Saul, LR., 1982

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WATER DEPTH INDICATIONS FROM LATE CRETACEOUS MOLLUSKS, SANTA ANA MOUNTAINS, CALIFORNIA

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ABSTRACT

Water depths inferred from mollusks suggest very shallow water for the lower Baker Canyon Member, deepening to middle and outer shelf for the lower Holz Shale Member. Molluscan remains are rare through most of the Holz Shale. Mollusks indicative of outer to shallow shelf depths are present in the upper Holz Shale and indicate shoaling. The Schulz Member apparently lacks mollusks. Overlying the Schulz is the lower Pleasants Member which has a shallow shelf fauna. This is succeeded up-section by a slightly deeper shelf fauna. Two transgressions and a regression are thus suggested by the mollusks of late Turonian to late Campanian age in the Santa Ana Mountains, Orange Co., California.

INTRODUCTION

Popenoe (1942) published a check list of mollusks from the Late Cretaceous sediments in the Santa Ana Mountains which indicated abundant, common, and rare species from 57 localities. A paleoecologic interpretation of these collections and 20 others, predominantly utilizing common and abundant species from these collections, suggests a shallow, warm-water fauna from sandstones of the Baker Canyon Member grading into a deeper, cooler-water fauna in the lower Holz Shale. Above a relatively unfossiliferous interval a similar molluscan fauna reappears, and again collections indicate grading into deeper water.

Most of the collections analyzed are from fossiliferous lenses or beds. In general the matrix at these localities is indurated, and specimens must be broken out, thus making an accurate counting of fossil content in a given volume impossible. For every bivalve recovered, five are doubtless broken. Because of the difficulty of recovery, specimens of a less common species receive priority over those of the more common ones, thus further skewing the count. Recovery of specimens is random. The volume of rock collected at the localities has varied greatly. The number of specimens recovered from any volume has depended as much on quality of preservation as upon the number of fossils in the rock. Species in these unsystematic samples have been subjectively divided into categories of abundant, common, or rare.

As most of the bivalves occur as single rather than paired valves, it is possible that the shells were transported and thus the site of deposition is not the site of habitation. At most localities the rock contains both relatively complete shells and shell fragments. Both shells and fragments are commonly bored by more than one kind of endolith. It is frequently possible to determine by the degree of boring which side of a shell lay upon the sediment. Attached oysters and in some cases bryozoan colonies further indicate which side of a shell lay facing-up. The extensive boring, the eroded aspect to many fragments, the attached oysters, etc., all suggest accumulations of dead shells on the sea floor. Separation of bivalve shells under such conditions is due more to decay of ligament with time than to extensive transport.

AGE

Age of the Cretaceous sediments is shown on the column (Fig. 1A). A late Turonian age for the Baker Canyon Member and basal Holz Shale in indicated by the ammonites *Subprionocyclus normalis* (ANDERSON) and *S.* cf. *S. neptuni* (GEINITZ). In addition, most of the late Turonian species also occur in the Melton Sandstone in the Redding area, Shasta Co., California. The Melton Sandstone is dated as late Turonian (Jones, Sliter, and Popenoe, 1978, p. XXII.3). An ammonite, *Canadoceras*? sp. or *Nowakites*? sp. from UCLA loc. 6952 suggests Santonian or early Campanian age for beds below the middle of the Holz Shale. The upper third of the Holz Shale is dated as early Campanian by *Turritella chicoensis holzana* SAUL MS, *Submortoniceras chicoense* (TRASK), and *Canadoceras* cf. *C. yokoyamai* (JIMBO). The uppermost Holz Shale is considered to be of mid Campanian age (Saul, in press) where it carries *Turritella chicoensis* GABB. Pleasants Sandstone collections contain *Metaplacenticeras* cf. *M. pacificum* (SMITH) and are of late Campanian age. There is no megafaunal evidence for beds of younger than late Campanian age in the northern Santa Ana Mountains.

FAUNAL ANALYSIS

Stratigraphic position of the faunas is indicated on Figure 1A and their interpreted relative water depth is graphed on Figure 1C. Geographic distribution of the faunas is suggested by Figure 1B. The localities are plotted on the outcrop map by faunal symbol. Although the percent of forms in common between deep and shallow water faunas is less than 50 per cent, there is a gradation from shallow to deeper shelf faunas, and the deepest shallow-water faunas could have been assigned to the moderate depth catagory. All of the faunal boundaries are similarly somewhat arbitrary, as can be seen on the abridged check lists (Figs. 2 and 3). Listed are all abundant and common forms; some rare ones whose presence seems ecologically notable have also been listed.

Shallow Shelf Fauna of Late Turonian Age (●)

Collections from the basal Baker Canyon Member are of low diversity (See Figure 2). They are characterized by common to abundant *Alleinacin sulcata* (PACKARD), *Liopistha anaana* (ANDERSON), and *"Actaeonella" oviformis* GABB. *Trigonarca californica* PACKARD is also common to abundant, but is not limited to this fauna. Where *Alleinacin sulcata* is rare or

in Bottjer, D.J., Colburn, I.P., and Cooper, J.D., eds., 1982. Late Cretaceous Depositional Environments and Paleogeography, Santa Ana Mountains, Southern California, Pacific Section, SEPM, Field Trip Volume and Guidebook, pg. 69-76.

absent, *Flaventia zeta* POPENOE is common to abundant. Except for *"Actaeonella" oviformis* the mollusks were probably suspension feeders. *"Actaeonella"* has been considered to be an opisthobranch by Kollmann (1967), able to inhabit somewhat brackish water, but Popenoe (pers. comm.) considered it to be a neogastropod related to *Oliva*. The thick shells are invariably worn as though rolled about by wave action. *"Actaeonella" oviformis*, *Trigonarca californica*, and *Liopistha anaana* are not part of the usual North Pacific fauna but are related to Tethyan groups. *Alleinacin sulcata*, which is thus far monotypic, may also be of Tethyan affinity; no other related species -- described or undescribed -- has yet been found in North Pacific faunas.

This fauna suggests warm, very shallow water. *"Actaeonella" oviformis* may well have lived intertidally, but the presence of *Glycymeris pacificus* (ANDERSON), *Syncyclonema* sp., *Lima beta* POPENOE, and *Subprionocyclus* spp. suggests that the fauna predominantly inhabited shallow sublittoral areas.

Moderate Depth Shelf Fauna of Late Turonian Age (▲)

Included in this grouping of fossil localities are collections from the upper Baker Canyon Member and the sandier beds in the lowermost Holz Shale. These localities yield faunas at least twice as diverse as those of the basal Baker Canyon Member. Characteristically present are *Turritella hearni* MERRIAM or *T. iota* POPENOE, *Pterotrigonia klamathonia* (ANDERSON), *Crassatella gamma* POPENOE, *Aphrodina arata* (GABB), *Corbula* spp., *Scaphites* spp. and *Sciponoceras* aff. *S. bohemicum* (FRITSCH)(See Figure 2). *Flaventia zeta* and *Ampullina pseudoalveata* PACKARD, also found at shallow shelf localities, are rarely present at deeper shelf localities, whereas *Tenea* cf. *T. inflata* (GABB), *Cucullaea (Idonearca) gravida* (GABB), and *Glossus delta* (POPENOE) are present at deeper shelf localities but not at the shallower. Collections included in the group which are from finer grained sediments have aporrhaiid gastropods *Anchura condoniana* ANDERSON. *Pyktes daiphron* POPENOE MS, and *Arrhoges (Latiala) californicus* (PACKARD). In sandier substrates the gryphaeid oyster *Exogyra* sp. is common. Heteromorphic ammonites *Bostrychoceras* sp. and *Hyphantoceras* aff. *H. venustum* (YABE) are also present. The Tethyan element of this fauna is much less than in the shallow shelf fauna, consisting only of *Trigonarca californica* and *Scaphites* spp. In Japan, Tanabe (1979) faund such strongly sculptured ammonites as *Subprionocyclus* sp. indicated shallow shelf environments and heteromorphs, including baculitids, scaphites, and nostocerids, probably inhabited mid-shelf areas. Differences in siphuncular strength suggested to him a deeper water habitat for the weakly sculptured desmoceratids.

Mollusks in these collections probably inhabited moderate-depth shelf areas. The change from largely Tethyan affinites to largely North Pacific affinities suggests a drop in temperature that could result from a deeper water habitat. Tanabe (1979) has suggested that the habitat of his heteromorphic ammonites was from shallow to deeper water, overlapping that of the shallow water collignoniceratids. Stenzel (1971, p. N1040) states that the Gryphaeinae indicate open, euhaline seas, and no molluscan species suggesting less than normal salinity was found in this group of collections.

Deeper Shelf Fauna of Late Turonian Age (■)

This grouping consists of a few localities from the lower siltier part of the Holz. Faunal diversity is moderate, about the same as that of the moderate-depth shelf assemblage (See Figure 2). Of the Tethyan forms only *Trigonarca californica* remains. Characteristically present are *Opis* cf. *O. triangulata* (COOPER), *Eriphyla ovoides* PACKARD, and *Clisocolus corrugatus* POPENOE. As in the moderate-depth shelf fauna, *Crassatella gamma*, *Tenea* cf. *T. inflata*, *Cucullaea (Idonearca) gravida*, *Glossus delta*, and *Pterotrigonia klamathonia* are common to abundant. *Turritella* sp. and *Flaventia zeta* are rarely found. *Indogrammatodon* sp. and aporrhaid gastropods, present in finer grained sediments of the moderate-depth shelf localities, are more common; and desmoceratoid ammonites, *Mesopuzosia* sp. and *Tragodesmoceras?* aff. *T.? ashlandicum* (ANDERSON), have been collected.

Mollusks of this assemblage probably inhabited deeper depth shelf areas. Some of the faunal change is probably due to finer grained substrate, but the absence of *Scaphites* spp. may result from cooler, off-shore water. The weakly sculptured desmoceratoids are suggestive of deeper water (Tanabe, 1979).

Deeper Shelf Fauna of Early Campanian Age (□)

Localities yielding this fauna are predominantly in small lenses in the upper third of the Holz Shale. The fauna is of low to moderate diversity and consists of typically North Pacific forms. The stratigraphically lowest localities characteristically have *Turritella packardi* MERRIAM and *Eriphyla veatchii* GABB and are of lowest diversity. Stratigraphically higher localities have a moderately diverse fauna characterized by *Turritella chicoensis holzana* SAUL MS, *Opis* aff. *O. triangulata* (COOPER), and *Indogrammatodon whiteavesi* (REINHART). In addition *Glycymeris veatchii* (GABB), *Cucullaea (Idonearca) youngi* WARING, *Crassatella* spp., *Etea angulata* (PACKARD), *Tenea inflata* (GABB), *Anchura* cf. *A. falciformis* GABB, *Volutoderma* spp., and *Biplica obliqua* (GABB) are common to abundant (See Figure 3). Early Campanian age is indicated by a specimen of *Submortoniceras chicoense* (TRASK) and rare *Canadoceras*

Figure 1. A, Generalized composite columnar section of Late Cretaceous rocks in northern Santa Ana Mountains with molluscan fossil localities in approximate stratigraphic position. Based on columnar sections of Popenoe (1942) in which the fossiliferous sandstone beds containing *Turritella chicoensis* GABB are included in the Holz Shale Member (rather than in the Schulz; see Bottjer, Colburn, & Cooper, this volume). The Schulz Member overlies these fossiliferous beds disconformably (Popenoe, 1942) -- to the south in the Cañada Gobernadora Quadrangle, the Schulz overlaps the Ladd Formation (Morton, 1974, p. 21) --, and only one locality in the Schulz, CIT 1066, provides marine fossils. Popenoe (1942, p. 174) suggested that these fossils were reworked from the Holz. B, Outcrop map of Late Cretaceous sedimentary rocks from vicinity of Black Star Canyon on the north, south to Plano Trabuco. Fossil localities plotted by symbols indicate similar faunal composition. See text for fuller explanation of symbols (Based on map of Popenoe, 1942). C, Graph of probable water depth indicated by the molluscan faunas, based largely on occurrences of abundant and common mollusks in Popenoe, 1942, fig. 4. See Locality Map (Saul & Bottjer, this volume) for plotting of numbered fossil localities.

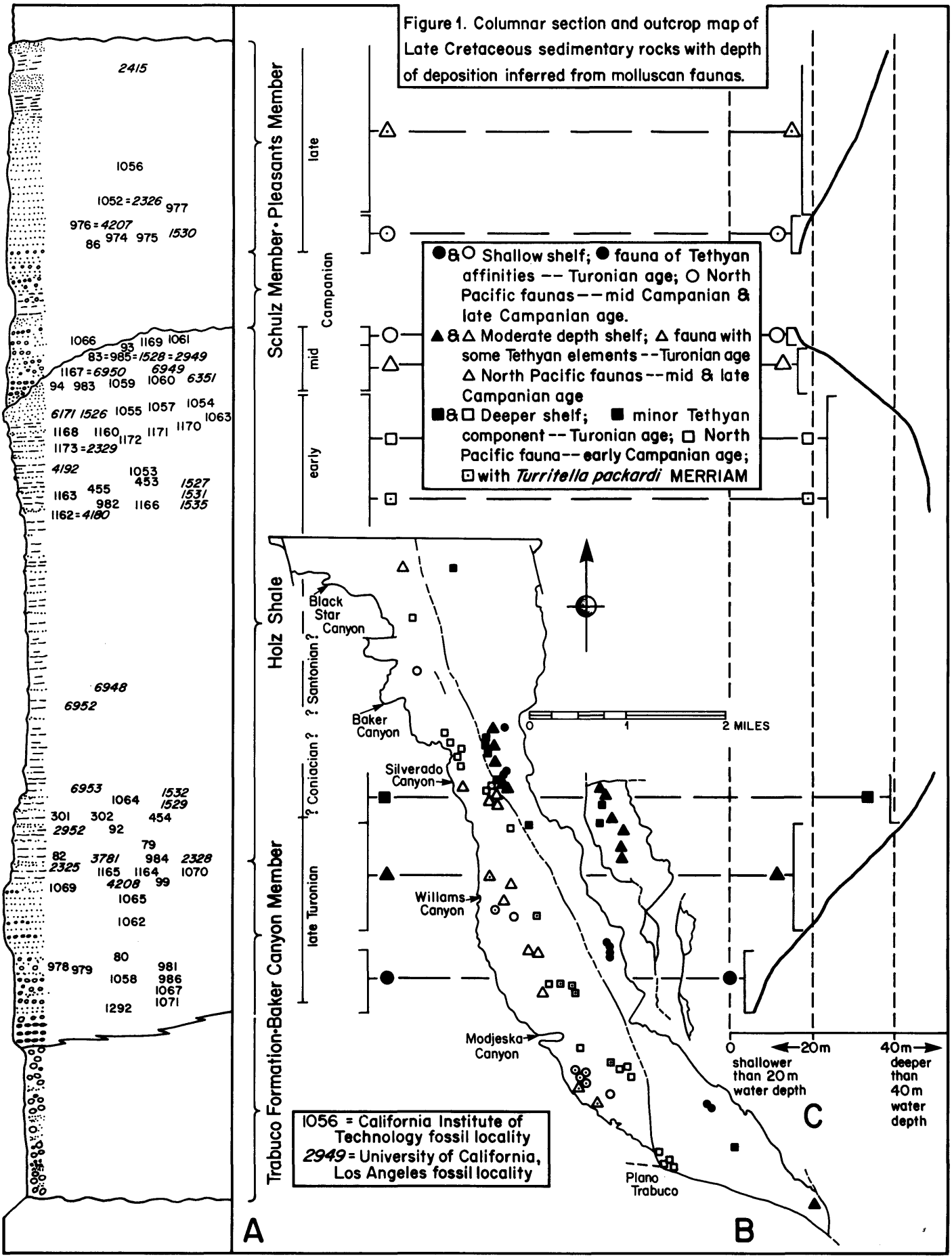
Figure 1. Columnar section and outcrop map of Late Cretaceous sedimentary rocks with depth of deposition inferred from molluscan faunas.
Schulz Member • Pleasants Member
Holz Shale
Trabuco Formation-Baker Canyon Member
late
Campanian
mid
early
? Santonian?
? Coniacian ?
late Turonian
●&○ Shallow shelf; ● fauna of Tethyan affinities -- Turonian age; ○ North Pacific faunas--mid Campanian & late Campanian age.
▲&△ Moderate depth shelf; △ fauna with some Tethyan elements --Turonian age
△ North Pacific faunas--mid & late Campanian age
■&□ Deeper shelf; ■ minor Tethyan component -- Turonian age; □ North Pacific fauna-- early Campanian age;
⊡ with Turritella packardi MERRIAM
Black Star Canyon
Baker Canyon
Silverado Canyon
Willams Canyon
Modjeska Canyon
Plano Trabuco
0 1 2 MILES
0 ←20m 40m→
shallower than 20 m water depth
deeper than 40 m water depth
C
1056 = California Institute of Technology fossil locality
2949 = University of California, Los Angeles fossil locality
A
B
2415
1056
1052=2326 977
976=4207
86 974 975 1530
1066 93 1169 1061
83=985=1528=2949
1167=6950 6949
94 983 1059 1060 6351
6171 1526 1055 1057 1054 1063
1168 1160 1172 1171 1170
1173=2329
4192 1053 453 1527
1163 455 1531
982 1166 1535
1162=4180
6948
6952
6953 1064 1532 1529
301 302 454
2952 92
79
82 3781 984 2328
2325 1165 1164 1070
1069 4208 99
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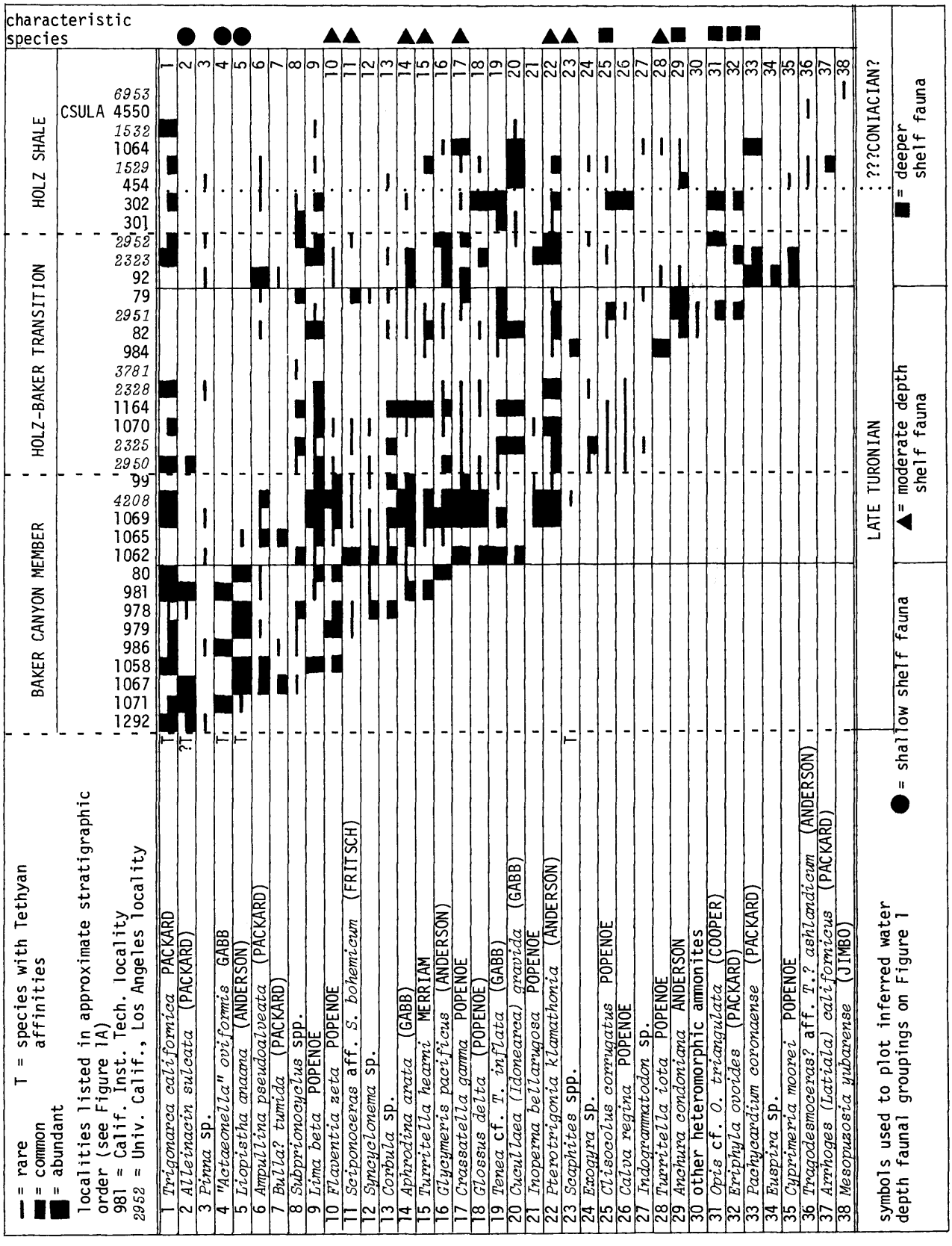

Figure 2. Abridged check list of Turonian and ?Coniacian species.

cf. *C. yokoyamai* (JIMBO). *Submortoniceras chicoense* resembles *Subprionocyclus* spp. of Turonian age and probably had a similar shallow-water habitat.

In generic make up the fauna of this group of localities resembles the deeper shelf, lower Holz localities, but the species have changed with the passage of time. The rarity of *Submortoniceras chicoense* in the Santa Ana Mountains collections may result from early Campanian deposits of this area being of a

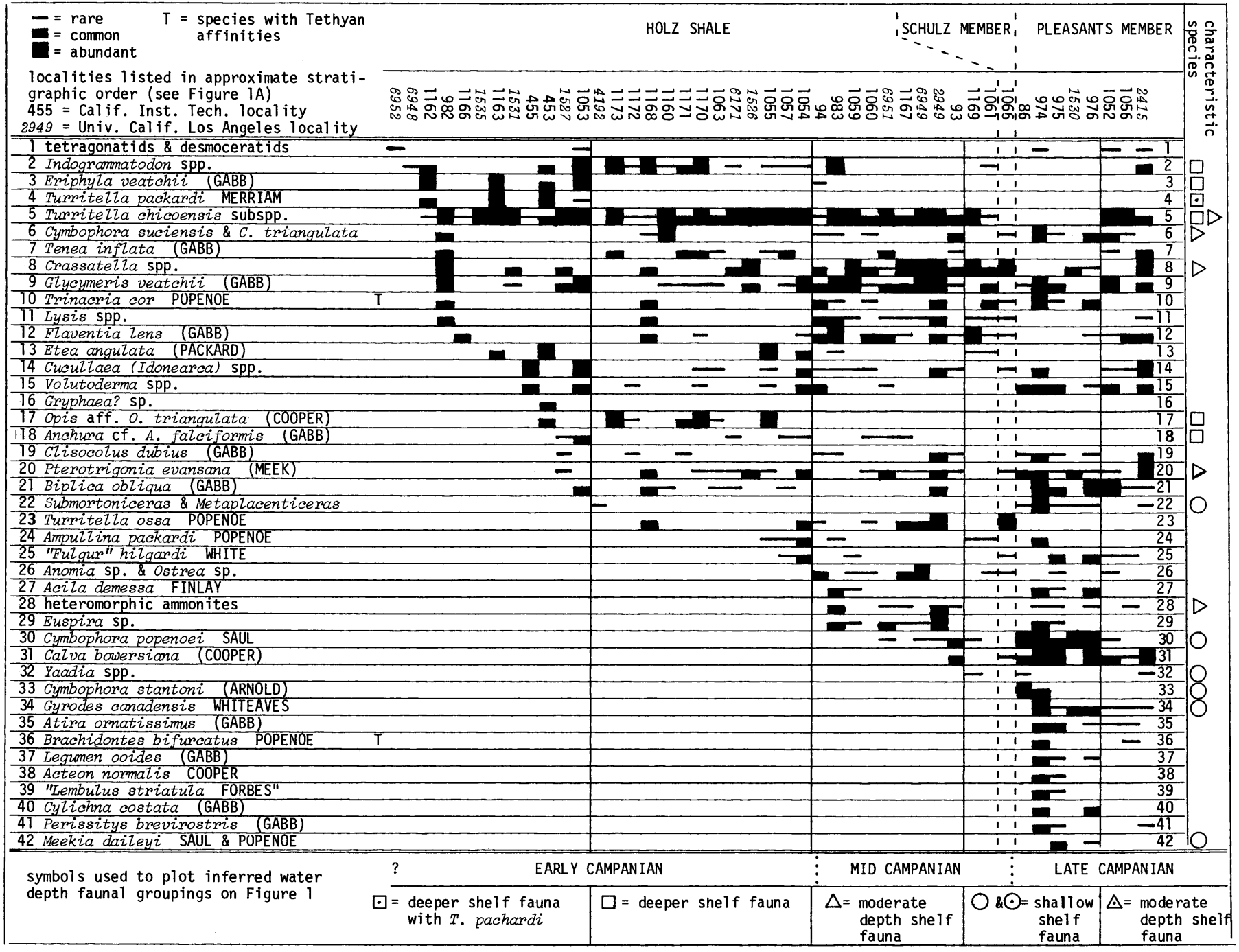

Figure 3. Abridged check list of Campanian species.

deeper water facies than the ammonite fancied.

Moderate Deptn Shelf Fauna of Mid Campanian Age (△)

At the top of the Holz Shale (=lower part of Schulz Member, see Bottjer, Colburn, and Cooper, this volume, Fig. 3) are sandstone lenses and beds with a more diverse fauna than that of the stratigraphically lower lenses yielding the deeper shelf fauna. This fauna also consists prodominantly of typically North Pacific forms. It is characterized by *Pterotrigonia evansana* (MEEK), *Crassatella* spp., *Cymbophora suciensis* (WHITEAVES), and *Turritella chicoensis* GABB. Common to abundant forms include *Trinacria cor* POPENOE, *Cucullaea (Idonearca) youngi*, *Clisocolus dubius* (GABB), *Flaventia lens* (GABB), *Lysis* spp., *Euspira* sp., and *Baculites* sp. (*B. inornatus* MEEK in part)(See Figure 3).

This fauna is similar to the Turonian, moderate depth shelf fauna in generic make up (Fig. 2). *Trinacria cor* may represent a Tethyan element in this fauna. The heteromorphic ammonites *Pseudoxybeloceras* sp., *Bostrychoceras?* sp., and especially *Baculites* sp. are present and perhaps suggestive of mid shelf habitats.

Shallow Shelf Faunas of Mid Campanian Age (○)

A few localities at the top of the Holz Shale have more species suggestive of shallow water and lack a few forms common at the moderate depth shelf localities. The moderately diverse fauna at these localities is, however, very similar to that of the moderate depth shelf. It is still characterized by the presence of *Turritella chicoensis* and *Crassatella* spp., but not by *Pterotrigonia evansana*. Both smooth and ribbed cymbophoras, *Cymbophora suciensis* and *C. popenoei* SAUL, are present (See Figure 3). *C. popenoei* and *Yaadia tryoniana* (GABB), which is uncommon, are considered suggestive of shallow water (Saul, 1974 & 1978).

Although referred to shallow shelf this fauna suggests deeper or quieter water than the shallow shelf fauna of late Turonian age.

Shallow Shelf Fauna of Late Campanian Age (⊙)

Localities in the lower Pleasants Sandstone Member of the Williams Formation have yielded the most diverse Late Cretaceous fauna from the Santa Ana Mountains (See Figure 3). The fauna is predominantly of North Pacific affinities, but *Trinacria cor* and *Brachidontes bifurcatus* POPENOE may be Tethyan elements. Characteristically *Cymbophora popenoei*, *Metaplacenticeras* cf. *M. pacificum* (SMITH), and *Gyrodes canadensis* WHITEAVES are present. *Meekia daileyi* SAUL & POPENOE and *Yaadia robusta* SAUL are suggestive of a shallow inner sublittoral habitat. Additional common to abundant bivalves include *Glycymeris veatchii* (GABB), *Pterotrigonia evansana*, *Cymbophora triangulata* (WARING), *C. stantoni* (ARNOLD), *Calva bowersiana* (COOPER), and *Legumen ooides* (GABB). The most common gastropods are herbivorous *Atira ornatissimus* (GABB) and probably carnivorous or detritophagus *"Fulgur" hilgardi* WHITE, *Perissitys brevirostris* (GABB), *Volutoderma* spp., and *Biplica obliqua* (GABB).

This fauna is essentially similar to the mid Campanian shallow shelf fauna. Its slight increase in diversity may or may not suggest somewhat shallower water or even a late Cretaceous warming trend. The ornate ammonite *Metaplacenticeras* cf. *M. pacificum* is morphologically equivalent to *Subprionocyclus* spp. and *Submortoniceras chicoense* and probably also indicates shallow water.

Moderate Depth Shelf Fauna of Late Campanian Age (△)

Collections from a few localities in the upper Pleasants Member are characterized by *Turritella chicoensis pescaderoensis* ARNOLD, *Pterotrigonia evansana* (MEEK), and *Crassatella* spp. The collections are of moderate diversity with bivalves *Cucullaea (Idonearca) cordiformis* PACKARD, *Clisocolus dubius* (GABB), *Calva bowersiana*, and gastropods *Volutoderma* spp., and *Biplica obliqua* common or abundant. Also present are ammonites *Metaplacenticeras* cf. *M. pacificum*, *Baculites* sp., and *Gaudryceras* cf. *G. (Vertebrites) kayei* (FORBES)(See Figure 3). *Metaplacenticeras* is less abundant in these collections than in the collections inferred to be from shallow shelf areas. *Gaudryceras* is a tetragonitid, and thus belongs to a group with greater siphuncular strength (Tanabe, 1979, p. 625) and may have been able to inhabit deeper water.

These collections are similar in generic make up to the late Turonian and mid-Campanian moderate depth shelf faunas.

DURATION OF INDICATED WATER DEPTH

Obradovich and Cobban (1975) suggest the following stage durations: Turonian -- 3 m.y., Coniacian -- 1 m.y., Santonian -- 4 m.y., and Campanian -- 12 m.y. Molluscan fossils older than late Turonian have not been shown to occur in the Baker Canyon Member. The shoreline suggested by the very shallow shelf fauna moved eastward from near the present confluence of Ladd and Silverado Canyons about 1.5 km. During the later third of the Turonian moderate depth faunas succeeded by deeper shelf faunas inhabited not only the present vicinity of the old Holz Ranch in Silverado Canyon but also areas 1.5 km to the east (see Figure 1B). These deep shelf molluscan faunas may be in part of Coniacian age if the *Mesopuzosia yubarense* (JIMBO) (Matsumoto, 1959, p. 71) found in the Holz Shale below a conglomerate lens (Saul & Bottjer, this volume, Locality Map, UCLA loc. 6953) is correctly determined. Almgren (this volume) finds bathyal Foraminifera in beds overlying those with the molluscan shelf faunas. In the present vicinity of the old Holz Ranch house, the change from littoral to bathyal depths may have taken two m.y.

In the upper third of the Holz, molluscan deeper shelf faunas, now of early Campanian age, again occur signalling a regression. The bathyal conditions thus probably prevailed for a least four m.y. and the deeper shelf conditions for perhaps 3 m.y.

A shallow water, but by no means littoral, fauna of mid Campanian age occurs at the top of the Holz, and the regression may have lasted four to five m.y.

A similar shallow water fauna, but of late Campanian age, is in the lower Pleasants Member succeeded by a moderate depth fauna also of late Campanian age. Mollusks from Pleasants Member outcrops near Bee Canyon (Saul & Bottjer, this volume, Locality Map sheet 1, UCLA loc. 2415) have been considered to be younger than others from the Pleasants Member (Matsumoto, 1960, p. 66) in the Santa Ana Mountains. The fauna suggests at least moderate depth. If the age is latest Campanian or earliest Maestrichtian (Matsumoto, 1960, p. 154), a late Campanian transgression

4 m.y. long may be indicated possibly with moderate depth waters for most of this time. The molluscan faunas suggesting moderate depth waters are more than 4 km south of the present Silverado Canyon, but to the north in the vicinity of the present Fremont Canyon, large late Campanian pachydiscid ammonites suggest water depths not shallower than those of the deeper shelf.

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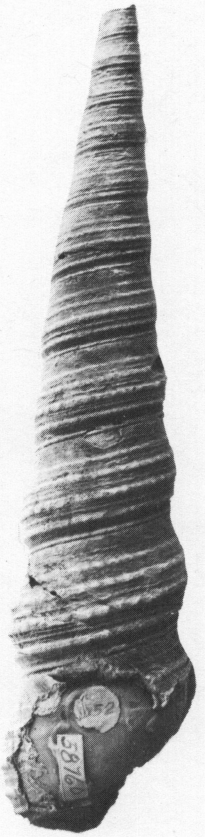
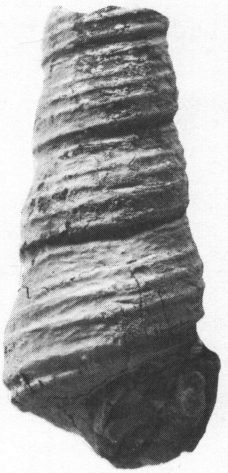
Turritella packardi MERRIAM, 1941 x1.75
Early Campanian
A species, small in size, that has been found only low in the upper third of the Holz Shale

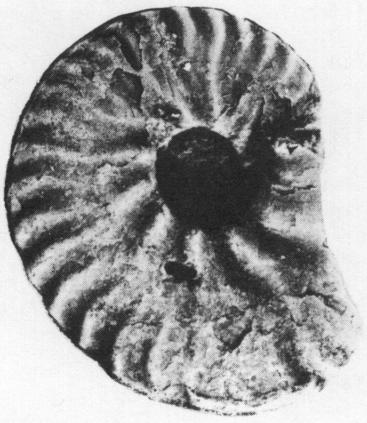
Turritella chicoensis n. subsp. x2
Early Campanian
The common-to abundant turritella in the upper (but not uppermost) Holz Shale



Turritella chicoensis pescaderoensis ARNOLD, 1908 x1
Late Campanian
The subspecies associated with *Metaplacenticeras* cf. *M. pacificum*; common-to abundant at several localities in the Pleasants Member



Turritella chicoensis GABB, 1864 x1
Mid Campanian
The species common-to abundant in the uppermost Holz Shale (lower Schulz Member of Bottjer, Colburn, & Cooper, this volume)



Subprionocyclus cf. *S. neptuni* (GEINITZ, 1849)
Late Turonian
Ladd Formation, Baker Canyon Member
UCLA loc. 2325

LATE CRETACEOUS MEGAFOSSIL LOCALITY MAP, NORTHERN SANTA ANA MOUNTAINS, CALIFORNIA

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Localities of megafossil samples listed in Saul (this volume) and Sundberg (1980; this volume). Maps compiled from U.S. Geological Survey Black Star Canyon, El Toro, and Santiago Peak quadrangles, as shown in index below. Contour interval for El Toro and Black Star Canyon quadrangles is 20 feet, and for Santiago Peak quadrangle is 40 feet.

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SCALE

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KM

N

LOCALITY LEGEND

- 2329 • Univ. California, Los Angeles
- 1068 • California Inst. Technology
- FAS BS-1 • Sundberg
- CSULA 4550 • California State Univ., Los Angeles

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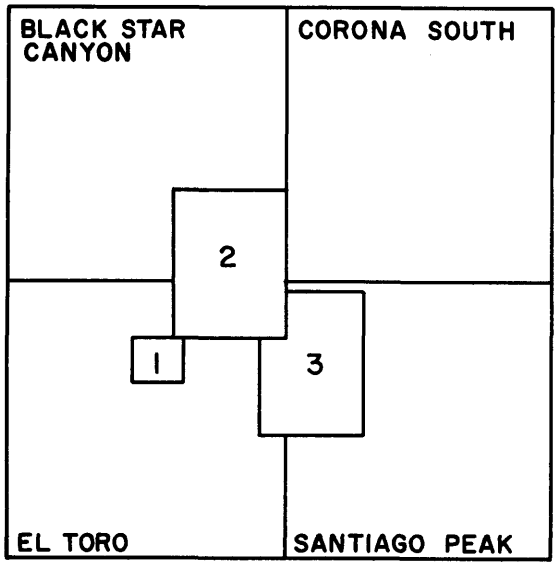
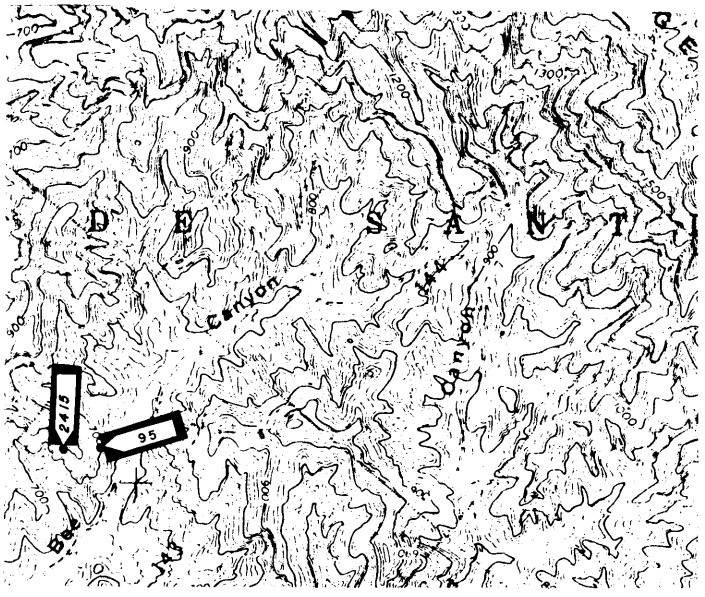
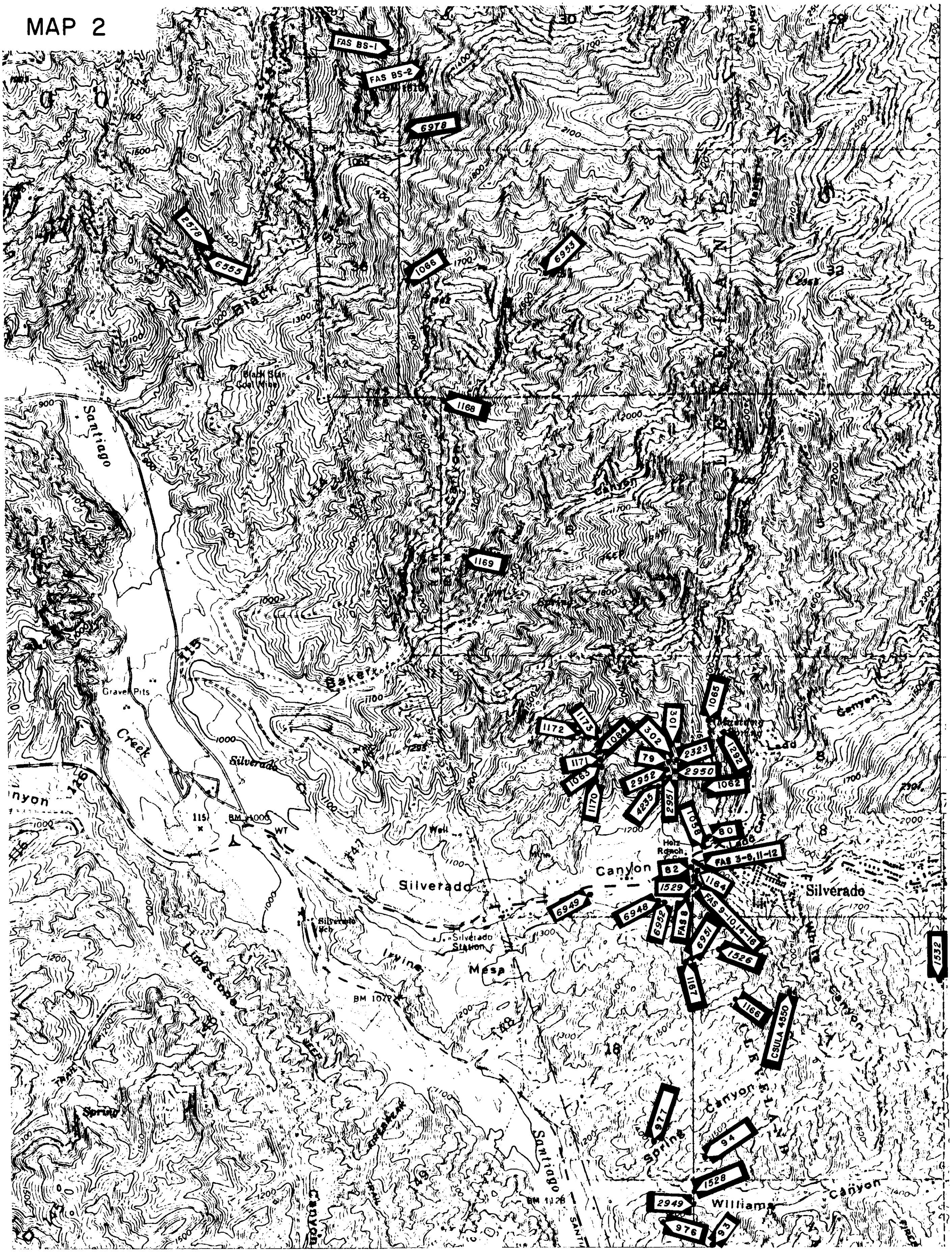


MAP 1



in Bottjer, D.J., Colburn, I.P., and Cooper, J.D., eds., 1982, Late Cretaceous Depositional Environments and Paleogeography, Santa Ana Mountains, Southern California, Pacific Section, SEPM, Field Trip Volume and Guidebook, pg. 77-80.

MAP 2


FAS BS-1
FAS BS-2
6978
2578
6555
1066
6953
Black Star Coal Mine
1168
Santiago
Santiago
Creek
1169
Baker
Gravel Pits
Silverado
Silverado
Silverado
Irvine
Mesa
Limestone
Canyon
Canyon
Canyon
Canyon
Canyon
Canyon
Spring
Williams
1172
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302
301
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2323
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1235
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80
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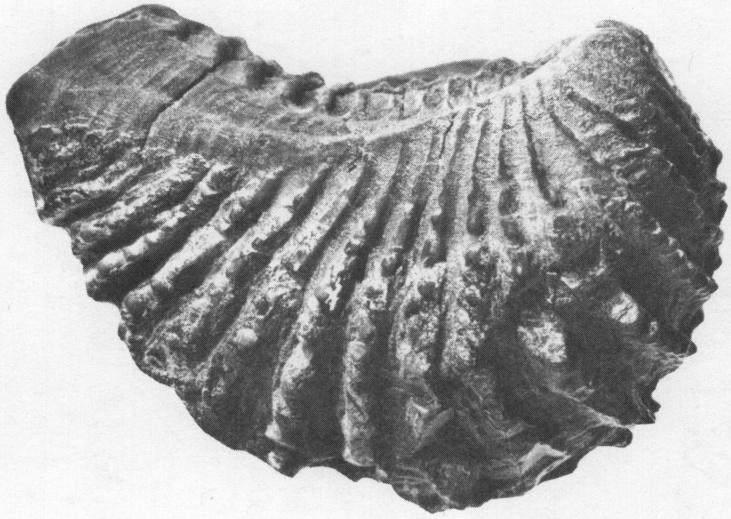
FAS 3-5, 11-12
82
1529
1164
6949
6948
6952
FAS 8
FAS 9-10, 14-18
6951
1526
1167
1166
CSULA 4550
1532
977
94
1528
2949
976
93
Well
WT
Silverado Station
BM 1000
BM 1012
BM 1128

MAP 3

Canyon
Williams
Shrewsbury Spring
Bear Flat
Harding
Canyon
Laurel Spring
Modjeska Reservoir
Modjeska
Modjeska Canyon
Santiago
Vulture Crags
Spring
Water Tank
S Ranch
DE LOS ALISOS
Creek
HAMILTON
TRUCK
TRAIL
Canyon
Live
BM 1436
BM 1042
FAS STTH-4
FAS STT-2
15
21
22
27
28
29
33
34
35
3
4
2



Pterotrigonia klamathonia (ANDERSON, 1958)
Late Turonian
Ladd Formation, Baker Canyon Member
CIT loc. 1068