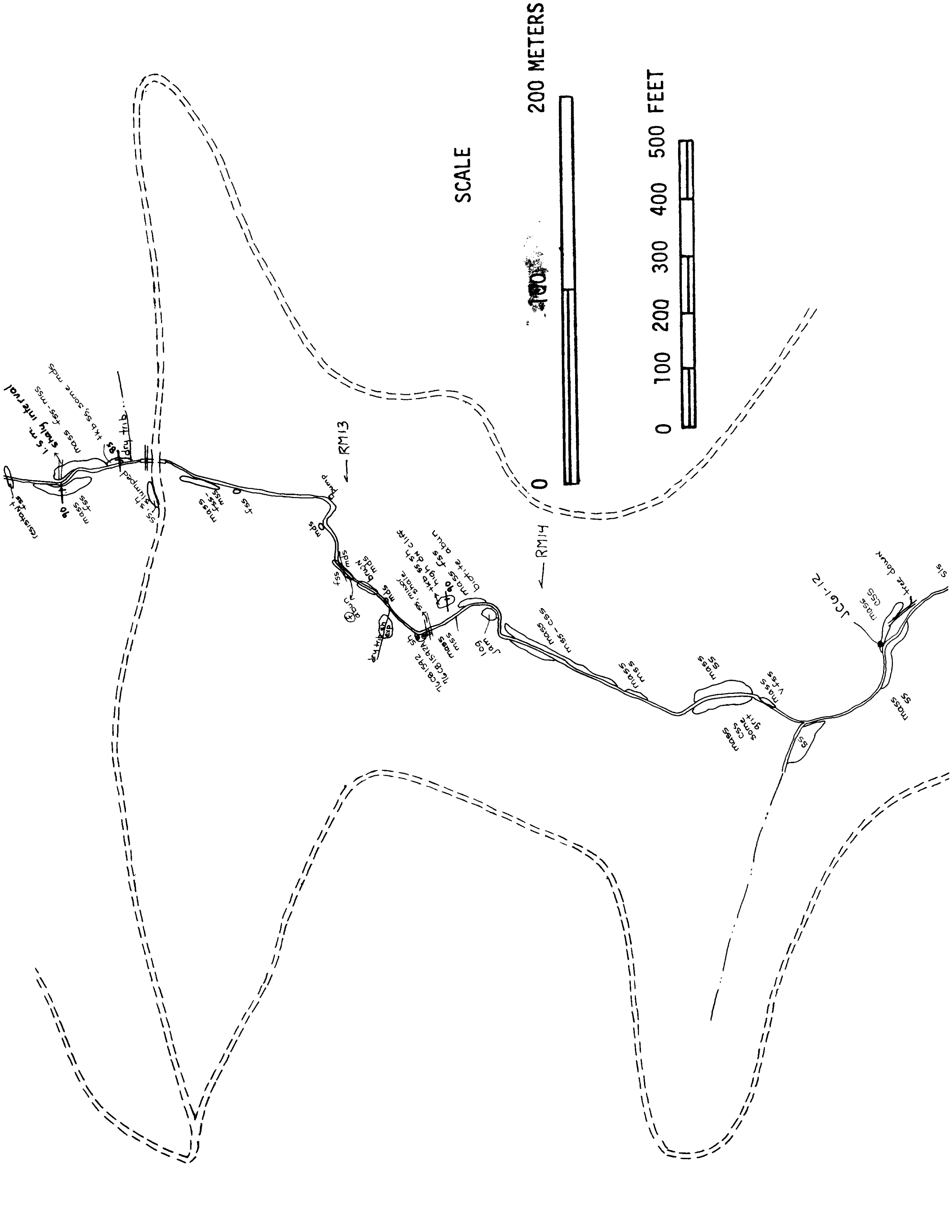


Figure 19.--continued on next page

ZAYANTE CREEK SECTION

Distinctive glauconitic sandstone marker beds were used by McCollom (1959) to tie the Vaqueros Sandstone of Bear Creek into a measured section along upper Zayante Creek, 6 km to the east. The Zayante Creek section has fewer exposures of the Butano Sandstone and San Lorenzo Formation but has good exposures of the Vaqueros Sandstone and includes the overlying Lambert Shale, which is not present along Bear Creek. It also has a basalt flow within the Vaqueros from which Turner (1970, p. 100-101) obtained a date of 23.1 plus or minus 0.7 m.y.


SCALE
0
100
200 METERS
0
100
200
300
400
500 FEET
RM13
RM14
JCG1-12

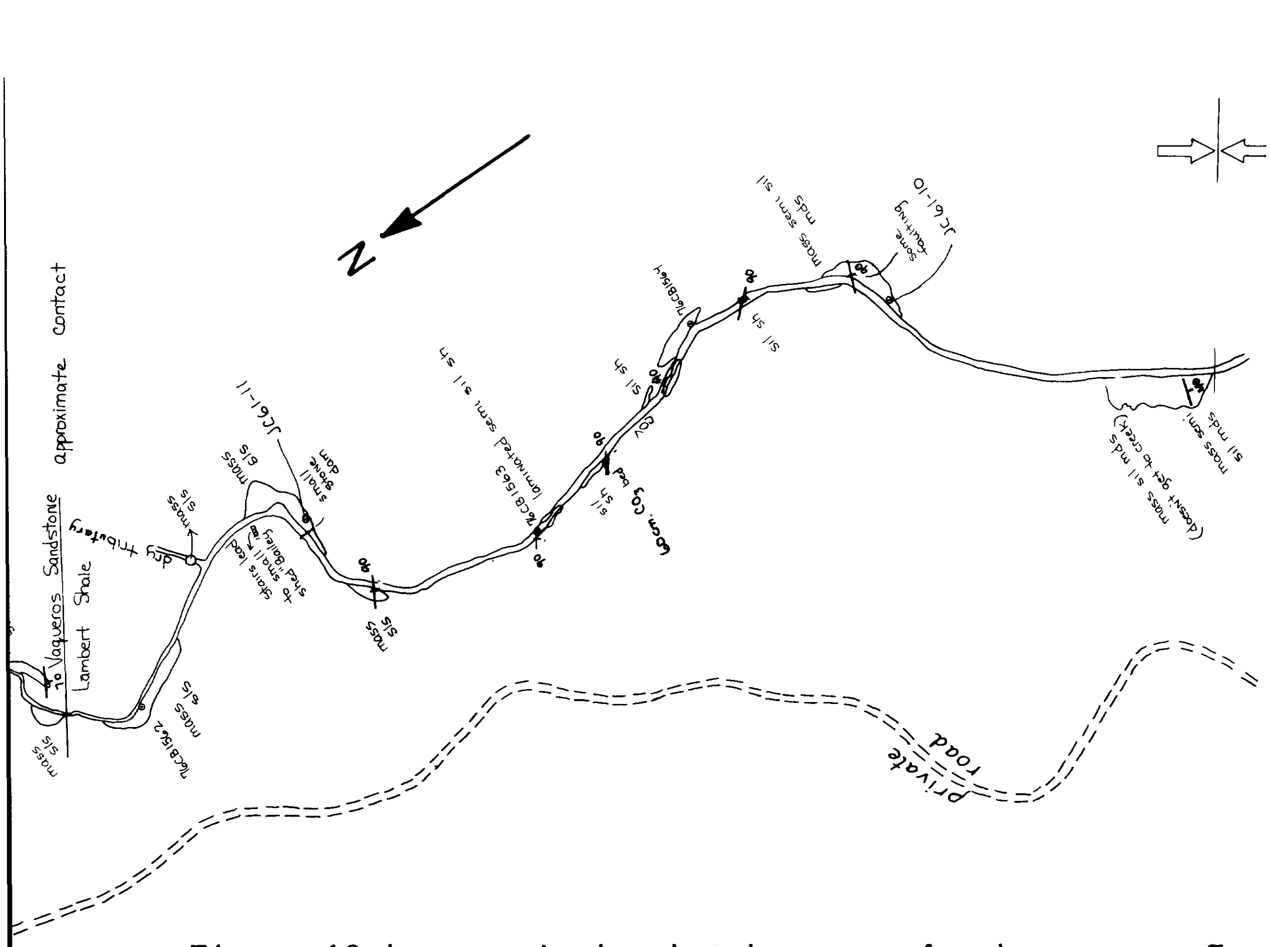


Figure 19.--Geologic sketch map, upper Zayante Creek, north limb of syncline

Figure 19 is a geologic sketch map of the upper Zayante Creek area showing the geologic units on the northern limb of the San Lorenzo syncline. Figure 20 is a stratigraphic column for the section. Figure 21 adjoins figure 19 to the south and shows the Vaqueros Sandstone and Lambert Shale on the south limb of the syncline.

The Zayante Sandstone is truncated to the south by the Zayante fault. Thus, the north limb of the San Lorenzo syncline has the Butano Sandstone, San Lorenzo Formation, Vaqueros Sandstone and Lambert Shale, whereas the south limb has only the latter two units and the Zayante Sandstone. Another complication is that the Zemorrian-Saucesian Stage boundary appears to fall lower in the section on the south limb of the syncline.

Figure 22 is a stratigraphic column for the south limb of the syncline. Mollusks from bioherms resting on the basalt within the Vaqueros were reported previously by Clark (1968, p. 177)--a more complete list is given on table 3. This larger invertebrate fauna includes stratigraphically diagnostic molluscan representatives of the Turritella inezana Zone, which Kleinpell (1938, fig. 14) correlates with his Zemorrian Stage.

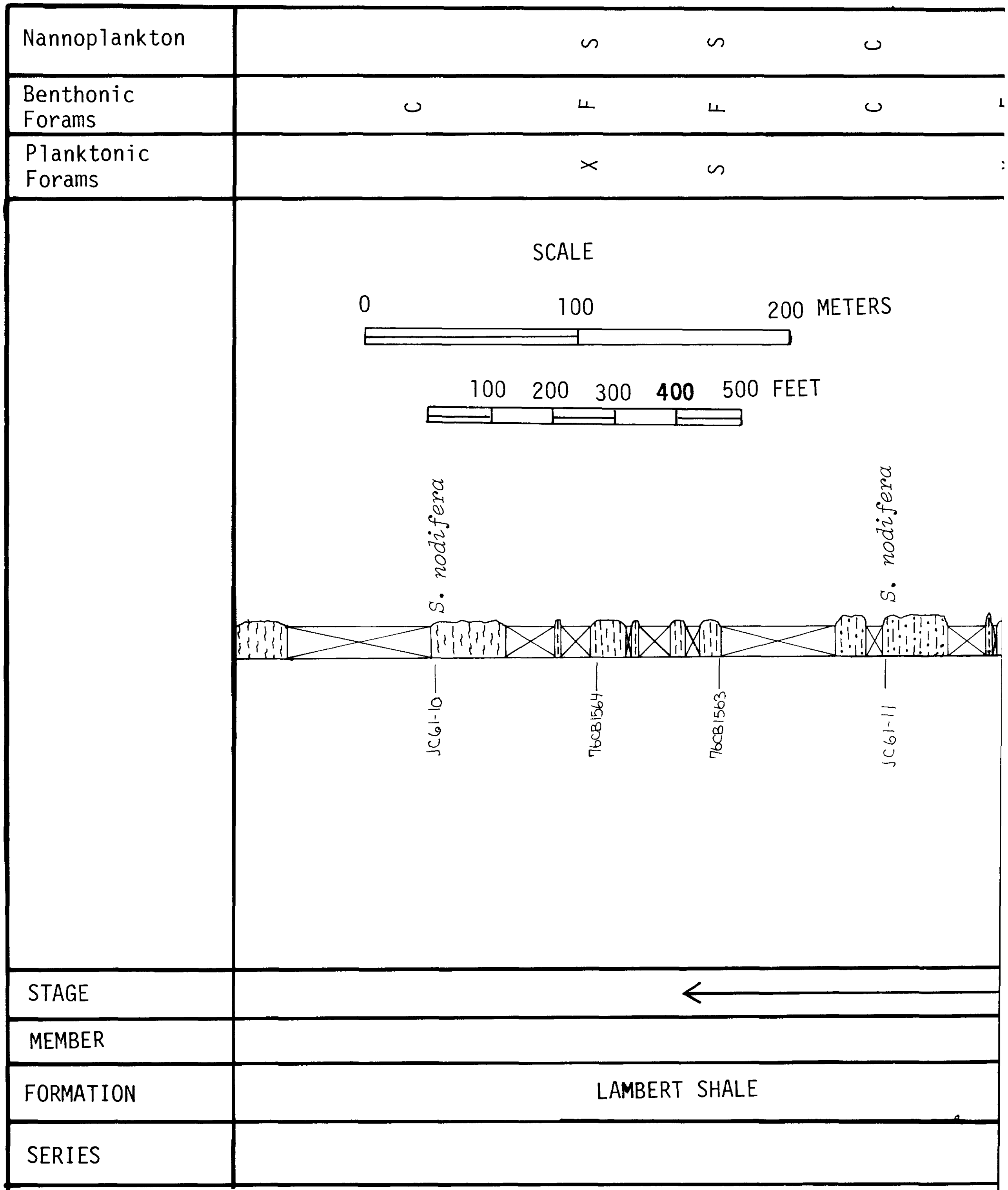
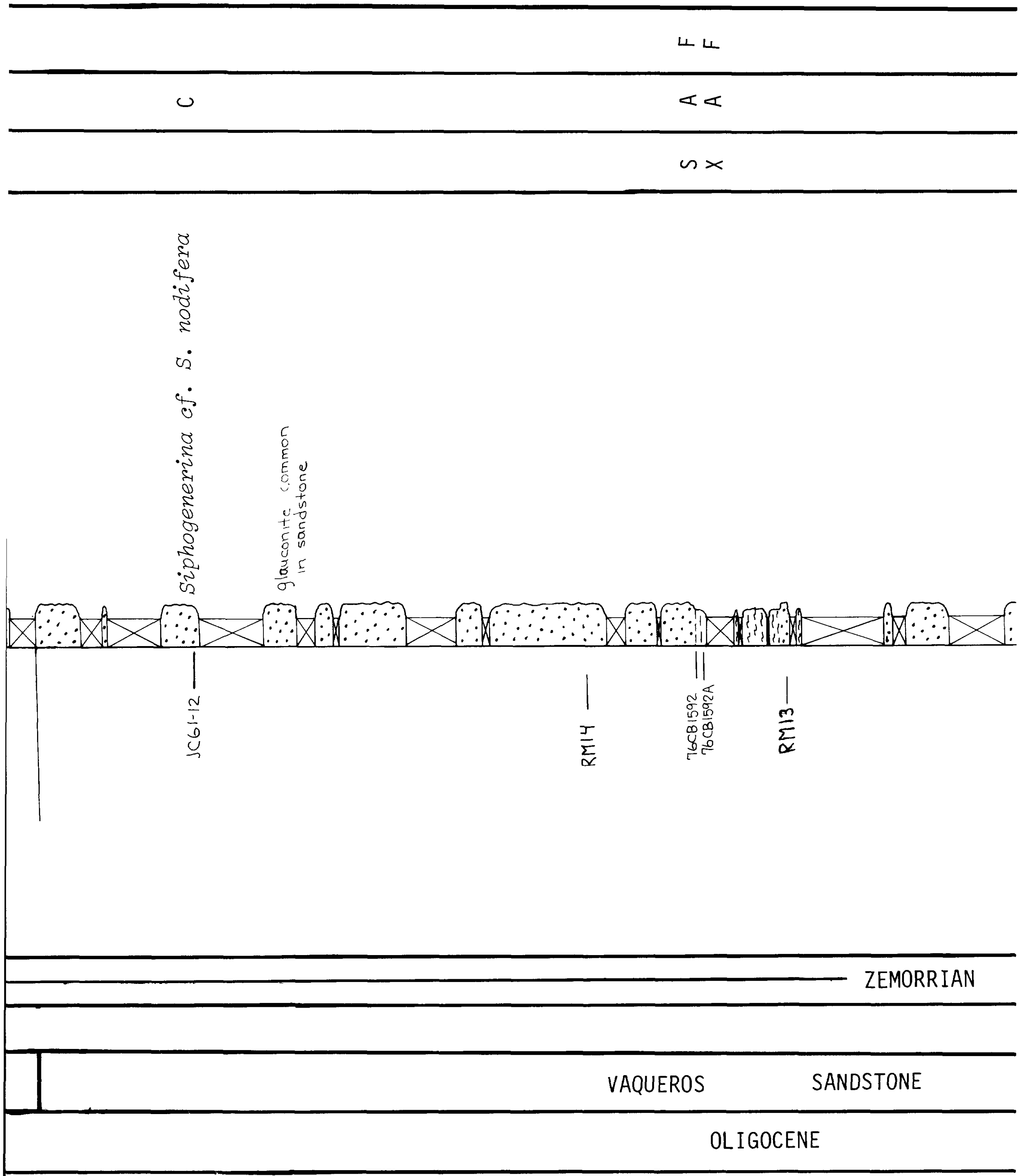


Figure 20.--Stratigraphic column, upper Zayan



reek area, north limb of San Lorenzo syncline.

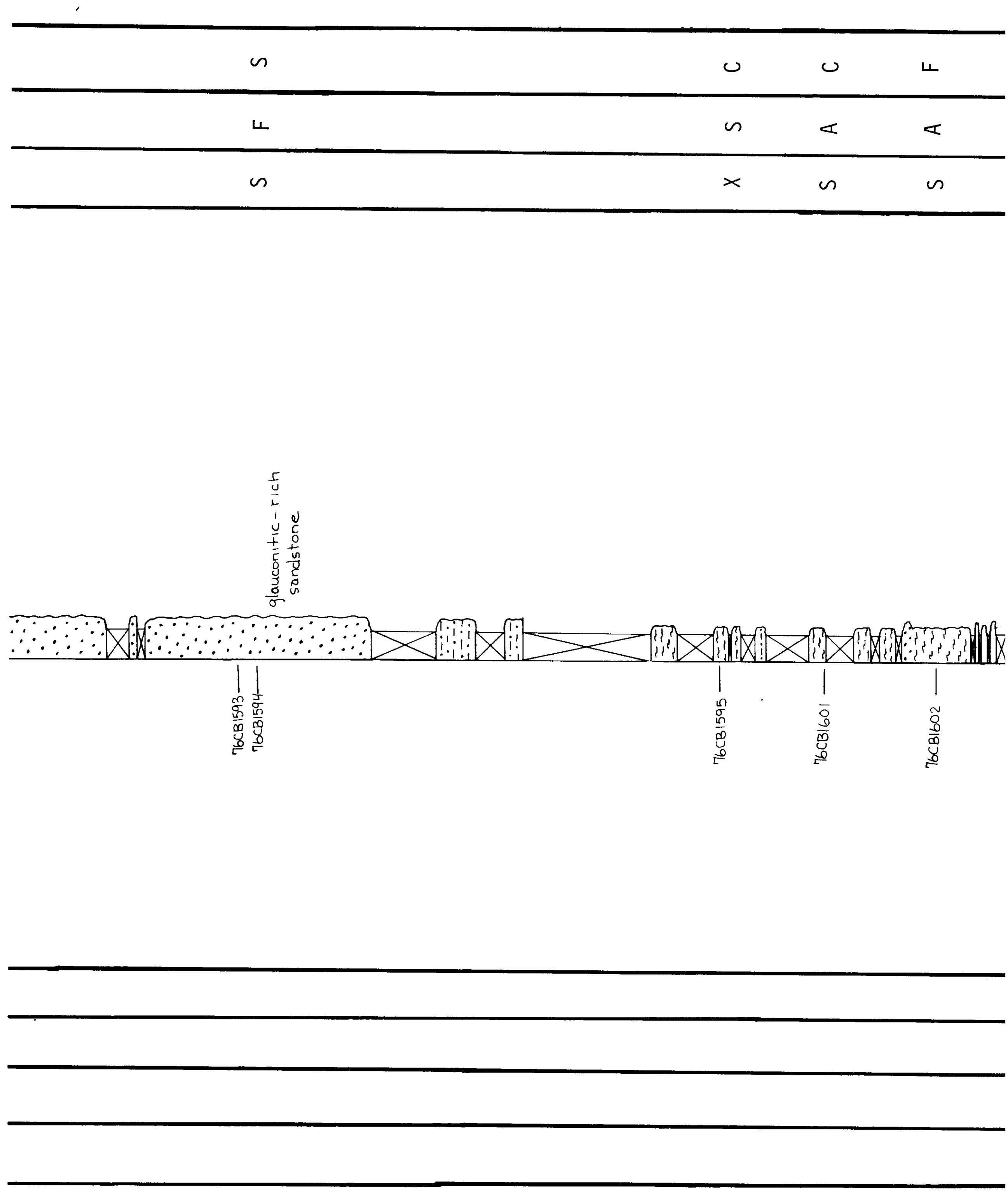
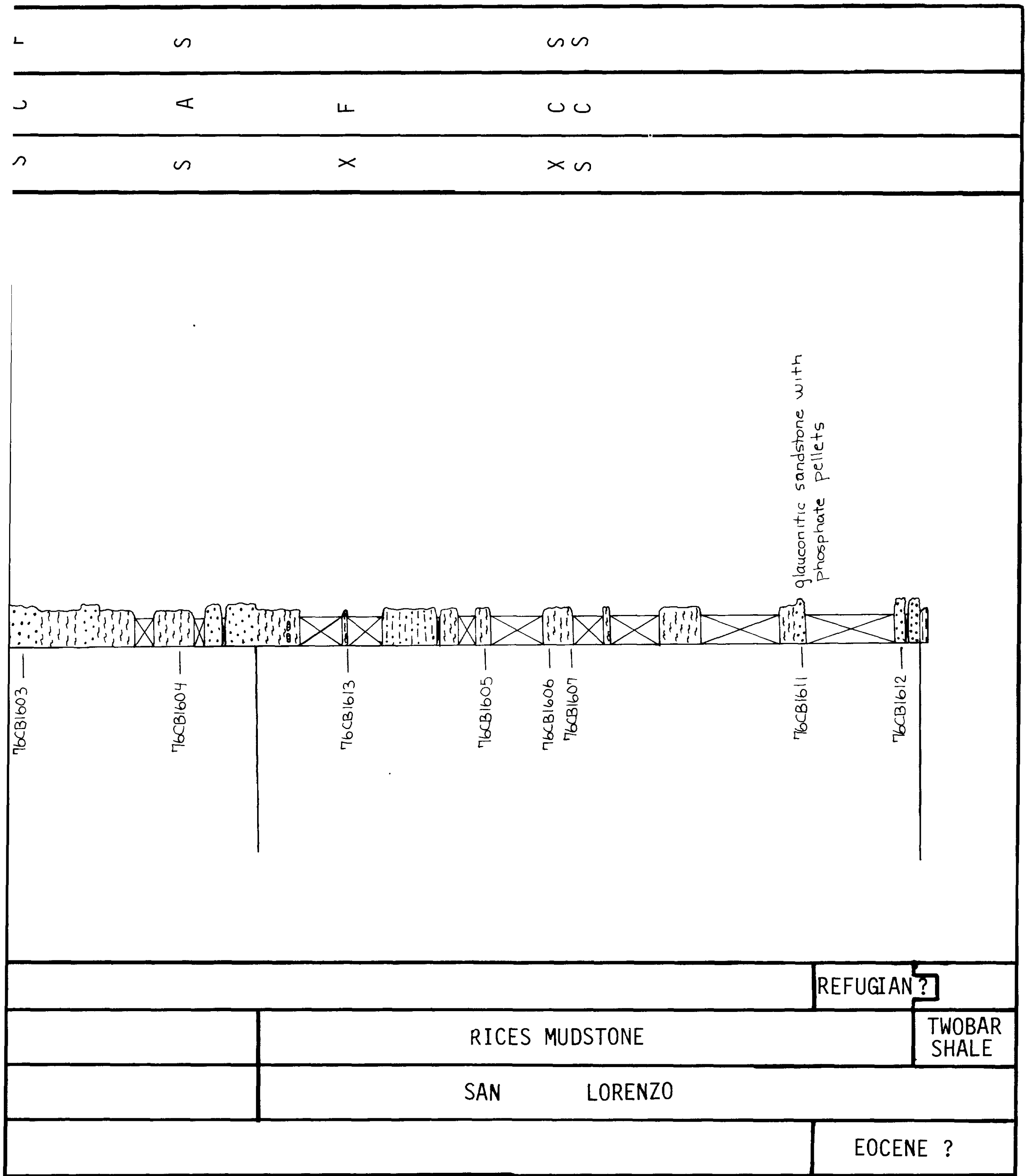

S
F
S
C
S
X
C
A
S
F
A
S
glauconitic - rich
sandstone
76CB1593
76CB1594
76CB1595
76CB1601
76CB1602

Figure 20.-


glauconitic sandstone with phosphate pellets
76CB1603
76CB1604
76CB1613
76CB1605
76CB1606
76CB1607
76CB1611
76CB1612
REFUGIAN ?
RICES MUDSTONE
TWOBAR SHALE
SAN LORENZO
EOCENE ?

ontinued

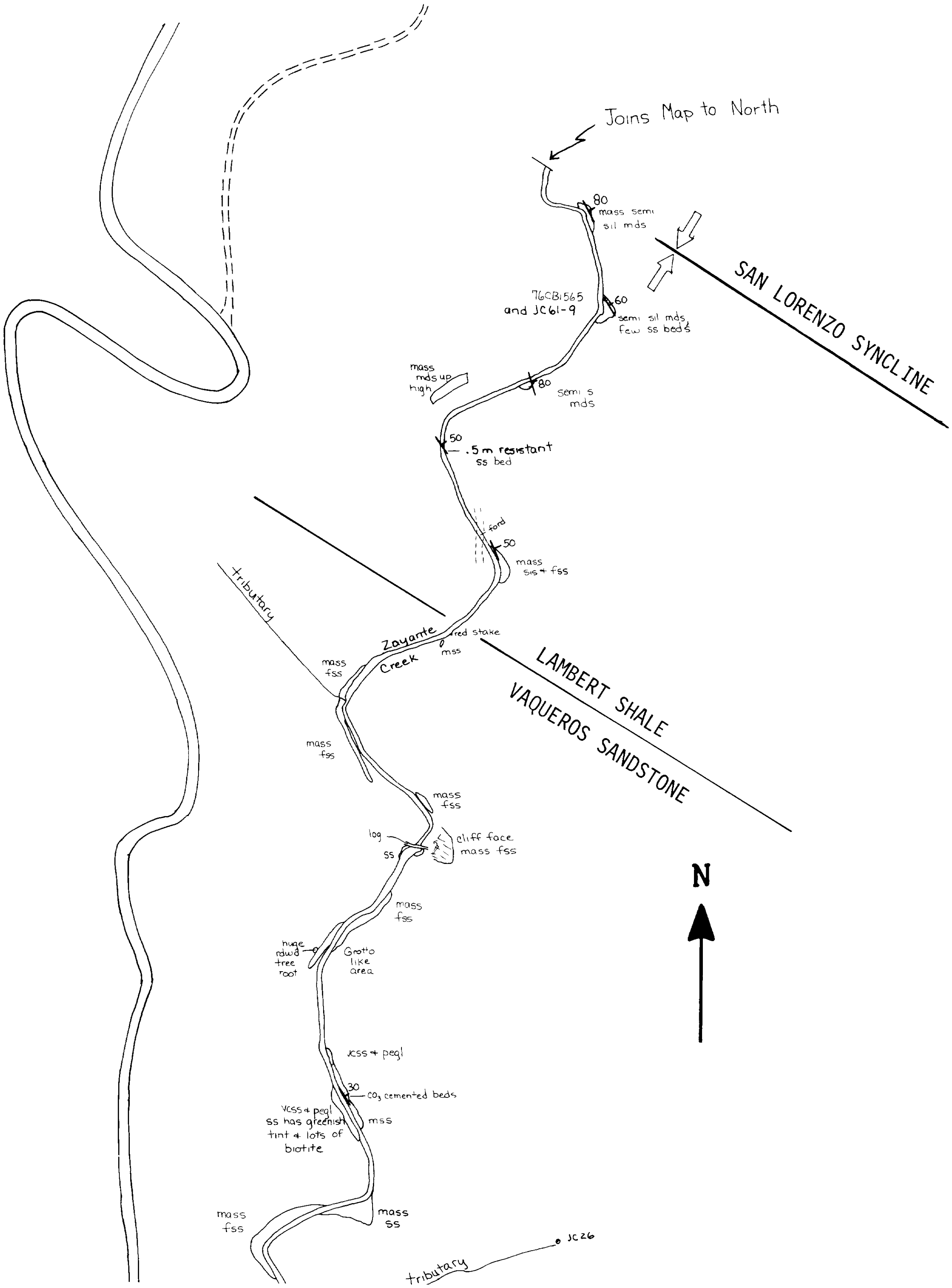
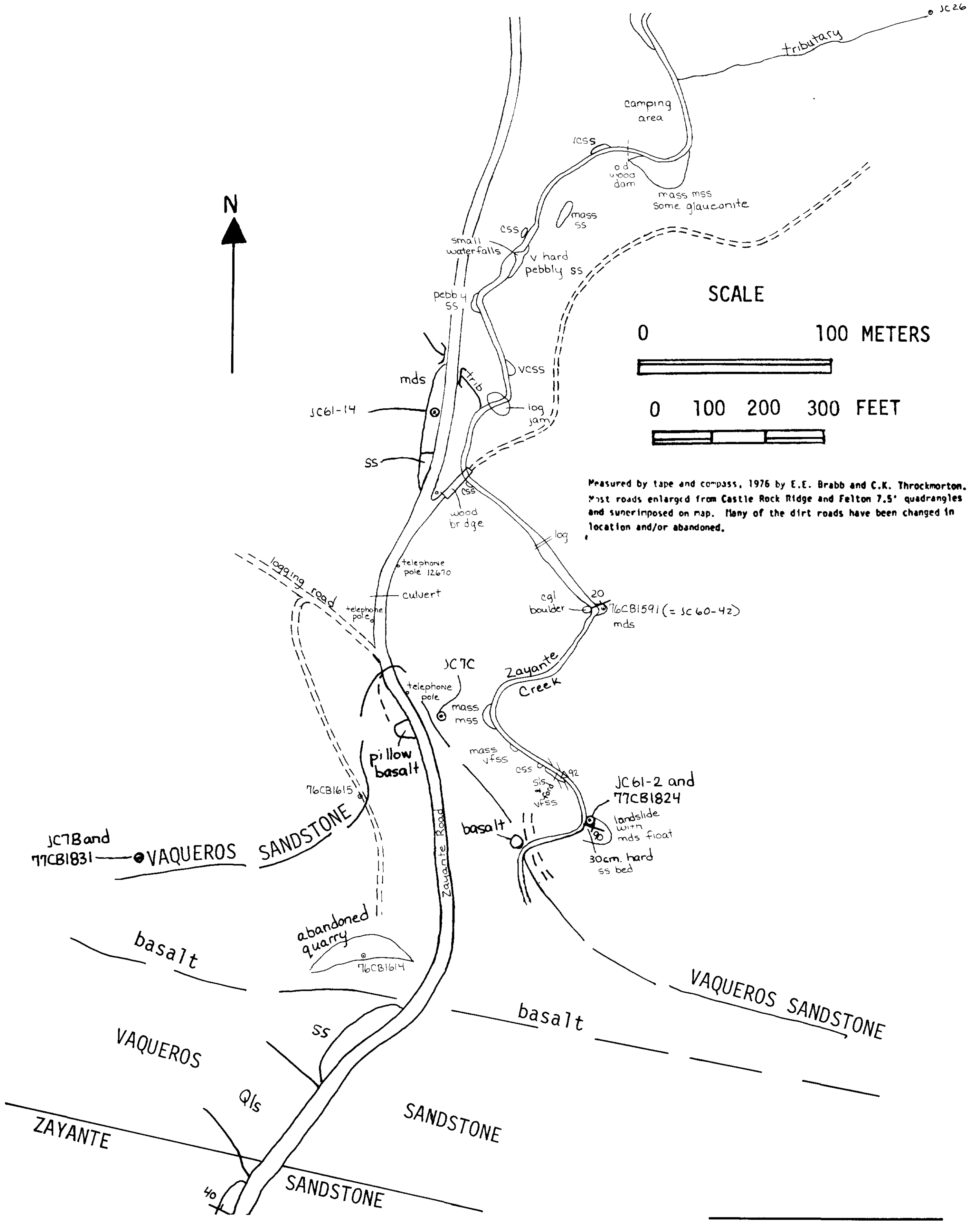


Figure 21.--Geologic sketch map of upper Zayante Creek area, south limb rocks and fossils were collected.



San Lorenzo syncline, showing formation contacts and localities where

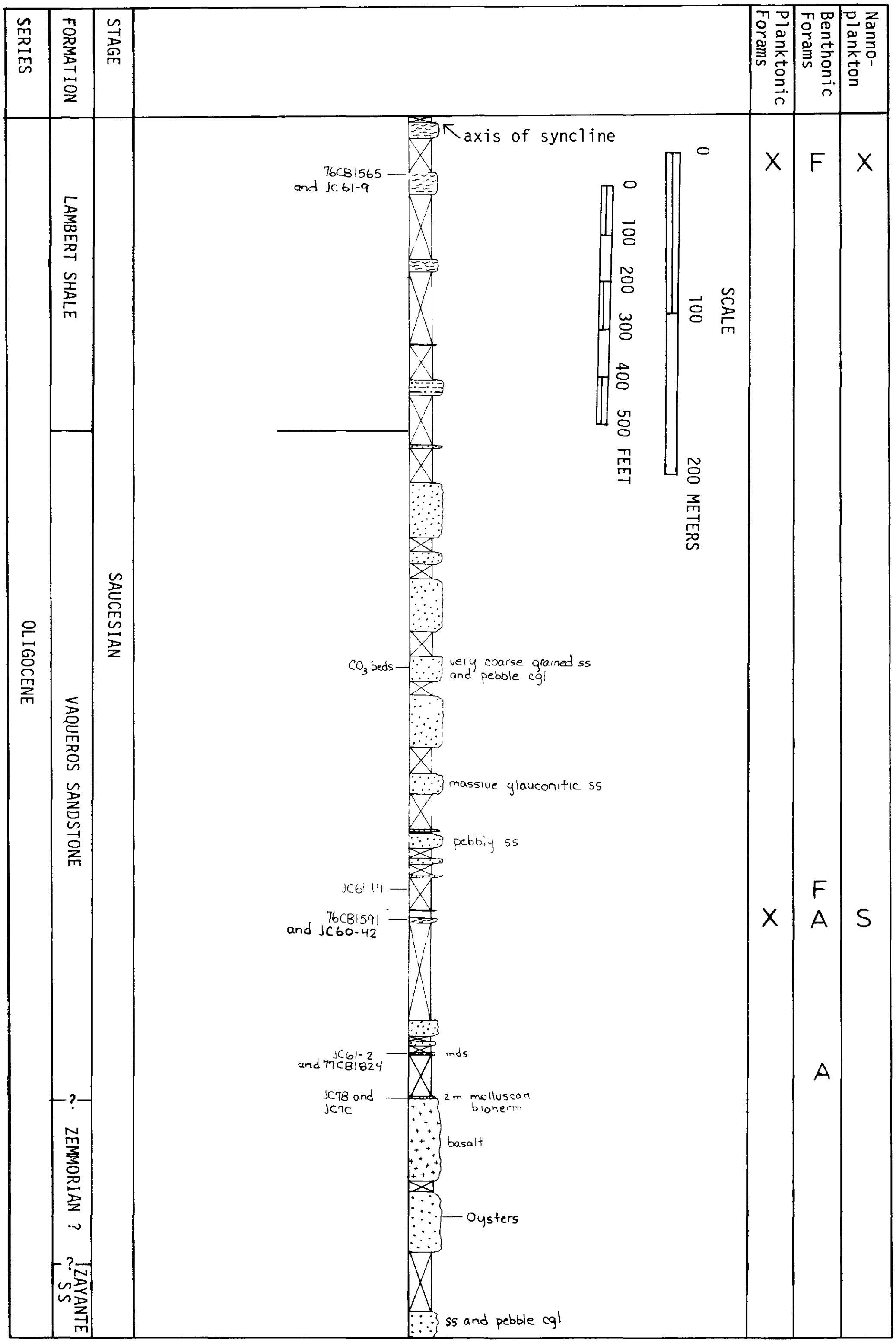


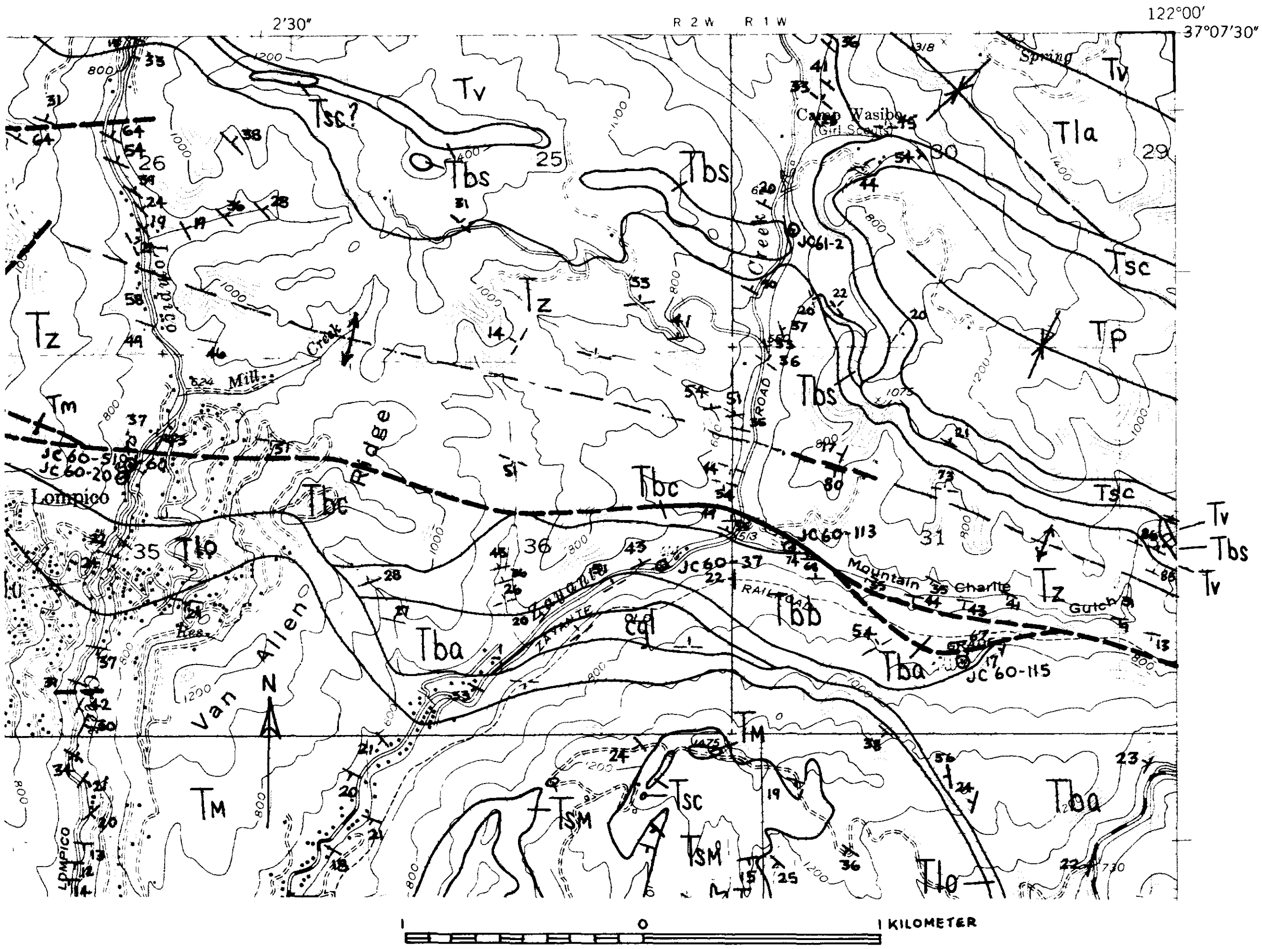
Figure 22.--Stratigraphic column, upper Zayante Creek area, south limb of San Lorenzo syncline.

Table 3.--Fossils from the Vaqueros Sandstone near Zayante Creek

	USGS Cenozoic locality	
	M5049 (JC7B)	M5050 (JC7C)
Gastropods		
Astraea aff. A. morani Loel & Corey	X	X
Bruclarkia santacruzana (Arnold)		
Calyptraea cf. C. inornata (Gabb)		X
Conus owenianus Anderson		X
Cymatium n. sp		X
Oliva sp		x
Olivella cf. O. pedroana var. subpedroana Loel & Corey		X
Scaphander(?) sp	X	
Sealesia sp		X
Turritella inezana Conrad	X	
Pelecypods		
Anadara(?) sp	X	
Chione latilaminosa Anderson & Martin	X	X
Chlamys sespeensis (Arnold)		X
Crassatella granti (Wiedey)	X	X
Dosinia margaritana Wiedey	X	X
Dosinia margaritana var. projecta Loel & Corey	X	X
Glycymeris sp	X	X
Mytilus cf. M. expansus Arnold		X
Trachycardium vaquerosense (Arnold)	X	X
Vertipecten cf. V. perrini (Arnold)	X	
Barnacle		
Balanus sp	X	
Echinoids	X	

LOMPICO SECTION

The area around Lompico (fig. 23) has the only exposures of Butano Sandstone with foraminifer and nannoplankton assemblages of early and middle Eocene age. The formation is truncated to the north by the Zayante fault and is overlapped to the south by the Lompico Sandstone of middle Miocene age, so that no creek or road has a complete section. The oldest beds, mapped informally by Clark (1966) as lower sandstone member (see fig. 24), crop out from Glenwood Highway, 4 km southeast of Lompico, to the vicinity of Zayante Creek. The middle siltstone member is generally poorly exposed and extensively landslid. An obscure locality (JC60-115) near an abandoned railroad grade has yielded a fairly rich foraminifer fauna (table 4). The youngest faunas that were recovered in stratigraphic sequence occur in the upper sandstone member near Lompico--one of them (JC60-51, fig. 24) contain nannoplankton that were correlated by F. R. Sullivan (written commun., 1964) with the Ulatisian Stage. Still younger faunas were collected from an unknown stratigraphic position within the Butano Sandstone south of the Zayante fault in the vicinity of the town of Boulder Creek. One of these (EB 444) has foraminifers of Narizian age, according to Brabb (1960, p. 35). Thus, the Zayante fault truncates progressively older beds from west to east.



EXPLANATION

Tp	Purisima Formation	Pliocene
Tsc	Santa Cruz Mudstone	Miocene
Tsm	Santa Margarita Sandstone	Miocene
Tm	Monterey Formation	Miocene
Tlo	Lompico Sandstone	Miocene
Tla	Lambert Shale	Miocene
Tv / Tbs	Tv, Vaqueros Sandstone; Tbs, Basalt	Miocene / Oligocene
Tz	Zayante Sandstone	Oligocene
Tbc, Tbb, Tba	Butano Sandstone: Tbc, U. ss member; Tbb, M. sls member; Tba, L. ss member	Eocene

Figure 23.--Geologic map of the Lompico area showing localities where fossils were collected. Base map from Felton 7.5' quadrangle. Geology by J. C. Clark.

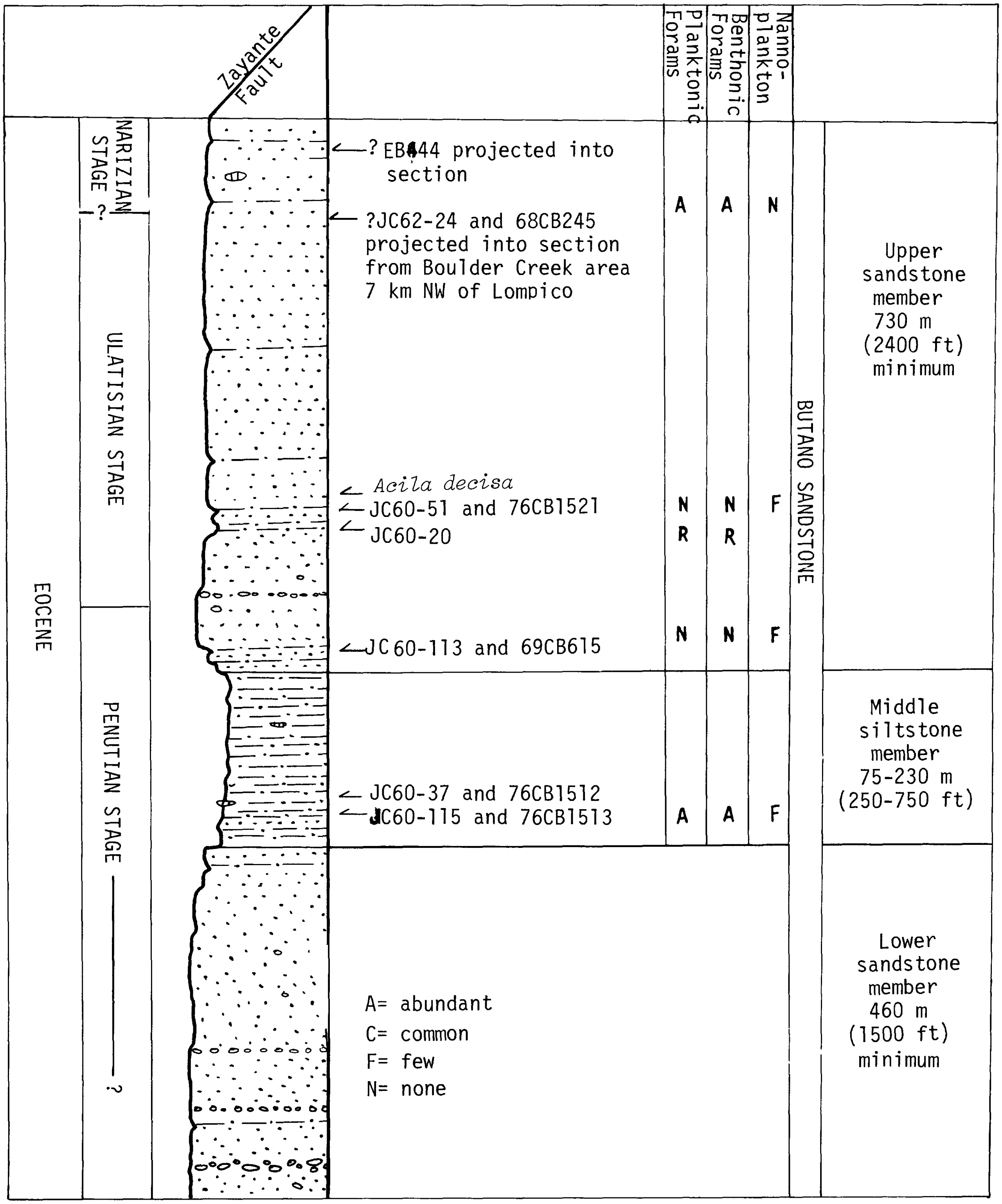


Figure 24.--Composite stratigraphic column of the Butano Sandstone in the vicinity of Lompico, California. Section estimated from geologic map by Clark (1966).

Table 4.--Foraminifers from the middle siltstone member of the Butano Sandstone near Lompico.

LOCALITY	JC60-115
Allomorphina trigona Reuss	R
Ammodiscus glabratus Cushman & Jarvis	VR
Amphimorphina cf. *A. ignota* Cushman & Siegfus	VR
Anomalina garzaensis Cushman & Siegfus	VR
Anomalina aff. *A. regina* Martin	R
Asterigerina crassaformis Cushman & Siegfus	C
Bathysiphon eocenicus Cushman & G. D. Hanna	A
Bathysiphon spp.	R
Bifarina nuttalli Cushman & Siegfus (?)	VR
Bolivina crenulata Cushman	VR
Bolivina (?) sp.	VR
Bulimina aff. *B. alazanensis* Cushman	R
Bulimina macilenta Cushman & Parker	R
Bulimina ovata d'Orbigny	VR
Bulimina pupoides d'Orbigny	VR
Bulimina aff. *B. pyrula* d'Orbigny, Mallory	A
Bulimina semicostata Nuttall	F
Bulimina cf. *B. tarda* Parker & Bermudez	VR
Bulimina aff. *B. whitei* Martin	VR
Bulimina spp.	VR
Cassidulina cf. *C. globosa* Hantken	VR
Chilostomella cylindroides Reuss	R
Cibicides martinezensis Cushman & Barksdale	F
Dentalina cf. *D. colei* Cushman & Dusenbury	VR
Dentalina consobrina d'Orbigny	C
Dentalina cf. *D. jacksonesis* (Cushman & Applin)	R
Dentalina sp.	VR
Dentalina (?) sp.	VR
Discorbis sp.	VR
Dorothia sp.	R
Eponides aff. *E. umbonata* (Reuss)	VR
Globigerina nitida Martin	A
Globigerina triloculinoides Plummer	A
Globigerina yeguaensis Weinzierl & Applin	R
Globigerina spp.	VR
Globorotalia acarinata (Subbotina)	A
Globorotalia imitata Subbotina	R
Globorotalia pseudomenardii Bolli	F
Globorotalia pseudotopilensis (Subbotina)	A
Globorotalia reissi Loeblich & Tappan	VR
Globorotalia rex Martin	F
Gyroidina orbicularis var. *obliquata* Cushman & McMasters	VR
Gyroidina (?) sp.	VR
Heterohelix (?) sp.	VR
Hoeglundina eocenica (Cushman & M. A. Hanna)	VR
Lagena acuticosta Reuss	VR
Lenticulina (?) sp.	VR
"*Nodogenerina*" cf. "*N.*" *adolphina* (d'Orbigny)	C
"*Nodogenerina*" *kressenbergensis* (Gumbel)	R
"*Nodogenerina*" spp.	VR
Nodosaria ewaldi Reuss, Mallory	VR
Nodosaria latejugata Gumbel	R
Nodosaria sp.	VR
Pleurostomella cf. *P. acuta* Hantken	R
Pleurostomella alternans Schwager	VR
"*Pseudoglandulina*" (?) sp.	VR
"*Pseudohastigerina*" *micra* (Cole)	VR
Robulus inornatus d'Orbigny	A
Robulus pseudovortex Cole	R
Robulus spp.	F
Siphonina wilcoxensis Cushman	VR
Virgulina cf. *V. danvillensis* Howe & Wallace	VR
Virgulina yazooensis Cushman & Todd	VR
Virgulina sp.	VR
diatoms	A
ostracods	VR
nannoplankton	F

VR=very rare; R=rare; F=few; C=common; A=abundant.
Benthonic identifications by J. C. Clark.
Planktonic identifications by J. C. Clark and Yokichi Takayanagi.

From Clark (1960, table 3).

SMITH GRADE SECTION

Mollusks from the Smith Grade area were important in documenting the presence of rocks of Paleocene age in the Ben Lomond Mountain area (Brabb, 1959 and Cummings and others, 1964, p.184). The rocks containing the fossils were mapped subsequently by Clark (1966), who also collected foraminifers from the Smith Grade section. Figure 25 is a sketch of the geology in the area, figure 26 is a stratigraphic column for the rocks of Paleocene age, and tables 5 and 6 list foraminifers and larger invertebrates from these rocks.

The basal sandstone beds commonly yield a shallow-water molluscan fauna associated with diverse calcareous benthonic foraminifers, whereas the overlying siltstone beds yield abundant large arenaceous foraminifers. At two localities (JC60-126=M4668 and JC60-120=M4669), mollusks characteristic of the "Martinez Stage" (Paleocene) of the California molluscan chronology are associated with benthonic foraminifers of the Ynezian Stage of Mallory (1959).

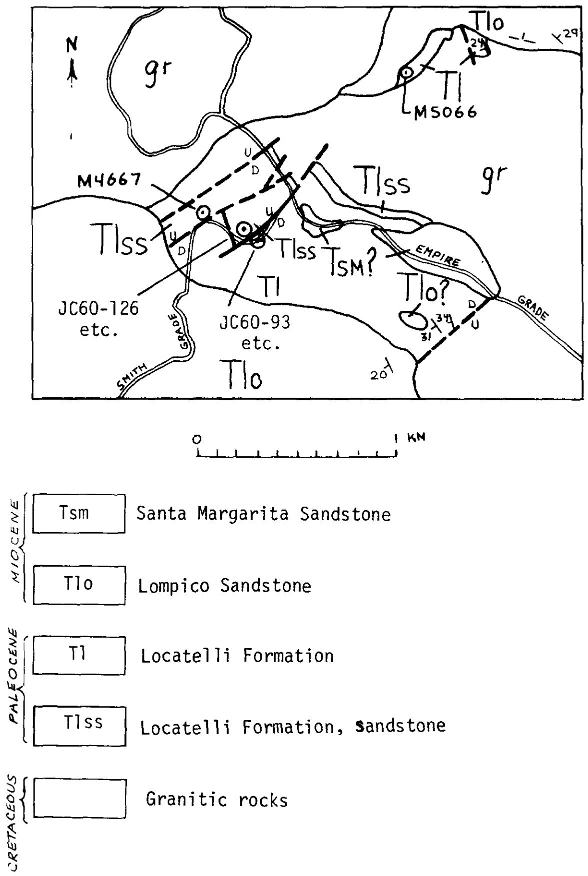


Figure 25.--Geologic map of the Smith Grade-Empire Grade area showing localities where fossils were collected. Base map from Felton 7.5' quadrangle. Geology from Clark (1966).

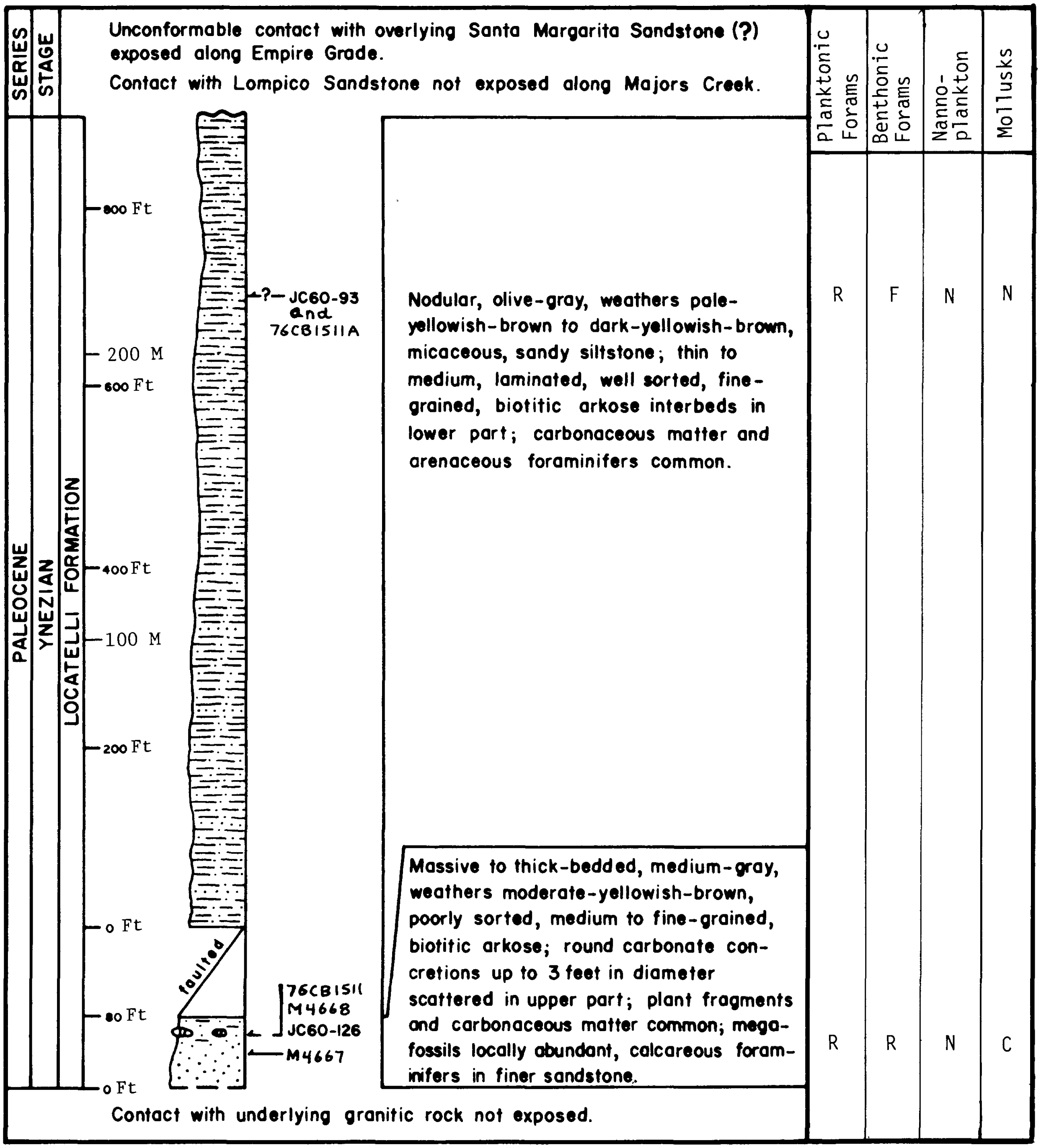


Figure 26.--Stratigraphic column, Smith Grade section. From Clark (1966, fig. 3).

Table 5.--Foraminifers from the Locatelli Formation. From Clark (1960, table 2).

LOCALITY	JC60-126 (JC14)	JC60-120 (JC23)	JC60-93	Vine Hill Ss.
Ammobaculites sp			VR	
Ammodiscoides turbinatus Cushman			VR	
Ammodiscus glabratus Cushman & Jarvis			VR	
Ammodiscus sp			VR	
Anomalina dorri var *aragonensis* Nuttall	VR	C		X
Anomalina regina Martin	VR			
Bathysiphon eocenicus Cushman & G D Hanna			VR	X
Bathysiphon spp			F	
Bathysiphon sp		R		
Bulimina cf *B. pachecoensis* Smith		VR		X
Cassidulina globosa Hantken		VR		
Cibicides martinezensis Cushman & Barksdale	C	C		
Cibicides whitei Martin	F			
Cibicides spp		F		
Cibicides sp	F			
Dentalina alternata (Jones)	VR			X
Dentalina cf *D approximata* Reuss	R			X
Dentalina cf *D. communis* (d'Orbigny)	VR			X
Dentalina cf *D consobrina* (d'Orbigny)	F			X
Dentalina sp	VR			
Dentalina (?) spp	VR			
Dorothia sp		R	VR	
Dorothia (?) sp			VR	
Eggerella (?) sp			VR	
Entosolenia hexagana Williamson		VR		?
Eponides mexicana (Cushman)	F			
Eponides cf. *E mexicana* (Cushman)		VR		
Gaudryina sp.	VR	C		
Globigerina aquiensis Loeblich & Tappan		R		
Globigerina triloculinoides Plummer	R	VR	VR	X
Globigerina sp.	VR		VR	
Globoconusa (?) sp.		VR		
Globorotalia convexa Subbotina			VR	
Glomospira charoides (Jones & Parker)			VR	
Glomospira charoides var *corona* Cushman & Jarvis			VR	
Guttulina sp.	VR	R		
Gyroidina soldanii var *octocamerata* Cushman & G D Hanna	F	C		X
Haplophragmoides caronata (Brady)			F	
Haplophragmoides excavata Cushman & Waters			R	
Haplophragmoides cf. *H excavata* Cushman & Waters		C		
Haplophragmoides kirki Wickenden			VR	
Haplophragmoides cf. *H longifissus* Israelsky		C		
Haplophragmoides protullisatus Israelsky			C	
Haplophragmoides sp.		VR		
Hyperammina cf *H. elongata* (Brady)			C	
Hyperammina (?) sp			VR	
Lagena acuticasta Reuss		VR		
Lenticulina sp.	F			
Lituotuba cf. *L lituiformis* (Brady)			VR	
"*Nodogenerina*" *adolphina* (d'Orbigny)	C	VR		
"*Nodogenerina*" (?) sp.		C		
Nodosaria arundinea Schwager		VR		X
Nodosaria deliciae Martin	VR	F		
Nodosaria latejugata Gumbel	R			X
Nodosaria cf. *N latejugata* Gumbel		VR		
Nodosaria spp.	VR	VR		
Nodosaria sp.			VR	
Pelosina complanata Franke			R	
Planularia sp.	VR			
"*Pseuoglandulina*" *canica* (Neugeboren)	F			X
Pseudouvigerina nahealensis Cushman & Todd		F		
Quinqueloculina sp	VR	VR		
Reophax sp		R		
Robulus inornatus d'Orbigny	C	VR		X
Robulus aff. *R midwayensis* (Plummer)	VR	VR		
Robulus spp.	R			
Rzehakina epigona var *lata* Cushman & Jarvis			F	
Silicosigmoilina californica Cushman & Church		R	C	X
Spiroplectammina perplexa Israelsky			C	
Spiroplectammina richardi Martin	C			
Spiroplectammina cf *S tejonensis* Mallory		VR		
Spiroplectammina (?) sp.		VR	VR	
Tritaxia sp		R		
Trochammina cf. *T globigeriniformis* (Parker & Jones)			R	
Trochammina spp			F	
Trochammina sp.		C		
Trochamminoides (?) sp.			VR	
Vaginulina suturalis Cushman	VR			X
Vaginulinopsis saundersi (Hanna & Hanna)	A	R		X
Valvulineria martinezensis Smith	R	C		
Verneulina sp.	VR	VR		
ostracods	F	VR		
radiolaria			VR	

VR=very rare; R=rare; F=few; C=common; A=abundant.
X=recorded from Vine Hill Sandstone by Smith (1957, Fig. 4).
Benthonic identifications by J C Clark.
Planktonic identifications by J C Clark and Yokichi Takayanagi.

Table 6.--Paleocene larger invertebrates from the Locatelli Formation.

	USGS Cenozoic locality				
	M4667	M4668	M4669	M5065	M5066
Gastropods					
Perissolax tricarnatus WEaver	X	X			
Surculites(?) sp.			X		
Turritella cf. T. infragranulata Gabb	X	X			
Turritella pachecoensis Stanton	X	X		X	
Turritella cf. T. pachecoensis Stanton					X
Pelecypods					
Acila sp.	X		X		X
Cucullaea mathewsonii Gabb			X		X
Cucullaea mathewsonii Gabb(?)	X				
Glycymeris sp.	X				
Lucinoma sp.	X	X			
Nuculana sp.	X	X			X
Pholadomya nasuta Gabb	X				
Pinna n. sp.	X				
Scaphopod					
Dentalium sp.	X	X			
Echinoids					
Cidaris martinezensis Kew	X				
Periaster n. sp.	X			X	
Pericosmus sp.	X				
Echinoid spines			X		
Arthropod					
Raninoides sp.		X			

Locality	Description of locality, collector, and date collected
M4667	Cut on northeast side of abandoned section of Smith Grade, 10m (30 ft) northwest of new road and 30m (100 ft) east of fork of Majors Creek, S-1/2, sec. 29, T. 10S., R.2W., Felton quadrangle. Lower part of Locatelli Formation, Paleocene. Same locality as LSJU 3401A. Collected by J. C. Clark, 1960.
M4668	North side of deep cut along Smith Grade, approximately 300 m (1000 ft) southwest of where Smith Grade joins Empire Grade, Felton quadrangle. Lower part of Locatelli Formation, Paleocene. Collected by J. C. Clark, 1960.
M4669	Bed in unnamed, westward-flowing tributary to San Lorenzo River, about 530m (1730 ft) east of where tributary joins river, in Henry Cowell Redwoods State Park, Felton quadrangle. Lower part of Locatelli Formation, Paleocene. Collected by J. C. Clark, 1960.
M5065	North bank of Gold Gulch, about 90m (300 ft) upstream from where stream passes under Highway 9, Felton quadrangle. Lower part of Locatelli Formation, Paleocene. Collected by J. C. Clark, 1962.
M5066	Bed in Gold Gulch, approximate elevation 160m (520 ft), Felton quadrangle. Lower part of Locatelli Formation, Paleocene. Collected by J. C. Clark, 1962.

MOUNTAIN CHARLIE GULCH SECTION

The Mountain Charlie Gulch area has a fairly complete section from Butano Sandstone to Lambert Shale, but most of the units are not well exposed. The reason for including the section in this report is that it yields faunas of both early and late Saucesian age that by the correlation of Tipton and others (1973) straddle the Oligocene-Miocene boundary. A sketch map of the geology and a stratigraphic column are shown on figure 27. Foraminifers from the section are listed on table 7.

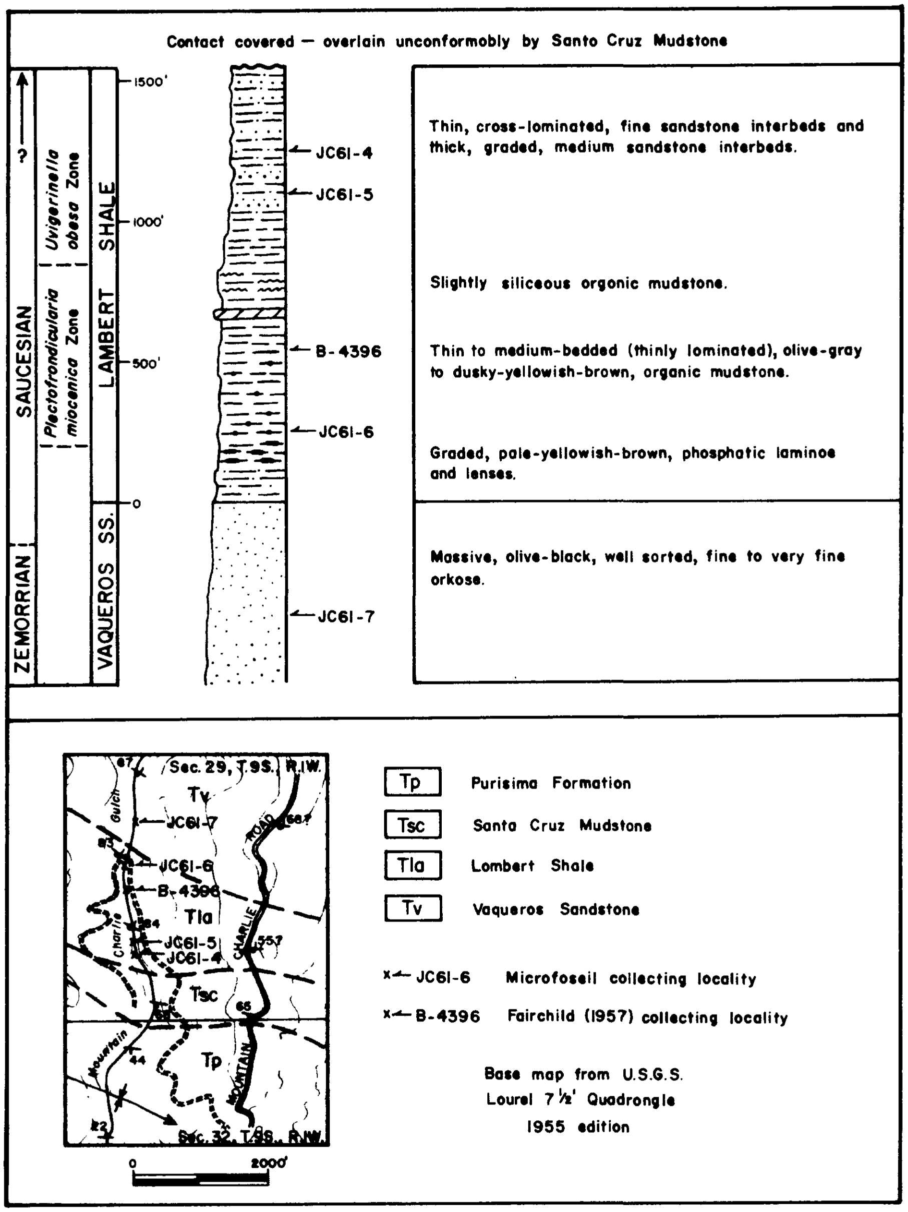


Figure 27.--Geologic sketch map and stratigraphic column for the Mountain Charlie Gulch area. From Clark (1966, fig. 6).

Table 7.--Foraminifers from the Lambert Shale in the Mountain Charlie Gulch area. From Clark (1960, table 5).

FORMATION	VAQUEROS SS.	LAMBERT SH.		
LOCALITY (shown on Figure 6)	JC61-7	JC61-6	B-4396	JC61-5
Baggina robusta Kleinpell		F		
Bathysiphon eocenicus Cushman & G D Hanna			F	
Bolivina marginata Cushman		C	R	C
Bolivina cf. *B. perrini* Kleinpell				VR
Bolivina sp				VR
Bulimina rinconensis Cushman & Laiming			R	
Buliminella cf. *B. brevior* Cushman		R		
Buliminella curta Cushman				R
Buliminella subfusiformis Cushman		VR		
Cibicides americanus (Cushman)		VR	C	
Cibicides americanus var. *crassiseptus* Cushman & Laiming	VR			
Cibicides cf. *C. americanus* var. *crassiseptus* Cushman & Laiming		VR		
Cibicides floridanus (Cushman)	F			
Cibicides aff. *C floridanus* (Cushman)			F	
Cibicides cf. *C. floridanus* (Cushman)				VR
Cyclammina cancellata Brady	C			
Dentalina cf. *D pauperata* d'Orbigny				VR
Dentalina quadrulata Cushman & Laiming			F	R
Dentalina spinosa d'Orbigny			R	
Dentalina sp.		VR		
Eponides cf. *E. keenani* Cushman & Kleinpell				VR
Globigerina sp.				VR
Globigerina spp.		F		
Gyroidina condoni (Cushman & Schenck)			R	
Gyroidina soldanii d'Orbigny			R	VR
Gyroidina sp.		F		
Haplophragmoides spp.				R
"*Nodogenerina*" *advena* Cushman & Laiming	F	?		F
Nonion costiferum (Cushman)				R
Nonion cf. *N. pompilioides* (Fichtel & Moll)	F			
Plectofrondicularia aff. *P. basi-spinata* Cushman			?	
Plectofrondicularia miocenica var. *directa* Cushman & Laiming				R
Proteonina (?) sp.			R	
Pullenia salisburyi R.E. & K.C. Stewart			R	
Pullenia cf. *P. salisburyi* R.E. & K.C. Stewart				VR
"*Pulvinulinella*" sp.				VR
Robulus inornatus (d'Orbigny)			R	
Robulus simplex (d'Orbigny)	C		R	
Robulus sp.				R
Siphogenerina kleinpelli Cushman		VR	R	VR
Siphogenerina nodifera Cushman & Kleinpell	VA			
Siphogenerina transversa Cushman		A	R	
Spiroplectammina (?) sp				F
Tritaxilina colei Cushman & Siegfus			R	
Uvigerina auberiana d'Orbigny			A	
Uvigerina cf. *U. beccarii* Fornasini			F	
Uvigerina rustica Cushman & Edwards			R	
Uvigerinella obesa Cushman				A
Uvigerinella obesa var *impolita* Cushman & Laiming				VR

VR=very rare; R=rare; F=few; C=common; A=abundant; ?=questionable identification.
JC61-7 identifications by micropaleontologists of Humble Oil & Refining Company.
JC61-6, JC61-5 identifications by J.C. Clark.
B-4396 identifications by Fairchild (1957, Fig. 6).

AÑO NUEVO SECTION

Stratigraphic contrasts across the active San Gregorio fault in the vicinity of Año Nuevo have been reported in an abstract by Clark and Brabb (1977). A summary of the stratigraphic sequences is shown on figure 28. The geology of the area and fossil localities are shown on figure 29.

Even within the area west of the San Gregorio fault, the geologic section is complicated by folds and faults. Figure 30 is a stratigraphic column for the area, and figure 31 shows the section in the vicinity of Año Nuevo Point. Some of the section is exposed only at very low stages of spring tides. Some of the section exposed in September, 1976 was covered by sand in August, 1977. Table 8 lists foraminifers from the Año Nuevo area; table 9 provides a description of most of the localities.

The Vaqueros(?) and Monterey Formations near Año Nuevo Point yield calcareous benthonic foraminifers diagnostic of the Zemorrian, Saucesian, and Relizian Stages of Kleinpell (1938) and are characteristic of bathyal depths. Large, well-preserved, benthonic foraminifers are especially abundant in the siltstone beds of the Vaqueros(?) 1.6 km (1 mi) north of the point, where the common occurrence in the lower part of the section of *Siphogenerina nodifera* is diagnostic of Zemorrian age. The upper part of this synclinal section ranges into the early Saucesian.

The Vaqueros(?) section that is exposed near the axis of the anticline that is east of Año Nuevo Point is mostly younger, ranging from early Saucesian to Relizian. Sheared mudstone on the east flank of the anticline (USGS loc. Mf2192 = JC68-3) locally yields a Relizian fauna that includes *Cassidulina laevigata carinata*, *Cibicides* of *C. floridanus*, *"Nonion" pompilioides* var., *Pullenia bulloides*, *P. moorei*, and *Spheroidina variabilis*. These species are diagnostic of the Pseudosaucesian faunal facies of Beck (1952). Although these deep-water species are generally considered typical of the Saucesian Stage, they are now known to recur in any stratigraphic position from the Upper Saucesian through the Lower Mohnian (upper Miocene). Planktonic foraminifers are sparse in the Vaqueros(?) beds north and east of Año Nuevo Point.

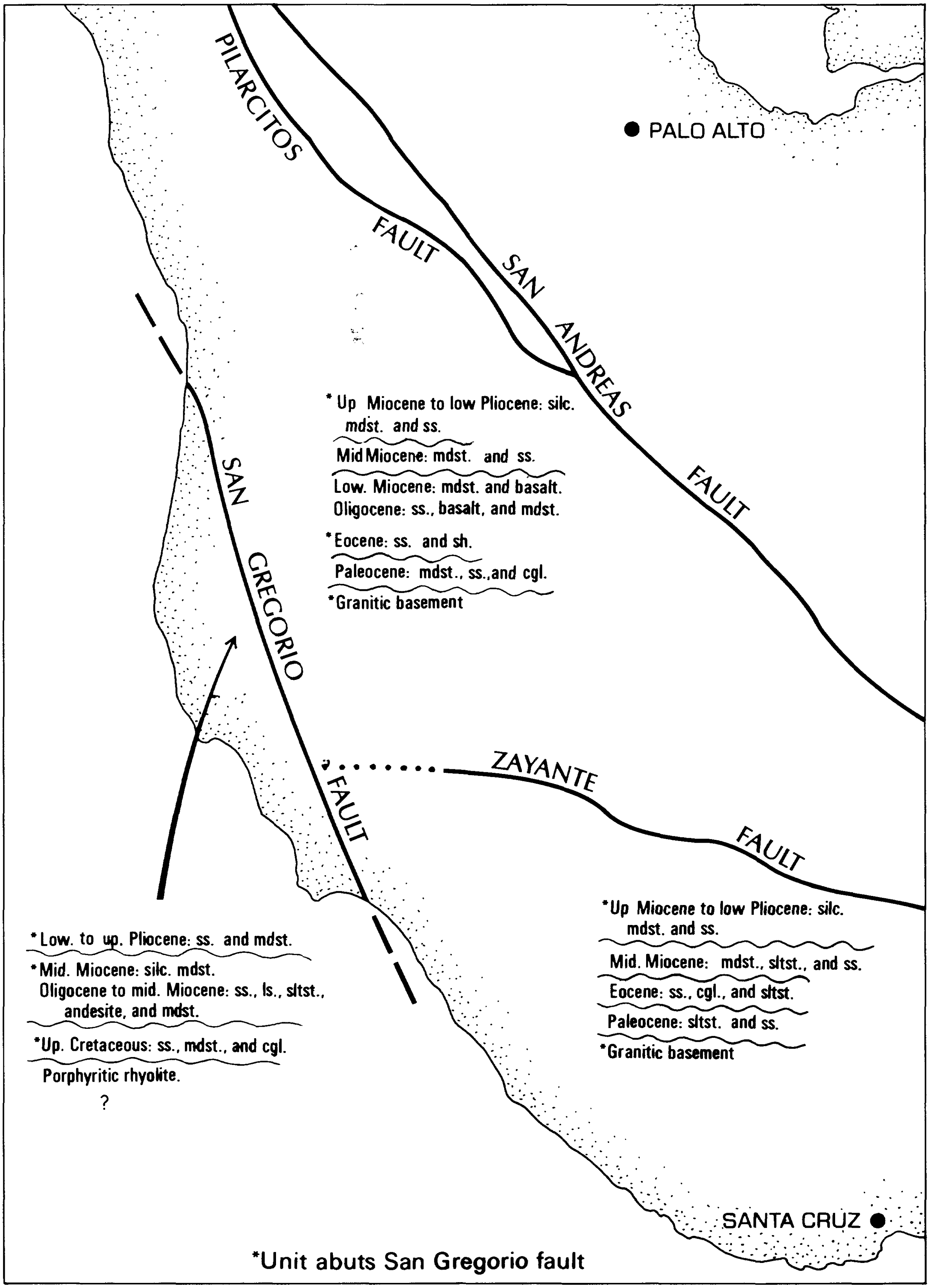


Figure 28.--Stratigraphic contrasts across the San Gregorio and Zayante faults

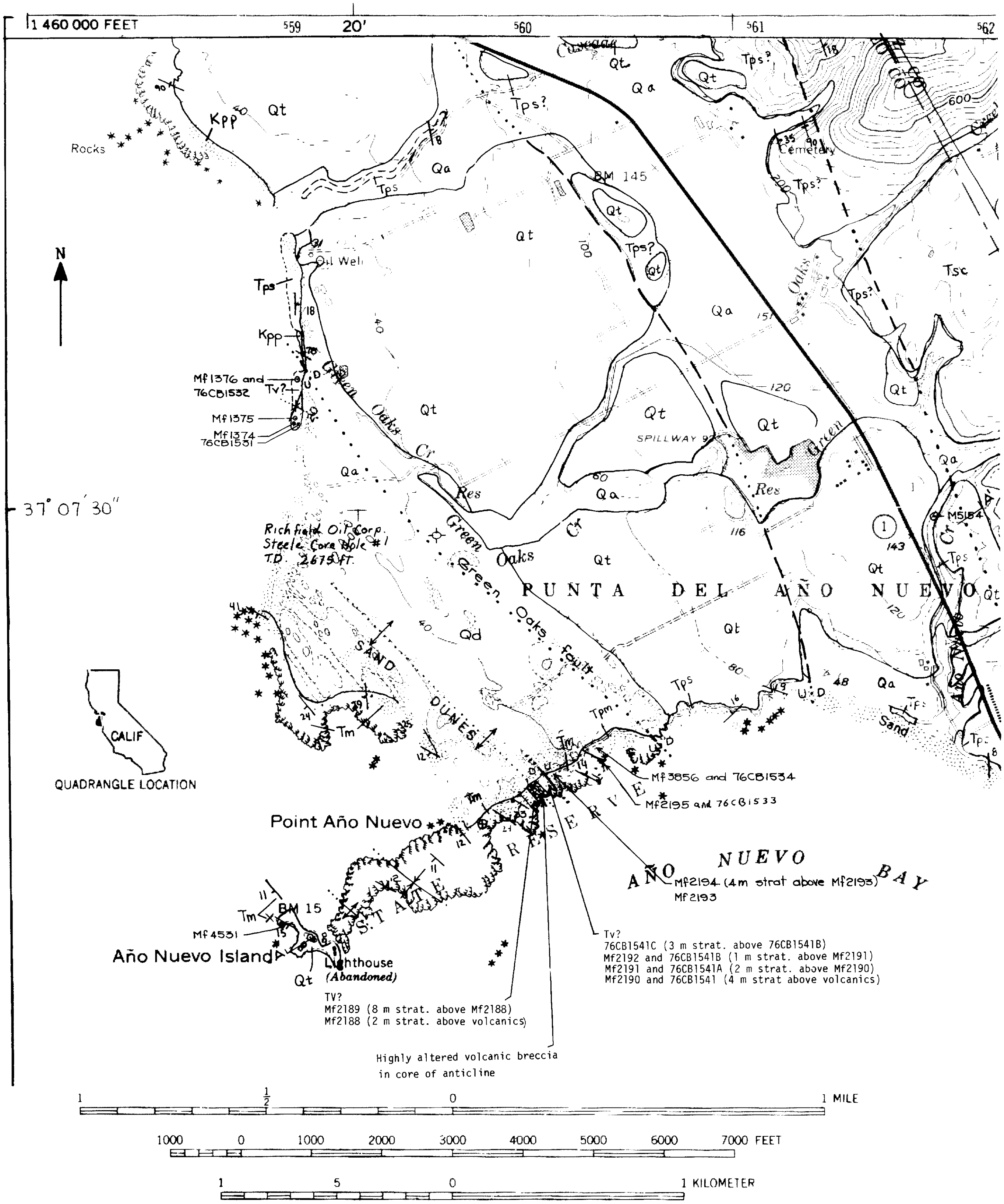
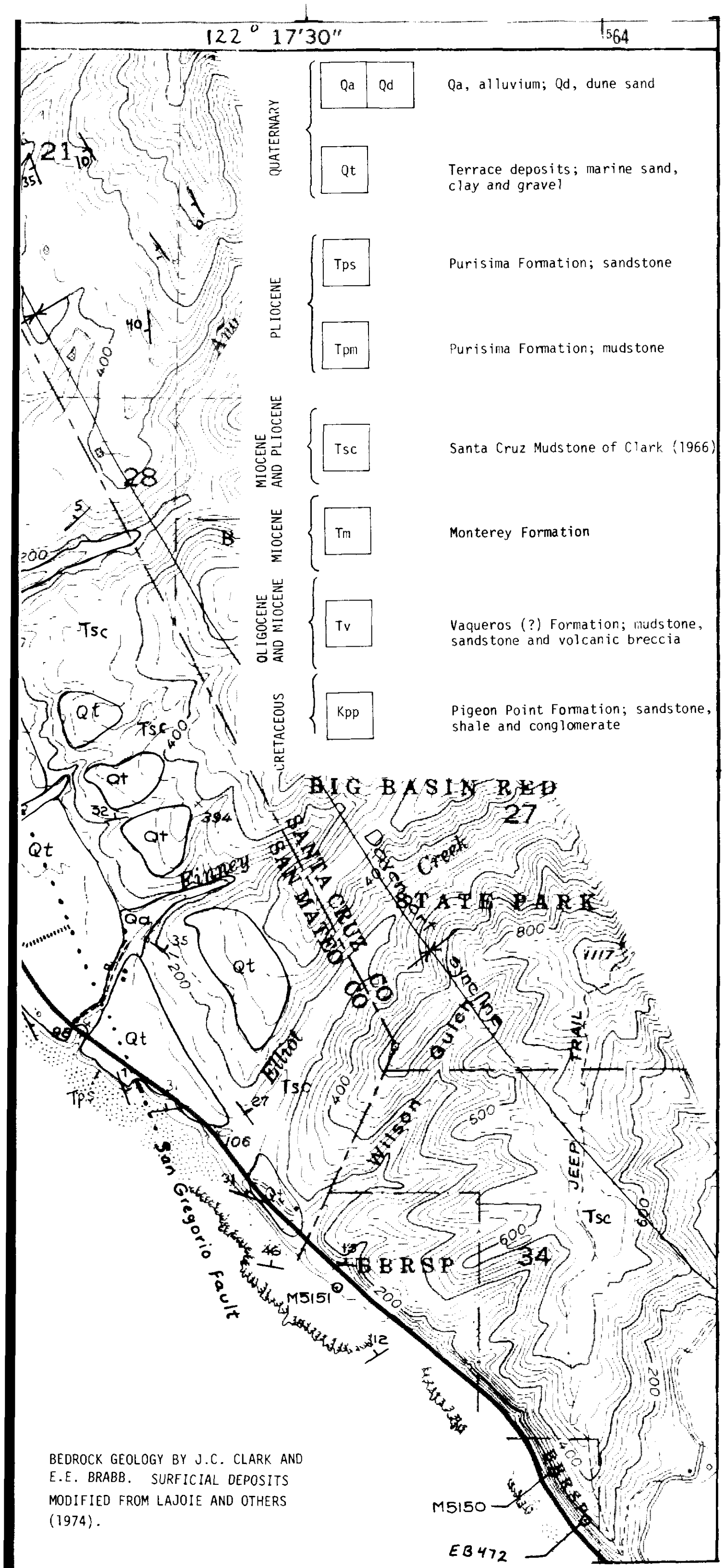


Figure 29.--Geologic map



of the Año Nuevo area.

Benthonic foraminifers are not as abundant or well preserved in the overlying siliceous beds of the Monterey Formation, where they are diagnostic of Relizian age and characteristic of middle bathyal depths. Planktonic foraminifers are common in one sample from Año Nuevo Island (USGS loc. Mf4531 = JC67-5) but are difficult to process from this siliceous mudstone and when recovered are poorly preserved.

The Monterey beds in the Año Nuevo area are lithologically similar to the rhythmically bedded siliceous strata of the type Monterey Formation, 65 km (40 mi) to the south, but are older than those of the type section, which are mostly of Mohnian (upper Miocene) age.

(Cross section on next page.)

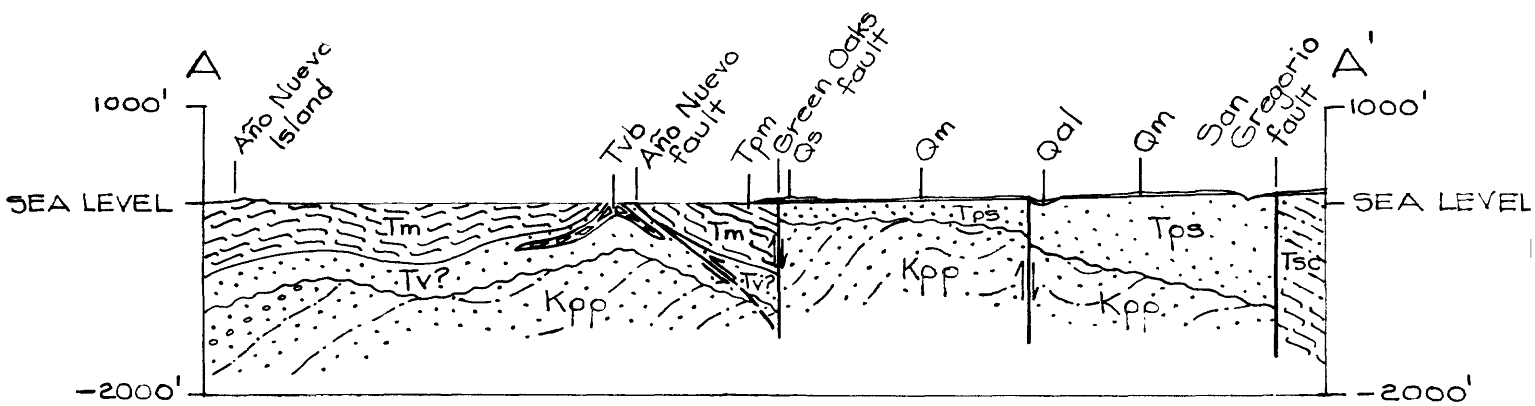


Figure 29--continued

SYSTEM	SERIES	STAGE	FORMATION	LITHOLOGY	THICKNESS Meters (feet)	DESCRIPTION
TERTIARY	PLIOCENE		Purisima Formation		360+ (1200+)	Thick to very thick bedded olive-gray, fine-grained lithic sandstone with thick to very thick interbeds of rhyolitic tuff and a few carbonate concretions
			Faulted against mudstone and unconformable on Pigeon Point Formation		76 (250)	Medium to thick bedded light-olive-gray, nodular mudstone
			Unconformity			
	OLIGOCENE TO MIOCENE	Relizian	Monterey Formation		215+ (700+)	Thin bedded and thinly laminated olive-gray to dusky-yellowish-brown, siliceous mudstone
		Zemorrian, Saucesian, Relizian	Vaqueras(?) Formation		230+ (770+)	Thick to very thick bedded arkosic sandstone and sandy limestone, olive-gray bioturbated siltstone, and dusky-yellowish-brown phosphatic mudstone Upper part contains altered andesitic breccia
			Unconformity			
CRETACEOUS	UPPER CRETACEOUS	Santonian(?), Campanian, and Maestrichtian	Pigeon Point Formation		2600+ (8500+)	Interbedded sequence of brownish-gray fine- to coarse-grained sandstone and dark-gray sandy siltstone in lower part, and sandy pebble to cobble conglomerate, pebbly mudstone, coarse-grained sandstone and laminated and cross-bedded fine-grained sandstone in upper part
			Contact not exposed			
CRETACEOUS OR OLDER						Porphyritic rhyolite, greenish, with phenocrysts of quartz, plagioclase, and orthoclase(?) in a silicic matrix

Figure 30.--Stratigraphic column for the area west of the San Gregorio fault

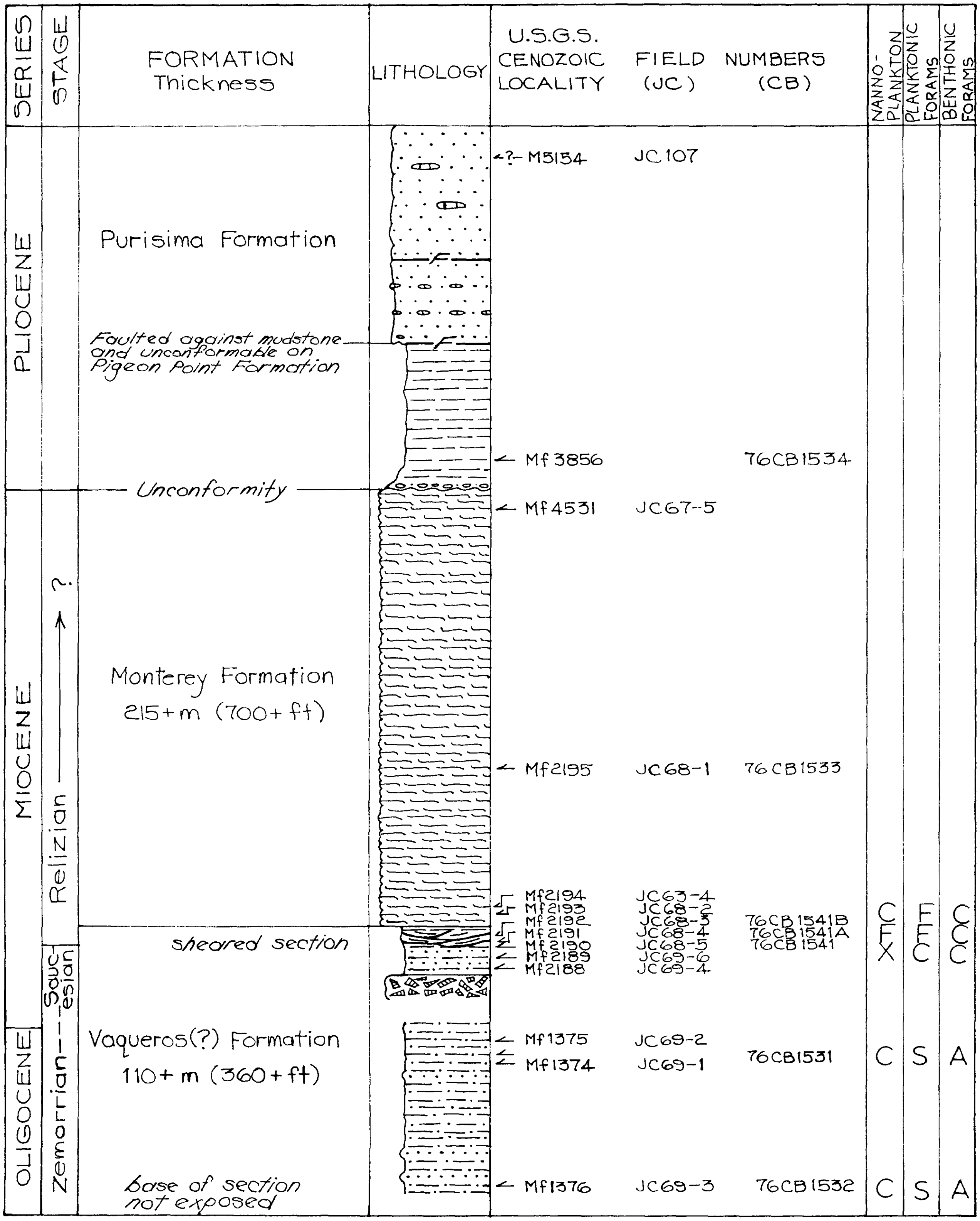


Figure 31.--Stratigraphic column for the Año Nuevo area.

Table 8.--Foraminifers from the Año Nuevo area

[Locality Mf1374-Mf1376 identifications by R. L. Pierce; other identifications by J. C. Clark and R. M. Kleinpell; A=Abundant, C=Common, F=Few, R=Rare, VR=Very Rare]

	USGS Cenozoic locality and field number											
	Mf1376 (JC69-3)	Mf1374 (JC69-1)	Mf1375 (JC69-2)	Mf2188 (JC69-4)	Mf2189 (JC69-6)	Mf2190 (JC68-5)	Mf2191 (JC68-4)	Mf2192 (JC68-3)	Mf2193 (JC68-2)	Mf2194 (JC63-4)	Mf2195 (JC68-1)	Mf4531 (JC67-5)
Anomalina californiensis Cushman & Hobson	R											
Anomalina aff. A. salinasensis Kleinpell						R						
Baggina robusta Kleinpell						C	A	R				
Baggina(?) sp								R				
Bolivina advena Cushman						F						
Bolivina advena var. striatella Cushman						F			C	F		
Bolivina cf. B. advena var. striatella Cushman								F				
Bolivina brevior Cushman							VR		F	F		
Bolivina californica Cushman				F		F						
Bolivina cf. B. floridana Cushman												C
Bolivina aff. B. hughesi Cushman						C						
Bolivina marginata Cushman	C			F	F		A	F	F	VR	VR	
Bolivina cf. B. marginata Cushman												R
Bolivina aff. B. seminuda Cushman											C	A
Bolivina aff. B. vaughani Natland										VR		
Bulimina alligata Cushman & Laiming			C	F	F							
Bulimina carnerosensis Cushman & Kleinpell	VR											
Bulimina inflata Seguenza								F				
Bulimina aff. B. inflata Seguenza							F					
Bulimina montereyana Kleinpell							F	C				
Bulimina ovata d'Orbigny				F								
Bulimina rinconensis Cushman & Laiming(?)				VR								
"Bulimina(?) sp." Kleinpell						R						
Bulimina sp.							R		VR		VR	F
Buliminella curta Cushman						R						
Buliminella subfusiformis Cushman						R	R		C	F		C
Buliminella cf. B. subfusiformis Cushman											VR	
Buliminella sp									VR			
Cassidulina crassa d'Orbigny of Kleinpell								C				
Cassidulina laevigata var. carinata Cushman						R		A	F	C		
Cassidulina pulchella d'Orbigny(?)						F						
Cassidulina subglobosa H. B. Brady							C	VR	R	R	VR	VR
Cassidulina sp.							F					VR
Chilostomella sp.				VR								
Cibicides americanus var. crassiseptus Cushman & Laiming		C	R									
Cibicides dohertyi Galloway & Morrey				R	VR							
Cibicides floridanus (Cushman)	C	C	F		F							
Cibicides cf. C. floridanus (Cushman)						R	F	F				
Cibicides aff. C. edgei Cushman & Schenck				F								
Cibicides pseudoungerianus var. evolutus Cushman & Hobson		F	F									
Dentalina pauperata d'Orbigny				R		F	R					
Dentalina quadrulata Cushman & Laiming				R	VR							
Dentalina sp								R	VR	F		
Dentalina(?) sp											VR	
Epistominella subperuviana (Cushman)									F	R	VR	
Epistominella cf. E. subperuviana (Cushman)												VR
Epistominella sp							R	VR	R			
Epistominella(?) sp												C
Eponides keenani Cushman & Kleinpell									F		F	C
Eponides nanus (Reuss)					F							
Eponides rosaformis Cushman & Kleinpell								F				
Eponides umbonatus (Reuss)		F	F									
Florilus incisus (Cushman)					F			F	F			
Frondicularia sp								R	R	VR		VR
Gaudryina(?) sp.								VR				
Globigerina sp												C
Globigerina spp						F	F		VR		VR	
Gyroidina soldanii d'Orbigny	VR	C	C	C	C			F				
Gyroidina cf. G. soldanii d'Orbigny									F			
Lenticulina hughesi (Kleinpell)						F	F					
Lenticulina warmani (Barbat & von Estorff)				F	F							
Lenticulina sp.										VR		
Lenticulina spp.								R				
Nodosaria longiscata d'Orbigny				VR								F
"Nonion" pompilioides (Fichtel & Moll) var.		F	VR	VR				A		R		
"Nonion" cf. "N." pompilioides (Fichtel & Moll) var.												VR
Plectofrondicularia advena (Cushman)		F	R									
Plectofrondicularia californica Cushman & Stewart			R		F							
Plectofrondicularia miocenica Cushman		VR	F	F								
Plectofrondicularia vaughani Cushman		C		R								
Pullenia bulloides d'Orbigny								R				
Pullenia moorei Kleinpell								R				
Pullenia aff. P. quinqueloba (Reuss)				VR								
Pullenia cf. P. bulloides d'Orbigny							VR					
Pullenia salisburyi R. E. & K. C. Stewart							R					
Pullenia aff. P. salisburyi R. E. & K. C. Stewart				VR								
Siphogenerina branneri (Bagg)						A	C					
Siphogenerina cf. S. collomi Cushman								R				
Siphogenerina cf. S. hughesi Cushman							R					
Siphogenerina kleinpelli Cushman						C		F				
Siphogenerina mayi Cushman & Parker		F										
Siphogenerina multicostata Cushman & Jarvis					VR							
Siphogenerina multicostata Cushman & Jarvis of Kleinpell			A									
Siphogenerina nodifera Cushman & Kleinpell	A	C										
Siphogenerina cf. S. reedi Cushman								R				
Siphogenerina transversa Cushman					R							
Sphaeroidina bulloides d'Orbigny		F	R									
Sphaeroidina variabilis Reuss								R				
Stilostomella advena (Cushman & Laiming)				R	R			R	R	F		R
Suggrunda sp												F
Uvigerina cf. U. auberiana d'Orbigny			R									
Uvigerina cf. U. beccarii Fornasini				F								
Uvigerina cf. U. mexicana Nuttall				R								
Uvigerina sp									VR			
Uvigerinella californica Cushman						F						
Uvigerinella aff. U. californica Cushman									C	C	C	C
Uvigerinella californica var. ornata Cushman						F				R		
Uvigerinella obesa Cushman						R						
Uvigerinella obesa var. impolita Cushman & Laiming					C							
Uvigerinella cf. U. obesa var. impolita Cushman & Laiming				VR								
Valvulineria aff. V. californica var. obesa Cushman								R				
Valvulineria cf. V. californica var. obesa Cushman										VR		
Valvulineria depressa Cushman						C						
Valvulineria cf. V. depressa Cushman												VR
Virgulina sp							VR	C				
Virgulina(?) sp										VR		

Table 9.--Locality descriptions for the Ano Nuevo area.

Ano Nuevo Mf (JC) localities

Mf2188: California, San Mateo County, Ano Nuevo 7.5' quad. From low intertidal exposure about 335m (1100 ft.) E. of Ano Nuevo Point. Unsectioned. Vaqueros(?) Formation, lower Miocene. From 2m (7 ft) stratigraphically above volcanic breccia exposed at low tide. Collected by J. C. Clark, 1969 (field number = JC69-4)

Mf2189: California, San Mateo County, Ano Nuevo 7.5' quad. From low intertidal exposure about 330 m (1080 ft) E. of Ano Nuevo Point. Unsectioned. Vaqueros(?) Formation, lower Miocene. From 8m (26 ft) stratigraphically above Mf2188. Collected by J. C. Clark, 1969 (field number = JC69-6)

Mf2190: California, San Mateo County, Ano Nuevo 7.5' quad. From low sea cliff at small beach about 400 m (1300 ft) E. of Ano Nuevo Point. Unsectioned. Vaqueros(?) Formation, lower Miocene. From 3.6m (12 ft) stratigraphically above volcanic breccia. Collected by J. C. Clark, 1968 (field number = JC68-5)

Mf2191: California, San Mateo County, Ano Nuevo 7.5' quad. Same locality as Mf2190; from 1.8 m (6 ft) stratigraphically above Mf2190. Unsectioned. Vaqueros(?) Formation, middle Miocene. Collected by J. C. Clark, 1968 (field number = JC68-4)

Mf2192: California, San Mateo County, Ano Nuevo 7.5' quad. Same locality as Mf2191, from about 1m (4 ft) stratigraphically above Mf2191. Unsectioned. Vaqueros(?) Formation, middle Miocene. Collected by J. C. Clark, 1968 (field number = JC68-3)

Mf2193 California, San Mateo County, Ano Nuevo 7.5' quad. From sea cliff on east side of small beach about 400m (1325 ft) E. of Ano Nuevo Point. Unsectioned. Monterey Formation, middle Miocene. Collected by J. C. Clark, 1968 (field number = JC68-2)

Mf2194: California, San Mateo County, Ano Nuevo 7.5' quad. From sea cliff about 2m (6 ft) above water level from E. side of small cove about 420m (1375 ft) E. of Ano Nuevo Point. Unsectioned Monterey Formation, middle Miocene. From 4m (13 ft) stratigraphically above Mf2193. Collected by J. C. Clark, 1963 (field number = JC63-4)

Mf2195: California, San Mateo County, Ano Nuevo 7.5' quad. From W. side of small headland about 640m (2100 ft) E. of Ano Nuevo Point. Unsectioned. Monterey Formation, middle Miocene. From 0.6m (2 ft) below unconformable contact with overlying Purisima Formation. Collected by J. C. Clark, 1968 (field number = JC68-1)

Mf4531: California, San Mateo County, Ano Nuevo 7.5' quad. From sea cliff 107m (350 ft) N.70°W. of lighthouse on Ano Nuevo Island. Unsectioned. Monterey Formation, middle Miocene. Collected by J. C. Clark, 1967 (field number = JC67-5)

LARGE FORAMINIFERS

Large foraminifers, such as *Discocyclina* sp., were collected from rocks of Eocene age and from reworked boulders in rocks of Miocene age at three areas in the San Francisco Bay region (fig. 32), and near Devils Den (fig. 2). In the San Francisco Bay region, the large foraminifers were collected near Mount Diablo (loc. EB 611), south of San Jose (locs. 74CB971, EB633, and 71CB983), and in the Sveadal area (Osbun locs. 1-1, 1-43, 1-49).

Mount Diablo Area

Many reports have been published on the Paleogene stratigraphy and paleontology of the Mount Diablo area. Colburn (1961) discusses most of this literature. The rocks are reasonably well exposed and fossiliferous but generally have shallower water assemblages than those in Santa Cruz Mountains.

Figure 33 shows just a few of the many fossil collections that have been made in a small part of the area. The map is from Watson (1941, pl. 4) and was part of a project of the late Hubert G. Schenck to study and correlate Eocene formations in California. Collection EB 611 was made at LSJU 986 from which Keenan (1932, pl. 3, figs. 1 and 2) described and illustrated two species of large foraminifers. The bed from which these fossils were obtained is just a few centimeters thick and was covered in 1976 when the section was revisited.

San Jose and Sveadal Areas

Large foraminifers from the San Jose area were first described and illustrated by Schenck (1929, p. 224-227). Bailey and Everhart (1964) have described the geology of the area. Locality 71CB983 (see fig. 34) is about one-half kilometer northwest of LSJU 309 from which the holotype of *Discocyclina californica* was obtained. Within a few centimeters of 71CB983C, which contains large foraminifers, another sample (71CB983A) was collected that contains the following smaller foraminifers, according to W. A. Berggren (written comm., 1977):

Acarinina coalingensis (Cushman and Hanna)
Subbotina patagonica (Todd and Kniker)
Acarinina acarinata Subbotina
A. soldadoensis (Bronnimann)
Morozovella subbotinae (Morozova)
M. gracilis (Bolli)
M. formosa (Bolli)
Several species of agglutinated foraminifers

Berggren believes that this assemblage is correlative with the *Morozovella formosa* zone (P7), early Eocene.

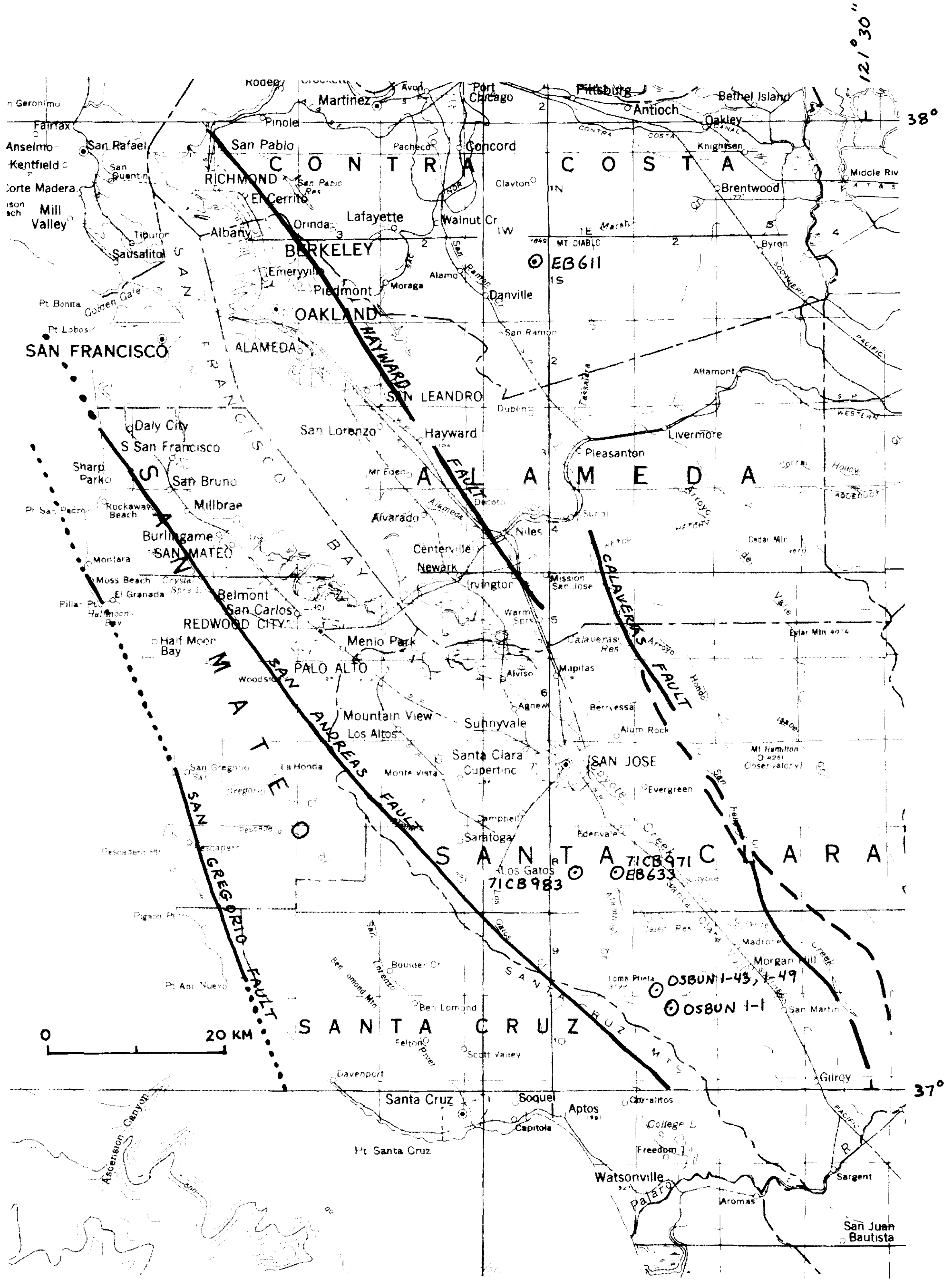


Figure 32.--Index map showing localities where large foraminifers, such as Discocyclina sp., were collected.

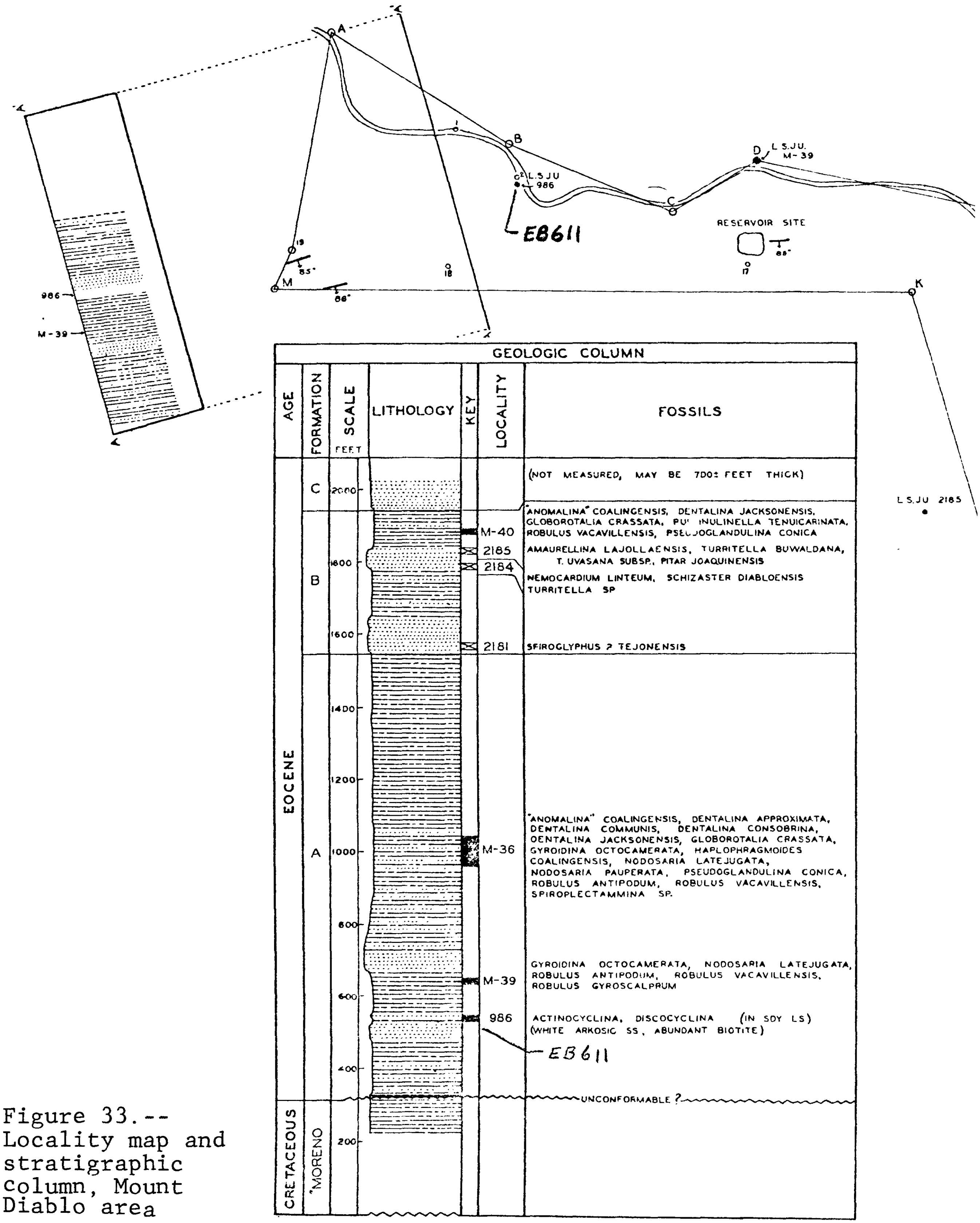


Figure 33.--Locality map and stratigraphic column, Mount Diablo area

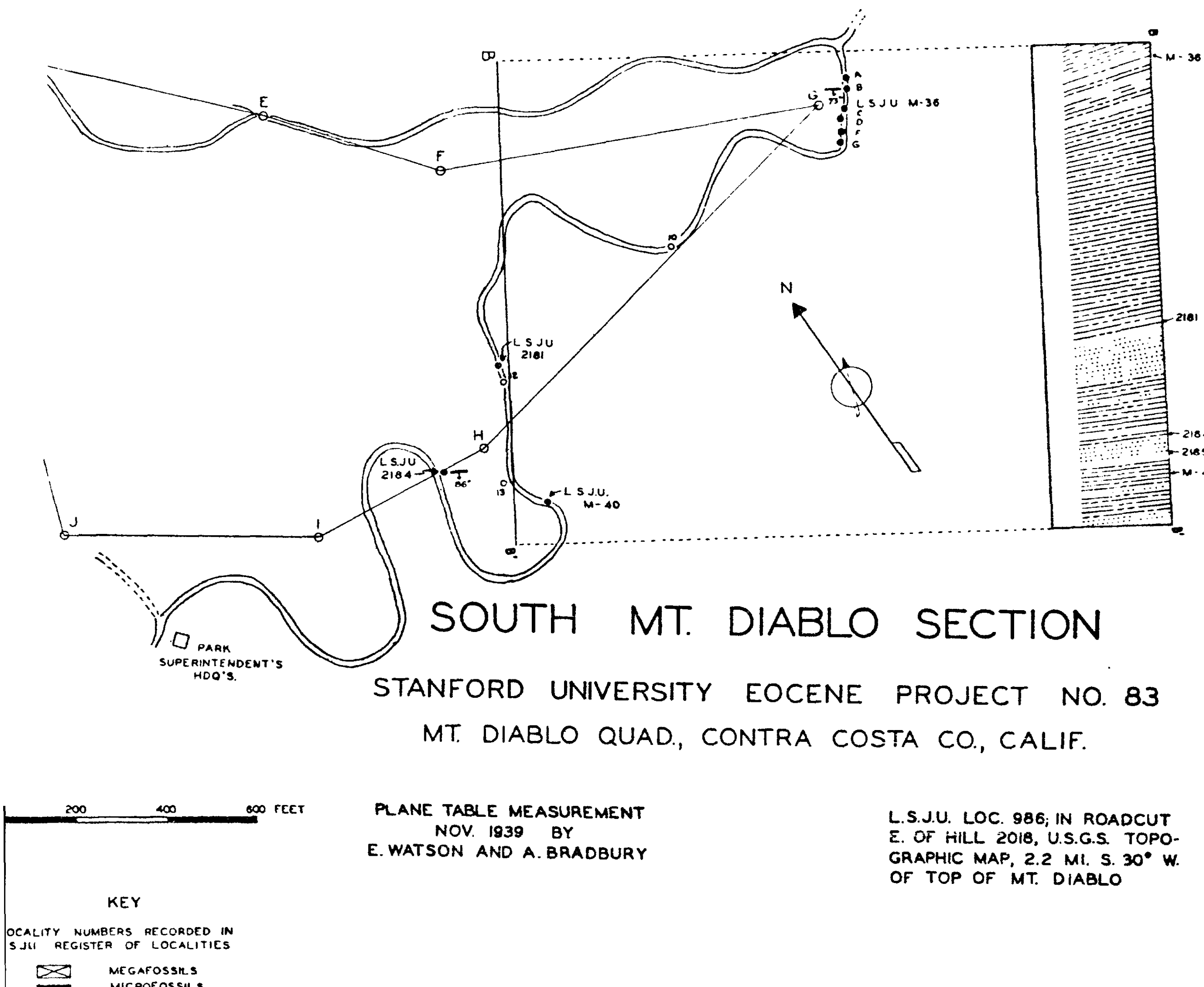


Figure 33.--continued

Locality 71CB983 is now covered by a newly constructed house. Locality 71B971 is in an abandoned limestone quarry that was still accessible in 1971 when it was last visited.

In the Sveadal area near Loma Prieta (see fig. 32), Osbun (1975) discovered large foraminifers in limestone boulders within the basal part of the Temblor Formation of middle Miocene age. The localities and a stratigraphic column are shown on figure 35. The boulders were presumably derived from the erosion of the limestone in the vicinity of 71CB983 and 71CB971.

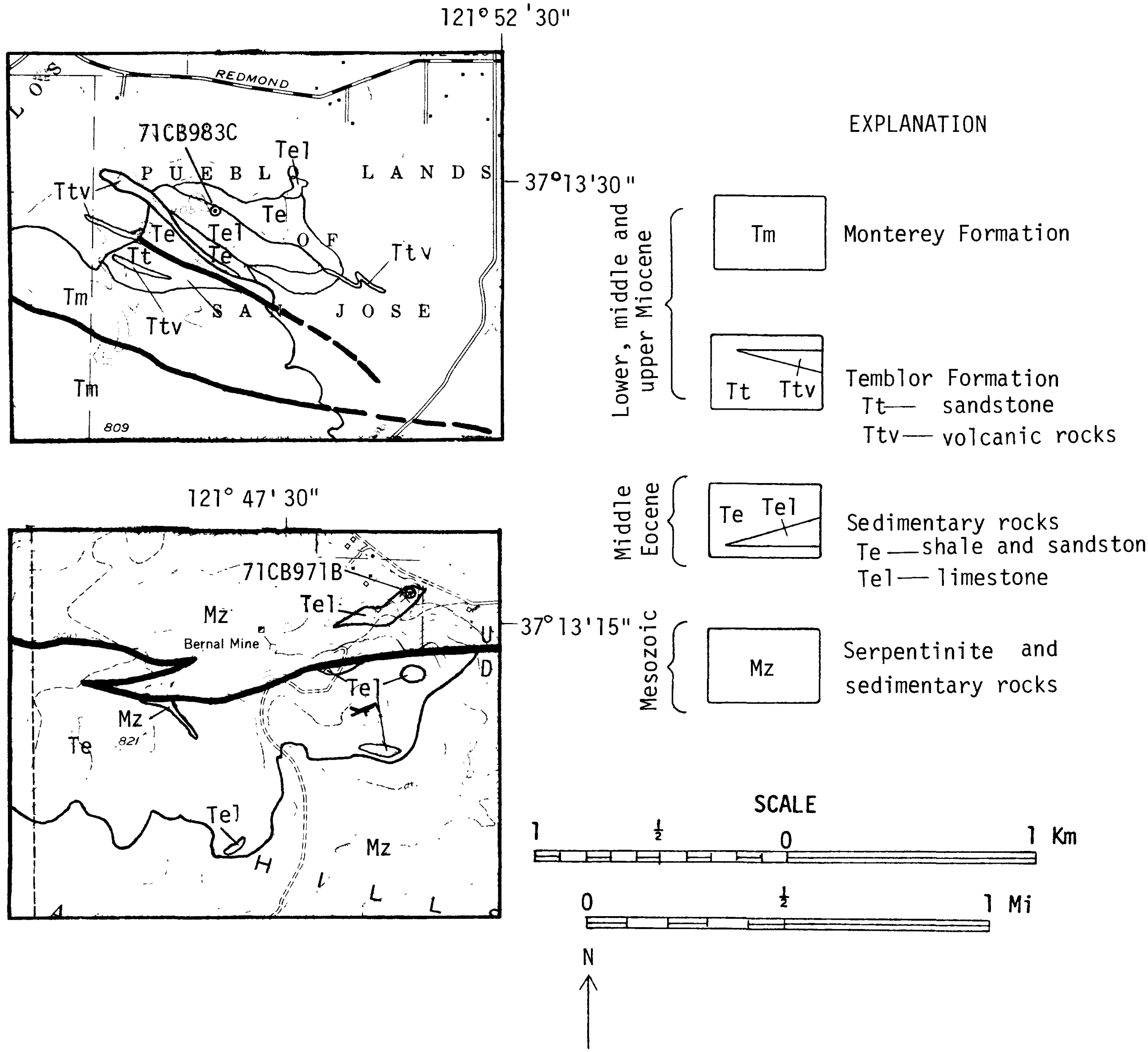


Figure 34.--Geologic maps of the southern San Jose area showing localities where foraminifers were collected. Map bases from Los Gatos and Santa Teresa Hills 7.5' quadrangles. Geology generalized from Bailey and Everhart (1964).

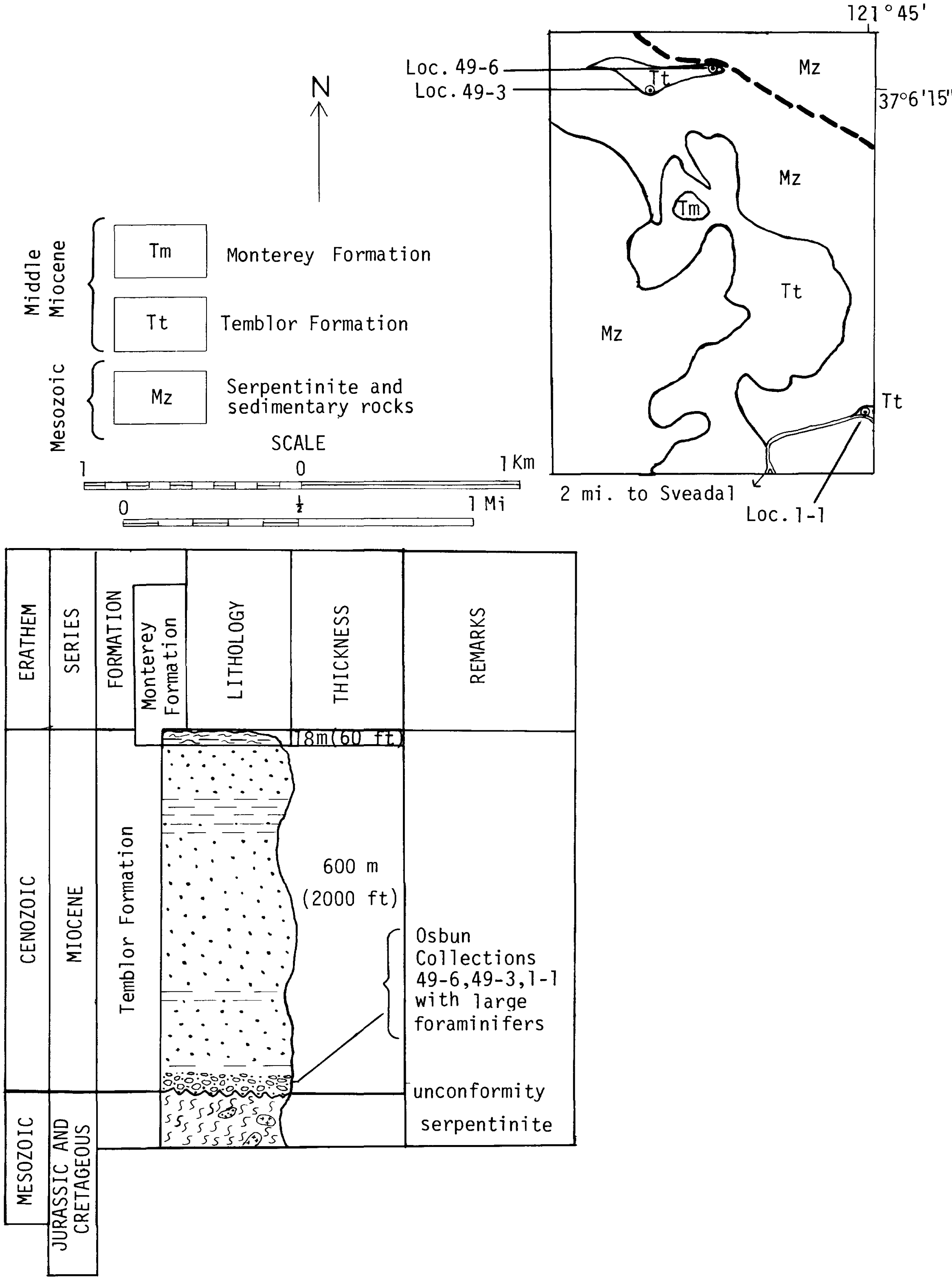


Figure 35.--Geologic map and stratigraphic column for the Sveadal area. Geology from Osbun (1975).

DEVILS DEN SECTION

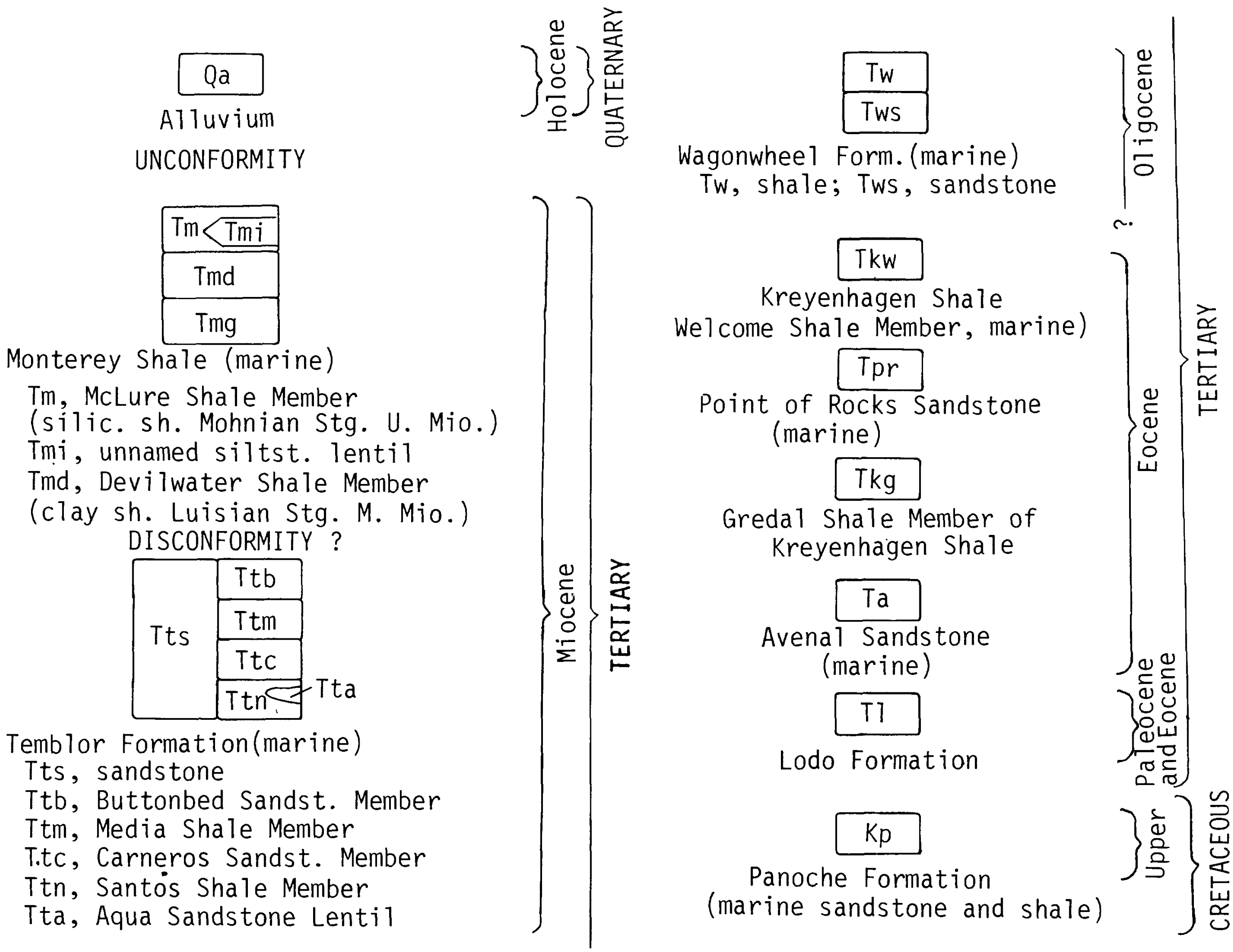
The Devils Den area (figs. 36 and 37) has a nearly complete section of Paleogene rocks that is easily accessible, moderately well exposed, and not too complicated structurally. Unfortunately, at most (but not all) localities the calcareous foraminifers have been leached out. Several trenches have been dug by oil company paleontologists in generally successful attempts to obtain fresh material--one of these may have provided the foraminifers that Mallory (1959) used to establish his Narizian Stage. The senior author found stakes and shallow pits that were probably left by Smith (1956) in his study of the Wagon Wheel Formation, but material dug from a depth of 1 m in these pits failed to yield any calcareous foraminifers. Auger holes or trenches to a depth of 3 m or more are probably required to recover calcareous material for most of the section.

Happily, the Barrenda Mesa Water District constructed a water distribution system in the late 1960's that has opened new exposures of the lower part of the Paleogene sequence. In particular, the afterbay area of pump station "A" has a continuous section from the Avenal Sandstone through the Gredal Shale Member of the Kreyenhagen Shale to the lower part of the Point of Rocks Sandstone (see figs. 38 and 39). The lower part of this section is repeated by a fault, and the relation of the lowest beds to the underlying Panoche Formation of Late Cretaceous age could not be determined. A small amount of siltstone below the Avenal Sandstone has been provisionally mapped as Lodo Formation.

The Devils Den area has been remapped recently by Dibblee (1971, 1974). Dibblee (1973) also has discussed the stratigraphy and nomenclature of the various rock units in the Devils Den area.

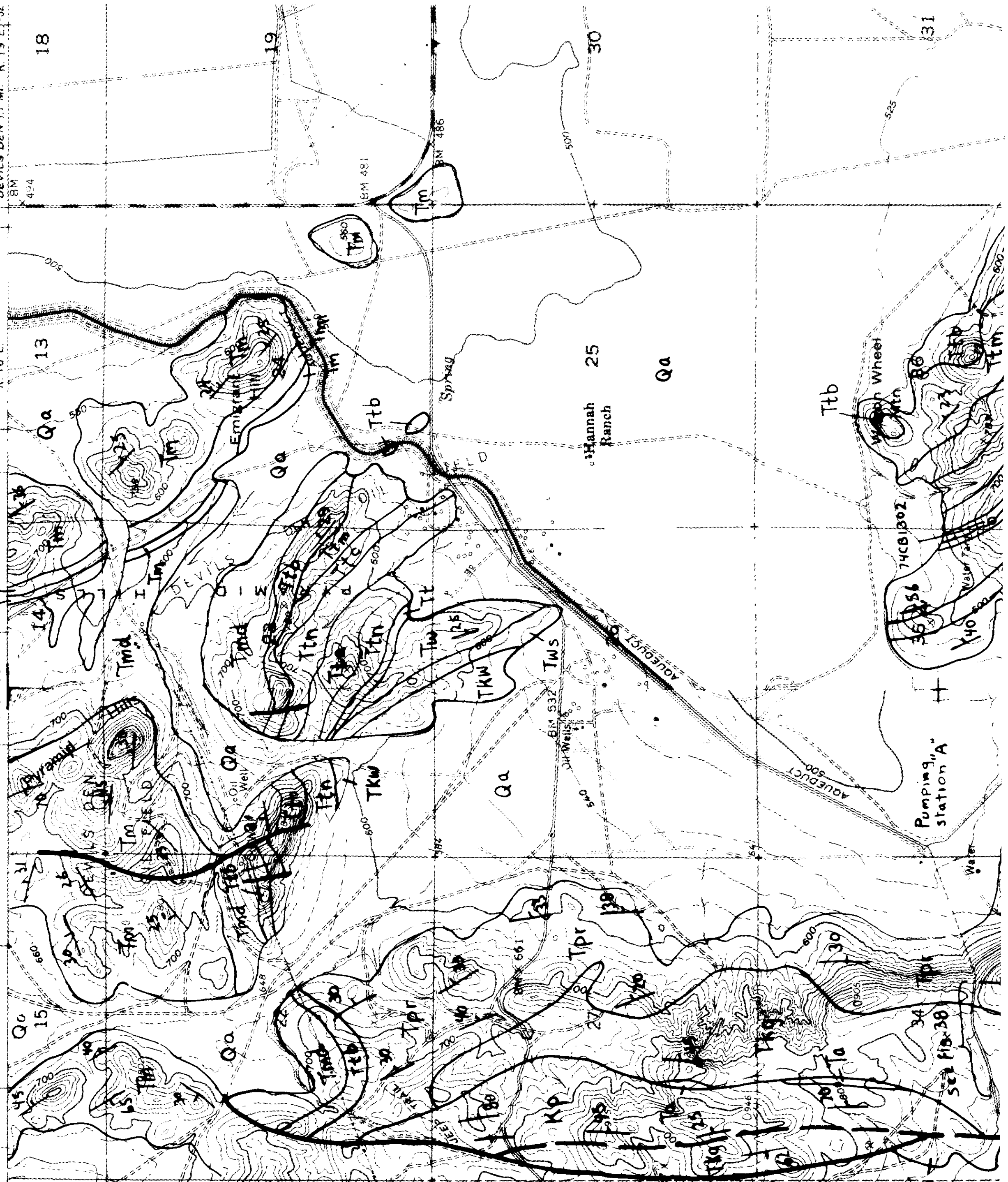
The Point of Rocks Sandstone and Kreyenhagen Shale of the Devils Den area are inferred by Clarke and Nilsen (1973) to have been contiguous with the Butano Sandstone and Twobar Shale Member of the San Lorenzo Formation in the Santa Cruz Mountain area (see figs. 3 and 5). They believe that these units have been displaced since Eocene time by about 300 km of right-lateral movement along the San Andreas fault.

EXPLANATION



(Map follows on next page.)

Figure 36.--Geologic map of the Devils Den area. Base maps from Sawtooth Ridge and Emigrant Hill 7.5' quadrangles. Geology from Dibblee (1971, 1973, and 1974).


AVENAL 20 MI
DEVILS DEN 1.1 MI.
R. 19 E.
R. 18 E.
120° 00'
Tm Tmi
Emigrant
Hannah Ranch
Spring
Wagon Wheel Mtn
AQUEDUCT
Pumping station "A"
Pyramid
Oil Well
Wells
Qa
Ttb
Tpr
TKw
Tws

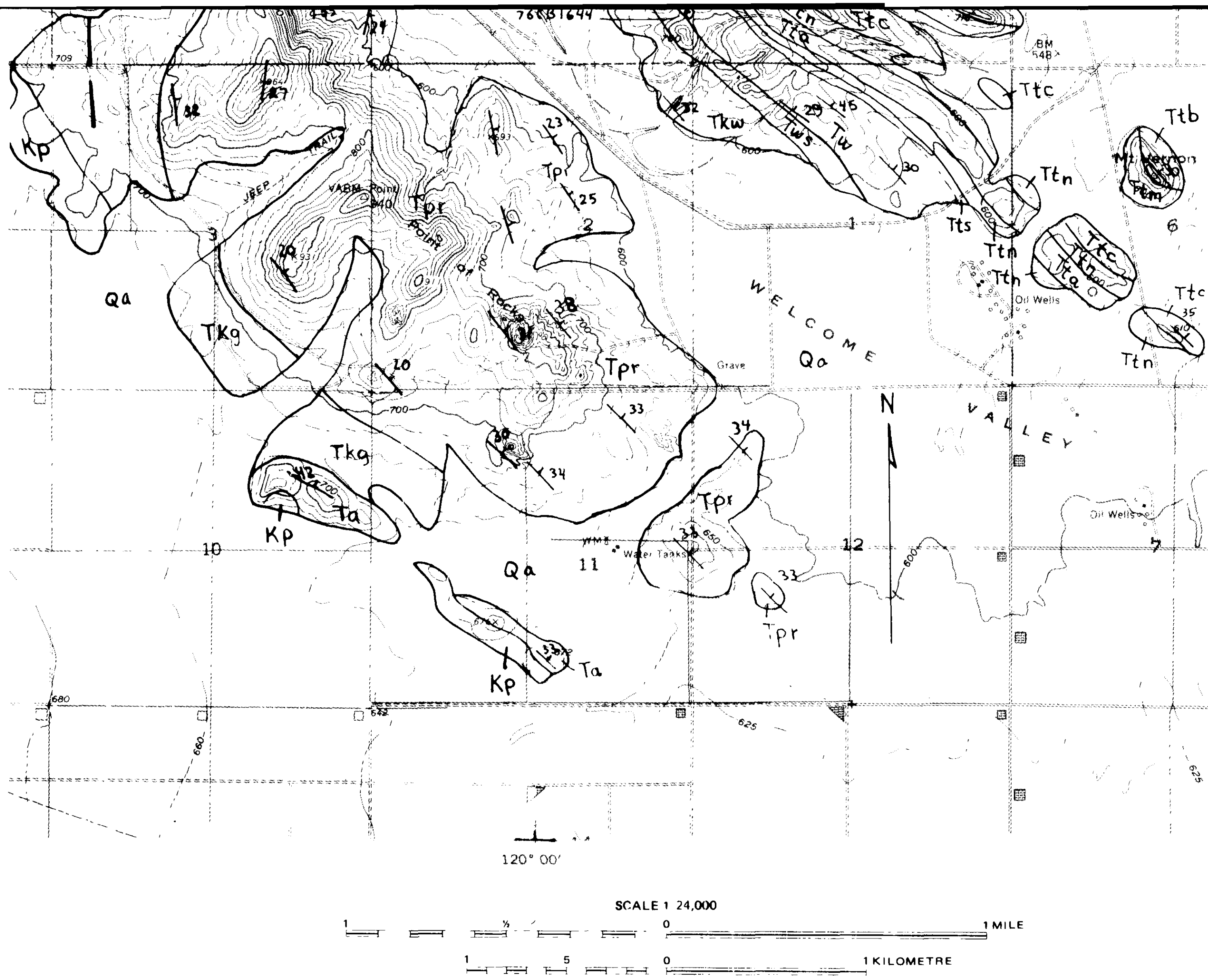
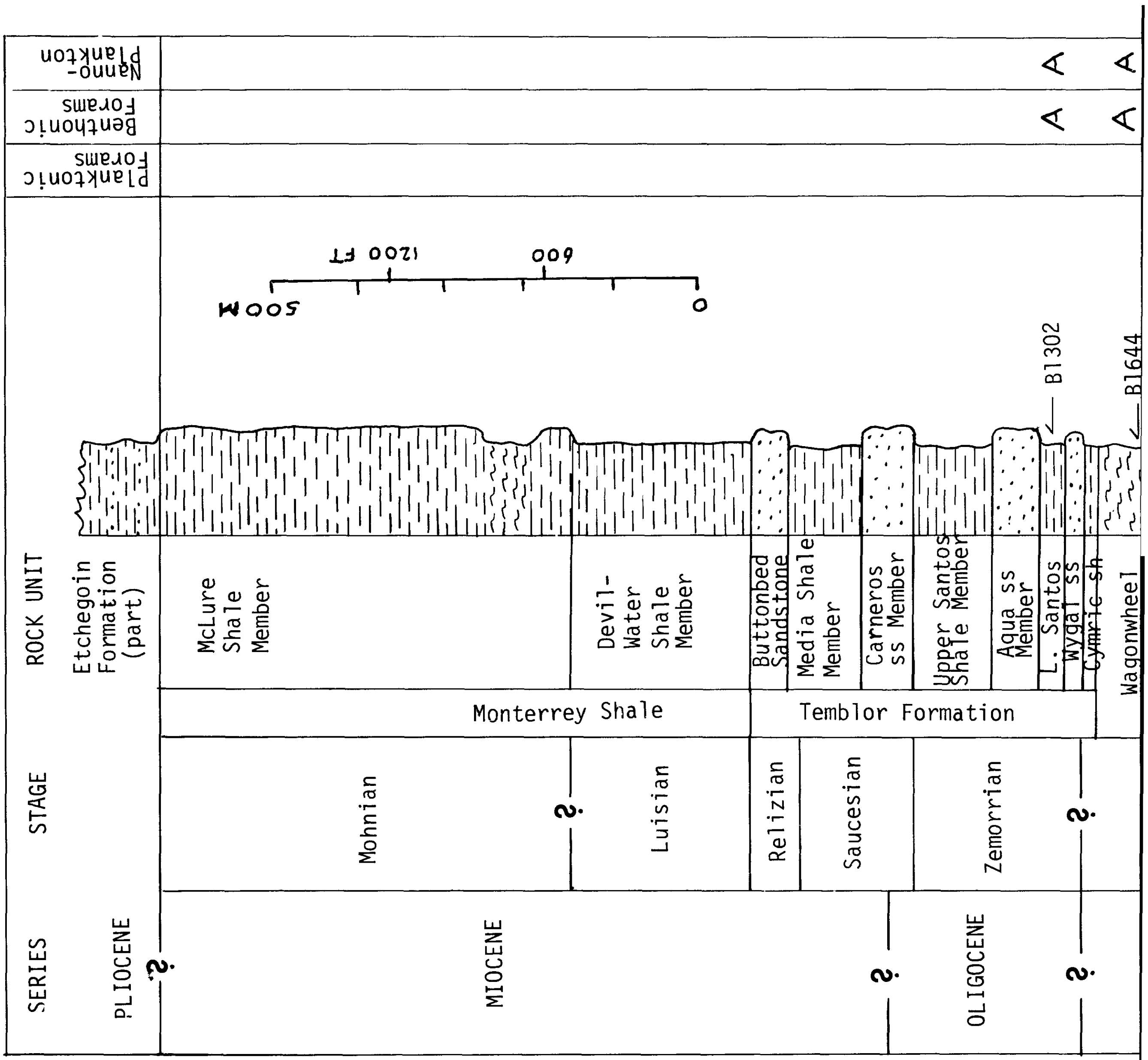


Figure 36.-- continued


SERIES
STAGE
ROCK UNIT
Planktonic Forams
Benthonic Forams
Nanno-Plankton
PLIOCENE
MIOCENE
OLIGOCENE
Mohnian
Luisian
Relizian
Saucesian
Zemorrian
Monterrey Shale
Temblor Formation
Etchegoin Formation (part)
McLure Shale Member
Devil-Water Shale Member
Buttonbed Sandstone
Media Shale Member
Carneros ss Member
Upper Santos Shale Member
Agua ss Member
L. Santos
Wygal ss
Cymric sh
Wagonwheel
B1302
B1644
A
0
600
1200 FT
500M

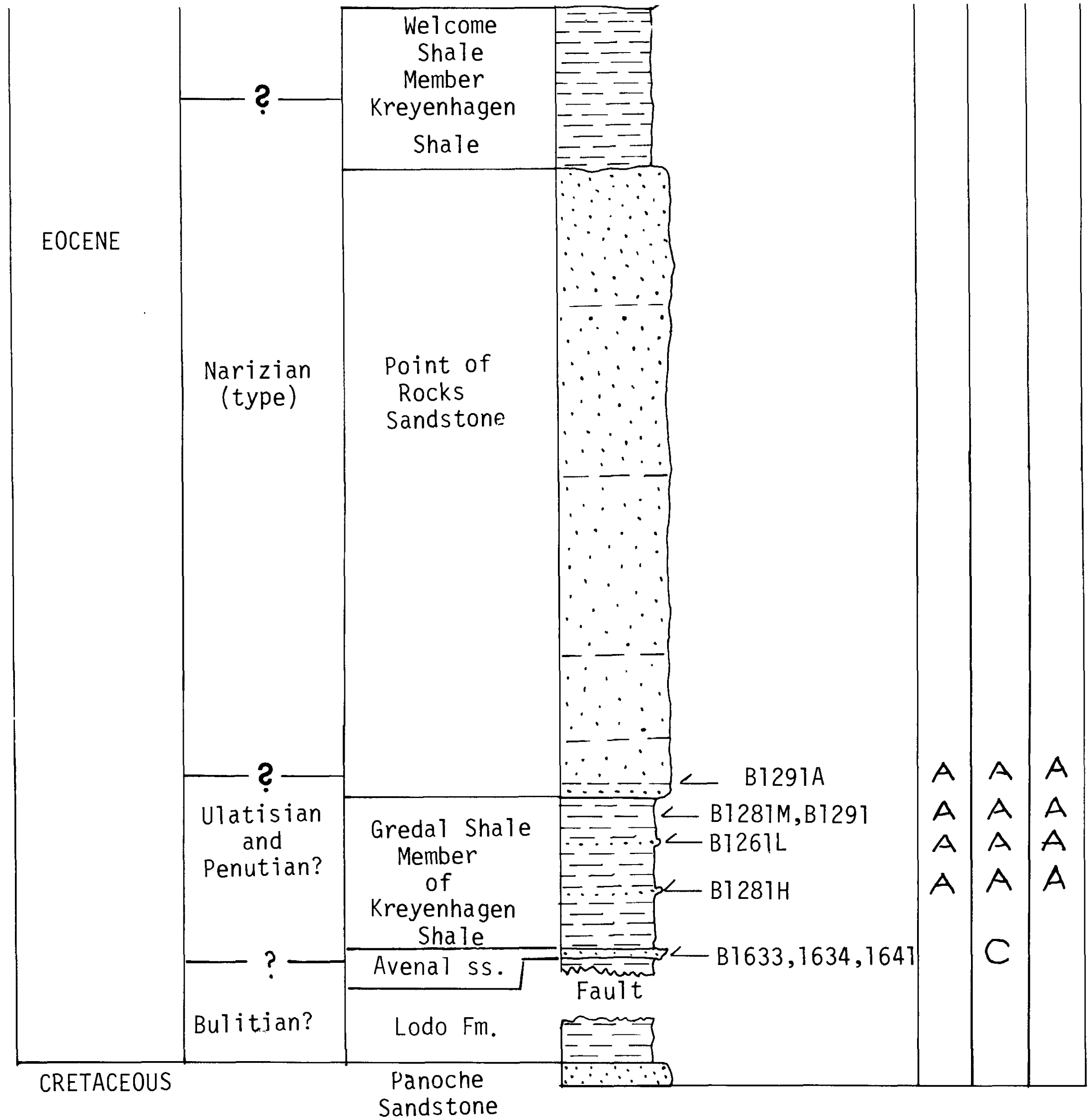


Figure 37.--Stratigraphic column for the Devils Den area. Data from Van Couvering and Allen (1943) and Dibblee (1973).

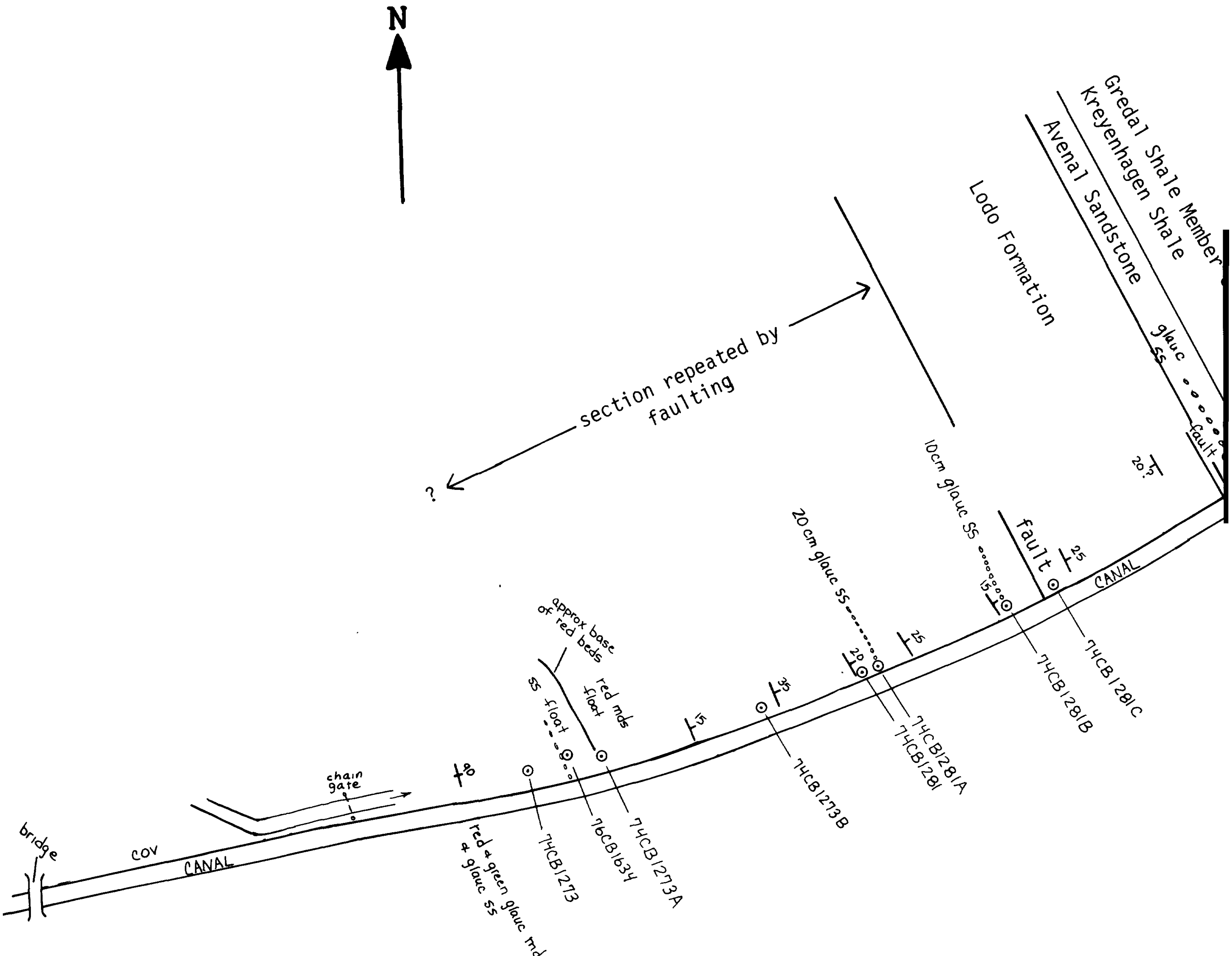
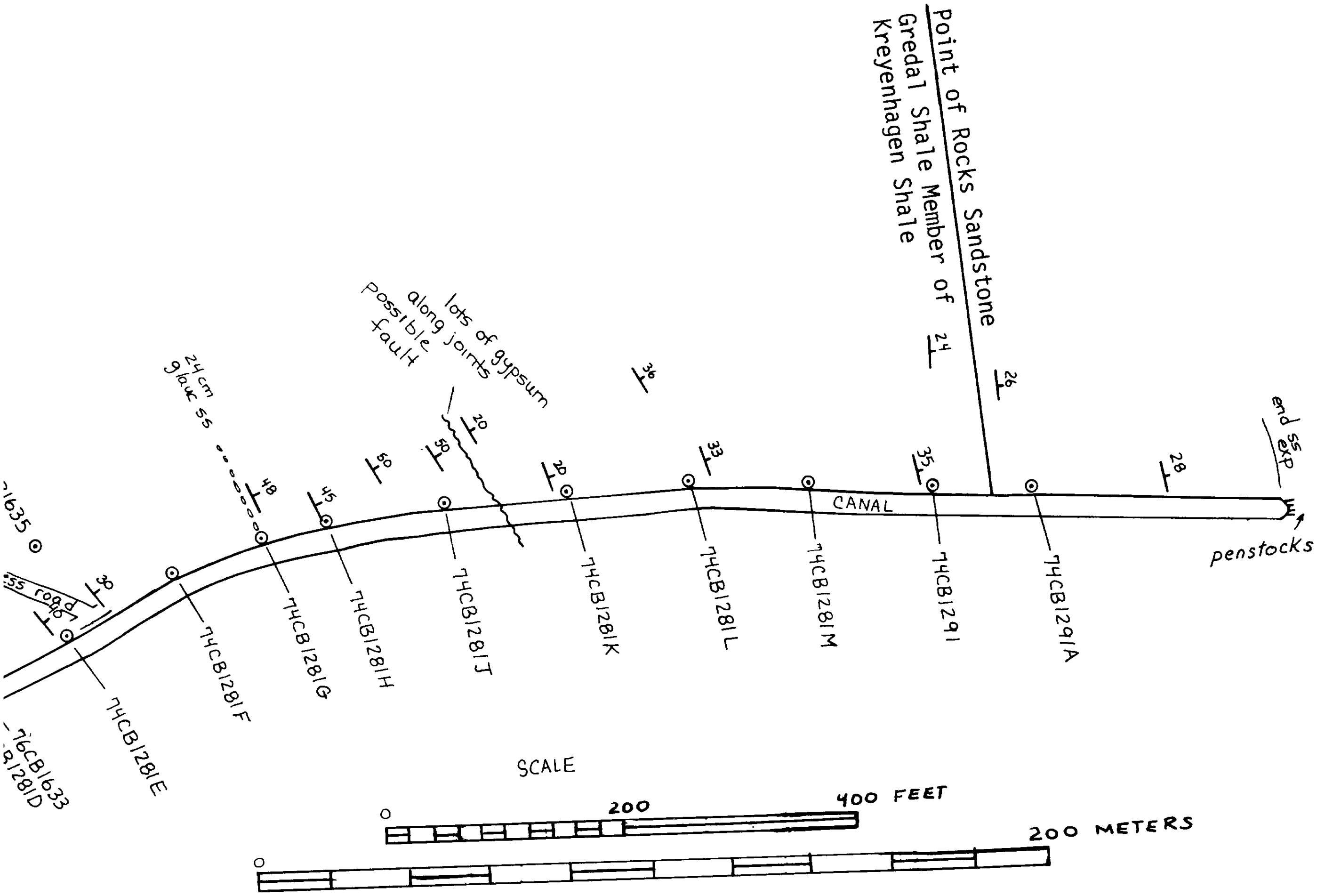


Figure 38.--Geologic sketch map of the aqueduct near Devils Den showing formation contacts, structures, and localities where fossils were collected



Measured by tape and compass, 1974, by E.E. Brabb, J.R. LeCompte, and S.W. Moore

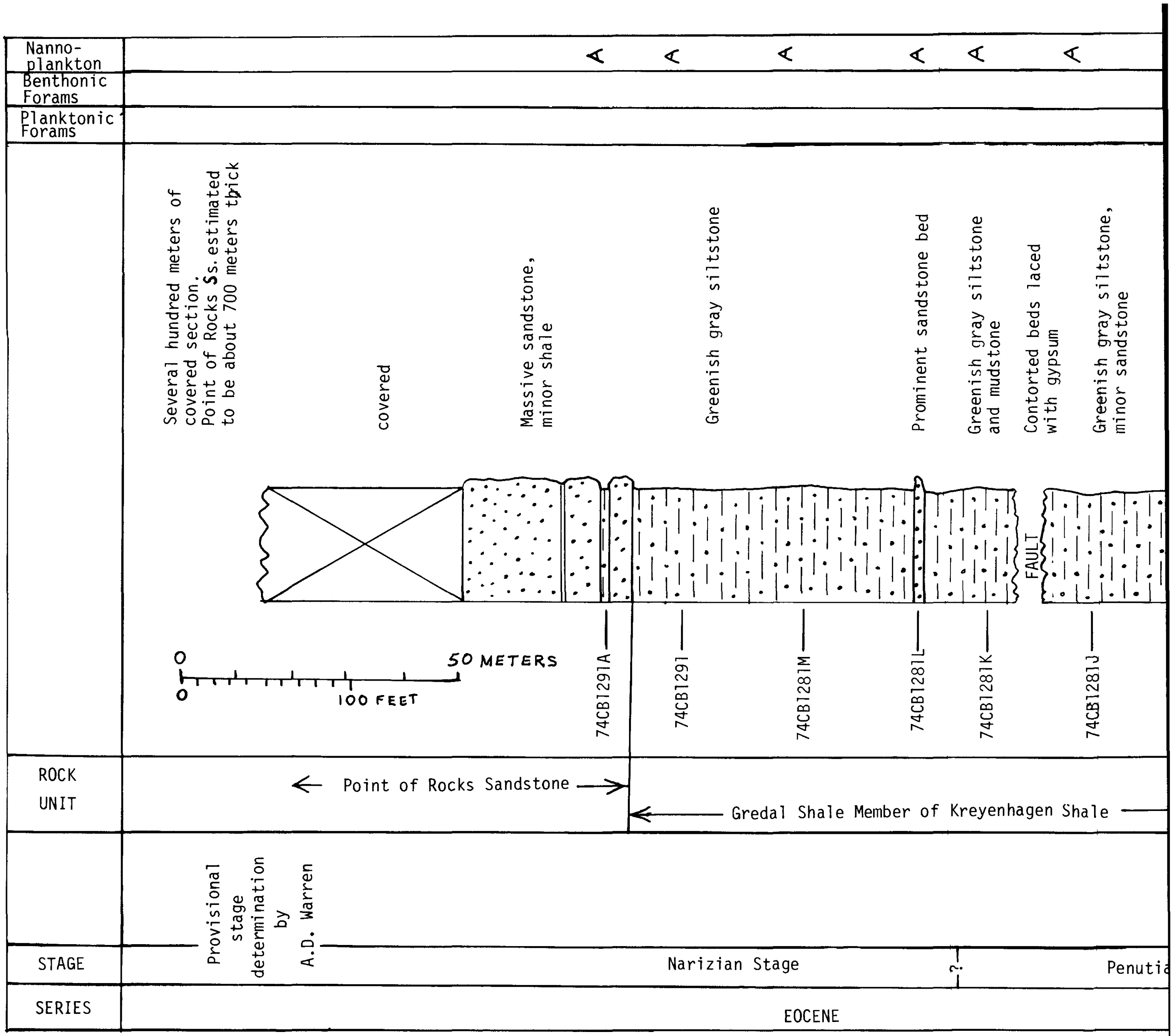
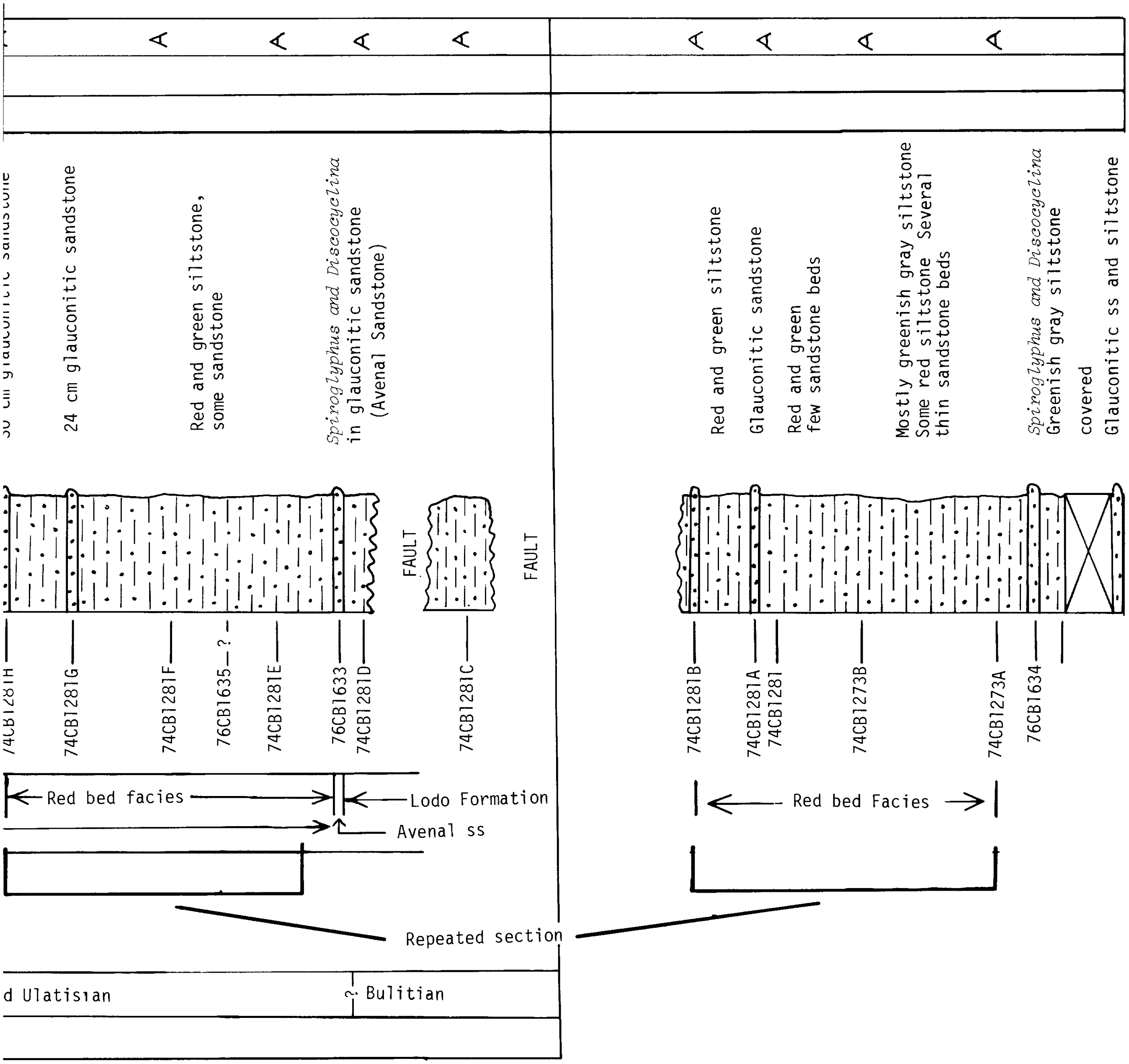


Figure 39.--Stratigraphic column, lower part of



section near Devils Den area, along aqueduct.

LODO GULCH SECTION

The Lodo Formation at its type locality (figs. 40 and 41) is one of the most important reference sections for the lower Paleogene in California. Foraminifers from the section have been described by Martin (1943), Israelsky (1951 and 1955), and Schmidt (1970). Nannoplankton have been described by Bramlette and Sullivan (1961). The integration of foraminifer and nannoplankton data and correlation with standard zonations has been done by Schmidt (1970, p. 50)--his time scale has been added to the stratigraphic column, figure 42.

The thickest section of the Lodo Formation (sec. A, fig. 40) is covered in its lower part. A supplementary section (B, fig. 40) was used by Israelsky (1951, pl. 1) to show the lower part of the formation and its contact with the underlying Moreno Shale of Late Cretaceous age. We have used still another section (C, fig. 40) to show this lower part. The section at C has locality LSJU 2073 shown on a map by Martin (1943, fig. 1) and on another map by Smith (1975, fig. 1). Smith lists more than 60 species of gastropods, pelecypods, brachiopods, and corals from LSJU 2073, and she compares them with similar species from the Bracheux sands, Rilly sands, and other units of Paleocene age in the Paris basin. The sandstone at LSJU 2073 is glauconitic and may have provided the material dated by Funnell (1964, p. 188, item 113) as 58.5 m.y. old.

The rocks in section A have slid extensively so that it is difficult in most places to obtain samples in correct stratigraphic position. Holes up to 1 m deep were dug with a shovel in an attempt to get below the landslide debris and into undisturbed rock, but some mixing of the samples is likely. A similar problem was noted by Israelsky (1951, p. 4).

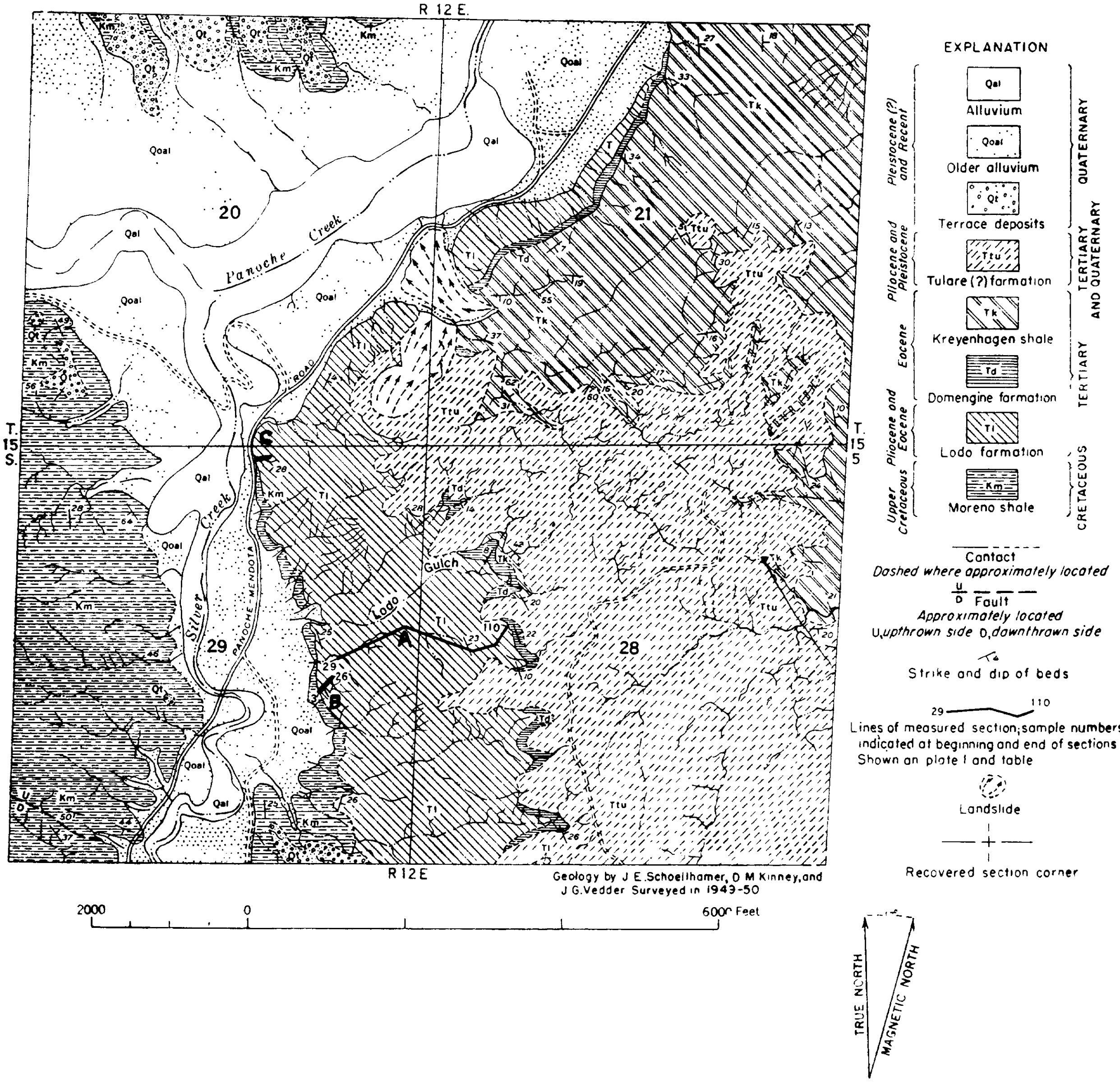


Figure 40.--Geologic map of the northwest Tumey Hills showing location of Lodo Gulch sections.

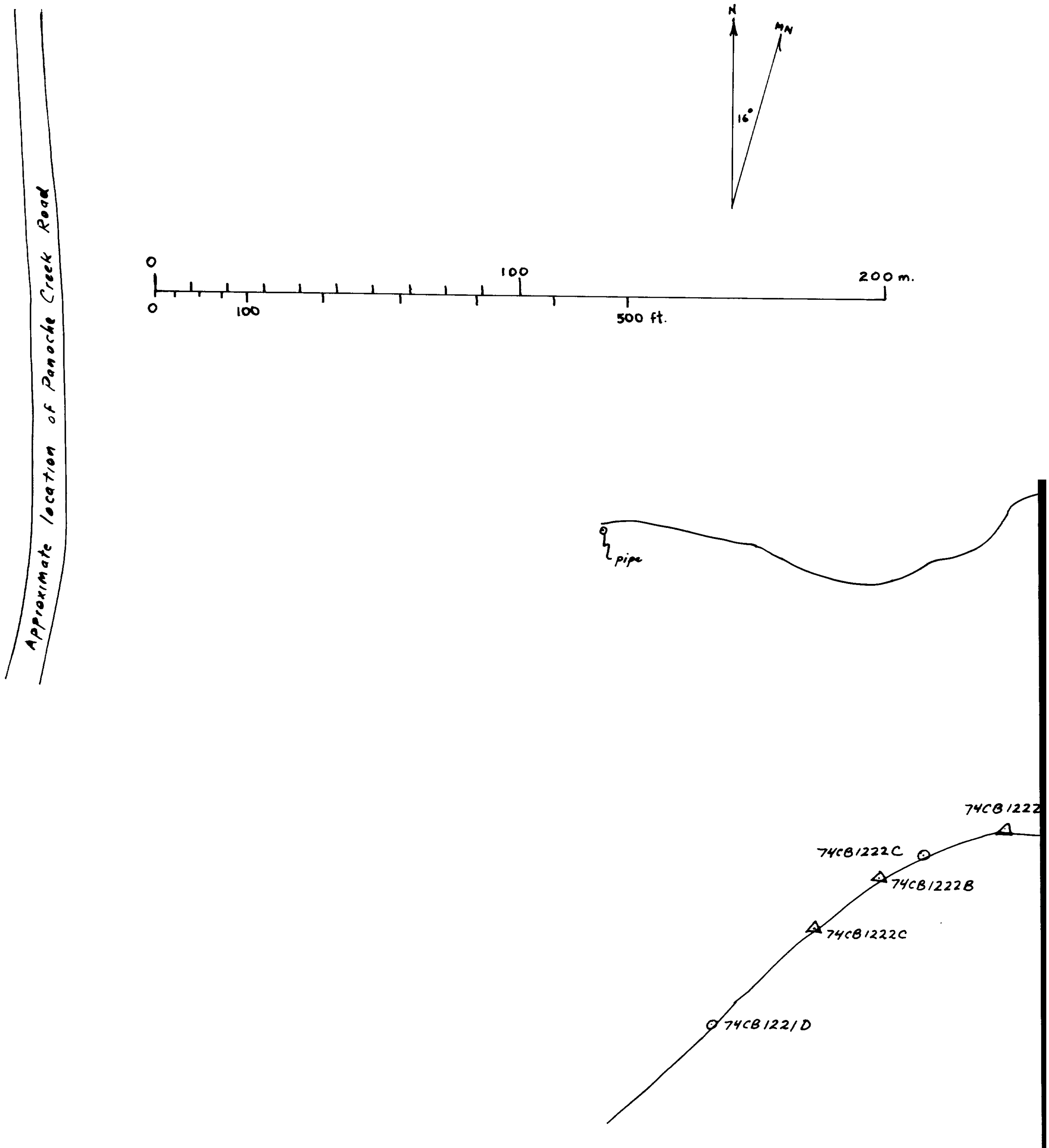


Figure 41.--Geologic sketch map of the Lod

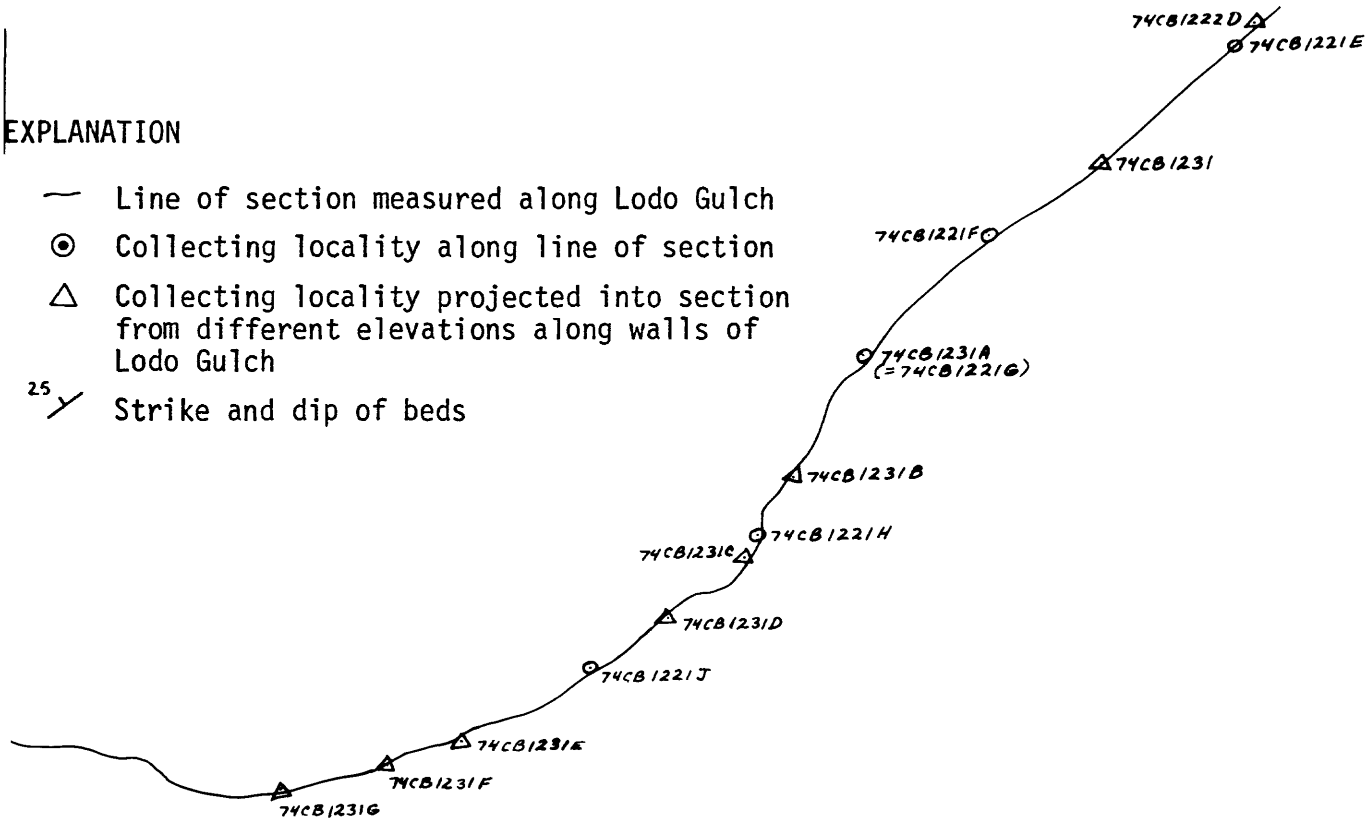
EXPLANATION

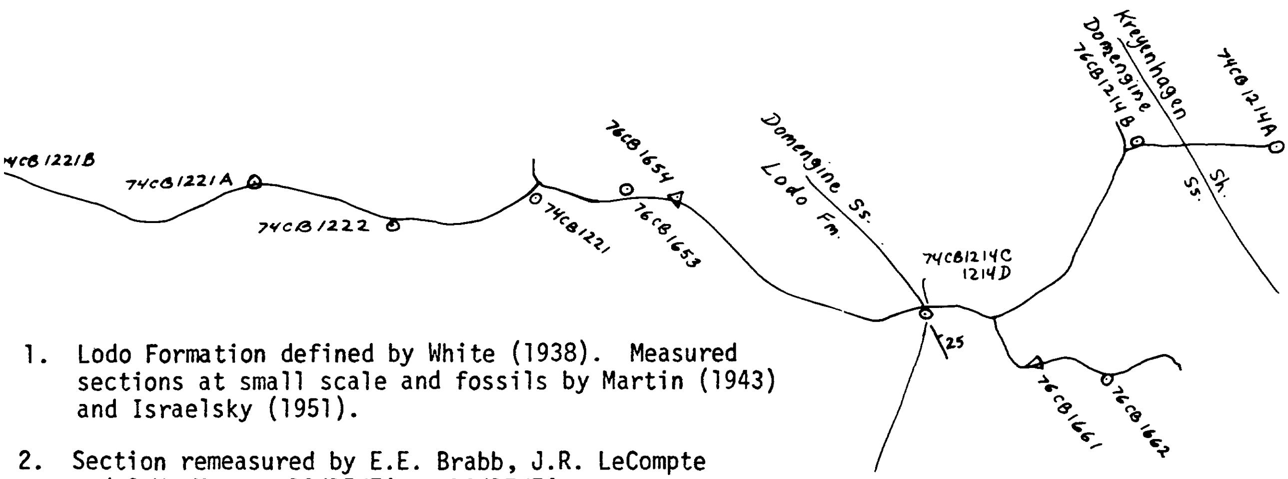
— Line of section measured along Lodo Gulch

⊙ Collecting locality along line of section

△ Collecting locality projected into section from different elevations along walls of Lodo Gulch

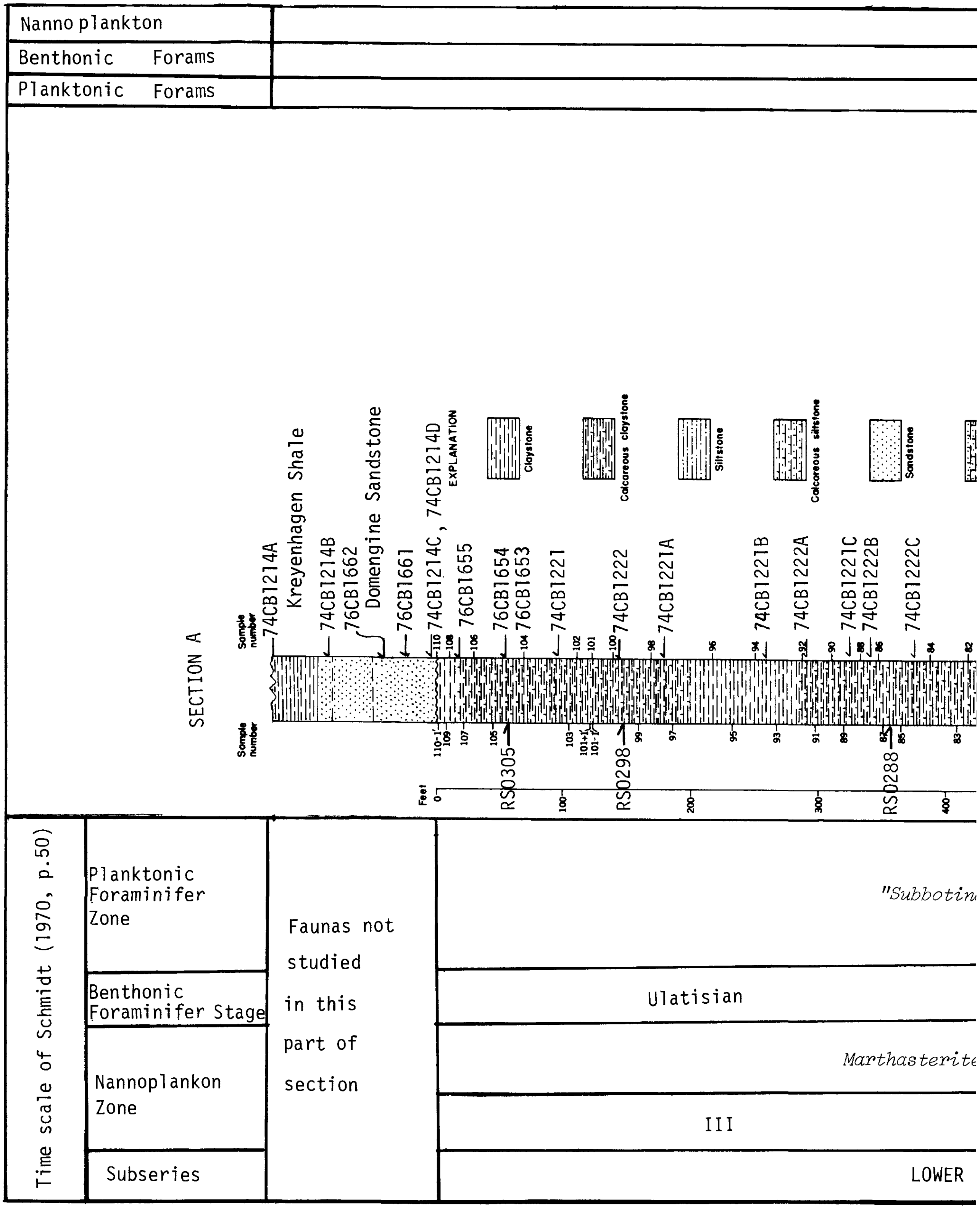
25 ⁄ Strike and dip of beds





1. Lodo Formation defined by White (1938). Measured sections at small scale and fossils by Martin (1943) and Israelsky (1951).
2. Section remeasured by E.E. Brabb, J.R. LeCompte and S.W. Moore, 10/15/74 to 10/17/74.
3. Most of the section is covered with landslide debris. Samples were collected by digging holes a few feet deep through the landslide deposits. Some mixing of the presumed bedrock with landslide debris is likely, a problem also noted by Israelsky (1951, p.4).

'ormation in its type section.



Nanno plankton
Benthonic Forams
Planktonic Forams
SECTION A
Sample number
74CB1214A
Kreyenhagen Shale
74CB1214B
76CB1662
Domengine Sandstone
76CB1661
74CB1214C, 74CB1214D
76CB1655
76CB1654
76CB1653
74CB1221
74CB1222
74CB1221A
74CB1221B
74CB1222A
74CB1221C
74CB1222B
74CB1222C
EXPLANATION
Claystone
Calcareous claystone
Siltstone
Calcareous siltstone
Sandstone
RS0305
RS0298
RS0288
Feet
0
100
200
300
400
Time scale of Schmidt (1970, p.50)
Planktonic Foraminifer Zone
"Subbotin
Benthonic Foraminifer Stage
Ulatisian
Nannoplankon Zone
Marthasterite
III
Subseries
LOWER
Faunas not studied in this part of section

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