BULLETIN OF THE AMERICAN ASSOCIATION OF PETROLEUM GEOLOGISTS
VOL. 50, NO. 11 (NOVEMBER, 1966), P 2464-2481, 9 FIGS., 2 TABLES

GEOLOGICAL NOTES

STRATIGRAPHIC RELATIONS OF PHOSPHATE- AND GYPSUM-BEARING UPPER MIOCENE STRATA, UPPER SESPE CREEK, VENTURA COUNTY, CALIFORNIA[1]

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In 1963 and 1964, Stanford summer field-geology classes under the direction of Dickinson, with Lowe as student in 1963 and instructor-paleontologist in 1964, mapped in detail an area including the little-known Miocene sequence of upper Sespe Creek, in the western Transverse Ranges at the south base of Pine Mountain ridge. Beds near the top of the sequence contain commercial gypsum deposits held under claim by the U. S. Gypsum Company, and phosphorite deposits now being evaluated by the same company. This company has obtained a phosphate prospecting permit from the U. S. Bureau of Land Management with the option to lease (R. C. Runvik, written commun., 1965). The work of the Stanford group was greatly facilitated by access roads built in 1962 for gypsum exploration by the company; the nearby phosphate occurrences were noted jointly by geologists of the company and the Stanford group in 1963. The cooperation of the U. S. Forest Service, and the hospitality of Mr. and Mrs. Harold Barraesen and Mr. and Mrs. Ralph Mott of Pine Mountain Inn, made the Stanford mapping program possible. The purpose of this note is to discuss the general nature and geologic setting of the gypsum and phosphorite deposits, but not to describe their economic geology.

Regional Setting
(Fig. 1)

The marine Miocene outcrops of the upper Sespe Creek-Pine Mountain area are midway between the well-known marine Miocene exposures of Cuyama Valley and Ojai Valley. Although there are limited marine Miocene exposures nearby, down Sespe Creek on the east and in the Mono Creek drainage on the west, the nearest extensive exposures of Miocene rocks are actually the continental deposits of the Cuyama Badlands (Hill *et al.*, 1958; Fig. 3).

The badlands continental sequence now lies between the Cuyama Valley and upper Sespe marine Miocene sequences, but this was probably not so at the time of deposition. Because a sizeable part of the left-lateral strike-slip offset of 8–14 mi. on the Big Pine fault reported by Hill and Dibblee (1953, p. 452) was probably post-Miocene, restoration of the exposed rocks to their Miocene positions would have the effect of removing the badlands sequence from its present outcrop position between the marine Miocene exposures of Cuyama Valley and those of upper Sespe Creek and Ojai Valley.

Structural Setting
(Fig. 2)

The Miocene strata of upper Sespe Creek are in the trough of a syncline south of the Pine Mountain anticline (Merrill, 1954). The two folds are separated by the broad (50–250 feet) crush zone of the Pine Mountain reverse fault, which dips 50°–80° N. and faults out most of the intervening steep fold limb. North of the fault, only Eocene strata are exposed in the broadly arched Pine Mountain anticline. They are faulted against the Miocene strata; at least the upper part of the Miocene section is overturned against the fault in a tightly folded syncline. Both the phosphorite and gypsum beds are repeated locally by the overturn.

Stratigraphic Relations
(Table I)

The Vaqueros Formation at the base of the Miocene sequence rests on continental deposits of

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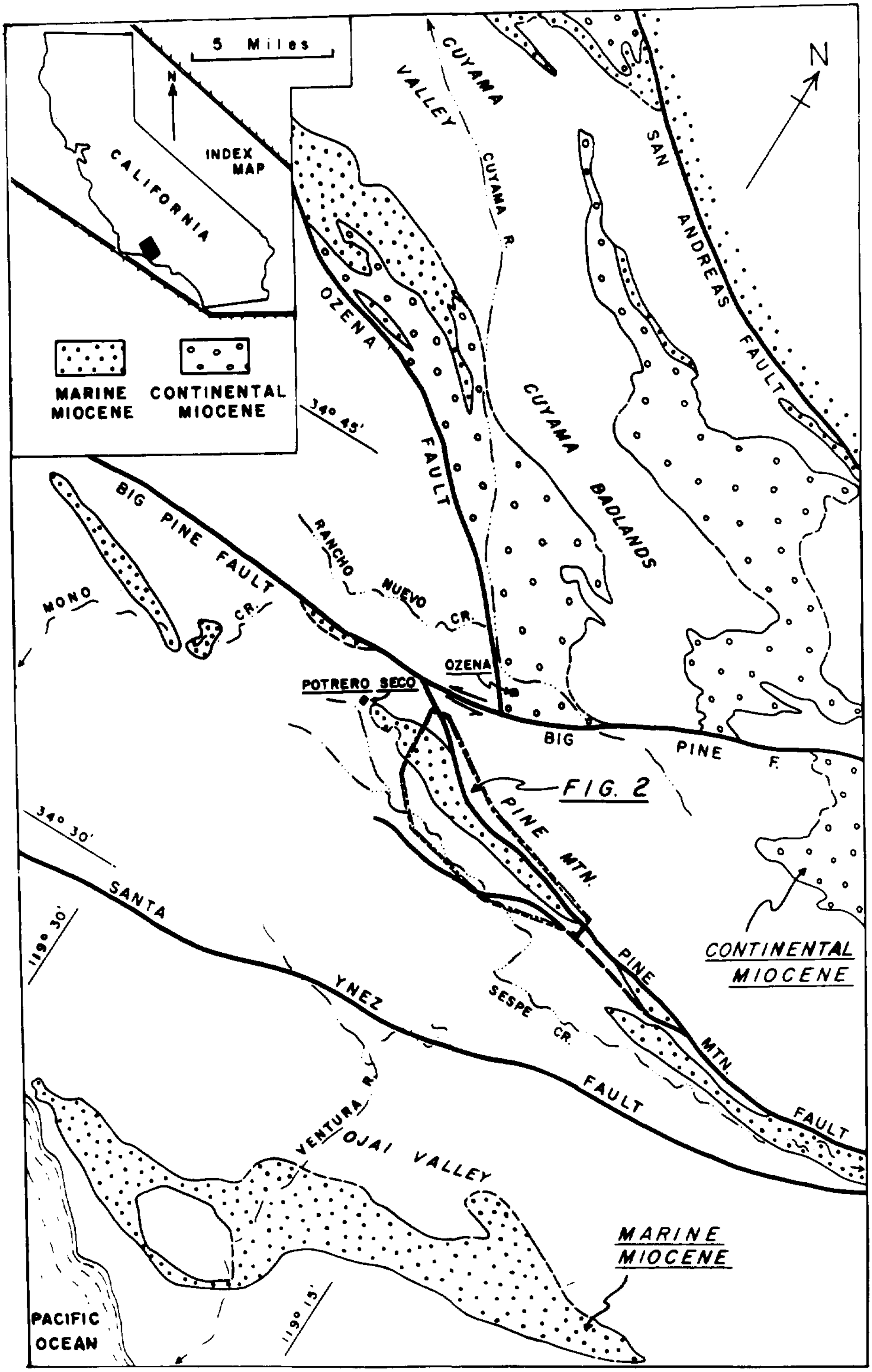

FIG. 1.—Location of upper Sespe Creek-Pine Mountain area, Ventura County, California.

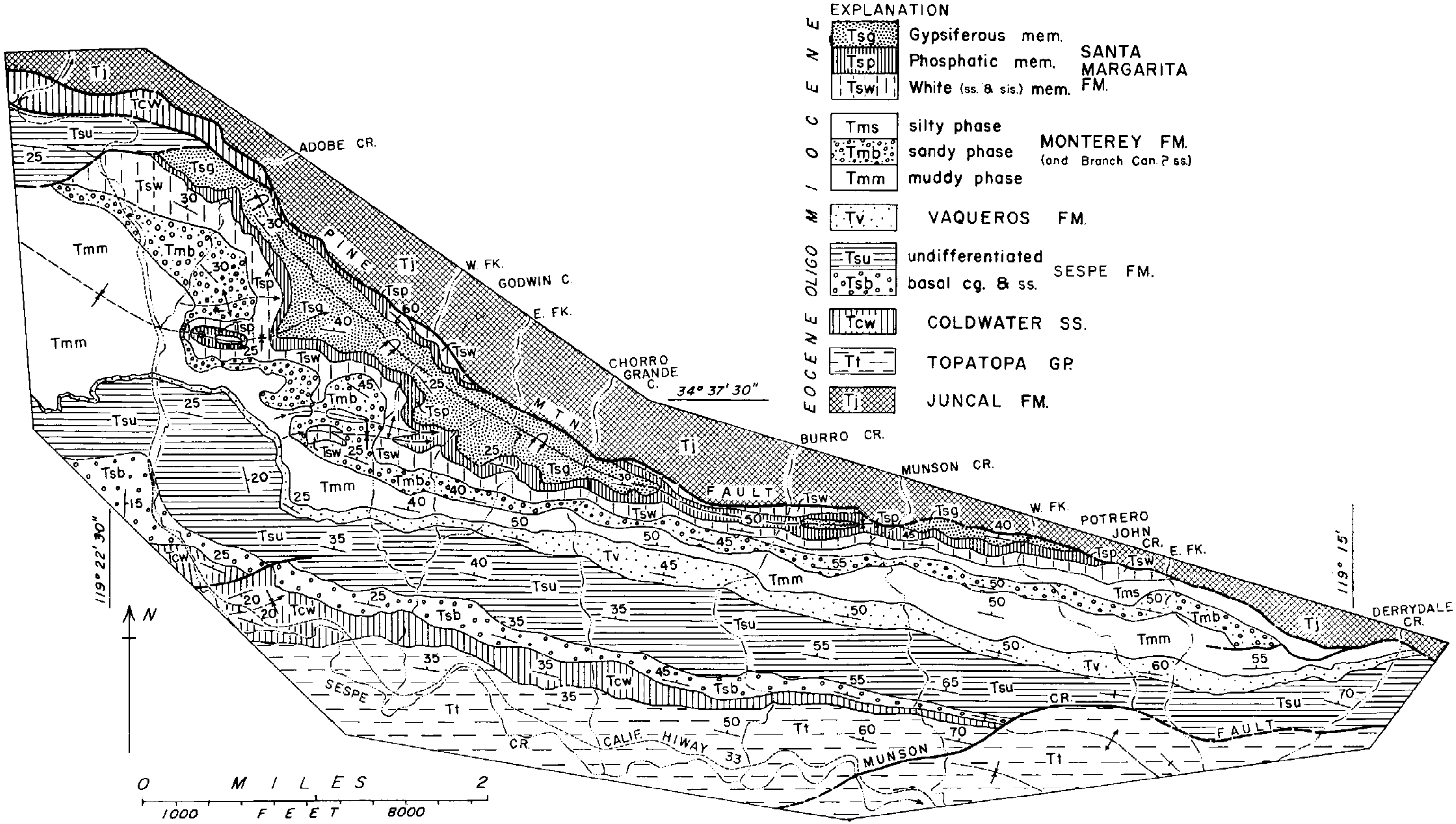

FIG. 2.—Geologic map of upper Sespe Creek-Pine Mountain area, Ventura County, California.

the Oligocene(?) Sespe Formation (Bailey, 1947, p. 1917); the contact is gradational through a zone 10 to 50 feet thick, and thus the two formations apparently are conformable within the area of Figure 2. Conglomerate of the basal Sespe generally grades downward into the variegated upper beds of the Coldwater Sandstone (upper Eocene), as may be seen in roadcut exposures along the highway at Adobe Creek, but disconformable scour is prominent locally, notably at Chorro Grande Canyon. Only 2 miles west of the area of Figure 2, the Sespe appears to overlap the Coldwater and to lie directly on the Eocene Cozy Dell Shale of the Topatopa Group at Potrero Seco (Merrill, 1954). However, the extent to which facies changes in the Eocene may contribute to the stratigraphic change is not now known with certainty.

The sharp contact of the Monterey Formation on the Vaqueros Formation probably is a disconformity or diastem; it is marked by 1–5 feet of highly glauconitic porcelanite and siliceous mudstone that grade upward into non-glauconitic strata. The marked westward thinning of the Vaqueros probably is caused mainly by non-deposition, because the sandstone becomes coarser and more cross-bedded as it becomes thinner. The wedge-out may be in part, however, the result of overlap by the Monterey, which rests directly on the Sespe at Potrero Seco where thin basal sandstone and coquinite beds are prominent in the Monterey. Intraformational contacts are conformable and gradational between the fine-grained Monterey strata and the sandy phase (see Table I, Footnote 3).

The Santa Margarita Formation rests with angular unconformity on siliceous strata and associated sandstone of the Monterey Formation (note map pattern of Fig. 2). The basal Santa Margarita is a pebble bed, a few inches to 1–2 feet thick, in which whitish porcelanite pebbles are prominent. In outcrops between Godwin Canyon and Adobe Creek, basal sandstone rests with angular discordance on Monterey beds. Elsewhere, the angular discordance is too slight to detect in outcrop.

Sedimentation

Beneath the Coldwater Sandstone are about 16,500 feet of marine Eocene strata. The Coldwater is a unit transitional between this marine sequence and the overlying fluvial strata. The massive and cross-bedded Coldwater Sandstone is probably a neritic deposit formed in part perhaps as submarine bars and bores. The upper variegated beds of the Coldwater may represent coastline deposits of a mixed deltaic environment.

The Sespe Formation was deposited on a great aggrading fluvial plain or gently sloping piedmont. The lower member, probably deposited as lens-shaped sand-and-gravel bars and channel deposits on a braided bar plain, displays abundant imbrication indicative of southerly current flow. In detail, the imbrication defines a succession of fan-like distributary systems spaced at intervals of about 2 miles along east-west strike. The more regular bedding and finer grain size of the sand-and-silt deposits of the upper member doubtless reflect decreases in slope and current flow on the alluvial plain. West of the area of Figure 2, the distinction between upper and lower members can not be made, perhaps reflecting approach to a highland margin of the depositional plain.

A surface of gentle relief constructed by deposition of the Sespe was inundated, and deposition of the Vaqueros Formation sandstone and siltstone in warm, shallow-marine waters began. The lenticular shape of the Vaqueros deposits is perhaps indicative of gently undulating topographic irregularities on the subsiding plain. The area west of Figure 2, in which Vaqueros beds are absent, may have continued to stand above the sea. The length of time represented by the Vaqueros beds, which contain a megafauna typical of that formation (best collected between Burro and Munson Creeks), and the length of possible non-deposition represented by the glauconitic base of the Monterey, are as yet undetermined, as is the length of time represented by deposition of the truncated Monterey.

The Santa Margarita Formation represents a transitional succession of environments upward from marine to non-marine deposition. The transgressive *white member* at the base probably is an open-shelf deposit. The succeeding *phosphatic member* is markedly less fossiliferous, yet is richer in dark organic remains; locally restricted bottom circulation in shelving waters, perhaps influenced by upwelling, may have contributed to a suitable environment for phosphate accumula-

TABLE I. STRATIGRAPHIC SEQUENCE ON UPPER SESPE CREEK SOUTH OF PINE MOUNTAIN[1]

Erosional Top

(6) 1,000 ft.—Santa Margarita Formation[2]

(c) 500 ft.—GYPSIFEROUS MEMBER

(iv) 400(?) ft. weakly consolidated white sandstone and conglomerate with intercalations of green to brown mudstone and siltstone; probably upper Miocene but possibly lower Pliocene.

(iii) 40 ft. laminated gray and green gypsum, locally anhydrite.

(ii) 10 ft. small-oyster coquina and bioclastic shell hash topped by 5–10 inches of green claystone.

(i) 50 ft. massive, well-sorted white sandstone, locally cross-bedded and largely medium- to coarse-grained; contains upper Miocene assemblage of *Astrodaspis arnoldi* Pack, *Pecten crassicardo* (Conrad), and *Ostrea titan* Conrad.

(b) 200 ft.—PHOSPHATIC MEMBER

Dark gray to black, weathers tan to brown; pelletal and oölitic phosphorite with phosphatic siltstone and sandstone; contains *Chione* sp. at one locality.

(a) 200–300 ft.—WHITE MEMBER

Massive white sandstone, locally cross-bedded, and tan siliceous siltstone that weathers white; contains varied vertebrate fauna including porpoise, sea lion, whale, and shark remains (C. R. Repenning, oral commun., 1964); contains the upper Miocene assemblage of *Astrodaspis arnoldi* Pack, *Pecten raymondi* Clark, *Mytilus loeli* Grant, *Trachycardium schencki* (Wiedey), and *Anadara trilineata* (Conrad).

Angular Unconformity

(5) 1,000–1,250 ft.—MONTEREY FORMATION[3]

(c) 250 ft.(?)—Upper silty phase: dark gray, siliceous, silty mudstone and siltstone; laminated bedding, platy parting; exposed between Chorro Grande and Potrero John Creeks only.

(b) 200–500 ft.—Middle sandy phase: laminated and cross-bedded, tan, biotitic, locally conglomeratic sandstone; contains middle Miocene assemblage of *Pecten crassicardo* Conrad, *Turritella carisaensis* Anderson and Martin, and *Ostrea titan* Conrad near Munson Creek.

(a) 500–700 ft.—Lower muddy phase: thin-bedded, dark brown, siliceous, and locally, calcareous mudstone with platy or pencil fracture; weathers white to tan; rare porcelanite; scattered orange carbonate concretions; contains widespread foraminifers, probably of Saucesian age (P. F. Taylor, written commun., 1964); becomes silty toward west where contains coquinite layers made of *Delectopecten peckhami* (Gabb).

Disconformity or Diastem

(4) 100–700 ft.—VAQUEROS FORMATION

Gray, calcareous sandstone and siltstone containing lower Miocene assemblage of *Turritella inezana* (Conrad) *bicarina* Loel and Corey, *Echinarachnius fairbanksi* Arnold, *Pecten sespeensis* Arnold, *Dosinia margaritana* Wiedey, *Ostrea eldridgei* Arnold, *Ostrea vespertina* (Conrad) *loeli* (Hertlein), *Anomia vaquerosensis* Loel and Corey, *Rapana vaquerosensis* (Arnold).

Gradational through 25–50 ft.

(3) 1,500–1,750 ft.—SESPE FORMATION

(b) 1,250–1,500 ft.—Undifferentiated: mainly laminated and cross-bedded, friable, tan sandstone with brown conglomerate lenses and intercalated red and green sandstone, siltstone, and claystone.

(a) 200–300 ft.—Basal member: interbedded and interlensed brown sandstone and red-brown pebble, cobble, and boulder conglomerate.

Gradation and Local Disconformity

(2) 250–500 ft.—COLDWATER SANDSTONE

Massive and cross-bedded, gray and tan sandstone, largely well-sorted and biotitic; interbedded white sandstone and red to green mudstone in uppermost part locally; intercalated drab green silty mudstone in lower part.

Gradation

(1) 5,000 ft.—TOPATOPA GROUP (after Eldridge and Arnold, 1907, p. 5)

Marine Eocene strata generally lithologically similar to the Cozy Dell Shale–Matilija Sandstone sequence of Ventura River section north of Ojai Valley but differing in stratigraphic and petrologic details.

Fault

(0) Lying gradationally beneath Topatopa Group on north side of Pine Mountain fault are interbedded sandstone, siltstone, and mudstone here referred to JUNCAL FORMATION (Page *et al.*, 1951).

[1] The stratigraphic thicknesses given are approximate as scaled from U. S. Geological Survey 1:24,000 topographic quadrangle maps Reyes Peak and Wheeler Springs showing ground within T. 6 N., R. 23 W.

[2] The names used for the three members described here are local field names without formal status or regional significance.

[3] The strata here referred to Monterey Formation by comparison with strata exposed around Cuyama Valley (Hill *et al.*, 1958, p. 2988–2991), also resemble and are doubtless in part correlative with the similar strata exposed near Ojai Valley and mapped as Modelo Formation by Kew (1924, p. 55–64). Bramlette (1946, p. 3, 8) has pointed out that the two names apply to correlative strata of similar lithologic character, and has therefore recommended that the name "Monterey" take precedence over "Modelo." The three lithologic units here described within the Monterey are given purely descriptive names with no formal status because their stratigraphic relation to recognized members of the Cuyama Valley and Ojai Valley sequences is not known with certainty. It is Dickinson's impression that the unit here designated the "middle sandy phase" is *lithologically* similar to the Branch Canyon Sandstone of the Cuyama Valley (Hill *et al.*, 1958, p. 2991) as well as to some sandstone members of Kew's "Modelo" near Ojai (Kew, 1924, p. 57–64). The writers' "upper silty" and "lower muddy" phases have close lithologic counterparts in the Saltos Shale Member of the Monterey Formation (Hill *et al.*, 1958, p. 2989) in the Cuyama Valley. The unit here designated the "lower muddy phase" is probably roughly the same age as the type Rincon Mudstone (Kerr, 1931, p. 156) exposed near Ojai Valley, but the distinct thin bedding, platy parting, and siliceous character of the unit make its referral to the Monterey more appropriate than lithologic correlation with the Rincon.

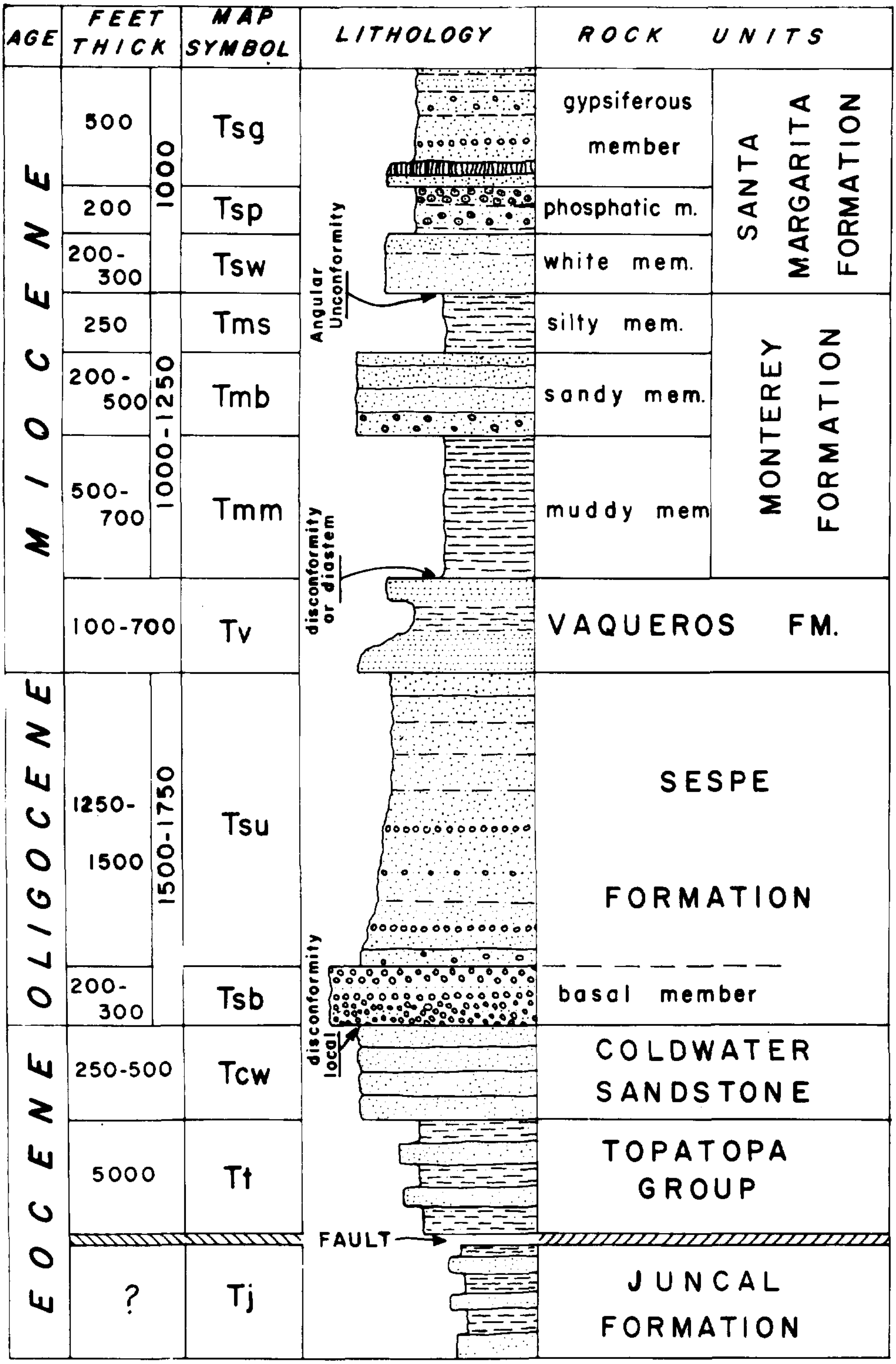

FIG. 3.—Stratigraphic column of upper Sespe Creek-Pine Mountain area, Ventura County, California.

tion. The *gypsiferous member* at the top records the transition to fluvial deposition as follows: (a) deposition of the massive, fossiliferous basal sandstone on an inshore shelf, perhaps as sub-aqueous bars; (b) deposition of the bioclastic oyster beds in a brackish coastline lagoon; (c) deposition of the bedded evaporite later in the same lagoon under hypersaline waters; and (d) deposition of the upper fluvial(?) sandstone, siltstone, and conglomerate on a coastal plain.

From a regional viewpoint, the 4,000 feet of Oligocene and Miocene strata preserved on upper Sespe Creek is an abbreviated sequence compared with the 12,500 feet of correlative strata in the Caliente Range north of Cuyama Valley (Hill *et al.*, 1958, Fig. 2) and in the Ventura basin near Ojai Valley (Bailey, 1947, Fig. 3). The paleotectonic setting of the area during the Miocene appears to have been that of a platform between two depositional basins. Because this general setting is known to exist elsewhere in the Coast Range Miocene, and because the phosphorite and gypsum were deposited in sedimentary environments possibly linked in origin to this tectonic environment, future exploration in the region may reveal the presence of similar deposits.

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IMPROVED FIELD DEVICE FOR RECORDING STRATIGRAPHIC SECTIONS[1]

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One of the commonest activities of the sedimentary geologist in the field is the measurement and description of stratigraphic sections. This information generally is recorded by words and numbers in the field notebook, commonly augmented by a crude columnar section. On return to camp or office, the geologist completes the process by re-plotting the information as the finished columnar section. A serious shortcoming is the need to re-plot all the information, with the attendant risks of omitting or incorrectly plotting it, not to mention the temptation to "improve" it. Wengerd (1956) and others cited in his references solved the problem by replacing the field notebook with a field log whereby the information is plotted at the outcrop in its final graphic form, and no re-plotting is required.

Wengerd's field log is hinged in order to reduce it to convenient size. This, however, introduces other inconveniences. The hinged log is bulky, it does not readily lie flat when it is opened out, and plotting across the hinge or fold is difficult. These inconveniences can be avoided by passing the log between two spools, in the same way that film is passed through a camera. This has been done in the device here described, which is merely the ancient scroll in modern dress.

The device (Fig. 1), which the writers call a *field log-holder,* comprises a surface over which

[1] Published by permission of the Director. Manuscript received, February 15, 1966; accepted, March 11, 1966.

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