6. Stratigraphy and Paleomagnetism of the Middle Eocene Friars Formation and Poway Group, Southwestern San Diego County, California

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ABSTRACT

The stratigraphy of the Friars Formation and Poway Group in southwestern San Diego County is informally revised. The Friars Formation is locally divisible into three units: a lower sandstone and mudstone tongue, a middle conglomerate tongue, and an upper sandstone and mudstone tongue. As far as can be determined, the Friars Formation is entirely of early Uintan age. The Stadium Conglomerate is stratigraphically and geographically restricted, but is nevertheless locally divisible into a lower member of late early Uintan and possibly late Uintan age, and an upper member of late Uintan age. The Mission Valley Formation of late Uintan age is stratigraphically and geographically restricted only to those strata that are correlative with the type section.

We corroborate previous reports that the lower and upper parts of the type outcrops of the Friars Formation are of normal and reversed polarity, respectively, and concur in the assignment of these polarity intervals to Chrons C21n and C20r. However, the polarity of the lower, conglomerate, and upper tongues of the Friars as recognized here is variable, and may reflect significant time-transgression of these units. The lower member of the Stadium Conglomerate is tentatively assigned to C20r. The upper member of the Stadium may straddle the C20r/C20n boundary. The lower normal and upper reversed magnetozones of the Mission Valley Formation in the type section of this formation are tentatively correlated with C20n and C19r, based on the $^{40}Ar/^{39}Ar$ date of 42.83 ± 0.24 Ma.

INTRODUCTION

Along the coastal plain of San Diego County, middle Eocene mammal-bearing fluvial strata assigned to the Uintan North American Land Mammal "Age" (NALMA; e.g., Krishtalka et al., 1987) interfinger with fossiliferous marine deposits (Kennedy and Moore, 1971; Golz and Lillegraven, 1977). San Diego County is the only place in North America that currently offers the potential of direct correlation of the Bridgerian and early Uintan NALMA's with various marine biochronologies, and is one of only two places in North America allowing such a correlation for the late Uintan (Westgate, 1988).

Due to the general lack of natural outcrops in San Diego County, the excellent but short-lived artificial exposures that are produced by construction activity are significant sources of stratigraphic information. Of particular importance are sections that display several lithostratigraphic units in superposition, and contain age-diagnostic fossils as well. Such sections are ideal for testing stratigraphic models, and are mandatory for the confident correlation of local magnetozones. Locations of the measured sections studied for this paper are shown in Figure 1, which illustrates the major cultural and geographic features of southwestern San Diego County.

A review of the middle Eocene mammal faunas of San Diego County is provided by Walsh (this volume, Chapter 5). Fossil mammals have proven to be useful in the correlation of local stratigraphic units that have rapid lateral facies changes, but few continuous outcrops. The main purpose of this paper is to discuss the stratigraphy and paleomagnetism of the Friars Formation and Poway Group, as these units have yielded most of the Uintan mammal assemblages of southwestern San Diego County. We have collected additional paleomagnetic samples from several important mammal-bearing Uintan sections, and will comment on recent paleomagnetic studies of the local Eocene (Flynn, 1986; Bottjer et al., 1991).

EOCENE STRATIGRAPHY OF SOUTHWESTERN SAN DIEGO COUNTY

Although the Eocene rocks of southwestern San Diego County are generally undeformed, the stratigraphic terminology for these deposits has had a complex history (Hanna, 1926; Milow and Ennis, 1961; Kennedy and Moore, 1971). Factors contributing to this complexity include: (1) the rapid lateral facies changes and obscure disconformities inherent in sedimentary deposits formed along oscillating coastlines; (2)

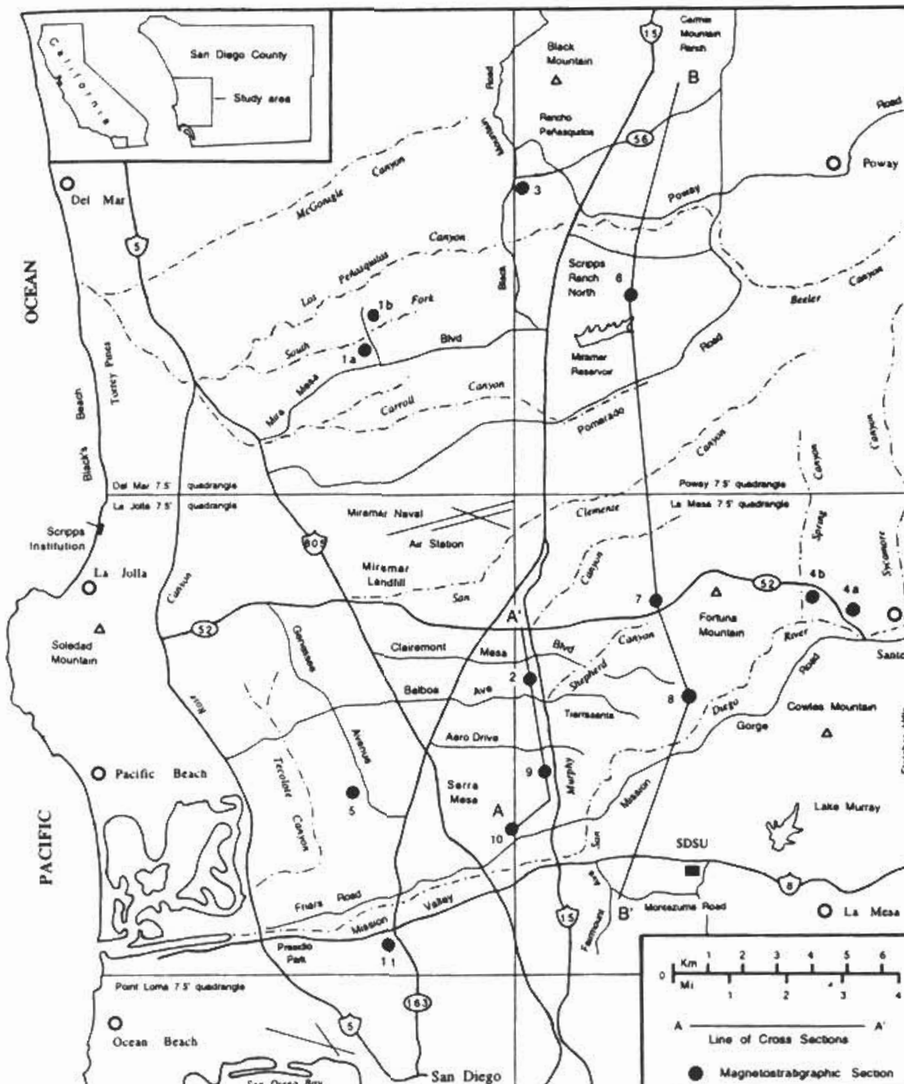

Figure 1. Location map of southwestern San Diego County showing relevant geographic and cultural features. Magnetostratigraphic sections 1-11 are described in Appendix 1.

lithological similarity of the numerous, relatively thin sandstone and conglomerate units that occur at different stratigraphic levels; (3) removal of much of the Eocene section by Plio-Pleistocene erosion (Peterson and Kennedy, 1974, fig. 2); (4) relatively poor outcrops due to the cover of the Eocene strata by Pleistocene terrace deposits, vegetation, and urbanization; and (5) locally significant faulting. Due to these factors, correlation of many isolated outcrops with named lithostratigraphic units must often be regarded as tentative.

Kennedy and Moore (1971), Peterson and Kennedy (1974), Kennedy (1975), and Kennedy and Peterson (1975) discussed the geologic setting of the coastal plain of San Diego County, and substantially modified the stratigraphic terminology of Hanna (1926) and Milow and Ennis (1961). Kennedy and Moore (1971) and Kennedy and Peterson (1975) organized the Eocene strata of southwestern San Diego County into the lower, dominantly marine La Jolla Group (consisting of the Mount Soledad Formation, Delmar Formation, Torrey Sandstone, Ardath Shale, Scripps Formation, and Friars Formation), and the overlying, dominantly nonmarine Poway Group (consisting of the Stadium Conglomerate, Mission Valley Formation, and Pomerado Conglomerate). Their model envisioned essentially continuous deposition during middle Eocene time, beginning with the Mount Soledad Formation and ending with the Pomerado Conglomerate. Three gradual marine transgressions (represented at their maxima by the Ardath Shale, Mission Valley Formation, and Miramar Sandstone Member of the Pomerado Conglomerate) and three gradual marine regressions (represented at their maxima by the Stadium Conglomerate, the lower and upper members of the Pomerado Conglomerate) were invoked to explain the lateral facies changes occurring perpendicular to the Eocene shoreline. No significant disconformities were recognized by Kennedy and Moore (1971) between any of the middle Eocene units, and all contacts between them were described as conformable.

Recently, certain aspects of the model of Kennedy and Moore (1971) have been modified or questioned. Kies (1982) and Walsh (1991) discussed the fact that some of the outcrops mapped by Kennedy (1975) as the Upper Cretaceous Cabrillo Formation were actually of Tertiary age. These distinctive strata were informally referred to by Milow and Ennis (1961) as the "greenstone lithic sandstone and conglomerate" unit. Kies (1982) and Kies and Abbott (1983) considered these strata to be a facies of the Mount Soledad Formation. Walsh (1991) demonstrated a Wasatchian (early Eocene) age for these deposits, and on the basis of their lack of Poway rhyolite clasts (Kies and Abbott, 1983) and stratigraphic position disconformably below the Mount Soledad Formation, he preferred to regard them as an unnamed formation. At the eastern base of Soledad Mountain, the unnamed formation disconformably overlies the Upper Cretaceous Cabrillo Formation of Kennedy and Moore (1971).

Several unsolved problems regarding the stratigraphy of the lower part of the La Jolla Group are potentially relevant to the stratigraphy, age, and paleomagnetic correlation of the Friars Formation and Poway Group. The most important of these concerns the stratigraphic position of the Mount Soledad Formation relative to the Delmar and Torrey formations. The latter two units are known to occur only on the north side of the Rose Canyon fault, while the Mount Soledad Formation is known to occur only on the south side of the fault (Kennedy, 1975, plates 1A and 2A). Kennedy's (1975, fig. 6, block diagrams 5 and 6) illustrations of the Delmar and Torrey formations overlying the Mount Soledad Formation in the subsurface east of Rose Canyon were hypothetical, and not based upon well data or other objective evidence (M. P. Kennedy, personal communication to SLW, 1995). Much has been written about these units and their possible stratigraphic relationships (Milow and Ennis, 1961; Kennedy, 1975; Lohmar et al., 1979; Flynn, 1983; May et al., 1991; Frederiksen, 1991), but the available evidence is inconclusive. If the type Mount Soledad Formation does occur above the Delmar and Torrey formations, the possibility also exists that this unit could be stratigraphically identical to the type Scripps Formation of Kennedy and Moore (1971), as maintained by Milow and Ennis (1961) and discussed by Lohmar et al. (1979). If so, the "Ardath Shale" as mapped by Kennedy (1975) could actually be composed of two different stratigraphic units (as maintained by Milow and Ennis, 1961). We raise these questions to impress upon others the fact that little can be assumed regarding the stratigraphy of the La Jolla Group, and considerable work remains to be done.

In addition to the complexities in the lower part of the Eocene section, the need for significant changes in Kennedy and Moore's (1971) model of the stratigraphy of the Friars Formation and overlying Poway Group has recently become apparent. The revision of these units as discussed below is informal, because new geologic mapping has not been accomplished, and related stratigraphic questions remain unresolved. In the meantime, use of the informal terminology proposed here is justifiable, because erroneous stratigraphic and age relationships of the units under study will result in erroneous biostratigraphic and paleomagnetic correlations of those units. Since the San Diego section occupies an important place in the Eocene global correlation network, it is essential that the stratigraphic model used for the local units reflect historical reality as closely as possible. Accordingly, the evidence indicating the need for a revision of Kennedy and Moore's (1971) model and Kennedy and Peterson's (1975) geologic mapping of the Friars Formation and Poway Group is discussed here in some detail.

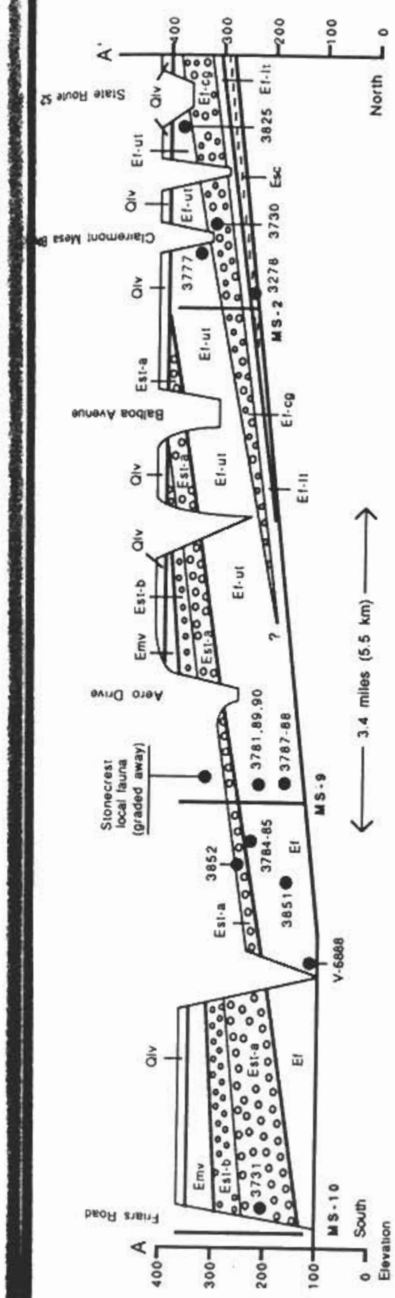

Figure 2. Generalized north-south geologic cross-section of the west wall of Murphy Canyon, showing southward dip of strata, superposition of Scripps Formation (Esc), lower tongue (Ef-lt), conglomerate tongue (Ef-cg), and upper tongue (Ef-ut) of Friars Formation, lower (Est-a) and upper (Est-b) members of Stadium Conglomerate, and Mission Valley Formation (Emv), all capped by the Pleistocene Lindavista Formation (Qlv). Some lithologic contacts from Kennedy and Peterson (1975, plate 3B). Numbered black dots represent significant fossil vertebrate localities. Measured sections 2, 9, and 10 indicated by bold vertical lines. Base of cross-section represents the surface of the west side of the bottom of Murphy Canyon. Vertical exaggeration 10X.

Recent Work on the Friars Formation and Poway Group

Mapping subdivisions of the Friars Formation and Poway Group is difficult, because the various conglomerate and sandstone horizons that occur within these units are generally very similar to one another in lithology. The typical "Poway-type sandstone" is a very light gray to white, friable, moderately sorted, medium-grained, feldspathic volcanic litharenite (Abbott et al., 1979), containing abundant reddish and purplish rock fragments derived from the Poway rhyolite clasts. These sandstones comprise most of the finer-grained strata of the Friars Formation and Poway Group, and hand samples from the lower tongue of the Friars, the upper tongue of the Friars, the Mission Valley Formation, and the Miramar Sandstone Member of the Pomerado Conglomerate are generally indistinguishable. As a result, the stratigraphic identification of "which sandstone is which" often depends on the observation of the superpositional relationships between the sandstone units and the conglomerate units with which they are interbedded. Unfortunately, the determination of "which conglomerate is which" is also difficult when dealing with isolated outcrops, and understandable errors in geologic mapping that have resulted from these problems will be discussed below. Fortunately, in accordance with the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983, Article 22d), fossil mammal evidence can often aid in the assignment of a given outcrop in San Diego to a particular unit (Walsh, this volume, Chapter 5).

Walsh (1991) proposed that certain strata cropping out in the Poway quadrangle that were mapped as the Mission Valley Formation by Kennedy and Peterson (1975) were not correlative with the type Mission Valley Formation of late Uintan age. These fluvial sandstones and mudstones yielded the early Uintan mammal assemblage from the Rancho Peñasquitos district discussed by Golz and Lillegraven (1977), and graded westward into shallow marine deposits in the Del Mar quadrangle. Walsh (1991) assigned these strata to a new lithostratigraphic unit, which was observed to gradationally overlie early Uintan mammal-bearing conglomerates that were mapped as Stadium Conglomerate by Kennedy and Peterson (1975). This alleged new unit was subsequently observed to be disconformably overlain by late Uintan marine sandstones and gritstones of the Mission Valley Formation (e.g., MS-6, MS-7). Walsh's (1991) recognition of the Rancho Peñasquitos strata as a new unit rested on a major assumption, namely, that the early Uintan conglomerates that occurred immediately below them represented the same stratigraphic unit as the lower member of the type Stadium Conglomerate as exposed on the north side of Mission Valley. Given this assumption, Walsh (1991) believed that the allegedly new unit occupied a stratigraphic position between the lower and upper members of the Stadium Conglomerate. If this assumption were correct, one would predict that a typical early Uintan mammal assemblage (Poway fauna of Walsh, this volume, Chapter 5) would be found in the lower member of the type Stadium Conglomerate. However, when fossil mammals were discovered in the latter unit in 1993, they unexpectedly pertained to a younger and unusual micromammal assemblage (Murray Canyon local fauna of Walsh, this volume, Chapter 5) dominated by the early myomorph? rodent *Pauromys* sp. cf. *P. perditus*. The significant faunal differences between the "lower member of the Stadium Conglomerate" in the Mission Valley and Poway areas raised the possibility that these outcrops might in fact pertain to two stratigraphically different conglomerate units.

Field work in the Murphy Canyon and Tierrasanta area has now corroborated this hypothesis. Briefly, an early Uintan conglomerate about 15 m thick crops out in the northern end of Murphy Canyon and in Shepherd Canyon, and was correctly mapped by Kennedy and Peterson (1975, plate 3B) as occurring within the Friars Formation. As exposed on the west side of Murphy Canyon (Fig. 2 and MS-2), this conglomerate erosionally overlies about 7 m of fluvial sandstones, which in turn overlie at least 8 m of concretionary, mollusc-bearing marine siltstones and sandstones of provincial "Transition" age (SDSNH Loc. 3278; Squires and Deméré, 1991; these authors followed Kennedy and Peterson (1975) in assigning these open marine strata to the Friars Formation, but assignment to the Scripps Formation is more consistent with Kennedy and Moore's (1971) and Kennedy's (1975) lithological and environmental concepts of these units). Throughout the Tierrasanta area, the early Uintan conglomerate unit is gradationally overlain by an early Uintan mammal-bearing, fluvial, light gray, medium-grained sandstone and green and reddish mudstone unit up to 30 m thick (SDSNH Locs. 3611, 3612, 3685, 3777, and 3825; University of California Museum of Paleontology (UCMP) Locs. V-68117, V-71056, V-71175, V-71176, and V-71223). On the west side of Murphy Canyon, this sandstone unit is overlain by light gray cobble conglomerates of the lower member of the Stadium Conglomerate (Fig. 2). Lithologically, faunally, and in its stratigraphic position gradationally overlying a fluvial early Uintan conglomerate, the 30 m-thick sandstone unit is identical to the allegedly new stratigraphic unit of Walsh (1991) that crops out in the Poway quadrangle. However, recognizing the small (<2°) but significant southwestward dip of these strata, this sandstone unit can be continuously mapped from Balboa Avenue southward into typical outcrops of the Friars Formation as exposed at the southern end of Murphy Canyon (as correctly shown by Kennedy and Peterson, 1975, plate 3B).

Given these observations, the allegedly new stratigraphic unit of Walsh (1991) is now recognized to correlate partly or entirely with the Friars Formation, and the early Uintan conglomerate cropping out in the Poway and Murphy Canyon-Shepherd Canyon areas is recognized as a widespread tongue, thickest in the Poway quadrangle, that divides the eastern outcrops of the Friars into lower and upper sandstone-mudstone tongues. This middle conglomerate tongue of the Friars Formation presumably pinches out in the subsurface below the communities of Lindavista and Serra Mesa, because it does not occur in the type section of the Friars in Mission Valley. Consequently, a stratigraphic distinction between the lower and upper tongues is not possible in the type area of the Friars (Fig. 2). It should be emphasized that although fossil mammal evidence was instrumental in first raising doubts about the stratigraphic model of Kennedy and Moore (1971), the revisions proposed here are justifiable entirely on lithostratigraphic and superpositional grounds. That is, the removal of certain strata (conglomerate tongue of the Friars Formation) from the Stadium Conglomerate is justified precisely because they do not represent the same lithostratigraphic unit as the type section of the Stadium Conglomerate. Similarly, removal of certain strata (upper tongue of the Friars Formation) from the Mission Valley Formation is justified precisely because they do not represent the same lithostratigraphic unit as the type section of the Mission Valley Formation.

To summarize these new interpretations in relation to the work of Kennedy and Peterson (1975), their mapping of the Shepherd Canyon-Murphy Canyon area was largely correct when they showed a conglomerate unit of substantial thickness within the Friars Formation, which was in turn overlain by the Stadium Conglomerate, and then the Mission Valley Formation. However, only three km to the northeast of the confluence of Murphy and Shepherd canyons (Fig. 3 and MS-7), Kennedy and Peterson inconsistently mapped the upper tongue of the Friars Formation as the Mission Valley Formation, because they were unaware of the northern pinchout of the Stadium Conglomerate, and did not recognize the resulting marine sandstone-on-fluvial sandstone disconformity between the Mission Valley Formation and the underlying upper tongue of the Friars Formation. This understandable error was compounded in their mapping of the northern part of the La Mesa quadrangle, the Poway quadrangle, and the eastern part of the Del Mar quadrangle, when Kennedy and Peterson mapped the conglomerate tongue of the Friars as the Stadium Conglomerate.

Revised Stratigraphic Model for the Eocene of Southwestern San Diego County

Figure 4 shows a revised hypothesis for the Eocene stratigraphy of southwestern San Diego County. It is still based largely on the transgressive-regressive model of Kennedy and Moore, but differs in the following

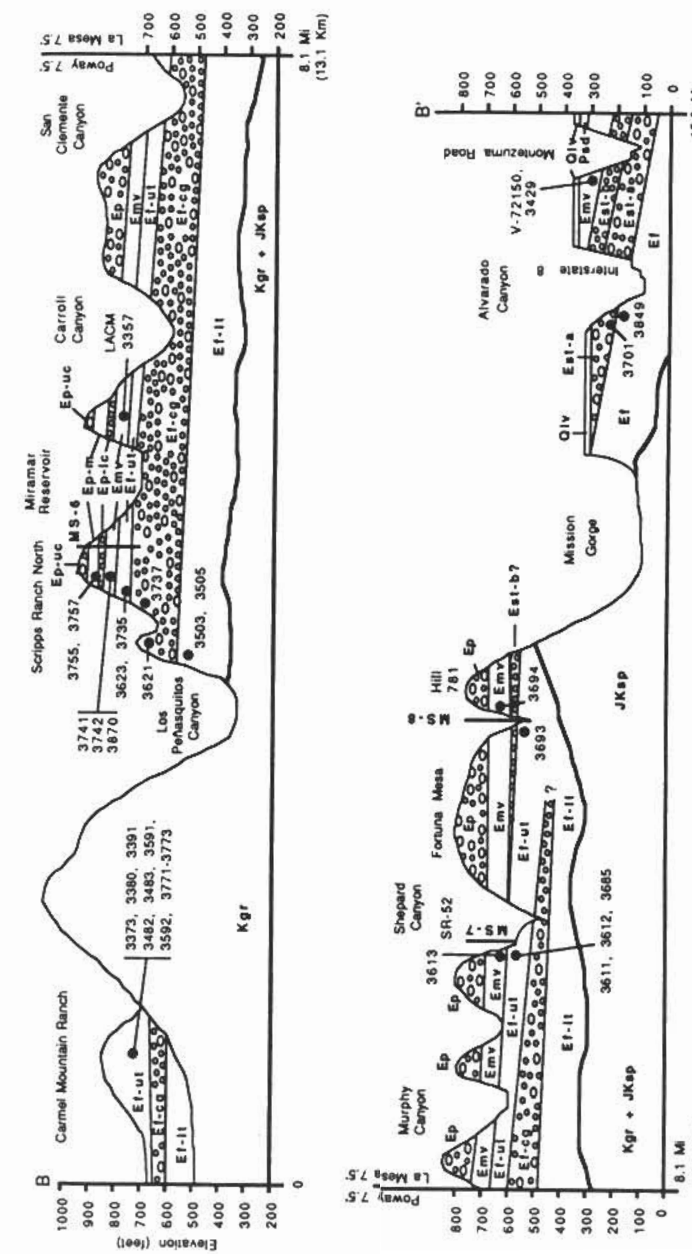

Figure 3. Generalized north-south geologic cross-section from Carmel Mountain Ranch to east San Diego, showing proposed stratigraphy of Friars Formation and Poway Group. Abbreviations: JKsp = Jurassic and Cretaceous metavolcanic basement rocks of the Santiago Peak Volcanics; Kgr = Cretaceous granitic basement rocks of the Peninsular Ranges Batholith; Ep-lc, Ep-m, and Ep-uc = lower, Miramar Sandstone, and upper members of Pomerado Conglomerate, respectively; Psd = Pliocene San Diego Formation. Other abbreviations as in Figure 2. Some lithologic contacts taken from Kennedy and Peterson (1975, plates 2B and 3B). Subsurface topography of Friars Formation-basement rock contact is hypothetical. Numbered black dots represent significant fossil vertebrate localities. Measured sections 6, 7, and 8 indicated by bold vertical lines. Vertical exaggeration 10X.

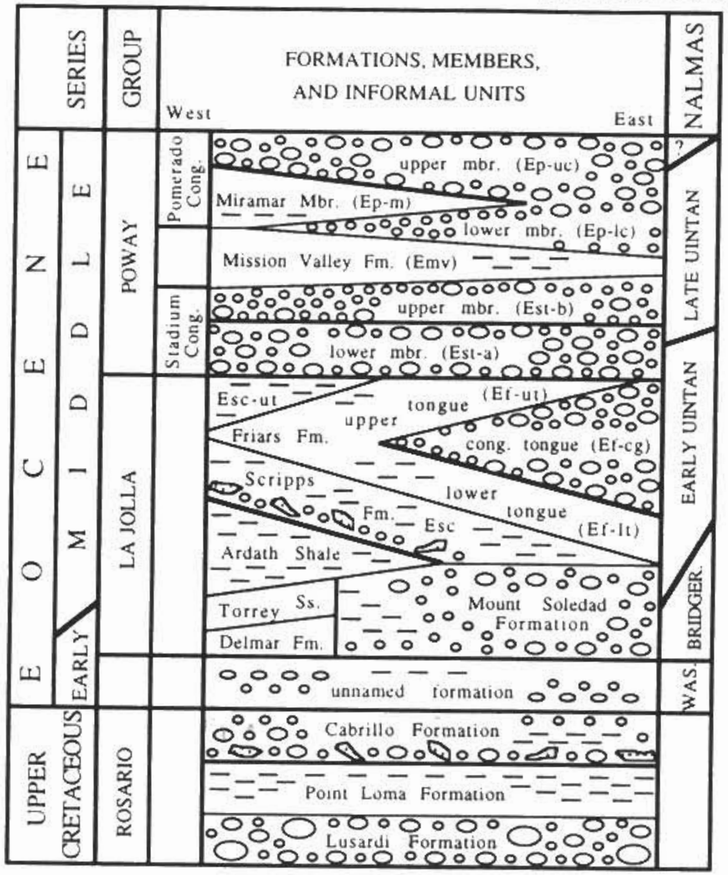

Figure 4. Proposed stratigraphic relationships of Upper Cretaceous and Eocene units in southwestern San Diego County. Substantially modified from Kennedy and Moore (1971).

respects: (1) An unnamed formation of Wasatchian age is recognized between the Cabrillo Formation and the Mount Soledad Formation (Walsh, 1991); (2) The stratigraphic position of the Mount Soledad Formation relative to the Delmar and Torrey formations is left in doubt, because Kennedy and Moore's (1971) placement of the type Mount Soledad entirely below the latter two units has not been convincingly demonstrated; (3) The Friars Formation is stratigraphically expanded, and subdivided into a lower sandstone-mudstone tongue, a middle conglomerate tongue, and an upper sandstone-mudstone tongue. The upper tongue of the Friars is hypothesized to be the dominantly fluvial, lateral equivalent of the upper tongue of the Scripps Formation; (4) The Stadium Conglomerate is subdivided into two locally distinguishable members (Milow and Ennis, 1961) and restricted in its stratigraphic and geographic extent only to those strata that are correlative with the type section; (5) The Mission Valley Formation is restricted in its stratigraphic and geographic extent only to those strata that are correlative with the type section; (6) Finally, as shown by bold lines in Figure 4, more disconformable contacts are recognized between certain units of the La Jolla and Poway Groups than were envisioned by Kennedy and Moore (1971). These include the contact between the lower tongue and the conglomerate tongue of the Friars Formation; the contact between the Friars Formation and the Stadium Conglomerate; the contact between the lower and upper members of the Stadium; the contact between the Friars Formation and Mission Valley Formation (where the Stadium is absent); and the contact between the Miramar Sandstone Member of the Pomerado Conglomerate and the upper conglomerate member of the Pomerado.

Due to the difficulties of portraying complex three-

dimensional facies relationships in a single two-dimensional diagram, it is necessary to clarify certain stratigraphic relationships implied by Figure 4. First, a contact between the unnamed formation and the Delmar Formation has not been observed. If this contact exists, it presumably occurs in the subsurface north of Mount Soledad. Second, a contact between the Scripps Formation and the Mount Soledad Formation has not been observed. If it exists, it would probably occur in the subsurface below Clairemont Mesa. Finally, a contact between the Stadium Conglomerate and the upper tongue of the Scripps Formation has not been observed. If it ever existed, it has probably been eroded away. Information on the lithology, thickness, areal distribution, and depositional environments of the units newly recognized, restricted, or resurrected here is summarized as follows.

Friars Formation

The Friars Formation (Ef) was named by Kennedy and Moore (1971) for the vertebrate-bearing, largely fluvial white sandstones and reddish and greenish siltstones and mudstones that occurred above the marine sandstones and siltstones of the Scripps Formation, and below the fluvial conglomerates of the Stadium Conglomerate. The type section of the Friars Formation is located on the north wall of Mission Valley, and typical outcrops of the Friars occur in Tecolote Canyon, Alvarado Canyon, and the southern end of Murphy Canyon. These sandstone-dominated strata will hereafter be referred to as the "type outcrops" of the Friars. As discussed above, our conception of the Friars Formation differs from that of Kennedy and Peterson's (1975) in that the conglomerate lens which they mapped within the Friars in the Shepherd Canyon area is interpreted here to be the southern edge of an extensive conglomerate body that thickens to the north, where it was erroneously mapped by Kennedy and Peterson (1975) as the Stadium Conglomerate.

Milow and Ennis (1961) recognized an "unnamed formation" similar in stratigraphic position and scope to the Friars Formation, and subdivided it into three units ("blocky sandstone," "massive sandstone," and "green mudstone" members), showing complex stratigraphic relationships. As noted above, we also divide the Friars Formation into three units, but our model differs from that of Milow and Ennis (1961) as follows. First, a distinct "mudstone member" cannot be recognized in the Friars, because significant thicknesses of mudstone occur in this formation only in close proximity to buried paleohills of the granitic and metavolcanic basement complex. These mudstones occur locally in both the lower and upper tongue of the Friars as recognized here, and are best regarded as lithofacies rather than lithostratigraphic units. Second, the middle unit of the Friars Formation in our model is a widespread conglomerate tongue. The resulting interpretation of the Friars Formation as a conglomerate tongue enclosed by underlying and overlying sandstone-mudstone tongues is fundamentally different from Milow and Ennis's (1961) concept of this unit.

Friars Formation, lower tongue

Lithology and Depositional Environment—The lower tongue of the Friars Formation (Ef-lt) is dominated by white, medium-grained, fluvial sandstones, and interbedded, caliche-bearing, greenish and reddish-brown, terrestrial sandy siltstones and mudstones. Lenses of Poway-type pebble and cobble conglomerate are locally common in the eastern outcrops of the Ef-lt (e.g., MS-4). The mudstones and siltstones are thickest and most common in the vicinity of buried paleohills of the crystalline basement complex. Adjacent to granitic basement rocks, these fine-grained strata are commonly interbedded with thin tongues of coarse-grained arkosic sandstones. Brackish water molluscs including *Ostrea* occur locally in the western outcrops of the Ef-lt (e.g., SDSNH Loc. 3727; MS-3).

Distribution and Thickness—The Ef-lt crops out from Rancho Bernardo in the north (Kennedy and Peterson, 1975), at least to Santee in the south, and from Poway Valley and Lakeside in the east to Murphy Canyon and Mira Mesa in the west. During excavations for State Route 52 northwest of Santee, a maximum composite thickness of about 55 m was measured for the Ef-lt (MS-4). Apparently due to substantial erosion at the base of the conglomerate tongue of the Friars, the Ef-lt is only 7 m thick in the north end of Murphy Canyon (MS- 2), and is absent in the gravel quarry of H. G. Fenton Materials Company in Carroll Canyon (SW1/4 Sec. 2 T15S R3W).

Contacts-The Ef-lt rests nonconformably upon metavolcanic and granitic rocks of Mesozoic age in most areas. In Los Peñasquitos Canyon and in the northern part of Murphy Canyon, this unit rests upon shelfal marine siltstones and sandstones assigned here to and/or mapped by Kennedy (1975) as the Scripps Formation. The Ef-lt is often overlain with as much as 5 m of local erosional relief by the conglomerate tongue of the Friars. This relationship is documented in MS-3, and was also seen in the Westview housing development in Mira Mesa (SDSNH Loc. 3496), and the South Creek housing development southwest of Poway (SDSNH Loc. 3505).

Fossils and Age—The upper part of the Ef-lt yields a typical early Uintan mammal assemblage, which has been collected from several localities in the Rancho Peñasquitos, Poway, and Santee areas. This assemblage is faunally indistinguishable from that collected from the type outcrops, the conglomerate tongue, and the upper tongue of the Friars (Walsh, this volume, Chapter 5). Given Flynn's (1986) faunal characterization of the beginning of the Uintan NALMA, an early Uintan age for at least the upper part of the Ef-lt is corroborated by the presence of *Leptoreodon major* at SDSNH Locs. 3655-3657 in Santee, and by the presence of tooth fragments of selenodont artiodactyls from SDSNH Locs. 3505 and 3496 (Poway and Mira Mesa areas). The Ef-lt also contains occasional fossil leaves (SDSNH Locs. 3653 and 3663) and pulmonate gastropods (e.g., SDSNH Loc. 3656).

Friars Formation, Conglomerate Tongue

Lithology and Depositional Environment—The conglomerate tongue of the Friars Formation (Ef-cg) is dominated by purplish metarhyolite clasts of the Poway suite. In the eastern part of its outcrop area (e.g., Scripps Ranch and upper Murphy Canyon), the Ef-cg is a light gray to dark rusty brown, moderately sorted, matrix-to-clast-supported, pebble to boulder conglomerate of fluvial origin. These outcrops also contain common lenses of light gray and yellowish-brown medium-grained sandstone, and channeled beds and rip-up clasts of greenish and reddish mammal-bearing siltstone, with common multicolored caliche horizons and nodules. In the western part of its outcrop area (e.g., western Carroll Canyon and south fork of Los Peñasquitos Canyon), the Ef-cg is a rust-stained, clast-supported, pebble-to-boulder conglomerate containing light gray and rust-stained, medium-grained sandstone lenses and occasional lenses and rip-up clasts of greenish-gray and rust-stained, mollusc-bearing siltstones. These western outcrops of the Ef-cg are of probable deltaic origin (e.g., May, 1985; referred to the Stadium Conglomerate).

The Ef-cg differs lithologically from the lower member of the Stadium Conglomerate in that the former unit does not have the pale greenish, muddy sandstone matrix that typifies the latter unit in the Mission Valley area. The Ef-cg is more similar to the upper member of the Stadium Conglomerate in color, lithology, and the range of depositional environments it represents, but these two units differ in maximum observed thickness, and are not known to occur in the same geographic area.

Distribution and Thickness—The maximum observed thickness of the Ef-cg is about 60 m at the South Creek, Eastview, and Scripps Ranch North housing developments southwest of Poway. The Ef-cg thins rapidly to the northwest, away from the Poway Fan (Howell and Link, 1979). For example, this unit is 21 m thick in the community of Carmel Mountain Ranch (Figs. 1 and 3; stratigraphic section by B. O. Riney on file at SDSNH), is locally only 11 m thick in the community of Rancho Peñasquitos (MS-3), and apparently pinches out within the Friars Formation in the northern part of the Del Mar quadrangle and the southern part of the Rancho Santa Fe quadrangle (mapped as Stadium Conglomerate by Kennedy, 1975, and Eisenberg, 1985). To the west, the Ef-cg can be traced at least as far as the western ends of Los Peñasquitos Canyon and Carroll Canyon, where Kennedy (1975) shows this unit (mapped as Stadium Conglomerate) to pinch out between the Scripps Formation and what he maps as the upper tongue of the Scripps. 3-5 km east of this mapped pinchout, the Ef-cg is still at least 50 m thick in the gravel quarries of H. G. Fenton Materials Company and CalMat Company in Carroll Canyon. The Ef-cg also thins to the southwest, where it is about 20 m thick in the City of San Diego Miramar Landfill (northern rim of San Clemente Canyon), and is 15 m thick in the Shepherd Canyon area (Figs. 2-3 and MS-2). South of Santee, the extent of the Ef-cg and its relationship with the Stadium Conglomerate has not been determined. The Ef-cg apparently pinches out within the Friars Formation below Serra Mesa and Tierrasanta, because it has not been identified in Mission Valley and San Carlos (Figs. 2 and 3).

Contacts—In the eastern part of the study area, the Ef-cg generally rests erosionally upon the Ef-lt (MS-2, MS-3, MS-4). However, in the south fork of Los Peñasquitos Canyon, western Carroll Canyon, and western San Clemente Canyon, erosion at the base of the Ef-cg has locally removed the lower tongue of the Friars Formation, probably because this area was located in the main east-west corridor through which the bulk of the conglomerate was transported toward the Eocene coastline during early Uintan time. Here, the Ef-cg overlies shelfal marine sandstones and siltstones mapped as Scripps Formation by Kennedy (1975). The Ef-cg is generally gradationally overlain by the upper tongue of the Friars Formation. This contact can be seen along Camino Santa Fe (MS-1), at Scripps Ranch North (MS-6), in the Shepherd Canyon area (MS-2), and in the Carroll Canyon quarry of H. G. Fenton Materials Company.

Fossils and Age—The Ef-cg has yielded a typical early Uintan mammal assemblage from several SDSNH localities at the Scripps Ranch North housing development, and SDSNH Loc. 3730 in the Shepherd Canyon area (Walsh, this volume, Chapter 5). Pulmonate gastropods and fossil leaves have been recovered from fluvial outcrops of the Ef-cg at Scripps Ranch North (SDSNH Locs. 3621, 3624), and sparse marine molluscs have been collected from deltaic outcrops of the Ef-cg on the south rim of San Clemente Canyon (SDSNH Locs. 3881-3882).

Overall Stratigraphic Position—Figure 4 illustrates the stratigraphic position of the Ef-cg as observed in the eastern part of the study area, where this unit occurs as a relatively thick lens occurring entirely (or nearly entirely) within a stratigraphically-expanded Friars Formation, all of which is assumed to occur stratigraphically above the Scripps Formation. However, the lateral relationship of the Ef-cg to the marine strata exposed along the present-day coastline is uncertain. It

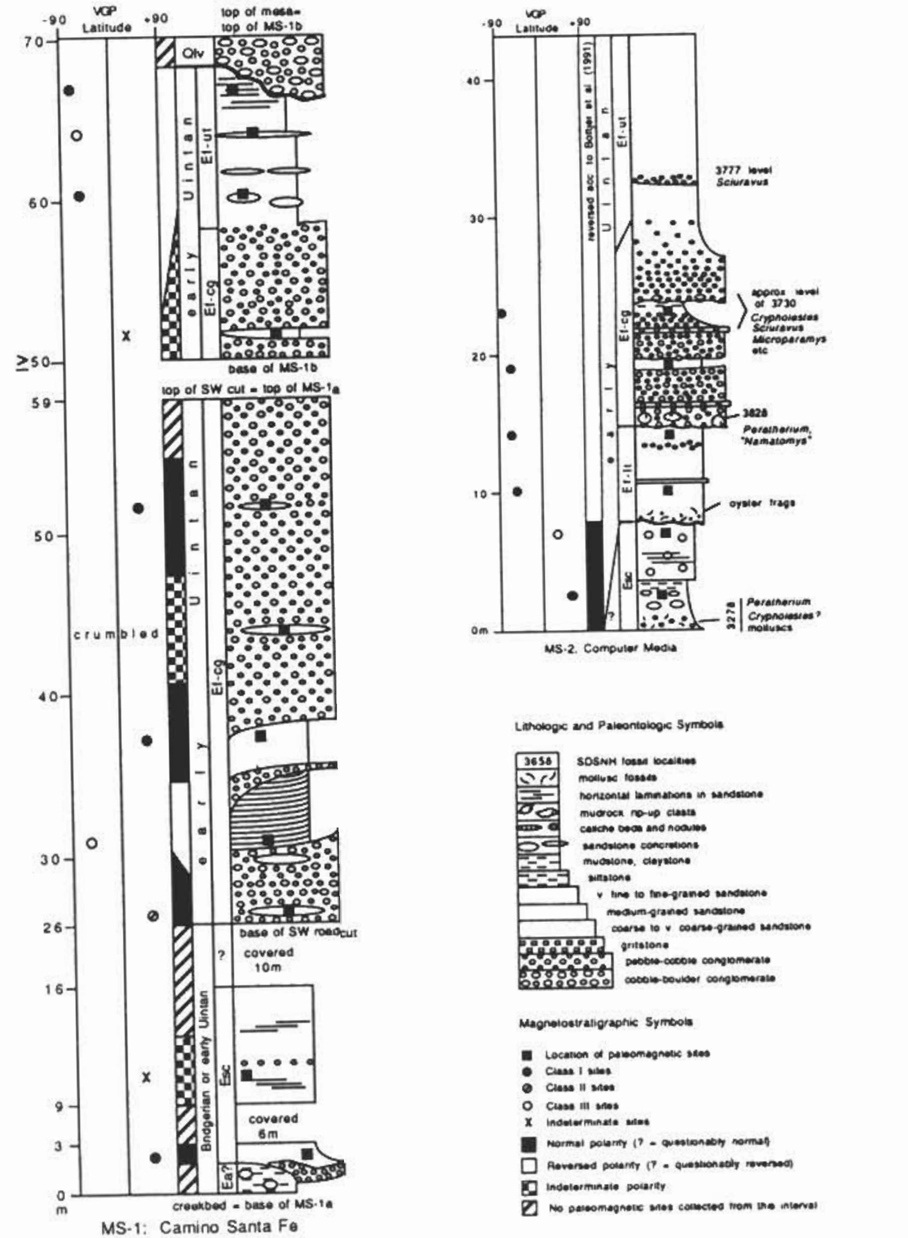

Figure 5. Magnetostratigraphic sections from Camino Santa Fe (MS-1) and Computer Media (MS-2). Key to symbols used in this and the following figures is also shown.

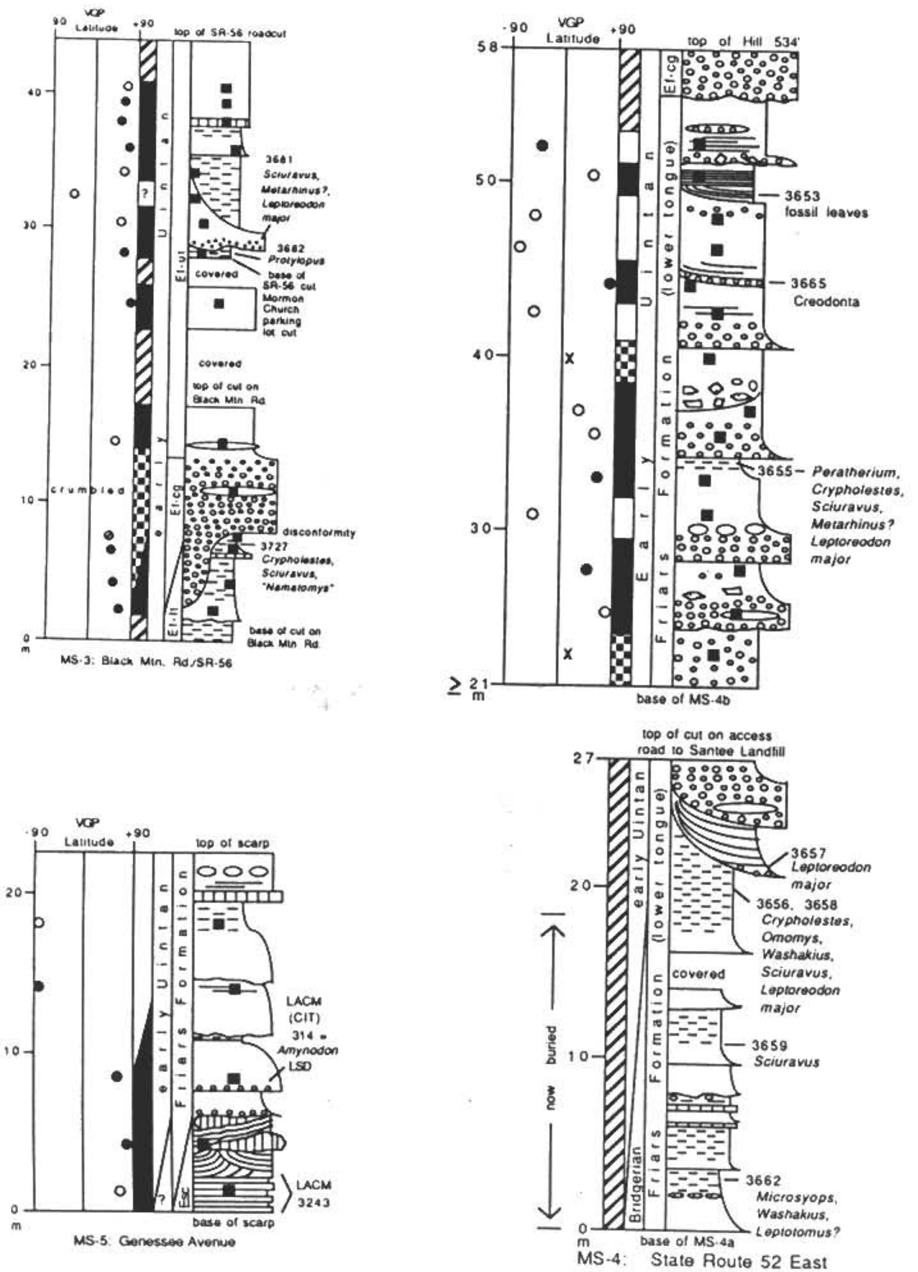

Figure 6. Magnetostratigraphic sections from Black Mountain Road/State Route 56 East (MS-3), State Route 52 East (MS-4), and Genessee Avenue (MS-5). Symbols as in Figure 5.

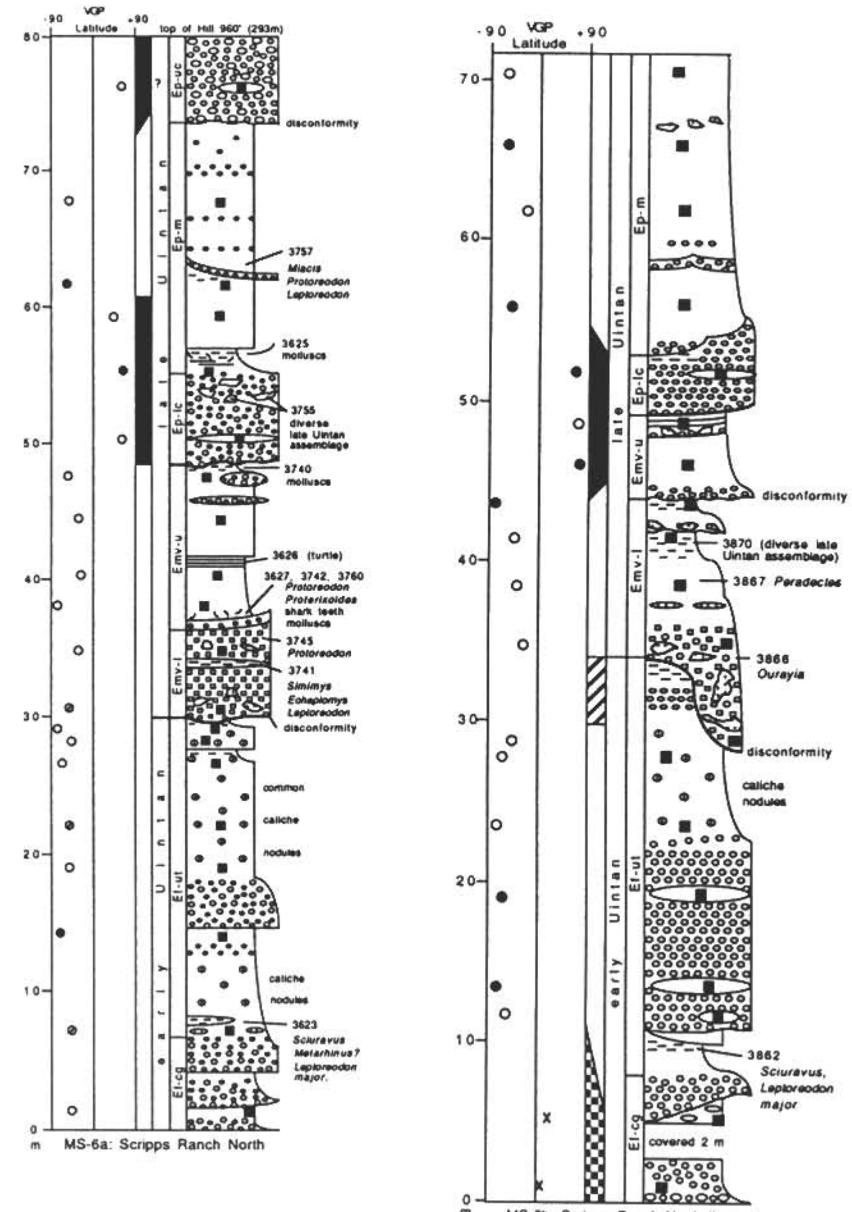

Figure 7. Magnetostratigraphic sections from Scripps Ranch North (MS-6a, b). Symbols as in Figure 5.

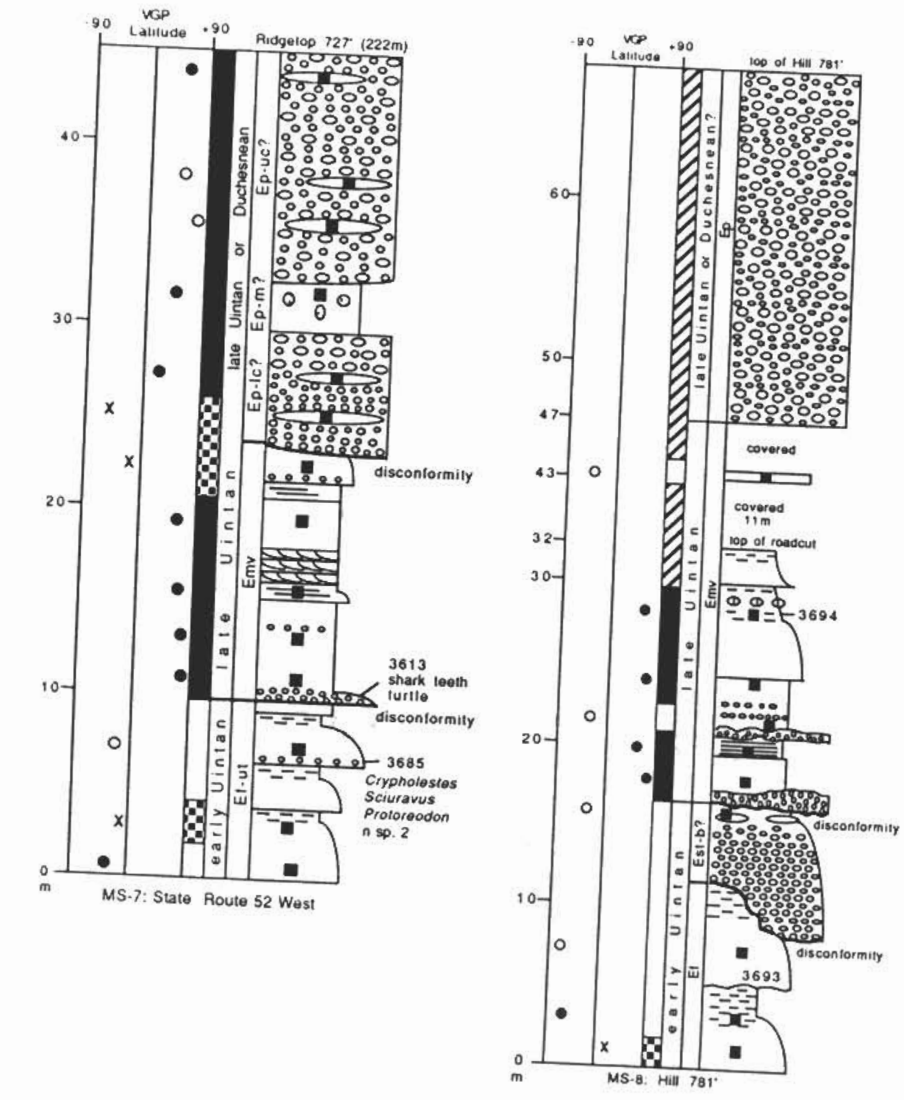

Figure 8. Magnetostratigraphic sections from State Route 52 West (MS-7) and Hill 781' (MS-8). Symbols as in Figure 5.

is tempting to speculate that the Ef-cg represents the coeval, eastern, largely fluvial facies of the marine conglomerates in the lower part of the Scripps Formation as exposed in the seacliffs north of Scripps Institution of Oceanography (Kennedy and Moore, 1971). If so, the Black's Beach local fauna (Walsh, this volume, Chapter 5) may prove to be of early Uintan age. Unfortunately, due to structural complexities in the southwestern part of the Del Mar quadrangle (Kennedy, 1975), it is difficult or impossible to directly correlate the Ef-cg as exposed in Carroll Canyon with the seacliff outcrops of the Scripps Formation.

Friars Formation, upper tongue

Lithology and Depositional Environment—The upper tongue of the Friars Formation (Ef-ut) is very similar to the Ef-lt in overall lithology, lithological variations, and in the east-to-west geographic distribution of the depositional environments it represents. Fluvial sandstones of the Ef-ut as exposed in the Poway quadrangle grade westward into brackish water strata in the eastern part of the Del Mar quadrangle. These deposits in turn appear to grade westward into shelfal marine strata that were mapped by Kennedy (1975, plate 1A) as the upper tongue of the Scripps Formation.

The Ef-ut was previously mapped as the Mission Valley Formation in the Poway and Delmar quadrangles (Kennedy, 1975; Kennedy and Peterson, 1975). The Ef-ut differs lithologically from the latter in that at a given longitude, the Ef-ut contains a greater proportion of medium-grained fluvial sandstones and floodplain siltstones and mudstones, while the Emv contains a greater proportion of fine- to very fine-grained marine sandstones. The Ef-ut also apparently lacks bentonite beds, and contains a greater proportion of reddish terrestrial mudstones and siltstones than the Mission Valley Formation, whose terrestrial mudrocks are usually green or brownish in color.

Thickness and Distribution—The maximum observed thickness of the Ef-ut is about 60 m in the Rancho Peñasquitos and Carmel Mountain Ranch areas. In the northern part of Murphy Canyon and Tierrasanta, the Ef-ut is about 30 m thick (MS-2, MS-7). The Ef-ut crops out to the northwest as far as the northwest part of the Del Mar quadrangle and southern part of the Rancho Santa Fe quadrangle (Kennedy, 1975; Eisenberg, 1985; mapped as Mission Valley Formation).

Contacts—The Ef-ut locally rests nonconformably upon metavolcanic and granitic rocks of the crystalline basement, but usually it gradationally overlies the Ef-cg (MS-1, MS-2, MS-3, MS-6). The Ef-ut is variably overlain by the lower member of the Stadium Conglomerate (Fig. 2), the upper member of the Stadium Conglomerate (MS-8), or the Mission Valley Formation (Fig. 3; MS-6, MS-7). The upper contact of the Ef-ut is erosional wherever it has been observed.

Fossils and Age—Early Uintan fossil mammals are common in the Ef-ut, and have been collected from many localities in the greater San Diego area, from Murphy Canyon and Tierrasanta north to Scripps Ranch North, Rancho Peñasquitos, and Carmel Mountain Ranch (Golz and Lillegraven, 1977; Walsh, this volume, Chapter 5). Fossils leaves (SDSNH Loc. 3590) and pulmonate gastropods (SDSNH Loc. 3648) have been collected from the Ef-ut in the Carmel Mountain Ranch and Rancho Peñasquitos areas, while brackish-water and freshwater molluscs have been collected from the Ef-ut in McGonigle Canyon (SDSNH Locs. 3641-3642 and localities 4231 and 4233 of Hanna, 1927, p. 266).

Stadium Conglomerate

Milow and Ennis (1961, pp. 27, 29, 30) recognized two "submembers" ("Ep-cg[a]" and "Ep-cg[b]") of their "conglomerate member of the Poway Formation." In discussions of their newly-named Stadium Conglomerate, Kennedy and Moore (1971) and Kennedy (1975) did not recognize this distinction. Although Milow and Ennis's "submembers" are probably not consistently separable throughout the entire outcrop area of the Stadium Conglomerate, two lithologically distinct conglomerate units do exist within this formation in the Mission Valley-Alvarado Canyon area, and their informal recognition calls attention to details of geologic history that would otherwise be ignored. Milow and Ennis's "submembers" are therefore resurrected here as the lower (Est-a) and upper (Est-b) members of the Stadium Conglomerate.

The type section of the Stadium Conglomerate of Kennedy and Moore (1971) is located in the now idle gravel quarry of H. G. Fenton Materials Company on the north side of Mission Valley, north of Friars Road and east of Interstate 805. Two large abandoned quarry faces currently expose the lower and upper members of the Stadium Conglomerate, the overlying Mission Valley Formation, and the Pleistocene Lindavista Formation (Fig. 2). Since 1971, the type section of the Stadium Conglomerate has been modified by quarrying activity, so it is redesignated here as the large south-facing quarry face about 800 m west of the intersection of Friars Road and Mission Village Drive (MS-10).

The Stadium Conglomerate is now recognized to occur over a much smaller geographic area than as mapped by Kennedy (1975) and Kennedy and Peterson (1975). As discussed above, this conclusion stems from the realization that most or all of the outcrops of the "Stadium" mapped by these authors in the Poway and Del Mar quadrangles pertain to a stratigraphically lower unit (regarded here as the conglomerate tongue of the Friars Formation). Neither member of the Stadium Conglomerate has been recognized north of State Route 52, where the upper tongue of the Friars Formation is disconformably overlain by the late Uintan Mission Valley Formation (MS-6, MS-7). Two scenarios that would explain the limited distribution and northward-thinning of both members of the Stadium Conglomerate are as follows: (1) Toward the end of the early Uintan, the Ballenas River (Steer and Abbott, 1984) may have flowed around the southern end of present-day Cowles Mountain. If so, a maximum thickness of the Stadium Conglomerate would have been deposited along the Alvarado Canyon-Mission Valley axis, with rapid thinning to the north resulting from a "clast shadow" effect caused by the granitic barrier of Cowles and Fortuna mountains. (2) From Tierrasanta northward, both members of the Stadium were completely removed by erosion associated with the marine transgression represented by the Mission Valley Formation. Further

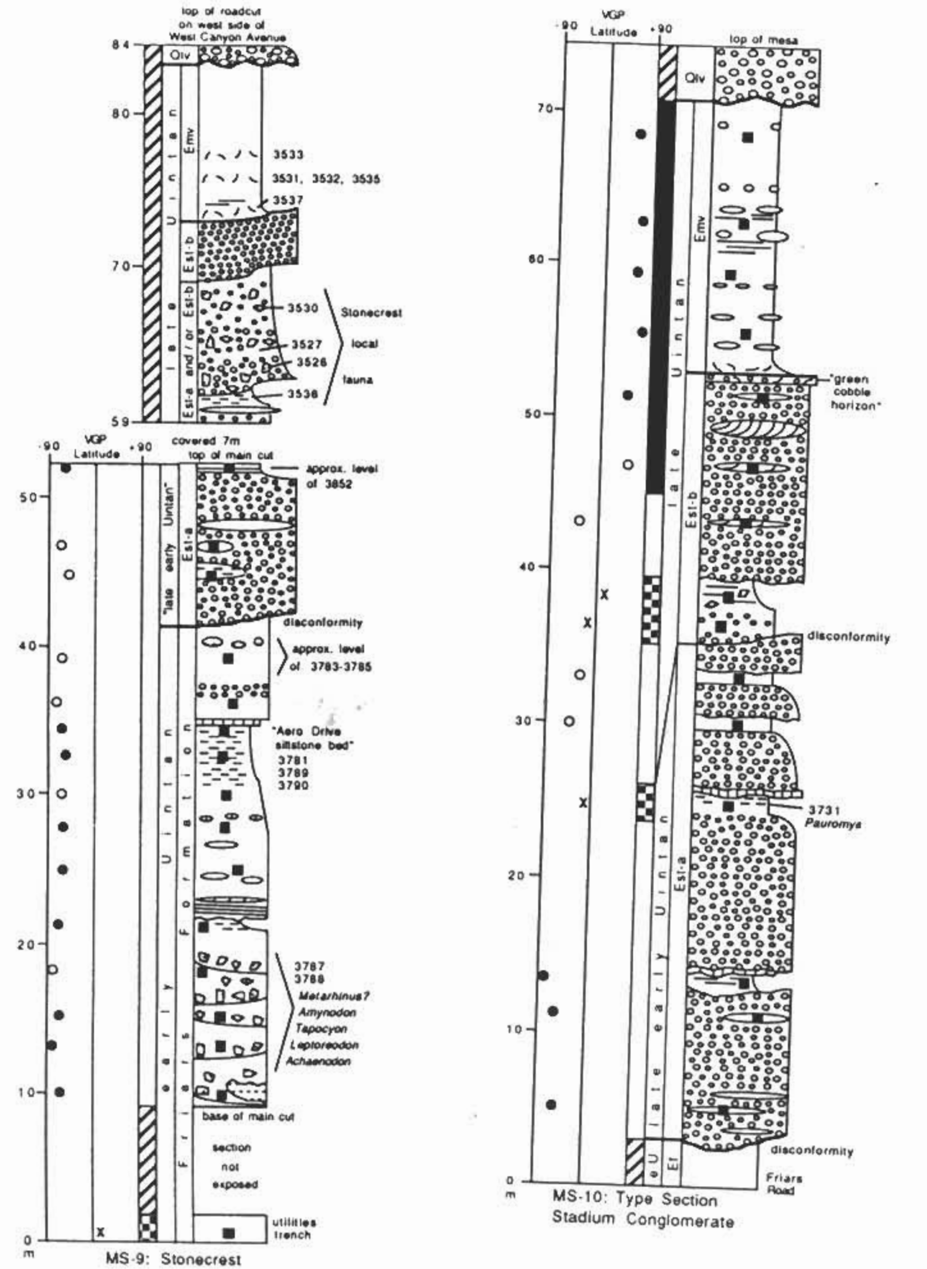

Figure 9. Magnetostratigraphic sections from Stonecrest (MS-9) and the type section of the Stadium Conglomerate (MS-10). Symbols as in Figure 5.

mapping, clast population, and paleocurrent work on the Ef-cg and both members of the Stadium Conglomerate must be done in order to test these scenarios.

Stadium Conglomerate, lower member

Type Section—At the type section of the Stadium Conglomerate, the lower member (Est-a) is composed of 34 m of light yellowish-brown and light gray and pale greenish-gray, moderately sorted, matrix-to-clast-supported, pebble to boulder conglomerate, with several lenses of light gray and pale greenish gray, medium-to-very fine-grained, moderately sorted, friable sandstone (MS-10). The matrix of the conglomerate is a very light gray to pale greenish gray, poorly sorted, muddy, fine- to medium-grained sandstone. This lithology typifies the Est-a in the Mission Valley, Murphy Canyon, and Alvarado Canyon areas. About 22 m above the base of the Est-a, a lens of medium gray, very fine-grained sandstone and caliche nodule-bearing siltstone contains sparse micromammals of late early Uintan age, including *Pauromys* sp. cf. *P. perditus* (SDSNH Loc. 3731). This bed may be stratigraphically equivalent to a laterally persistent bed of micro-mammal-bearing bluish gray and greenish gray siltstone up to 2 m thick ("*Pauromys* bed"; SDSNH Locs. 3691-3692) that occurs within the upper part of the Est-a in Murray Canyon.

Lithology and Depositional Environment—The general lithology of the Est-a is as described above for the type section. Clast assemblages have not been studied in detail, but are dominated by Poway rhyolites (Kies and Abbott, 1983). Milow and Ennis (1961) implied that the Est-a contained a greater variety of less resistant clasts than the Est-b, but detailed clast counts have not been done to corroborate these differences. In general, the light gray, "bleached" appearance of the Poway clasts in the lower member contrasts sharply with the darker, purplish and reddish colors of the unweathered Poway clasts in the upper member of the Stadium. The light gray and pale greenish gray, generally massive sandstone lenses within the lower member also contrast with the iron oxide-stained and generally cross-bedded sandstone lenses within the upper member.

Depositional environments of the Stadium Conglomerate have been studied by Howell and Link (1979), who did not recognize a division of this conglomerate into distinct lithostratigraphic units. However, Howell and Link concluded that in the Mission Valley area, the lower part of the Stadium Conglomerate was largely or entirely of fluvial origin. A non-marine setting for most of the Est-a is supported by the occurrence of caliche layers and local concentrations of fossil micromammals in this member. However, Milow and Ennis (1961) reported a sparse hyposaline microfossil assemblage from near the base of this member.

Thickness and Distribution—North of the 34 m-thick type section, the Est-a decreases rapidly in thickness before being either truncated by the Pleistocene Lindavista Formation (Fig. 2), or pinching out between the upper tongue of the Friars Formation and the Mission Valley Formation (Fig. 3). The Est-a has been recognized as far east as the campus of San Diego State University, and as far south as the intersection of Montezuma Road and Fairmount Avenue in East San Diego (Fig. 1), where it dips below the mesa surfaces south of Mission Valley.

Contacts—The Est-a erosionally overlies the type outcrops of the Friars Formation on the north side of Mission Valley and in the southern end of Murphy Canyon, and erosionally overlies the upper tongue of the Friars in the northern end of Murphy Canyon. A maximum of 5 m of relief was observed on the Est-a/Ef contact at the Stonecrest development on the west wall of Murphy Canyon (MS-9). The Est-a is locally erosionally overlain by the Est-b, with a maximum relief of about 2 m observed in the gravel pit of H. G. Fenton Materials Company, immediately east of Interstate 805. East of Murphy Canyon, the nature of the contact between the lower and upper members of the Stadium is unclear. Milow and Ennis (1961) believed this contact to be entirely disconformable, with the lower member pinching out below the upper member in the San Diego State University area. Outcrops of the Stadium Conglomerate between Alvarado Canyon and El Cajon Valley must be studied in order to resolve this question.

Fossils and Age—As discussed by Walsh (this volume, Chapter 5), the distinctive fossil mammal assemblage definitely known to occur in the Est-a (Murray Canyon local fauna) is assigned a late early Uintan age on the basis of the presence of *Microparamys* sp. cf. *M. minutus*, "*Namatomys*" new sp. 1, and *Leptoreodon major*, and on the apparent absence of *Sespedectes*, *Proterixoides*, *Simimys*, and other late Uintan indicators. However, the late Uintan Stonecrest local fauna (Walsh, this volume, Chapter 5) may have been collected from the upper part of the Est-a, in which case this unit would span the early Uintan-late Uintan boundary as recognized in southern California.

Stadium Conglomerate, Upper Member

Type section—At the type section of the Stadium Conglomerate, the Est-b is 17 m thick, and disconformably overlies the Est-a with about 1 m of erosional relief (MS-10). Here, the upper member is composed largely of rusty brown, clast-supported, Poway-type pebble and cobble conglomerate with a rusty brown, friable, well-sorted, medium-grained sandstone matrix. Two meters above the base of this member, a 2 m-thick, light gray, laminated, very fine-grained sandstone lens contains plant debris and red siltstone rip-up clasts up to 0.3 m in diameter. Several light rusty brown, massive to cross-laminated, well-sorted, friable-to-well-cemented, medium-grained sandstone lenses from 0.2 to 1 m thick occur in the type section. The top of the Est-b is marked by a distinctive, 0.6 m-thick bed of pale yellow, concretionary, matrix-supported, oyster-bearing, pebble-to-cobble conglomerate, whose clasts are all stained a dark green color. A similar (diagenetic?) horizon is also present at the top of the Est-b at the type section of the Mission Valley Formation (MS-11) and along Montezuma Road.

Lithology and Depositional Environment—Throughout the Mission Valley area, the general lithology of the Est-b is as described above for the type section. At and west of the type section, this unit is largely of deltaic origin (Howell and Link, 1979). East of Murphy Canyon, the Est-b is apparently largely of fluvial origin.

Thickness and Distribution—The Est-b displays a maximum observed thickness of 17 m on the north side of Mission Valley. North and east of the type section, the Est-b thins rapidly before either being eroded out by the Pleistocene Lindavista Formation (Fig. 2), or pinching out between the Ef-ut and the Mission Valley Formation (Fig. 3). The southernmost known outcrops of the Est-b occur in the National City quadrangle, in Chollas Valley and along Imperial Avenue (Kennedy and Tan, 1977).

Contacts—In the Mission Valley area, the Est-b erosionally overlies the Est-a. East of San Diego State University, the relationship between these two units is unclear. The Est-b is abruptly overlain by the Mission Valley Formation in the Mission Valley and La Mesa areas (Kennedy and Moore, 1971).

Fossils and Age—As discussed by Walsh (this volume, Chapter 5), the late Uintan Stonecrest local fauna may have been collected from the lower part of the Est-b. If this local fauna was actually collected from the upper part of the Est-a, however, the Est-b would still be of late Uintan age on the basis of superposition. Fossil marine molluscs were documented to occur within what is here regarded as the Est-b by Howell and Link (1979) and Givens and Kennedy (1979). The latter authors assigned a "Tejon" age to the upper member in part because of its gradational contact with the overlying Mission Valley Formation of undoubted "Tejon" age. Some of the foraminifer localities of Dusenbury (1932), Cushman and Dusenbury (1934), Gibson (1971), and Steineck et al. (1972) (variously assigned to the Poway Conglomerate or the upper part of the Stadium Conglomerate) may have been in the basal Mission Valley Formation, which contains common microfossils throughout the Mission Valley area (E. D. Milow, personal communication). However, according to M. P. Kennedy (personal communication), the calcareous nannofossil assemblage discussed by Kennedy and Moore (1971, p. 719) was definitely collected from the Stadium Conglomerate (presumably upper member).

Mission Valley Formation

The Mission Valley Formation (Emv) was named by Kennedy and Moore (1971) for a sandstone unit that had previously been recognized to occur within the old "Poway Conglomerate" by Hanna (1926) and Milow and Ennis (1961). As discussed above, the fluvial early Uintan strata in the Poway quadrangle that were mapped by Kennedy (1975) and Kennedy and Peterson (1975) as the Mission Valley Formation are here assigned to the upper tongue of the Friars Formation. Certain strata in the La Mesa quadrangle mapped by Kennedy and Peterson (1975) as the "lower tongue of the Mission Valley Formation" are probably also referable to the upper tongue of the Friars Formation. Accordingly, the stratigraphic and areal extent of the Mission Valley Formation is substantially restricted here.

Lithology and Depositional Environment—In its western outcrops, the Emv is of shelfal marine origin, and is composed almost entirely of very light gray, fine-to-very fine-grained sandstone with common concretionary horizons containing fossil molluscs (Kennedy and Moore, 1971; Givens and Kennedy, 1979). In the eastern part of its area of outcrop, the Emv is predominantly of fluvial origin, and is composed largely of very light gray, medium-grained, friable "Poway-type" sandstones with common caliche-bearing, light brown and greenish mudstone and siltstone beds, often containing terrestrial vertebrates (Lillegraven and Wilson, 1975). A distinctive lithofacies in the lower part of the Emv occurs at Scripps Ranch North, and consists of light gray, poorly sorted, arkosic coarse-grained sandstones and gritstones, interbedded with vertebrate-bearing, greenish bentonitic mudstones. This lithofacies reaches a maximum thickness of 16 m.

A 25 cm-thick, pink bentonite bed in the Emv was recently exposed at two different places during freeway construction near the intersection of Interstate 8 and State Route 125 in La Mesa. *Simimys* and *Sespedectes* occurred at both sites (SDSNH Loc. 3428 and 3539), about 2 m stratigraphically below the bentonite. Samples of the bentonite from SDSNH Loc. 3428 have yielded a single-crystal $^{40}Ar/^{39}Ar$ age of 42.83 ± 0.24 Ma (Obradovich and Walsh, in prep.; the age of 42.18 Ma reported for this bentonite in Berry, 1991, and Walsh, 1991, is incorrect). It is possible that a laterally persistent, 1-2 m-thick reddish mudstone bed occurring in the upper part of the Mission Valley Formation on the south wall of Mission Valley (e.g., MS-11 and roadcuts along Interstate 15) represents the reworked deposits of this bentonite. However, this bentonite was of normal polarity at SDSNH Loc. 3428 (Prothero, 1991), whereas the red mudstone bed in MS-11 is reported below to be of reversed polarity.

Distribution and Thickness—The Emv crops out discontinuously from Otay Valley in the south to

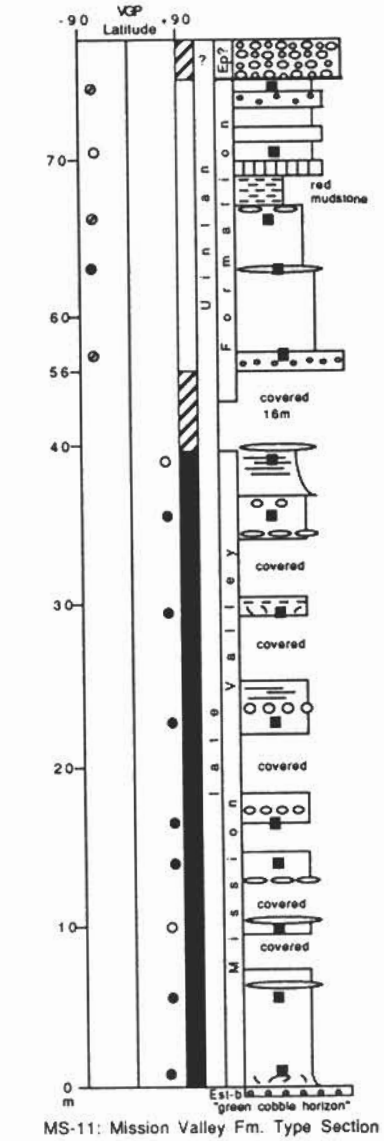

Figure 10. Magnetic stratigraphy of the type section of the Mission Valley Formation (MS-11). Symbols as in Figure 5.

Mission Valley, La Mesa, and Scripps Ranch in the north (Kennedy, 1975; Kennedy and Peterson, 1975; Kuper, 1977). The 75 m-thick type section of the Emv represents the maximum preserved thickness of this unit, due to its position in the core of the southern continuation of the gently south-plunging syncline mapped by Kennedy (1975) on the north side of Mission Valley. North of Mission Valley and east and west of the syncline axis, the preserved thickness of the Emv decreases rapidly, due to erosion at the base of the Pleistocene Lindavista Formation. At the type section of the Stadium Conglomerate (MS-10), the Emv is only 20 m thick, and is eroded out completely between Aero Drive and Balboa Avenue, on the west rim of Murphy Canyon (Fig. 2). East of the Lindavista Terrace, variable thicknesses of the Mission Valley Formation are preserved below the Pomerado Conglomerate. For example, at Hill 781 (MS-8), State Route 52 West (MS-7), and Scripps Ranch North (MS-6), the Emv is 30 m, 15 m, and 22 m thick, respectively.

Contacts—In the Mission Valley area, the Emv rests abruptly upon the Est-b. East of San Diego State University, the Mission Valley rests both abruptly and gradationally upon fluvial conglomerates of the undivided Stadium Conglomerate. In the northern part of Tierrasanta, as exposed along roadcuts on State Route 52, 1.5 km and 2.5 km east of Santo Road, white, fine- to very fine-grained marine sandstones of the Emv rest disconformably upon white, medium-grained fluvial sandstones and greenish and reddish mudstones of the Ef-ut (MS-7). The disconformity is locally marked in this area by large granitic boulders in the base of the Emv (roadcut on State Route 52, 2.5 km east of Santo Road), or by a basal conglomerate of well-polished Poway pebbles set in a matrix of white, very fine-grained sandstone (MS-7). At Scripps Ranch North, a distinctive "arkosic gritstone facies" of the Emv disconformably overlies the Ef-ut with as much as 6 m of relief (MS-6a, 6b). The Emv is overlain gradationally and erosionally by the Pomerado Conglomerate in the Scripps Ranch and La Mesa area. From Spring Valley and Encanto south to Otay Valley (south of the area covered by Fig. 1), the Emv is overlain by reddish mudstones of the latest Uintan and/or Duchesnean "Sweetwater" Formation (Walsh and Deméré, 1991).

Fossils and Age—Mammals from many localities in the Emv in the greater San Diego and Miramar Reservoir areas are assignable to the late Uintan, based on a variety of distinctive taxa such as *Simimys*, *Sespedectes*, *Proterixoides*, and *Protoreodon* new sp. 1 (Walsh, this volume, Chapter 5). Pulmonate gastropods are also common in the Emv (SDSNH Locs. 3273, 3870). Marine molluscan assemblages from the Emv have been assigned to the Pacific Coast "Tejon" stage (Givens and Kennedy 1979). Squires (1988) presented a chart wherein the "Tejon" stage was correlated with low-latitude coccolith subzones CP13B through CP15B (Okada and Bukry, 1980). As noted above, benthonic foraminifera described by Dusenbury (1932), Cushman and Dusenbury (1934), and Gibson (1971) from the "Poway Conglomerate" may have been collected from the base of the Mission Valley Formation. These shelfal assemblages were assigned to the California Narizian "Stage" by Milow and Ennis (1961) and Gibson (1971). Almgren et al. (1988) have correlated an emended concept of the Narizian with the middle Eocene low-latitude coccolith subzones CP12b through CP14b. Steineck and Gibson (1971) and Steineck et al. (1972) assigned planktonic foraminifera from the "Poway Formation" (possibly from the base of the Emv) to the late middle Eocene, and suggested an equivalence with the *Orbulinoides beckmanni* Zone of Bolli, 1957 (now the *Globigerapsis beckmanni* Zone = P13; Berggren et al., 1995). Precision of age assignments and other aspects of the work of these authors was questioned by McWilliams (1972) and Phillips (1972). Nevertheless, a correlation of no older than Zone P13 for the Mission Valley Formation planktonic foram assemblage is supported by the fact that the first appearance of *Globorotaloides suteri* and the last appearance of *Truncorotaloides collactea* (both recorded by Steineck et al., 1972) are shown by Toumarkine and Luterbacher (1985, fig. 5-6) to occur at the base of Zone P13 and the top of Zone P14, respectively. Kennedy (1975, p. 28) reported on a sample of the Emv collected from the Miramar Reservoir filtration plant (his locality 15 = LACM 3357), which contained the coccoliths "*Reticulofenestra umbilica* (Levin) and *Discoaster distinctus* Martini, which together suggest either a late middle Eocene or early [late] Eocene age" (Flynn, 1983, p. 185). According to Bukry (1973) and Okada and Bukry (1980), the base of low-latitude coccolith Subzone CP14a is defined by the first appearance of *R. umbilica*. According to Perch-Nielson (1985), *D. distinctus* "has its [last occurrence] in the upper part of Zone NP16," which is approximately equivalent to CP14a. Although the biochronological utility of *R. umbilica* is problematical (see discussion below), these data suggest that the Emv may be assignable to Subzone CP14a, which is correlated by Berggren et al. (1995) with the middle part of the middle Eocene.

Pomerado Conglomerate

The Pomerado Conglomerate (Ep) was named by Peterson and Kennedy (1974) for the cobble conglomerate unit that overlies the Mission Valley Formation in the Poway and La Mesa quadrangles. These authors also named the Miramar Sandstone Member of the Pomerado Conglomerate, which occurs between unnamed lower and upper conglomerate members of the Pomerado in the Miramar Reservoir area.

Pomerado Conglomerate, lower member

Lithology and Depositional Environment—The lower member of the Pomerado Conglomerate (Ep-lc) is composed mainly of iron oxide-stained, Poway clast-bearing pebble to cobble conglomerate. Lenses of light rusty brown, medium-grained friable sandstone are common in this unit, and occasionally contain greenish and reddish rip-up clasts of mammal-bearing siltstone. The Ep-lc appears to be mostly of fluvial origin, but local facies of probable shallow-marine origin were noted at Scripps Ranch North.

Distribution and Thickness—The Ep-lc is known to crop out only in the Miramar Reservoir area, where it is 7-10 m thick (Peterson and Kennedy, 1974; MS-6). Only a few kilometers south of the type section, the Ep-lc has not been recognized, and may pinch out rapidly within the sandstone lithosome composed of the Mission Valley Formation and Miramar Sandstone Member of the Pomerado Conglomerate (Peterson and Kennedy, 1974). Exactly where this pinchout occurs, however, is unknown.

Contacts—The contact between the Ep-lc and the Emv was erosional at the Eastview development on the west rim of Beeler Canyon, and was variably erosional and gradational at the Scripps Ranch North development north of Miramar Reservoir. The contact between the Ep-lc and the overlying Miramar Sandstone Member of the Pomerado Conglomerate was variably erosional and gradational at the Eastview and Scripps Ranch North developments.

Fossils and Age—Walsh (this volume, Chapter 5) discusses the late Uintan Eastview local fauna, which was collected from the upper part of the Ep-lc at the Eastview and Scripps Ranch North housing developments. Most of these specimens were collected from siltstone rip-up clasts, and the sandstone lenses that contained them (e.g., SDSNH Loc. 3755; MS-6a). The siltstone clasts are lithologically similar to the extensive beds of siltstone that occur in the lower part of the Mission Valley Formation at Scripps Ranch North, so it is possible that the fossils from the Eastview local fauna were derived from the Mission Valley Formation. Nevertheless, presence of *Protoreodon* new sp. 1 from the Miramar Sandstone Member (see below) independently suggests that the Ep-lc is of late Uintan age.

Pomerado Conglomerate, Miramar Sandstone Member

Lithology and Depositional Environment—The Miramar Sandstone Member (Ep-m) consists almost entirely of very light gray and pale greenish gray, fine- to medium-grained, friable sandstone, with rare interbeds of reddish siltstone, common lenses of Poway-type conglomerate, and rip-up clasts of green sandy mudstone, often oxidized to a bright rust color. The Ep-m is of both fluvial and shallow-marine origin.

Distribution and Thickness—The Ep-m is definitely known to crop out only in the Miramar Reservoir area, where it is 20 m thick (Peterson and Kennedy, 1974). It extends eastward at least as far as the Eastview housing development on the west rim of Beeler Canyon. Assuming that the lower member of the Pomerado pinches out rapidly to the south and southwest of Miramar Reservoir, it is possible that the Ep-m is stratigraphically correlative with the upper part of the Mission Valley Formation in the type area of the latter. Unfortunately, paleomagnetic results from these units are difficult to interpret, and can neither support nor refute this hypothesis.

Contacts—In general, the Ep-m appears to gradationally overlie the Ep-lc, although an erosional contact was observed at MS-6b. The Ep-m is erosionally overlain by the upper member of the Pomerado Conglomerate at Scripps Ranch North (MS-6a).

Fossils and Age—A small collection of internal molds of marine molluscs has been obtained from the Ep-m from Scripps Ranch North. The fossils occurred in a 0.5 m-thick bed of reddish laminated siltstone (SDSNH Locality 3625; MS-6a), and include *Crassatella* sp. indet., Lucinidae gen. indet., Tellinidae gen. indet., and one indeterminate gastropod (T. A. Deméré, personal communication). Preservation of these fossils is inadequate for species-level identifications, so the biostratigraphic utility of this collection is limited.

Two fossil mammal localities were also discovered within the Ep-m at Scripps Ranch North (SDSNH Locs. 3756 and 3757; MS-6a). Only SDSNH Loc. 3757 has yielded identifiable specimens, which include *Miacis* cf. *M. hookwayi*, *Protoreodon* new sp. 1, and a small unidentified species of *Leptoreodon*. These specimens suggest that the Ep-m is of late Uintan age, but still older than the latest Uintan or Duchesnean Laguna Riviera local fauna of northwestern San Diego County, which is characterized by *Protoreodon annectens* (Kelly et al., 1991; Walsh, this volume, Chapter 5).

Pomerado Conglomerate, Upper Member

Lithology—The upper member of the Pomerado Conglomerate (Ep-uc) is a poorly-sorted, light gray to pale greenish gray, Poway-type, pebble to boulder conglomerate. The Ep-uc contains common lenses of light gray medium-grained sandstone, and occasional thin lenses and rip-up clasts of green sandy mudstone. The mudstone clasts are often oxidized to a bright rust color.

Distribution and Thickness—The Ep-uc reaches a maximum preserved thickness of 32 m north of Miramar Reservoir (Peterson and Kennedy, 1974), and extends southward to Tierrasanta, Santee, and apparently La Mesa, where it thins to less than 10 m (Kennedy and Peterson, 1975). The light gray cobble to boulder conglomerate unit overlying the type section of the Mission Valley Formation may also be referable to the Ep-uc (Kennedy and Moore, 1971).

Contacts—In the Miramar Reservoir area, the Ep-uc erosionally overlies the Ep-m with less than 1 m of observed relief. In the Fletcher Hills and La Mesa areas, the Pomerado Conglomerate (upper member?) gradationally(?) overlies late Uintan, mammal-bearing, white fluvial sandstones mapped by Kennedy and Peterson (1975) as Mission Valley Formation.

Fossils and Age—Only one fossil is known from the Ep-uc. It was collected on the Scripps Ranch North development, from a green sandy mudstone bed (SDSNH Loc. 3759) within gray cobble-to-boulder conglomerate, at an elevation of 293 m. The fossil is a heavily damaged dentary of a small artiodactyl, and is not identifiable. The Ep-uc is of late Uintan or younger age, based on its stratigraphic position above the late Uintan Ep-m.

PALEOMAGNETIC CORRELATION OF EOCENE STRATA IN SOUTHWESTERN SAN DIEGO COUNTY

Previous Work

Flynn (1986) integrated paleomagnetic data with mammalian biochronology in an attempt to correlate the early Uintan rocks and faunas of San Diego with those of Wyoming. The key correlation point in Flynn's analysis was the Ardath Shale, which had been assigned an early middle Eocene age (low-latitude coccolith Subzone CP12b; Bukry and Kennedy, 1969; Okada and Bukry, 1980). Given Flynn's finding that the type section of the Ardath Shale was almost entirely of normal polarity, and given the placement by Berggren et al. (1985) of the early Eocene/middle Eocene boundary at the Chron C22n/C21r boundary, Flynn correlated the Ardath Shale normal polarity interval with Chron C21n. Bottjer et al. (1991) sampled the Ardath Shale along the seacliffs between Scripps Institution of Oceanography and Torrey Pines, reported that all sites were of normal polarity, and followed Flynn (1986) in assigning this interval to C21n.

The type section of the Delmar Formation was reported by Flynn (1986) to be of reversed polarity, with the exception of a single normal site at the top of the section. Flynn correlated this normal site with Chron C21n, and the lower reversed sites with C21r. Bottjer et al. (1991) sampled the Delmar Formation at Torrey Pines State Beach, and found this section to be entirely of reversed polarity. The significance of Flynn's (1986) normal site at the top of the Delmar is therefore uncertain, especially since the overlying Torrey Sandstone has not been sampled.

Flynn (1986) reported that the type section of the Scripps Formation was entirely of normal polarity. Flynn also reported that the lower part of the Friars Formation type section (uppermost Scripps and basal Friars Formation) was of normal polarity, while the upper part of the Friars Formation here was of reversed polarity. Flynn's Genesee Avenue section in the Friars produced similar results. We resampled this section because it contains the significant mammal locality LACM (CIT) 314, the results of which are discussed below (Appendix 1). Flynn (1986) correlated the normal polarity interval in the Scripps and basal Friars formations with Chron C21n, and the reversed polarity interval in the upper part of the Friars Formation with Chron C20r. Bottjer et al. (1991) sampled the Friars Formation at an outcrop about 3 km northwest of Flynn's Genessee Avenue section, and reported that all eight of their sites from the base of the Friars were of normal polarity, which they also correlated with C21n (however, some of the lower sites reported by Bottjer et al. (1991) may have been taken from the upper part of the Scripps Formation). Bottjer et al. (1991) also sampled the Friars Formation at Boyd Road and at Clairemont Mesa Boulevard, found both sections to be entirely of reversed polarity, and correlated these intervals with C20r. The Clairemont Mesa Boulevard section of Bottjer et al. (1991) is located in the upper tongue of the Friars as recognized here, immediately above the conglomerate tongue of the Friars (Fig. 2, MS-2).

Flynn (1986, fig. 8 and p. 378) briefly described two paleomagnetic sections from Murphy Canyon, collected from the Friars Formation and ?Stadium Conglomerate. Flynn shows the stratigraphically lowest section to be entirely of normal polarity, and the stratigraphically highest section to be entirely of reversed polarity. Based on Flynn's (1983, p. 191) statement that his Murphy Canyon section was collected from cuts along Interstate 15 between Friars Road and Clairemont Mesa Boulevard, it is probable that some of his "?Stadium Conglomerate" sites were actually taken from the conglomerate tongue of the Friars Formation. On the basis of the Murphy Canyon sections, Flynn (1986, p. 384) raised the possibility of an upper normal polarity interval in the Friars Formation that might correlate with Chron C20n. However, as he pointed out, correlation of these non-superposed sections in the Friars Formation is difficult, and there is presently no convincing evidence for the recognition of an upper normal polarity interval in the Friars Formation in this area. Flynn (1986, p. 353) indicated that three paleomagnetic sections (two in the Miramar Reservoir area and one near Fairmount Avenue) were collected from the Mission Valley Formation, but only two of them are shown in his summary of magnetostratigraphic data (Flynn, 1986, fig. 8), one of which is entirely of normal polarity, and the other entirely of reversed polarity. Unfortunately, it is not possible to determine which of Flynn's three sections are illustrated.

Of the four paleomagnetic sections collected in the Mission Valley Formation by Bottjer et al. (1991), the Presidio Park section is actually located in the Scripps Formation. The Eocene strata forming the south wall of Mission Valley between Presidio Park and State Route 163 were assigned entirely to the Stadium Conglomerate and Mission Valley Formation by Kennedy (1975, plate 2A), but the anticline and syncline mapped by Kennedy on the north side of Mission Valley continue through to the south, such that the Scripps (SDSNH Loc. 3834) and Friars formations (SDSNH Loc. 3639) crop out on the south wall of Mission Valley in and east of Presidio Park (T. A. Deméré, personal communication). Bottjer et al. (1991) reported that the Presidio Park section is entirely of normal polarity, which is consistent with Flynn's (1986) report that the type section of the Scripps is entirely of normal polarity. The Miramar Reservoir section of Bottjer et al. (1991) clearly pertains to the Mission Valley Formation, but this section yielded only two sites of unequivocal polarity, both of which were normally magnetized (Powers, 1988, p. 71). The Pomerado Road section of Bottjer et al. (1991) apparently pertains to the Mission Valley Formation, but it produced only three sites of unequivocal polarity, all of which were normally magnetized (Powers, 1988, p. 69). The Montezuma Road section of Bottjer et al. (1991) clearly pertains to the Mission Valley Formation. They report that two sites occurring near the base of their section are of reversed polarity, whereas five sites from the middle and upper part of their section are of normal polarity. However, the original data presented by Powers (1988, p. 67) shows two reversed and two normal magnetozones from Montezuma Road, so the significance of this section is uncertain. Bottjer et al. (1991) correlated the putative reversed and putatively overlying normal magnetozones in the Mission Valley Formation with Chrons C18r and C18n, based largely on the tentative correlation (Steineck et al., 1972) of the upper part of the Stadium Conglomerate (possibly basal Mission Valley Formation) with planktonic foramini-feral Zone P13, which was correlated with Chron C18 by Berggren et al. (1985).

NEW PALEOMAGNETIC STUDIES

Methods

In an effort to clarify some of the ambiguities evident in previous paleomagnetic work on the Friars Formation and Poway Group, we collected samples from several new sections containing both early and late Uintan mammal assemblages (MS 1-11; Appendix 1). All sections were measured by Walsh with the exception of MS-11, which was measured by T. A. Deméré and Walsh. Block samples were collected using simple hand tools, with the top surface planed horizontal. Many samples were hardened with dilute sodium silicate to prevent them from crumbling. At least three samples were collected per site so that site statistics could be calculated. Sites were typically spaced 5-10 m apart stratigraphically, depending upon exposure and availability of suitable lithologies. Samples from MS-3,

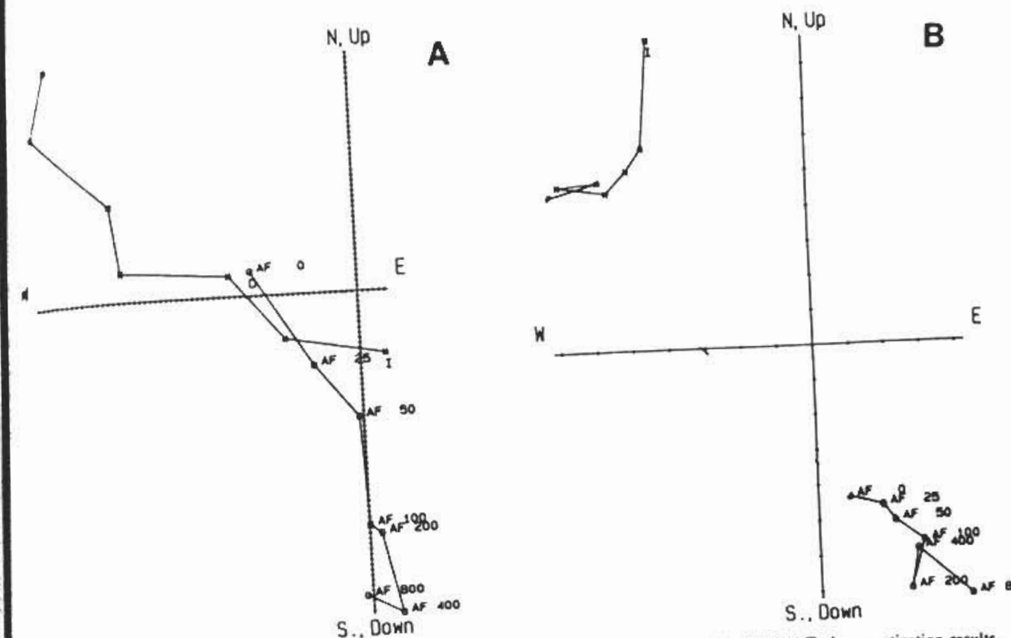

Figure 11. Representative orthogonal demagnetization ("Zijderveld") plots of alternating field (AF) demagnetization results. Solid circles indicate horizontal component, "x" indicates vertical component. AF intensity in Gauss is shown on each step. Each division = 10^{-7} emu. (A) This sample shows a rapid decline in intensity in AF demag, indicating that magnetite is a major carrier of remanence. It also changes from north and down at NRM ("AF0") to south and up (reversed polarity) after the first demagnetization step. (B) This sample does not respond to AF demagnetization, indicating that hematite is a primary carrier of the remanence.

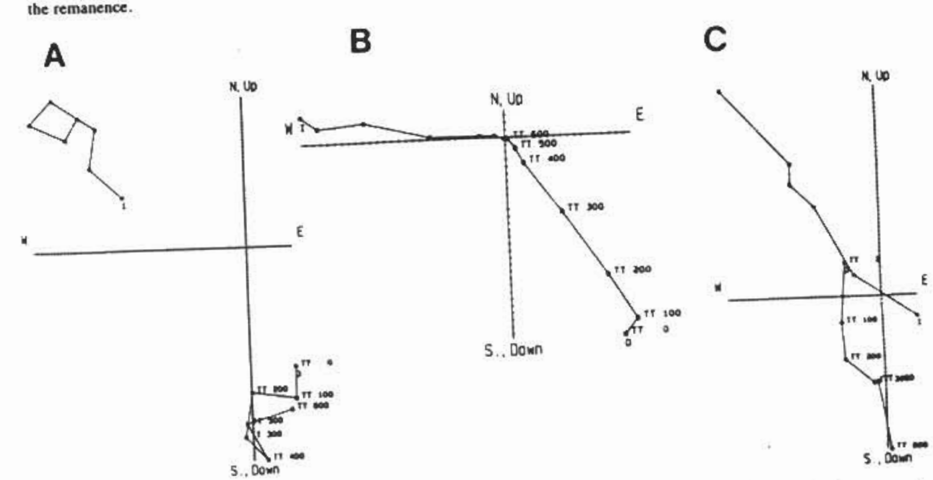

Figure 12. Representative orthogonal demagnetization plots of thermal demagnetization results. Demagnetization temperature ("TT") shown at each step. All other conventions as in Figure 11. (A) This sample shows clear reversed polarity from NRM ("TT0"), but did not lose intensity even at 600°C, indicating that hematite is the primary carrier of remanence. (B) This sample also shows reversed polarity, but completely demagnetizes by 600°C, indicating that all the remanence is carried by magnetite. (C) This sample contained a remanence in hematite, and a normal overprint was removed by 200°C, revealing a reversed polarity.

MS-4, MS-6a, MS-7, MS-10, and MS-11 were collected by Prothero, Lundquist, and their colleagues at Occidental, while samples from the remaining sections were collected by Walsh. Samples were trimmed into 2.5-cm cubes on a band saw with a tungsten carbide blade, and analyzed at the California Institute of Technology paleomagnetics lab by Prothero and Lundquist.

A suite of samples of representative lithologies was subjected to alternating field (AF) and thermal demagnetization. Under AF demagnetization (Fig. 11A), most samples showed a rapid drop in intensity, suggesting that the main carrier of the remanence is a low-coercivity mineral such as magnetite. However, some samples (Fig. 11B) were relatively resistant to AF demagnetization, so their remanence appears to be carried by a high-coercivity mineral such as hematite or goethite.

Under thermal demagnetization (Fig. 12), most samples showed no remanence above the Curie point of magnetite at 580°C; however, a few samples still had significant intensity at 600°C, showing that some of their remanence is carried by hematite. Overprints were typically removed by 100-200°C. Most samples produced a stable vectorial component between 400-500°C, and that component was used in the statistical analysis.

Analyses of IRM (isothermal remanent magnetization) acquisition further confirmed that both magnetite and hematite were present in many samples. Some rocks (Fig. 13B) reached saturation IRM values at 100-300 mT (millitesla); the remanence in these rocks is carried mostly by magnetite. Other specimens (Fig. 13A) showed no evidence of IRM saturation, even at fields of 1300 mT; these samples clearly contained much hematite. A modified Lowrie-Fuller ARM (anhysteretic remanent magnetization) test (e.g., Johnson et al., 1975) was also conducted during the IRM analysis (see Pluhar et al., 1991, for details). This test compares the resistance of AF demagnetization of both an IRM acquired in a 100 mT peak field, and an ARM gained in a 100 mT oscillating field. In almost all samples, the ARM (black squares) demagnetizes at higher peak fields than does the IRM (open squares), indicating that the remanence is carried by single-domain or pseudo-single domain grains. Finally, thin sections of representative samples were examined under reflected light. In several slides, euhedral magnetite grains with oxidized rims of hematite could be seen.

The stable sample directions were then clustered by site, and statistically analyzed by the methods of Fisher (1953; see Butler, 1992). Class I sites of Opdyke et al. (1977) showed a clustering that differed significantly from random at the 95% confidence level. In Class II sites, one sample was lost or crumbled, but the remaining samples gave a clear polarity indication. In Class III sites of Opdyke et al. (1977), two samples

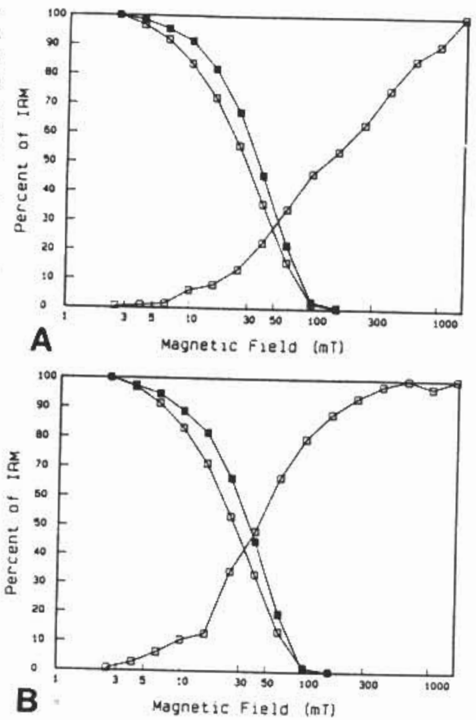

Figure 13. Typical results of IRM acquisition analysis and the modified Lowrie-Fuller test (see Pluhar et al., 1991, for details of methods). IRM values shown in open boxes, ARM in solid boxes. The IRM acquisition test is shown by the ascending curve on the right; the modified Lowrie-Fuller test by the two descending curves on the left. (A) The IRM fails to saturate in this sample, showing that hematite is the predominant magnetic mineral. The ARM is more resistant to AF demagnetization than the IRM, suggesting that the grains are single-domain or pseudo-single-domain. (B) IRM saturation occurs at about 300 millitesla (mT), showing that magnetite predominates in this sample. This sample also shows a single-domain Lowrie-Fuller test.

showed a clear polarity preference, but the third sample was divergent because of insufficient removal of overprinting. A few samples were considered indeterminate if their magnetic signature was unstable, or their direction uninterpretable.

Means for all Class I normal and reversed sites were calculated using the methods of Fisher (1953). The mean for all normal sites was D = 349.2°, I = 47.5°, k = 22.0, and α_{95} = 8.7; the mean for all reversed sites was D = 181.1, I = -26.2, k = 4.4, α_{95} = 19.9. These two means are antipodal within their margins of error, so this positive reversal test suggests that the magnetization is primary depositional remanence and not a later overprint.

Based on these inclinations, the Eocene paleolatitude for the area was about 28.6° (present latitude = 33°), suggesting about 4-5° of northward translation since the Eocene. This is within the range of values reported by Flynn (1986), Prothero (1991), and Powers (1988) for the area. However, given the large error bars, this result is not very definitive for paleolatitudinal studies.

Correlation of Magnetostratigraphic Sections

Simplified versions of the magnetostratigraphic sections studied for this paper are illustrated in Figure 14, and arranged from left to right in general order of decreasing age. The relative age of the sections is inferred from the lithostratigraphic correlations discussed above, and the mammalian biostratigraphy discussed by Walsh (this volume, Chapter 5).

Early Uintan

Magnetostratigraphic interpretation of the Friars Formation in the type area appears to be straightforward. Thus, the type section and the three Genessee Avenue sections are consistent in that the lowermost part of the Friars is of normal polarity, while the upper part is reversed (Flynn, 1986; Bottjer et al., 1991; this chapter). This reversed interval is reasonably correlated with the reversed interval in the Friars Formation at MS-9, and with the reversed interval in the upper tongue of the Friars at MS-2, MS-6, MS-7, and MS-8.

Magnetostratigraphic interpretation of the Friars Formation becomes more difficult north and east of the type area, where the formation is divided into lower and upper tongues by the conglomerate tongue. The thickest sampled section in the Ef-lt (MS-4b) shows mostly normal polarity in the lower part, and mostly reversed polarity in the upper part of the section. This normal-to-reversed transition may correlate with the similar transition observed a short distance above the Friars/Scripps contact in the type area (e.g., type section, MS-2, and MS-5). If so, the relative thickness of the normal magnetozone at MS-4 suggests that the lower part of the lower tongue of the Friars Formation is indeed coeval with the upper part of the Scripps Formation, in accordance with the time-transgressive model of Kennedy and Moore (1971). The short sections of the Ef-lt at MS-2 and MS-3 were entirely of reversed and entirely of normal polarity, respectively. However, since erosional relief at the base of the Ef-cg may be considerable over several kilometers, the significance of these results is uncertain.

More discrepancies are evident in the results obtained from the Ef-cg and Ef-ut. The Ef-cg was found to be of reversed polarity at MS-2, but was largely of normal polarity at MS-1. The Ef-ut was found to be entirely of reversed polarity at MS-1, MS-2, MS-6, MS-7, and MS-8, but was found to be almost entirely normal at MS-3. Conceivably, the "Ef-cg" and "Ef-ut" in certain sections may be different stratigraphic units than the "Ef-cg" and "Ef-ut" in other sections. A more parsimonious explanation would invoke lithostratigraphic time-transgression (e.g., Kennedy, 1975), such that deposition of these units as preserved in one area began earlier than deposition of the same units as preserved in another area. If so, the normal magnetozones in MS-1 and MS-3 may correlate with the normal magnetozone in the lower part of the type area of the Friars Formation. Finally, the normal magnetozone at MS-3 could represent a distinct upper normal polarity interval in the Friars. This seems unlikely, since no definite reversed polarity interval was detected in this section, but it is also possible that a reversed interval was originally present in the Ef-lt here, only to be eroded away prior to the deposition of the Ef-cg.

Late Uintan

A potential tiepoint between the early and late Uintan magnetozones is represented by the reversed interval that occurs in the late early Uintan Est-a (MS-9 and MS-10). If the contact between the Est-a and Est-b is assumed not be a chron-encompassing disconformity, then the two reversed sites in the lower part of the Est-b (MS-8 and MS-10) would represent the same chron as the reversed interval in the Est-a. The late Uintan normal interval in MS-10 (upper part of Est-b and Emv) likely correlates with the normal intervals in the Mission Valley Formation at the type section and at MS-7 and MS-8. Unfortunately, other Mission Valley Formation sections are difficult to interpret. Most of the type section (MS-11) is of normal polarity, with the uppermost five sites being reversed. In contrast, the lower part of the Montezuma Road section of Bottjer et al. (1991) was reported to be of reversed polarity. We found the Mission Valley to be of variable, but largely reversed polarity in two adjacent sections at MS-6 (see Appendix 1). However, only 1.5 km to the south and 3 km to the southeast of MS-6a, all five of Powers's (1988, p. 71) determinable Mission Valley Formation sites were of normal polarity. These discrepancies cannot be resolved at this time. Assuming that the polarity has been correctly determined, it is also unclear whether the reversely-magnetized lower unit of the Mission Valley Formation at MS-6 correlates with the reversed magnetozone in the upper part of the Mission Valley type section, or whether the lower unit at MS-6 is entirely older than the type section. In view of these uncertainties, no satisfactory overall magnetostratigraphic hypothesis can be proposed for the Mission Valley Formation at this time.

Stratigraphic uncertainties and limited samples also make interpretation of the Pomerado Conglomerate magnetozones difficult. First, it is uncertain whether the entire thickness of the Pomerado Conglomerate at MS-7 correlates with the Ep-lc, Ep-m, and Ep-uc at MS-6a, or just with the Ep-uc at MS-6a. Second, as noted previously, it cannot be assumed that the lower

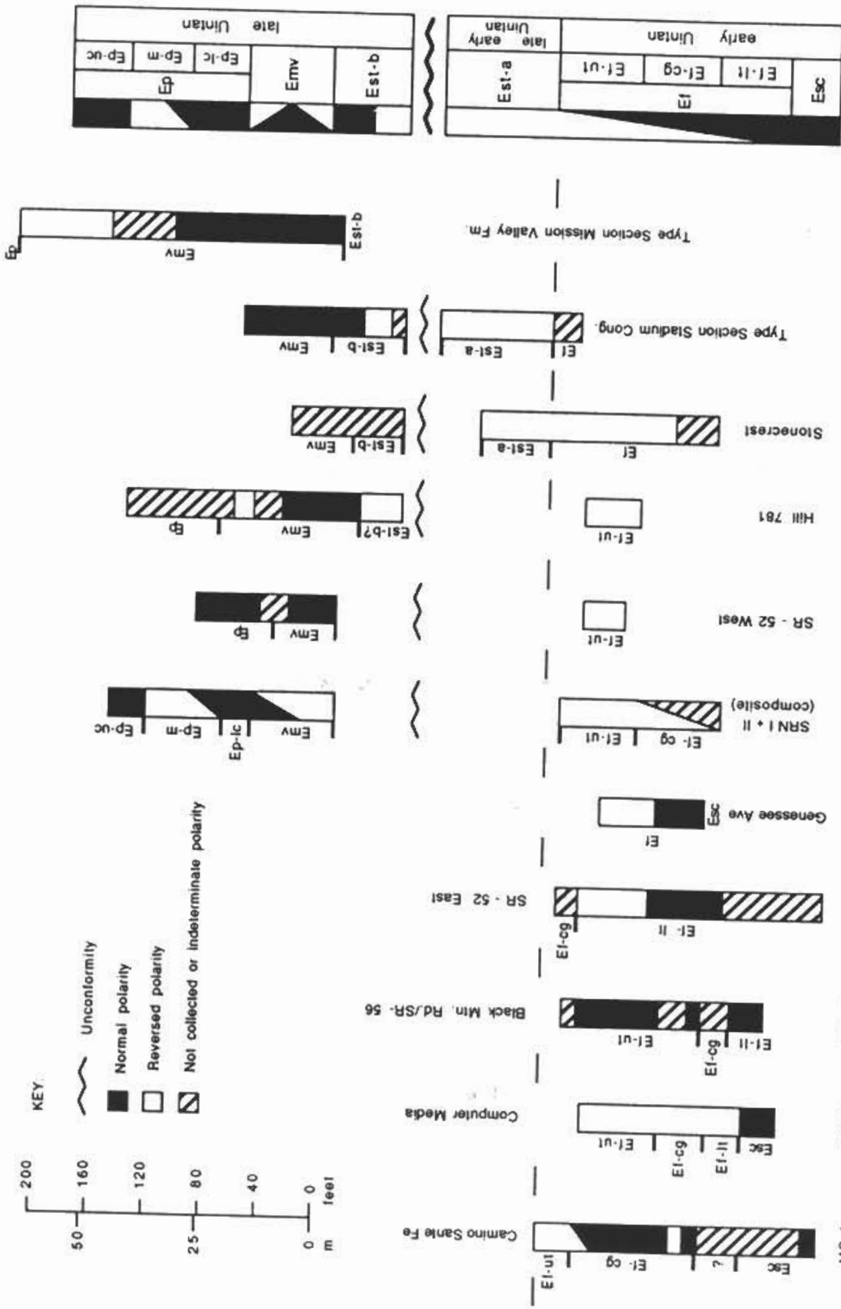

Figure 14. Correlation of magnetostratigraphic sections studied for this paper. Vertical scale applies to the individual sections, not the composite section. Abbreviations as in Figs. 2-3. See text for discussion.

conglomerate and Miramar Sandstone members of the Pomerado are entirely younger than the type outcrops of the Mission Valley Formation. In the absence of a convincing demonstration of the correct stratigraphic and/or temporal relationships between these units, correlation of the magnetozones within them is inadvisable.

Chron Correlations of San Diego Eocene Polarity Intervals

Given the difficulties in magnetozone correlation discussed above, the attempt to identify many of them with specific chrons is questionable. Nevertheless, tentative chron correlations for various lithostratigraphic units of southwestern San Diego County are shown in Figure 15 (after Berggren et al., 1995), and the evidence for these assignments is reviewed below. We emphasize that numerical calibration of the boundaries of the Eocene chrons rests upon a large number of assumptions involving many different sources of error, and that the values given for these boundaries cannot be taken literally to within about ± 1 m.y. (Harland et al., 1990, p. 154).

Delmar Formation

As noted, Flynn (1986) and Bottjer et al. (1991) assigned the Delmar Formation reversed polarity interval to the earliest middle Eocene Chron C21r. This assignment appears to be corroborated by Frederiksen's (1991) correlation of a pollen assemblage from the Delmar with the earliest middle Eocene coccolith Subzone CP12b (Okada and Bukry, 1980; Berggren et al., 1995).

Ardath Shale

The normal polarity interval in the Ardath Shale both at the type section and at the seacliff outcrops north of La Jolla was assigned by Flynn (1986) and Bottjer et al. (1991) to Chron C21n. This assignment was based on the early middle Eocene age of the Ardath as determined by planktonic foraminifera (Zone P10 and/or P11; Steineck et al., 1972) and coccoliths (Subzone CP12b; Bukry and Kennedy, 1969; Okada and Bukry, 1980), in conjunction with the correlations of Berggren et al. (1985). The report by May et al. (1991) that the upper part of the Ardath Shale contains coccoliths assignable to Subzones CP13a and CP13b further supports identification of the Ardath normal polarity interval as C21n (Berggren et al., 1995). Although a literal reading of the time scale of Berggren et al. (1995) would indicate that Subzone CP13b is entirely younger than C21n, these authors note that magnetochronological control on certain middle Eocene microfossil biochrons is poorly constrained. The beginning of CP13b as shown by Berggren et al. (1995) will have to be moved downward into Chron C21n if the presence of Subzone CP13b in the Ardath Shale can be corroborated (assuming that the normal polarity obtained by Bottjer et al. (1991) for the Ardath Shale at Black's Beach is correct).

Scripps Formation

The normal polarity interval comprising the entire thickness of the type section of the Scripps Formation was assigned by Flynn (1986) to C21n, based on the reasonable assumption that the contact between the Scripps and the Ardath Shale was not a chron-encompassing disconformity. If May et al. (1991) are correct that the Ardath Shale is as young as coccolith Subzone CP13b, and if the normal polarity interval in the type Scripps does correlate with Chron C21n, and if the correlations between the coccolith zones of Okada and Bukry (1980) and chron boundaries illustrated by Berggren et al. (1995) are taken literally, then the entire thickness of the type Scripps must have been deposited extremely rapidly during the latest part of Chron C21n and during the earliest part of Subzone CP13b. Marine mollusc assemblages from the lower and upper parts of the Scripps are assigned by Givens and Kennedy (1979) to the "Domengine" and "Transition" stages, respectively. Since Squires (1988) placed the "Transition" stage entirely within Subzone CP13a, correlation of the Scripps normal polarity interval with Chron C21n would again seem to be indicated (Berggren et al., 1995). However, a partial correlation of the "Domengine" stage with Subzone CP13b would be required if the upper part of the Ardath Shale is in fact assignable to this Subzone (May et al., 1991).

Alternatively, the Scripps-Ardath contact was regarded as a sequence boundary by May et al. (1991), and it is conceivable that the disconformity is of such magnitude that the normal interval in the type Scripps is a full chron younger than the normal interval in the Ardath, in which case the former would correlate with C20n. If so, the Scripps should contain coccoliths assignable to Subzones CP13c and/or CP14a, and planktonic forams assignable to Zones P11 and/or P12, according to the correlations of Berggren et al. (1995). Obviously, a stratigraphically-controlled micropaleontological study of the Scripps Formation should be undertaken in order to clarify the age range of this unit.

Despite these difficulties, we prefer to correlate the Scripps normal interval with Chron C21n for the following reasons. First, if this interval did pertain to C20n, the Scripps-Ardath disconformity would have to represent at least the entire duration of C20r, and the beginning of the Friars Formation reversed interval would then correlate with the beginning of C19r (42.6 Ma according to Berggren et al., 1995). However, given the $^{40}Ar/^{39}Ar$ date of 42.83 ± 0.24 Ma from the Mission Valley Formation (Obradovich and Walsh, in prep.), this would in turn require that most of the Friars Formation, both members of the Stadium Conglomerate, and the lower part of the Mission Valley

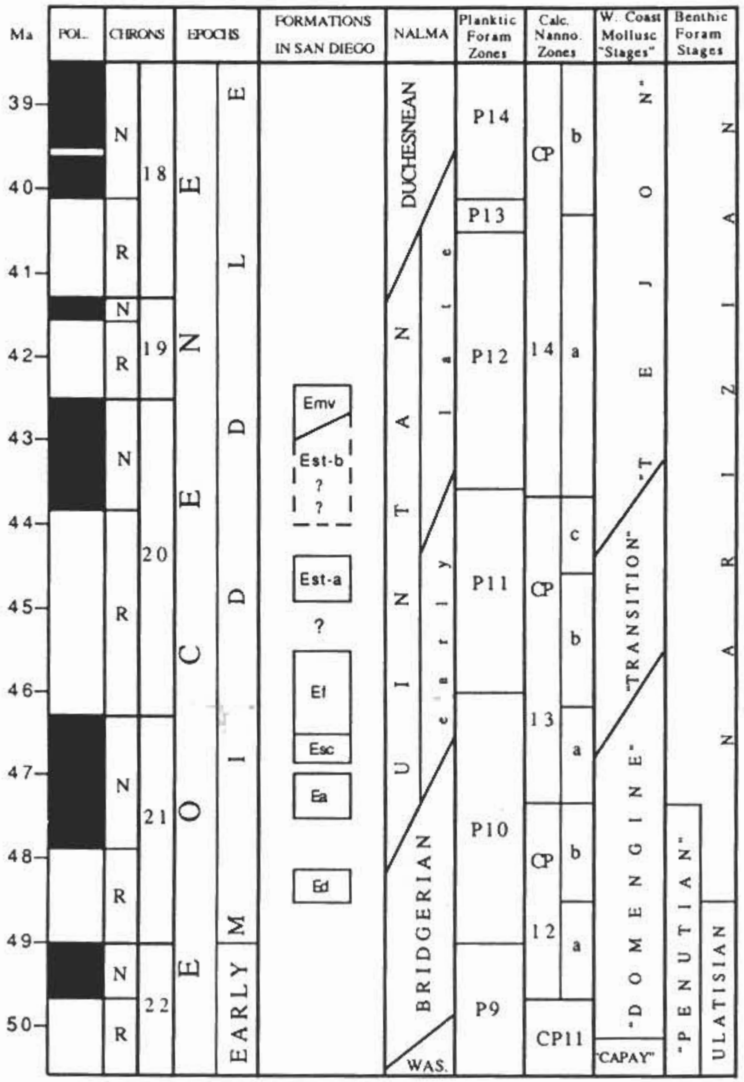

Figure 15. Tentative correlations of certain San Diego lithostratigraphic units with the Geomagnetic Polarity Time Scale (Berggren et al., 1995) and various biochronologies. Based largely on Flynn (1986), Bottjer et al. (1991), Almgren et al. (1988), Squires (1988), Frederiksen (1991), Obradovich and Walsh (in prep.), Walsh (this volume, Chapter 5), and this paper. Ed = Delmar Formation, Ea = Ardath Shale. Other abbreviations as in Figures 2-3. Note that the numerical ages of the chron boundaries cannot be taken literally to within about ± 1 m.y. (Harland et al., 1990, p. 154).

Formation were all deposited in an interval of "negative" 0.2 m.y. Further, an age of about 42.6 Ma for the early Uintan Friars Formation would conflict with the fact that several mammal assemblages in North America of about this age have all been assigned to the late Uintan (Walsh, this volume, Chapter 4). These implications suggest that the Scripps Formation normal polarity interval probably correlates with C21n rather than C20n.

Friars Formation

Because the Friars Formation either conformably overlies the Scripps Formation (Kennedy and Moore, 1971), or locally overlies the Scripps with minor erosional relief, the normal polarity interval in the base of the Friars Formation in the type area can be confidently assumed to pertain to the same chron as the normal interval in the Scripps Formation. As discussed above, the latter is best correlated with C21n, so the Friars reversed interval probably correlates with C20r, as concluded by Flynn (1986) and Bottjer et al. (1991).

Stadium Conglomerate, lower member

The contact between the lower member of the Stadium and the Friars Formation is gradational according to Kennedy and Moore (1971), but was erosional wherever we have seen it, and the amount of time represented by this contact is unknown. Nevertheless, the reversed interval in the lower member of the Stadium is tentatively assigned to Chron C20r on the basis of its late early Uintan mammal assemblage. If the lower member reversed interval does in fact pertain to C19r, then the Friars-Stadium contact would be a disconformity representing at least the entire duration of C20n (1.3 m.y. according to Berggren et al., 1995).

Stadium Conglomerate, upper member

Paleomagnetic evidence from the Est-b is limited. Two sites from the base of the type section of this unit (MS-10) were of indeterminate polarity, and one site each from MS-8 and MS-10 were reversed. If the above assignment of the Est-a to C20r is correct, and if the Est-b/Est-a contact is not a chron-encompassing disconformity, then the lower part of the Est-b may also pertain to C20r, and the normally-magnetized upper part of the Est-b (MS-10) may pertain to C20n. If so, based on the late Uintan age of the Stonecrest local fauna (Walsh, this volume, Chapter 5), the early Uintan/late Uintan boundary as recognized in San Diego would occur during late C20r. However, these scenarios must be regarded as tenuous in view of the small number of paleomagnetic sites from the Est-b, and the discussion of the Mission Valley Formation below.

Mission Valley Formation

As noted above, a planktonic foraminiferal assemblage from either the upper member of the Stadium Conglomerate or the Mission Valley Formation has been correlated with Zone P13 (Steineck et al., 1972). Berggren et al. (1985) correlated Zone P13 with Chron C18n, which led Bottjer et al. (1991) to assign the Mission Valley Formation to the latter. However, Berggren et al. (1995) now correlate Zone P13 with the upper part of C18r. Although little confidence can be placed in the meager planktonic foraminiferal evidence available, if the Mission Valley Formation is indeed approximately of "Zone P13 age," then the lower normal and upper reversed magnetozones in the type section of the Mission Valley Formation could correlate with C19n and C18r, or perhaps C18n.2n and C18n.1r.

As discussed above, a sparse coccolith assemblage from the Mission Valley Formation at the Miramar Reservoir filtration plant may be assignable to Subzone CP14a, based in part on the reported occurrence of *Reticulofenestra umbilica*, which is the defining taxon for the base of this subzone (Bukry, 1973; Okada and Bukry, 1980). Unfortunately, there are problems with the use of this species as a biochronologic marker. Backman and Hermelin (1986) concluded that the "appearance" (defined as a size increase) of *R. umbilica* took place over a period of about 2.3 m.y. According to their redefinition of this taxon (using a lower size limit of 14 microns), the first appearance of *R. umbilica* took place during Chron C19r. As discussed by Berggren et al. (1995, table 15), Wei and Wise (1989) report examples of this species greater than 14 microns from the upper part of a normal magnetozone interpreted as Chron C20n, and Berggren et al. (1995) correlate Subzone CP14a with all of C20n, all of C19, and almost all of C18r. Unfortunately, the original samples collected from Miramar Reservoir that were analyzed by D. Bukry cannot be located (Bukry, personal communication to SLW), so it is impossible to determine if the specimens that Bukry identified in the 1960s were larger than 14 microns (several matrix samples from the Mission Valley Formation recently submitted to Bukry for analysis proved to be barren of coccoliths). To further complicate matters, the coccolith-bearing strata at Miramar Reservoir are of uncertain polarity, and cannot be confidently correlated with the magnetozones in the type section of the Mission Valley Formation. Nevertheless, assuming that Kennedy's (1975) coccolith sample does pertain to CP14a, and that the Miramar Reservoir strata are time-equivalent to the lower part of the type Mission Valley Formation, and that the correlations of Berggren et al. (1995) are correct, then the type Mission Valley magnetozones could correlate with either C20n and C19r, or C19n and C19r, but not C18n.

Frederiksen (1991) correlated a pollen assemblage from an outcrop near the base of the Mission Valley Formation in the type area with coccolith Subzone CP13c, suggesting a correlation of the Mission Valley magnetozones with C20r-C20n (Berggren et al., 1995). However, Frederiksen's age assignment should be regarded as tentative, because it is based largely on weak negative evidence, namely, the apparent absence of three taxa (*Psilodiporites*, *Corsinipollenites thiergartii*, and *Juglans* type) from only one locality.

Prothero and Swisher (1992) report an $^{40}Ar/^{39}Ar$ date of 39.74 ± 0.07 Ma on the LaPoint Ash which, following the time scale of Berggren et al. (1995), establishes at least a partial correlation between the Duchesnean NALMA and the older part of Chron C18n. Correlation of the late Uintan Mission Valley Formation with C18n therefore seems unlikely, especially since an $^{40}Ar/^{39}Ar$ date of 42.83 ± 0.24 Ma has been obtained on bentonite from the Mission Valley Formation at SDSNH Loc. 3428 (Obradovich and Walsh, in prep.). Strata of the Mission Valley Formation at this locality were reported by Prothero (1991) to be of normal polarity, which, given the time scale of Berggren et al. (1995), is consistent with an assignment of the type Mission Valley magnetozones to C20n and C19r.

In summary, chron correlation of the Mission Valley Formation is made difficult by the contradictory correlations (C20n-C18n) indicated by a variety of radiometric and biostratigraphic evidence in conjunction with current time scales. We prefer to place more weight on the radiometric evidence, and tentatively correlate the type Mission Valley Formation lower normal and upper reversed polarity intervals with C20n and C19r. However, it should be emphasized that the temporal difference between the C20n-C19r boundary and the C19n-C18r boundary is only about 1.3 m.y. according to Berggren et al. (1995), which is about the same magnitude as the potential errors in the numerical calibration of the Eocene chrons (~ ± 1 m.y.; e.g., Harland et al., 1990, p. 154). Other workers must be aware of these uncertainties before using our tentative chron correlation of the Mission Valley Formation as a primary piece of data upon which to base other conclusions. Further micropaleontological work on the Mission Valley Formation should be done in order to corroborate the suggested correlation.

Pomerado Conglomerate

Chron correlation of the Pomerado Conglomerate is made difficult by the uncertain stratigraphic and temporal relationship of the lower and Miramar Sandstone members of the Pomerado to the type Mission Valley Formation, and by the lack of a well-corroborated magnetostratigraphic pattern for these units. Accordingly, no chron correlations are proposed for the Pomerado Conglomerate here.

DISCUSSION

When the paleomagnetic part of this project was begun, it was hoped that with the revised stratigraphic model discussed above, and better age control provided by mammalian biostratigraphy (Walsh, this volume, Chapter 5), some of the ambiguities in the results obtained by Flynn (1986) and Bottjer et al. (1991) from the Friars, Stadium, and Mission Valley formations could be resolved. This goal has been only partially achieved. Consistent results were obtained from the lower member of the Stadium Conglomerate, and the Mission Valley Formation in the type area. However, the variable polarities indicated for the Friars and Mission Valley formations in the composite magnetostratigraphic section in Figure 14 reflect the large proportion of apparently contradictory paleomagnetic data involved. Additional magnetic sections might be collected in an effort to resolve these discrepancies, and continued field work is being done in order to test the stratigraphic interpretations proposed here. However, it is our opinion that the facies relationships, inherent time-transgressivness, and internal disconformities of the Friars Formation and Poway Group are so complex that a completely consistent magnetostratigraphic pattern for every unit will probably never be obtained. The nature of the outcrops in San Diego also hampers these efforts, since it is difficult to determine the superpositional relationships of the widely separated and relatively short sections available. For perspective, the *thickest* single section studied in San Diego (80 m; MS-6a) is thinner than the 90 m *sampling gap* in Flynn's (1986) Washakie Formation section. From this standpoint, it is highly questionable whether a given magnetozone in a given section of the Friars Formation or Poway Group corresponds to a worldwide geomagnetic event, and if it does, whether it represents a formally recognized chron, or an unrecognized "cryptochron" (Cande and Kent, 1992). Indeed, recent work has shown that many of the short polarity events long ignored by magnetostratigraphers may be real (Hartl et al., 1993).

Despite these difficulties, consistent paleomagnetic results have been obtained in San Diego from the composite, but superposed sections of the fine-grained marine strata of the Delmar, Ardath, and Scripps formations, as exposed in the seacliffs north of La Jolla, and less than a few kilometers inland from the coast (Flynn, 1986; Bottjer et al., 1991). Consistent results have also been obtained by these authors and ourselves from the Friars Formation in the type area. As noted above, the normal polarity interval in the lower part of the Friars Formation in the type area is confidently assignable to Chron C21n (Flynn, 1986; Bottjer et al., 1991; this paper). Given this correlation, (1) the occurrence of *Amynodon* and *Leptoreodon* in the Friars Formation in the upper part of this polarity interval at Genessee Avenue (MS-5); and (2) the presence of *Leptoreodon* in the lower tongue of the Friars Formation, stratigraphically well below the top of a normal interval correlated with C21n at State Route 52 East (MS-4), indicate that the Bridgerian/Uintan NALMA boundary is older than the beginning of Chron C20r. As discussed by Walsh (this volume, Chapter 4), this conclu-sion is relevant to the stratigraphic position of the Bridgerian/Uintan boundary in the Aycross/ Tepee Trail sequence of Wyoming, the Washakie Formation of Wyoming and Colorado, the Uinta Formation of Utah, and the Devil's Graveyard Formation of Texas.

CONCLUSIONS

The stratigraphy of the Friars Formation and Poway Group in southwestern San Diego County is informally revised. The Friars Formation is locally divisible into three units. The lower tongue of the Friars consists largely of sandstone and mudstone, is of fluvial origin in the east, and is partly of lagoonal origin in the west. The middle unit of the Friars is an extensive conglomerate tongue (formerly mapped as part of the Stadium Conglomerate) that erosionally overlies the lower tongue. This conglomerate is of fluvial origin in the east, and of deltaic origin in the west. The upper tongue of the Friars (previously mapped in part as the Mission Valley Formation) gradationally overlies the conglomerate tongue, and consists largely of sandstone and mudstone. The upper tongue is again of fluvial origin in the east, and partly of lagoonal origin in the west. All three units of the Friars produce early Uintan mammal taxa that are collectively referred to as the Poway fauna (Walsh, this volume, Chapter 5).

The type Stadium Conglomerate is locally divisible into two members. The lower member is generally a light yellowish gray and pale greenish gray, matrix to clast-supported conglomerate, is largely of fluvial origin, and produces a distinctive late early Uintan micromammal assemblage dominated by the rodent *Pauromys* sp. cf. *P. perditus*. The upper part of the lower member may be of late Uintan age. The upper member of the Stadium Conglomerate is an iron oxide-stained, clast-supported conglomerate, of marine origin in the western part of its outcrop area, and apparently of fluvial origin in the eastern part of its outcrop area. The upper member of the Stadium is late Uintan in age. The Mission Valley Formation is restricted only to those rocks that are stratigraphically correlative with the type section. The Mission Valley Formation is of late Uintan age, and disconformably overlies the early Uintan upper tongue of the Friars Formation north of the northern pinchout of the Stadium Conglomerate.

The reports of Flynn (1986) and Bottjer et al. (1991) of normal and reversed polarity intervals in the lower and upper part of the type outcrops of the Friars are corroborated here, and we agree with their assignment of these intervals to Chrons C21n and C20r. The polarity of the lower, conglomerate, and upper tongues of the Friars as recognized here is variable, and may reflect significant time-transgression of these units. The lower member of the Stadium Conglomerate is tentatively assigned to C20r. The upper member of the Stadium may straddle the C20r-C20n boundary. Radiometric and biochronologic evidence from the Mission Valley Formation indicate partly contradictory chron correlations. However, more weight is given to an $^{40}Ar/^{39}Ar$ date of 42.83 ± 0.24 Ma from a bentonite in this formation (Obradovich and Walsh, in prep.), which suggests a correlation of the lower normal and upper reversed magnetozones in the type section of this formation with Chrons C20n and C19r.

The existence of *Amynodon* and *Leptoreodon* during Chron C21n in San Diego has important implications for the occurrence of the Bridgerian/Uintan North American land mammal "age" boundary in other sections in the western interior.

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APPENDIX 1. DESCRIPTION OF PALEOMAGNETIC SECTIONS

MS-1. Camino Santa Fe

A 70 m-thick composite section consisting of two subsections was measured in the community of Mira Mesa. The base of the first subsection (MS-1a) is located in a cutbank outcrop on the south side of the south fork of Los Peñasquitos Canyon, about 300 m west of the south abutment of the Camino Santa Fe bridge. The lowest paleomagnetic site was collected from rust-stained, medium-grained, conglomeratic sandstones of the Esc, from 1 m above the creekbed. These sandstones erosionally overlie at least 2 m of medium gray, concretionary siltstones that may pertain to the Ardath Shale. Above a covered interval of 6 m, a second site was collected from light brown fine-grained sandstones of the Esc as exposed in a landslide scarp 50 m east of the first site. Above a covered interval of 10 m, five sites were collected from light yellowish-gray, fine-to-medium-grained sandstone lenses within the Ef-cg, as exposed in a large roadcut on the west side of Camino Santa Fe, immediately south of the bridge.

The second subsection (MS-1b) is located on the second, third, and fourth roadcuts extending from about 100-250 m south of Sorrento Valley Boulevard, on the east side of Camino Santa Fe, north of the bridge. One site was collected from a light yellowish-gray, medium-grained sandstone lens in the upper part of the Ef-cg, and three sites were collected from light gray to light rusty brown, locally concretionary, fine-to-very-fine grained sandstones of the gradationally-overlying Ef-ut. Since the Ef-ut does not crop out in MS-1a, the indicated level of the Ef-ut/Ef-cg contact in meters above the base of the composite section is a minimum value.

For MS-1a, the lowest Scripps Formation site was of normal polarity, while the overlying Scripps site showed indeterminate polarity. Three sites from the Ef-cg were of normal polarity, one was reversed, and the samples from one site disintegrated before they could be analyzed. The lowest site from MS-1b was of indeterminate polarity, and all three sites from the Ef-ut were reversed.

MS-2. Computer Media

A 42 m-thick continuous section was measured from the bottom to the top of the east-facing cut slope behind 4760 Murphy Canyon Road, on the west side of Murphy Canyon, about 0.6 km south of Clairemont Mesa Boulevard. The lower 8 m of the section consists of shallow-marine sandstones and siltstones assigned here to the Scripps Formation. SDSNH Loc. 3278 occurs at the base of the section and has yielded a marine mollusc assemblage of "Transition" age, and isolated teeth of *Peratherium* sp. and *Crypholestes*? sp. (Squires and Demere, 1991). These marine strata are erosionally overlain by fluvial white sandstones and yellowish-gray conglomerates of the Ef-lt and Ef-cg, respectively. The upper part of this section consists of white, medium-grained sandstones of the Ef-ut, and is stratigraphically equivalent to the roadcut outcrop of this unit on Clairemont Mesa Boulevard determined to be of reversed polarity by Bottjer et al. (1991). About 0.5 km southwest of the top of the Computer Media section, in an artificial cut slope 100 m north of View Ridge Avenue, about 10 m of the lower member of the Stadium Conglomerate (not sampled) overlies the Ef-ut, and is in turn disconformably overlain by the Pleistocene Lindavista Formation.

The lower two sites from the Scripps Formation were found to be of normal polarity, and all samples from the Ef-lt and Ef-cg were of reversed polarity.

MS-3. Black Mountain Road and State Route 56

A 44 m-thick composite section consisting of two subsections was measured in the community of Rancho Peñasquitos. The first subsection (paleomagnetic sites 1-6) was located in a roadcut on the east side of Black Mountain Road, about 100-200 m south of the intersection with State Route 56, and spanned the uppermost part of the Ef-lt, the Ef-cg, and the base of the Ef-ut. Site 7 was collected from the Ef-ut as exposed in a short artificial cut slope immediately north of the parking lot for the Mormon Church complex at 12835 Black Mountain Road.

The second subsection (sites 8-15; all from the Ef-ut) was located in the now-filled median of State Route 56, and the north-facing roadcut on the south side of this highway, about 0.5 km east of Black Mountain Road. Correlation of the two subsections is based on elevation, and the essentially horizontal attitude of the beds in this area.

The four sites from the Ef-lt consisted of fine-grained sandstones and greenish siltstones, and all were of normal polarity. The single site from a rust-stained sandstone lens in the Ef-cg disintegrated before it could be analyzed. The ten sites collected from the Ef-ut consisted of fine-to-medium-grained sandstones and multicolored siltstones. Nine of these were of normal polarity, and one was questionably of reversed polarity.

MS-4. State Route 52 East

A 58 m-thick composite section consisting of two subsections was measured west of the community of Santee. The base of the stratigraphically lowest subsection (MS-4a) was located in the bottom of a now-filled shear key about 15-20 m below the present surface of State Route 52. The upper part of this subsection is located on the east side of the mouth of Little Sycamore Canyon, north of SR-52, on a roadcut on the north side of the access road to the Santee Landfill. No paleomagnetic samples were collected from this subsection. The stratigraphically highest subsection (MS-4b) is located on a large roadcut on the south side of State Route 52, in the saddle on the ridge between Spring Canyon and Little Sycamore Canyon, and ends at the summit of Hill 534'. The base of MS-4b is roughly correlated with the upper part of MS-4a on the basis of elevation, the assumption of essentially horizontal strata, and the first appearance of conglomeratic sandstones in the latter section.

A total of 14 sites were collected from MS-4b, from strata assigned entirely to the Ef-lt, and consisting of conglomeratic sandstones, medium-grained sandstones, and mudstones. These strata are erosionally overlain by several tens of meters of yellowish-brown cobble conglomerate mapped as Stadium Conglomerate by Kennedy and Peterson (1975). No fossils or paleomagnetic samples were collected from this unit. These conglomerates are assigned here to the Ef-cg, because they represent the stratigraphically lowest conglomerate unit of significant thickness in the area, and they occur at an appropriate elevation to pertain to this tongue.

Since two single-site normal and three single-site reversed intervals occur in MS-4b, the magnetostratigraphic pattern obtained cannot be taken literally. However, the lower part of this subsection is largely of normal polarity, while the upper part is mostly reversed.

MS-5. Genessee Avenue

Flynn's (1986) Genessee Avenue section is located north of Mission Valley, about 3.5 km north of the type section of the Friars Formation. This outcrop exposes about 22 m of strata, most or all of which pertain to the undifferentiated Friars Formation (as mapped by Kennedy, 1975, plate 2A). As shown by Flynn (1986, fig. 8), however, the basal few meters of ledgy and cross-bedded sandstones here could also be assigned to the Scripps Formation, as these strata appear to represent a transitional Scripps-Friars facies. LACM locality 3243 occurs at the base of the section (LACM[CIT] Photograph 894) and has yielded the type specimen of the rodent *Pseudotomus littoralis* (Wilson, 1949; Korth, 1985), the mesonychid cf. *Harpagolestes* sp., and a lower molar of a small brontothere tentatively assigned here to *Metarhinus*? *pater* (Golz and Lillegraven, 1977, table 1). This small assemblage cannot be assigned with confidence to either the Bridgerian or the Uintan at this time, although *P. littoralis* is known to occur together with definite Uintan assemblages in the conglomerate tongue (SDSNH Loc. 3621) and upper tongue (SDSNH Loc. 3883) of the Friars Formation. The Genessee Avenue outcrop also contains the vertebrate locality LACM(CIT) 314 (= UCMP V-6882), which is located in the Friars Formation about 8-9 m above the base of the section. This locality has produced the Lowest Stratigraphic Datum of *Amynodon reedi* in San Diego, as well as the selenodont artiodactyl *Leptoreodon major* and a micromammal assemblage typical of the San Diego early Uintan (see Stock, 1939; Golz and Lillegraven, 1977, table 1).

Flynn (1986, fig. 8) showed that one site collected from the base of the Genesee Avenue outcrop is of normal polarity, while the remaining four sites from the upper part of the outcrop are of reversed polarity. The location of the normal-to-reversed transition in this section relative to LACM (CIT) 314 is unclear from Flynn's paper, because there is a 13 m sampling gap between the only normal site and the lowest reversed site. Therefore, we re-collected this section with the following results. The lower three sites were found to be of normal polarity, and the highest of these was taken from the bed in which LACM(CIT) 314 appears to be located, based on LACM (CIT) Photograph 893. The overlying two sites were of reversed polarity, so the general pattern obtained corroborates that reported by Flynn. The importance of this section is that the normal magnetozone in the lower part of the Friars Formation is of early Uintan age. Therefore, if this magnetozone correlates with Chron C21n, as suggested by Flynn (1986) and supported here, the Bridgerian/Uintan boundary cannot occur within Chron C20r, as proposed by Flynn (1986).

MS-6a. Scripps Ranch North I

A composite stratigraphic section about 80 m thick was produced from two subsections in the Scripps Ranch North housing development, north of Miramar Reservoir and south of Cypress Canyon. The stratigraphically lowest subsection was located on the west side of the small hill in the center of Sec. 28, T14S R2W, and begins in the upper part of the Ef-cg. The lower part of this subsection is now heavily graded and suburbanized, but the upper part is still exposed on an abandoned jeep road on the SW side of the hill. The top of the lower subsection is the disconformity between the Ef-ut and the lower "arkosic gritstone unit" of the Emv ("Emv-l" in MS-6a). This same disconformity occurs about 3 m above the base of the upper subsection, which is located on the large roadcut (now partially buttressed and landscaped) on the south side of Spring Canyon Road (NW SE Sec. 28). The upper subsection encompassed the uppermost part of the Ef-ut, the Emv-l, the Emv-u, and the Ep-lc, Ep-m, and Ep-uc.

Most sites consisted of light gray to light rusty brown, fine-to-medium-grained sandstones. All three sites from the Ef-cg were of reversed polarity, as were all five sites from the Ef-ut. All sites from both the lower arkosic gritstone unit and the upper marine sandstone unit of the Emv were of reversed polarity. The single site from the Ep-lc was of normal polarity. The two lowest sites from the Ep-m were of normal polarity, while the two highest sites were of reversed polarity. Finally, the single site from the Ep-uc was of normal polarity.

MS-6b. Scripps Ranch North II

A continuous stratigraphic section about 72 m thick was measured along the entire length of the prominent NW-trending ridge that straddles the boundary between Sections 27 and 28, T14S R2W, on the south side of Cypress Canyon. This section is located about 1 km east of MS-6a, and covers essentially the same stratigraphic interval. MS-6b began in the upper part of the Ef-cg at the NW base of the ridge, and ended in the top of the Ep-m, as exposed at the SE end of the ridge, on the now-graded hill immediately north of Spring Canyon Road, in the center W1/2 SW1/4 Sec. 27. The outcrops on this ridge are now suburbanized. Lateral facies changes in this area are demonstrated by the rapid thinning of a prominent conglomerate body within the Ef-ut from 12 m thick in MS-6b to only 5 m thick in MS-6a. In addition, the "lower gritstone unit" of the Emv is thicker than the upper unit of the Emv in MS-6b, whereas these relative thicknesses are reversed in MS-6a.

Two sites were collected from medium-grained sandstone lenses within the Ef-cg, three sites were collected from medium-grained sandstone lenses within a conglomerate body within the Ef-ut, two sites were collected from medium-grained sandstones of the upper part of the Ef-ut, five sites were collected from medium-grained sandstones and siltstones of the "lower arkosic gritstone unit" of the Emv, two sites were collected from fine-grained sandstones of the upper unit of the Emv, one site was collected from a medium-grained sandstone lens within the Ep-lc, and four sites were collected from medium-grained sandstones of the Ep-m.

Comparison of the magnetic results from MS-6a and MS-6b is interesting. First, the Ef-ut was entirely reversed in both sections. In MS-6a, both units of the Mission Valley Formation were of reversed polarity, but in MS-6b, the upper unit of the Mission Valley was normal. The single site from the Ep-lc in both sections was normal. However, the Ep-m was entirely of reversed polarity in MS-6b, whereas the lower two sites from the Ep-m in MS-6a were normal. The discrepancies between two proximate sections traversing the same lithostratigraphic units demonstrate that the magnetic pattern obtained from a single section in the Friars Fomation and Poway Group may not be meaningful. Therefore, proposed correlations of short magnetozones in different sections must be viewed with skepticism.

MS-7. State Route 52 West

A continuous 45 m-thick section was measured on a large roadcut on the north side of State Route 52, 200 m east of the Second San Diego Aqueduct, and 1.5 km east of Santo Road. This section spanned white, fluvial, medium-grained sandstones of the upper part of the Ef-ut, the disconformably overlying, white, fine-to-very fine-grained marine sandstones of the Emv, and light gray and rust-stained cobble-to-boulder conglomerates of the Ep (undifferentiated). The 3 m-thick white sandstone lens within the Ep may represent the Ep-m, or the entire thickness of the Ep here may correlate only with the Ep-uc as exposed at Scripps Ranch North. Approximately 25 m of the Ef-ut is present below the base of this section. 600 m WSW of MS-7, the Ef-ut was observed to gradationally overlie the Ef-cg in a small south-draining canyon immediately north of State Route 52 and immediately east of Hill 518.

Two of the three sites from the Ef-ut were of reversed polarity, while one was of indeterminate polarity. The lower four sites from the Emv were of normal polarity, while the uppermost site from this formation was indeterminate. The basal site from the Ep was also indeterminate, while the remaining five sites from this unit were of normal polarity.

MS-8. Hill 781

A substantially covered, 69 m-thick section was measured east of Tierrasanta, starting at the base of a roadcut on the south side of a dirt access road for the Second San Diego Aqueduct, located in the saddle immediately north of Hill 781. The section begins in the upper part of the Ef-ut and spans 8 m of yellowish-gray conglomerates tentatively assigned to the Est-b, 30 m of the Emv, and 22 m of the Ep. The upper 37 m of this section is poorly exposed along the jeep road up to the summit of Hill 781.

The lowest site from the Ef-ut was indeterminate, while the upper two sites from this unit were reversed. The single site from a sandstone lens in the top of the Est-b? was reversed. Four sites from the lower part of the Emv were normal, one was reversed, and the uppermost site from the Emv was reversed. No sites were collected from the Ep.

MS-9. Stonecrest

An 84 m-thick composite section was measured in the undifferentiated Friars Formation, the Est-a, Est-b, and Emv, during grading for two different phases of the Stonecrest development on the west wall and rim of Murphy Canyon, south of Aero Drive. Paleomagnetic sites were collected only from the lower 52 m of this section (Ef and Est-a). The upper 32 m of the measured section have been largely graded away, but the Est-b and Emv are currently exposed in artificial cuts behind commercial buildings at the NW corner of the intersection of Aero Drive and Ruffin Road, and in a landscaped roadcut on the west side of West Canyon Avenue. If the Ef-cg is present below the surface of Murphy Canyon at Stonecrest, then the sampled Friars strata would pertain entirely to the upper tongue. However, it is equally likely that the Ef-cg pinches out north of Aero Drive (Fig. 2), in which case the Friars here would be equivalent to all or part of both lower and upper tongues.

The stratigraphically lowest paleomagnetic site was obtained from the wall of a large utilities trench immediately west of Murphy Canyon Road. This site was located about 300 m east of and at least 9 m stratigraphically below the base of the main section, and was of indeterminate polarity. The main section is located on the large east-facing cut on the west wall of Murphy Canyon, about 500 m south of Aero Drive. All sites from the Ef were of reversed polarity, as were all sites from the overlying Est-a.

MS-10. Type Section of Stadium Conglomerate

A composite 73 m-thick section consisting of two subsections was measured in the idle gravel quarry of H. G. Fenton Materials Co., on the north side of Mission Valley, north of Friars Road and east of Interstate 805. This section is essentially the same as Kennedy and Moore's (1971) type section of the Stadium Conglomerate. The lower subsection was located in a roadcut on the north side of Friars Road, about 200 m east of Northside Drive, directly opposite Friars Road from the northwesternmost entrance to the parking lot for San Diego Jack Murphy Stadium. Two sites were collected from light yellowish-brown, fine-to-medium-grained sandstone lenses within the Est-a, from 5 m and 11 m above the Est-a/Ef contact. The base of the upper subsection is located about 400 m northwest of the first section, on the surface of the graded lot immediately below the large south-facing quarry face in the NE part of the Fenton property. The two subsections are correlated on the basis of elevation. Samples from the upper subsection consisted of light gray and pale greenish-gray medium-grained sandstones from lenses in the Est-a, light rusty brown medium-grained sandstones from lenses in the Est-b, and very light gray, very-fine-grained sandstones of the Emv.

All six sites from the Est-a were of reversed polarity. Five sites were collected from the Est-b, of which the lower two were indeterminate, the next-highest was reversed, and the uppermost two were normal. All four sites from the Emv were of normal polarity.

MS-11. Type Section of Mission Valley Formation

A continuous, but substantially covered section spanning the maximum preserved thickness of the Emv (approx. 75 m) was collected from roadcuts on the west side of State Route 163, between Interstate 8 and the Sixth Avenue exit. This section is located immediately east and southeast of the type section of the Emv (Kennedy and Moore, 1971), which is currently obscured by vegetation.

Most sites were collected from light gray, fine-to-very fine-grained, often concretionary sandstones, while some of the uppermost sites consisted of light gray, medium-grained, poorly sorted sandstones. Of the 14 sites collected, the lower 9 were of normal polarity, and the uppermost 5 were reversed.