CALIFORNIA STATE UNIVERSITY, NORTHRIDGE

DEPOSITIONAL ENVIRONMENTS OF THE SIMMLER FORMATION IN SOUTHERN CUYAMA VALLEY, SANTA BARBARA AND VENTURA COUNTIES, CALIFORNIA

A thesis submitted in partial satisfaction of the requirements for the degree of Master of Science in

Geology

by

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California State University, Northridge

DEDICATION

To my loving and supportive

Judy Elaine

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ABSTRACT

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SIMMLER FORMATION IN SOUTHERN CUYAMA VALLEY,
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The Simmler Formation (Oligocene (?)-early Miocene) of the southern Cuyama Valley area in Santa Barbara and Ventura Counties, California, is a nonmarine sequence overlying pre-Oligocene sedimentary and igneous rocks and underlying the Vaqueros Formation. The Simmler is exposed in a narrow, folded strip along the northern side of the Ozena fault. Eight members, herein informally designated A through H, are recognized.

Rocks of Members A and B consist of southeastern fluvial conglomerate, sandstone, and mudstone and northwestern sabkha claystone and mudstone deposits. The fluvial deposits originated from low-sinuosity meandering streams which in turn flowed into locally evaporative sabkha areas. A relatively greater abundance of gypsum in

Member B may indicate that more permanent evaporative depressions characterized the Member B depositional basin. Rocks of Member C consist of a lower sand and gravel of traction-flow origin and an upper muddy conglomerate of debris-flow origin, all of which probably formed on alluvial fans. Rocks of Member D are massive, boulder conglomerates which accumulated as a narrow band of talus along the Ozena-fault-controlled northeastern flank of the San Rafael uplift. Member E, consisting of locally gypsiferous, interbedded conglomeratic sandstone and mudstone, originated from low-sinuosity meandering streams like those of Members A and B. The interbedded, coarse-grained, conglomeratic sandstone and siltstone rocks of Member F were deposited from low-sinuosity meandering streams. Conglomeratic sandstone beds of lenticular Member G accumulated as subaqueous, delta distributary channels within a delta-front environment. Mudstone of Member H, with a few interbeds of sandstone and limestone, formed in interdistributary bays and lagoons within a delta environment.

Paleocurrent data indicates a northwest direction of sediment transport. Pebbles from Members A, B, and C are predominantly granitic/metamorphic types and reflect a crystalline source terrain to the southwest, probably in the Mutau-Piru Creek area. Clasts from Members D, E, F, and G are predominantly sandstone and siltstone and reflect a sedimentary source terrain south of the Ozena fault.

Three distinct phases of deposition are indicated. Time I, represented by Members A and B and parts of Members C, D, and F, was a time of fluvial in-filling of the area. Northwestward-prograding alluvial fan/wadi stream/sabkha deposits, derived from a granitic/metamorphic source terrain southeast of the basin, dominated, while less important, northward-prograding, low-sinuosity meandering streams were derived from a sedimentary source terrain south of the basin. Time II, represented by Member E, and parts of C, D, and F, was also a time of fluvial in-filling, but during this period northward-prograding streams from a sedimentary source area south of the Ozena fault dominated over those from the granitic/metamorphic terrain to the southeast. Rocks of Time III, represented by Members G and H, indicate that a perennial river, presumably flowing through the Cuyama Badlands area, swept around the west end of the Blue Rock uplift to deposit a river-dominated delta in which subaqueous delta channels of Member G interfingered with interdistributary bay deposits of Member H.

INTRODUCTION

LOCATION, BACKGROUND, AND PURPOSE

This report describes the Oligocene (?) and early Miocene nonmarine sedimentary rocks of the Simmler Formation which crop out and were mapped along the southeastern edge of the Cuyama Valley in the vicinity of Santa Barbara Canyon, northeastern Santa Barbara County and northwestern Ventura County, California (Fig. 1).

The objectives of this report are to present a detailed geologic map of an area that has never been mapped in detail before, to make paleoenvironmental and paleocurrent interpretations of the various lithofacies of the nonmarine Simmler Formation, to show the lithostratigraphic relationships of the Simmler with correlative marine rocks, and to interpret the Oligocene (?) and early Miocene paleogeography of the area.

Discovery of the Russell Ranch oil field in 1948 and the South Cuyama oil field in 1949, located about 25 and 16 km, respectively, northwest of the area described in this report, brought exploration activity to the surrounding region. During this exploration period, which extended through the 1950's and into the mid 1960's, one wildcat well was drilled along the northern margin of the Sierra Madre Mountains within the area mapped for this report. Also at this time, several oil companies made geologic maps

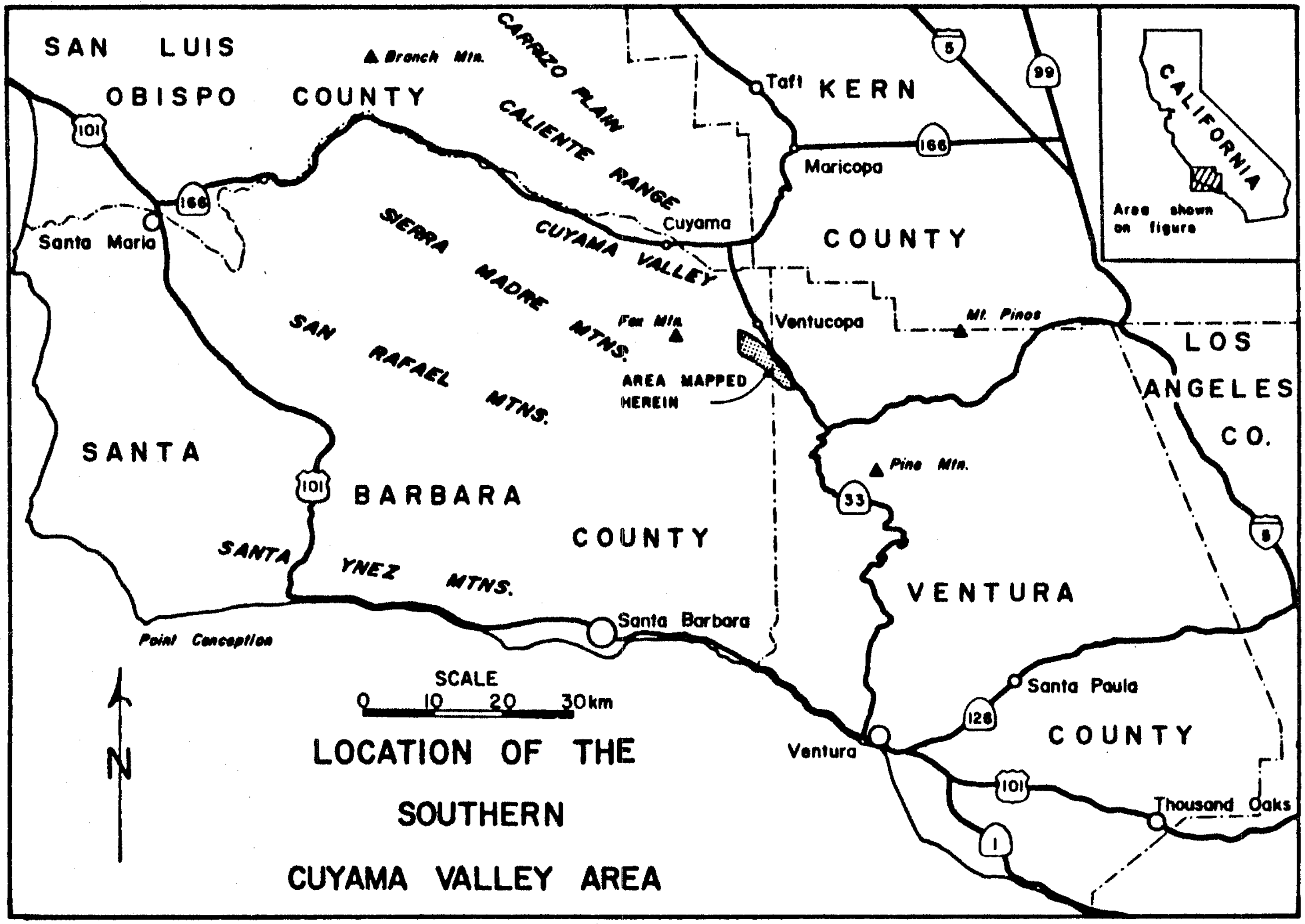

Figure 1. Location of the southern Cuyama Valley area.

of parts of the area, but none of these has been published.

In contrast to this lack of published geologic information, several detailed geologic maps are available for regions which surround the area mapped, such as the Fox Mountain quadrangle (Vedder, 1968), the Caliente Range (Hill and others, 1958; Vedder and Repenning, 1965), the Cuyama and New Cuyama quadrangles (Vedder and Repenning, 1975), the Mono Creek-Pine Mountain area (Vedder and others, 1973), and the Santa Ynez Mountains (Dibblee, 1950 and 1966). Oligocene (?) and early Miocene nonmarine rock units in these areas are lithologically similar to each other, but due to the scarcity of fossils they are difficult to correlate.

GEOGRAPHIC SETTING

Figures 2 and 3 show the main geographic features of the area which consist of moderately high mountains that are drained by broad, flat-bottomed, sub-parallel canyons that trend to the northeast. Most canyons are between 70 and 170 m (200 and 500 ft) in depth and have gentle to moderately steep slopes. The highest point, located along the southwestern edge of the area shown on Plate 1, is approximately 1,300 m (4,000 ft) elevation, and the lowest point, along the Cuyama River, is 1,000 m (3,000 ft) elevation.

The climate is semiarid Mediterranean. Rainfall, mostly in the winter months, averages 15 to 50 cm (5 to

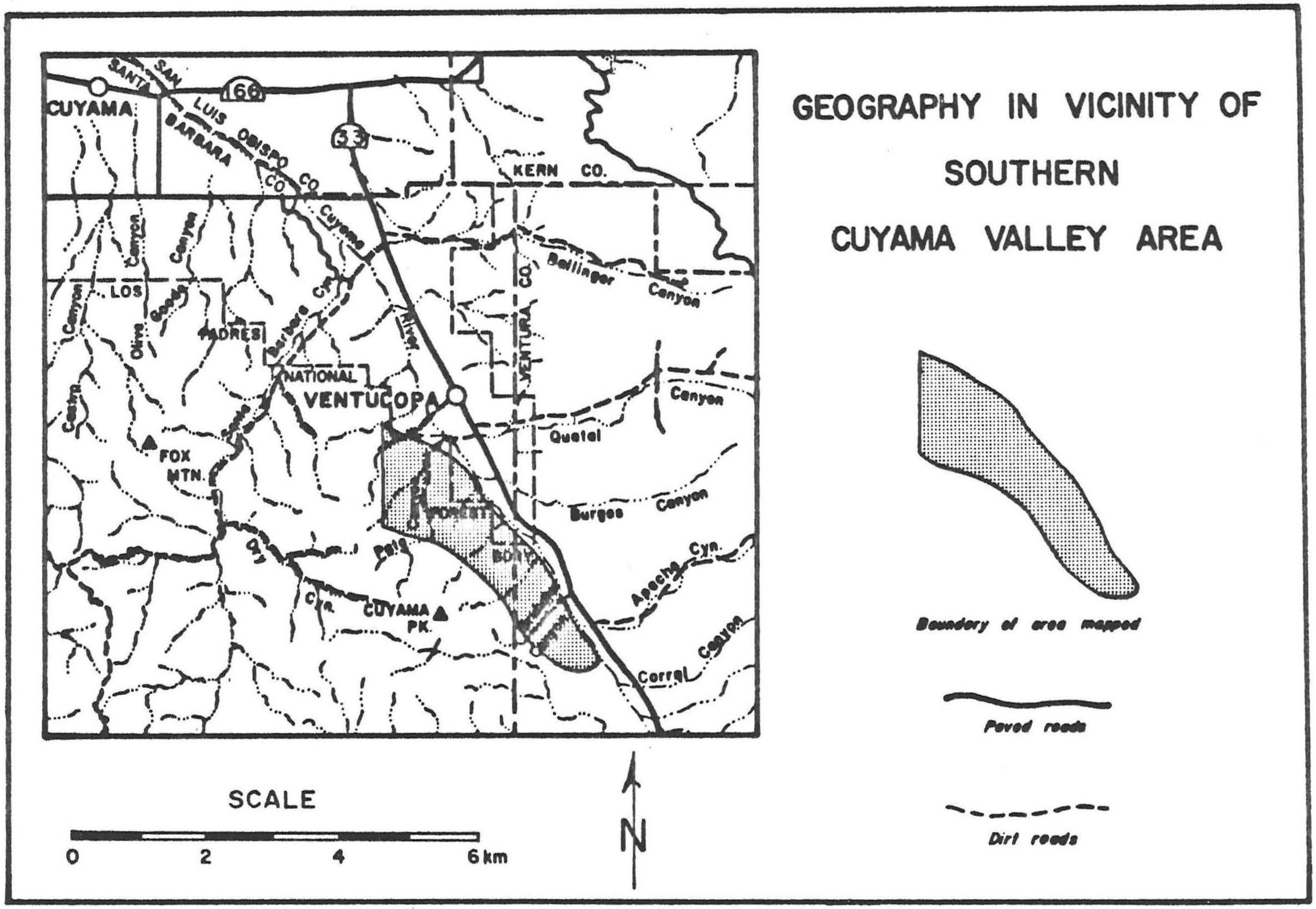

Figure 2. Geography in vicinity of southern Cuyama Valley area.

Figure 3. Air view of the southern Cuyama Valley area between Santa Barbara Canyon and Pato Canyon. Note the topographic break along the Ozena fault.


Santa Barbara
Ozena Fault
Pato Canyon

20 in) per year in the higher mountains. Winter daytime temperatures are about 15° to 20°C (55° to 65°F), whereas summer temperatures reach 30° to 35°C (85° to 95°F) (Elford and others, 1965, p. 17, 23-24, 28).

Chaparral and grassland are the two dominant vegetation types. Trees present include oak, juniper, sycamore, and in the higher elevations, a few pines. Vegetation is moderately influenced by lithology. Short grasses grow on the terrace deposits, in the alluvial valleys, and on densely soil-covered slopes of Member B of the Simmler Formation. Chaparral, with scattered yucca, is common throughout the other members of the Simmler. Southwest of the mapped area in the area underlain by Eocene rocks, vegetation consists of a dense growth of chaparral and large trees.

There is only sparse human habitation within the area studied. Most of the area mapped is within Los Padres National Forest and cattle grazing is common. Scattered farms and cattle ranches are on private land adjacent to the National Forest. Abandoned equipment and prospect holes, attesting to the existence of several now abandoned gypsum mines, were noted during the course of field work. Information furnished by local ranchers and petroglyphs observed in Santa Barbara Canyon indicate some Indian habitation in the past.

Some of the unnamed canyons and hills within the study area have informal designations which are used by the local residents. Where known, these local informal geographic names are shown on the geologic map (Pl. 1), on Figure 4, and are referred to in the text in order to better locate significant geologic features.

ACCESSIBILITY

All access roads (Fig. 2) are controlled by locked gates and private property must be crossed to get to them. Keys may be obtained from individual ranch owners.

The area is open year-round, but following heavy rain storms, Cuyama River is impassable. During dry weather, most of the access roads may be negotiated by a vehicle having adequate ground clearance, although some roads are largely impassable without the use of four-wheel drive.

PREVIOUS WORK

Thomas Antisell (1857, p. 53-57), who traveled with one of the Pacific Railroad survey parties, was the first geologist to visit the Cuyama Valley. Antisell made only very general statements regarding geologic structure and stratigraphy. Other reconnaissance work was done by Fairbanks (1894) and Lawson (1908).

The first geologic mapping of the area was done by English (1916) who mapped the Simmler Formation as the non-marine Pato Red Member of the Vaqueros Formation. He (English, 1916, p. 191) was concerned chiefly with the

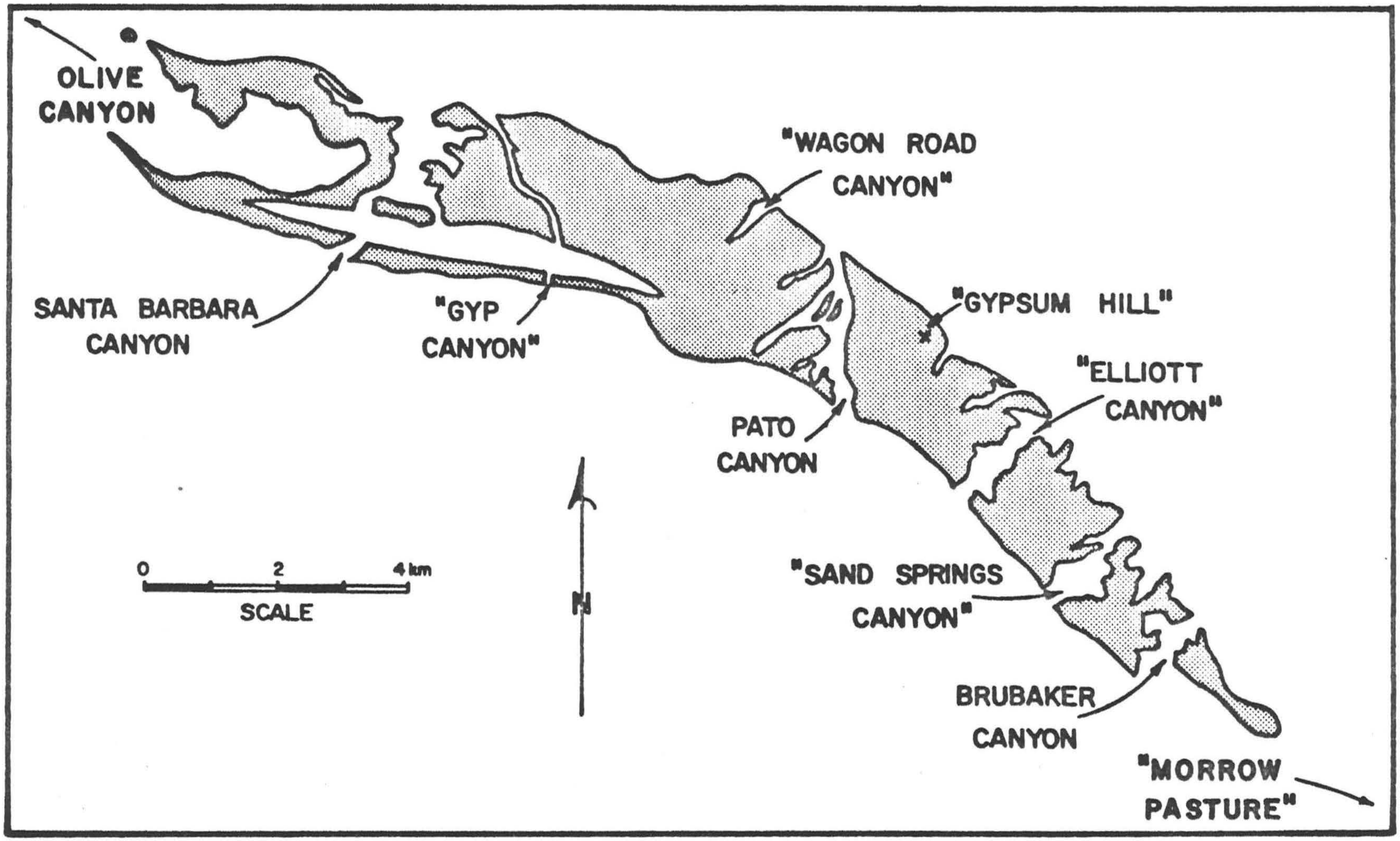

Figure 4. Present outcrops of the Simmler Formation in southern Cuyama Valley in the vicinity of Santa Barbara Canyon. Local informal geographic names are shown in quotation marks.

prospects of finding oil in the area, about which he stated "the chance for the development of a commercially successful oil field in the Cuyama Valley may be regarded as poor." Two later reports by Eaton (1939 and 1943) supported this conclusion regarding local oil possibilities. Eaton (1943, p. 453), however, recognized the value of the well-exposed marine-nonmarine interdigitation in the Caliente Range and recommended that other "workers spend at least several weeks in the district before arriving at conclusions on regional Miocene problems of the State."

The first attempt at paleogeographic reconstruction in the area was made by Eaton and others (1941). These authors described part of the abundant fauna of the region north of the present study and made small-scale paleogeographic maps.

A report by Hill and others (1958) contains a small-scale geologic map (1 in equals 4.25 mi) of most of the area mapped herein. Other small-scale maps which include the area are in Dibblee (1952, 1 in equals 5.3 mi), Schwade (1954, 1 in equals 3.1 mi), Dibblee (1972, 1 in equals 1 mi), and Dibblee (1973a, 1 in equals 2 mi). Upson and Worts (1951) discuss ground water in the Cuyama Valley and include a geologic map at a scale of 1 in equals 1 mi.

Three large-scale maps (1 in equals 0.25 mi) by Hart (1959, unpublished), Frakes (1959, unpublished), and Exum (1957, unpublished) cover the area of this study. Some of their strike and dip measurements and geologic contacts are included on the map presented in this thesis (Pl. 1). A geologic map (1 in equals 0.4 mi) by Fritsche (1969, unpublished) covers the western portion of this report.

A detailed study of the sedimentology of the Simmler and Vaqueros Formations in the Caliente Range was performed by Bartow (1974 and 1978).

The first organized vertebrate paleontological study of the Cuyama Valley area was made by Gazin (1930). His examination of mammalian remains from the Cuyama Badlands led the way for further studies by VanderHoof (1939), Stock (1947), and James (1963).

FIELD WORK

Field work began in summer, 1976, and was carried on intermittently through winter, 1976. Additional mapping and field checking were done during spring and summer, 1979. A total of about 55 days was spent in the field.

Field work, in addition to geologic mapping and field checking of previous geologic maps, included examination and measurement of vertical stratigraphic sequences, examination of primary sedimentary structures, measurement of paleocurrent data, pebble counts, and sample collection for thin-section analysis.

Geologic mapping was done on aerial photographs taken by the United States Forest Service in 1942 at a scale of approximately 1:15,840. Geology was then transferred to a topographic base map enlarged to a scale of 1:12,000 from the Cuyama Peak and Rancho Nuevo Creek quadrangles published by the United States Geological Survey. Primary sedimentary structures studied for this report include cross bedding, current lineations, pebble imbrications, channel orientations, and ripple marks. In all cases, the directional properties were restored to their original dip by the use of stereonet rotation methods (Potter and Pettijohn, 1977; Ragan, 1968). Pebble counts, consisting of counting 100 clasts in an approximately one square-meter area were performed in conglomeratic units at selected localities throughout the study area. Data on the largest clast size, sorting, and angularity of the clasts were also gathered. Representative lithologic samples were collected and analyzed with the aid of a petrographic microscope. The descriptions and rock names used herein are based on both microscopic and hand specimen petrographic analysis. Four samples were collected and prepared for pollen analysis.

ACKNOWLEDGEMENTS

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LITHOLOGY AND DEPOSITIONAL ENVIRONMENTS

INTRODUCTION

In order to provide precision and understanding, the following standardized terminology is used. Nomenclature and definitions for alluvial fan environments are from Reineck and Singh (1975, p. 253-263), with adaptations and additional definitions from Hooke (1967), Bull (1972), Spearing (1974), Collinson (1978a), and Rust (1979). Classification for deltaic and shallow marine environments is from Coleman and Gagliano (1965), Galloway (1975), Reineck and Singh (1975, p. 264-279), Coleman (1976), and Miall (1979). Nomenclature for sabkha environments is from Friedman (1966), Kinsman (1969), Ameil and Friedman (1971), Collinson (1978c), and Friedman and Sanders (1978).

Study of the fluvial environment has received much attention in the geological literature since the end of the Second World War (Miall, 1978a). Our knowledge of fluvial sedimentary processes has come from an examination of modern fluvial environments and their deposits. Up to the present our study of fluvial systems has been limited to those areas which are relatively easily accessible and to those rivers whose size lent themselves readily to investigation (Miall, 1978a). Based upon modern examples, two "end-member" river types, braided and meandering, have emerged in the geological literature (Miall, 1977).

Meandering rivers generally are considered to form deposits primarily by the action of lateral accretion on point bars within the concave sides of meanders, along with a lesser amount of vertical accretion on flood plains, due to overbank flooding (Miall, 1977). Meandering rivers are ideally of high sinuosity (sinuosity is the ratio of a channel length to the length of the meander-belt axis) and fining-upward cycles typify their deposits (Miall, 1977; Rust, 1978a). Early reports by Allen (1965a, 1965b, and 1970) provide descriptions and interpretations of meandering sequences, and Jackson (1978) provides the most recent critical summary and evaluation of research on the meandering river environment.

The study of braided rivers has received less attention in the literature and prior to work by Miall (1977 and 1978b) no comprehensive model of braided-river sedimentation had been developed (Miall, 1977). It is generally agreed that braided rivers are characterized by high width/depth ratios, steep slopes, and low sinuosities.

An analysis of the sedimentary structures and vertical sequences of both meandering and braided rivers shows that these two "end-members" are not always readily distinguished (Miall, 1977). Several authors in fact (Allen, 1965b and 1970; Moody-Stuart, 1966; Schumm, 1968 and 1977; McGowan and Garner, 1970; Shelton and Noble, 1974; Collinson, 1978d; Friedman and Sanders, 1978; and Schwartz,

1978) have expressed their opinions in the geological literature that, assuming meandering and braided rivers are end-members, a continum of river types exists between them. Some authors (Allen, 1965b; Moody-Stuart, 1966; McGowan and Garner, 1970; Shelton and Noble, 1974; Collinson, 1978d; and Friedman and Sanders, 1978) describe deposits of "low-sinuosity meandering rivers" which they believe to be intermediate between braided and strongly meandering.

Varying emphasis has been placed on one or more of the sedimentological aspects of these models to allow their application to paleoenvironmental interpretation. Elements considered by many of these authors to be characteristic of either braided, meandering, or some type in between, have been demonstrated to be common to more than one environment (Jackson, 1978), thus compounding the difficulties of paleoenvironmental interpretation. The potential for preservation of one sedimentological aspect over another in the geologic record is also of significance in the interpretation of ancient sequences and this problem has not been extensively discussed in the literature (Jackson, 1978).

In spite of the difficulties of classification and interpretation, several preliminary fluvial facies assemblege models have recently emerged in the literature (Miall, 1977 and 1978b; Jackson, 1978; and Rust, 1978b). Although these preliminary facies assembleges are not a universal panacea for sorting out all of the complexities of fluvial deposits, considering the state of our current knowledge, the author herein chooses to utilize the classifications of Miall (1977 and 1978b), Jackson (1978), and Rust (1978b) to facilitate paleoenvironmental interpretation of the fluvial aspects of the Simmler Formation within the study area. As our knowledge of the fluvial system increases, more accurate environmental models may emerge and perhaps refinements or revisions of the paleoenvironments postulated in this paper will be necessary.

Descriptive colors and codes are those of Goddard (1970). Roundness of clastic particles is based on the scale of Powers (1953). Descriptive terminology for bedding, cross bedding, and ripple bedding is based on classifications from Reineck and Singh (1975, p. 24-47 and 82-113) and Jacob (1973). Grain size (Wentworth, 1922), roundness, sorting, and sphericity were determined by thin-section analysis and supplemented by hand sample identification. Recognition and identification of sedimentary structures was aided by the use of Pettijohn and Potter (1964) and Conybeare and Crook (1968).

NOMENCLATURE

The rock units cropping out in the vicinity of Santa Barbara Canyon (Fig. 4) are considered herein to belong to the middle Tertiary Simmler Formation. Schwade and Dibblee

(1952) made the first informal reference to the Simmler Formation in their field trip road log through the Cuyama Valley area. The first formal use of the name Simmler was made by Hill and others (1958) for the sequence of red to green and gray continental conglomerate, sandstone, and siltstone beds that unconformably overlie the Upper Cretaceous-lower Tertiary marine sequence of the Caliente and La Panza Ranges and Cuyama Valley area. Subsequently, the name was formally adopted by the U. S. Geological Survey (Dibblee, 1973b).

In the area southeast of Santa Barbara Canyon, bright red sandstone and conglomerate, and gray and red clay rocks were mapped as the Pato Red Member of the Vaqueros Formation by English (1916) and as the Caliente Formation by Exum (1957), Hill and others (1958), Frakes (1959), Hart (1959), Vedder (1968), Fritsche (1969), Dibblee (1972, 1973a, and 1973b), and Woodburne (1975). The first worker to recognize that the red beds southwest of the Cuyama River in the area of Santa Barbara Canyon did not resemble the Caliente Formation of Hill and others (1958) was James (1963), who suggested that the Pato Red Member of English (1916) should be considered a separate formation from the Caliente. More recently, this view has been shared by Vedder and Brown (1968) and Bartow (1974) who suggested that these rocks be considered a part of the Simmler Formation. The writer shares this opinion and herein adopts the use of the name Simmler Formation for the Oligocene (?) and early Miocene nonmarine rocks exposed in the Santa Barbara Canyon area. This designation is due primarily to similarities in lithologic character and stratigraphic position between the rocks exposed here and those at the Simmler type locality.

STRATIGRAPHIC SETTING

In Santa Barbara Canyon, the Simmler rests unconformably on unnamed sedimentary rocks of Eocene age (Vedder, 1968). To the southeast, in the Cuyama Badlands, Simmler conglomerate is unconformable on granitic basement rocks (Vedder and others, 1973). In most places, however, the contact relationships with pre-Simmler rocks are obscured by faulting.

The overlying Painted Rock Sandstone Member of the Vaqueros Formation rests conformably on the Simmler in Santa Barbara Canyon. Within the mapped area, the Quatal Formation seems to overlie Member C of the Simmler unconformably, but quality of the available exposures precludes an accurate determination of the relationships. In the Cuyama Badlands, the Quatal rests unconformably on rocks that are younger than the Simmler Formation (Vedder and others, 1973).

The true stratigraphic thickness of the Simmler Formation cannot be accurately determined for the study area due to the complexity of the geologic structure, the interfingering relationships of the various members, and the lack of laterally persistent stratigraphic horizons with which to correlate. Thinning and thickening of the individual members is common and they interfinger laterally as well as vertically with each other. The result is that an approximate thickness of 2,100 m represents an estimation of the aggregate thickness exposed.

MEMBERS OF THE SIMMLER FORMATION

In order to facilitate detailed geologic mapping and to provide an understanding of paleoenvironments, rocks of the Simmler Formation are herein divided informally into locally recognizable members. Informal member designations of Vedder (1968) are used where applicable, although different symbols have been assigned herein. In addition to the six informal members mapped by Vedder (1968) in the Fox Mountain quadrangle, two more informal members of the Simmler that are not exposed in that quadrangle are described herein. The eight members, designated A through H, from base up, are shown in Table 1 and Figure 5.

AGE AND CORRELATION

Fossil remains are rare in the Simmler Formation. Members G and H have yielded scattered shell fragments of insufficient quality to allow age designations. Some smooth-shelled ostracods (?) occur near the upper portion

Table 1. Capsule descriptions of the members of the Simmler Formation. Symbols in parentheses following member designations correspond to the map units of Vedder (1968).

MEMBER A - (southeastern portion) Pink to reddish-brown, medium to thin beds of coarse- to fine-grained, parallel- and cross-bedded, and in some places massive sandstone; thin-bedded mudstone; occasional lenses of granule to pebble conglomerate.

(northwestern portion) Alternating red and gray, gypsiferous, medium- to thin-bedded claystone and mudstone with occasional thin, fine-grained sandstone beds.

MEMBER B - (Tcg)(southeast of "Gypsum Hill") Gray to brown, thin- to thick-bedded, fine- to medium-grained, parallel and cross-bedded sandstone with occasional thin-bedded granule to cobble conglomerate lenses; thin- to medium-bedded mudstone; local grayish-yellow, bentonitic tuff; local channeling, scour marks, convoluted bedding, parting lineations, ripple marks, and mudcracks.

(northwest of "Gypsum Hill") Gray, indistinctly stratified, thin-bedded, gypsiferous claystone and mudstone; local thin-bedded, nodular limestone; local medium-bedded, nodular gypsum.

MEMBER C - (lower portion) Brown to gray, medium-bedded, well stratified, locally cross-laminated, medium- to coarse-grained sandstone; thick- to very thick-bedded, lenticular, pebble to boulder conglomerate.

(upper portion) Brown, very thick-bedded, cobble to boulder conglomerate; very thick-bedded, parallel-bedded, muddy sandstone; local red-brown, very thin-bedded, limonitic (?) layers.

MEMBER D - (Tcb) Light brown to gray, very thick-bedded, indistinctly stratified, boulder conglomerate and breccia.

MEMBER E - (Tcr) Reddish-brown, thick-bedded, cobble to boulder conglomerate lenses; thin- to medium-bedded, coarse- to fine-grained, locally gypsiferous sandstone, with abundant parallel bedding, cross bedding, graded bedding, channeling, and scour marks; local parting lineations, ripple marks, and mudcracks (?); thin- to medium-bedded, mudstone with burrows (?) and root (?) structures; white, thin-bedded, nodular gypsum, locally.

MEMBER F - (Tc) Red to reddish-brown, thin- to very thick-bedded and lenticular, pebble to boulder conglomerate and coarse- to medium-grained, cross-bedded and parallel-bedded sandstone; alternates with red-brown, thin- to thick-bedded, fine-grained sandstone and siltstone; sparse vertebrate fossils.

MEMBER G - (Tco) Light olive-brown, thick-bedded, lenticular, pebble to boulder conglomerate; thin- to medium-bedded, parallel- to cross-laminated, medium- to coarse-grained sandstone; occasional thin- to medium-bedded, mottled and disrupted mudstone with burrows; local marine fossil fragments.

MEMBER H - (Tcv) (Varigated red, green, and purple, medium- to very thick-bedded mudstone; thin- to medium-bedded, cross-laminated, flaser-bedded, and convoluted, fine- to medium-grained sandstone with parting lineations, desiccation cracks, and burrows; rare medium-bedded, conglomerate lenses; local nodular limestone; white, siliceous limestone marker bed at top of member; local beds of marine fossils.

Figure 5. Diagramatic representation of facies relationships for the Simmler Formation in the southern Cuyama Valley area. Members of the Simmler: Tsa=Member A, Tsb=Member B, Tsc=Member C, Tsd=Member D, Tse=Member E, Tsf=Member F, Tsg=Member G, Tsh=Member H. KT=Pre-Oligocene, undifferentiated, Tv=Vaqueros Formation, Ts=Saltos Shale Member of Monterey Shale, Tb=Branch Canyon Formation.

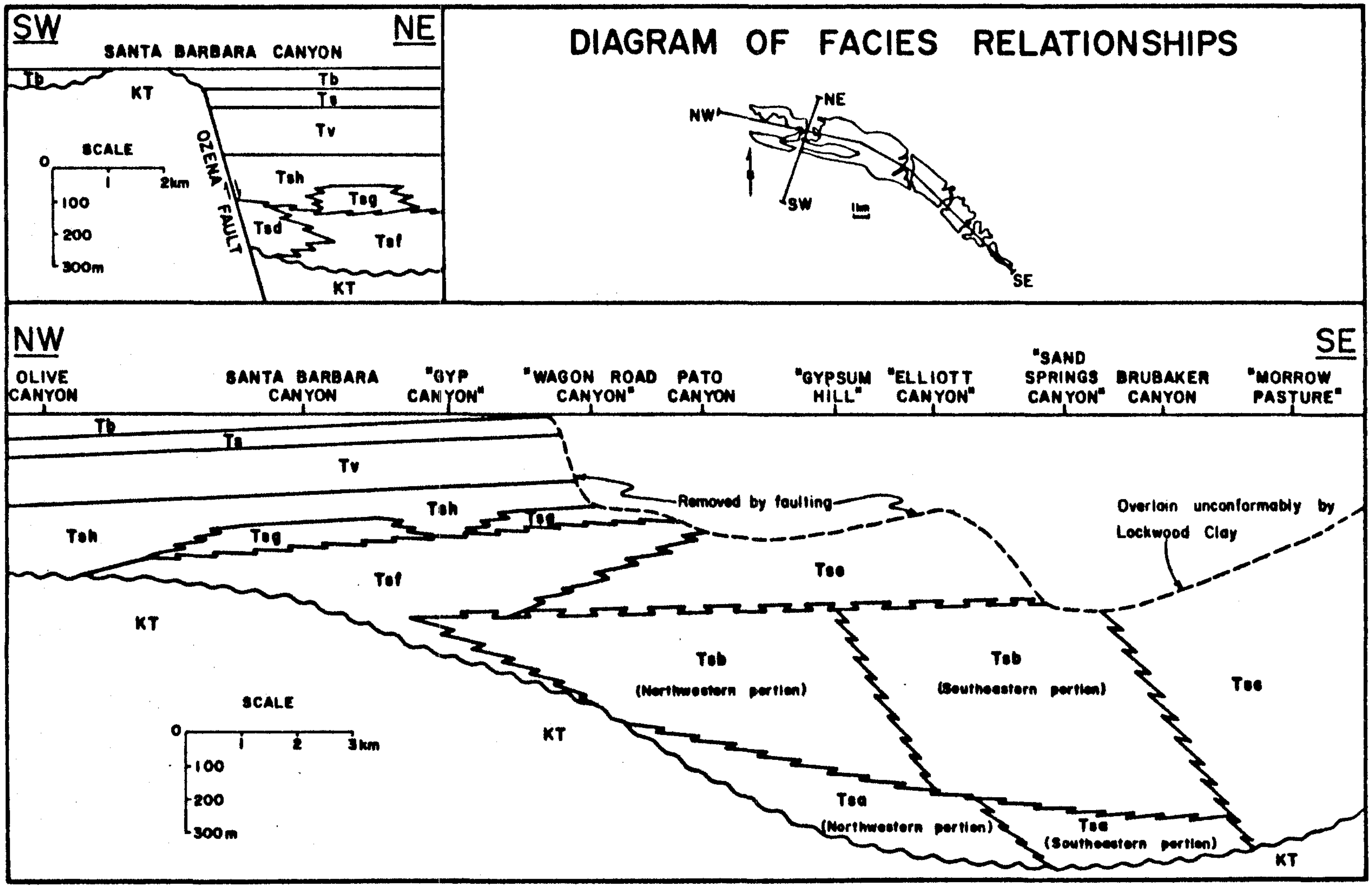


DIAGRAM OF FACIES RELATIONSHIPS
SW
NE
SANTA BARBARA CANYON
Tb
KT
Ts
Tv
SCALE
0
1
2km
100
200
300m
OZENA FAULT
Tsh
Tsg
Tsd
Tsf
NW
SW
SE
NW
SE
OLIVE CANYON
SANTA BARBARA CANYON
"GYP CANYON"
"WAGON ROAD CANYON"
PATO CANYON
"GYPSUM HILL"
"ELLIOTT CANYON"
"SAND SPRINGS CANYON"
BRUBAKER CANYON
"MORROW PASTURE"
Removed by faulting
Overlain unconformably by Lockwood Clay
Tse
Tsb
(Northwestern portion)
(Southeastern portion)
Tsa
3km

of Member H and rare plant remains or root structures are known from Members A, B, E, F, and H. Sparse vertebrate fossils, collected by Vedder (1968) from Member F in the Santa Barbara Canyon area, are considered Arikareean age (early Miocene of the North American land mammal chronology)(Bartow, 1974, p. 32). Plant remains and rare bone fragments are reported from Simmler outcrops of the Caliente Range and Carrizo Plain area (Bartow, 1974, p. 30).

Due to the general lack of diagnostic fossils in the Simmler, the age assignment of the formation must be based mainly upon its relationship to overlying and underlying formations. The possible age range of the Simmler is from late Eocene to early Miocene (Dibblee, 1973b). Its conformable relationship with the overlying early Miocene Vaqueros Formation (Bartow, 1974, p. 32) and the presence of the aforementioned vertebrate fossils in its upper portion, suggest that the Simmler is at least, in part, early Miocene in age. Its unconformable relationship with the underlying Eocene rocks implies the passage of sufficient time to allow for significant deformation prior to Simmler deposition. Unfortunately, however, no certain age assignment of the base of the Simmler Formation, beyond "post middle Eocene", is possible within the area studied. An Oligocene (?) to early Miocene age assignment for the formation is generally accepted by other workers in the vicinity (Hill and others, 1958; Vedder, 1968; Dibblee, 1973b; Vedder, 1973; and Bartow, 1974 and 1978), and this presumed age is hereby tentatively applied to the study area.

The exact age relationship between the various members of the Simmler within the mapped area is not certain. Presumably, the interpreted lateral interfingering of some of the members (Fig. 5) suggests their time equivalence.

The Simmler Formation can be correlated with other red-bed formations in California that occupy similar stratigraphic positions. The Simmler is probably correlative with the Oligocene Sespe Formation of the Ventura basin and Santa Ynez Mountains (Bailey, 1947) as well as with the Oligocene Berry Formation of the Salinas Valley (Thorup, 1943). The nearby Plush Ranch Formation of the Lockwood Valley area (Carmen, 1964) may be correlative, however, Crowell (1973) and Bohannon (1976) suggest that it may be younger. Formations with which the Simmler may be in part correlative are the Lospe Formation of the Santa Maria basin (Wissler and Dreyer, 1943), the Vasquez Formation of the Soledad basin (Oakeshott and others, 1954), the Tecuya Formation of the San Emigdio and Western Tehachapi Mountains (Nilsen and others, 1973), and the Diligencia Formation of the Orocopia Mountains (Crowell, 1975).

DESCRIPTIONS OF MEMBERS AND ENVIRONMENTAL INTERPRETATIONS

MEMBER A

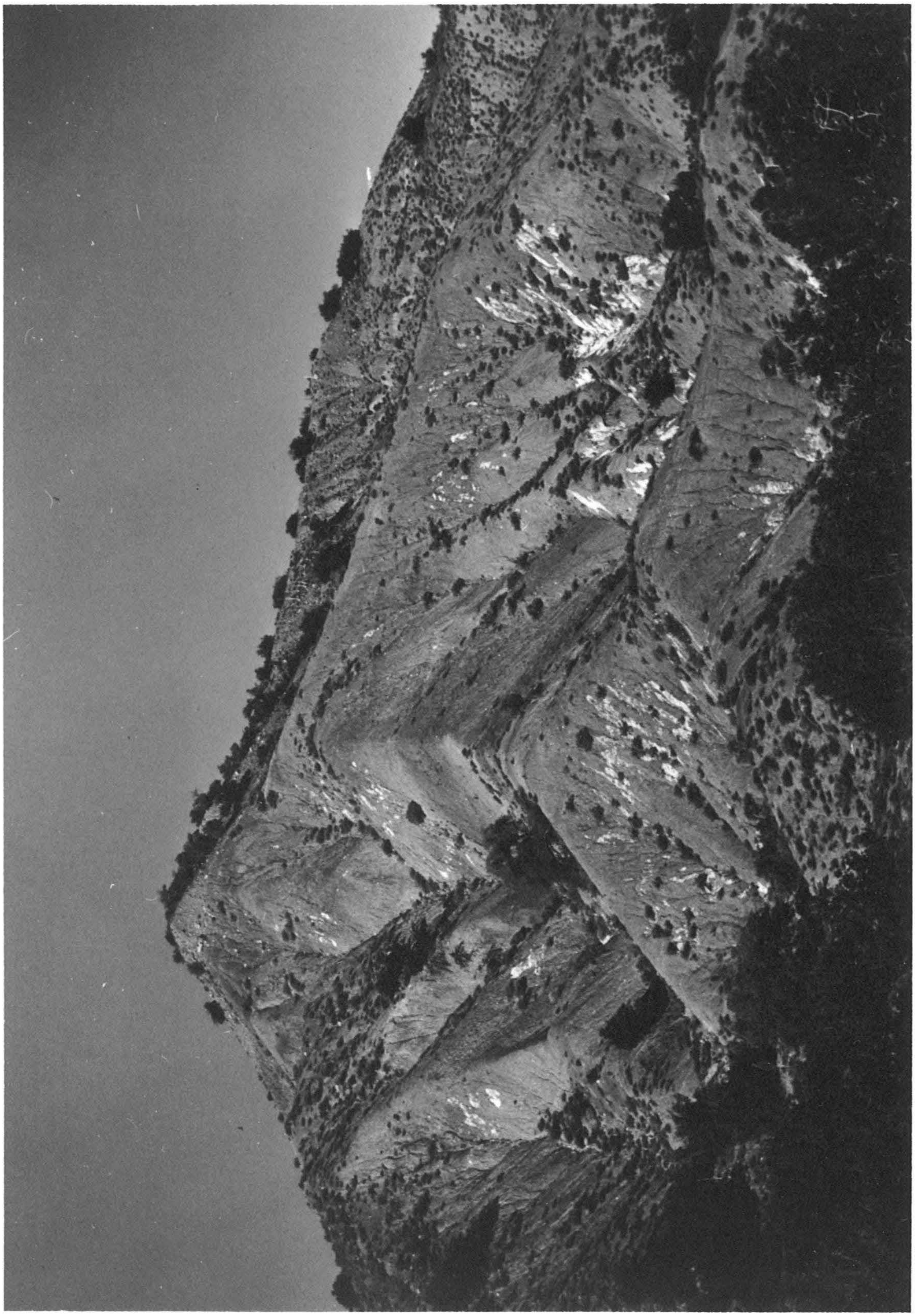
Introduction

Member A consists of reddish-brown and greenish-gray sandstone, mudstone, and conglomerate which is exposed in a narrow band about 0.5 km wide that extends from Pato Canyon on the north to "Sand Springs Canyon" on the south. The member, which forms the central portion of a southeast-northwest trending anticline, exhibits notable lateral grain size and color variations and is divided into south-eastern and northwestern portions for lithologic description.

The mostly fine-grained and poorly indurated rocks of Member A form subdued, rounded slopes which support sparse brush and grassy vegetation (Fig. 6).

The upper stratigraphic limit of Member A is mapped at a distinct color change from alternating red and gray beds to the brown and gray units of the overlying Member B. Accompanying the color change, although somewhat more subtle, is a variation in grain size from the predominantly mudstone rocks of Member A to the medium- and coarse-grained sandstone rocks of Member B. A maximum exposed stratigraphic thickness of 185 m crops out south of "Gypsum Hill". The accuracy of this measurement may be

Figure 6. Exposure of southeastern portion of Member A along the northwestern side of "Elliott Canyon". White patches are secondary gypsum deposits which have been leached out of the rocks. Terrace gravels cap the top of the ridge.



somewhat questionable, however, owing to intraformational shearing and faulting of an undetermined magnitude. This thickness should be regarded as an estimate of the minimum thickness of the member due to the fact that its base is not exposed within the mapped area.

Lithology

Southeastern Portion

Southeast of "Elliott Canyon", Member A is indistinctly stratified to well bedded and consists of moderate pink (5 R 7/4), fine- to medium-grained sandstone (60-70 percent), moderate reddish-brown (10 R 4/6) mudstone (25-35 percent), and a few pale reddish-brown (10 R 5/4), granule to pebble conglomerate lenses (5-10 percent). Conglomerate lenses are 30-40 cm thick and about 2-3 m long. Conglomerate clasts are rounded to well-rounded metamorphic/ granitic rocks (70-80 percent) and rounded sandstone (20-30 percent). Sandstone beds 0.1-10 cm thick are arranged in units averaging 1-2 m. Cross-bedded sets 5-15 cm thick are abundant within sandstone units of the southeastern exposures of Member A. Sandstone ranges in composition from arkose to lithic arkose and is composed of subangular to subrounded, moderately sorted grains. Gypsiferous cement is common in the sandstone. Erosionally channeled surfaces are common, and mudcracked (?) claystone lenses are present locally. Mudstone units 5-10 cm thick generally contain laminated beds 0.25-1 mm thick, but massive units up to 1 m are present. Irregularly shaped carbonaceous tubes, 5-8 cm long and about 2 mm in diameter, occur as root structures in sandstone and mudstone layers.

A well-developed vertical sequence of strata and sedimentary structures is repeated consistantly throughout the exposures of Member A in the southeastern portion of the study area (Fig. 7).

Northwestern Portion

Exposures of Member A between Pato and "Elliott" Canyons exhibit a crude stratification visible from a distance as alternating moderate red (5 R 4/6) and greenish-gray (5 GY 6/1) color bands. On close examination, this apparent bedding is less noticeable, although massive to indistinctly parallel-bedded sandstone (10-20 percent) and mudstone (80-90 percent) layers are visible. Sandstone units range in thickness from 1-25 cm with individual parallel beds generally 1-5 mm thick. Ripple bedding, small-scale cross laminations, and ripple marks are locally present in fine-grained sandstone units. Lens-shaped pods of claystone contained within sandstone units seem to be the remnants of mudcracked clay layers. Arkose to lithic arkose sandstone is composed of subangular to subrounded, moderately sorted particles, predominantly less than 0.05 mm in diameter, which include metamorphic (?), volcanic (?), and chert fragments. Gypsum cement and

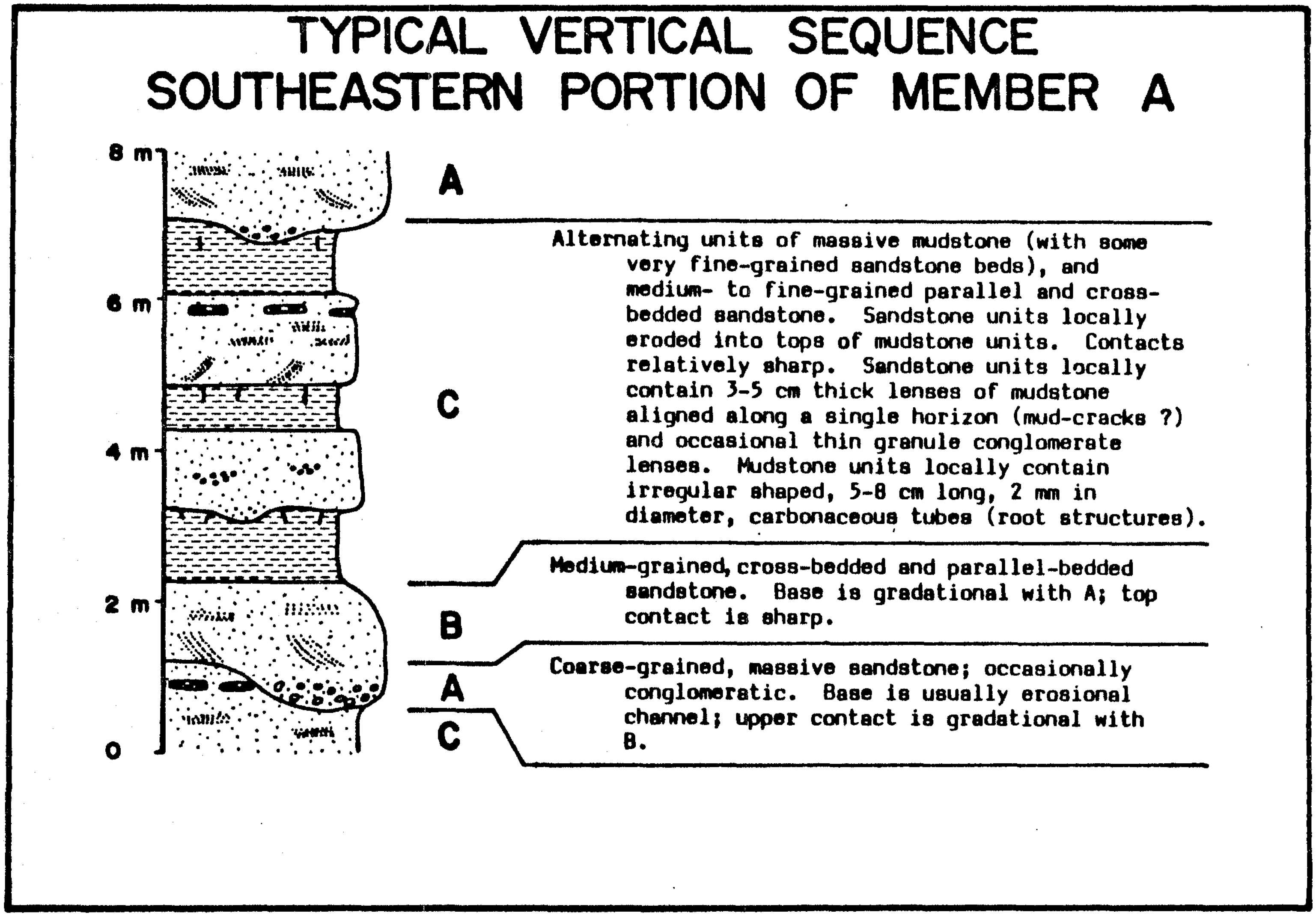


Figure 7. Typical vertical sequence in the southeastern portion of Member A. Letters indicate repetition of lithologic description.

selenite veins are common throughout the northwestern exposures of Member A. Mudstone interbeds are arranged in massive units less than 50 cm thick. Where thin laminations and ripple marks are present in mudstone, disruption and convolution of laminae is common. Mudstone units are overlain locally by 1-3 cm thick crusts of colloidal (?) limonite and hematite, containing about 60 percent gypsum laths (1.5-3.0 mm long). Some carbonized wood fragments, up to 3 cm in largest dimension, are concentrated between sandstone laminations. Casts of faint trails (?) are present on the bottoms of some sandstone layers. Tapered tubular-shaped sandstone and mudstone pods oriented perpendicular to bedding (0.1-3.0 cm in diameter and up to 7 cm long) are apparently root structures.

Where exposed in the northwestern portion of the study area, Member A consists of alternating bands of red and gray, fine-grained sedimentary rocks (Fig. 8).

Interpretation of Depositional Environment

Southeastern Portion

Exposures of Member A in the southeastern portion of the study area exhibit a predominance of parallel bedded sandstone (facies code Sh of Miall, 1978b)(Table 2) with some low-angle cross-bed sets (facies code Sl). Fine-grained rocks (characteristic of facies Fm, Fl, and Fr) are of secondary importance and gravel deposits (facies code

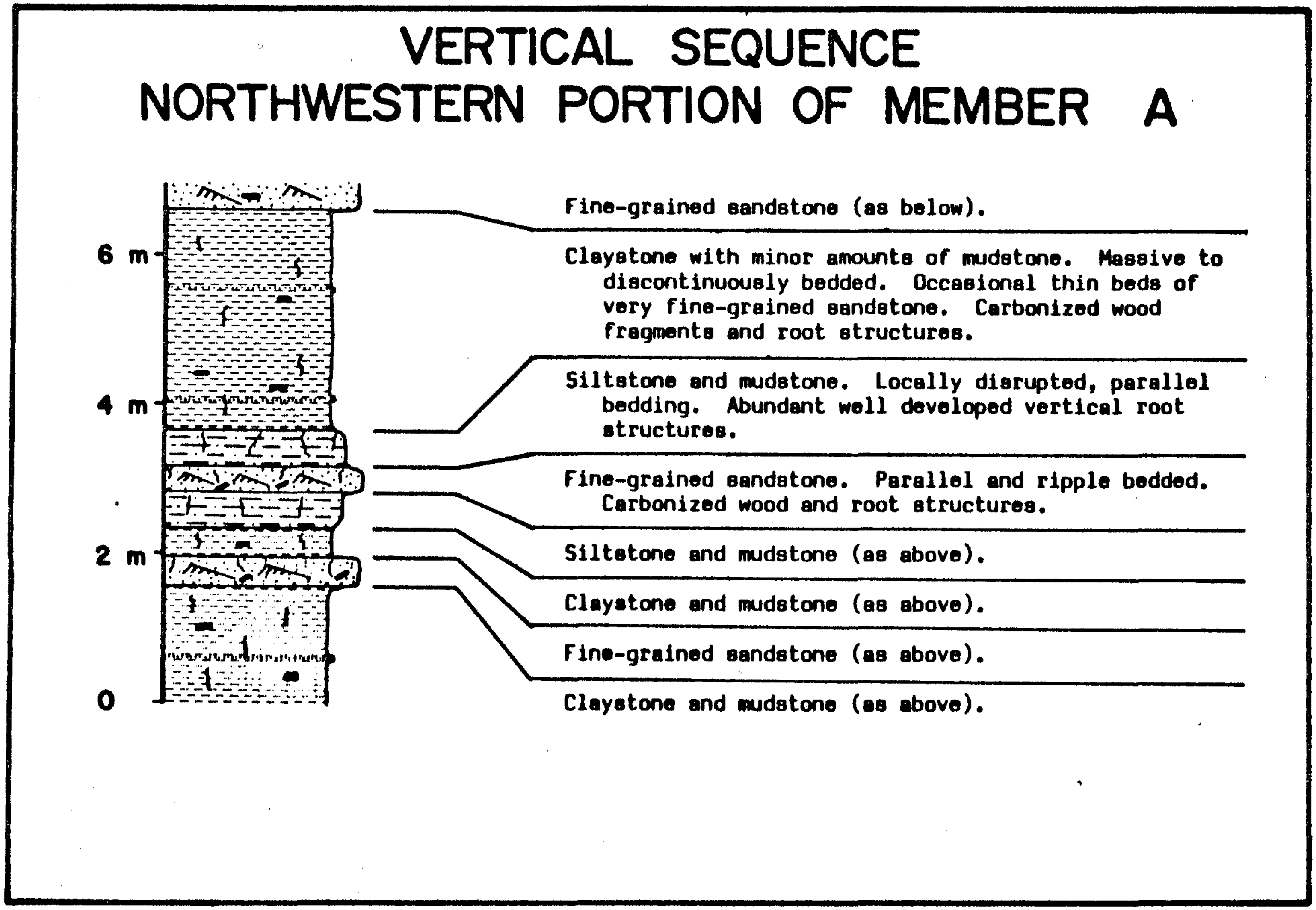


Figure 8. Vertical sequence in the northwestern portion of Member A.

Table 2. Explanation of facies codes used on Figure 9 and Table 3 (from Miall, 1978b, table 1).

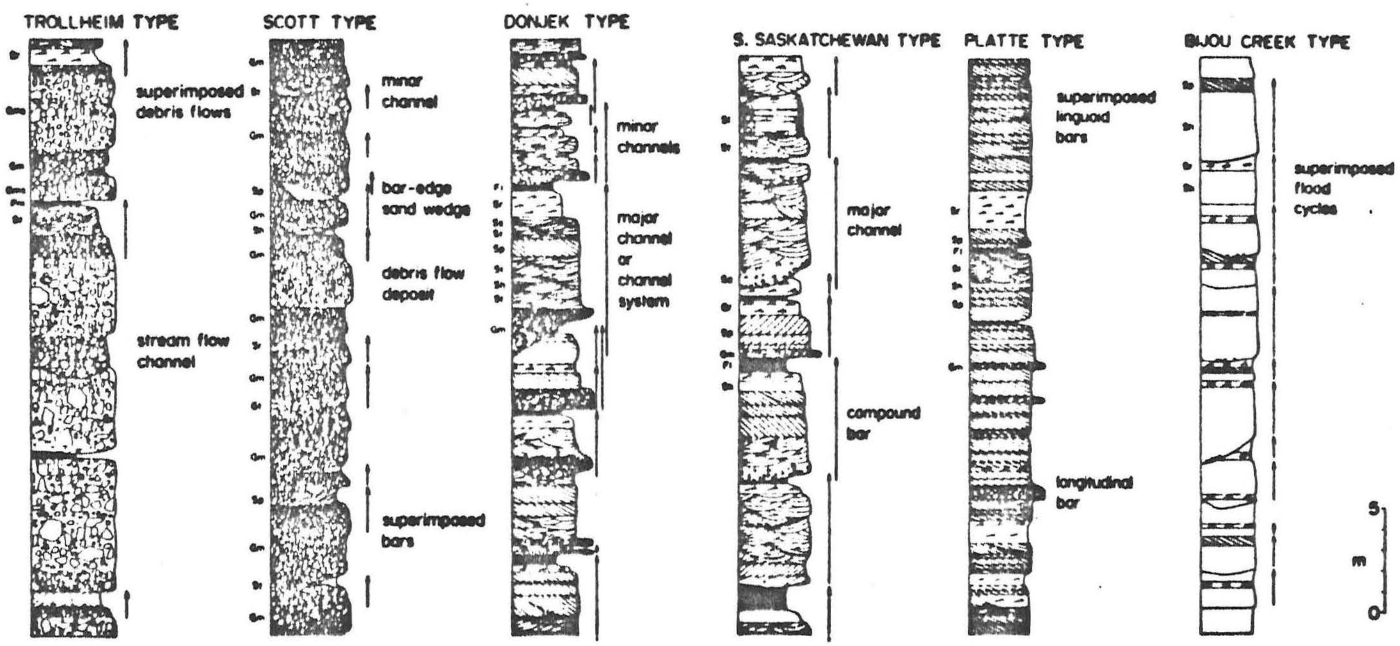
Facies Code	Lithofacies	Sedimentary structures	Interpretation
Gms	massive, matrix supported gravel	none	debris flow deposits
Gm	massive or crudely bedded gravel	horizontal bedding, imbrication	longitudinal bars, lag deposits, sieve deposits
Gt	gravel, stratified	trough crossbeds	minor channel fills
Gp	gravel, stratified	planar crossbeds	linguoid bars or deltaic growths from older bar remnants
St	sand, medium to v. coarse, may be pebbly	solitary (theta) or grouped (pi) trough crossbeds	dunes (lower flow regime)
Sp	sand, medium to v. coarse, may be pebbly	solitary (alpha) or grouped (omikron) planar crossbeds	linguoid, transverse bars, sand waves (lower flow regime)
Sr	sand, very fine to coarse	ripple marks of all types	ripples (lower flow regime)
Sh	sand, very fine to very coarse, may be pebbly	horizontal lamination, parting or streaming lineation	planar bed flow (l. and u. flow regime)
Sl	sand, fine	low angle (<10°) crossbeds	scour fills, crevasse splays, antidunes
Se	erosional scours with intraclasts	crude crossbedding	scour fills
Ss	sand, fine to coarse, may be pebbly	broad, shallow scours including eta cross-stratification	scour fills
Sse, *She*, *Spe*	sand	analogous to *Ss*, *Sh*, *Sp*	eolian deposits
Fl	sand, silt, mud	fine lamination, very small ripples	overbank or waning flood deposits
Fsc	silt, mud	laminated to massive	backswamp deposits
Fcf	mud	massive, with freshwater molluscs	backswamp pond deposits
Fm	mud, silt	massive, desiccation cracks	overbank or drape deposits
Fr	silt, mud	rootlets	seatearth
C	coal, carbonaceous mud	plants, mud films	swamp deposits
P	carbonate	pedogenic features	soil

Gm) occur in minor quantities. The presence of these facies suggests that the rocks of this portion of Member A may belong to the Bijou Creek type assemblage of Miall (1978b)(Fig. 9) which corresponds to type S_1 of Rust (1978b)(Table 3).

The Bijou Creek assemblage is considered to originate from ephemeral or perennial streams subject to flash floods (Miall, 1978b). The association of parallel-bedded sandstone with streams of reduced sinuosity that are occasionally subjected to flooding has been shown by several authors (McKee and others, 1967; Allen, 1970; McGowan and Garner, 1970; and Friedman and Sanders, 1978).

An environment similar to that of Bijou Creek has been described as "lithofacies #2" by Jackson (1978) (Table 4). Variable channel dimensions, upward-fining coarse-member deposits, and relatively thick "overbank" muds are some of the characteristics that the rocks of the southeastern part of Member A share in common with Jackson's (1978) "lithofacies #2" (Table 4). Jackson (1978) uses the modern Little Dry Creek of Wyoming (Table 5), which is subjected to ephemeral flooding, as a model for his "lithofacies #2". The stream which deposited the southeastern part of Member A probably had characteristics similar to those listed for Little Dry Creek (Table 5).

The three dimensional geometry of lithologic units



Name	Environmental setting	Main facies	Minor facies
Trollheim type (G_I)	proximal rivers (predominantly alluvial fans) subject to debris flows	*Gms, Gm*	*St, Sp, Fl, Fm*
Scott type (G_{II})	proximal rivers (including alluvial fans) with stream flows	*Gm*	*Gp, Gt, Sp, St, Sr, Fl, Fm*
Donjek type (G_{III})	distal gravelly rivers (cyclic deposits)	*Gm, Gt, St*	*Gp, Sh, Sr, Sp, Fl, Fm*
South Saskatchewan type (S_{II})	sandy braided rivers (cyclic deposits)	*St*	*Sp, Se, Sr, Sh, Ss, Sl, Gm, Fl, Fm*
Platte type (S_I)	sandy braided rivers (virtually non cyclic)	*St, Sp*	*Sh, Sr, Ss, Gm, Fl, Fm*
Bijou Creek type (S_I)	Ephemeral or perennial rivers subject to flash floods	*Sh, Sl*	*Sp, Sr*

Figure 9. Miall's six principal facies assemblages in gravel- and sand-dominated braided river deposits (from Miall, 1978b, fig. 1 and table 2).

Table 3. Lithotypes and facies assemblages of braided alluvium (from Rust, 1978b, table 1).

Lithotype	Facies	Special characteristics
Gravel		
Fac. assemblage G_I: (alluvial fans)	*Gms, Gm, St, Sp, Fl/Fm*	Great lithological variation. Crude cycles may be present.
Fac. assemblage G_{II}: (Proximal braided rivers and alluvial plains)	*Gm, Gp, Sp, Sh*	*Gm* dominant; usually with well-developed imbrication. *Gp* more abundant in pre-U. Paleozoic deposits.
Fac. assemblage G_{III}: (Distal braided rivers and alluvial plains)	*Gt, St, Gm, Sh, Fl*	Fining-upward cycles.
Sand		
S_I: Fac. assemblages: (Proximal braided rivers and alluvial plains)	*Sh, Sp, Sr* (Bijou Ck. type) *Se, Sl, St (Ss)* (Malbaie type)	*Sh* dominant. Vertical and lateral variability.
Fac. assemblage S_{II}: (Distal braided rivers and alluvial plains)	*Se, St (Ss), Sp, Sr, Fl/Fm*	Fining-upward cycles. Transitional to deposits of meandering rivers.
Silt		
(Distal braided rivers and alluvial plains)	*Fl, Fm*	Lack of association with sandy channel deposits. Eolian reworking and thixotropic deformation common.

TABLE 4. Characteristics of Jackson's (1978) lithofacies class #2 for Holocene meandering streams (from Jackson, 1978, table 7). The stream which deposited the southeastern part of Member A probably had characteristics similar to those listed herein.

#2 Sand-bed streams with modest thickness of fine member

1. Channel shows variable width-depth ratio, prominent point bars of modest transverse slope, the usual asymmetrical triangular cross section in bends, and substantial scour and fill during major floods.

2. Upward fining of coarse member common but not ubiquitous. Generally poor development of transitional and fully developed textural zones.

3. Fine member is thinner than, but comparably thick to, coarse member; its mud is largely "overbank".

4. Epsilon-cross-stratification likely in coarse member and can dip steeply in small streams. Prominent natural levees and channel-fill mud deposits common. Scroll bars and chutes can be both common and prominent.

5. Rates of channel migration uniformly large; both chute and neck cutoffs expected.

6. Chutes, chute cutoffs, and major scouring surfaces (which truncate any epsilon-cross-stratification) predominate in ephemeral streams.

TABLE 5. Geomorphic and sedimentary features of Little Dry Creek used by Jackson (1978) to develop his preliminary lithofacies class #2 (from Jackson, 1978, table 6). The stream which deposited the southeastern part of Member A probably had characteristics similar to those listed for Little Dry Creek.

<u>Little Dry Creek</u> (7 km SE of Mountain View, Wyoming; 41°15'N 110°15½'W)

1. Ephemeral: summer floods show flashy discharges, high suspended loads with much mud, and much scour and fill of bed. Spring flood due to snow melt.

2. Many chute cutoffs; each bend typically shows multiple chutes in varying stages of development. No chute bars; rare neck cutoffs.

3. Abundant presence and preservation of lower-regime bedforms in dominantly sand bed; upper-regime bedforms absent. Occasional, subdued scroll bars. No evidence of epsilon-cross-stratification.

4. General, erratic upward fining of vertical sequences. Dune cross strata common near base and small-scale cross strata prevail near top. Surficial sediment usually not indicative of preserved lithofacies.

5. Fine member ranges from sandy silt to fine sand with scattered silt beds and does not show cross stratification; thickness ranges from <0.1 m to >0.8 m--extremely variable along a single bend.

within fluvial environments has been given only limited attention in the literature. Allen (1965b) suggested that low-sinuosity meandering rivers are likely to produce predominantly fining-upward, coarse-grained channel deposits that extend across the sedimentary basin in tabular to wedge-shaped sheets within which interbedded, thin, fine-grained overbank deposits are not laterally persistent. Such deposits do not contain the restrictive clay plugs common to highly sinuous streams (Schumm, 1968 and 1977; Collinson, 1978a and 1978d; Friedman and Sanders, 1978; and Walker and Cant, 1979). The limited exposures of Member A in the southeastern portion of the area exhibit sandstone deposits which are not markedly lenticular at an outcrop scale and which contain somewhat thinner discontinuous mudstone interbeds. Although structural complications obscure the overall geometry of the member, the available exposures indicate that the geometry of the lithologic units in Member A is very similar to that proposed by Allen (1965b) for low-sinuosity meandering rivers. The ephemeral nature of the streams which deposited the southeastern portion of Member A suggests that the water course was similar to modern, sporadically active desert wadis (Reineck and Singh, 1975).

Northwestern Portion

In the northwestern portion of the area, the very fine-grained rocks of Member A locally contain thin limonite beds with gypsum crystals. Secondary gypsum veins are interspersed throughout the fine-grained rocks of Member A, suggesting that prior to diagenesis gypsum may have been more abundant in the member. Gypsum is known to form in modern environments ranging from marine basins, through marginal lagoon, to supratidal-continental areas (Kinsman, 1969). Lack of thin, laterally continuous gypsum laminae in Member A and the interbedded relationship of the member with fluvial rocks are used to rule out a possible marine basin origin for the gypsum of Member A. Geochemical data from the gypsiferous rocks of Member A were not obtained during the preparation of this report, so that mineral assemblages are not available to aid in determining whether the unit originated in a marginal or supratidal environment, but because a considerable thickness of nonmarine Members B, E, F, G, and H intervene between this member and the marine Vaqueros Formation, it seems reasonable to assume that a marginal lagoon origin is not likely for the rocks of Member A. The remaining modern gypsum forming environment (supratidal-continental) is typified by the sabkha (playa) areas of the Arava Valley between the Dead Sea and the Red Sea (Amiel and Friedman, 1971). Kinsman (1969) suggests that although an arid climate is essential for evaporite formation, the major requirement is limited diluting water.

Intermittent stream flow in the Arava Valley acts to bring sediment and dissolved minerals into the depositional basin where the water seeps into the soil creating a water table very near the surface (Friedman and Sanders, 1978). Sabkha environments occur in low lying, deflation hollows, generally devoid of eolian sediment (Friedman and Sanders, 1978). Gypsum precipitation is known to occur within the framework of sedimentary particles at or near the ground surface (Collinson, 1978c).

Deposits of continental sabkhas (playas) consist of interbedded thin layers of sand, silt, clay, and evaporite minerals. Although the surface of recent sabkhas is often oxidized to a red or brown color, the lack of permeability below the surface results in gray colors typical of a reducing environment (Friedman and Sanders, 1978). Due to alternate flooding and drying, sabkha deposits are commonly cyclic and may consist of "couplets" or "triplets" (Friedman and Sanders, 1978). A couplet is formed from a coarser-grained sandy or silty layer that grades upward into a much finer-grained, often mudcracked, clay layer. A triplet results when the clay layer contains or is overlain by a thin layer of evaporite minerals (Friedman and Sanders, 1978). These sequences are the result of the gradual settling out of clastic minerals borne by flood waters and the subsequent evaporation of the water leaving mineral salts (Friedman and Sanders, 1978). Friedman

(1966) reports the occurrence of iron sulphide minerals within the sediments of a modern sabkha (playa) in west Texas.

The rocks in the northwestern portion of Member A bear remarkable similarity to the sabkha sequence described above. Thin sandstone beds probably represent deposits of bedload sediments borne by flood waters, whereas thin mudstone interbeds represent deposition of suspended sediments which settled to the basin floor after the flood. Thicker mudstone sequences, without sandstone interbeds, represent superimposed deposits of suspended sediments only, which are typical of the playa environment. Local limonite layers may be analogous to the iron sulphide-rich layers noted in modern sabkha sediments (Friedman, 1966). The alternating pink and gray color of the rocks of this portion of Member A may have resulted from fluctuating ground water conditions at the depositional site or they may have resulted from slight variations in permeability of the sediments. Gypsum crystals probably formed by evaporation of calcium sulphate-rich water in local depressions within the depositional basin. The apparent lack of thick, well-developed, nodular gypsum deposits, such as those found in Member B, may indicate that only small, short-lived pools of sulphate-bearing water were present or that post-depositional diagenesis has removed all traces of these deposits. The poor quality of exposures of this portion of Member A precludes an accurate determination of the presence or absence of many of the sedimentary structures typically found in sabkha (playa) environments.

Environmental Summary

The low-sinuosity meandering stream which deposited the southeastern portion of Member A graded laterally into the sabkha (playa) environment of the northwestern portion. Coarse-grained sediments borne by occasional flash floods, apparently originating from a highland to the southeast, were deposited by a low-sinuosity, wadi stream to form the southeastern part of the member. Fine-grained sediments, which remained in suspension, were transported to the low-lying, evaporative sabkha environment of the northwestern portion.

MEMBER B

Introduction

Rocks of Member B are composed of greenish- to brownish-gray, gypsiferous claystone, mudstone, sandstone, and conglomerate. Locally, thin beds of gray tuff are present.

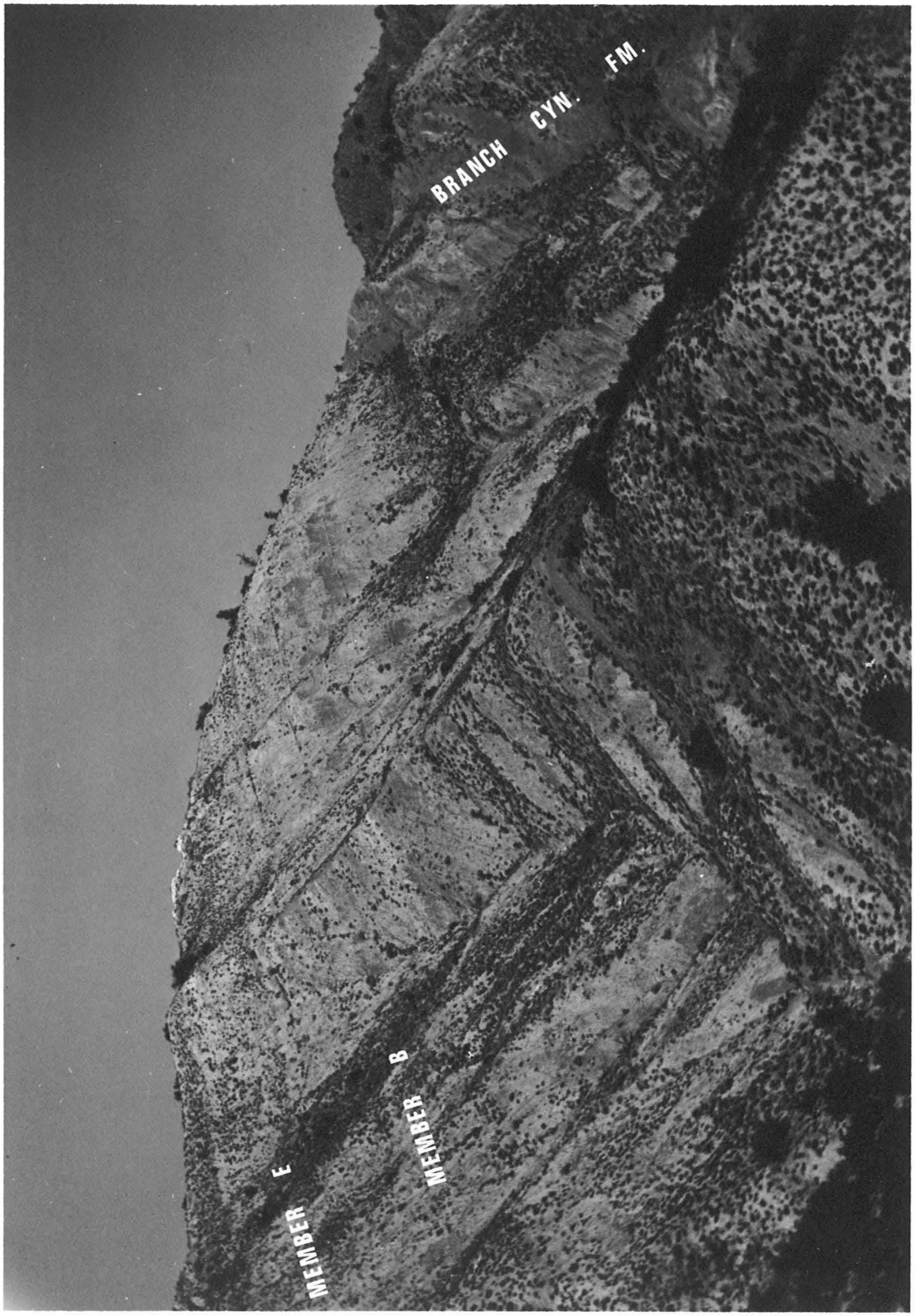
Member B is poorly exposed throughout nearly the entire study area from "Gyp Canyon" southeastward to Brubaker Canyon in narrow, tightly folded, generally fault-bounded segments.

As with Member A, Member B displays noticeable lateral grain-size variations and the two extremes are described separately. The most northwesterly exposures of Member B, between "Gyp Canyon" and "Gypsum Hill", consist of gray-colored, gypsiferous mudstone and claystone interbedded with rare, thin, fine- to medium-grained sandstone beds. Lenticular units of nodular gypsum are exposed in prospect pits within this fine-grained portion of Member B. A marked increase in both maximum and average grain size is apparent toward the southeast. From an area slightly northwest of "Elliott Canyon", southeastward to Brubaker Canyon, Member B is composed of mostly pale-brown and a few reddish beds of fine- to medium-grained sandstone interbedded with coarse-grained sandstone and conglomerate and gray-colored mudstone.

Fine-grained, poorly indurated northwestern exposures of the member form gentle, soil-covered, grassy, rolling hills, whereas the slightly better indurated southeastern part of the member supports moderate slopes possessing only limited soil and vegetative cover (Fig. 10).

A distinctive characteristic of Member B throughout the area mapped is its predominance of gray-colored rocks. The abundance of fine-grained rocks, in conjunction with this gray coloration, allows distinction between the northwestern exposures of the member and its surrounding members. Toward the southeast, the distinctive color domi-

Figure 10. Photograph of Members B and E exposed along the southeastern flank of "Gypsum Hill". Branch Canyon Formation is in fault contact with Member B.


BRANCH CYN. FM.
MEMBER E
MEMBER B

nates as the distinguishing characteristic for recognition of Member B, although the smaller average grain size of the underlying Member A and the larger average grain size of the overlying Member E are used to distinguish the unit locally.

The upper and lower contacts of Member B (Fig. 5) are mapped on the basis of the above color variations with the overlying and underlying members. The color change from Member A to Member B is distinct. Member E rests on Member B with a gradational, possibly interfingering contact throughout the mapped area. In "Sand Springs Canyon" a few tongues of conglomerate from Member C apparently interfinger with the sandstone of Member B. Member B may also interfinger with Member D, but poor exposures make this relationship uncertain. In "Gyp Canyon", where fine-grained rocks of Member B are overlain by coarse-grained rocks of Member F, a sharp contact is formed.

Although complete, unfaulted stratigraphic sections of Member B are rare within the study area, two exposures suggest that the unit exhibits marked thickness variations from east to west. A maximum exposed thickness in excess of 600 m crops out in the vicinity of "Sand Springs Canyon". To the northwest, the member thins to about 400 m in the Pato Canyon area and apparently lenses out altogether in the area of Santa Barbara Canyon where Member F rests unconformably on unnamed Eocene rocks.

Lithology

Southeastern Portion

Within the southeastern portion of the area mapped, Member B is composed of well-stratified, pale to dark yellowish-brown (10 YR 6/2, 10 YR 4/2), dark yellowish- and grayish-orange (10 YR 6/6, 10 YR 7/4) and light olive-brown (5 Y 5/6), fine- to medium-grained sandstone (65 percent), moderate yellowish-brown (10 YR 5/4) to grayish-orange (10 YR 7/4) mudstone (30 percent), and pinkish-gray (5 YR 8/1), thin granule to cobble conglomeratic sandstone lenses averaging 5-10 cm in thickness (5 percent).

Fining-upward sandstone sequences are arranged in sets up to 2 m thick, which contain units averaging 5-50 cm in thickness consisting of predominantly a single grain size. Within these uniform-grain-size units are individual beds averaging 1-5 cm thick. Gradational contacts are common in sandstone between beds of different grain sizes. Sandstone grains are angular to subrounded and moderately to poorly sorted. Metamorphic and volcanic fragments are present within the generally lithic arkose sandstone. Cements include carbonate, gypsum, limonite, and silica (rare).

Mudstone units are less than 40 cm thick and commonly average 5-10 cm. Individual mudstone beds range in thickness from a few millimeters to 15 cm and average 1-5 cm. Generally sharp contacts occur at the top and bottom of mudstone units.

Beds of nearly pure limonite with some gypsum inclusions occur locally at the top of mudstone units of fining-upward sequences.

Grayish-yellow-green (5 GY 7/2) to light-gray (N7), fine- to medium-grained, arkosic, sandy tuff beds crop out in various isolated locations throughout the member. These layers weather to form conspicuous bands of silver-white bentonitic (?) claystone, which are in marked contrast to the surrounding dark-colored sedimentary rocks. Attempts to follow and correlate these beds in the field met with little success due to a general lack of good exposures.

Parallel bedding is the most abundant bedform, although small-scale cross laminations are common throughout the southeastern portion of Member B. Other primary sedimentary structures observed are listed in Table 6.

At several locations trail-like markings are present on bedding surfaces. Vertically oriented tubular structures a few centimeters in diameter may be burrows or root traces. Carbonized wood and plant fragments are present locally as impressions on bedding planes.

Typically, the coarse-grained portion of Member B, southeast of "Gypsum Hill", is arranged in fining-upward sequences of sandstone and mudstone (Fig. 11).

Northwestern Portion

Where Member B crops out in the northwestern portion of the study area, a distinct lack of well-defined strati-

Table 6. Lithologic characters of Member B.

[C=common, X=present, R=rare]

	NORTHWESTERN PORTION	SOUTHEASTERN PORTION
Cross-bedding*		
small scale (ripples)	C	C
medium scale		R
Flaser or wavy bedding	R	
Planar stratification	C	C
Parting lineation	X	X
Channels (erosion surfaces)	C	C
Graded bedding	R	R
Claystone intraclasts	R	X
Desiccation cracks		R
Convolute bedding	C	R
Trace fossils (trails, burrows, etc.)	X	C
Carbonaceous plant impressions	X	
Nodular gypsum	R	
Old caliche horizon (?)	R	
Ironstone	X	
Ripple marks	R	R

*Magnitude of cross-bedding is based on set thickness--small scale, <5 cm; medium scale, 5-50 cm.

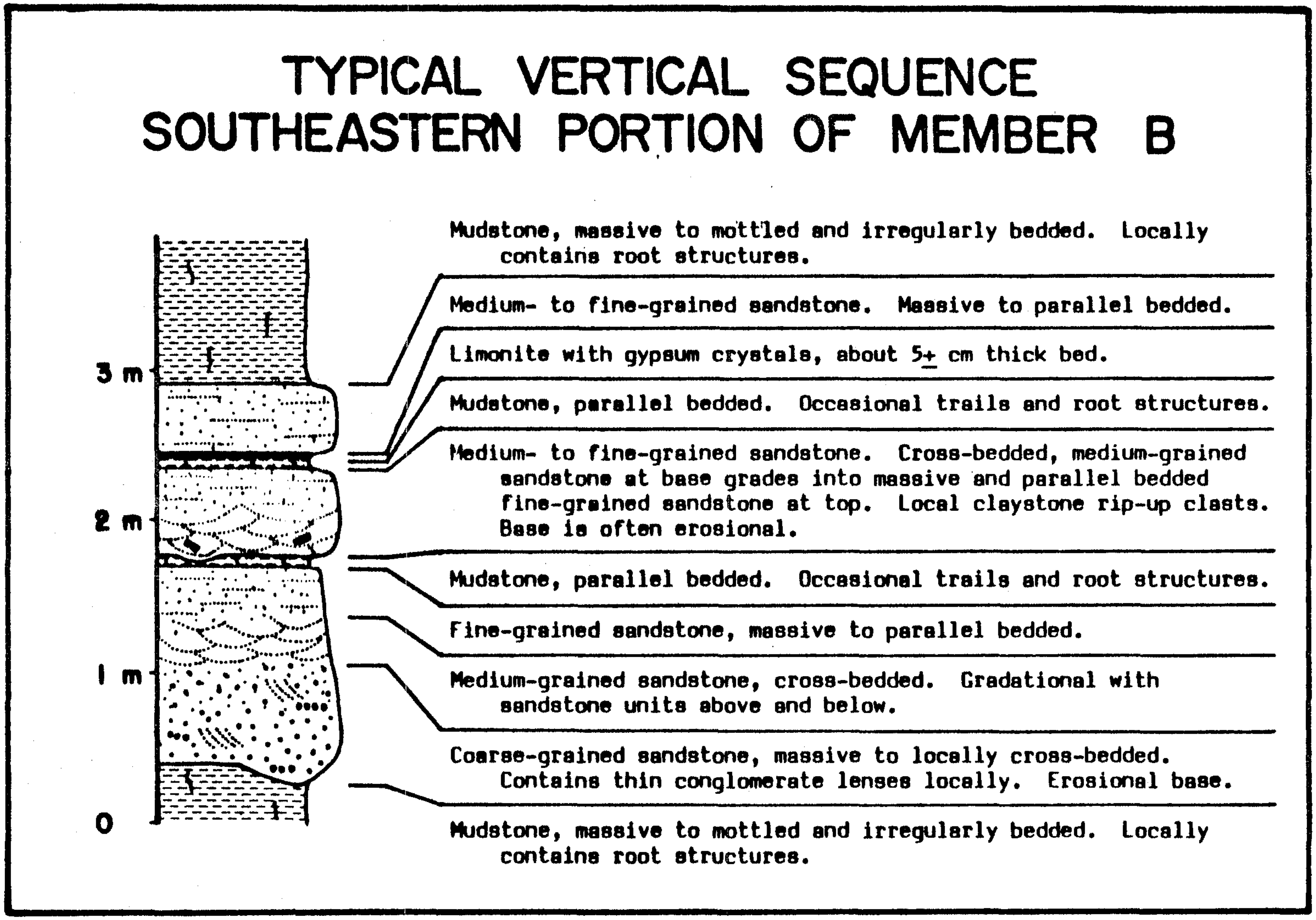


Figure 11. Typical vertical sequence in the southeastern portion of Member B.

fication is noted. Due to the poor quality of available exposures, numerous shallow shovel holes were excavated to allow direct examination of the rocks. This limited artificial exposure disclosed poorly defined units of light-olive-gray (5 Y 5/2) to light-gray (N7) mudstone and claystone, usually less than 20 cm thick. Within these units, individual beds 2-3 cm thick are present locally. Stratification within the mudstone is commonly shown by slight color variations. At one location a 15-30 cm thick layer of nodular limestone combined with gypsum was observed in the mudstone.

Interbedded with mudstone are a few light-olive-gray to light-olive-brown (5 Y 5/2, 5 Y 5/6), fine- to medium-grained sandstone units less than 50 cm thick. These rare sandstone units form less than 5 percent of this portion of Member B. Individual beds of sandstone range in thickness from 3 cm to laminations of less than 1 mm. Lithic arkose to arkose is composed of subangular to rounded, moderately to poorly sorted particles, generally less than 0.5 mm in diameter. Gypsum as well as carbonate cement is common. Locally, a 5-cm-thick cap of limonite cement is present at the top of sandstone interbeds.

Abandoned prospect pits in "Gyp Canyon" and "Wagon Road Canyon" expose lens-shaped pods, less than 2 m thick of nodular and bedded gypsum. Nodular gypsum beds 20-30 cm thick commonly pinch and swell, displaying mottled and irregular textures. Associated with the gypsum are massive interbeds of fine- to medium-grained sandstone about 30 cm thick.

Although some of the mudstone exposures exhibit crude parallel stratification, the majority display mottled, broken, and convoluted structure. Thin sandstone interbeds show a predominance of plane bedding with some small-scale cross laminations and ripple bedding.

Member B, northwest of "Gypsum Hill", forms a rather monotonous sequence of mudstone and claystone rocks interrupted only locally by thin, fine- to medium-grained, sandstone interbeds. A typical sequence of strata, observed at the stratigraphic interval of one of the sandstone interbeds, displays finely interbedded sandstone, mudstone, and claystone (Fig. 12).

Interpretation of Depositional Environment

Southeastern Portion

The geometry, sedimentary structures, and vertical sequences of the southeastern portion of Member B are remarkably similar to those observed in the southeastern portion of Member A. Rocks of Member B, however, are slightly better exposed and crop out over a much larger area than those of Member A. Fining upward-sequences, the predominance of plane-bedded sandstone (facies code Sh), the tabular shape at outcrop scale of lithologic units, and the observed sedimentary structures (Table 6) indicate that

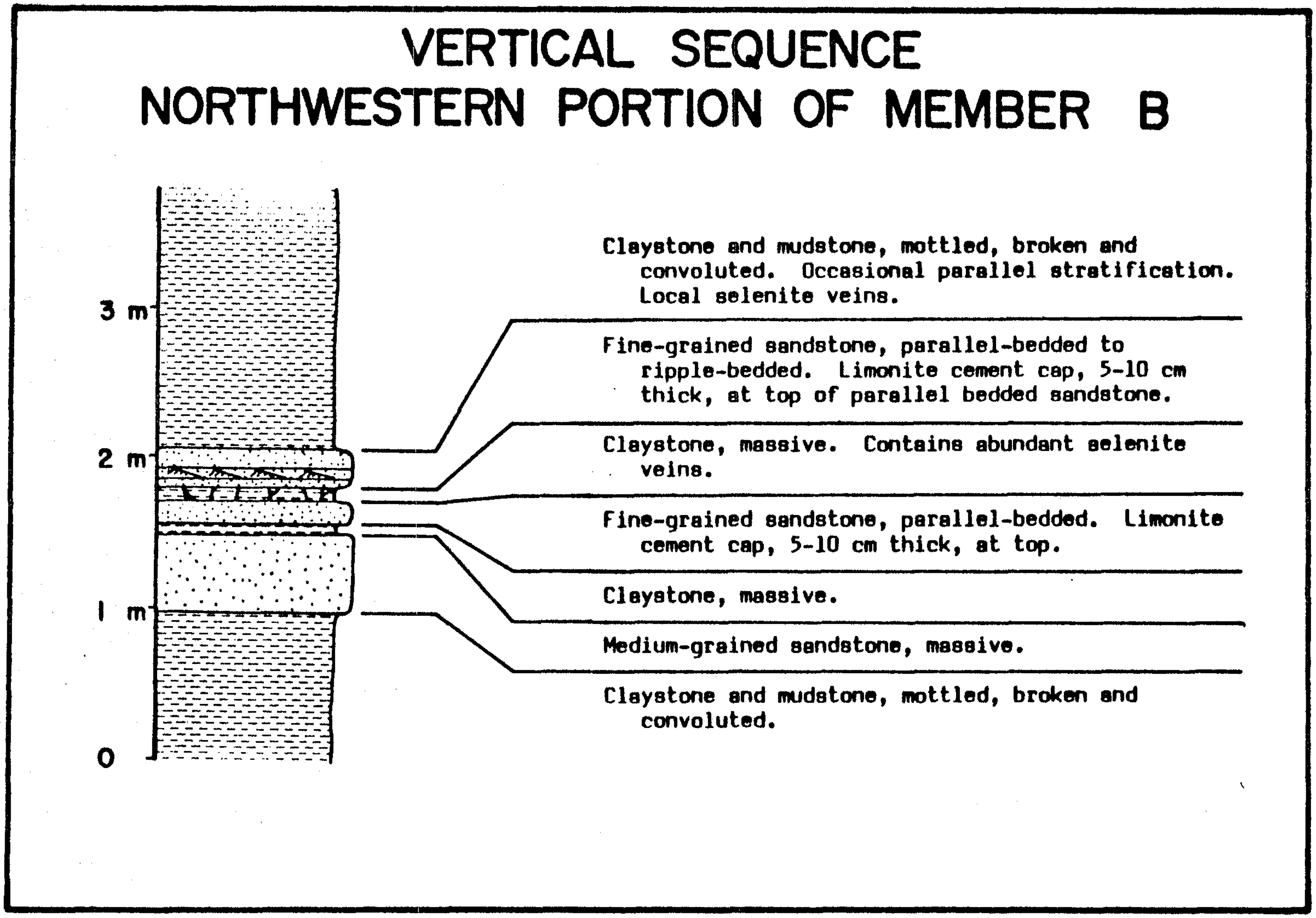


Figure 12. Vertical sequence in the northwestern portion of Member B.

this portion of Member B probably also formed in a low-sinuosity ephemeral stream, subject to occasional flash floods, like that described for the southeastern portion of Member A.

Northwestern Portion

The very fine-grained rocks of Member B northwest of "Gypsum Hill" are similar to those observed in the northwestern portion of Member A. Aside from better quality exposures, rocks of Member B differ from those of Member A in that they contain several thick beds of nodular gypsum. Although the depositional environment of this portion of Member B was probably very similar to that of the northwestern portion of Member A, the thick gypsum beds may indicate that somewhat more permanent evaporative depressions characterized the depositional basin when rocks of Member B were deposited. The general lack of clastic particles coarser than silt size throughout much of the lower portion of the member suggests that inundation by floods that contained bedload sediment was rare. The greater abundance of these coarse-grained beds in the upper part of this portion of Member B, indicates that sand-laden floods reached the site of deposition more frequently. Such a coarsening-upward trend in the member is supportive of a depositional model in which fine-grained playa sediments are overridden by prograding coarse-grained fluvial deposits. Local limonite cement caps at the tops of sandstone interbeds may be similar to the iron sulphide-rich layers noted in modern sabkha sediments (Friedman, 1966) and recognized in Member A. The consistently gray color of this portion of the member probably is due to a lack of permeability within the sediment. Like Member A, the poor quality of exposures of this portion of Member B precludes an accurate determination of the presence or absence of many of the sedimentary structures typically found in sabkha (playa) environments.

Environmental Summary

As with Member A, the fluvial environment of the southeastern portion of Member B graded laterally into the sabkha environment of the northwestern portion. The principal difference between Members A and B is their coloration. The predominance of reddish-colored rocks in Member A is in contrast to the brownish- and grayish-colored rocks of Member B. The reddish color of Member A may have been the result of *in situ* oxidation of iron-bearing minerals due to a deep ground water table. The brownish and grayish color of Member B may have formed due to a shallower ground water table or a general lack of permeability within the sediments, thus resulting in neutral to slightly reducing conditions.

Due to the reported absence of a similar fine-grained unit within the Simmler Formation of the Cuyama Badlands, less than 10 km away (Bartow, 1974), the paleodepositional environment of the northwestern portion of Member B may have been of limited areal extent. Paleocurrent data (from pebble imbrications) collected in the Cuyama Badlands, indicate a northward direction of sediment transport for the Simmler in that area (Bohannon, 1976), thus suggesting the need for a highland source area south of the Cuyama Badlands. The presence of the sabkha deposits of Member B within the study area, less than 10 km south of the Cuyama Badlands, suggests that perhaps a barrier existed between these two locations during Simmler time, thus creating separate depositional basins. However, the lack of correlative sabkha deposits in the Cuyama Badlands may be due simply to a lateral facies change.

MEMBER C

Introduction

Within the study area, Member C consists of brown boulder conglomerate, sandstone, and mudstone. Rocks of Member C crop out only in the southeastern portion of the area as a continuous band extending from "Sand Springs Canyon" southeastward. The quality of exposures ranges from poor to good, with many slopes being covered by a thick accumulation of sandy, boulder colluvium. Sparse vegetation is commonly all that grows on slopes underlain by Member C, and includes sage, yucca, and grasses.

The basal contact of Member C is not exposed within the mapped area; however, exploratory oil and gas wells drilled east of Brubaker Canyon penetrated Eocene marine sedimentary rocks below rocks that probably are equivalent to Member C (California Division of Oil and Gas, 1964). About 3-9 km southeast of the mapped area, exploratory wells have penetrated granitic basement rocks below Simmler Formation (?) rocks that may be correlative with Member C (Vedder and others, 1973). Within the study area Member C is underlain by and interfingers with rocks of Member B (Fig. 5). Although the upper contact of Member C is obscured within the study area, the Lockwood Clay Member of the Quatal Formation apparently overlies Member C with angular unconformity. Due to this unconformity, it is not possible to determine the members true stratigraphic thickness, but the maximum exposed thickness occurs in Brubaker Canyon where about 300 m of the member crops out.

Conglomerate clast size in the member increases upsection. In addition, stratification within the upper part of the member is characterized by sharply-defined, tabular, parallel-bedded units, whereas the lower part is predominated by gradational, lenticular bedding. The contact between the texturally dissimilar upper and lower portions of the member is gradational and probably interfingering.

Lithology

Lower Portion of Member

Stratification, which is readily apparent when viewing outcrops of the lower portion of the member from a distance, is difficult to recognize on close inspection. In the lowermost exposures of Member C, light brown (5 YR 6/4) medium- to coarse-grained sandstone (60 percent) and pebble to boulder conglomerate (40 percent) are interbedded with each other in gradational and interfingering units. Mudstone is conspicuously absent from the lower portion of Member C. Conglomeratic units range from 0.5-3 m in thickness (averaging 1 m) and sandstone units range from 1-5 m (averaging 1 m). Channeling and scour surfaces are evident at the bases of conglomerate units. Small-scale cross laminations are present locally within sandstone units. The maximum clast size is about 1.5 m in diameter, with the average size being about 0.1-0.3 m. Lenticular concentrations of clasts with closed framework are common. Rocks of the lower portion of Member C have individual beds which are moderately to well sorted. Large clasts are rounded to well rounded granitic and metamorphic fragments, generally clast supported, set in an arkosic sandstone matrix of subangular to subrounded grains.

Rocks of the lower part of Member C are arranged in graded, fining-upward sequences as depicted in Figure 13.

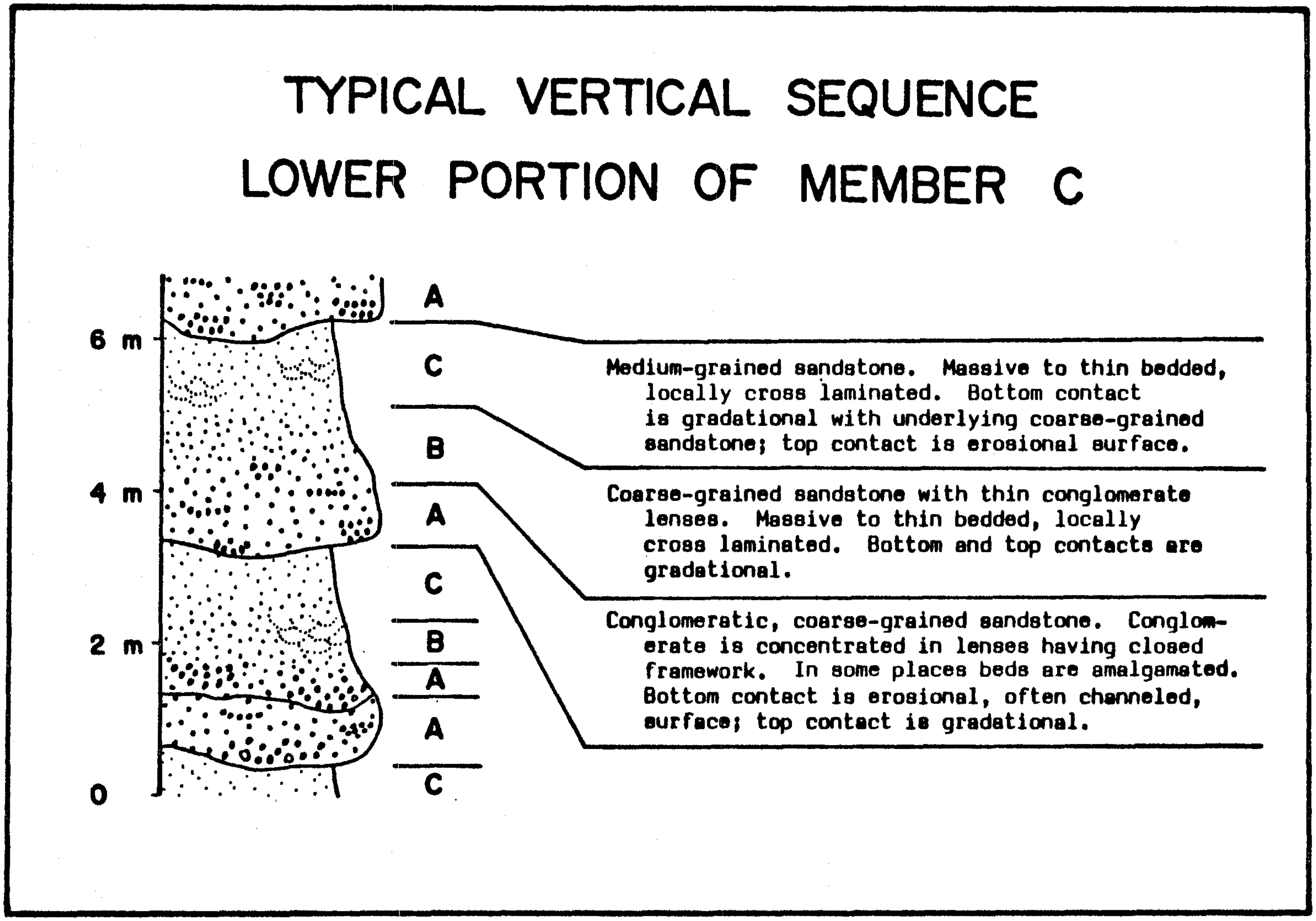
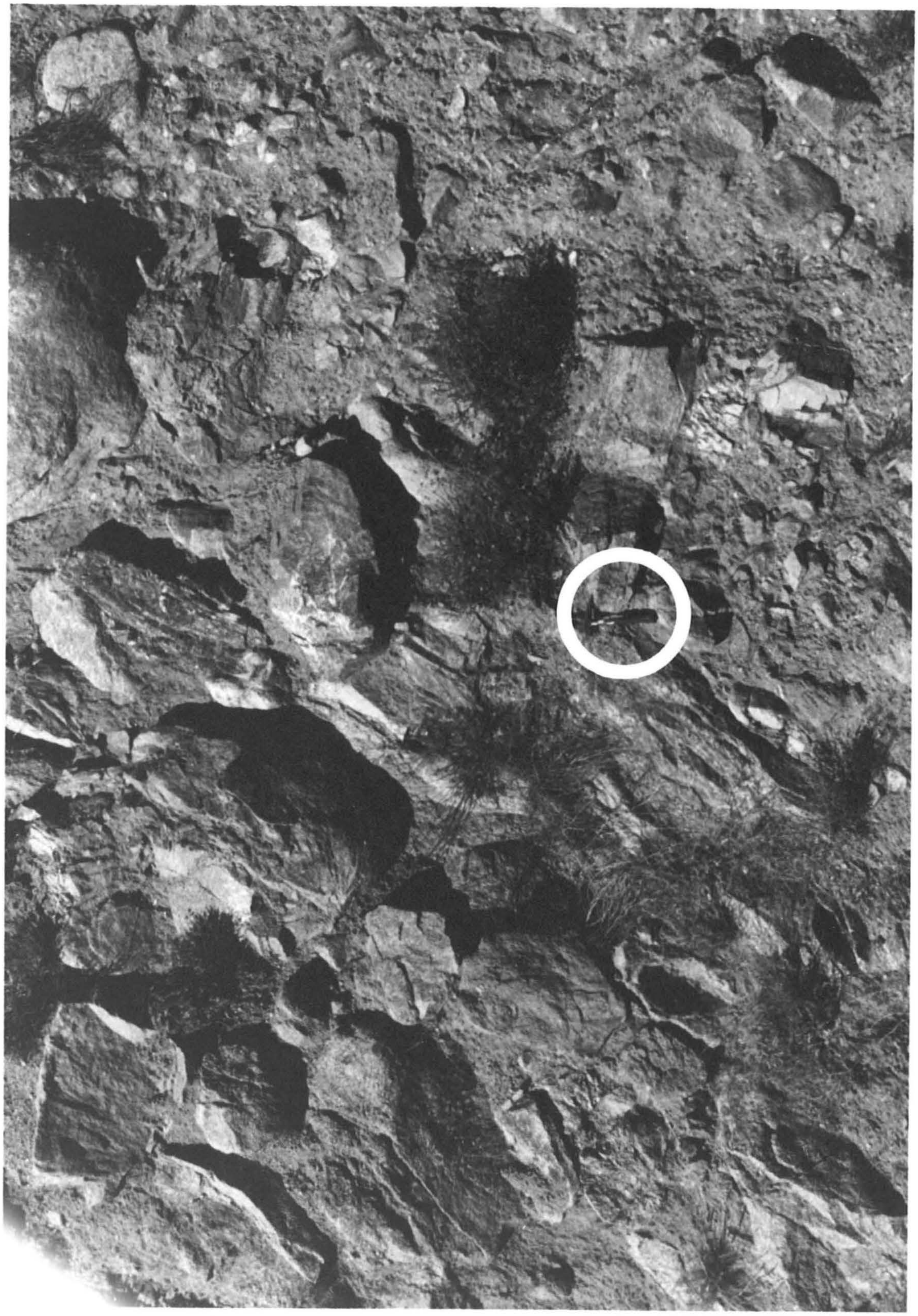


Figure 13. Typical vertical sequence in the lower portion of Member C. Letters indicate repetition of lithologic description.

Upper Portion of Member

The coarse sedimentary rocks of Member C generally exhibit well-defined layering in the stratigraphically highest exposures of the member. Orange-pink (5 YR 8/4) cobble to boulder conglomeratic sandstone (65 percent) alternates with light brown (5 YR 6/4), medium- to very coarse-grained sandstone (30 percent). A few thin, dark reddish-brown (10 R 3/4) limonitic (?) mudstone (5 percent) layers are situated between conglomerate and sandstone units. Massive conglomerate units range from 1-5 m in thickness and average 2-3 m. Sandstone units are commonly up to 3 m thick (averaging 2 m) and contain individual beds of about 1 m. At outcrop scale, tabular units with planar, well-defined upper and lower contacts are most common. Rare occurrences of channeling 2-3 m wide and about 1.5 m deep are known within the upper portion of the member. The maximum clast size observed within this part of the member is about 2.5 m in diameter. Numerous boulders approximately 1.5-2.5 m in diameter are present and the average size is about 0.2-0.5 m (Fig. 14). Conglomerate boulders frequently occur as matrix-supported floating clasts. Coarse- to very coarse-grained sandstone, sometimes with 20-40 percent admixed mudstone, forms a matrix for the poorly sorted conglomeratic units. Interbedded sandstone units are generally coarse- to medium-grained, usually devoid of muddy sediments, and moderately to poorly

Figure 14. Granitic-boulder conglomerate of Member C exposed in roadcut along Highway 33 about 2 km southeast of the mapped area. Hammer in circle shows scale.



sorted. Clast composition in conglomerate units reflects a dominance of rounded to well rounded granitic and metamorphic types. A minor quantity of rounded sandstone clasts that seem to increase in abundance southwestward toward the Ozena fault is apparent. A few well rounded volcanic clasts, some showing evidence of secondary rounding along fractured edges, are found locally. Sandstone matrix and interbeds are composed of subangular to subrounded arkosic grains.

Hard, limonitic layers with thin, wavy laminations are situated between sandstone and conglomerate units and closely follow surface irregularities of the underlying beds. About 10-15 percent coarse sand- to granule-sized grains are interspersed within the limonitic (?) layers. Some of the rounded cobbles which protrude into the limonite (?) layers from the underlying conglomerate have shiny, limonite(?)-coated surfaces.

Distinctly stratified rocks of the upper portion of Member C are arranged in alternating layers of poorly sorted boulder conglomerate and moderately sorted sandstone (Fig. 15).

Interpretation of Depositional Environment

Lower Portion of Member

Exposures of the lower portion of Member C exhibit a predominance of crudely bedded conglomerate (facies code Gm, Table 2) and medium- to coarse-grained sandstone

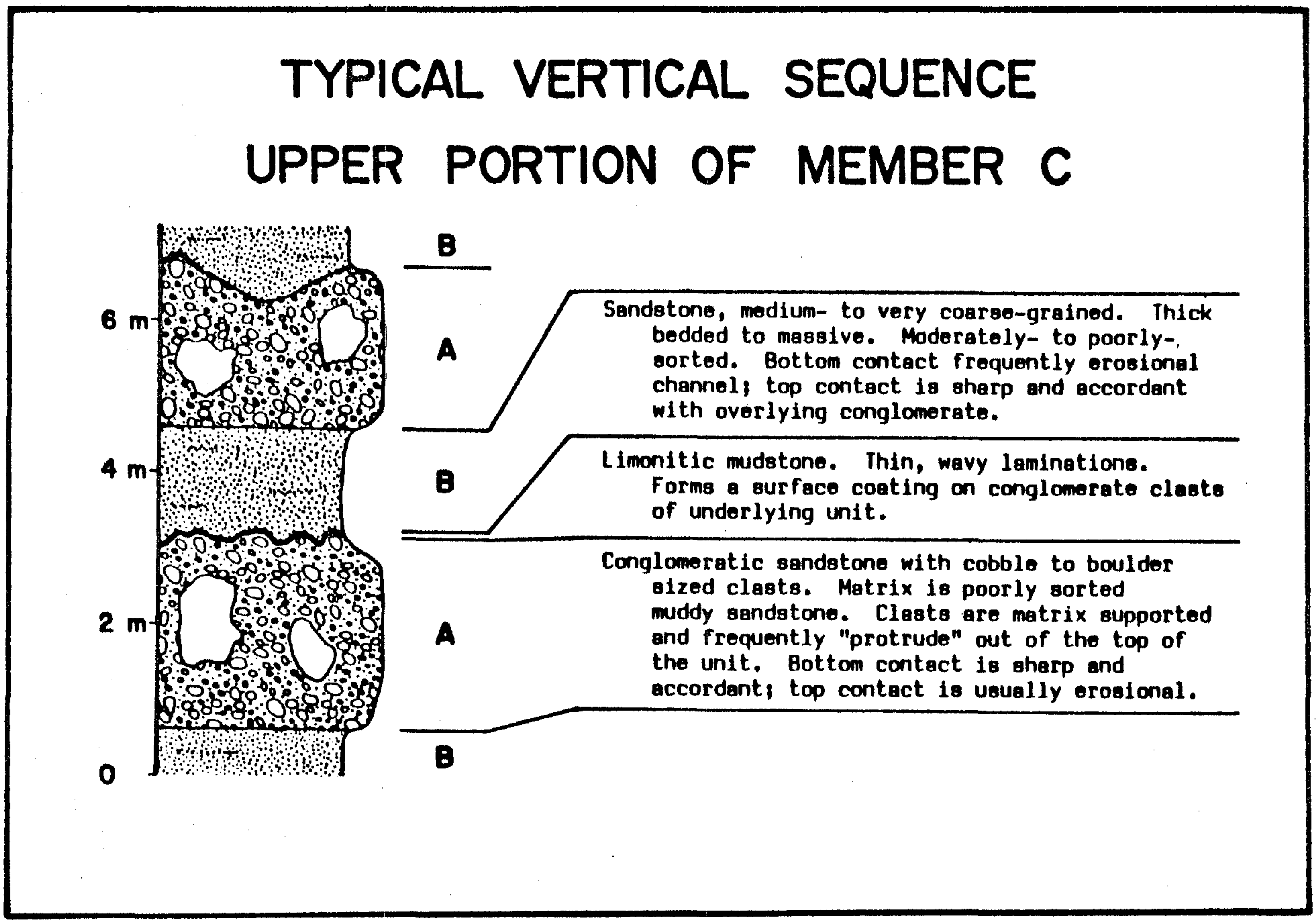


Figure 15. Typical vertical sequence in the upper portion of Member C. Letters indicate repetition of lithologic description.

(facies code St and Sp). Fine-grained mud rocks (characteristic of facies Fm and Fl) are absent from this portion of the member. The presence of these facies suggests that the rocks of this portion of Member C may belong to the Donjek type assemblege of Miall (1977 and 1978b)(Fig. 9) which corresponds to type G_{II} of Rust (1978b)(Table 3).

The Donjek type assemblege is considered to originate from proximal streams (including alluvial fans) with stream flows, rather than debris flows (Miall, 1978b). Water-laid proximal river and alluvial fan deposits commonly display abundant scour-and-fill structures and crudely developed parallel bedding is rather common in pebble-sized sediments (Reineck and Singh, 1975). Where stream activity is common, pebble-sized sediment forms channel lag deposits and fining-upward sequences result from channel migration during floods (Reineck and Singh, 1975).

Several authors have reported on water-laid deposits of alluvial fans (Hooke, 1967; Bull, 1972; Spearing, 1974; Collinson, 1978a; Rust, 1979) and their work has resulted in the recognition of three types; sieve, sheet-flood, and stream-channel deposits.

Typical Recent sieve deposits consist of massive, well-sorted, clast-supported gravel beds with poorly defined contacts (Hooke, 1967; Bull, 1972; Spearing, 1974; Collinson, 1978a). Rocks of the lower portion of Member C do not exhibit these characteristics, however, this apparent lack of sieve deposits in the member might be expected because Bull (1972, p. 69) points out that sieve deposition is rare on alluvial fans.

According to Rust (1979, p. 11) the last two types, sheet-flood and stream-channel deposits, can rarely be distinguished from each other in ancient sequences because channel dimensions are commonly greater than those of outcrops. The presence of channels in the rocks of the lower portion of Member C suggests that stream-channel deposition probably occurred.

Upper Portion of Member

Exposures of the upper portion of Member C exhibit numerous beds of massive, matrix-supported conglomerate (facies code Gms, Table 2) and crudely bedded conglomerate (facies code Gm). Medium- to very coarse-grained sandstone (facies code St and Sp) and local mudstone layers (facies code Fm) are also represented. The presence of these facies suggests that the rocks of this portion of Member C may belong to the Trollheim type assemblege of Miall (1978b)(Fig. 9) which corresponds to type G_I of Rust (1978b)(Table 3).

The Trollheim type assemblege is considered to originate in proximal streams (predominantly alluvial fans) subject to debris flows (Miall, 1978b). Modern debris flows which consist of poorly sorted deposits of chaotically oriented cobbles and boulders, commonly in excess of

1 m in diameter, set in a matrix of fine-grained material (Bull, 1972; Spearing, 1974; Reineck and Singh, 1975; and Collinson, 1978a), are comparable with conglomerate units found in the upper portion of Member C (Fig. 15). Clasts which protrude from the top of Member C debris-flow units typify debris-flow deposits (Bull, 1972). Individual debris-flow deposits, like those observed in the study area, typically range in thickness from 30 cm or less to several meters (Spearing, 1974; and Bull, 1972).

Debris flows, such as those found in the upper portion of Member C, are particularly characteristic of alluvial fans (Rust, 1979) and when considered in conjunction with the associated rocks they provide excellent environmental indicators. As typically occurs on alluvial fans, debris-flow units are interbedded with and in distinct contrast to water-laid sediments (Rust, 1979; and Bull, 1972). This variety of interbedded depositional types is typical of the upper portion of Member C and is a distinctive feature of alluvial fan deposits (Bull, 1972). The interbedded water-laid sediments found in the upper portion of Member C display textural characteristics similar to those of the sheet-flood deposits of Bull (1972, p. 66-68).

In keeping with the interpreted depositional environment, the observed limonitic (?) layers between sedimentation units may be subaerially formed desert varnish or ferrugenous crusts. It is also possible that the ferrugenous horizons could have accumulated as a result of diagenetic alteration.

Environmental Summary

The present stratigraphic relationship of the upper and lower portions of Member C represents the basinward progradation of alluvial fan deposits. The association of traction-flow deposits in the lower portion of the member with debris-flow deposits in the upper portion of Member C is supportive of a postulated alluvial fan origin. In those alluvial fans where both debris-flow and traction-flow deposits are present, the proportion of debris-flow to traction-flow deposits decreases down-fan from the apex (Bull, 1972, p. 81; and Hooke, 1967, p. 453). This situation suggests that the terms proximal and mid fan should be used in describing the upper and lower portions of Member C, respectively. The term alluvial fan, however, implies a specific geometry, a factor for which available exposures of Member C do not allow interpretation. Therefore, it should be recognized that additional data on the overall geometry of the lithologic units is needed before the deposits of Member C can be attributed with certainty to an alluvial fan origin.

The probable alluvial fan deposits of Member C interfinger laterally with the stream deposits of Members A and B which in turn grade laterally into the sabkha deposits of Members A and B. Hence Members A, B, and C represent a progradational alluvial fan/wadi stream/sabkha sequence, a modern analog of which is the Arava Valley between Israel and Jordan (Amiel and Friedman, 1971).

MEMBER D

Introduction

Member D is composed of yellowish-gray, pebble to boulder conglomerate and sandstone. These rocks crop out in a narrow band along nearly the entire southwestern edge of the study area northeast of the Ozena fault. Owing to its limited degree of induration, the member generally exhibits poor quality exposures. Artificial cuts, local steeply eroded cliffs, and scoured canyon bottoms provide the only good outcrops. Cobble- and boulder-strewn, soil-covered slopes of the member usually support only sparse vegetative cover.

Due to the poor quality of exposures, the exact relationship of Member D to the other members of the Simmler is uncertain. In the Santa Barbara Canyon area, conglomerate of Member D seems to rest on horizontal beds of Member F with as much as 40 degrees of angular discordance (Fig. 5). Southeast of Santa Barbara Canyon, Member D may interfinger with rocks of Member B. Everywhere observed, Member D is in fault contact with early Tertiary marine rocks along the Ozena fault. A maximum exposed stratigraphic thickness of about 200-250 m is likely for the member, although accurate determination is not possible on such limited exposures.

Lithology

Exposures of Member D generally exhibit massive beds of grayish-orange (10 YR 7/4) to yellowish-gray (5 Y 7/2), poorly sorted, pebble to boulder conglomerate (80-95 percent) with coarse- to fine-grained sandstone and conglomeratic sandstone (5-20 percent). Beds vary from tabular to lenticular in shape. Where crude stratification is apparent, beds are commonly 0.5-1 m thick. Angular to subangular (some rounded) clasts of sandstone and siltstone predominate (Fig. 16). A very small percentage of second cycle granitic and volcanic clasts are present. The maximum clast size observed during this study was about 1.5 m in diameter, although sandstone boulders up to 3 m have been reported (Vedder, 1968). Conglomerate clasts of Member D usually have a closed to condensed (Pettijohn, 1975, p. 72-76) framework.

Massive beds of clast-supported conglomerate contain locally interbedded layers of sandstone and conglomeratic sandstone. Due to the lack of good exposures, characteristic repetative vertical sequences are not recognizable within Member D.

Interpretation of Depositional Environment

Rocks of Member D consist of massive, commonly clast-

Figure 16. Photograph of boulder conglomerate and breccia of Member D near Santa Barbara Canyon.

supported conglomerate (facies code Gm, Table 2) with a massive sandstone matrix. This single facies by itself does not appear to be characteristic of any of Miall's (1978b) or Rust's (1978b) principal facies assemblages (Fig. 9). A modern example of such a deposit, however, has been described by Friedman and Sanders (1978) at the base of a fault scarp along the western edge of the Dead Sea on the Sinai Peninsula. In this modern example, spall weathering along joint systems in an arid climate generates large, angular to rounded boulders that fall or slide down steep slopes and form piles of closed-framework, boulder conglomerate (Friedman and Sanders, 1978). Similar talus or scree deposits are commonly found along steep cliffs in the southwestern portion of the United States. In fact, such talus deposits have recently formed along the present trace of the Ozena fault within the study area.

The distribution of the rocks of Member D near the trace of the Ozena fault suggests that these rocks represent talus deposits which accumulated along the flanks of the ancestral Sierra Madre Mountains (San Rafael uplift of Corey, 1954) as a result of erosion of the scarp of the Ozena fault. Rocks of Member D probably were deposited throughout most of "Simmler time" and are likely to have interfingered with most of the other members of the Simmler Formation in the study area.

MEMBER E

Introduction

Sedimentary rocks of Member E are composed of pink to yellowish-gray sandstone, conglomerate, and mudstone. Locally, beds of nodular gypsum and veins of selenite are common in the member.

Rocks of Member E are exposed only in the eastern portion of the study area, from "Gyp Canyon" eastward to "Elliott Canyon". Exposures of Member E are usually of moderate quality, however, a few well-exposed sections crop out along active drainage courses. Sparse vegetative cover grows on thinly soil-covered slopes of the member.

Although Member E is lithologically similar to rocks of Member F and rocks of the southeastern portion of Member B, its generally light pink coloration serves to distinguish it from these units. The basal gradational contact of Member E with the underlying Member B occurs where pink-colored, coarse-grained sedimentary rocks of Member E predominate over gray-colored, fine-grained rocks of Member B. Along this lower contact the two members probably interfinger (Fig. 5). Due to faulting, the upper stratigraphic boundary of Member E is not present within the study area. Based on stratigraphic position and strong similarities in lithologic character between Members E and F, it is suspected that these members are laterally equivalent and may locally interfinger with each other. The most likely area for this postulated interfingering to occur is between "Gyp Canyon" and Pato Canyon, although limited exposures preclude direct examination of the relationships.

Due to the lack of exposure of the upper stratigraphic limits of Member E, only an estimation was made of the maximum exposed thickness, which is about 425 m in the vicinity of "Elliott Canyon". Available exposures suggest a reduction in thickness toward the northwest where Member E lenses out east of Santa Barbara Canyon (Vedder, 1968).

Lithology

Rocks of Member E are well-stratified interbeds of pale reddish-brown (10 R 5/4), to moderate orange-pink (10 R 7/4), and yellowish-gray (5 Y 7/2), coarse- to fine-grained sandstone (75-85 percent), pebble to boulder conglomerate (10-20 percent), and mudstone (5-15 percent). Lithologic units are usually tabular, but small-scale lensing of individual beds, particularly conglomerate and mudstone, is common.

Lenticular-shaped conglomeratic units attain a maximum thickness of about 2-3 m, averaging 1 m or less. Bedding within conglomeratic units is commonly less than 50 cm thick. Lenses of conglomerate with lateral dimensions of less than a few meters are often concentrated and have a closed framework along the bases of channels. The maximum dimension of conglomerate clasts is 0.9 m. Clasts are composed of subrounded to rounded sandstone (50-80 percent) and well-rounded granitic/metamorphic rocks (20-50 percent).

Coarse- to fine-grained lithic arkose to arkose forms sandstone interbeds and matrix for conglomerate. Tabular sandstone units range from 0.3-4 m thick and average about 0.5-1 m. Individual sandstone beds are a few millimeters to decimeters thick. Parallel bedding, small-scale cross bedding, graded bedding, channeling, and scour marks are abundant. Locally, current and parting lineations, ripple marks, and mudcracks (?) are present.

Massive to poorly stratified units of mudstone, usually less than 30 cm thick, locally attain a thickness of 2-3 m. Mudstone is present as tabular and lenticular interbeds within sandstone and conglomeratic sequences. Mudstone commonly has a scoured and eroded upper contact. The commonly mottled and disrupted character of mudstone interbeds may have been caused by animals and plants which left their traces as possible burrow and root structures.

Gypsum veins are common throughout Member E. In the eastern portion of the study area, gypsum is exposed within the member on "Gypsum Hill", where nodular gypsum beds a few centimeters thick are interbedded with mudstone and fine-grained sandstone. Locally, alabaster layers are laminated between mudstone beds.

Rocks of Member E generally are arranged in fining-upward sequences of conglomerate, sandstone, and mudstone identical to those described below in Member F (Fig. 20). An erosional channel surface usually is present at the base of a typical sequence. Overlying the erosional basal surface is poorly stratified, closed-framework, conglomeratic sandstone. Stratification of conglomerate clasts is better defined a few decimeters above the base of a sequence, where coarse-grained sandstone matrix is more abundant than clasts. A gradual fining upward continues in the sequence through medium- and fine-grained, massive, cross-bedded, and parallel-bedded sandstone layers. Complete sequences are capped by mottled to massive, bioturbated (?) and locally mudcracked (?) beds of mudstone.

Interpretation of Depositional Environment

Rocks of Member E consist predominantly of horizontally bedded sandstone (facies code Sh of Miall, 1978b) (Table 2) with some low-angle cross-bed sets (facies code Sl). Erosional scours (facies code Se), fine- to coarse-grained sandstone (facies code Ss), and mudstone (facies code Fsc and Fr) also occur. The presence of these facies suggests that the rocks of Member E may belong to the Bijou Creek type assemblege of Miall (1978b)(Fig. 9), type S_I of Rust (1978b)(Table 3), and lithofacies #2 of Jackson (1978)(Table 4).

These assembleges are considered to originate from ephemeral streams subject to flash floods (Miall, 1978b). Well-stratified units in Member E which, except for conglomerate beds, are not markedly lenticular at outcrop scale typify the member and support a low-sinuosity meandering stream interpretation like that postulated for the southeastern portion of Members A and B.

Rocks of Member E differ from those of the south-eastern portions of Members A and B in that Member E rocks contain local occurrences of nodular gypsum. Small, seasonal sabkha-like lakes which can contain dissolved sulphates such as gypsum are found in deflation hollows on modern stream flood-plains (Reineck and Singh, 1975; Collinson, 1978b). The thin gypsum beds found in Member E may have originated in such a manner. Alternatively, the gypsum deposits of Member E may represent the local inter-fingering of sabkha sediments derived from southeast of the study area with the stream deposits of Member E.

Rocks of Member E also differ in color from those of Member B. These color differences may be related to variations in ground water characteristics which determine the oxidation/reduction potential of the site of deposi-tion. As noted by Friedman and Sanders (1978), flood plains may range from those which are well drained, sub-aerially exposed flats to swamps which are always under water. The typical pink color of Member E is due to the presence of hematite and limonite within the rocks. A discussion of the formation of red-bed pigments is in the description of Member F. The pink rocks of Member E probably were deposited in a slightly oxidizing environment. Perhaps a seasonally fluctuating ground water table, coupled with the relatively permeable nature of the rocks typically found in Member E, may have allowed for the characteristic pink, rather than dark red, coloration.

Pebble counts show a predominance of sedimentary clasts identical to those found in nearby early Tertiary rocks that presently crop out south of the trace of the Ozena fault. This difference in clast type from Members A, B, and C indicates a change in the source terrain for Member E.

MEMBER F

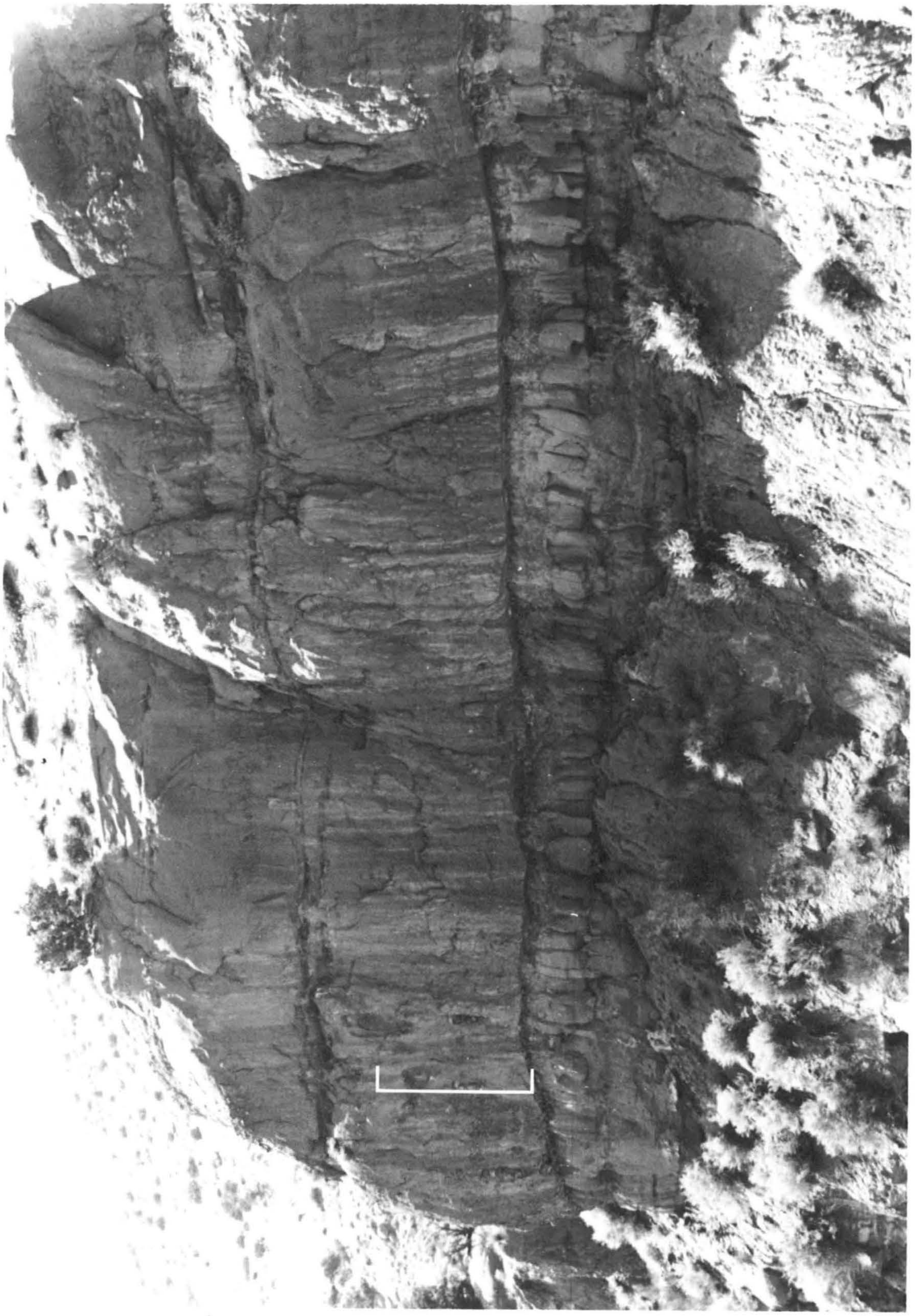
Introduction

Rocks of Member F consist of interbedded reddish-brown sandstone, conglomerate, and siltstone. Locally, nodular calcareous beds crop out within the member.

Member F is exposed only in the western half of the study area from Santa Barbara Canyon eastward to Pato Canyon. The member is deformed into broadly folded, gently plunging anticlines and synclines that are laterally truncated by faulting. Exposures of Member F are usually of good quality due to the resistant, cliff-forming nature of its sandstone and conglomerate interbeds (Fig. 17). Only sparse grasses and yucca grow on the relatively steep, thinly soil-covered slopes of the member.

Lateral and vertical relationships between Member F and surrounding rocks are obscurred by lack of exposure and soil cover within the study area. The distinctive red coloration of Member F is used to distinguish it from surrounding rocks. The lower stratigraphic boundary of the member is placed at the distinct but apparently interfingering contact with Member B, where reddish-colored coarsely conglomeratic sandstone overlies gray mudstone. In Rainbow Canyon, Member F unconformably overlies undifferentiated Eocene marine rocks (Vedder, 1968). At its upper contact, exposed in Santa Barbara Canyon, Member F is overlain by and interfingers with olive-colored sandstone and mudstone rocks of Member G. The distinctive contrast in color between Members F and G forms a sharp boundary. Due to its lenticular nature, Member G is locally absent above Member F. Where Member G is missing, a sharp, apparently conformable contact between Member F and the overlying varigated mudstone of Member H is formed. Detailed mapping in the Fox Mountain quadrangle suggests that Member F interfingers laterally with Members B, D, E, and G (Vedder, 1968). About 1.8 km west of Santa Barbara Canyon Ranch, an angular discordance of about 40 degrees is observed between flat lying Member F and an overlying

Figure 17. Exposure of Member F sandstone and siltstone beds near the Santa Barbara Canyon Ranch. Note bar scale at left is approximately 2 m long.



tongue of Member D. A few lenticular units of olive-colored sandstone and mudstone within Member F may belong to Member G. In the area east of the Fox Mountain quadrangle, Member E replaces Member F stratigraphically above Member B, thus suggesting the possible lateral equivalence of Members E and F.

The only location within the study area where there is a complete exposure of both the top and bottom of Member F is in Santa Barbara Canyon. Based upon approximate measurements, a maximum exposed thickness of about 275 m is attained in Santa Barbara Canyon, between undifferentiated Eocene rocks and Member G. From Santa Barbara Canyon, the member pinches out both eastward and westward (Vedder, 1968).

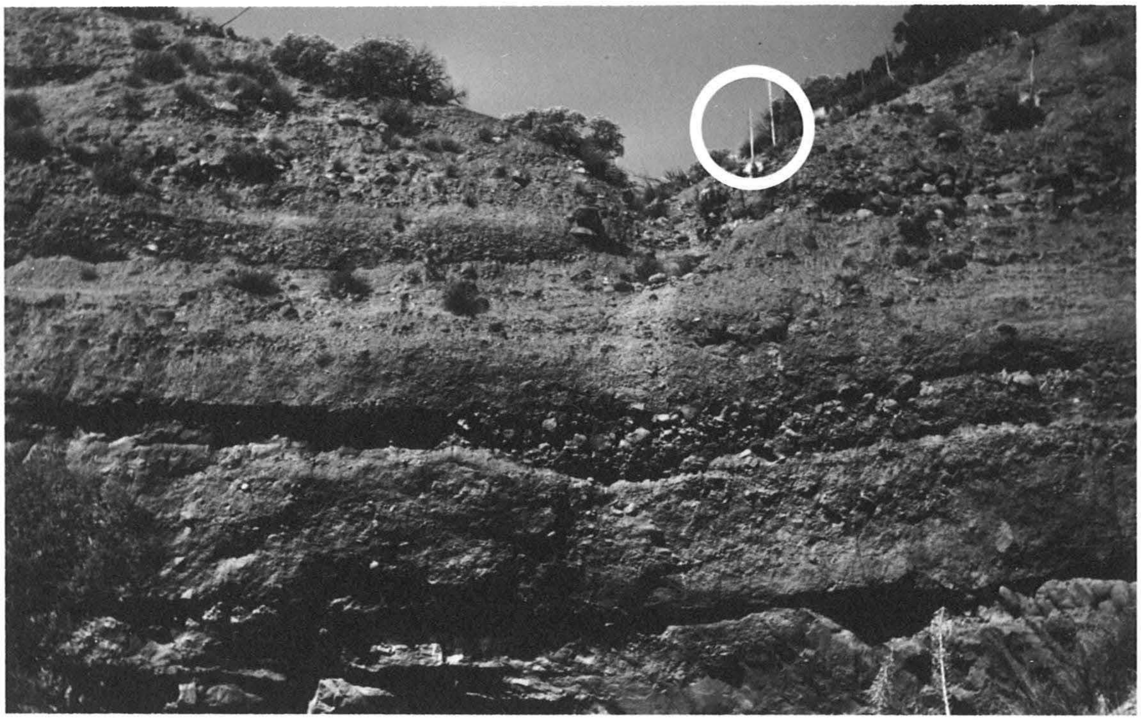
Lithology

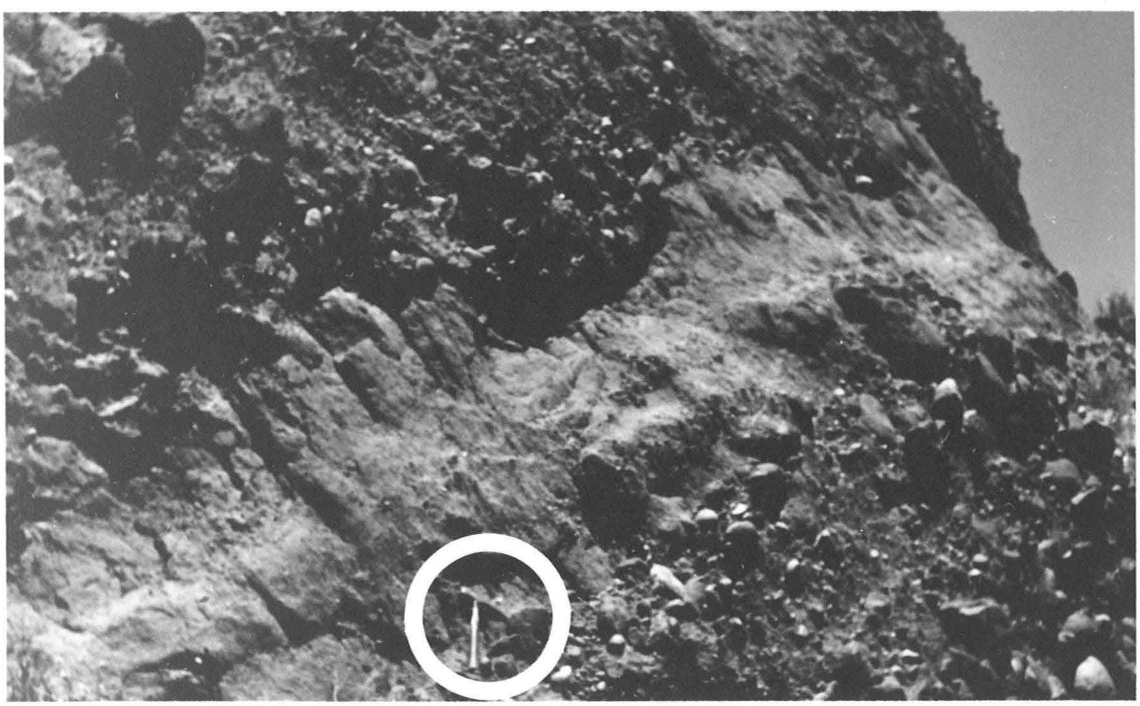
Member F is a well stratified, interbedded, moderate reddish-brown (10 R 4/6), pale reddish-brown (10 R 5/4), and grayish-red (10 R 4/2), coarse- to medium-grained sandstone (60-75 percent), pebble to boulder conglomerate (20-40 percent), and fine-grained sandstone or siltstone (5-15 percent). The units generally are tabular in shape, but small-scale lensing of individual beds is common (Fig. 18).

Conglomeratic layers, usually lenticular in shape, attain a maximum thickness of about 3 m, averaging 1 m or less. Individual beds of conglomerate clasts 10-50 cm

Figure 18. Sandstone and conglomerate beds of Member F near Santa Barbara Canyon. Note the lenticularity of the beds and the channel near the center of the photo. Yucca plants (circled) at top of photo (about 1.5 m high) provide scale.

Figure 19. Exposure of sandstone and conglomerate of Member F in "Gyp Canyon". Note conglomerate-filled channel cut into the underlying sandstone bed directly above hammer (circled).





thick are common within the otherwise massive units. Conglomerate occurs below medium- to coarse-grained sandstone units and in many places is concentrated in the bottoms of channels, some of which are over 6 m wide and 1.5 m deep (Fig. 19). In small channels, clasts have a matrix-supported framework, whereas in large channels they have a clast-supported framework. The largest clasts at each exposure consist of subrounded to rounded sandstone. Well rounded granitic, metamorphic, and volcanic clasts are commonly smaller than the average clast size.

Coarse- to medium-grained lithic arkose to arkose forms both sandstone interbeds and matrix for conglomerate. Tabular sandstone units range from 0.5-3 m thick and average about 1 m. Individual sandstone beds, where recognizable in the otherwise predominantly massive units, are a few centimeters to decimeters thick. Conglomeratic lenses and sandstone layers commonly are interbedded with each other throughout vertical intervals of 6-8 m with no intervening siltstone units. Small-scale cross bedding, parallel bedding, graded bedding, and channeling are abundant. Locally, scour marks and rip-up clasts are common. Numerous tubular-shaped structures, about 5 mm in diameter and over 30 cm long, are probable root fossils.

Interbedded with tabular sandstone and conglomerate units are 0.1-2.5-m-thick, fine-grained sandstone to siltstone beds. These fine-grained interbeds usually are massive and commonly mottled. The presence of numerous burrows (?) or root structures (?) about 2.5 cm in diameter, probably accounts for the lack of well defined stratification.

Although no vertebrate fossil remains from the Simmler were found during field work for this project, it is reported that jaw fragments of the camel _Oxydactylus_ cf. _O. exilis_ Matthew have been found at two localities within Member F (Vedder, 1968).

Rocks of the member are arranged in fining-upward sequences varying from coarse conglomerate at the base to fine-grained sandstone and mudstone at the top (Fig. 20).

Interpretation of Depositional Environment

Exposures of Member F exhibit a predominance of tabular, parallel-bedded and cross-bedded sandstone (facies codes Sh and Sl of Miall, 1978b)(Table 2), with erosional scours, massive fine-grained sandstone, and siltstone (facies codes Se, Fsc, and Fm). The presence of these facies suggests that the rocks of Member F may belong to the Bijou Creek type assemblege of Miall (1978b)(Fig. 9) which corresponds to type S_I of Rust (1978b)(Table 3) and lithofacies #2 of Jackson (1978)(Table 4).

These assembleges are considered to originate from ephemeral streams subject to flash floods (Miall, 1978b). Well-stratified, tabular, lithologic units in Member F support a low-sinuosity meandering stream interpretation

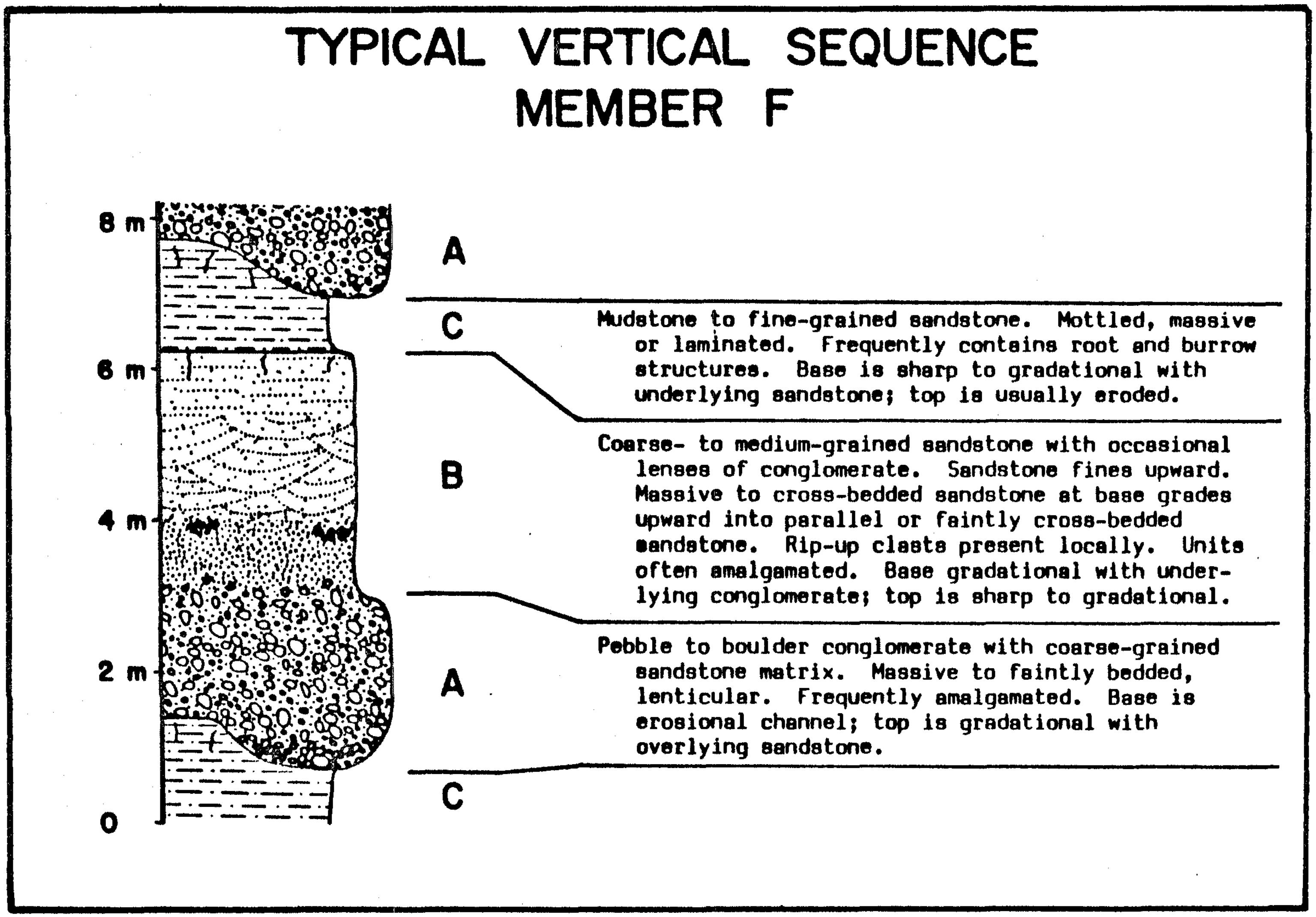


Figure 20. Typical vertical sequence in Member F. Letters indicate repetition of lithologic description.

like that postulated for Member E and the southeastern portions of Members A and B. Rocks of Member F differ from the other fluvial members of the Simmler in that they contain more coarse-grained and conglomeratic units, they contain a predominance of sedimentary clast types, and they are a pronounced dusky red color.

The presence of significant quantities of large clasts suggests a nearby source area for the sediments of Member F and requires that strong transporting currents were operative. The lack of claystone and other mudrocks in Member F may indicate that the rocks of Member F were deposited more near their source area than the other fluvial members of the Simmler. Pebble counts from Member F reflect an abundance of sedimentary clasts like those found in Member E, thus supporting the hypothesis that north-flowing streams drained an early Tertiary sedimentary source terrain.

The dusky-red coloration typically found in the rocks of Member F is due to the presence of clay-sized particles of hematite and limonite that stain the grain surfaces and small, rounded lumps of fine-grained hematite and limonite found in some places within sandstone beds. At present it is proposed that red-bed pigments can form by the following five mechanisms (Friedman and Sanders, 1978):

1. The hematite is formed in a lateritic soil in a humid-tropical climate and is physically transported to the depositional site where it is not

subject to any further major changes.

2. Same as number 1, but formation of hematite continues at the site of deposition by further alteration of iron-bearing minerals.
3. The hematite forms over a long period in a hot, arid climate by _in situ_ alteration of minerals which contain ferrous iron.
4. The hematite is derived from a pre-existing red-bed unit and exists as second-cycle particles.
5. The hematite is precipitated directly out of sea water during the initial stages of evaporation.

In light of the postulated fluvial origin of the members, mechanism 5 seems unlikely. The absence of red coloration within the assumed source rocks suggests that mechanism 4 is also unlikely. The presence of aggregates of fine-grained hematite and limonite suggests that transportation of some of the red pigment occurred, and the presence of highly altered and sutured iron-bearing minerals indicates that _in situ_ formation also took place. Such evidence is supportive of mechanism 2, but the presence of evaporative minerals and duracrusts in other members of the Simmler suggests that an arid to semi-arid paleoclimatic setting, typically found where mechanism 3 is operative, may be more likely. In view of the interpreted deltaic setting discussed in Member G, it is possible that *in situ* alteration of iron-bearing minerals may have been promoted by the presence of a shallow ground water table commonly found on such deltaic plains. Near-surface genesis of iron oxide minerals and subsequent erosion, transportation, and deposition by river floods could have produced the observed deposits. The fact that the dusky-red coloration is best developed in Member F of the Simmler and not so well developed in the other members appears to be supportive of this ground water *in situ* alteration hypothesis. It is also possible that the abrupt color change from brown and gray in Members B, C, and D to pink and red in Members E and F may have been related to the source area. Perhaps the early Tertiary sedimentary source rocks for Members E and F may have provided more iron minerals than the granitic source rocks for Members B, C, and D. Unfortunately, no knowledge of the climatic conditions that prevailed during the deposition of Member F can be inferred from the presence of the red beds alone.

MEMBER G

Introduction

Rocks of Member G consist of olive-green sandstone, conglomerate, and mudstone. These rocks crop out within the study area west of Pato Canyon. Member G is well exposed in the Santa Barbara Canyon area in nearly vertical, vegetation-free cliffs (Fig. 21). Eastward from there, near "Wagon Road" and Pato Canyons, the rocks are obscured by soil and sparse vegetative cover. Usually, Member G is easily distinguished from surrounding members of the Simmler by its distinctive olive-green color. The lower contact is recognized at the color change from the dusky red of the underlying Member F to the olive-green color of Member G. The upper contact is drawn at the highest occurrence of olive-green sandstone and conglomerate, below varigated mudstone and limestone of Member H.

Although complete sections of Member G are rare within the study area, a maximum exposed thickness of about 50 m crops out in Santa Barbara Canyon. The lenticular-shaped Member G thins to zero thickness so that locally Member H rests directly upon Member F (Vedder, 1968).

Lithology

Rocks of Member G consist of light olive-brown (5 Y 5/6) to moderate yellowish-brown (10 YR 5/4), medium- to coarse-grained sandstone (50-60 percent) and cobble to boulder conglomerate (30-35 percent) interbedded with mottled, moderate reddish-brown (10 R 4/6) and pale olive (10 Y 6/2) mudstone (10-15 percent). Well-exposed outcrops of Member G display moderately well-defined stratification recognizable by grain-size variations. Massive conglomerate lenses range from 0.3-3 m thick, averaging 30-60 cm. Evidence of erosional scour is present at the base of many

Figure 21. Photograph of Members F, G, and H, and overlying Painted Rock Sandstone Member of the Vaqueros Formation west of the Santa Barbara Canyon Ranch.


VAQUEROS FM.
MEMBER H
MEMBER G
MEMBER F

conglomerate units. Mudstone intraclasts about 0.1-1 m in diameter are common in conglomerate beds. Conglomerate clasts reach a maximum diameter of about 1 m with an average of about 5 cm. Rounded to subrounded clasts, commonly with closed framework, are embedded in a matrix of medium- to coarse-grained sandstone. Conglomeratic clasts consist of over 80 percent sedimentary rocks with about 10 percent volcanics and 10 percent granitic/metamorphic fragments.

Lithic arkose to arkose, which forms the matrix for conglomerate units, is also interbedded with conglomeratic lenses. Medium- to coarse-grained sandstone units are 0.5-2 m thick and contain individual beds 1-30 cm thick. Sedimentary structures include parallel and cross laminations, channels, and scour marks. Subangular to angular, poorly sorted sandstone grains are mixed with rare fragments of broken and abraded bivalves and barnacles (?).

Relatively minor mudstone interbeds are present throughout Member G. Mudstone units commonly are lenticular and range from 0.3-1.5 m thick. Individual beds, which are usually a few millimeters thick, are rarely found intact due to the throughly mottled and disrupted character of the mudstone. Distinct burrows 1-3 m in diameter attest to the biologic disruption of these rocks and account for the mottled texture.

The rocks of Member G are arranged in repetitive, fining-upward sequences as shown on Figure 22.

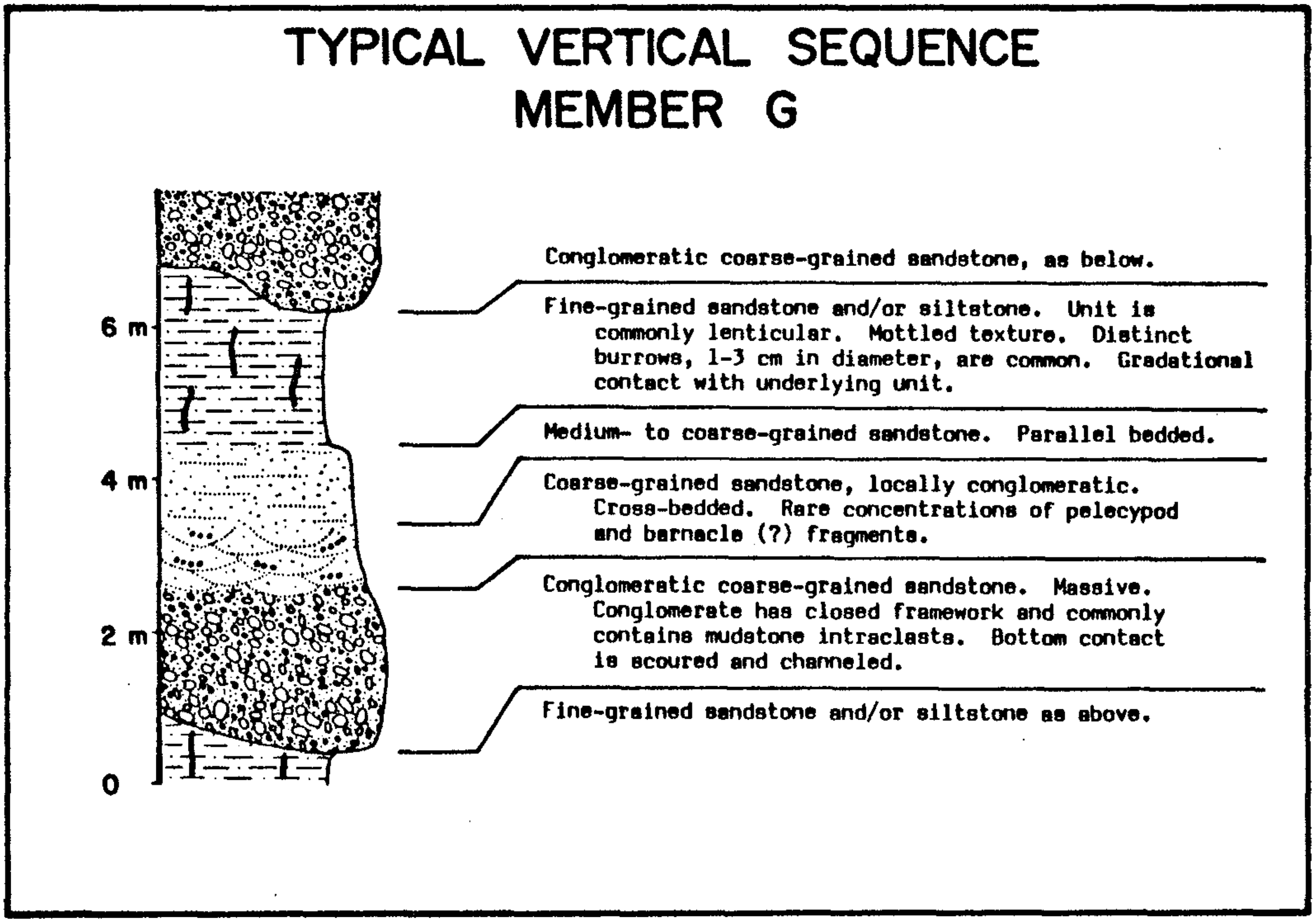


Figure 22. Typical vertical sequence in Member G.

Interpretation of Depositional Environment

Upward-fining sequences similar to those commonly found in fluvial environments are well represented throughout Member G. Lithofacies types Gt, Se, Sh, Sl, and Fsc (Table 2) of Miall (1978b) occur in the member, but do not seem to fit well into any of the classifications of Miall (1978b), Rust (1978b), or Jackson (1978). The presence of marine fossils and bioturbation indicate that at least some of the member is of marine rather than fluvial origin. Also the lenticular shape of the member is unlike the tabular nature of the other fluvial members of the Simmler. If the rocks of Member G, however, are interpreted as subaqueous distributary channels of a delta, then both the fluvial and marine nature of the unit would be accounted for. In order to produce delta deposits a large sediment supply is needed. To satisfy this condition a perennial river, much different from the ephemeral streams of Members A through F, must have been present when Member G was deposited.

Subaqueous distributary channels of modern deltas act as natural flumes to direct a portion of the discharge and transported sediment from the river system to the depositional basin (Fig. 23). Although the channel is considered to be a part of the delta-front environment, it is actually an extension of the main river system to the point where the channel broadens, shoals, bifurcates, and

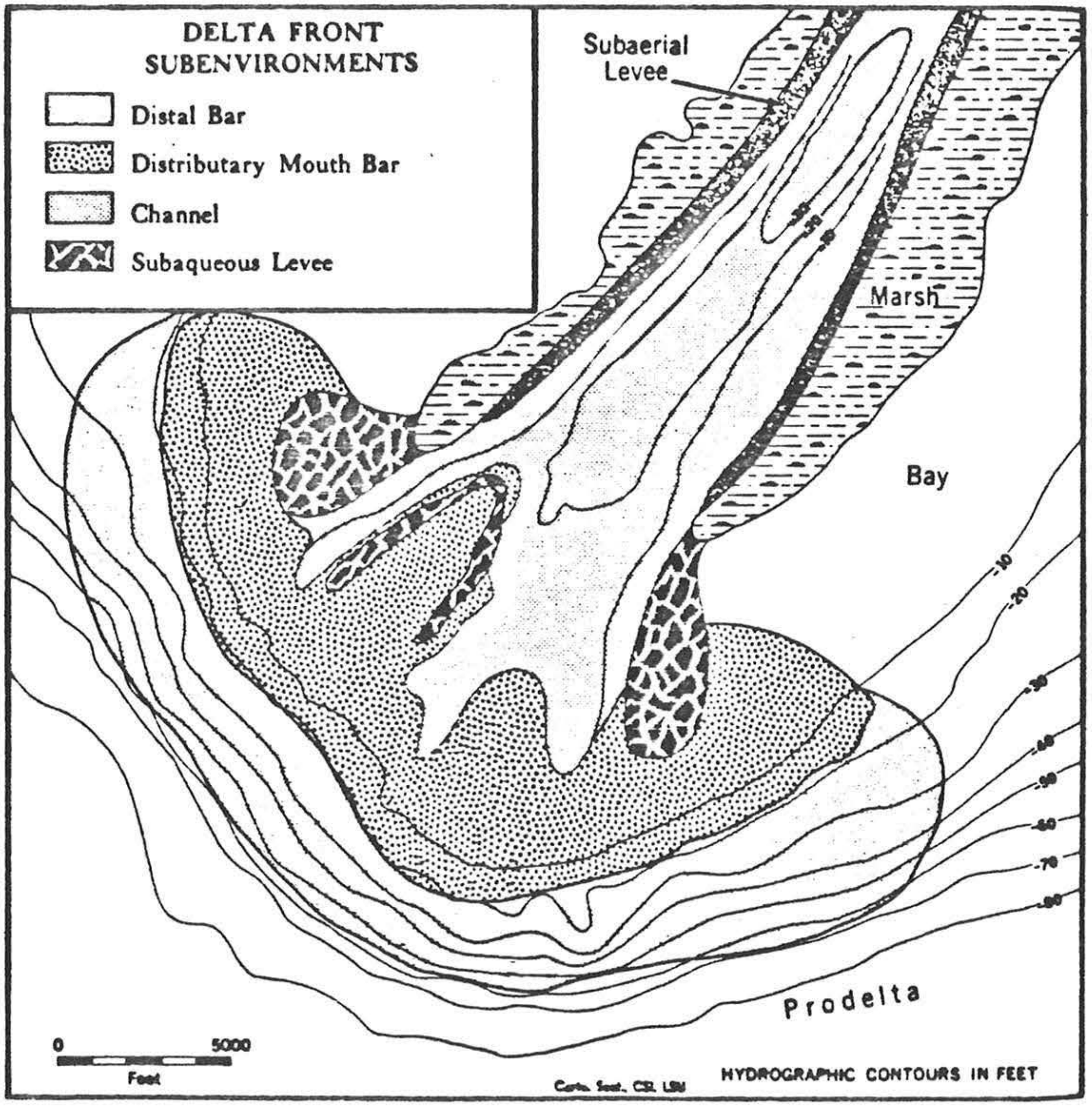


Figure 23. Delta front subenvironments at the mouth of Southwest Pass, Mississippi River delta (from Coleman and Gagliano, 1965, fig. 9).

loses its identity (Coleman and Gagliano, 1965). Coleman (1976) reports that the distributary channels of the Mississippi River are rather stable and thus do not form point-bar or meander-belt deposits. No point-bar deposits are known within Member G rocks and the lenticular shape of the member suggests that stable channels characterized the depositional environment. Channels in Member G are in keeping with typical channel dimensions (less than 2-3 m wide and about a meter deep to 1 km wide and 30 m deep) described by Coleman (1976). Depositional sequences occurred chiefly as a result of channel abandonment. Once abandonment began, the lower portions of the Member G channels were deprived of an active influx of sediment and water, and consequently became filled with poorly sorted gravel, sand, and silt containing transported organic debris. Deposition of finer-grained sediment, such as the fine-grained sandstone and siltstone interbeds of Member G, occurred as the water of the channel became more stagnated and lower velocity currents were maintained (Coleman, 1976). Cross laminations, current-ripple laminations, scour and fill, and erosional truncations, abundant in distributary channel deposits (Coleman and Gagliano, 1965), commonly occur in Member G. Clay layers deposited during low river stage may be eroded during subsequent floods and the numerous angular clay inclusions found in the coarser material of Member G probably are the remnants of such eroded clay layers. The greenish coloration of Member G is typical of the slightly reducing environment that occurs in submerged, delta distributary channels (Donaldson and others, 1970).

MEMBER H

Introduction

The highly variegated Member H consists of purple, red, gray, and brown mudstone, sandstone, limestone, and conglomerate. The member crops out only in the western portion of the study area, in and around Santa Barbara Canyon (Vedder, 1968). A brightly colored, highly variegated crust of clay soil makes Member H easily recognizable from a distance. Almost no vegetation grows on slopes underlain by Member H (Fig. 21).

The upper and lower contacts of Member H are well-exposed in the Santa Barbara Canyon area. The olive-green sandstone and mudstone of Member G interfingers with the lower portion of Member H. The contact is mapped at the distinct change in color and grain size between the members. Locally the lenticular shaped Member G is missing below Member H. In these locations, Member H rests directly on Member F with a sharp, apparently conformable contact. Overlying Member H with apparent conformity is the Painted Rock Sandstone Member of the Vaqueros Formation. The contact is recognized at the highest occurrence of variegated mudstone in Member H below white, calcareous, fossiliferous, coarse-grained sandstone of the Painted Rock. Throughout much of its exposure, the contact is further delineated by a white, siliceous limestone bed beneath the Vaqueros sandstone. A thickness of about 50 m of Member H is exposed in Santa Barbara Canyon.

Lithology

Member H is composed of pale purple (5 P 6/2), light gray (N7), light greenish-gray (5 G 8/1), moderate red (5 R 4/6), moderate yellowish-brown (10 YR 5/4), and white (N9) mudstone (70 percent), sandstone (20 percent), limestone (10 percent), and conglomerate (trace). Stratification in Member H is generally in the form of tabular units ranging in thickness from 0.1 m to over 5 m. A few scattered lenses of conglomerate, 15-45 cm thick, are present within sandstone layers. Clasts, consisting of isolated, rounded, coarse-grained sandstone are up to 15 cm in diameter and average 8 cm.

Greenish-gray, coarse- to medium-grained, calcitic, fossiliferous, lithic arkose to sandy biosparudite units, 0.25-1.6 m thick, occur in the lower one-third of Member H. These beds are massive accumulations of both whole and broken specimens of barnacles, sand dollars, gastropods, and bivalves, mixed with angular to subangular sand grains and thoroughly cemented with spar calcite. The basal surfaces of these beds commonly exhibit erosional scour.

Fine- to medium-grained, light-green to gray, lithic arkose, interbedded with thin siltstone layers, occurs throughout Member H. These units range from 0.5-2.8 m, although they are usually less than 1 m in thickness. Numerous sedimentary structures include small-scale cross laminations, flaser bedding, lenticular bedding, parting lineation, erosional scour, convoluted bedding, and desiccation cracks (?). Evidence of organic activity is common throughout these beds. Burrows 0.1-1.5 cm in diameter are abundant, and some burrows up to 10 cm in diameter are known. About 20 m above the base of the member, a green, fine-grained sandstone bed contains ostracod (?) or immature bivalve (?) shells about 2 mm in diameter. Carbonaceous plant impressions are concentrated locally along sandstone parting surfaces.

Abundant red, green, and brown mudstone units average 1-3 m in thickness with a maximum of 5.8 m and a minimum of 0.1 m. Where recognizable, individual mudstone beds are a few millimeters to 5 cm thick. In most exposures, mudstone is thoroughly mottled and disrupted, displaying little or no primary bedding. Numerous distinct burrows and escape structures are present in the mudstone beds.

At two stratigraphic horizons, one about 7 m above the base of the member and the other within 3 m of the top, are beds of nodular limestone. These beds are white to very light gray in color and are irregular in thickness, pinching and swelling from 0.1-1 m. At each horizon, irregular limestone pods are interbedded with and contain veins and blebs of red and green mudstone.

Along the top contact of Member H is a distinctive pinkish-gray (5 YR 8/1) to white (N9), siliceous, sandy micrite unit about 1-2 m thick that was mapped as a tuff bed by Vedder (1968). This unit is irregularly layered in massive beds a few decimeters to nearly a meter in thickness. Moderately sorted, angular to subangular, quartz and feldspar sand grains about 0.1-0.15 mm in diameter are concentrated in rounded blebs, about 2-5 mm in diameter, of dense micrite, which in turn are scattered throughout a less dense micrite matrix. Locally, the micrite matrix is very siliceous and is almost chert. Tubular, silicified roots (?), 1.5-3.3 mm in diameter, and chert-filled fractures form about 10-20 percent of the rock.

No repetitive typical vertical sequence of strata is apparent for the rocks of Member H. A characteristic predominance of brightly colored, fine-grained mudrocks, with a few interbeds of sandstone and limestone, typifies the member.

Interpretation of Depositional Environment

The predominantly fine-grained sandstone and mudrocks found in Member H indicate that the rocks accumulated in a low energy depositional environment. Beds containing whole and broken shallow-marine fossils are supportive of a marine origin for at least the fossiliferous beds of the member. Distributary channels found in the overlying Vaqueros Formation (Fritsche, pers. comm., 1981) and in the underlying and interfingering Member G suggest an interdistributary bay origin for Member H.

Coleman (1976) describes the interdistributary bay environment of the Mississippi River delta as "areas of open water within the active delta which may be completely surrounded by marsh or distributary levees but which are more often partially open to the sea or connected to it by small tidal channels". According to Coleman (1976), these bays are shallow, brackish to marine water bodies usually less than 4 m in depth. Bay deposits are characterized by fine-grained sediments brought into them during periods of high flood or abnormal high tides associated with the passage of storms. Abundant lenticular laminae in Member H, which rarely extend laterally more than 50 cm, are a product of wave reworking and concentration as a result of flooding by the river (Coleman, 1976). Overbank flooding, involving sheet flow of sediment-laden water over the channel banks, deposits fine-grained, laminated sediment over the entire bay area, although subsequent bioturbation frequently disrupts the laminations (Elliott, 1978). Coarser sediment is confined to the channel margins where it contributes to levee development which results in repeated alternations of thin, erosive-based sand beds (from sediment-laden flood incursions) and silt-mud intervals deposited from suspension)(Elliott, 1978). Current-ripple marks, scour-and-fill structures, and bioturbation are common features. Faunal remains are often abundant within bay deposits (Coleman, 1976). Calcrete development has been reported by Elliott (1978) in association with interdistributary areas of deltas.

The sedimentological and paleontological characteristics of Member H fit the depositional model of the modern interdistributary bay environment described above very well. The interbedded mudrocks and sandstone units represent, respectively, deposition during periods of quiescence and periods of overbank flooding from the deltaic river. Beds of whole and fragmented marine invertebrates could have been transported and deposited by overbank flooding, but probably reflect accumulation during periods of tidal or wave influence on the delta. Bioturbation noted in the member indicates the existance of an abundant fauna and local carbonaceous layers suggest that at least some vegetation grew in the interdistributary areas.

Irregular nodular limestone beds observed within the member as well as the white siliceous micrite bed at the top of the unit, may represent calcrete duracrusts which formed on the delta environment. By comparison with modern environments, a semiarid to subtropical climate is inferred to have been in effect during the formation of the calcrete layers found in Member H (Goudie, 1973).

PALEOCURRENTS

INTRODUCTION

Paleocurrent data for this study were obtained from measurements of flute marks, trough cross-beds, current lineations, channel orientations, scour marks, and foreset beds of small-scale cross bedding and ripple bedding.

When plotted on current-rose diagrams, it is apparent that measurements of lineal current features (such as flute casts, channels, scour marks, etc.) show a great deal of consistancy, whereas cross-bed foresets display significant scatter.

In order to show more clearly the paleocurrent patterns for the Simmler Formation within the study area, measurements of lineal features are described separately from those of cross bedding.

All paleocurrent directions are based on the present orientation of the Transverse Ranges without allowance for possible post-depositional tectonic rotation (Kamerling and Luyendyk, 1979).

LINEAL CURRENT FEATURES

In keeping with a postulated difference in source area between the rocks of Members A, B, and C, and the rocks of Members E, F, G, and H, linear paleocurrent data are presented on two separate paleocurrent maps (Figs. 24 and

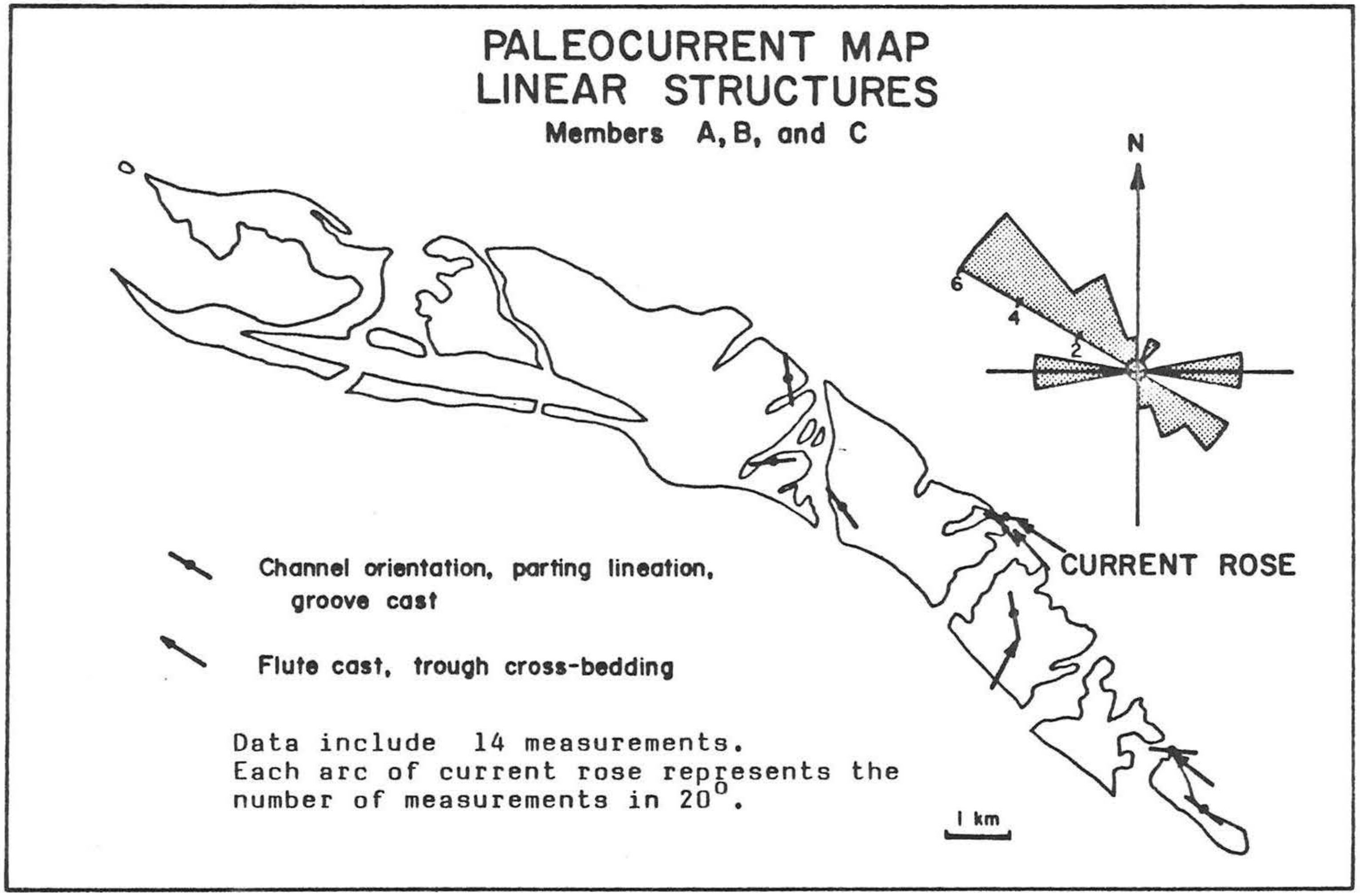


Figure 24. Paleocurrent map showing the orientations of linear structures from Members A, B, and C of the Simmler Formation.

25). Of the 14 measurements used to compile the paleocurrent map for Members A, B, and C (Fig. 24), only 5 provided an indication of unidirectional current flow. The remainder of the features measured allowed for an analysis of only the trend of paleocurrents. Of the 24 measurements used to compile the paleocurrent map for Members E, F, G, and H (Fig. 25), only 4 provided an indication of unidirectional current flow. As shown on the current-rose diagrams for lineal structures (Figs. 24 and 25), a strong clustering of data displaying a northwest-southeast orientation is apparent for both the lower and upper parts of the Simmler Formation. There are a few more measurements from Members E, F, G, and H that tend to indicate a slightly more north-northwesterly paleocurrent direction than measurements from Members A, B, and C. This subtle difference may reflect the addition of northerly flowing currents into the depositional area during the deposition of Members E, F, G, and H or it may be due to statistical errors introduced by the limited data base. An analysis of a larger volume of data is needed before reliable interpretations of a change in paleocurrent direction between Members A, B, and C, and Members E, F, G, and H can be made.

In either case, when considered in conjunction with an inferred fluvial origin and the absence of data suggesting a bipolar paleocurrent pattern, it seems reasonable to assume that all of the lineal features observed originated

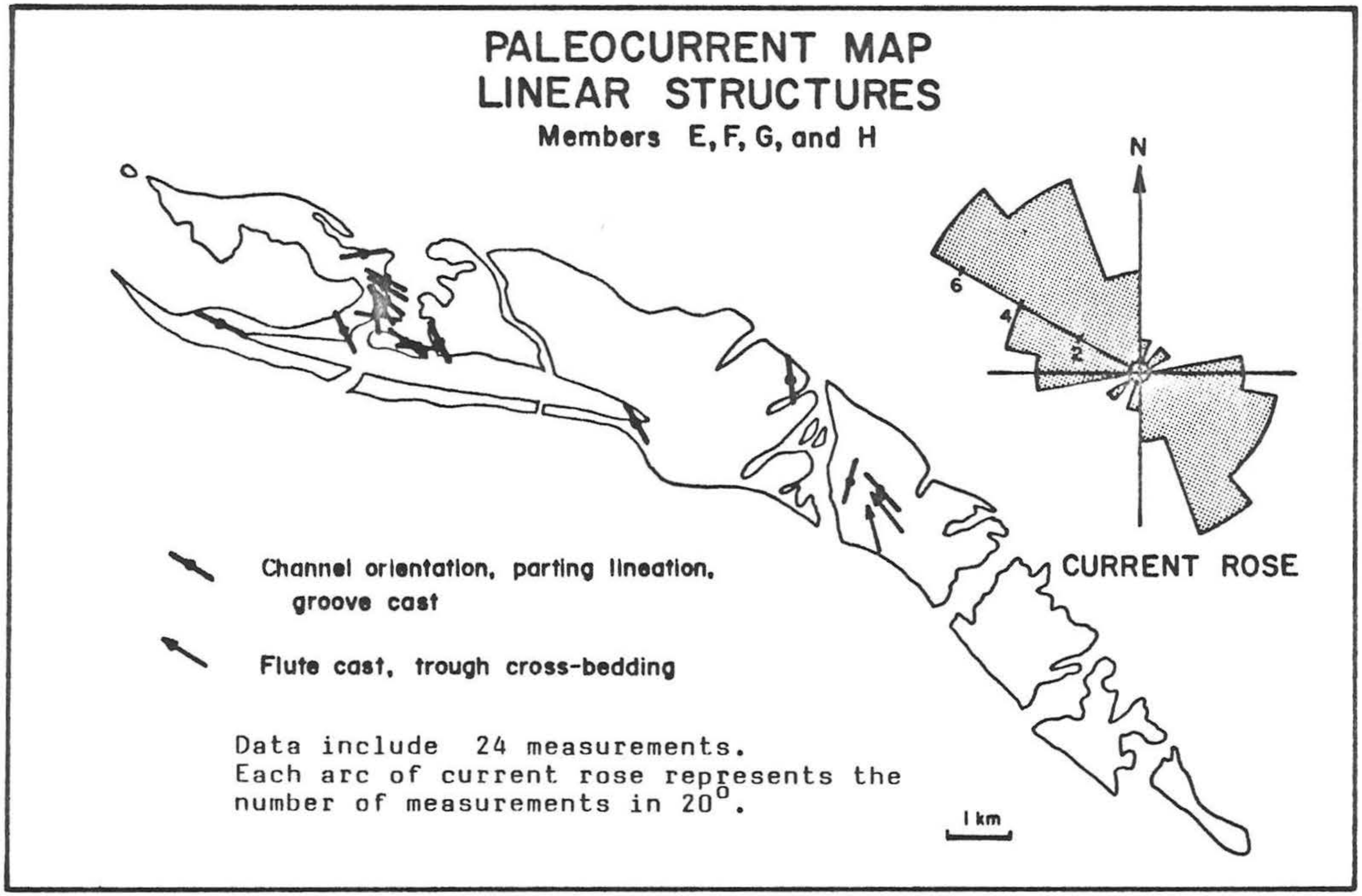


Figure 25. Paleocurrent map showing the orientations of linear structures from Members E, F, G, and H of the Simmler Formation.

as a result of unidirectional northwest-flowing currents. The small amount of variation in azimuth among the lineal current features supports the hypothesis that low-sinuosity streams characterized the Simmler depositional environment.

NON-LINEAL CURRENT FEATURES

Due to the limited number of measurements and the lack of distinctly different lineal feature paleocurrent directions between Members A, B, and C, and Members E, F, G, and H, the map of non-lineal features (Fig. 26) includes data from all members. A total of 10 measurements made at different localities were used to compile the map and current-rose diagram for non-lineal features (Fig. 26), which is distinctly different from that of the lineal features.

In low-sinuosity meandering streams of fluvial environments, however, cross bedding and ripple bedding can originate on the surface of point bar deposits. Cross bedding thus formed, called longitudinal cross bedding, is inclined more or less perpendicular to the orientation of the major channel (Reineck and Singh, 1975). Although point bar deposits are not known from the Simmler Formation within the study area, it is possible that such an origin may help explain the apparent variability of cross-bed orientations. Some of the ripple bedding could have formed as a result of wind-generated currents in shallow bodies

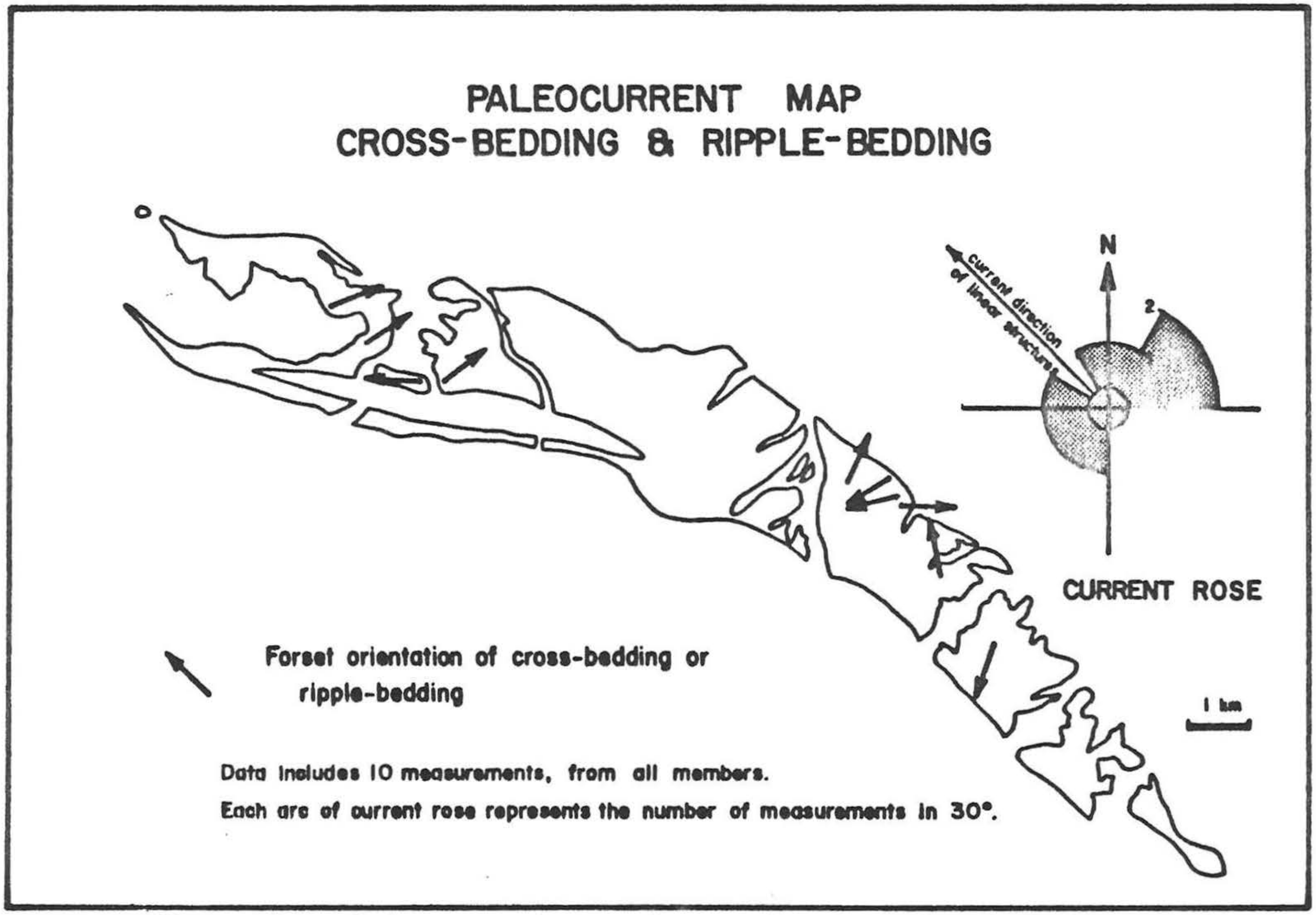


Figure 26. Paleocurrent map showing the forset orientations of cross-bedding and ripple-bedding.

of standing water and therefore may bear no relationship to the overall basin paleocurrent direction.

PROVENANCE

Pebble count data were collected from the various members of the Simmler Formation at 28 locations throughout the study area (Table 7, Fig. 27).

In the southeastern portion of the study area, within the stratigraphically lowest members of the Simmler (Members A, B, and C), the most common clasts are rounded to well-rounded felsic granitic rocks. Also common, although not nearly as abundant, are clasts of gneissic metamorphic rocks. Locally, minor quantities of sedimentary clasts, consisting of rounded sandstone and siltstone are found in abundance near the Ozena fault. A few well-rounded and second-cycle, reddish or purplish, siliceous volcanic clasts are found in those exposures which contain sedimentary clasts.

Toward the northwestern portion of the study area, within the stratigraphically highest members of the Simmler (Members E, F, and G), the most common clast type is subangular to subrounded sandstone. Well-rounded siltstone, chert, granitic, and metamorphic rocks are also present in minor quantities. Rounded to well-rounded siliceous porphyritic and aphanitic volcanic rocks are another distinctive but less common clast type.

The presence of the above described clast types in the rocks of the Simmler Formation is suggestive of at least

TABLE 7. Pebble count data.

Locality	Member	Clast type	Percent
1.	Member C	Granitic	80%
		Metamorphic	20%
2.	Member C	Granitic	91%
		Metamorphic	9%
3.	Member B	Granitic	78%
		Metamorphic	11%
		Sandstone	9%
		Siltstone	2%
4.	Member B	Granitic	50%
		Sandstone	35%
		Siltstone	15%
5.	Member C	Granitic	50%
		Metamorphic	14%
		Sandstone	32%
6.	Member C	Granitic	79%
		Metamorphic	6%
		Sandstone	4%
		Volcanic	10%
7.	Member B	Granitic	100%
8.	Member B	Granitic	70%
		Metamorphic	7%
		Sandstone	20%
		Siltstone	3%
9.	Member C	Granitic	10%
		Sandstone	85%
		Siltstone	5%
10.	Member B	Granitic	79%
		Sandstone	21%
11.	Member A	Granitic	80%
		Sandstone	20%
12.	Member E	Granitic	15%
		Metamorphic	10%
		Sandstone	75%
13.	Member E	Granitic	59%
		Metamorphic	11%
		Sandstone	21%
		Siltstone	9%
14.	Member E	Granitic	10%
		Metamorphic	5%
		Sandstone	85%
15.	Member D	Granitic	3%
		Sandstone	96%
		Siltstone	1%
16.	Member E	Granitic	30%
		Metamorphic	15%
		Sandstone	45%
		Conglomerate	10%
17.	Member E	Granitic	18%
		Metamorphic	27%
		Sandstone	55%
18.	Member F	Granitic	20%
		Metamorphic	23%
		Sandstone	52%
		Volcanic	5%
19.	Member F	Granitic	22%
		Metamorphic	15%
		Sandstone	44%
		Siltstone	7%
		Chert	3%
		Volcanic	9%
20.	Member B	Granitic	5%
		Sandstone	95%
21.	Member D	Granitic	2%
		Sandstone	98%
22.	Member F	Granitic	19%
		Sandstone	71%
		Volcanic	10%
23.	Member F	Granitic	9%
		Metamorphic	3%
		Sandstone	71%
		Conglomerate	8%
		Volcanic	9%
24.	Member D	Granitic	5%
		Sandstone	67%
		Siltstone	27%
		Volcanic	1%
25.	Member D	Granitic	4%
		Sandstone	90%
		Conglomerate	4%
		Siltstone	2%
26.	Member F	Granitic	9%
		Metamorphic	2%
		Sandstone	71%
		Siltstone	2%
		Volcanic	9%
		Clay Rip-Up clasts	7%
27.	Member G	Granitic	4%
		Metamorphic	2%
		Sandstone	83%
		Conglomerate	2%
		Siltstone	1%
		Volcanic	8%

(Locality numbers correspond to those shown on Fig. 27)

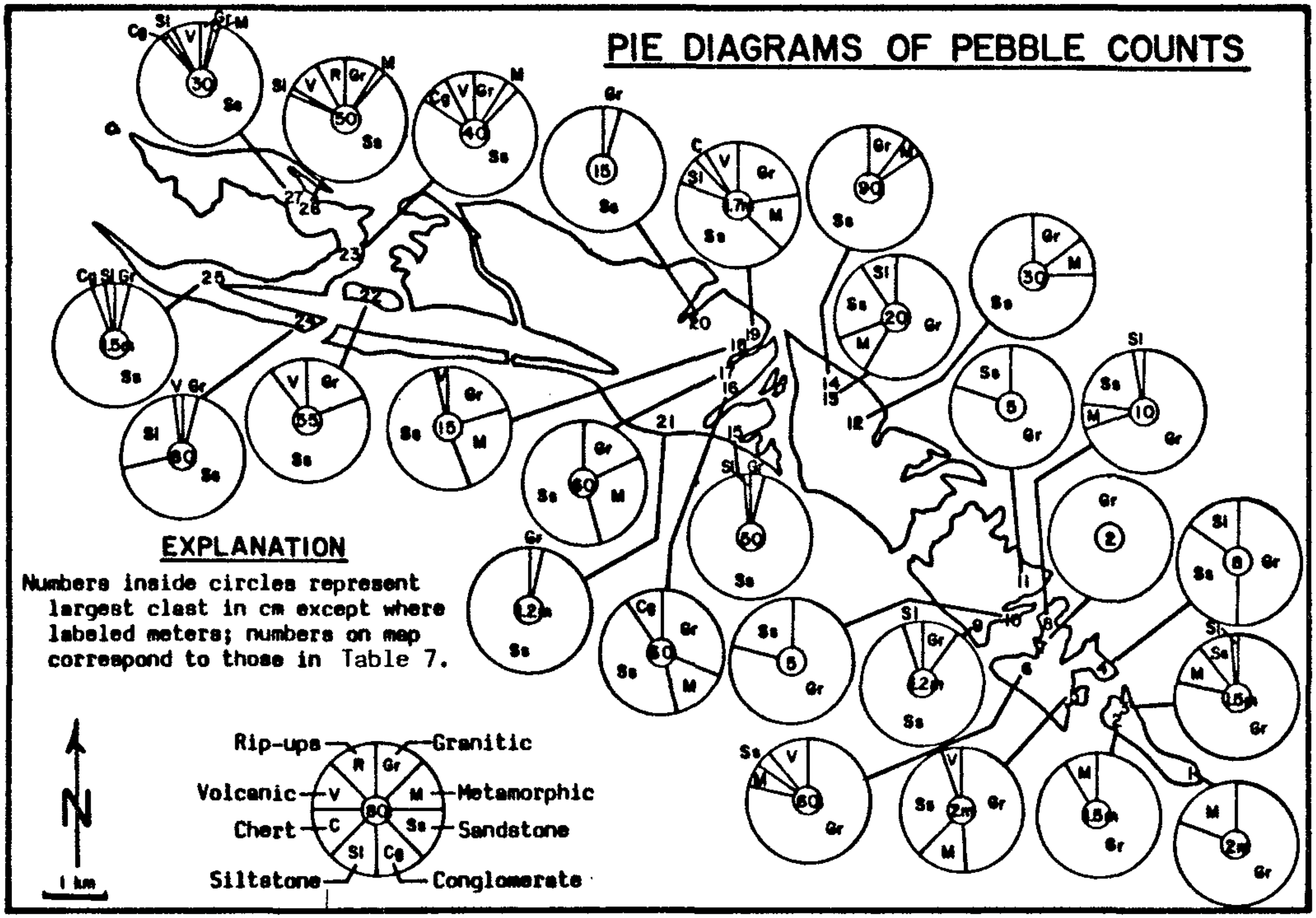


Figure 27. Pie diagrams of pebble counts.

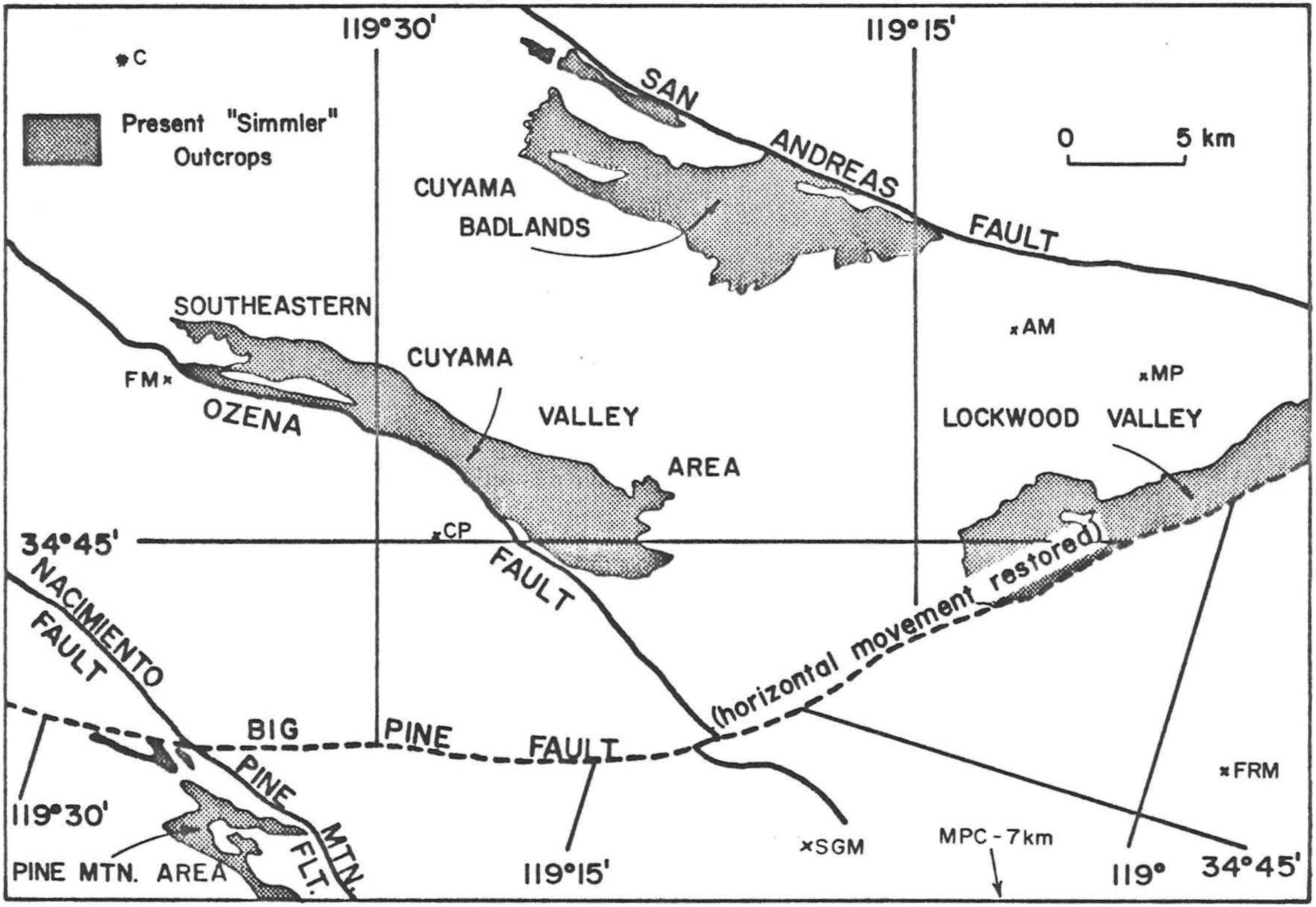
two distinctive source areas: plutonic/metamorphic and sedimentary.

Granitic and metamorphic clasts, most abundant in the older southeastern exposures of the Simmler Formation, are of large size (up to 2 m in diameter) and are relatively unweathered. Although granitic and metamorphic clasts are reported to be present in nearby early Tertiary sedimentary rocks, their size is too small to have provided the source terrain for the large boulders found in the Simmler (Hart, 1959; Vedder and others, 1973). Consequently, a primary crystalline rock terrain with exposed granitic and metamorphic rocks is likely to have provided the source for at least some of the Simmler clasts.

Ross (1972) has described basement rock exposures in the Mutau-Piru Creek areas a few tens of kilometers southeast of the study area. Although detailed petrographic analysis of the clasts of the Simmler Formation and their inferred source terrain were not a part of this study, the available northwest-trending paleocurrent data suggest that the Mutau-Piru Creek area would have been the most likely source for the crystalline clasts. After palinspastic removal of 14 km of left slip on the Big Pine fault (Crowell, 1968), the study area would lie directly northwest of the Mutau-Piru Creek area (Fig. 28).

Logs of oil and gas wells drilled a few kilometers southeast and northeast of the study area indicate that

Figure 28. Regional map showing the present outcrops of the Simmler Formation and correlative rocks in the vicinity of Santa Barbara Canyon. Approximately 14 km of left slip has been restored along the Big Pine fault. C=Cuyama, FM=Fox Mountain, CP=Cuyama Peak, AM=Abel Mountain, MP=Mount Pinos, FRM=Frazier Mountain, SGM=San Guillermo Mountain, MPC=Mutau-Piru Creek.


119°30'
119° 15'
C
Present "Simmler" Outcrops
0 5 km
SAN ANDREAS FAULT
CUYAMA BADLANDS
SOUTHEASTERN CUYAMA VALLEY AREA
AM
MP
FM
OZENA
LOCKWOOD VALLEY
CP
34°45'
FAULT
NACIMIENTO FAULT
(horizontal movement restored)
BIG PINE FAULT
PINE MTN. FLT.
FRM
119°30'
PINE MTN. AREA
119°15'
SGM
MPC - 7km
119°
34°45'

"granitic" basement rocks directly underlie rocks of the Simmler Formation (Calif. Division of Oil and Gas, 1964). This suggests that a larger area of granitic terrain was exposed in the vicinity of the study area during Simmler deposition than at the present time. Although the principal source of granitic clasts in the older parts of the Simmler Formation was probably an exposed primary basement terrain, it is possible that at least some of the small, more rounded pebbles were reworked from an early Tertiary sedimentary source.

Sandstone clasts, found predominantly in the younger, northwestern portion of the Simmler, are identical to sandstone rocks found in the early Tertiary formations that crop out southwest of the Ozena fault. These older formations also include siltstone, shale, and chert, all of which are represented as clasts in the Simmler conglomerates. The subangular to subrounded nature of the sedimentary clasts, which are among the softest found in the Simmler conglomerates, attests to the closeness of the source terrain.

No primary volcanic terrains capable of providing the type of volcanic clasts found in the Simmler Formation are known in the surrounding area. Franciscan volcanic rocks crop out in the Coast Ranges west of the study area, but they are basaltic rather than the acidic type present in the Simmler. Oligocene volcanic rocks interbedded with sedimentary rocks in the correlative Vasquez Formation of the Soledad basin, but they are also more basic than the volcanic clasts observed in the Simmler Formation (Bohannon, 1976). Although volcanic source areas are known across the San Andreas fault, none of their unique exotic clasts were noted in the Simmler Formation (Ehlig, pers. comm., 1976).

With no identifiable volcanic rock source terrain, it seems likely that a sedimentary source containing volcanic clasts contributed pebbles to the Simmler. Early Tertiary strata exposed south of the Ozena fault contain conglomerate beds with silicic to intermediate porphyritic volcanic clasts like those found in the Simmler. Also, the volcanic pebbles occurring in the older strata are generally small and rounded (Hart, 1959). It seems likely, therefore, that the sedimentary and volcanic clasts in the younger, northwestern parts of the Simmler came from an early Tertiary sedimentary source terrain from south of the Ozena fault.

PALEOGEOGRAPHY AND GEOLOGIC HISTORY

INTRODUCTION

All paleogeographic reconstructions are plotted on Figure 28 which is a partial palinspastic map on which about 14 km of left slip on the Big Pine fault (Crowell, 1968) is removed. True geographic relationships on the paleogeographic maps are shortened in a north-south direction because folding has not been removed.

Provenance and paleocurrent data and the interpreted depositional environments provide the basis for defining paleogeographic features shown on the maps. South of the Santa Barbara Canyon area, a highland called the San Rafael uplift has been postulated by several workers (Reed and Hollister, 1936; Corey, 1954; Fritsche, 1969; Fischer, 1976; and Reid, 1979). It was a southeast-northwest-trending highland which connected the ancestral Sierra Madre Mountains with the Alamo Mountain area and which perhaps was developed in part by movement on the Ozena fault. The existence of a Blue Rock-fault-controlled highland to the north of the Santa Barbara Canyon area, in the area directly south of the Cuyama Badlands, has been postulated by Bohannon (1976).

Geologic data from this study as well as from work by Bohannon (1976) suggest that north of the San Rafael uplift, locally formed interior-drainage basins were present in the southeastern Cuyama Valley and the Vasquez Rocks areas. These small evaporative basins were in contrast to the broad, continuous flood plain that characterized the depositional area of the correlative Sespe Formation in the Ventura basin south of the San Rafael uplift (Fritsche, pers. comm., 1981). The formation of these small basins may be attributable to a localized, pre-Simmler orogeny that may have been linked in some way to local plate tectonic events. The southeastern Cuyama Valley area provided the depositional basin for the Simmler Formation rocks studied herein.

The geology of the San Rafael uplift probably was similar to that exposed in the present Sierra Madre Mountains and the Alamo Mountain area. Early Tertiary sedimentary rocks were exposed to the south and west of the southeastern Cuyama Valley area, whereas outcrops of granitic and metamorphic rocks were exposed to the southeast (Fig. 29). The geology of the highland which existed to the north of the study area was probably that of a primary granitic/metamorphic terrain based upon drill hole data and clast types found in the Simmler of the Cuyama Badlands (Bohannon, 1976).

Interpretive subsurface mapping by Vedder (1968) and Vedder and Repenning (1975) indicates that the Simmler Formation is thickest adjacent to the Ozena fault and gradually thins toward the north. This relationship places

Figure 29. Paleogeologic map showing the possible pre-Simmler paleo-outcrop pattern of sedimentary and granitic/metamorphic rocks. Paleogeology is based upon present outcrop distribution and exploratory oil well data.

EXPLANATION

Exploratory oil well location. Symbols indicate the type of "basement" rock penetrated by well. KT=pre-Oligocene sedimentary rocks, G=granitic rocks.

KT — Present outcrop of pre-Simmler sedimentary rocks.

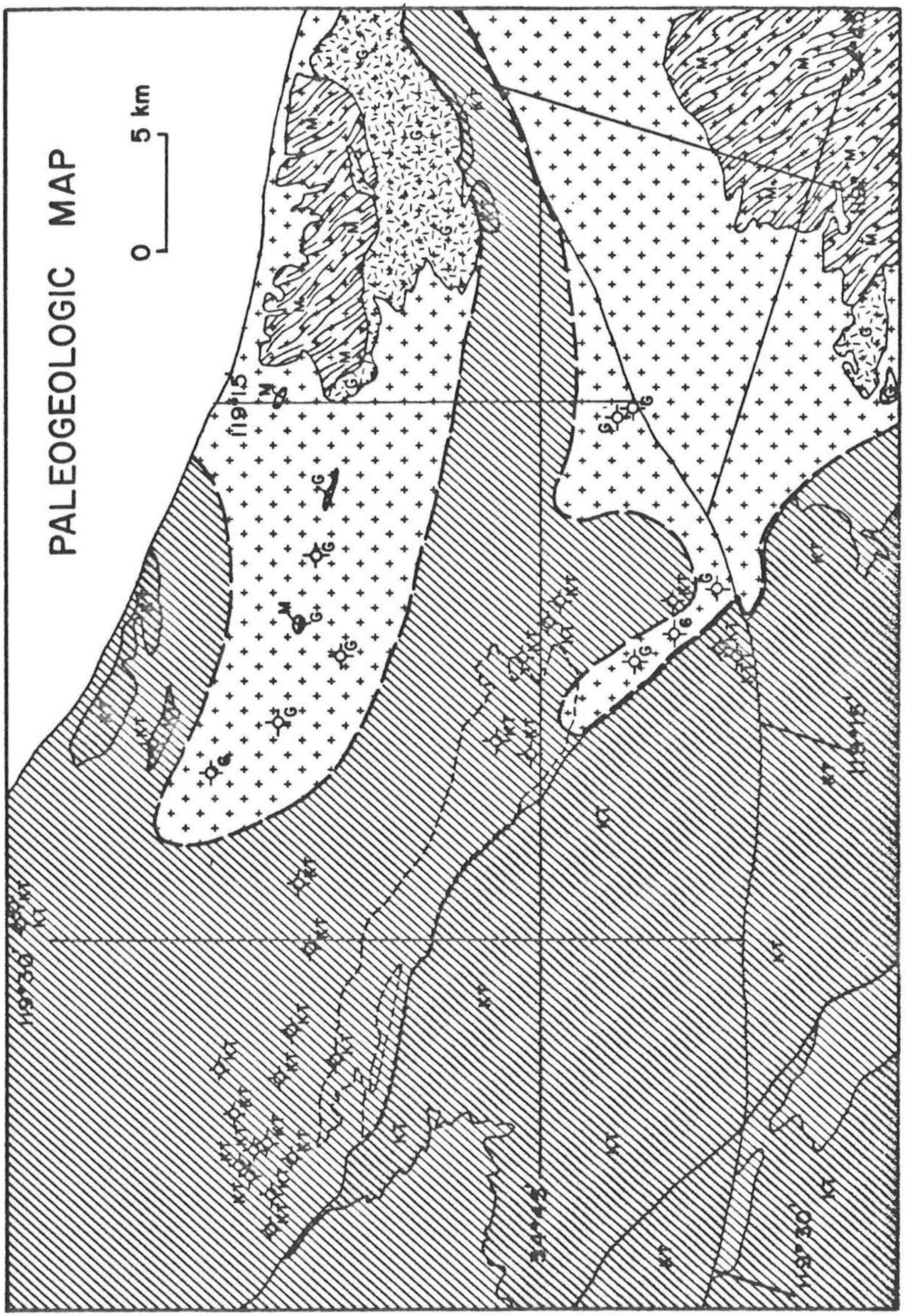
G — Present outcrop of pre-Simmler granitic rocks.

M — Present outcrop of pre-Simmler metamorphic rocks.

Paleo-outcrop pattern of pre-Simmler sedimentary rocks.

Paleo-outcrop pattern of pre-Simmler granitic/metamorphic rocks.

Boundary of present Simmler exposures.


PALEOGEOLOGIC MAP
0
5 km
119°15
119°30
KT
G
M

the hinge of the southeastern Cuyama Valley Simmler depositional area in the approximate location of the present outcrops, southwest of the Cuyama River. Such a location is considerably southwest of a line midway between the Blue Rock and Ozena faults, thus supporting the hypothesis of an asymmetrical cross section for the southeastern Cuyama Valley depositional area. The absence of north to south current direction indicators may be further supportive evidence for a gently sloping northerly margin, but the measured current directions were not always definitive.

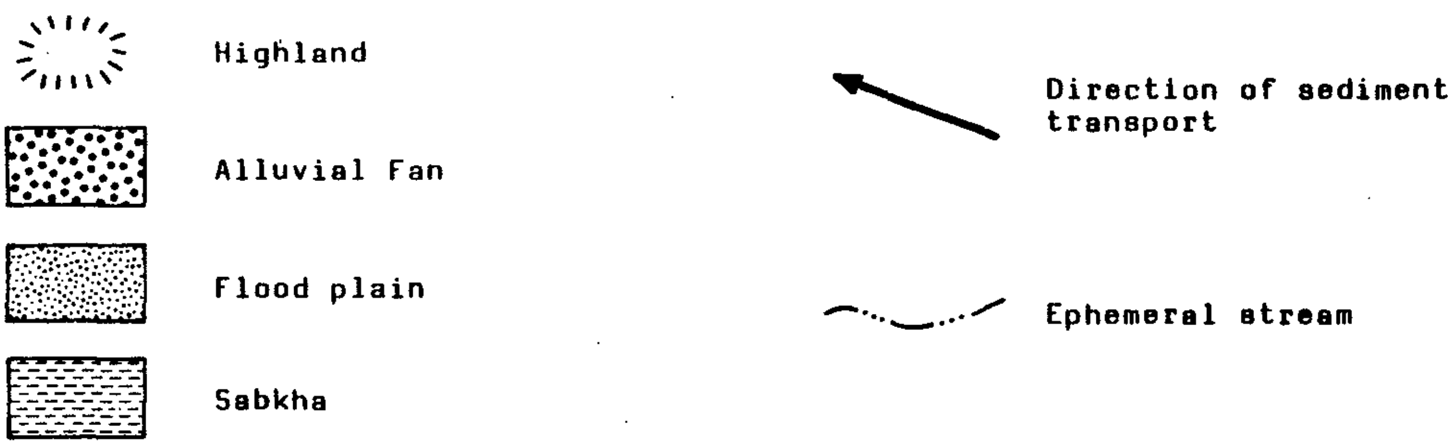
The eight members of the Simmler Formation can be divided into three distinct phases of laterally contiguous deposition: the oldest (Time I) represented by deposition of Members A, B, and parts of C, D, and F; the middle (Time II) represented by deposition of Member E, and parts of C, D, and F; and the youngest (Time III) represented by deposition of Members G and H.

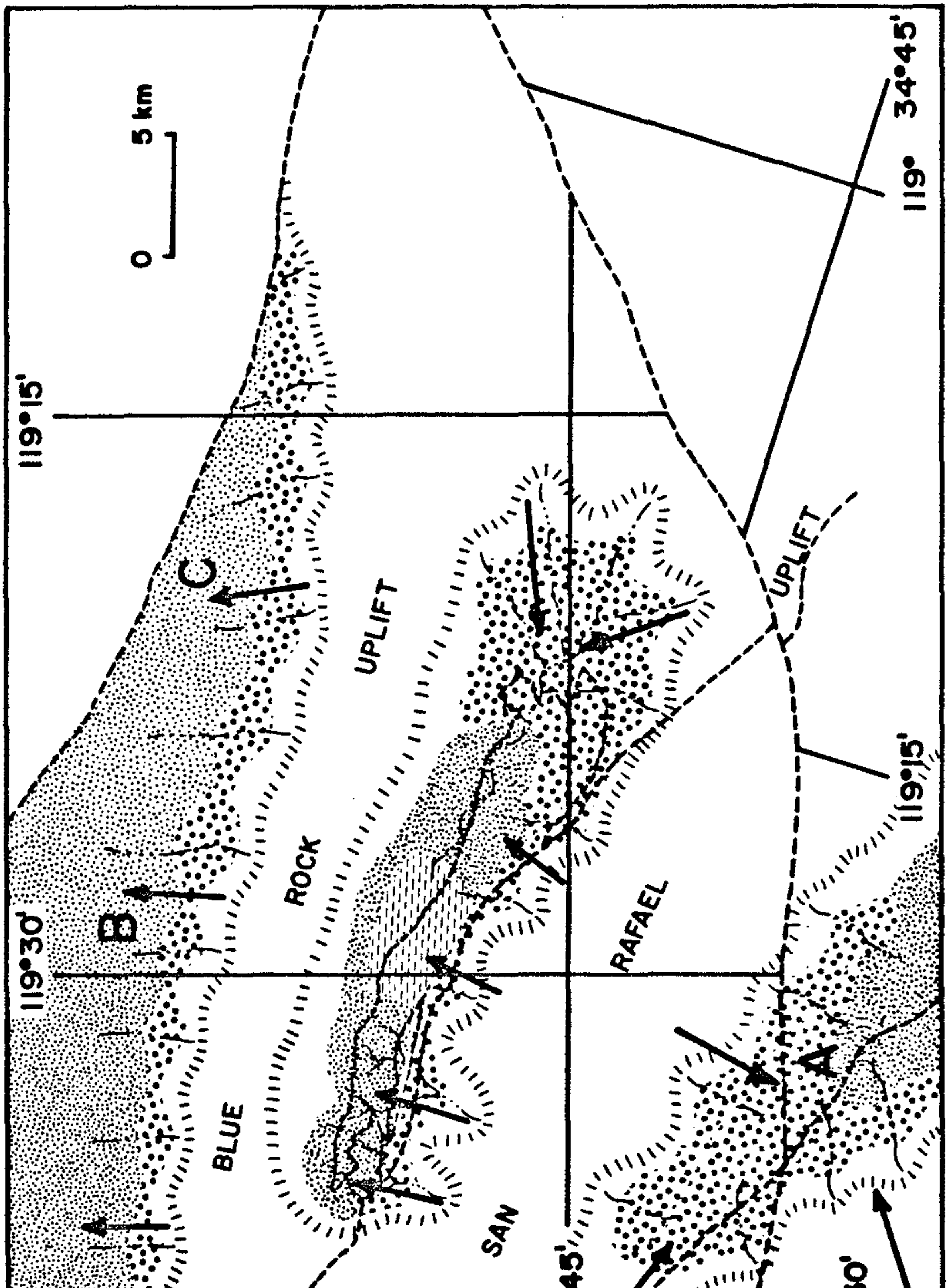
TIME I

Members A and B and parts of Members C, D, and F represent a time of fluvial in-filling of the southeastern Cuyama Valley area (Fig. 30). Alluvial fans of Member C formed chiefly at the southeastern end of the basin from debris shed off a predominantly crystalline basement terrain, while deposits of part of Member F and less significant talus deposits of Member D formed from sedimentary clasts derived from south of the trace of the

Figure 30. Paleogeography during Time I represented by Members A and B and parts of Members C, D, and F. Letters represent areas where paleogeography is constructed in part from interpretations of: (A) Reid (1979), (B) Bartow (1974 and 1978), and (C) Bohannon (1976). Paleogeography base map from Figure 28. Thin-dashed lines represent Holocene geology and show major faults and Simmler outcrops in the study area.

EXPLANATION





0
5 km
119°15'
119°30'
119° 34°45'
C
B
A
UPLIFT
BLUE
ROCK
SAN
RAFAEL
UPLIFT
119°15'
119°30'
34°45'

Ozena fault. Coarse material was supplied principally by debris-flow deposition in the proximal portion of the Member C alluvial fans represented by the upper part of the member. The fan sediments graded laterally toward the northwest into finer grained, traction-flow, mid-fan, and ephemeral, wadi-stream deposits of the lower portion of Member C and the southeastern portions of Members A and B. The stream sediments in turn graded laterally into the evaporative and clay-rich sabkha deposits of the northwestern portions of Members A and B. Present exposures in the study area do not provide good evidence for the existence or absence of an outlet for the southeastern Cuyama Valley area during the deposition of Members A and B. The presence of evaporative deposits, however, suggests that perhaps the basin had no direct outlet, as in the Arava Valley (Amiel and Friedman, 1971), and was instead characterized by a topographic restriction at its northwestern end resulting in interior drainage. The presence of transgressive marine deposits, which later moved into the basin from the west across the top of the Simmler Formation, suggests that the postulated topographic restriction at the northwestern end of the southeastern Cuyama Valley depositional area was of low relief. Although the Ozena fault probably was active at the time of deposition of Members A and B, based on tongues of Member D that interfinger with these members, the lack of sedimentary clast types in these rocks suggests that basin in-filling kept pace with subsidence so that only low relief was present along the northern flanks of the San Rafael uplift in the southeastern Cuyama Valley area. The rocks of Member F which interfinger with those from part of Member B in the northwestern portion of the study area indicate that at the same time as alluvial-fan sediments were prograding northward from the southeastern (granitic/metamorphic) portions of the San Rafael uplift, a similar fan system was prograding northward toward the study area from the southwestern (early Tertiary) portions of the uplift.

Paleoclimatic evidence for the time period during which the Simmler was deposited has been presented by Savage and Downs (1954), Flemal (1967 and 1968), Bartow (1974 and 1978), and Bohannon (1976). Faunal evidence of paleoclimate from rocks correlative with the Simmler Formation (Savage and Downs, 1954) is limited. In the South Mountain-Simi Valley-Las Posas Hills area, about 70 km southeast of the study area, fauna from the Sespe Formation suggests a savanna (Savage and Downs, 1954), very similar to a seasonal, semiarid climate.

Evidence for the paleoclimate of the correlative "Sespe Formation" has been reviewed by Flemal (1967 and 1968). Flemal included in his discussions all late Eocene to early Miocene redbed units in southern California, of which the Simmler is one. Flemal interpreted an arid climate chiefly on the basis of three lines of evidence: 1) the absence of intense weathering products; 2) the presence of arid-climate sedimentary features such as alluvial fan deposits and playa deposits; and 3) the occurrence of evaporite minerals.

Rocks of the Simmler Formation in the Caliente Range area provide evidence, which includes 1) a lack of intense weathering products, 2) abundance of feldspar, 3) alluvial fan deposits, 4) mudcracks, 5) calcareous paleosols, and 6) an almost complete absence of flora and fauna, that has been used to support an interpretation of a semiarid climate (Bartow, 1974 and 1978; and Bohannon, 1976).

Petrographic analyses of rocks from the study area indicate a lack of intense weathering products, and an abundance of relatively fresh feldspar grains. This data, however, is not conclusively in support of an arid to semiarid climate due to the fact that the combined effects of the interpreted moderately high relief and short distance of sediment transport could produce the same petrographic data. A similar explanation may apply to the work of Flemal (1967 and 1968), Bartow (1974 and 1978), and Bohannon (1976).

Evidence for alluvial fan deposition, with abundant debris-flow units, is present in Member C of the Simmler. From findings on modern alluvial fans, Blissenbach (1954) suggested that debris-flow deposits become more numerous with decreasing precipitation.

Beds of gypsum occur within the Simmler and in order for such deposits to form Kinsman (1969) suggests that an arid climate is essential.

All aspects considered, the data available within the study area are supportive of a semiarid paleoclimate.

TIME II

Member E, and parts of C, D, and F represent a continuation of fluvial in-filling of the southeastern Cuyama Valley area (Fig. 31). Intermittent, wadi-streams continued to flow into the area from the granitic/metamorphic highland located to the southeast, resulting in the deposition of a portion of Member C. Increased uplift of the San Rafael high also resulted in the northward progradation of stream sediments from the early Tertiary highland located to the south. Increase in deposition of sediments represented by Member E and parts of D and F, derived from the early Tertiary source rocks, resulted in the lateral expansion of the fan depositional-system previously described during Time I for parts of Members D and F. The continued northward progradation of the Member D, E, and F fan-system resulted in its becoming more dominant in the southeastern Cuyama Valley area, while the Member A, B, and C system became less dominant. The reason for this change in dominance of the two fan systems is unknown. Local deposits of gypsum-bearing, fine-grained sandstone to

Figure 31. Paleogeography during Time II represented by Member E, and parts of C, D, and F. Letters represent areas where paleogeography is constructed in part from interpretations of: (A) Reid (1979), (B) Bartow (1974 and 1978), and (C) Bohannon (1976). Paleogeography base map from Figure 28. Thin-dashed lines represent Holocene geology and show major faults and Simmler outcrops in the study area.

EXPLANATION

Highland

Alluvial Fan

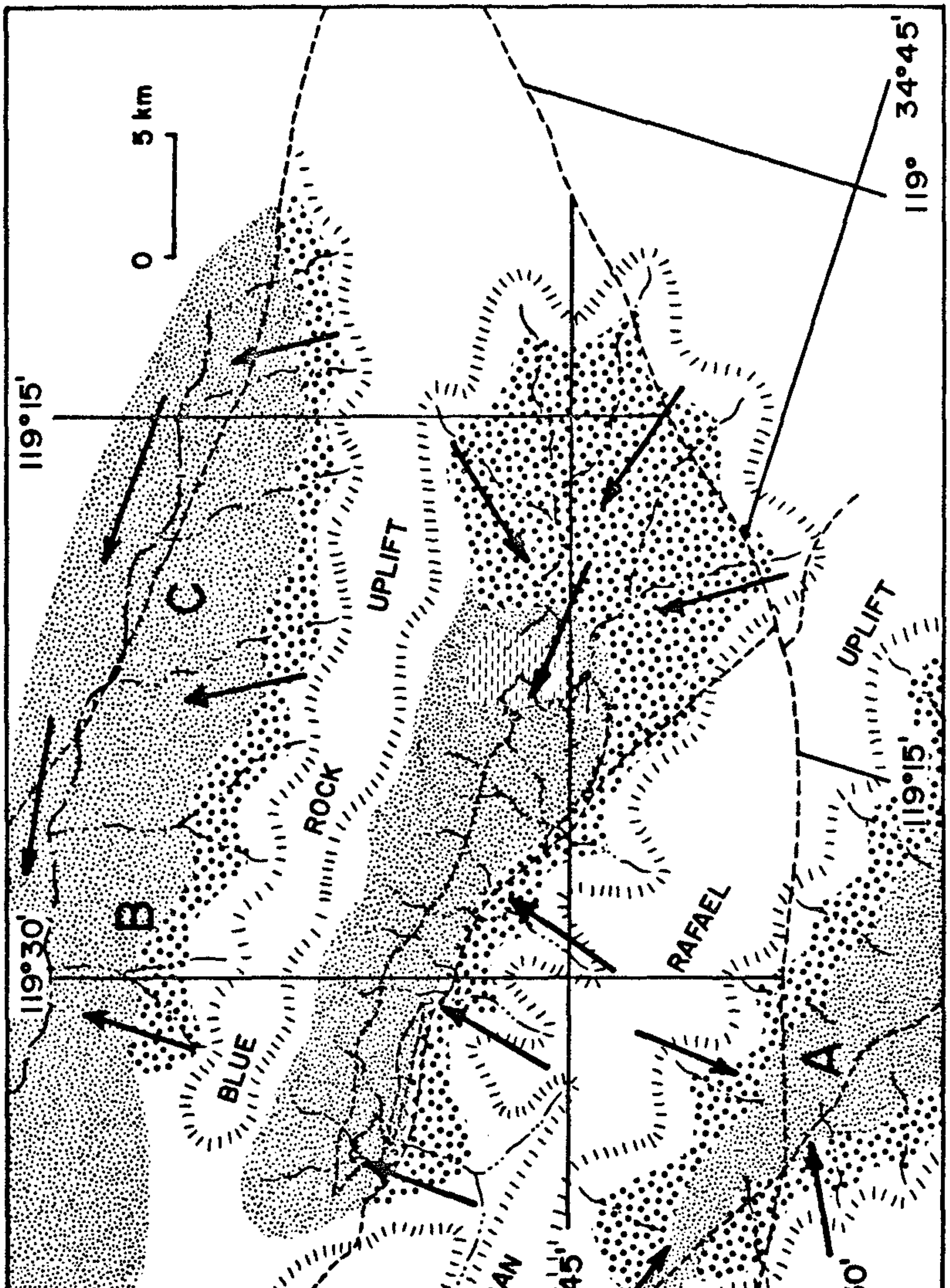
Flood plain

Sabkha

Direction of sediment transport

Ephemeral stream

Perennial river



119°15'
119°30'
0
5 km
119°
34°45'
B
C
BLUE
ROCK
UPLIFT
SAN
RAFAEL
UPLIFT
A
119°15'
34°45'
119°30'

mudstone rocks present in Member E may represent sabkha tongues that extended from the Member C fan system into the Member D, E, and F fan where they interfingered laterally with each other.

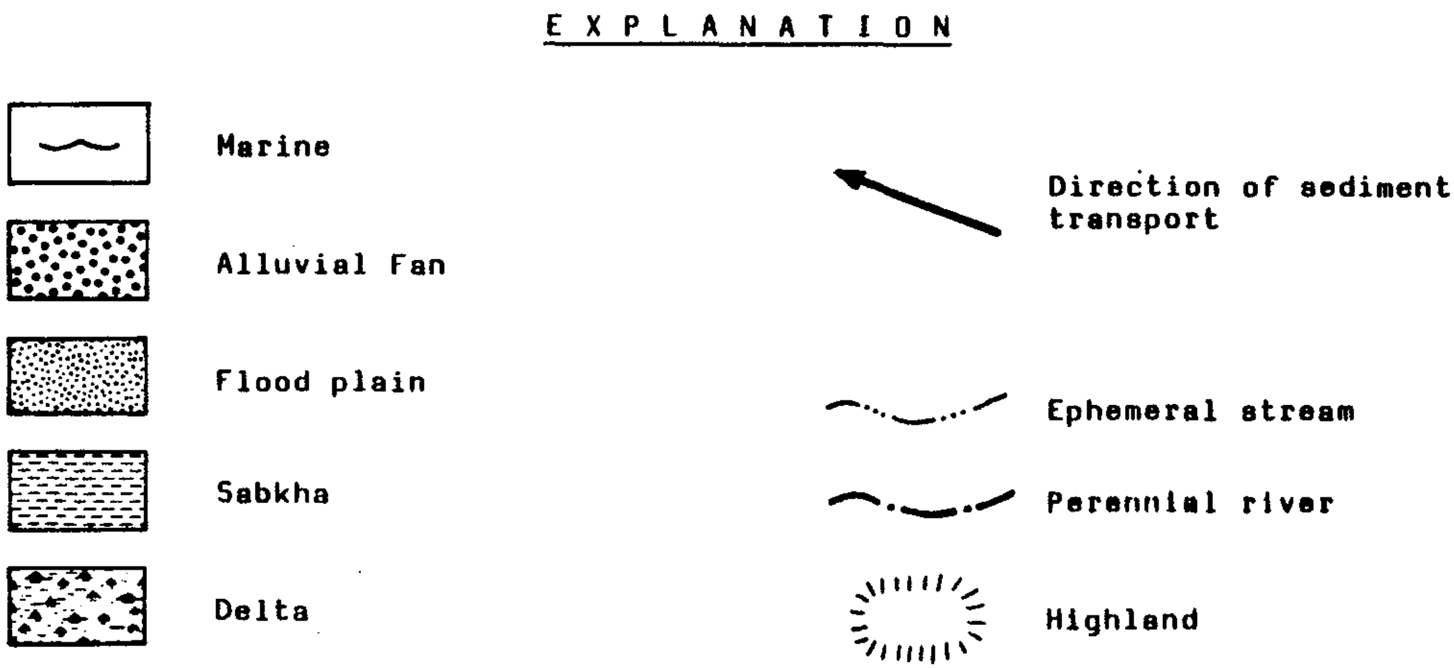
The continued presence of evaporative deposits and debris-flows in Time II suggests that the climate remained relatively unchanged from Time I.

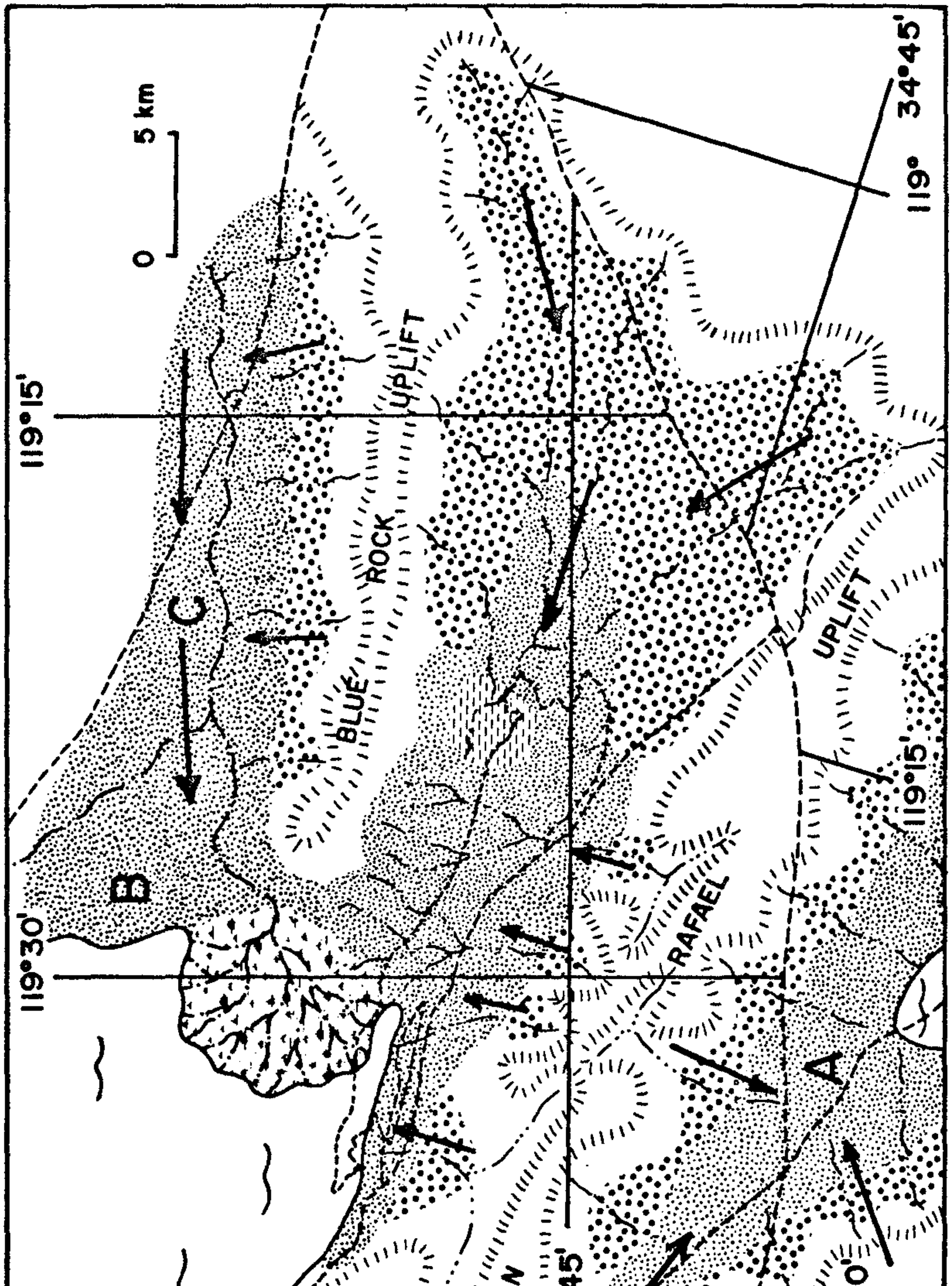
TIME III

Rocks of Members G and H, deposited during Time III, record a significant change in the sedimentological character of the southeastern Cuyama Valley area (Fig. 32). The previous ephemeral streams were rather suddenly replaced by a perennial, delta-depositing river system. Finger-like distributary channels of sediment in the delta front environment represented by Member G, interfingered with interdistributary bay deposits of Member H. These environments graded seaward into prodelta and shelf deposits represented by the Vaqueros Formation and Saltos Shale Member of the Monterey Shale, respectively (Fritsche, 1969).

To explain the sudden existence of a perennial river in the southeastern Cuyama Valley area at least two alternatives seem possible. One explanation is that the previous ephemeral stream system expanded its watershed area through headward erosion. Perhaps the southeastward expansion of the drainage area could have resulted in the

Figure 32. Paleogeography during Time III represented by Members G and H. Letters represent areas where paleogeography is constructed in part from interpretations of: (A) Reid (1979), (B) Bartow (1974 and 1978), and (C) Bohannon (1976). Paleogeography base map from Figure 28. Thin-dashed lines represent Holocene geology and show major faults and Simmler outcrops in the study area.





119°30'
119°15'
0
5 km
119°
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BLUE
ROCK
UPLIFT
SAN
RAFAEL
UPLIFT
34°45'
119°15'
119°30'
A
B
C

linking of the southeastern Cuyama Valley area with the Lockwood Valley, Texas Canyon, and Vasquez Rocks basins resulting in one large watershed. This explanation, however, has at least two serious drawbacks. First, based upon potassium-argon dates of basalt flows in the Plush Ranch Formation (Crowell, 1973), the Lockwood Valley basin apparently did not exist at the time the Simmler was being deposited in the southeastern Cuyama Valley area (Woodburne, 1975, fig. 2). Secondly, the stratigraphic relationships of the members of the Simmler in the southeastern Cuyama Valley area suggest that the change from ephemeral streams to a perennial river system was a very sudden event, not at all like the gradual change that would be expected to accompany a steadily expanding watershed area.

A second alternative, which better explains the sudden existence of perennial river deposits in the southeastern Cuyama Valley area, relies on the interpretations of Bohannon (1976) and Bartow (1974 and 1978) in the Cuyama Badlands and Charlie Canyon areas. They concluded that a low-sinuosity, meandering river, which drained through Charlie Canyon and the Cuyama Badlands, deposited a delta in the Cuyama Badlands area north of the southeastern Cuyama Valley. It seems reasonable that as the Cuyama Badlands basin filled up the delta deposits could have swept around the western end of the Blue Rock-fault-controlled highland, which separated the Cuyama Badlands from the southeastern Cuyama Valley area, resulting in the delta deposits found in the western portion of the study area. This incursion of delta deposits from a perennial river north of the study area seems to be the best explanation for the sudden origin of Members G and H. The presence of anorthosite and Pelona Schist fragments in the Vaqueros of the Santa Barbara Canyon area (Ehlig, pers. comm., 1976) suggests that a later perennial river from the Cuyama Badlands provided an avenue to conduct these clasts from their San Gabriel Mountains source area to the sea. The occurrence of similar exotic clasts in the Caliente Formation of the Cuyama Badlands (Ehlig, pers. comm., 1976), suggests that the river system continued at least into the middle Miocene.

Nodular calcareous beds within Member H, interpreted as calcrete duracrusts, are supportive of a semiarid to subtropical paleoclimatic interpretation (Goudie, 1973; and VanHouten, 1973). This data may suggest a possible change from the semiarid paleoclimate indicated by the older members of the Simmler. The presence of abundant water in the delta's micro environment, however, could account for the localized formation of calcrete deposits without the need for a significant change in paleoclimate.

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