Late Miocene (Santa Margarita Sandstone) Shallow Marine Clastics

Field trip guidebook

by

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This may have been an un official field trip for the August, 1984 SEPM pacific section meeting in San Jose, Ca

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This area was his PhD from U.C. Santa Cruz in 1981

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INTRODUCTION

The Santa Margarita Sandstone of late middle and early late Miocene age is located in the western Santa Cruz Mountains of central California. It represents a marine, tide-dominated, transgressive deposit which, during the early stage of the marine transgression formed a seaway connection between the Pacific Ocean and the interior San Joaquin basin to the east. The strong tidal current flow which developed as a result of this setting caused the deposition and preservation of large-scale, essentially unidirectional cross-bedded sets of shelf sand and gravel.

During this field trip 3 quarry exposures within Scotts Valley (figure 1 and 2) located near the central part of the seaway deposits will be examined observing both lateral and vertical facies relationships as well as textural variations preserved within the Santa Margarita Sandstone. On the last stop, stop 4, located to the west within the seaway deposits both lateral facies relationships in relation to the previous stops will be observed and discussed as well as examine petroleum-saturated sandstones.

GEOLOGIC SETTING

The Santa Margarita Sandstone rests unconformably on the middle Miocene Monterey Formation and older Tertiary strata (Lompico Sandstone, Vaqueros Sandstone and the Butano Formation), and nonconformably on Cretaceous granodiorite and associated Paleozoic or Mesozoic metamorphic rocks. Erosion of the granitic rocks supplied much of the sediment to the arkosic sandstone in the Santa Margarita.

A marine transgression over an irregular bedrock terrane within the Santa Cruz Mountains of central California, during late middle Miocene time, created a connection with the interior marine San Joaquin Basin to the east (figure 3). The seaway, bounded and partly controlled by topographic bedrock highs, was subject to strong tidal current flow. Nondeposition and pinchout of the Santa Margarita Sandstone as well as deposition of the overlying Santa Cruz Mudstone on bedrock defines the paleotopographic highs (figure 4). Eventual deepening of the marine environment due to transgression or subsidence, resulted in widening of the seaway and reduced current velocities. The Santa Cruz Mudstone was then deposited over the Santa Margarita Sandstone.

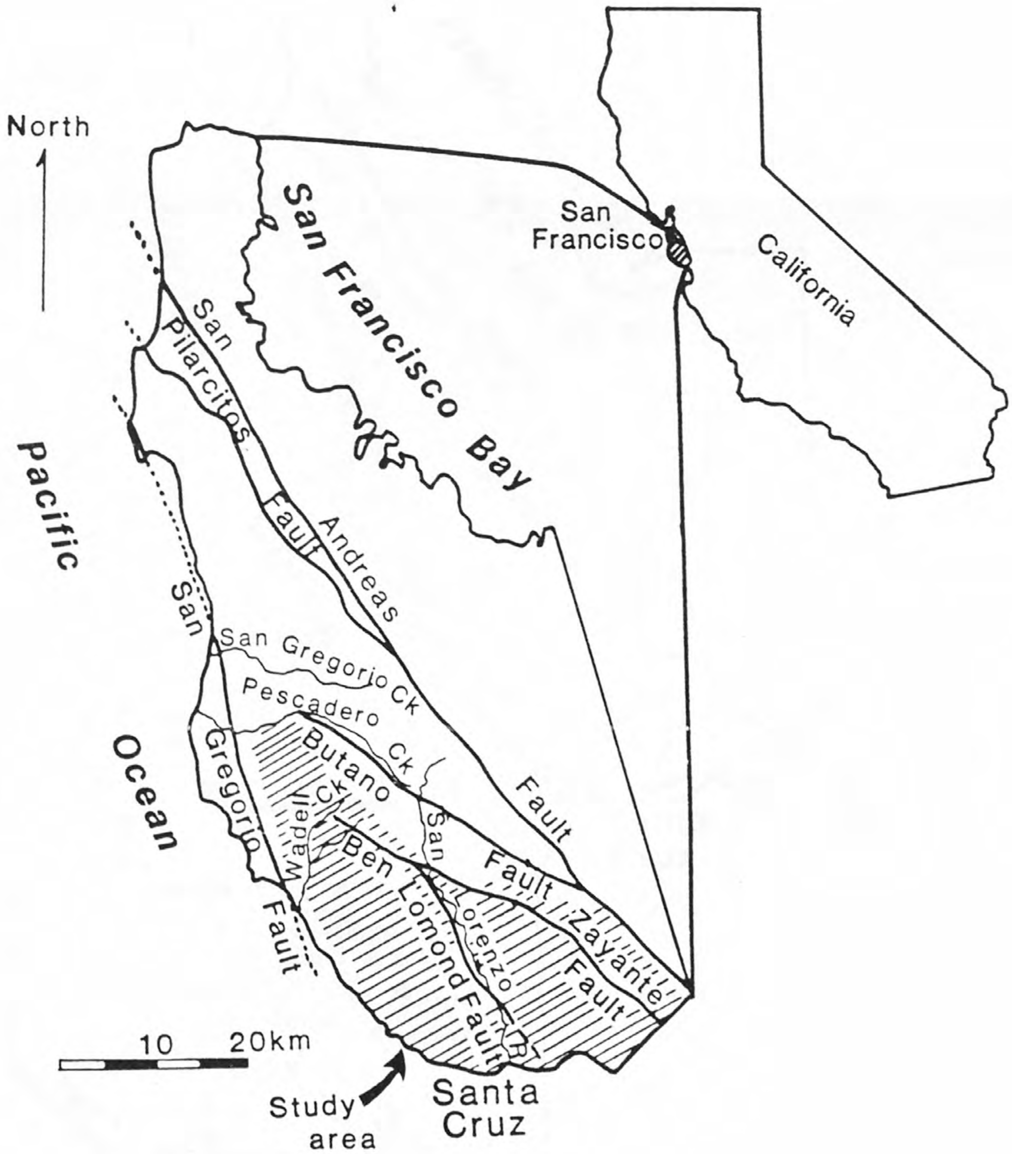


Figure 1. Location of study area.

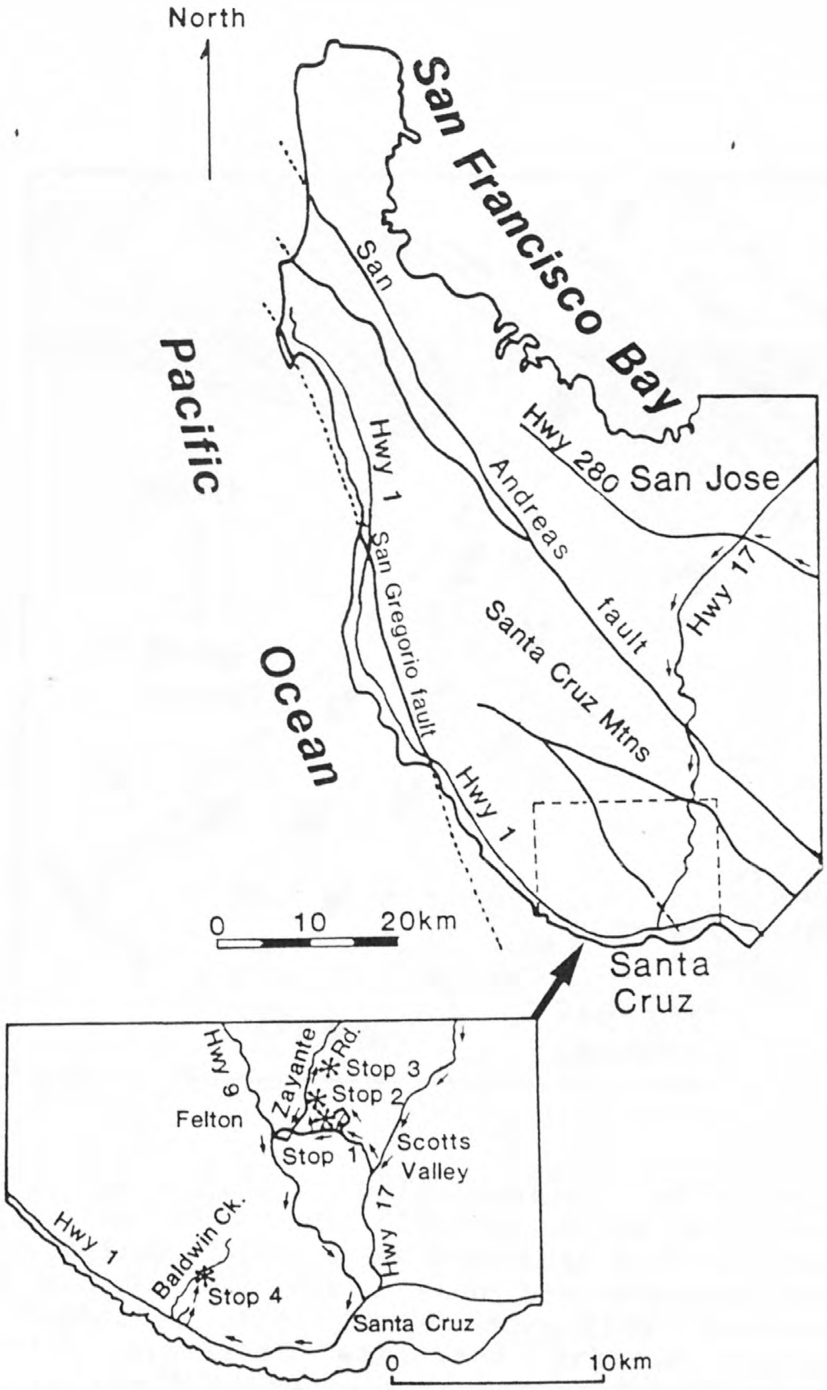


Figure 2. Location of measured sections and field trip stops.

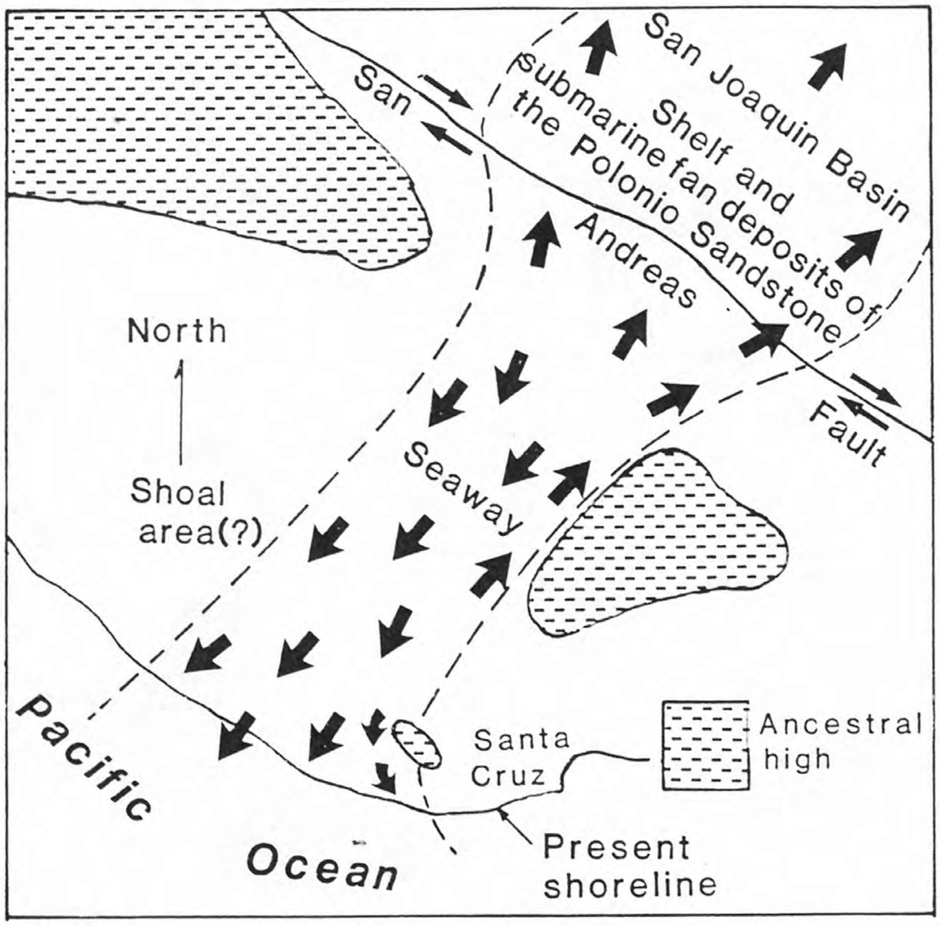


Figure 3. Late Miocene paleogeography after palinspastic restoration to the south 226 km along the San Andreas fault. A seaway, bounded by ancestral highs, connected the interior San Joaquin Basin with the Pacific Ocean. The seaway deposits, the Santa Margarita Sandstone, are tentatively correlated with the arkosic submarine fan deposits of the Polonio Pass Sandstone Tongue on the McLure Shale of Marsh (1960).

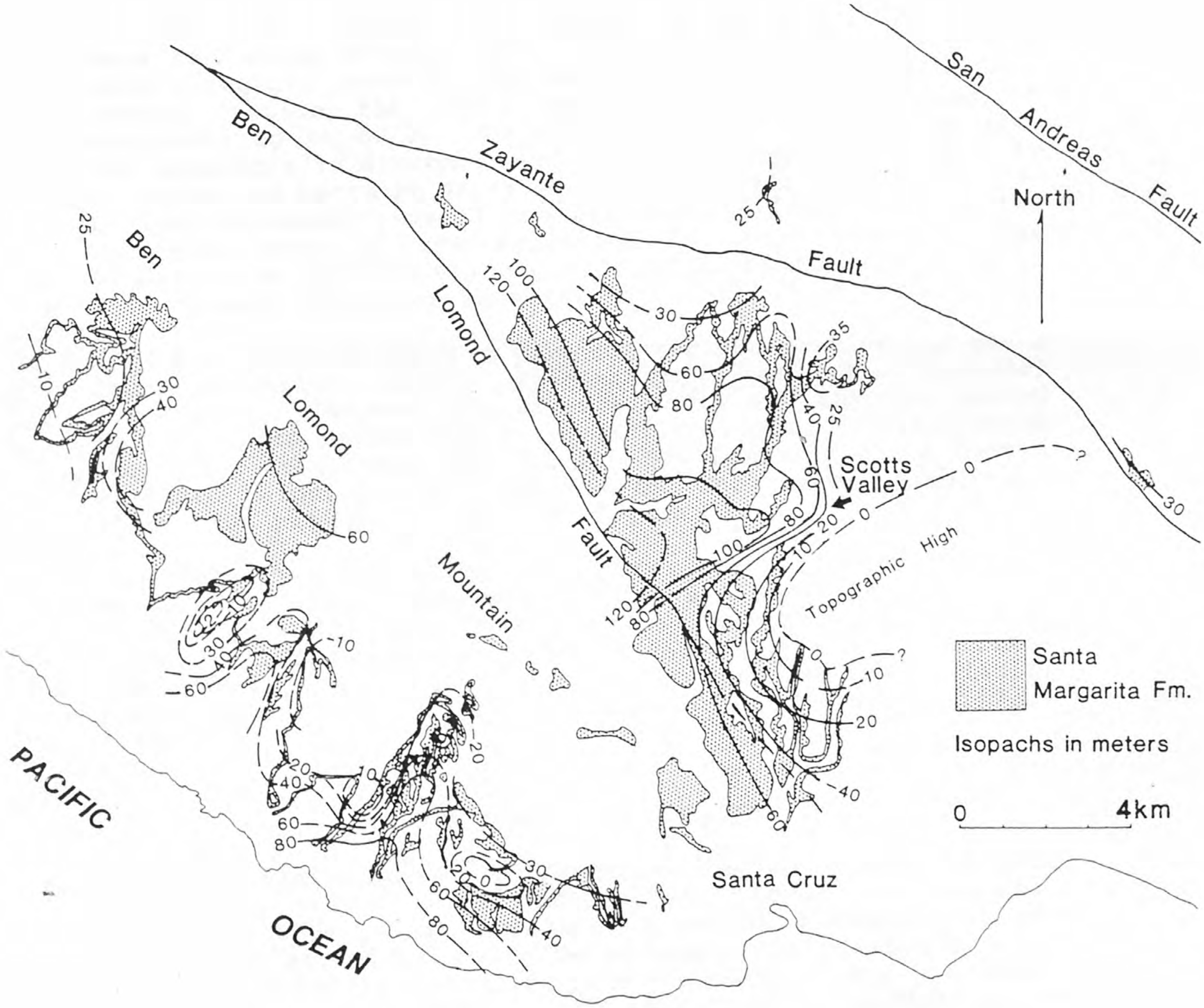


Figure 4. Map of part of the Santa Margarita Sandstone in the Santa Cruz Mountains. The isopachs are determined from measured sections and from well data. Granodiorite locally forms bedrock highs southeast of Scotts Valley and on the southwest flank of Ben Lomond Mountain.

The Santa Margarita Sandstone varies in thickness from zero (in areas of pinchout) up to 130 m within the Scotts Valley region, west of the Ben Lomond fault zone along the coastal region the Santa Margarita Sandstone varies in thickness up to 80 m. To the northwest of the study area the sandstone is discontinously exposed for 45 km eventually thinning and becoming interbedded with glauconitic mudstone; to the northeast (toward the San Andreas fault) and to the southeast most of the sandstone has been eroded. The sandstone is continously exposed for approximately 20 km in as east-west direction parallel to the trend of the seaway.

Post-Miocene folds within the western part of the Santa Cruz Mountains follow pre-existing (pre-late Miocene) structures. Between the Zayante fault and the Ben Lomond fault (Scotts Valley region) a gentle dipping syncline forms the major structure, west of the Ben Lomond fault a gentle westward dipping homocline forms the major structural element of the coastal region (figure 5).

Major faults in the Santa Cruz Mountains trend to the northwest. Two right-lateral strike-slip faults, the San Andreas to the east and the San Gregorio to the west (offshore) dominate the region. Between these two strike-slip faults lie the Zayante fault and the Ben Lomond fault, recording vertical displacements (Clark and Rietman, 1973), (figure 5).

SANTA MARGARITA SANDSTONE

The Santa Margarita Sandstone is a friable arkosic sandstone with abundant cross-strata, local conglomerate, extensive invertebrate remains, abundant bioturbation and local tar accumulations. An overall fining-upward grain size characterizes most of the deposit. The sandstone varies from well-bedded to indistinctly bedded where bioturbation dominates. Conglomerate is concentrated in the basal part of the section but also occurs as up to 6 m sets of trough and tablar cross-strata near the top of the formation to the southwest. Abundant sets of cross-bedding, up to 17 m in thickness, associated with invertebrate fossils and bioturbated sediment are characteristic of the seaway deposits.

The seaway deposits, represented by abundant cross-bedding, range up to 8 to 10 km in width. Bioturbated sandstone interfingers with and bounds the cross-bedded strata to the northwest and to the southeast on the flanks of the seaway. Within the thickest vertical section (130 m), the cross-bedded sets change from trough to tabular geometry and eventually to bioturbated sandstone. Laterally

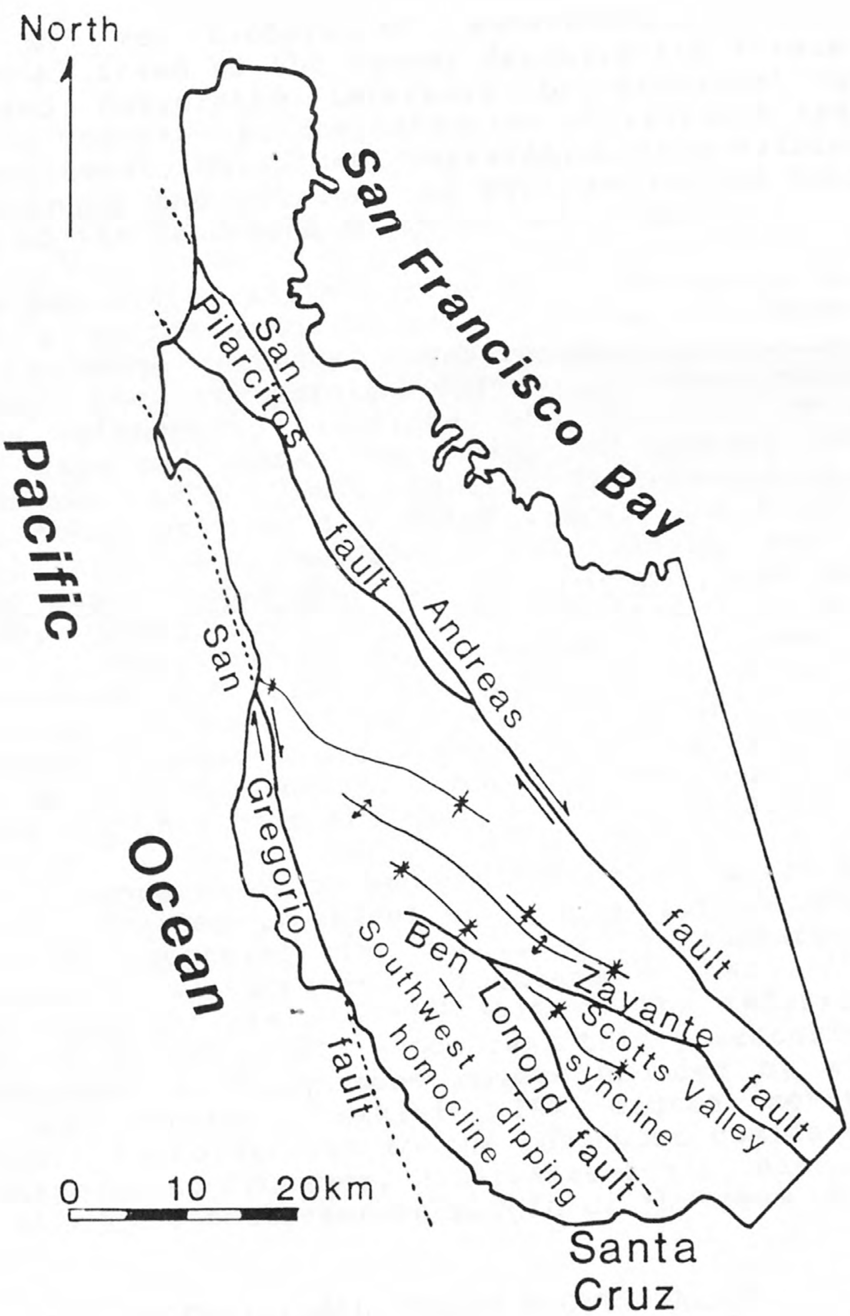


Figure 5. Major folds and faults within the Santa Cruz Mountains.

the cross-beds may change to repeated beds of invertebrate remains or to bioturbated sandstone. Across the depositional trend of the seaway deposits the strata can be traced and correlated laterally by erosional surfaces containing gravel. In the direction of sediment transport, to the southwest, only local correlation is possible due to facies changes and erosion, as well as to thickening and thinning of the sandstone on ancestral highs.

The abundant fossils in the Santa Margarita Sandstone indicate a marine environment. The marine invertebrate fauna includes pectens, gastropods, barnacles, and echinoids; the vertebrate fauna includes remains of cetaceans, pinnepeds, sirenians, and teleosts, as well as teeth of rays and sharks (Repenning and Tedford, 1977; and Clark et al., 1979; Clark, 1981). Terrestrial vertebrate remains, found only in the basal gravels (Stop 1) include desmostylians, a mastodont, a camel and horses (Archeohippus, Hipparion, and Pliohippus), (Mitchel and Repenning, 1963; Repenning and Tedford, 1977; Clark, 1979). The terrestrial vertebrate remains are disarticulated and lie in association with articulated cetaceans and marine fish remains, thereby implying that the land mannal remains are reworked (Phillips, 1981). Trace fossils are also abundant throughout the Santa Margarita Sandstone and many beds are thoroughly bioturbated.

The abundant cross-bedding in the Santa Margarita Sandstone provides an excellent basis for reconstructing paleocurrent patterns in detail. A summary of the paleocurrent measurements indicates that flow was predominantly parallel to the axis of the inferred seaway (figure 6). At most exposures the paleocurrents are unidirectional although some cosets bounded by widespread gravel lag deposits exhibit 180 degree reversals in direction. Paleocurrents to the southwest dominate in most of the exposures. However, a persistent northeasterly trend occurs along the southeastern margin of the seaway.

DEPOSITIONAL STAGES SCOTTS VALLEY

Four stages of evolution of this coarse clastic deposit are identified in the stratigraphic section east of the Ben Lomond fault zone in the Scotts Valley region (figure 7). The depositional stages are defined based on texture, cross-strata type and size, vertical depositional sequence, bounding surfaces (gravel lag deposits) and fossils. Both lateral and vertical transitions are identified and these can be related to tidal current flow direction, possible flow intensity based on cross-strata type (tabular or trough), sea bed processes (migrating sand waves, dunes or

Figure 6. Paleocurrent map of part of the Santa Margarita Sandstone in the Santa Cruz Mountains. The paleocurrent data determined from cross-bed dip-direction measurments. A southwest-dominant current pattern is evident, reversing northeast-directed currents are abundant along the northeast flank of the cross-bedded zone. The southeast current trend west of Santa Cruz reflects a counter clockwise rotation around a local topographic high located directly to the north of the paleocurrent measurements.

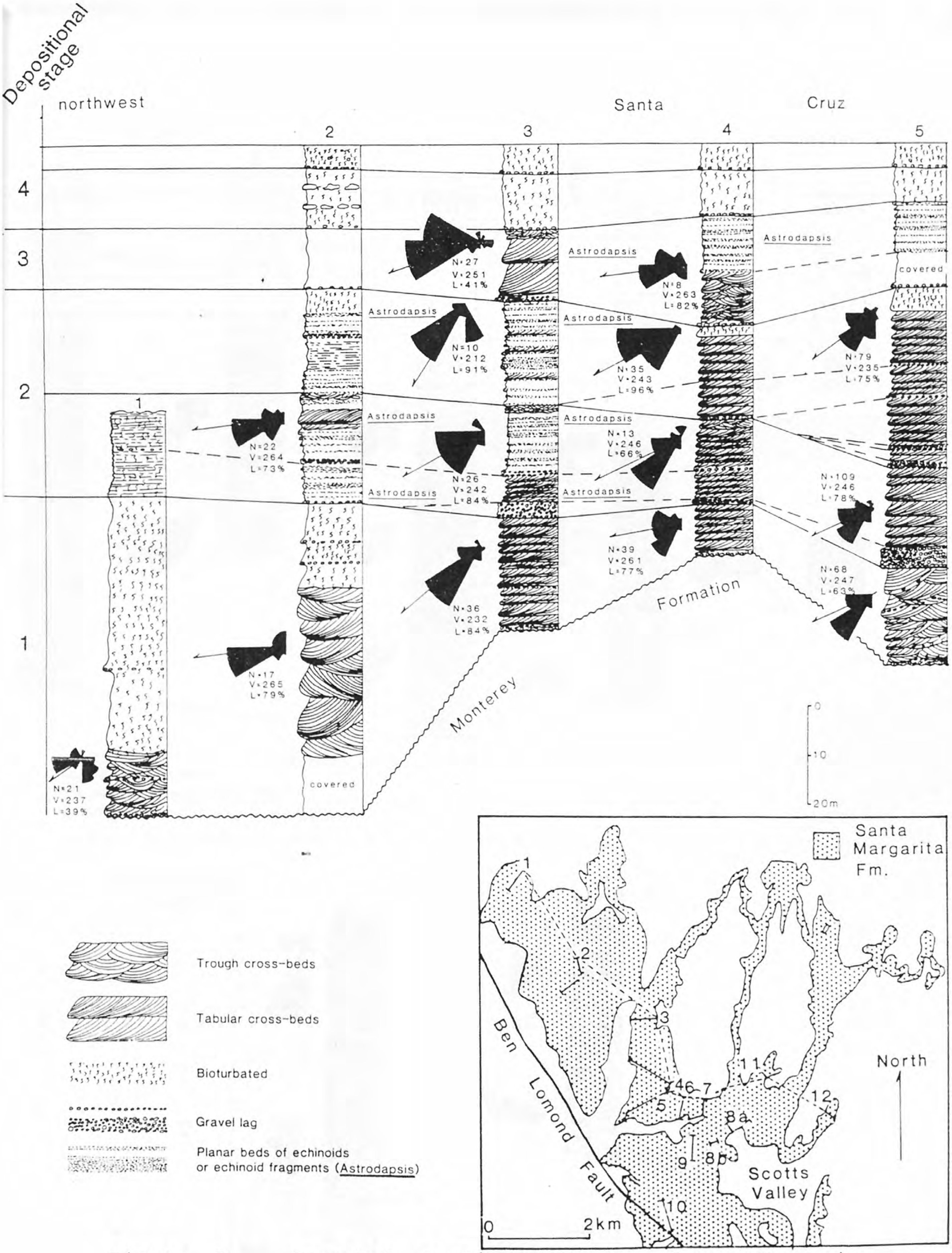
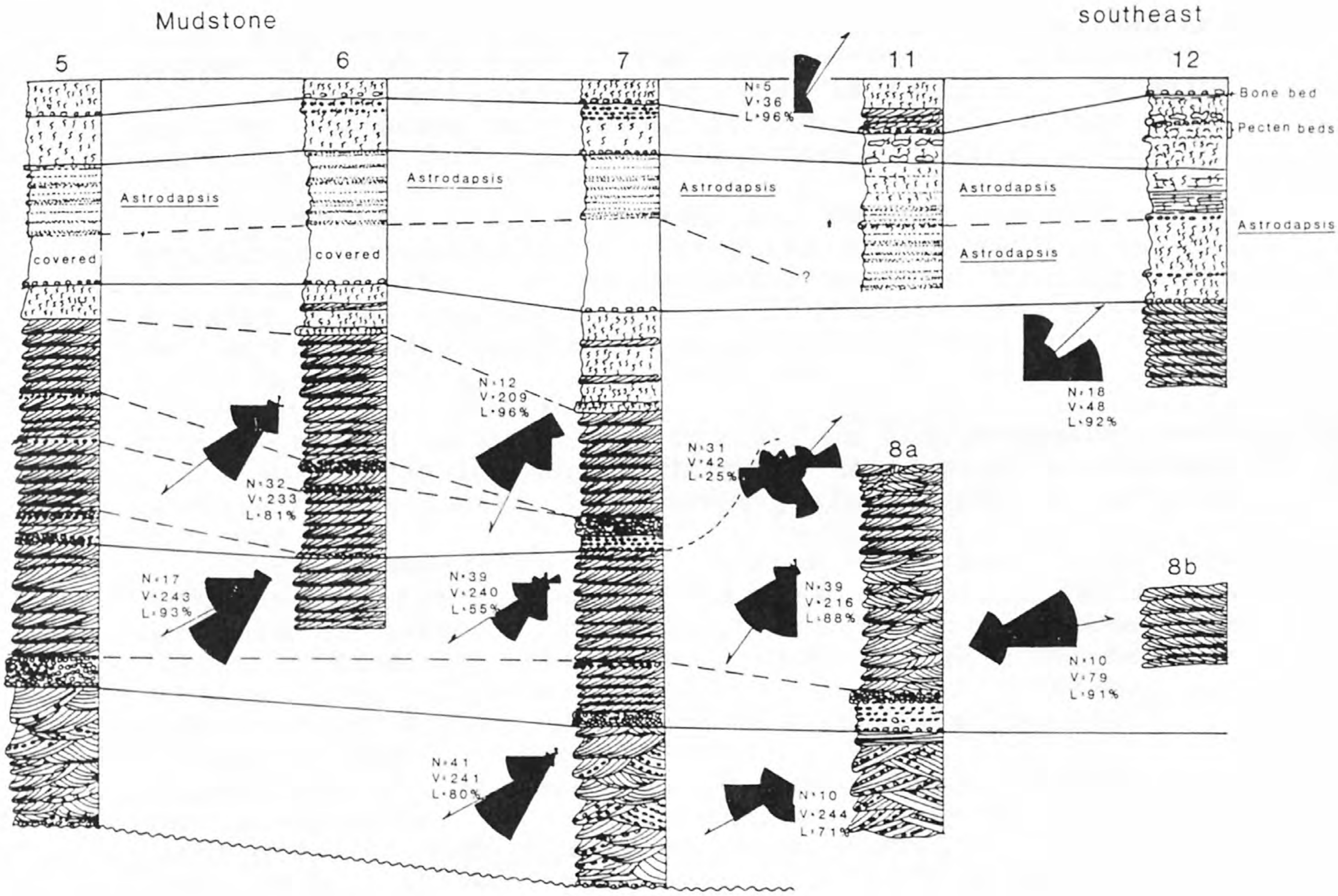
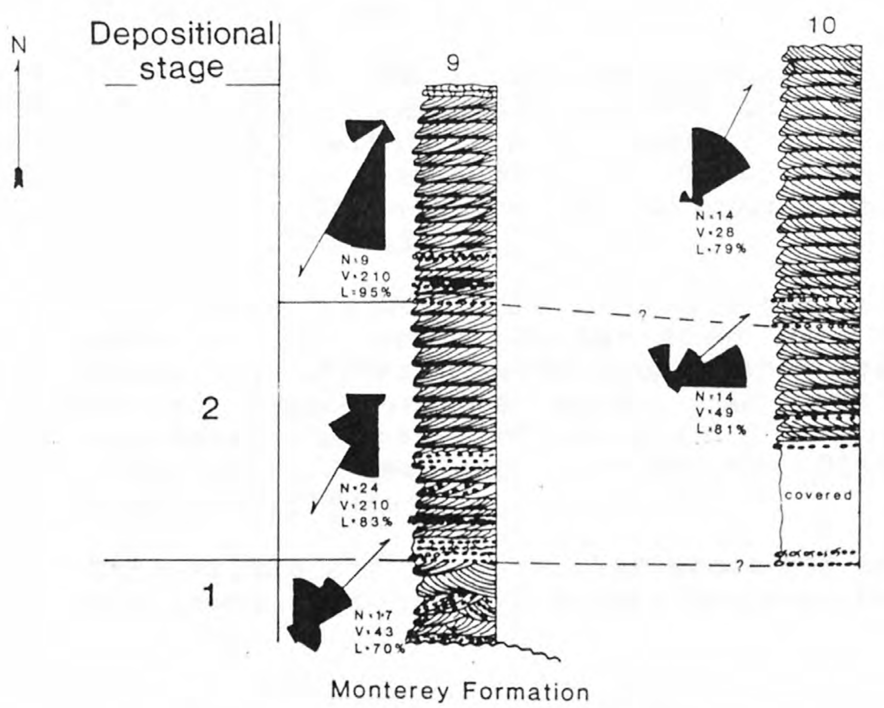


Figure 7. Measured sections of the Santa Margarita Sandstone across the cross-bedded zone. The Santa Margarita Sandstone is divided into 4 major depositional stages based on cross-strata type and size, fossil communities, texture and lateral correlation of erosional lag deposits.



N = sample number
V = vector mean azimuth
L = vector magnitude in percent



tidal sand banks), composition of biological communities and degree of bioturbation. The main effort in interpreting these lateral and vertical sequences is to define the major sea bed processes and resulting depositional environments that dominated during an overall increasing water depth.

STAGE 1. A basal gravel lag deposit rests with an angular unconformity on an irregular eroded surface of the Monterey Formation. A fining-upward sequence developes from a basal mixed coarse-grained sand, granules and gravel to well-sorted medium-grained sand in the northwest part of the cross-bedded region in sections 1 and 2 (figure 7). To the southeast the sediment coarsens laterally changing to coarse-grained sand in section 3, to coarse-grained sand mixed with granules and pebbles in section 4 to abundant gravel with granules and coarse-grained sand in sections 5,7, and 8.

The cross-strata also change laterally from the northwest to the southeast. Large-scale trough cross-beds dominate in secton 1 changing to giant (greater than 3 m thick, terminology from McCabe, 1977) trough cross-beds in section 2 to large-scale and giant tabular cross-beds in section 3 and 4 where the sequence rests on a local Monterey Formation high. Southeast of this local high giant and large-scale trough cross-beds dominate. Large-scale tabular cross-beds are also abundant. Parts of some of the giant gravel trough cross-beds are preserved as wedge-shaped beds to 8 m thick. Bioturbation is also abundant within most cross-beds.

The paleocurrent data suggest dominant transport to the southwest (vector mean of 244 degrees). Oppositely directed currents (northeast directed) are found starting in section 5, sections 7 and 9.

STAGE 2 An irregular erosional surface containing a gravel lag deposit defines the base of the next stage. Internally within this depositional stage gravel lag deposits are common as well as abrupt vertical changes in grain size which allow lateral correlation of the internal sedimentation units.

Coarse pebbbly sand to coarse-grained sand and granules dominate the texture in the lower part of this stage; the upper part fines upwards from coarse pebbly sand to well-sorted medium-grained sand. An erosional lag deposit separates the basal coarse-grained sequence from the upper finer-grained sequence in to two distinctive sandstone deposits (figure 7).

Large-scale and giant tabular cross-bed sets are abundant in the lower part of this stage, large-scale cross-bedded sets are the most abundant type of cross-strata in the upper part of this depositional sequence. A transition from giant and large-scale cross-beds (sections 5 and 6) to large-scale tabular cross-strata in section 4 to extensive planar echinoid lags occurs laterally to the northwest.

To the northwest within the upper part of this stage echinoid lags, containing abundant remains of Astrodapsis, occur as repeated parallel beds or as thick-bedded bioturbated lags. Bioturbated parallel thick beds in section 1 represent leached fossil accumulations. Bioturbation also increases toward the upper parts of this stage.

The paleocurrent data define a reversing, parallel current pattern. A southwest trend of 240 degrees is recorded for the basal coarse-grained beds within this stage and a vector mean of 234 degrees for all the cross-beds above the gravels in the upper part of this stage. Current reversals, northeast-directed, again are restricted to the southeast flank of the cross-beds and are represented by unidirectional tabular sets and cosets in sections 8b, 10, and 12 (figure 7).

STAGE 3 Stage 3, as with stage 2, is dominated by Astrodapsis lags and large-scale cross-beds. However, a lateral shift of these depositional elements resulted in the cross-strata occurring across the northwest flank and the fossil lag deposits dominating to the southeast (figure 7). The basal erosional surface is overlain by a thin, less than 30 cm thick, bioturbated gravel bed.

Slightly oxidized medium- coarse-grained sand make up most of the sequence, though, coarser-grained sediment, granules and pebbles form thin bioturbated planar beds in section 11 and 12 (figure 7).

The cross-strata occur in a variety of styles and scales. Large-scale trough sets are found above the basal lag within the the thickest stratigraphic section (section 4, figure 7). Giant (to 6.4 m thick tablar cross-bedded sets form most of the stratigraphic section to the northwest. Small-scale trough sets overlie the upper giant tabular cross-bed at the top of this stage. Echinoids also occur within the foreset and bottomset beds of the giant cross-strata.

To the southeast, echinoids occur as whole leached fossils, as cemented concretions or only as abundant disarticulated plates and occupy much of the stratigraphic sections from secton 4 to 11 (figure 7). Thin to thick, horizontal planar beds composed of lag concentrations form the dominant bedding features over much of this stratigraphic section where cross-beds are not abundant.

The paleocurrent vector mean azimuth trends to the west at 294 degrees. A western-directed current pattern characterizes the large-scale trough cross-beds within section 4 (figure 7). The giant tabular sets in section 3 also record a westward trend, however, the small-scale trough sets overlying the giant cross-strata show a bimodal pattern indicating current reworking, possibly on the stoss slope of giant bedforms. Lateral correlation of this stage to the north also records large-scale northeast-directed cross-bedded sets associated with echinoids. The currents were still divided into a southwest- and a northeast-directed flow during deposition of this stage.

STAGE 4 Biological processes now dominate over physical processes in the upper-most depositional stage. A vertebrate-gravel lag (bone bed, figure 7) separates this stage into 2 distinctive deposits. A thin gravel lag also defines the base of this sequence.

Well-sorted quartzose sand, concretions, abundant bioturbation, locally scattered vertebrate remains, and horizontal pecten lags are abundant in the lower depositional unit of this stage. Poorly sorted, coarse-grained sand, granules and scattered pebbles, intense bioturbation and a distinctive yellow-green color identifies the upper-most depositional sequence.

Physical sedimentary structures are rare within this stage. Thin, bioturbated horizontal pebble beds, concretions or fossil lag accumulations are the only bedding features observed in the lower depositional unit of this stage. In the upper part of this stage, cross-strata are preserved directly above the vertebrate-gravel lag at one locality. Large-scale, tabular cross-beds occur as repeated northeast-directed sets over the lag deposit (figure 7). Bioturbation dominates above the cross-beds and in all other exposures of the upper unit of this stage.

The sparce paleocurrent data (mean azimuth of 36 degrees) still suggests northeast-directed current flow exisited along the southeast flank of the seaway.

DEPOSITIONAL MODEL SCOTTS VALLEY SECTION

The four stages within the thickest stratigraphic section record distinctive depositional processes that apparently reflect both the dominant seabed processes and reducing current velocities during deposition of the Santa

Margarita Sandstone.

A marine environment with the sea floor covered by large migrating bedforms (dunes) dominate the depositional environment at the earliest stage. The bedforms were separated into ebb- and flood-dominate fields as indicated by the bimodal opposed cross-bedded cosets (figure 8). High current velocities are suggested based on the coarse-grained sediment and abundance of giant trough cross-strata (gravel cross-beds to 8 m thick). The trough cross-strata represent migrating lunate dunes (Harms and others, 1975). The transition to tabular cross-strata in the middle part of the seaway suggests a reduction in flow velocity or depth with sinuous- to straight-crested sand waves migrating on the sea floor.

Migrating bedforms and biological communities dominated the depositional environment of the second stage (figure 8). The second stage began with erosion of sediment deposited in the first stage thus forming a widespread lag deposit. Large-scale sinuous-crested sand waves, biological communities containing Astrodapsis and laterally migrating tidal sand banks dominated the sea floor. A change from dune bedforms in stage 1 to sinuous- to straight-crested sand waves in stage 2 suggests a reduction in the current velocity.

Sand banks occurred to the east adjacent to the biological communities and are represented by unidirectional cross-bedded sets and cosets. The western-most ridge may have propagated from a bedrock high that existed to the north. Evidence for migrating sand banks is suggested by the inclined sedimentation surfaces (5 degree dip) and the opposed unidirectional cross-bedded cosets. Lateral migration of sand banks produced the vertical sequence of sedimentary structures in much of this stage.

The reconstructed depositional environment of the third stage records a lateral shift in both the biological communities and bedforms in relation to the underlying stages. Giant sinuous- to straight-crested sand waves containing superimposed small-scale dunes occuppied the west flank of the cross-bedded zone, echinoids occurred across much of the region to the southeast (figure 8). Slowly migrating large-scale, straight- to sinuous-crested sand waves with echinoids living between the sand waves covered much of the sea floor. Continous bedform migration and repeated erosion produced the multiple horizontal fossil lag deposits now found to the southeast of the giant cross-strata.

Stage 4 depositional environment suggests reduced

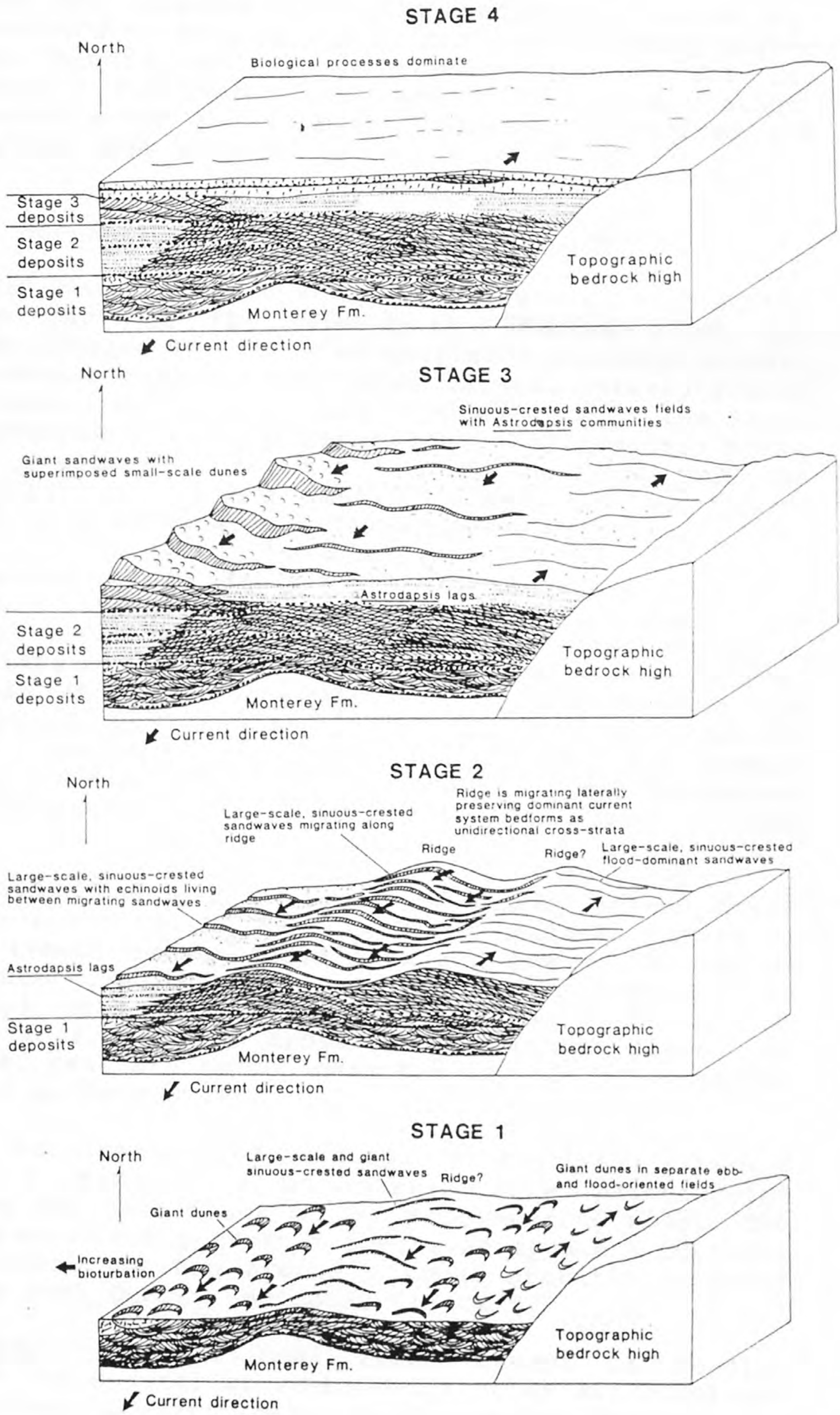


Figure 8. Depositonal model of the stages of development of the Santa Margarita Sandstone within the Scotts Valley region.

current velocities on the sea floor and resulting intensive bioturbation and reworking of the sediment (figure 8). Abundant vertebrate remains, planar shell and locally planar gravel lags record periods of erosion forming the lag concentrations followed by intensive bioturbation. Migrating sand waves and ripples probably transported the sediment within this stage.

DEPOSITIONAL FEATURES COASTAL REGION

Possibly two stages of deposition are suggested within the western part of the cross-bedded facies along the coastal area (figure 9). Limited continous outcrops as well as poor exposures prevents extensive lateral correlation of the depositional units. The cross-bedded zone of the Santa Margarita Sandstone rests on metamorphic and granitic rocks as well as younger strata, the Lompico Sandstone and the Monterey Formation, on the western flanks of Ben Lomond Mountain. A thin basal gravel lag overlies bedrock.

The texture of the Santa Margarita Sandstone along the coastal region varies from fine-grained sand to gravel. The coarse gravel fraction is greatly reduced in size, averaging 1 cm in diameter in comparison with the coarse gravel (clasts to 15 cm) in Scotts Valley. Gravel, however, is found throughout the stratigraphic section in the center of the seaway. Mixed coarse sand and granules are common throughout the measured sections, however, local fining or coarsening upward sequences exist. Likewise, abrupt lateral changes in grain size are also common.

Large-scale and giant (to 17 m thick, Majors Creek section, and 7.6 m thick, Baldwin Creek section, figure 9) tabular and trough cross-bedded sets and low angle dipping parallel-bedded bioturbated strata are found as unidirectional sets and cosets within this part of the cross-bedded zone. Trough cross-strata in both gravel and coarse-grained sand are common near the top of the formation in Majors and Baldwin Creek.

The paleocurrent data records a southwest-directed pattern with a change to a southeast-directed paleocurrent pattern along the east flank of the cross-bedded zone. The southeast paleocurrent pattern reflects an apparent counter-clockwise current rotaton around a local granitic basement high (Granite Rock Quarry sections, figure 9).

A systematic depositional model cannot be readily developed for the coastal cross-bedded zone as was developed in Scotts Valley, however, some of the seabed features, at least in the upper part of the Santa Margarita Sandstone,

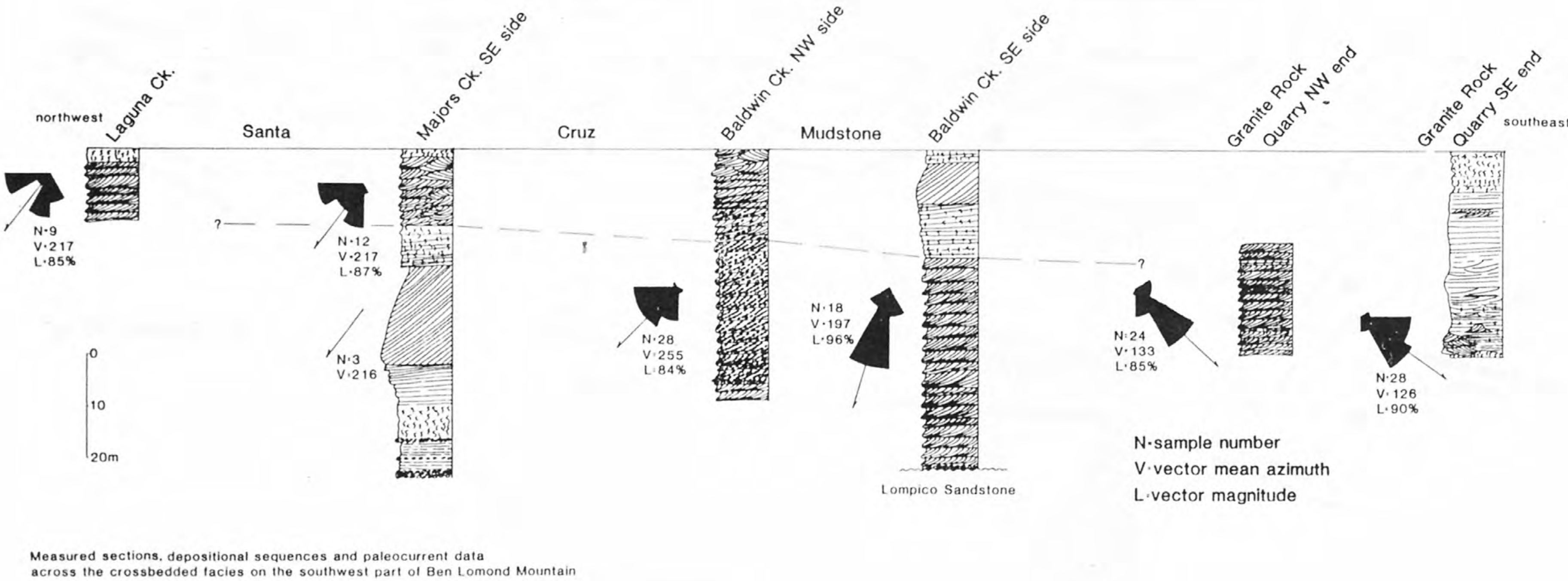


Figure 9. Measured sections, depositional sequences and paleocurrent data across the cross-bedded zone on the southwest part of Ben Lomond Mountain. The dashed line represents the possible boundary between two different depositional stages.

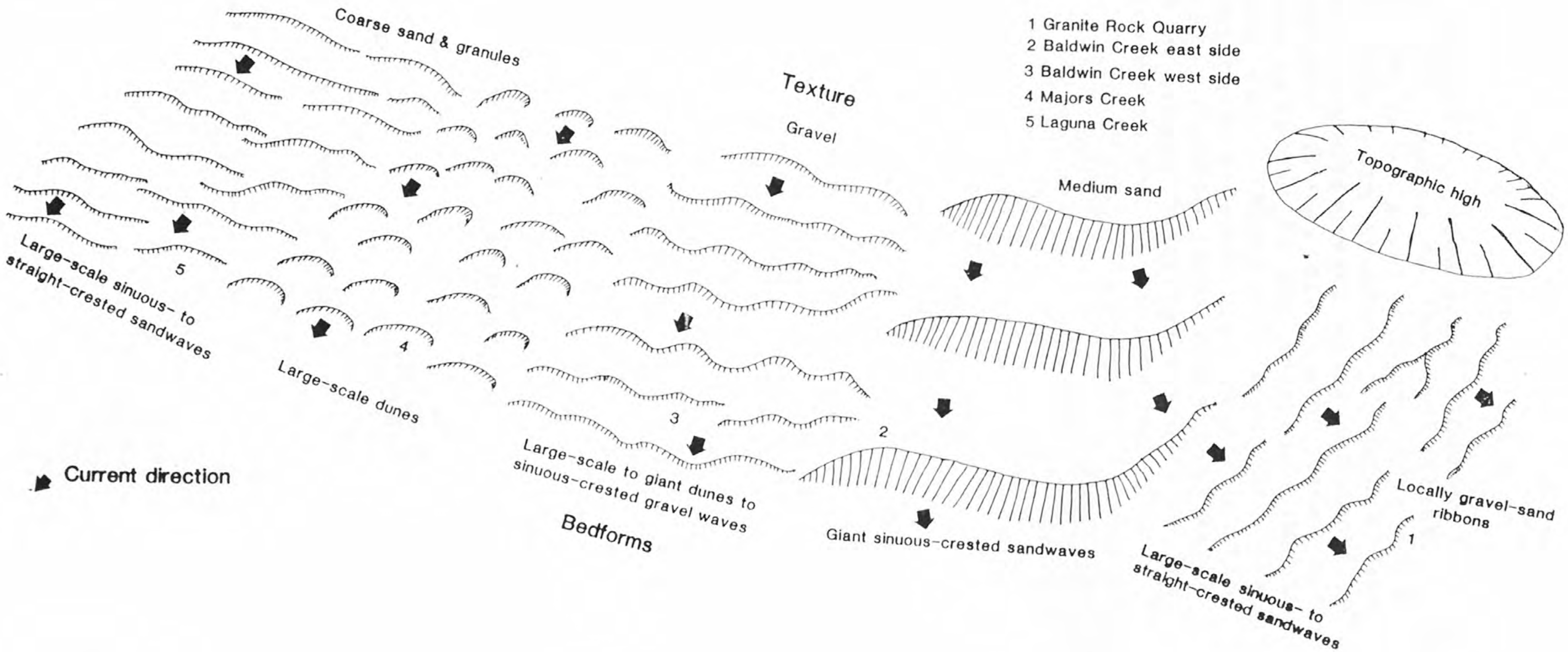


Figure 10. Possible textural relationships and bedforms present on the sea floor within the cross-bedded facies for the western-most exposures on the Santa Margarita Sandstone.

are apparent. Large-scale sinuous- to straight-crested sand waves are common on the west flank of the seaway (Laguna Creek section, figures 9 and 10); to the southeast large-scale dunes are abundant in Majors Creek area changing to sinuous-crested gravel waves and dunes on the northwest side of Baldwin Creek; giant sand waves occur parallel to the gravel bedforms to the southeast (Baldwin Creek east side, figure 10). Along the southeast flank of the seaway a topographic bedrock high caused currents to rotate around the high forming large-scale sand waves and locally gravel-sand ribbons. Bioturbated sandstone forms the boundaries of the cross-bedded zone along both flanks of the seaway.

FIELD TRIP LOCATIONS

1. Take Hwy 17 from San Jose to Scotts Valley (approximately 45 minutes). Turn right off Hwy 17 on to the Scotts Valley-Felton Road--continue through Scotts Valley heading west to Lockhart Gulch Road. Turn right on Lockhart Gulch and continue on to Geyer Road. Turn left on Geyer Road and follow until dead ends at gate and quarry.

STOP 1

2. Return to Scotts Valley-Felton Road, turn right (toward Felton). At approximately 1 mile (top of hill) turn right into Lone Star Industries quarry. Continue on road (watch out for trucks--have right of way) to plant office. HARD HATS ARE REQUIRED AT THIS STOP.

STOP 2

3. Return to Scotts Valley-Felton Road, turn right to Felton, turn left on Hwy 9 to Henry Cowell State Park, turn left into park.

LUNCH

4. Return to Felton, turn right on Scotts Valley-Felton Road, stay to the right until Zayante Road. Turn left on Zayante Road, pass Lone Star Quarry and continue to the old Kaiser K-4 Quarry located on right across from fish farm-stop at the gate.

STOP 3

5. Follow Zayante Road west toward Santa Cruz. Turn right heading north through Santa Cruz on Hwy 1. Pass Granite Rock Quarry (on right) and turn right on next road (refuse disposal site) and follow road to dump. Walk across terrace to Baldwin Creek landslide area.

STOP 4

6. Return to San Jose.

STOP 1

At this stop within the main part of the Santa Cruz Aggregrate Quarry we will be examining the basal part of the Santa Margarita Sandstone containing abundant gravel, large-scale and giant trough and tabular cross-beds and biogenetic structures. Figures 11 to 20 characterize the depositional features within this part of the quarry.

In the upper part of the quarry (higher stratigraphic section) planar gravel lags and essentially unidirectional (southwest-directed) cross-bedded sets which grade vertically into bioturbated sandstone will be observed. Figures 21 to 27 characterize the upper quarry section.

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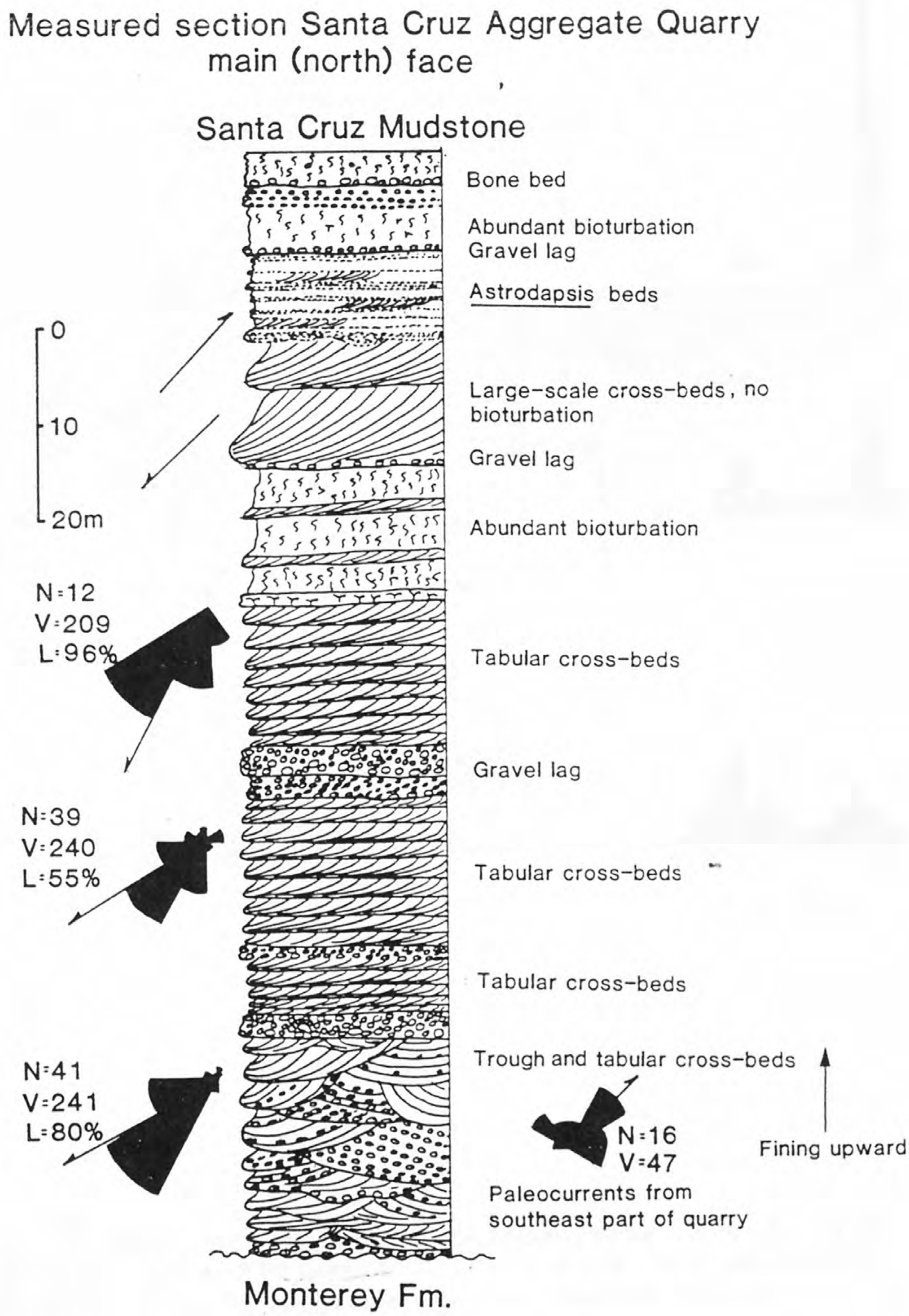


Figure 11. Measured section and paleocurrents of the Santa Margarita Sandstone, main cliff face, Santa Cruz Aggregrate Quarry, Scotts Valley.

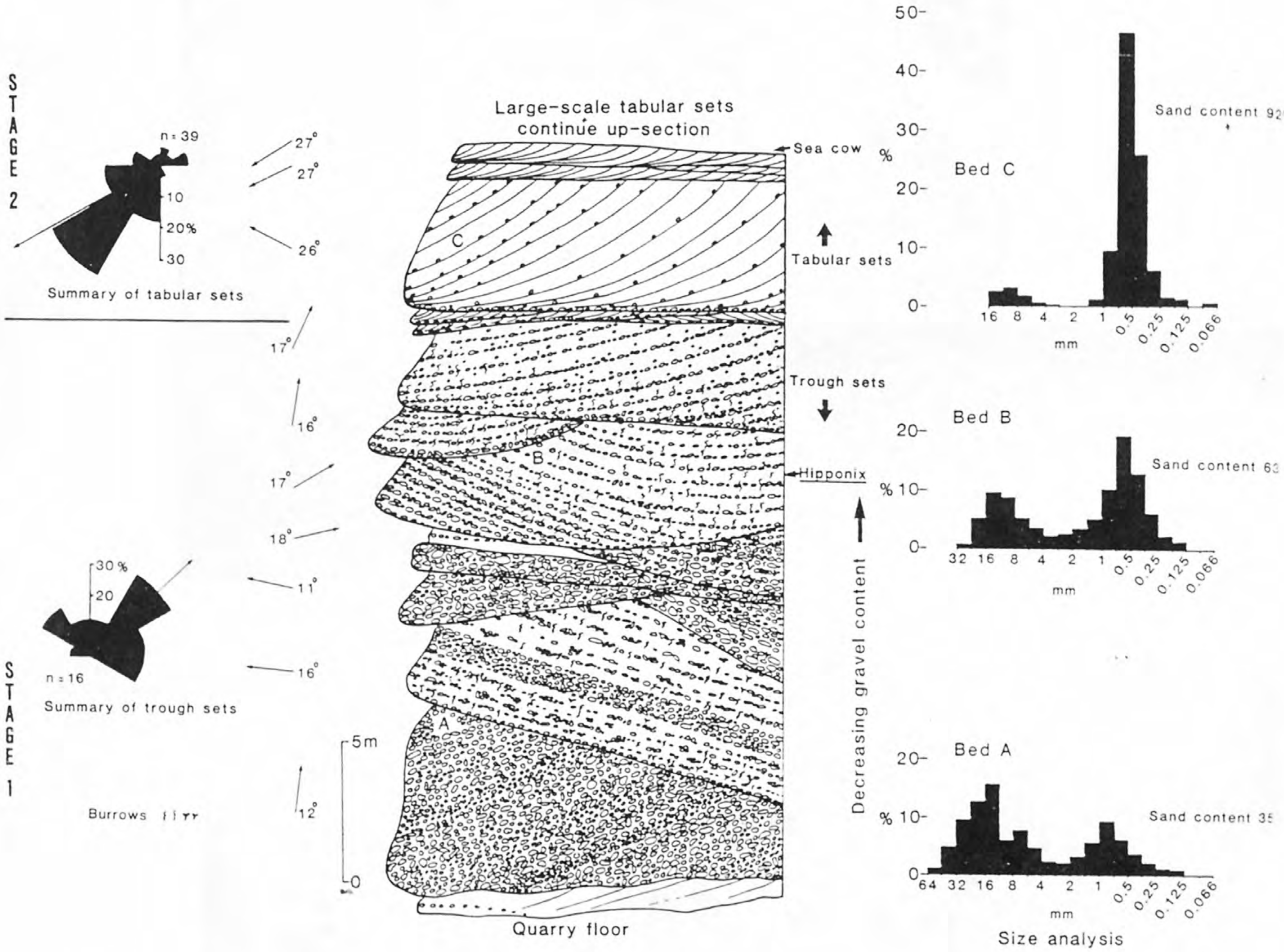


Figure 12. Measured section, paleocurrent trends and texture of the Santa Margarita Sandstone in the southeast end of the Santa Cruz Aggregrate Quarry, Scotts Valley.

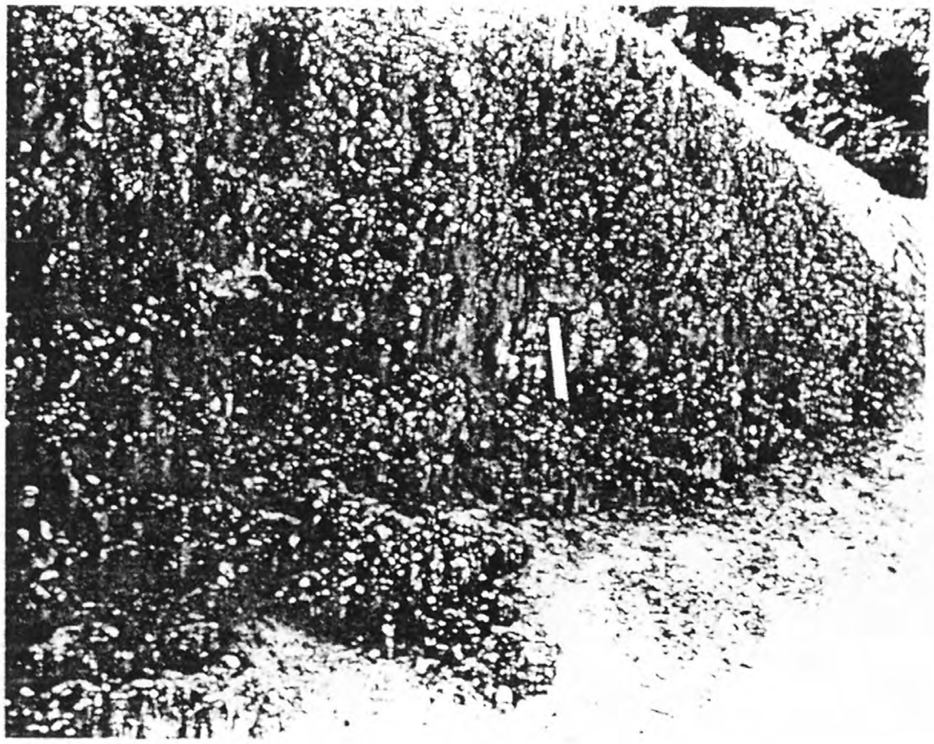


Figure 14. Bioturbated gravels within a trough cross-bed in the Santa Margarita Sandstone in the Santa Cruz Aggregrate Quarry.

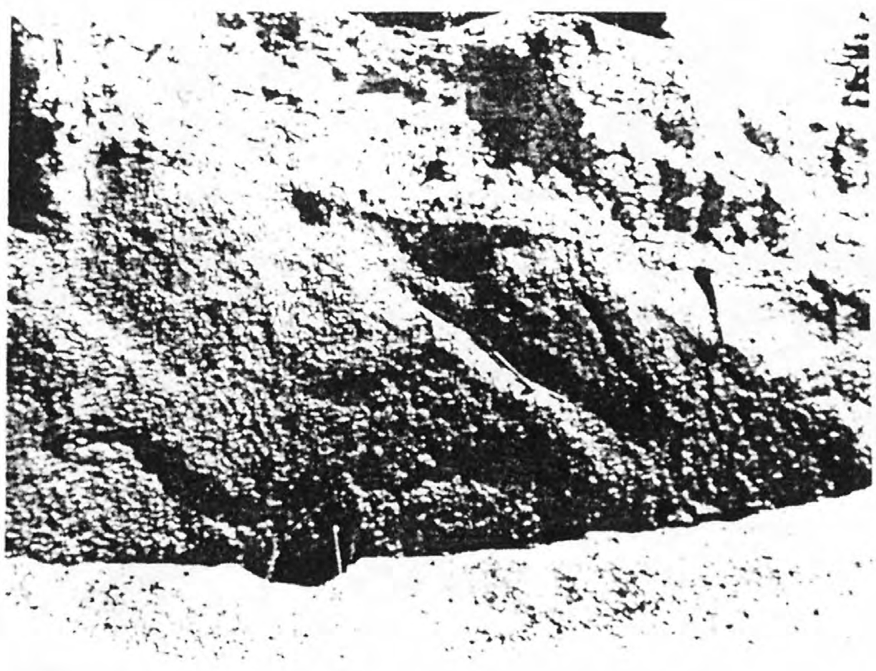


Figure 13. Part of a large-scale, 8 m thick, conglomerate trough cross-bed in the Santa Margarita Sandstone in the Santa Cruz Aggregate Quarry (bed A, figure 12).

Figure 16. Large-scale tabular cross-bed within the Santa Margarita Sandstone in the Santa Cruz Aggregrate Quarry. The cross-stratified set in the center of the photograph is 4.4 m thick (bed C, figure 12).

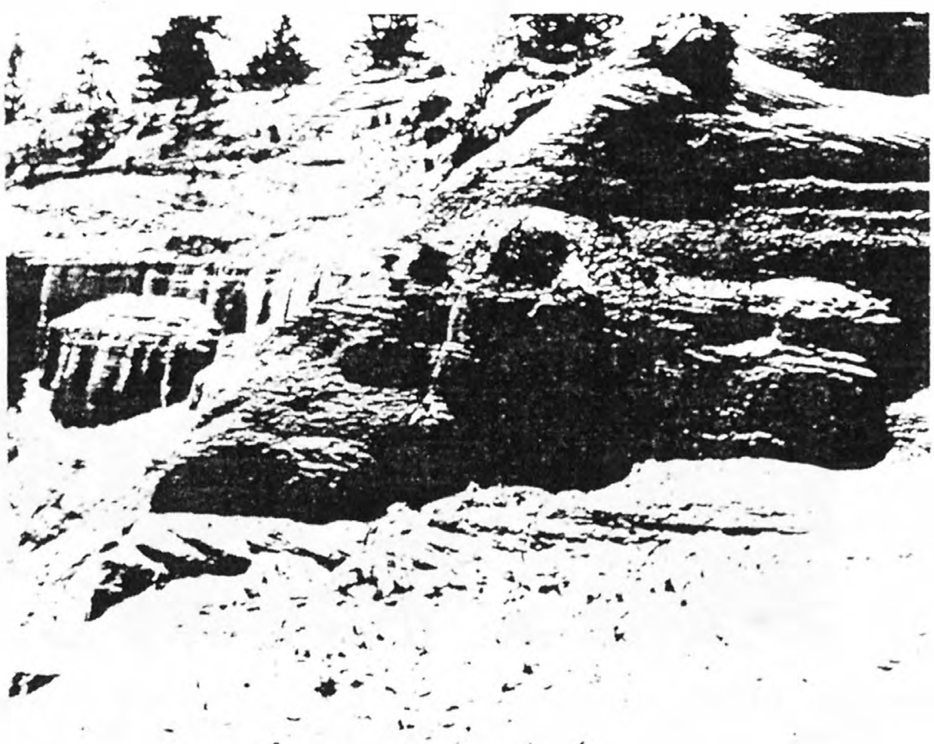


Figure 15. Large-scale cross-beds in the Santa Cruz Aggregate Quarry.

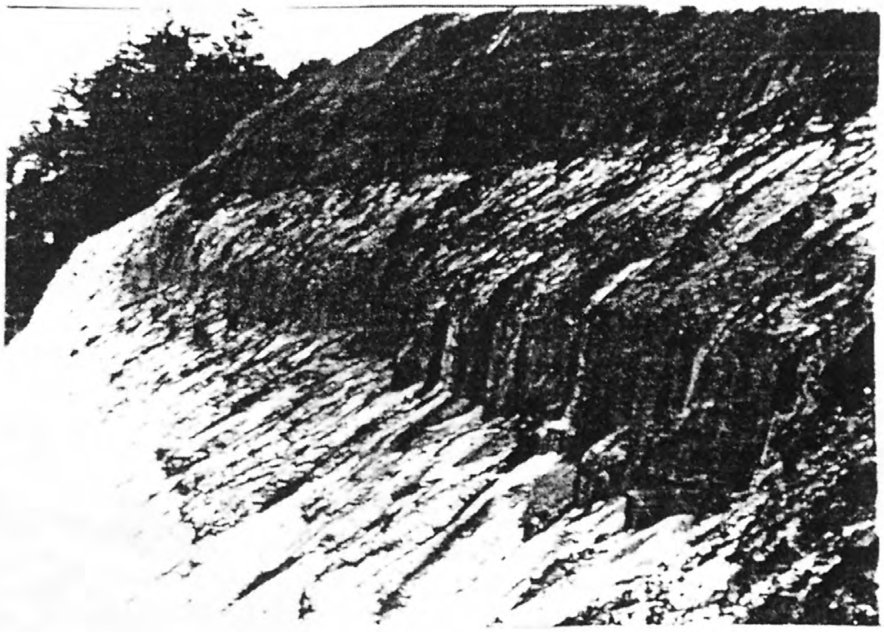


Figure 18. Parallel-bedded gravel lag deposits in the Santa Margarita Sandstone near the top of the formation, main cliff face, Santa Cruz Aggregrate Quarry.

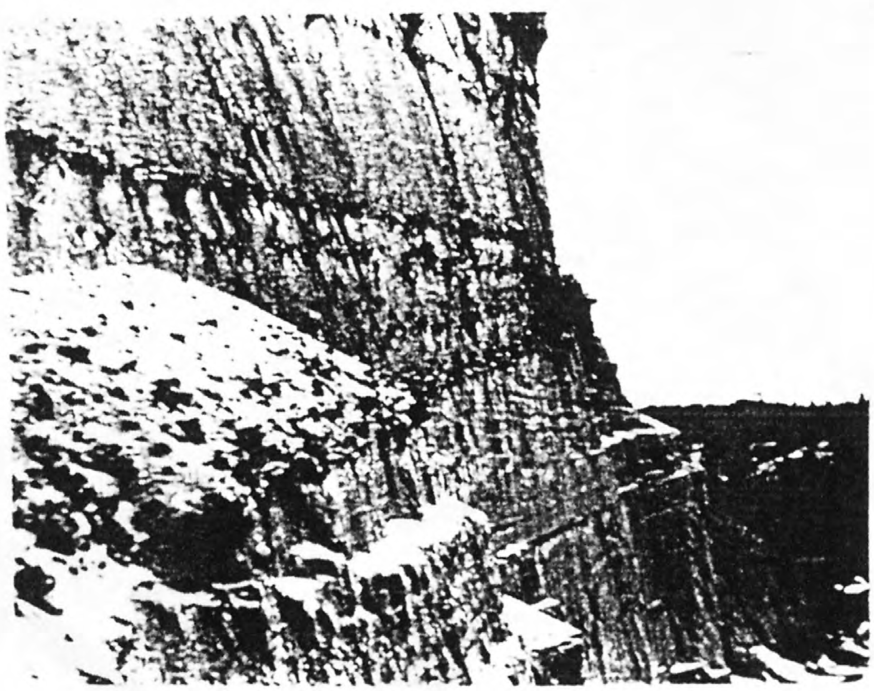


Figure 17. Gravel lag deposits in the Santa Margarita Sandstone, main cliff face, Santa Cruz Aggregate Quarry.

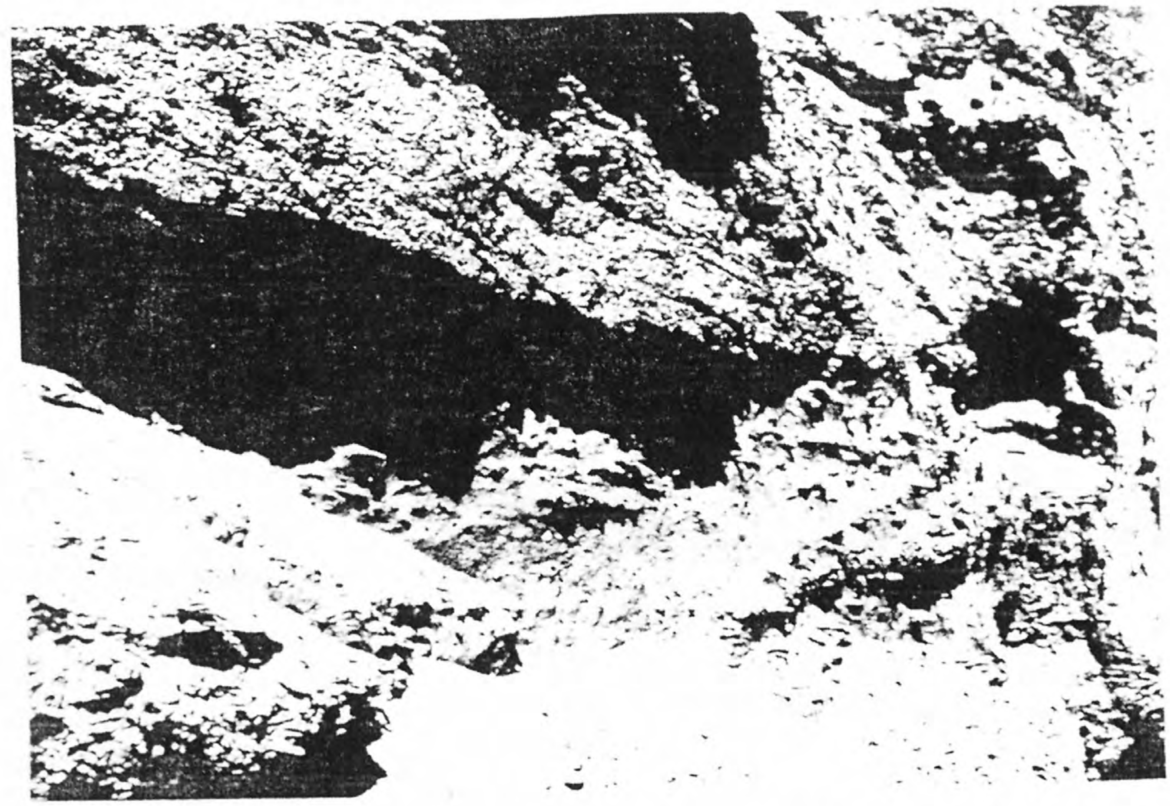


Figure 20. Large-scale trough cross-bed composed of echinoid plates overlying whole echinoids scattered in sand, main cliff face, Santa Cruz Aggregate Quarry.

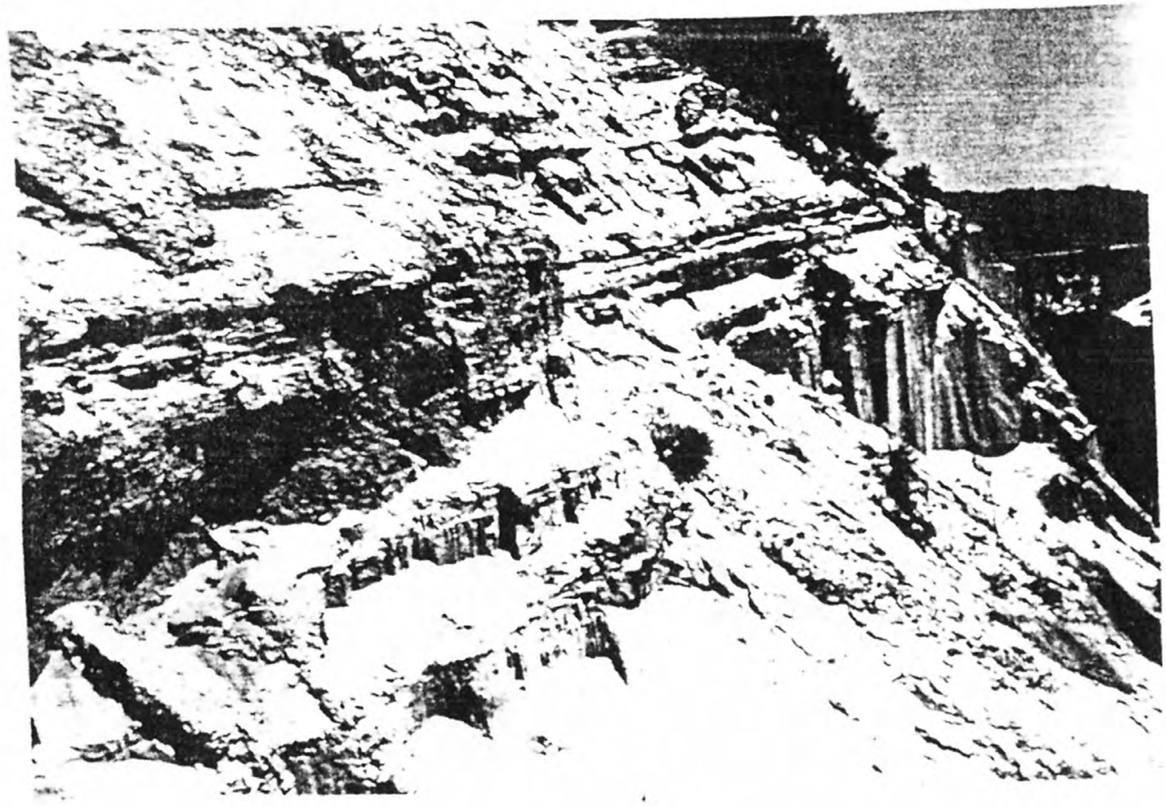


Figure 19. Parallel-bedded echinoid (Astrodapsis) lags in the Santa Margarita Sandstone, main cliff face, Santa Cruz Aggregrate Quarry.

STOP 1

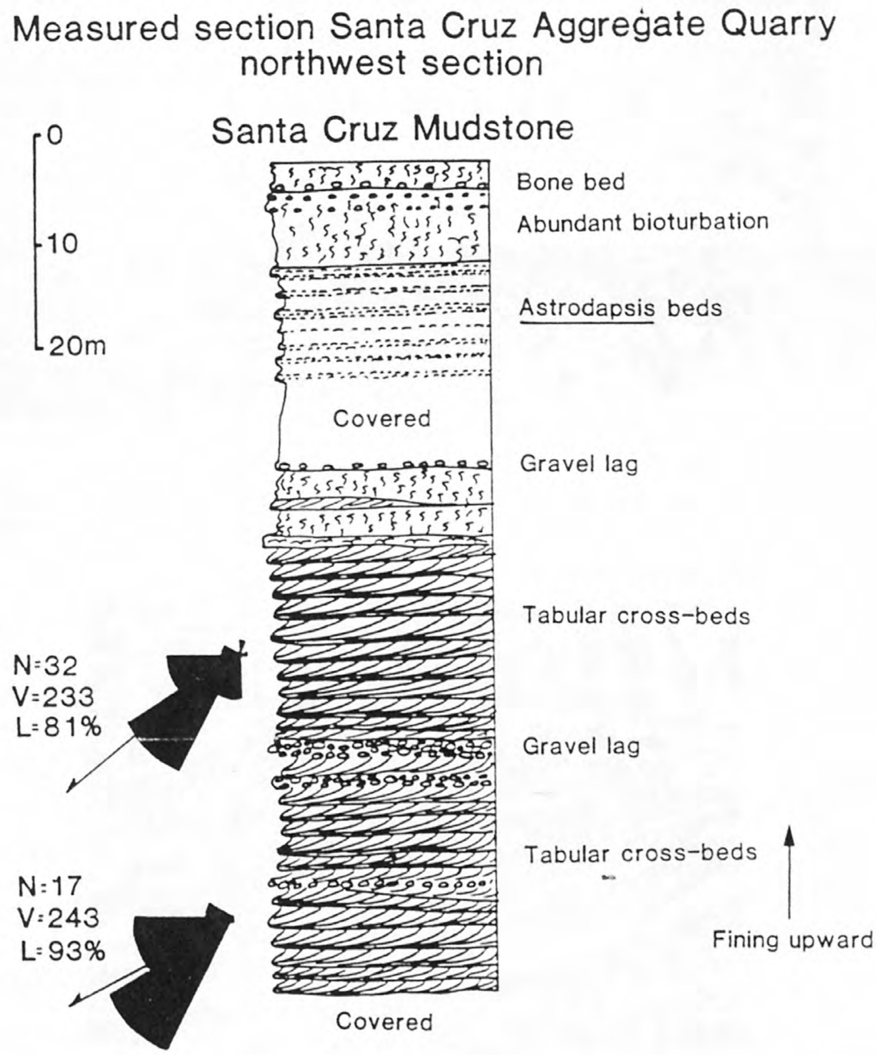


Figure 21. Measured section and paleocurrent trends in the Santa Margarita Sandstone in the west end of the Santa Cruz Aggregate Quarry, Scotts Valley.

Figure 23 Large-scale tabular cross-beds in the Santa Margarita Sandstone in the Santa Cruz Aggregate Quarry directly above figure 22.

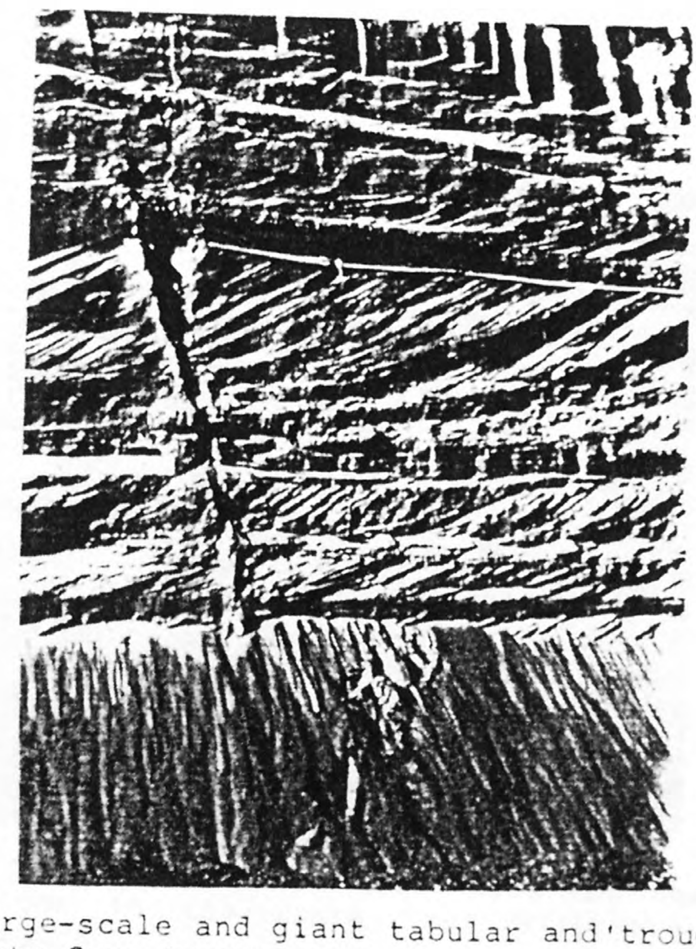


Figure 22. Large-scale and giant tabular and trough cross-beds in the Santa Cruz Aggregate Quarry, Scotts Valley. The pick is 50 cm.

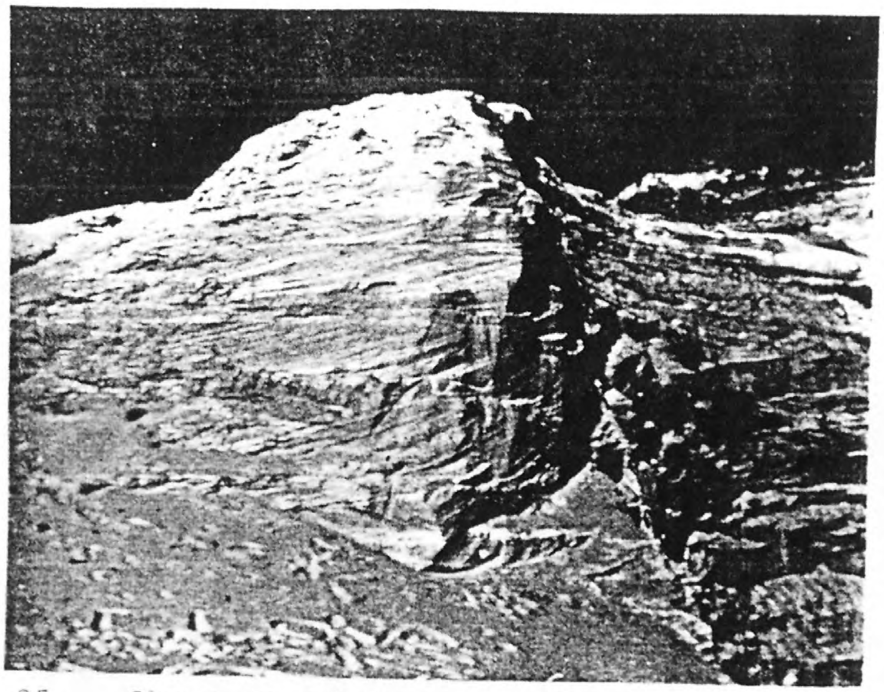


Figure 25. Close-up of large-scale tabular cross-beds in the Santa Margarita Sandstone in the Santa Cruz Aggregate Quarry.

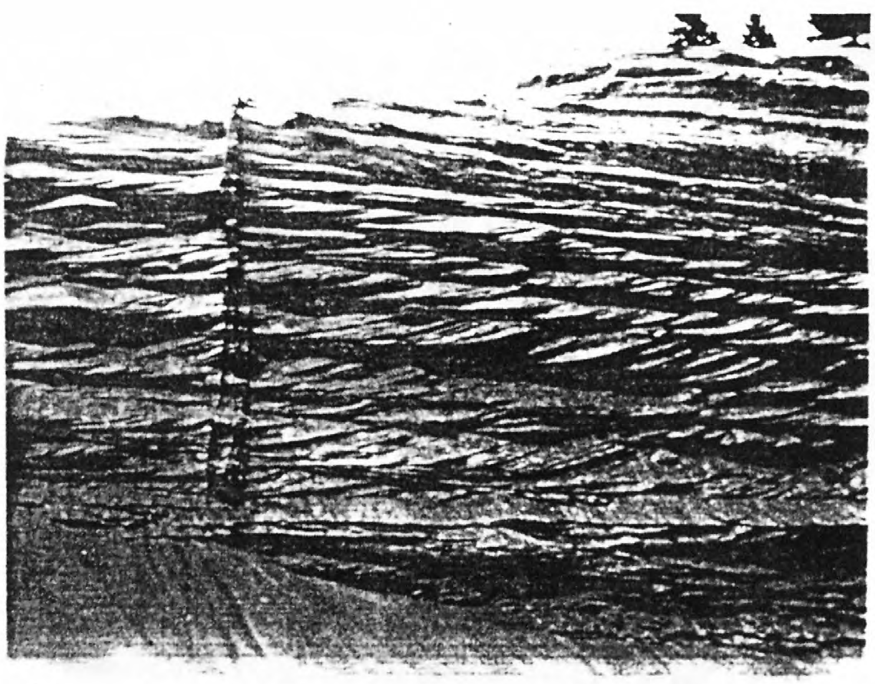


Figure 24 Large-scale tabular cross-beds in the Santa Margarita Sandstone in the, Santa Cruz Aggregate Quarry directly above figure 23.

Figure 27. Bioturbated sediment in the Santa Margarita Sandstone located directly above the cross-beds in figure 25.

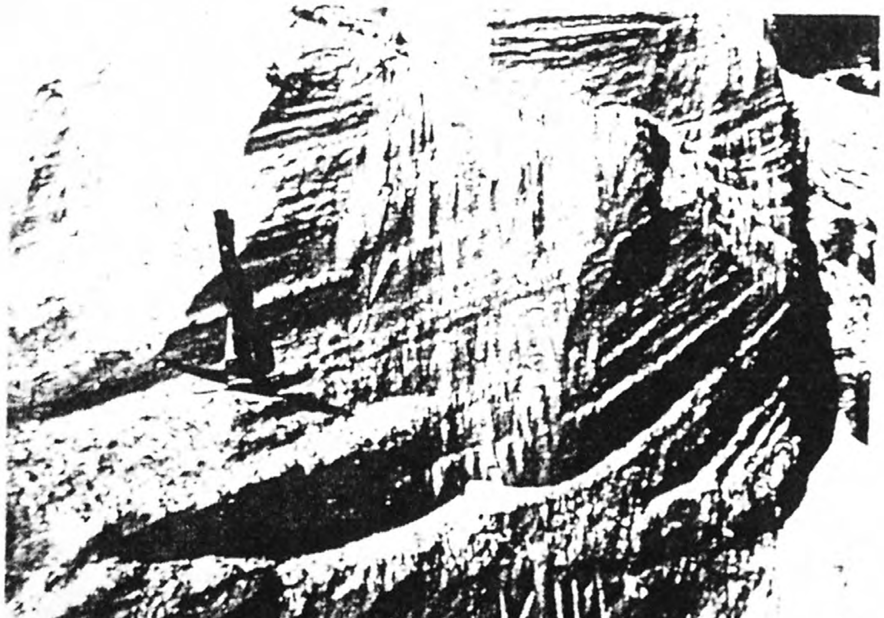


Figure 26. Close-up of a tabular cross-bed in the Santa Margarita Sandstone containing bioturbated foresets.

STOP 2

We will examine lateral equivalents of strata observed in the upper part of the section in the Santa Cruz Aggregate Quarry. Again, unidirectional large-scale tabular cross-bedded sets, bioturbated pebble lags as well as trough cross-strata and leached echinoid lags (in the upper-most part of the cliff exposures) are the dominante features in this quarry.

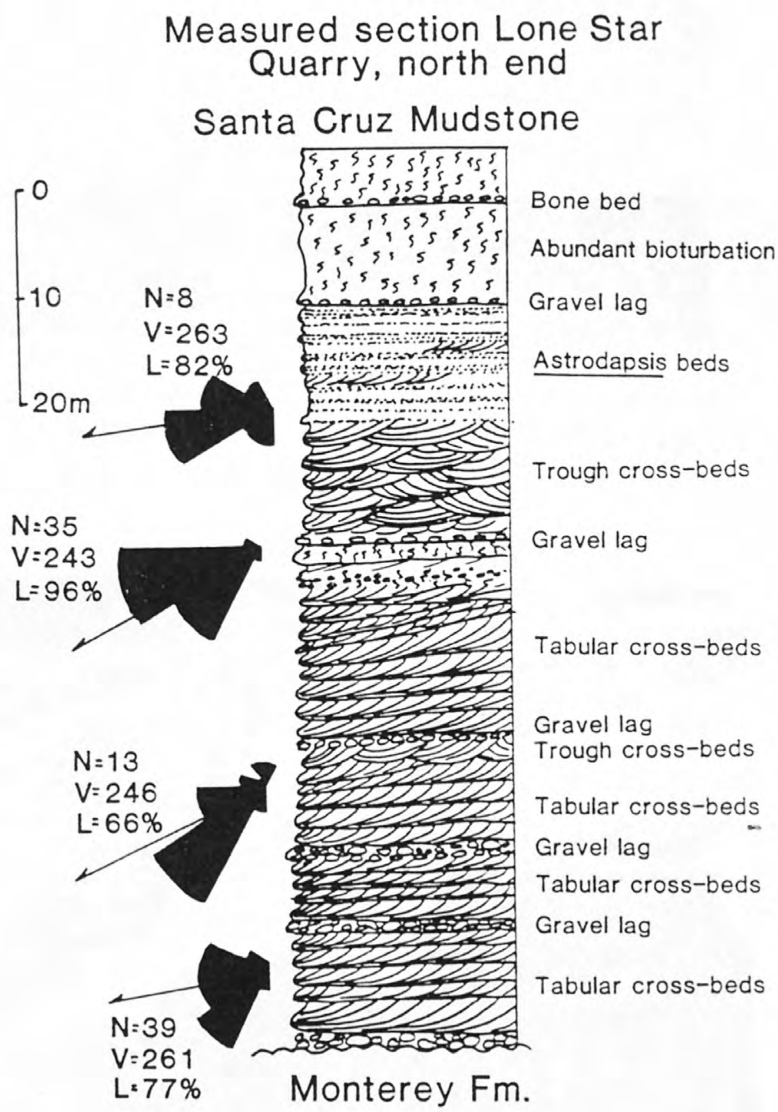


Figure 28. Measured section and paleocurrent trends in the Santa Margarita Sandstone in Lone Star Quarry.

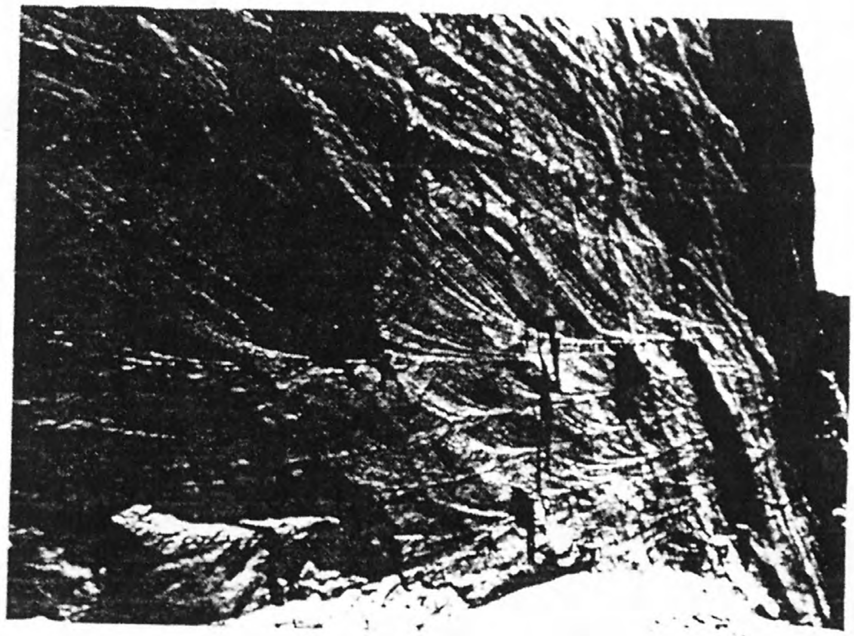


Figure 30. Large-scale unidirectional cross-bedded sets in the Santa Margarita Sandstone in the Lone Star Quarry.

Figure 29. Large-scale and giant tabular cross-beds in the lower part of the Santa Margarita Sandstone in the Lone Star Quarry.

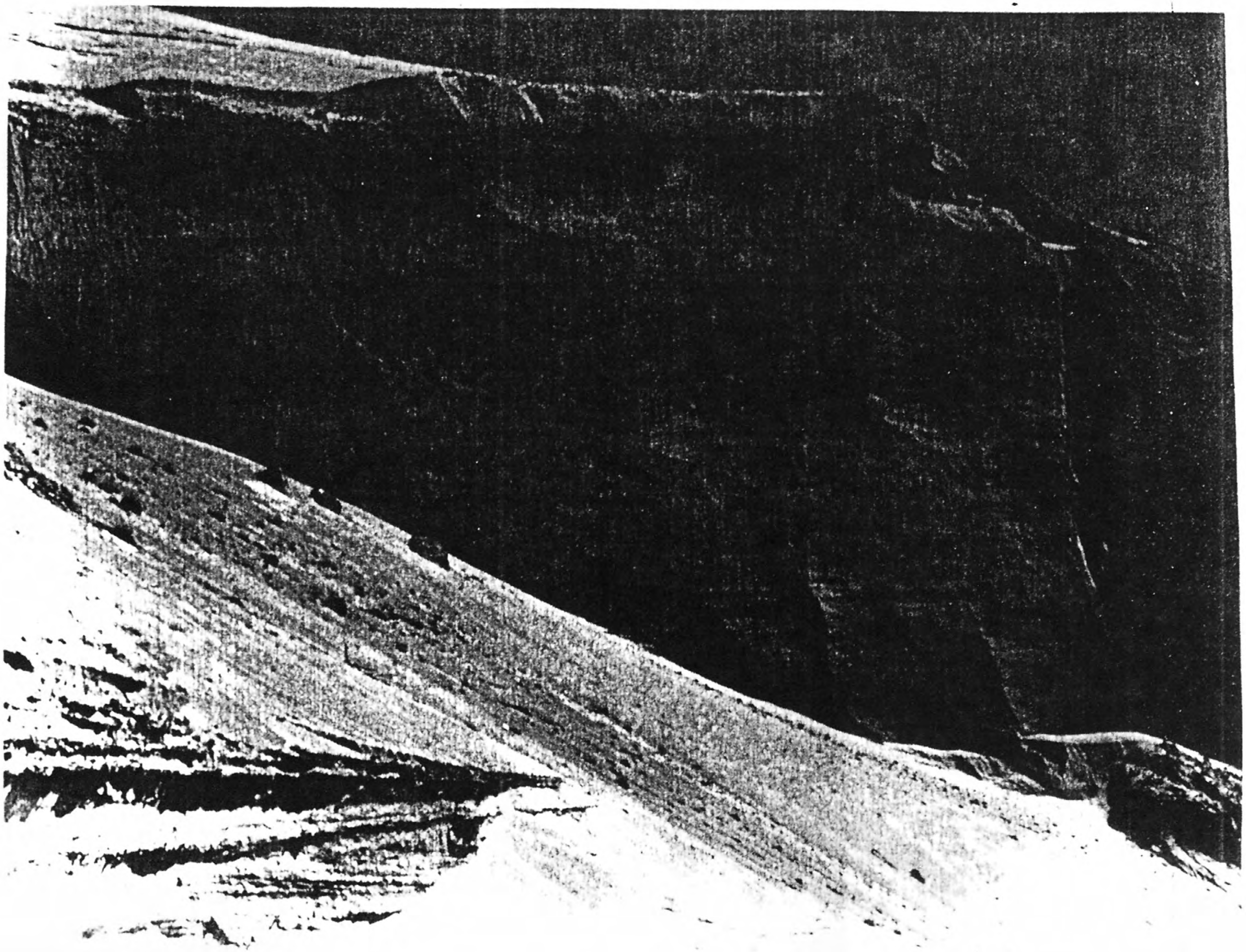


Figure 31. Large-scale cross-bedded sets in the Santa Margarita Sandstone in the Lone Star Quarry. The upper sets

STOP 3

Most of the depositional stages of the Santa Margarita Sandstone can be observed within this quarry. We will first view the basal large-scale tabular cross-bedded sets at the southeast end of the quarry before proceeding up the cliff exposures. Extensive biological communities bounded by gravel lag deposits represent the lateral equivalents of the cross-bedded strata visited at stop 2 and in the upper part of stop 1. Finally, depending on the temperature, we will view the giant tabular cross-strata in the upper part of the quarry. Figures 28 to 39 represent the section and outcrop exposures at this stop.

STOP 3

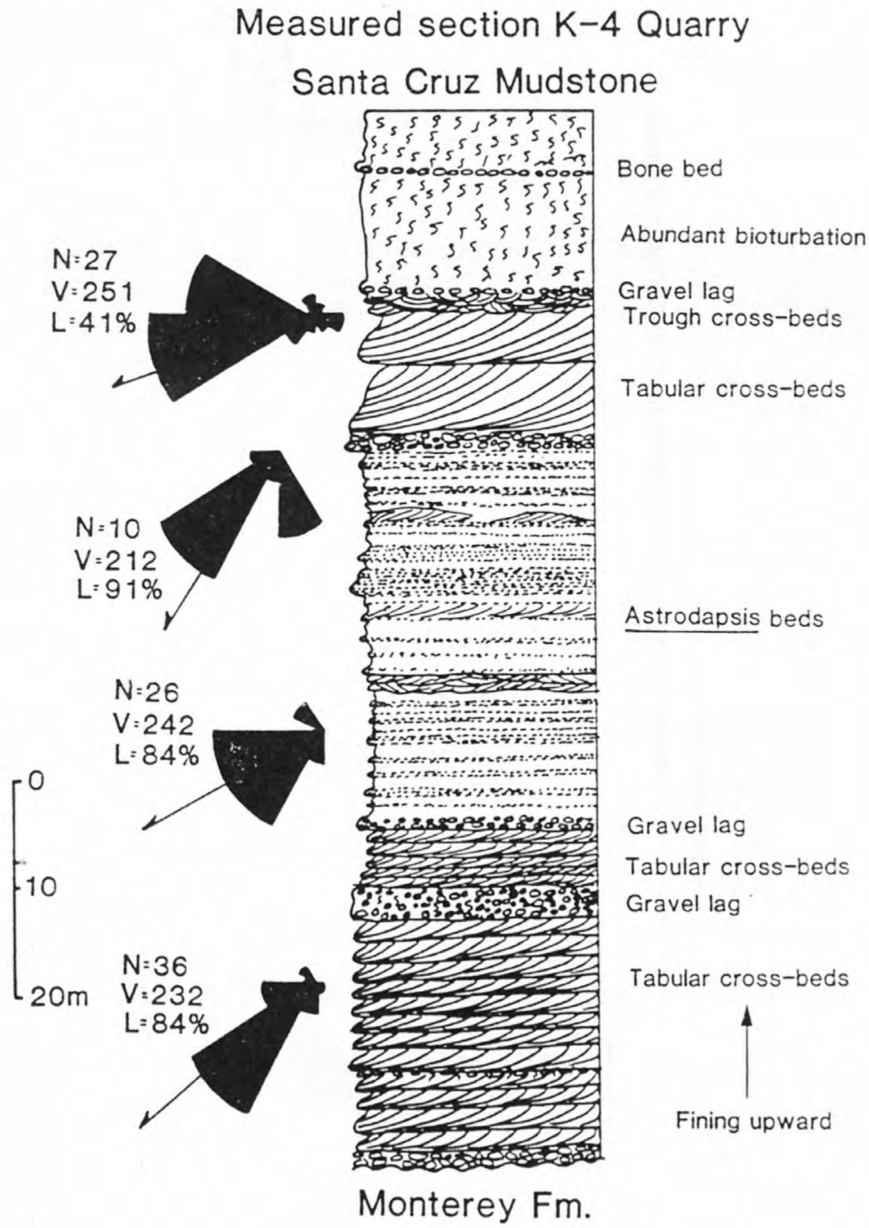


Figure 32. Measured section and paleocurrent trends in the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

STOP 3

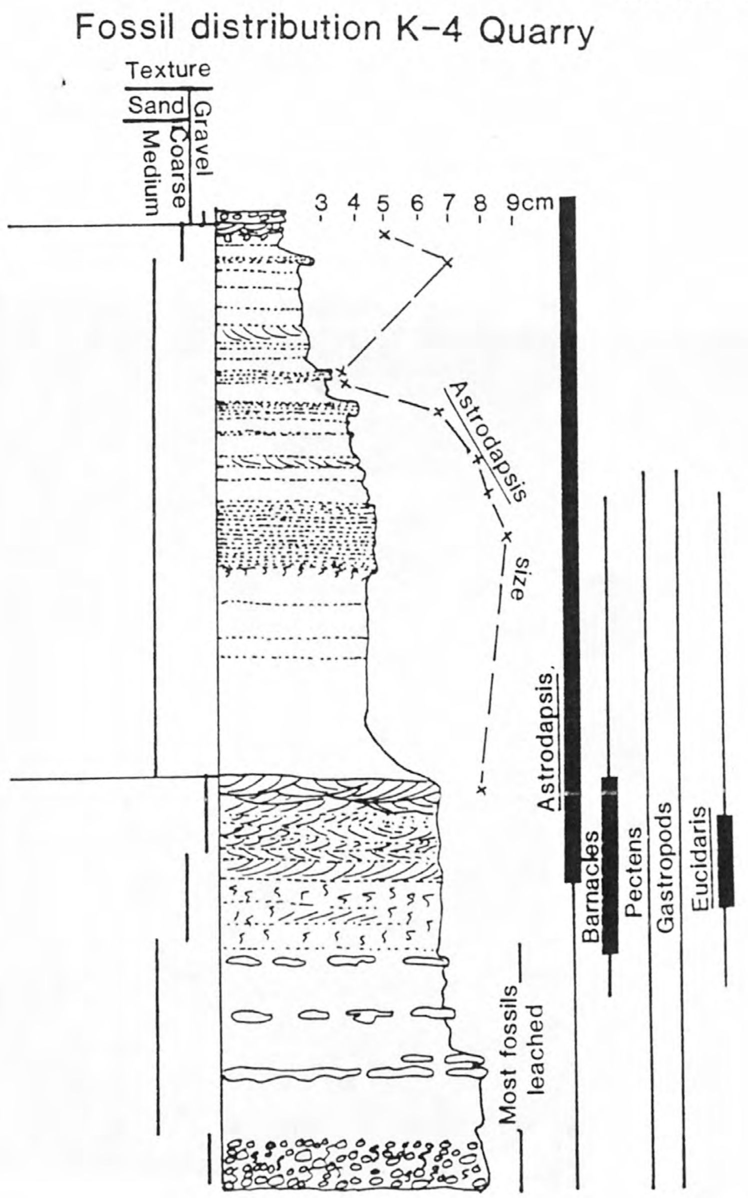


Figure 33. Texture and main faunal composition of the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

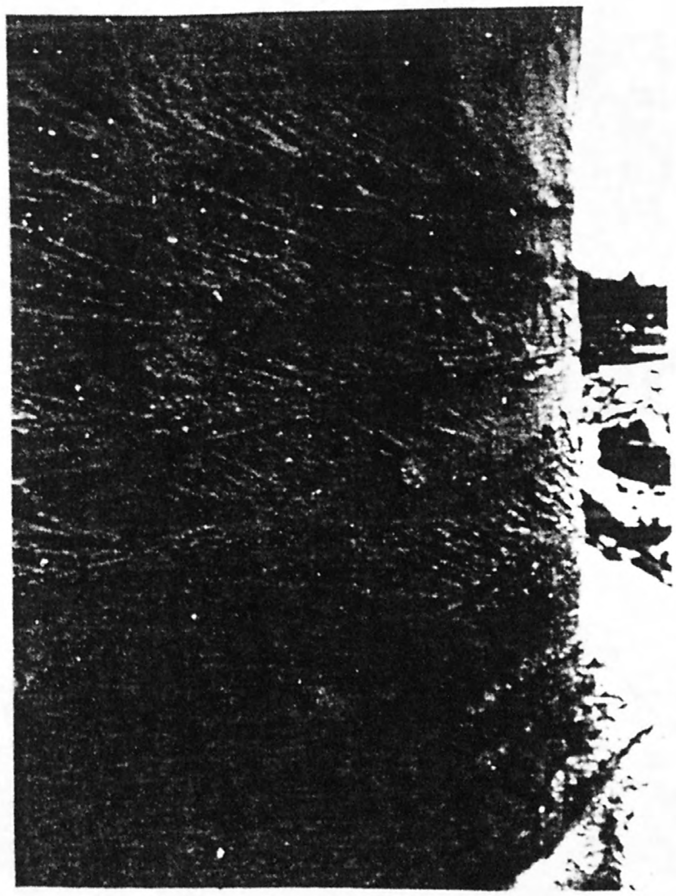


Figure 34. Large-scale cross-bedded sets in the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

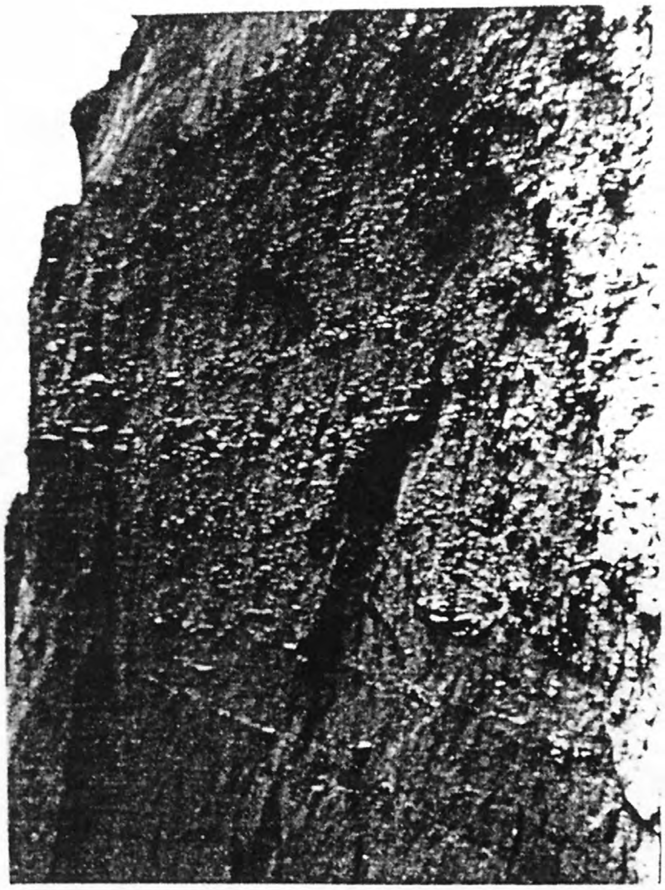


Figure 36. Echinoid lags (bed is 2 m thick) in the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

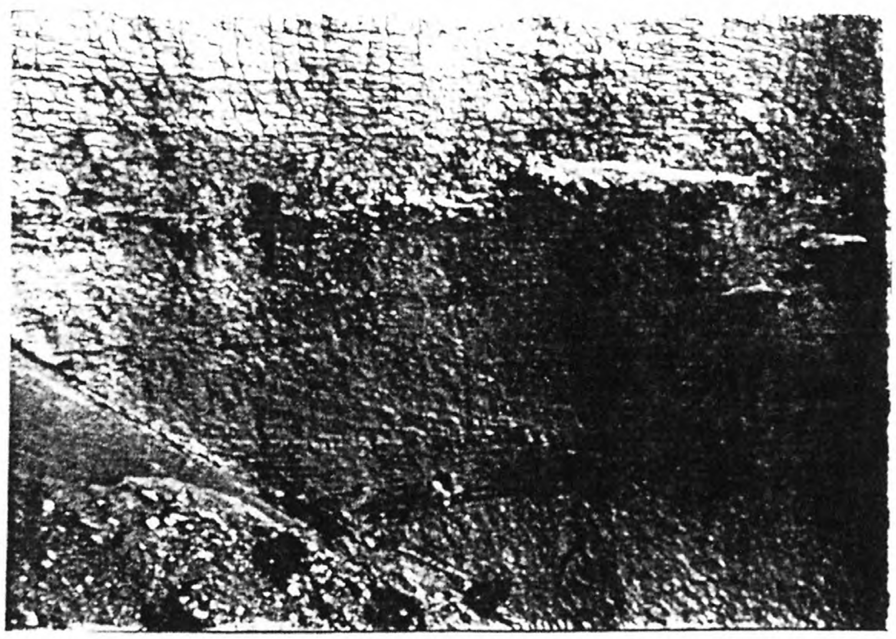


Figure 35. Large-scale cross-bedded sets containing echinoid lags in the bottom set beds in the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

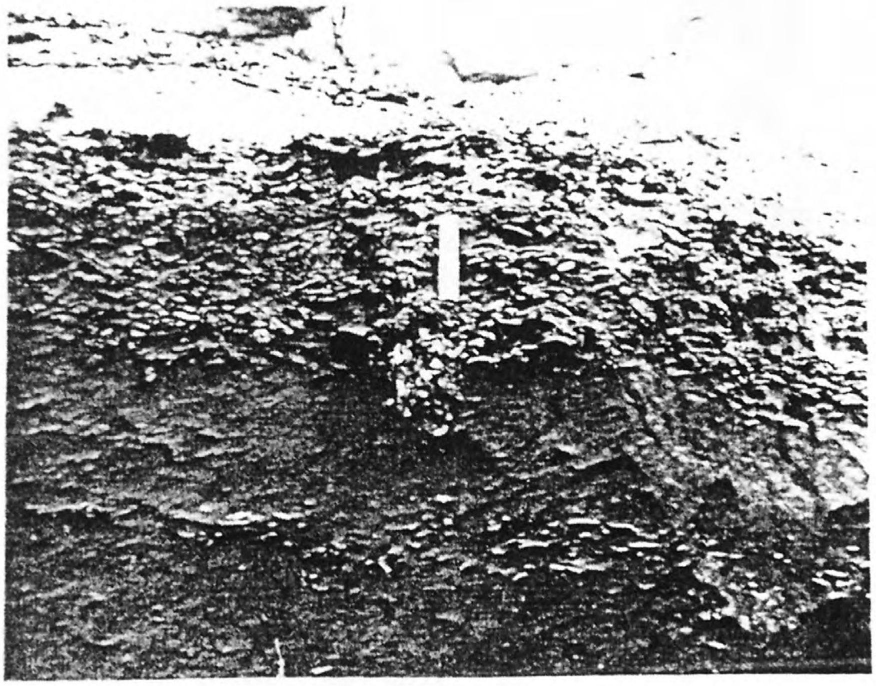


Figure 37. Bioturbated echinoid lags in the Santa Margarita Sandstone in the Kaiser K-4 Quarry. The scale is 15 cm.

Figure 39. Small-scale trough cross-beds in the Santa Margarita Sandstone overlie the giant cross-beds in the Kaiser K-4 Quarry.

Figure 38. Giant tabular cross-beds above the echinoid lags in the Santa Margarita Sandstone in the Kaiser K-4 Quarry.

STOP 4

Be careful on cliffs and on landslide. Unidirectional southwest-directed large-scale cross-beds, abundant bioturbation and a fining upward texture and over 30 m of petroleum saturated sandstone will be examined at this stop. Figures 40 to 42 represent the section and the tar-saturated sandstone at this stop.

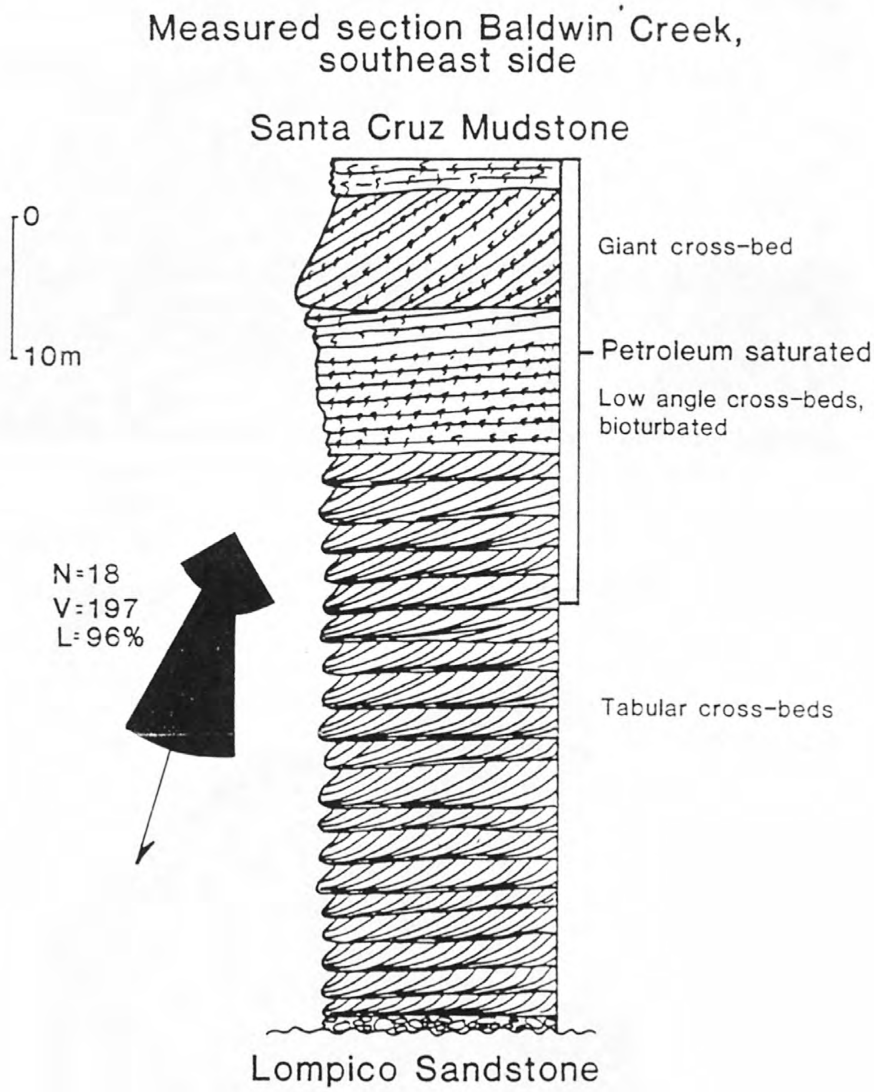


Figure 40. Measured section and paleocurrent trend in the Santa Margarita Sandstone on the southeast side of Baldwin Creek. The upper 30 m of the cross-bedded sands are petroleum saturated.

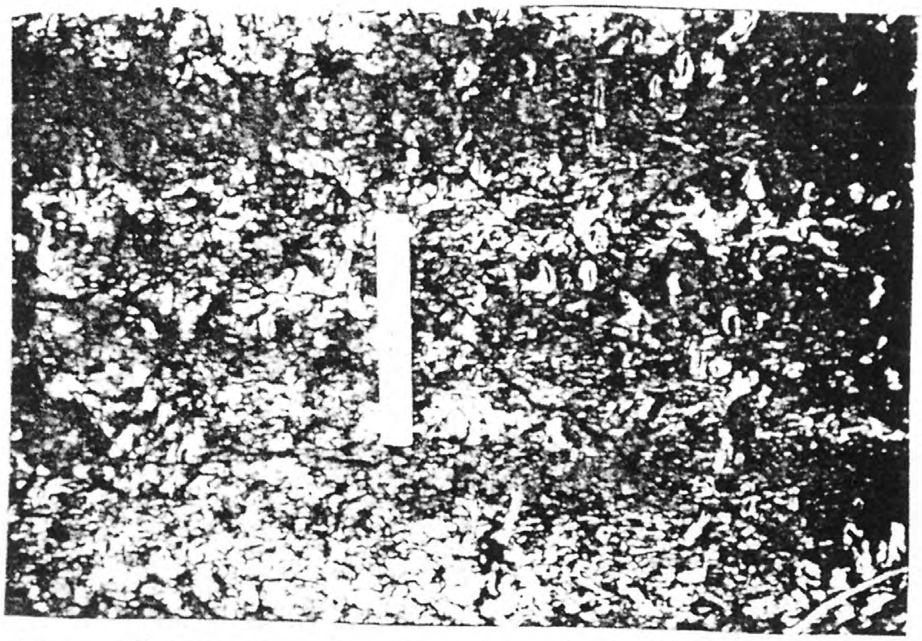
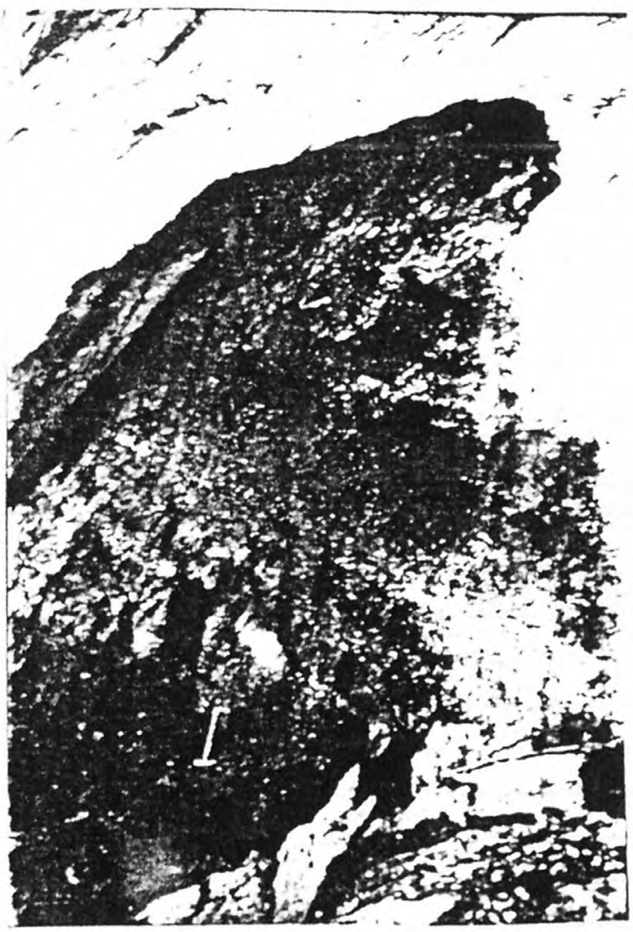


Figure 42. Close-up of tar saturated bioturbated foreset beds in giant cross-bed in the Santa Margarita Sandstone on the southeast side of Baldwin Creek.



5425

Figure 41. Giant (7.6 m thick) tar saturated cross-bed near the upper part of the Santa Margarita Sandstone on the southeast side Baldwin Creek.