[PS]Updated Nomenclature for Plio-Pleistocene Formations in the Onshore Ventura Basin, Los Angeles and Santa Barbara 30′ × 60′ Quadrangles*

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Abstract

The Plio-Pleistocene bedrock nomenclature of the onshore Ventura basin and associated San Fernando Valley embayment was re-evaluated from a basin-wide perspective during preparation of the Preliminary Geologic Map of the Los Angeles 30′×60′ Quadrangle, which was recently updated by the California Geological Survey and issued in July of 2014 as part of the STATEMAP project. The nomenclature adopted for this map will likely be extended to the eastern half of the Santa Barbara 30′×60′ Quadrangle in a future update. Strata of this age have a complex history of nomenclature: conflicting terminologies have developed due to a combination of complex depositional conditions (such as facies changes and local unconformities near the basin margins, and the time-transgressive nature of contacts due to westward migration of the paleoshoreline during basin infilling), and inconsistent methodologies used to define formations (such as the use of fauna rather than lithology, the use of formation names defined in other basins, and differing techniques used in surface mapping vs. subsurface exploration for oil). The basic stratigraphic sequence is regressive, ranging up section from bathyal hemipelagic and submarine fan turbidite deposits to granular shallow marine, local transitional/paralic, and granular continental deposits. The definitions of the marine Pico Fm. and Towsley Fm. and the nonmarine Saugus Fm. published by Winterer and Durham (1962) for the type sections in the eastern Ventura basin are adopted and extended to the western portion of the basin. Marine strata formerly assigned by some workers to the Saugus Fm. in the southern Santa Susana Mountains are reassigned as an informal member of the upper Pico Fm. Strata formerly assigned to the San Pedro Fm. near South Mountain are reassigned to the Saugus Fm., if nonmarine, or to the Las Posas Fm. if marine. The informally defined term Mudpit shale member of the upper Pico Fm. is adopted in preference to Santa Barbara Fm. for strata west of Fillmore. The term “Repetto” is defined by Repettian Stage microfauna rather than lithology and is therefore considered a biozone rather than a formation. The Sunshine Ranch and Camarillo members of the Saugus Fm. are adopted, and the terms Elsmere Canyon delta-plain facies of the Saugus Fm. and Grimes Canyon deltaic facies of the Pico Fm. are also informally defined. The formational terms Santa Barbara, San Pedro, and Fernando are excluded to areas outside of the Ventura basin.

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UPDATED NOMENCLATURE FOR PLIO-PLEISTOCENE FORMATIONS IN THE ONSHORE VENTURA BASIN, LOS ANGELES AND SANTA BARBARA 30'x60' QUADRANGLES

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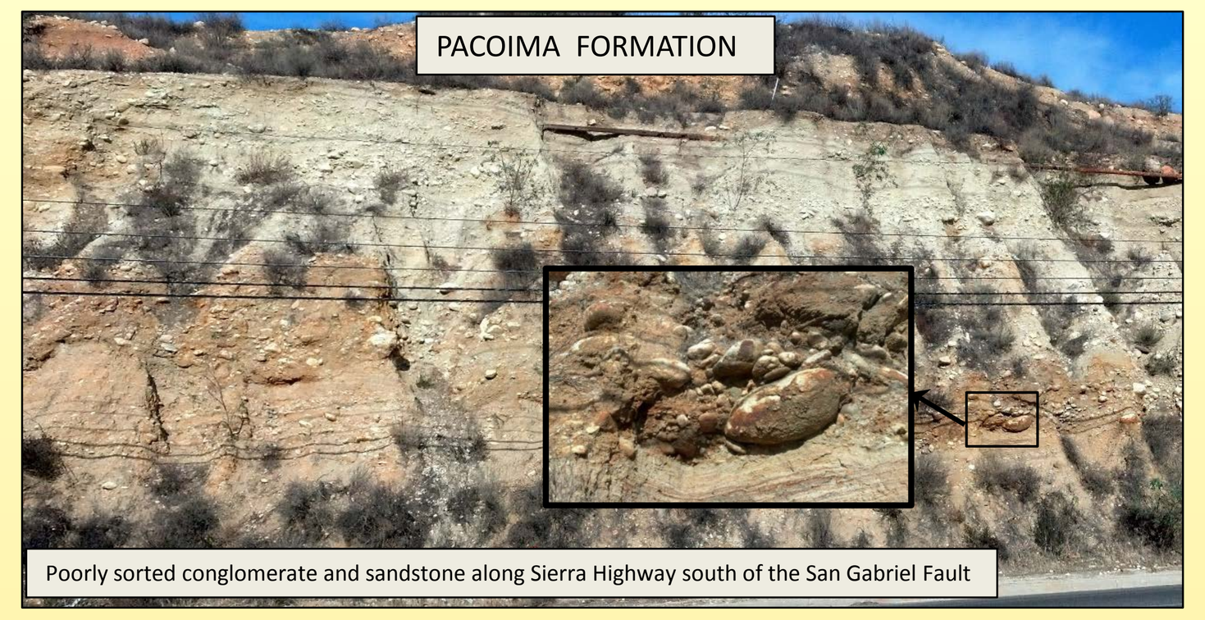
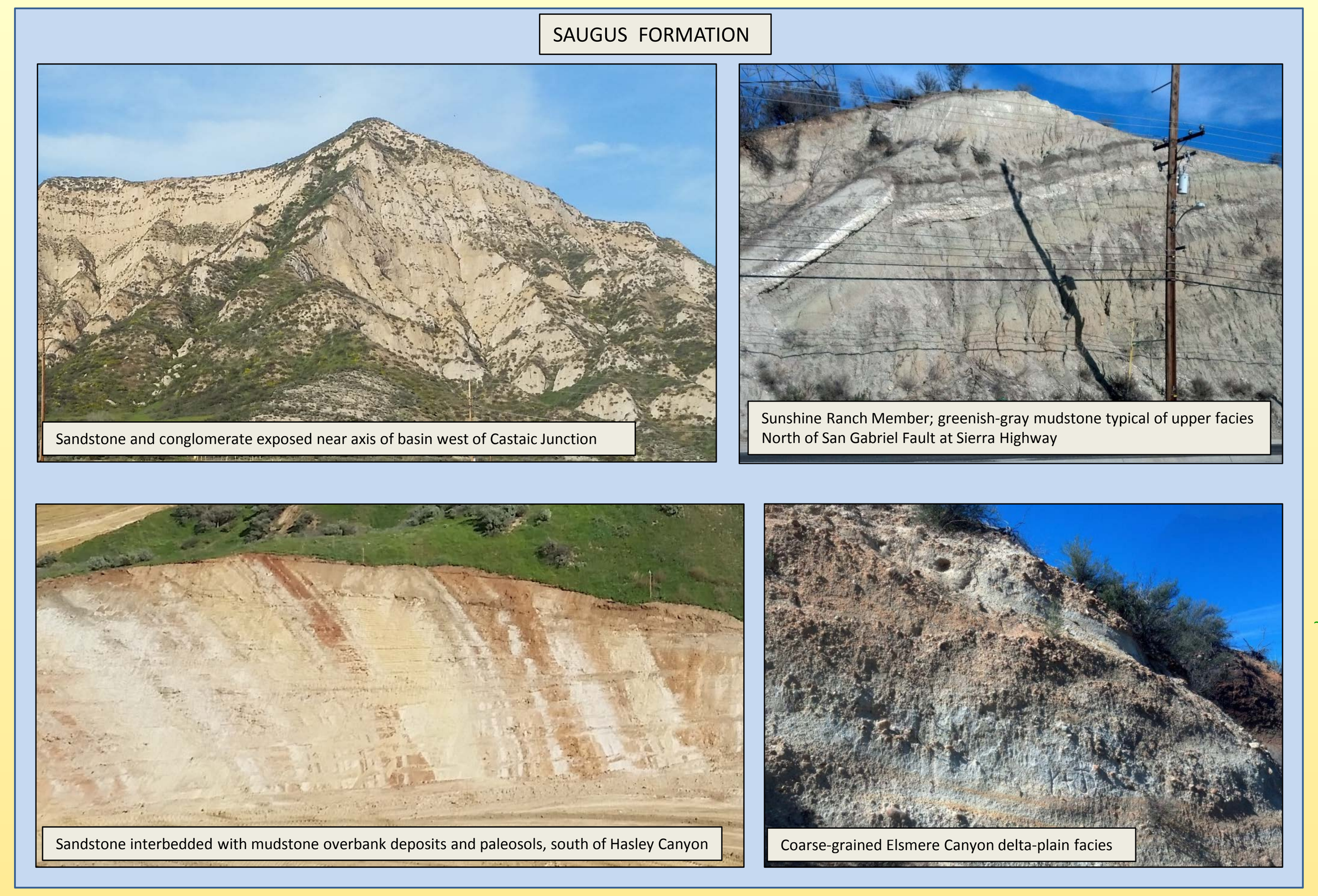
CGS CALIFORNIA GEOLOGICAL SURVEY

Fossiliferous fine-grained sandstone at Arroyo Verde Park



Poorly sorted conglomerate and sandstone along Sierra Highway south of the San Gabriel Fault

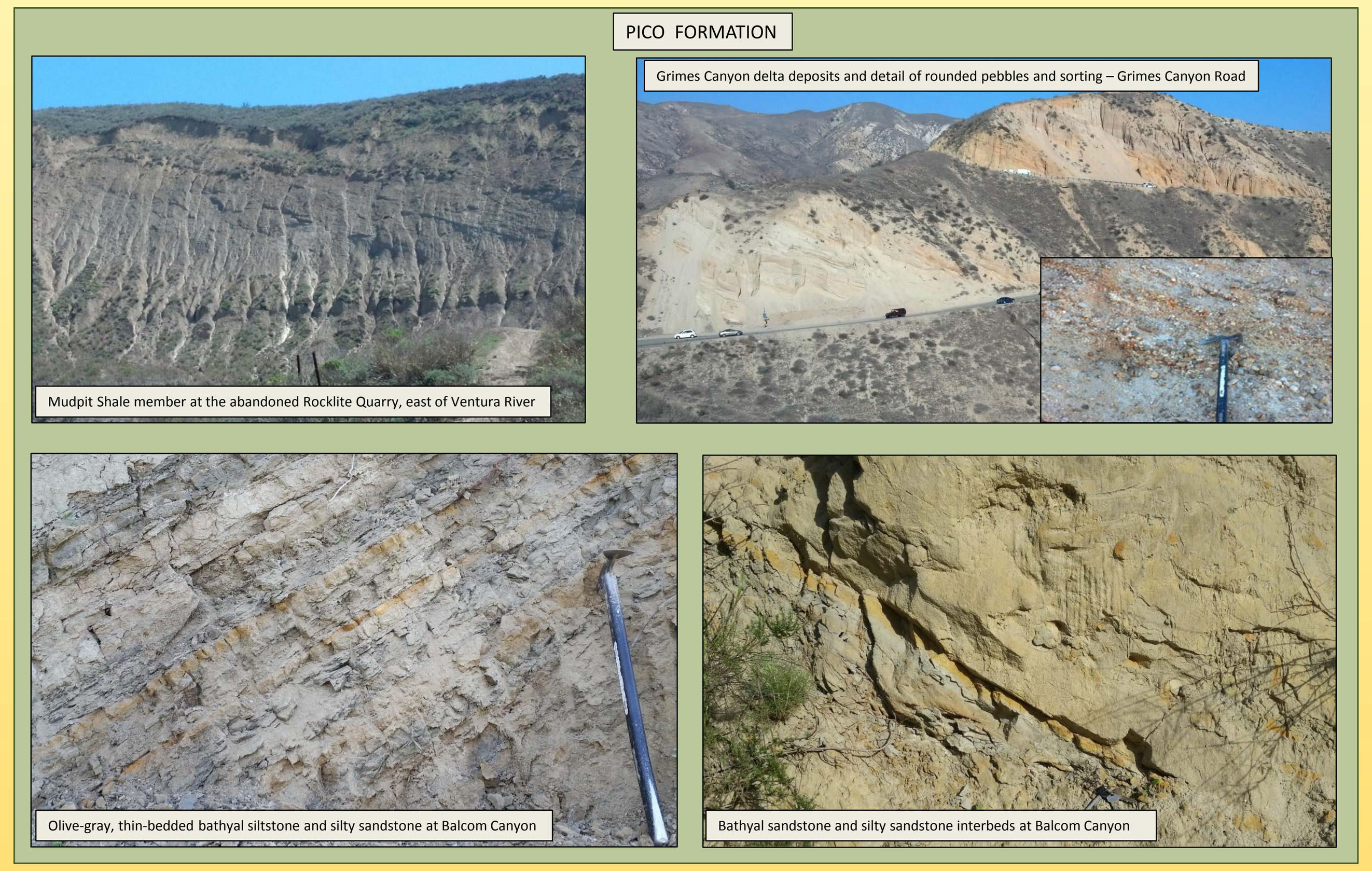


Sandstone and conglomerate exposed near axis of basin west of Castaic Junction

Sunshine Ranch Member; greenish-gray mudstone typical of upper facies North of San Gabriel Fault at Sierra Highway

Sandstone interbedded with mudstone overbank deposits and paleosols, south of Hasley Canyon

Coarse-grained Elsmere Canyon delta-plain facies

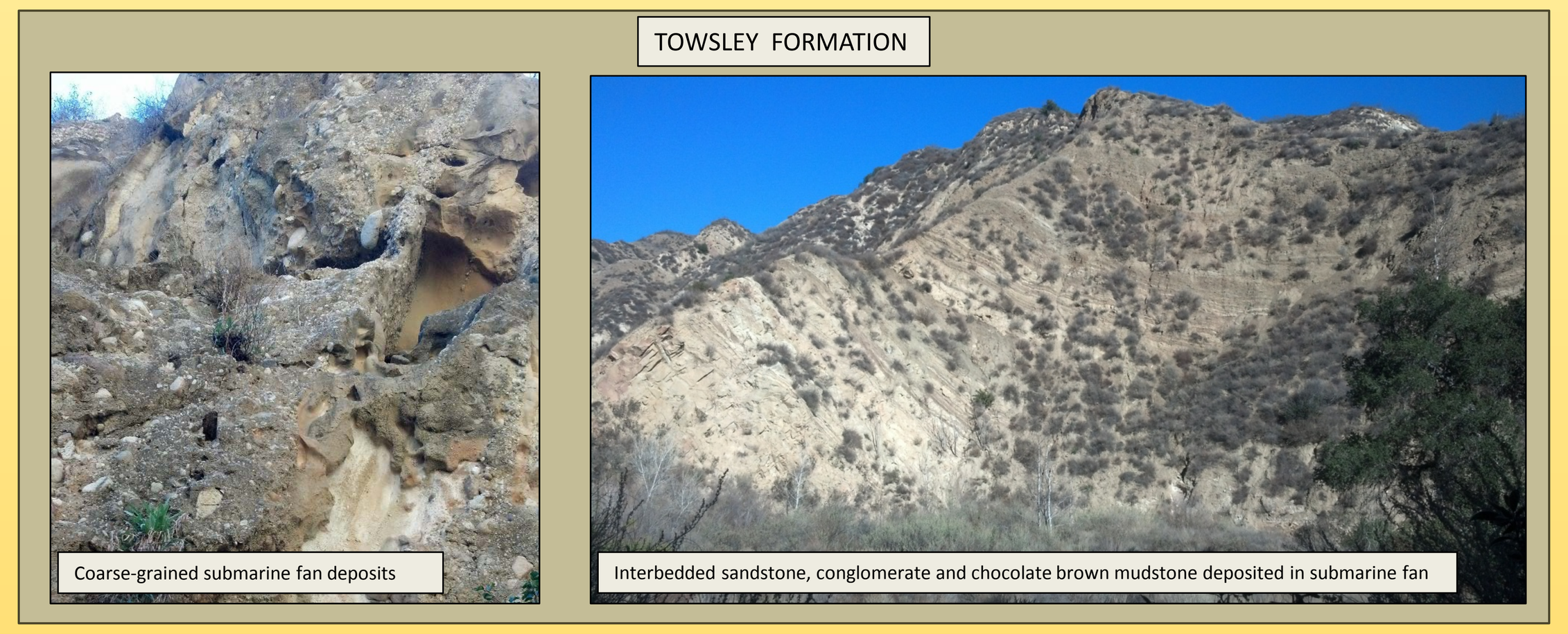


Grimes Canyon delta deposits and detail of rounded pebbles and sorting – Grimes Canyon Road

Mudpit Shale member at the abandoned Rocklite Quarry, east of Ventura River

Olive-gray, thin-bedded bathyal siltstone and silty sandstone at Balcom Canyon

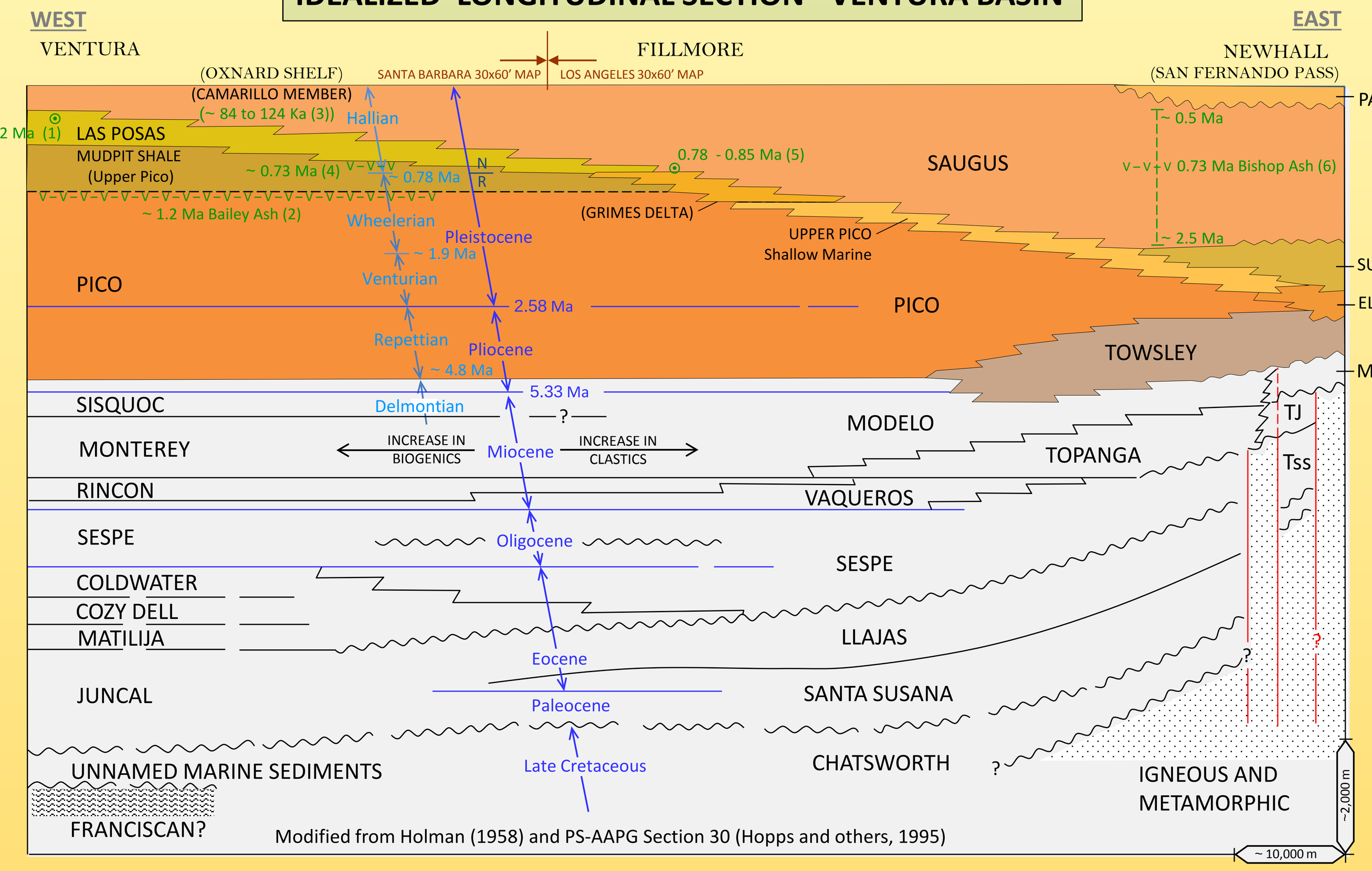
Bathyal sandstone and silty sandstone interbeds at Balcom Canyon



Coarse-grained submarine fan deposits

Interbedded sandstone, conglomerate and chocolate brown mudstone deposited in submarine fan

IDEALIZED LONGITUDINAL SECTION - VENTURA BASIN



Modified from Holman (1958) and PS-AAPG Section 30 (Hopps and others, 1995)

SUMMARY OF PLIO-PLEISTOCENE FORMATIONS ADOPTED FOR THE VENTURA BASIN - 2015

Qpa **PACOIMA FORMATION** – Middle Pleistocene fanglomerate/breccia in eastern Ventura basin; following definition of Oakeshott (1952; 1958); extended to include finer grained deposits in Santa Clarita (Treiman, 1986, 1987)

Qs/QTs **SAUGUS FORMATION** – Late Pleistocene to late Pliocene nonmarine sandstone and conglomerate with siltstone and mudstone interbeds; clasts derived primarily from the San Gabriel Mountains and Sierra Pelona; includes transitional nonmarine to brackish water deposits and delta-plain deposits in the eastern Ventura basin; formation is time transgressive, becoming progressively younger to the west where it is entirely Pleistocene; nonmarine following the definition of Hershey (1902), Winterer and Durham (1962), and usage by subsequent workers in the eastern Ventura basin type area (e.g. Saul, Weber, Treiman, Dibblee, Yeats)

- **Qsc** -**CAMARILLO MEMBER** – Late Pleistocene pebbly siltstone and sandstone with paleosols mapped in the Las Posas and Camarillo Hills areas; distinguished based on prevalence of locally derived shale and volcanic rock clasts rather than crystalline rock of San Gabriel Mountains; following definition of DeVecchio (2012)
- **Qsv** -**VOLCANICLASTIC BRECCIA-CONGLOMERATE** – Pleistocene deposit composed of angular to subrounded, pebble- to boulder-size clasts derived from the Conejo Volcanics in a caliche-rich matrix (Dibblee, 1992)
- **QTsu** -**UPPER SAUGUS MEMBER** – Middle Pleistocene sandstone and conglomerate containing shale and sandstone clasts derived from the newly emergent Santa Susana Mountains; following usage of Saul (1975; 1979) near Horse Flats; tentatively correlated with strata southwest of Castaic Junction
- **QTsg** -**BASAL CONGLOMERATE** – Early Pleistocene basal conglomerate mapped in the Mint Canyon quadrangle by Saul and Wootton (1983)
- **QTsr** -**SUNSHINE RANCH MEMBER** – Early Pleistocene to late Pliocene sulfur-yellow to light-brown and light-gray sandstone and conglomerate, greenish-gray sandy siltstone and mudstone, and local freshwater limestone beds; locally subdivided into an upper and lower facies, with the diagnostic greenish-gray mudstone beds prevalent in the upper facies; initially defined by Hazzard (1940) and Oakeshott (1950; 1958), but included in the Saugus Formation following Winterer and Durham (1962); nonmarine per Saul (1975)
- **QTse** -**ELSMERE CANYON DELTA-PLAIN FACIES** – Pliocene sandstone and conglomerate deposited in a braided river delta plain; interfingers with the Pico Formation to the west; following the definition of Squires (2012)

Qlp **LAS POSAS FORMATION** – Middle to late early Pleistocene light-gray to yellowish-gray, shallow marine, locally fossiliferous sandstone, greenish-gray mudstone, and subordinate conglomerate; following definition of Pressler (1929) and subsequent usage on Dibblee Foundation maps; includes strata previously assigned to the San Pedro or "lower marine Saugus" formations in the western onshore Ventura basin

QTp **PICO FORMATION** – Middle Pleistocene to Pliocene marine olive-gray siltstone with limonite nodules, and light-gray to light-brown sandstone and subordinate conglomerate deposited primarily by turbidity currents and hemipelagic sedimentation at bathyal to neritic depths; mappable coarse-grained beds shown as QTpc; grades up section into shallow water shelf and delta sandstone, conglomerate, and local fossil hash beds; top is time-transgressive and interfingering with the Saugus Formation; following definition of Winterer and Durham (1962) in the type area and usage of subsequent workers in the eastern Ventura basin; the term Fernando Formation is restricted to the Los Angeles basin and "Repetto" is not used as a lithologic formation, following Durham and Yerkes (1964)

- **QTpg** -**GRIMES CANYON DELTAIC FACIES** – Medium- to coarse-grained, cross-bedded sandstone and pebble to cobble conglomerate with well rounded clasts and local fossiliferous interbeds in the Grimes Canyon area; interpreted as a delta deposit following Dibblee (1992) and expanded eastward into Happy Camp Canyon based on reconnaissance mapping; interfingers with upper Pico Fm. to west
- **QTpcu** -**UPPER COARSE-GRAINED FACIES** – Shallow marine sandstone and conglomerate underlying and/or gradational with the Grimes Canyon deltaic facies to the west; assigned to Pico Fm. following definition of Winterer and Durham (1962) in the type area; includes strata previously assigned to the "lower marine Saugus" in the Santa Susana Mountains and Oak Ridge areas
- **QTpms** -**MUDPIT SHALE MEMBER** – Middle to early Pleistocene marine olive-gray to bluish-gray mudstone with local interbeds and lenses of sandstone and conglomerate and rare ash beds deposited at upper bathyal to outer shelf depths; following past informal usage in the Ventura basin (e.g. Nagle and Parker, 1971) and subsequent use on Dibblee Foundation maps; includes strata previously assigned to the Santa Barbara Formation, which is excluded from the onshore Ventura basin based on discrepancies with the type Santa Barbara lithology, age, and an intervening basin boundary

Tw **TOWSLEY FORMATION** – Early Pliocene to late Miocene marine, light yellowish-brown sandstone and conglomerate, and diagnostic brown-weathering sandy siltstone and mudstone; deposited in submarine fan lobes and inter-lobe areas in the eastern Ventura basin; mappable siltstone strata shown as Tws and mappable coarse-grained beds shown as Twc; may be equivalent to the Sisquoc Formation to the west; following Winterer and Durham (1954; 1962)

- **Twhc** -**HASLEY CONGLOMERATE MEMBER** – Basal conglomerate member mapped in the Val Verde and Piru quadrangles

CHRONOLOGIC SUMMARY OF MILESTONES IN THE DEVELOPMENT OF PLIO-PLEISTOCENE FORMATION NOMENCLATURE IN THE VENTURA BASIN

2012 – ***Squires*** describes late Pliocene **braid delta unit of the Saugus Formation** at Elsmere Canyon. ***DeVecchio (2012)*** informally defines the **Camarillo member of the Saugus Formation** based on locally derived clast content.

2005 – ***Yerkes and Campbell***: USGS publishes Version 1.0 of the Los Angeles 30x60' geologic map; Ventura basin mapping is based primarily on Weber and others (1973) in Ventura County and Winterer and Durham (1962) to the east.

1988-1996 – ***Dibblee Foundation maps***: Dibblee adopts the term "Mudpit shale" member of the Pico Formation in place of Santa Barbara Formation in the western Ventura basin. The term Las Posas Sand is adopted for shallow marine sands in the western Ventura basin rather than San Pedro or lower marine Saugus Formation. Coarse-grained deposits in Grimes Canyon that interfinger with offshore siltstone of the Pico Formation are mapped as delta deposits from west-flowing streams. The Saugus Formation as defined as generally nonmarine, and coarse-grained strata below the Sunshine Ranch Member in Elsmere Canyon are included within this formation.

1982 – ***Jackson and Yeats*** publish mapping in the Carpinteria area and report the presence of a Pleistocene boundary between the Ventura basin southeast of the Red mountain fault and the Carpinteria basin to the northwest.

1975 – ***Ricketts and Whaley*** use the terms Fernando Formation and "Pico member" for Pliocene strata in the Ventura basin, reportedly based on Jennings and Strand (1969). This usage is adopted by some subsequent workers in the Ventura basin apparently based on this criterion (e.g. Yeats, 1976; Yeats and others, 1994). This appears contrary to the actual usage of Jennings and Strand (1969) and Durham and Yerkes (1964), and therefore is **not adopted** herein.

1973 – ***Weber and others*** compile a geologic map of Ventura County based largely on numerous master's theses and on unpublished mapping by Bailey (1951); They use the terms San Pedro, Santa Barbara, Pico and Towsley Formation.

1969 – ***Jennings and Strand***: CDMG publishes geologic map of the 1:250,000-scale Los Angeles sheet; summarizes usage recommended by Durham & Yerkes (1964) in the Los Angeles basin and usage of Pico Formation in the Ventura basin.

1964 – ***Durham and Yerkes*** conclude that Pico and Repetto cannot be differentiated lithologically in most portions of the Los Angeles basin; they formally recommend abandonment of the term Repetto as a lithologic formation and exclude usage of the term Pico Formation to areas outside of the Los Angeles basin. They recycle the term Fernando, with the reduced rank of formation in the Los Angeles basin, and assign former Repetto and Pico strata to this formation. The Fernando is subdivided into an upper and lower member roughly equivalent to former Pico and Repetto Formations.

1958 & 1962 – ***Winterer and Durham*** remap the eastern Ventura basin and redefine the Pico and Saugus Formations based on depositional environment: Shallow marine sands are reassigned from the lower Saugus to the upper Pico Formation, and the Sunshine Ranch Member transitional facies is reassigned from the upper Pico Formation to the lower Saugus Formation. They also map and more thoroughly define the Towsley Formation. The nomenclature of Winterer and Durham is adopted by most subsequent workers in the eastern Ventura basin, and is largely adopted for the remainder of the basin for the 2014revision of the Los Angeles 30x60' geologic map.

1959 – ***Durham and Yerkes*** report that the term Pico Formation is considered synonymous with upper Pliocene strata by geologists in the Los Angeles basin; however, at the type locality in the Ventura basin, they report the Pico Formation is largely early Pliocene in age. They conclude that it would be desirable to replace the term Pico Formation in the Los Angeles basin with a new name, based on a new type locality.

1958 – ***Oakeshott*** maps the Pacoima Formation in the type area and extends it into the eastern Santa Clarita Valley. ***Holman (1958)*** publishes an updated version of Grant and Gale's longitudinal section of the Ventura basin.

1952 – *Oakeshott* proposes the term **Pacoima Formation** for Pleistocene alluvial fan deposits at the mouth of Pacoima Canyon in the northern San Fernando Valley.

1951 – ***Winterer and Durham*** propose a new (unnamed) formation for late Miocene to early Pliocene strata in the eastern Ventura basin formerly assigned primarily as a sandstone member of the Modelo Formation by Kew (1924). Winterer and Durham (1954; 1958) name this section to the Towsley Formation, with a type locality at Towsley Canyon; replaces "Repetto Formation " of Oakeshott (1950) and Willis (1952) in the Elsmere/Placerita Canyon area.

1950 – ***Oakeshott*** formally publishes description of Hazzard's **Sunshine Ranch** "formation", but assigns it as an **upper member of the Pico Formation**.

1943 – ***Stewart*** informally uses term "Mudpit shale" for strata previously assigned to the Santa Barbara Formation in the Ventura basin, based on exposures at a quarry for drilling mud and bricks on the east side of the Ventura River. ***Wissler (1943)*** publishes summary of the development of Pliocene nomenclature in the Los Angeles basin.

1940 – ***Hazzard*** proposes the term "**Sunshine Ranch formation**" in an unpublished report, for distinctive paralic deposits at the transition between the Pico and Saugus Formations in the eastern Ventura basin. The type locality is in the Mission Hills area of the northern San Fernando Valley. ***Woodring and others (1940)*** formally define usage of Santa Barbara Formation.

1935 – ***Bailey*** adopts the terms **Santa Barbara** and **San Pedro Formations** in the Ventura basin, and describes the interfingering, time-transgressive nature of these formations to the east.

1933 – *Natland* uses the term **"mud pit shale"** for sediments in his Zone III foram faunal zone; this appears to be the first published use of this term, which is used sporadically by subsequent workers on an informal basis.

1932 – ***XVI International Geological Congress***: Subcommittee of the Pacific Section SEPM is convened in 1930 to address Pliocene nomenclature in the Los Angeles basin and proposes a two-fold classification: **Pico Formation** is adopted for upper and middle Pliocene strata and the term **Repetto Formation** is proposed for strata containing a distinctive, early Pliocene benthic foram fauna, with the type section located along Atlantic Blvd in the Repetto Hills (footnote in ***Reed, 1932***). Reed notes that the lower portion of the Pico Formation at the type locality may include beds of Repetto age, but the facies is reportedly different and the section incomplete. The term Pico Formation becomes synonymous with upper Pliocene in the Los Angeles basin. The term Repetto Formation is adopted by some workers in the western Ventura basin for strata containing Repettian foram fauna. Some field geologists object to usage of Repetto formation because it is based on foram faunas rather than field characteristics (as noted by Woodring, 1938).

1931 – ***Grant and Gale*** publish a schematic cross section along the axis of the Ventura basin illustrating the time transgressive, westward younging nature of the marine/nonmarine contact across the basin. They reiterate that the term **Saugus** was originally applied to nonmarine deposits and strongly suggest that this term should not be used for Pleistocene marine strata in the western Ventura basin; they adopt the term **San Pedro** Formation for this section.

1929 – ***Waterfall*** notes the similarity between cold temperate molluscan fauna in the upper portion of the Pico Formation north of Ventura and fauna at the Bath House Beach beds in Santa Barbara. Many subsequent workers adopt the name **Santa Barbara Formation** for this section in the Ventura basin based on this criterion (e.g. Pressler, 1929; Grant and Gale, 1931; Bailey, 1935). ***Pressler (1929)*** proposed the name "**Las Posas formation**" for shallow marine sands that contain a distinctive warm water "Saugus" molluscan fauna above the "Santa Barbara horizon" in the Las Posas Hills and adjacent areas.

1926 – ***Kew in Tieje*** assigns the term **San Pedro Formation** to the lower San Pedro Series of Arnold (1903).

1923 & 1924 – ***Kew*** proposes to elevate **Fernando** to **Group** status and subdivides it into a lower, Pliocene marine unit designated as the **Pico Formation**, based on a type area at Pico Canyon, and an upper, Plio-Pleistocene unit designated as the **Saugus Formation**, generally following Hershey's original nonmarine definition, except for the inclusion of shallow marine sandstone and conglomerate at the base (these revisions foreshadowed in Clark, 1921). Kew notes that the "Saugus" of Eldridge and Arnold (1907) actually refers to terrace deposits and that the "Saugus division" of Hershey had always been included in the Fernando Formation. This usage was quickly adopted by most workers in the Ventura basin, and the term Pico Formation was extended to the Los Angeles basin based primarily on microfaunal criteria.

1914 – ***McLaughlin and Waring*** publish a geologic map covering much of the onshore Ventura basin, following and extending Eldridge and Arnold's usage of **Fernando Formation**. ***English (1914)*** noted that the Fernando likely contains more than one formation and referred to it as a group.

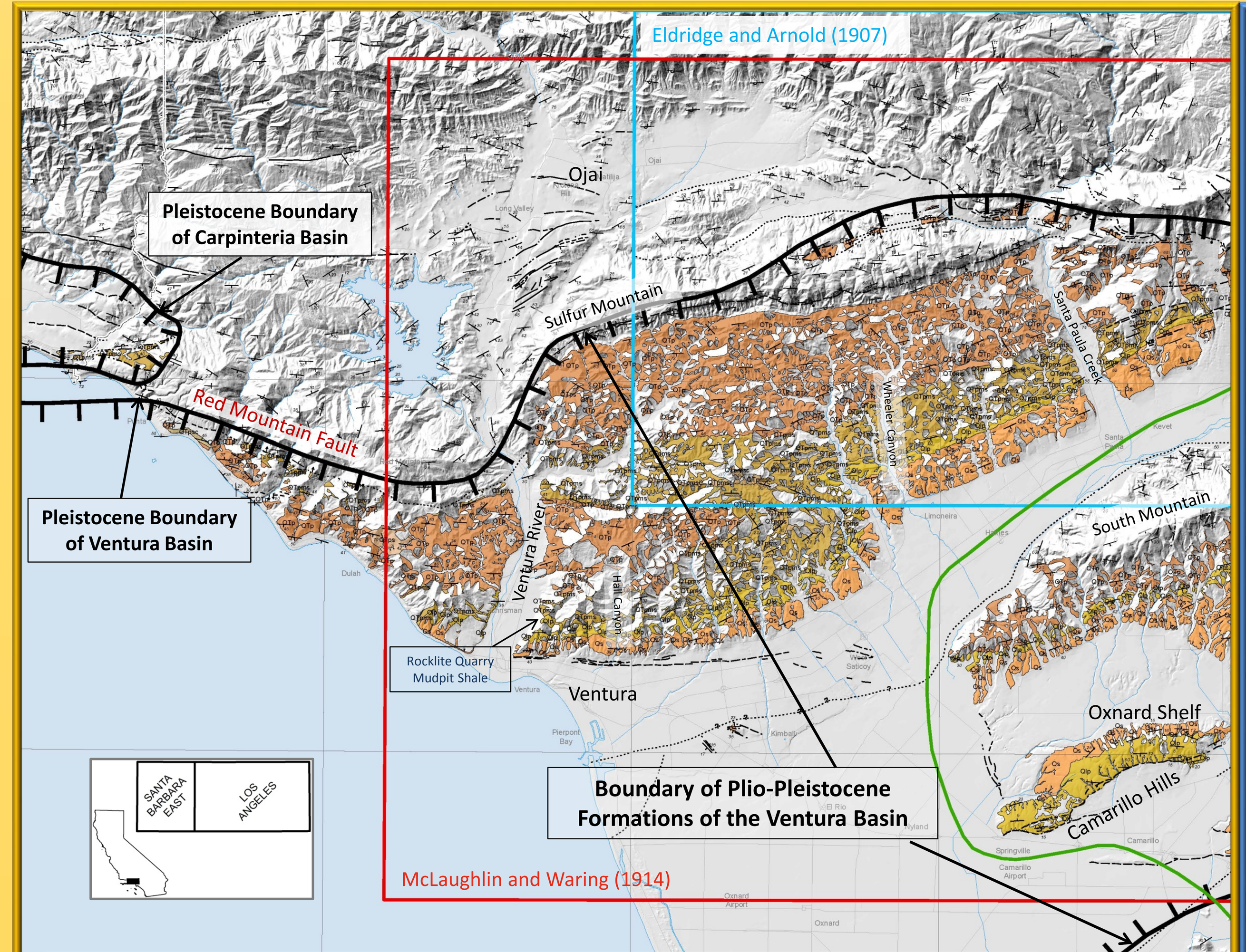
1912 – ***Smith*** uses the term "**Santa Barbara**" in a faunal sense for Pleistocene, fossiliferous sands exposed at Packard's Hill (Hill 406) in the *Santa Barbara basin* (credited as first use of this term in the Lexicon by Wilmarth, 1938). The term Santa Barbara formation was previously used for this section by Arnold and Arnold (1902) but Arnold (1907) subsequently assigned it to the Fernando Formation.

1907 – ***Eldridge and Arnold*** assign all Pliocene and Pleistocene strata above Miocene siliceous shale and below terrace deposits in the eastern Santa Clara River Valley to the **Fernando Formation**. This term was originally proposed in unpublished work by Homer Hamlin for post-Modelo, "pre-Saugus" (terrace deposit) strata skirting the San Fernando Valley. No geologic map of the San Fernando Valley showing the location of the type section was published by these workers. This term was generally adopted at the time for deformed Pliocene to lower Pleistocene strata in the Ventura basin, and from the Los Angeles basin on the south to the Santa Maria basin on the north.

1902 – ***Arnold and Arnold*** propose the name "**San Pedro series**" (upper and lower) for Pleistocene, shallow marine fossiliferous sands exposed at the San Pedro (Palos Verdes) Hills, in the *Los Angeles basin*. They correlated strata with similar fauna near Ventura and at Bath House beach in Santa Barbara to this series; ***Arnold (1903)*** described the type San Pedro section in much greater detail.

1902 – ***Hershey*** coins the term "**Saugus division**" for tilted, late Pliocene (i.e. deformed by the "great orographic disturbance") alluvial deposits exposed in cuts along the Southern Pacific Railroad in Soledad Canyon near the town of Saugus, in the eastern Ventura basin.

Prior to 1902 – No formation names assigned for Plio-Pleistocene strata in the Ventura basin.



UPDATED NOMENCLATURE FOR PLIO-PLEISTOCENE FORMATIONS IN THE ONSHORE VENTURA BASIN, LOS ANGELES AND SANTA BARBARA 30' X 60' QUADRANGLES

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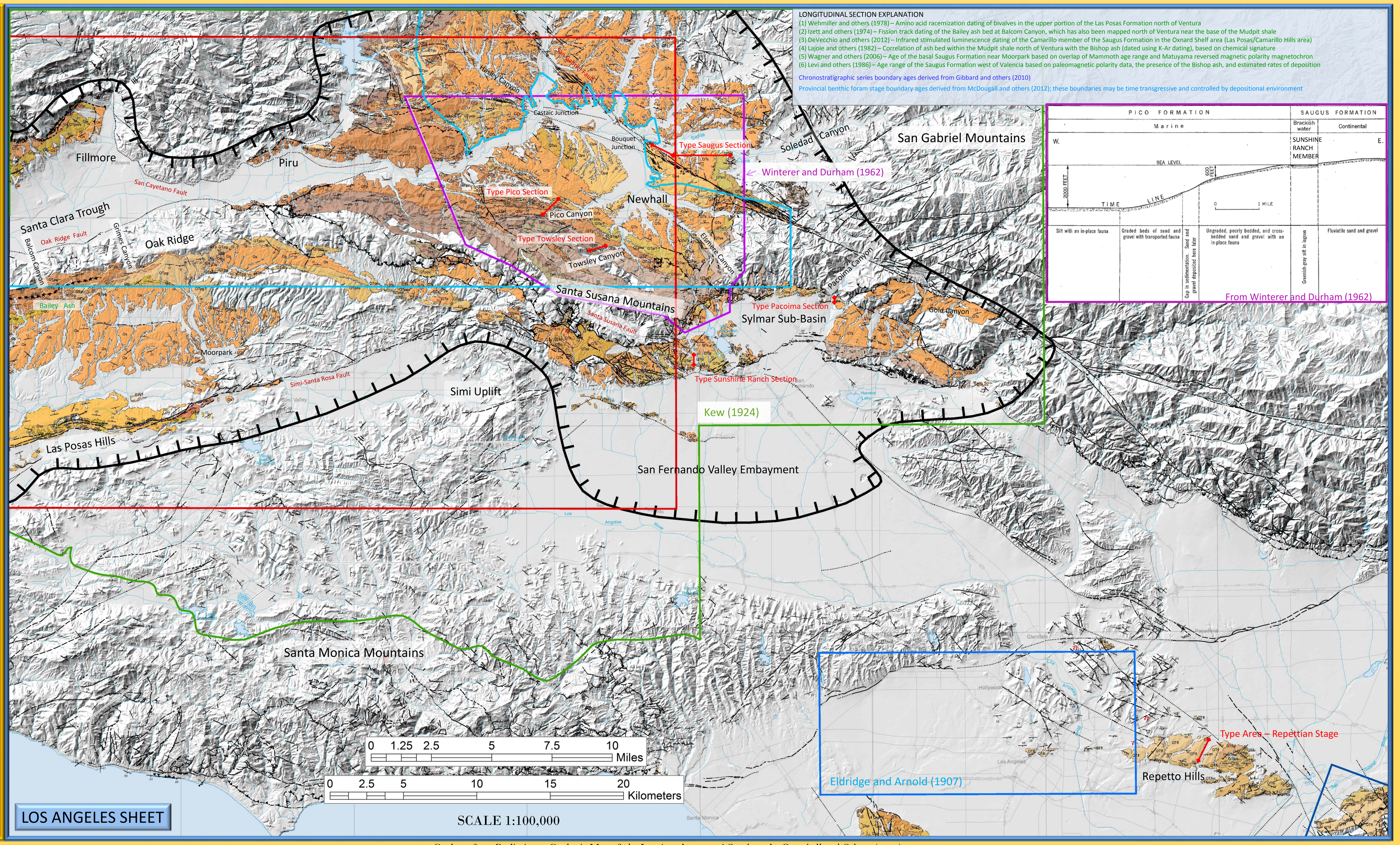
The Plio-Pleistocene bedrock nomenclature of the onshore Ventura basin and associated San Fernando Valley embayment was re-evaluated from a basin-wide perspective during preparation of the Preliminary Geologic Map of the Los Angeles 30'x60' Quadrangle, which was recently updated by the California Geological Survey and issued in July of 2014 as part of the STATEMAP project. The nomenclature adopted for this map will likely be extended to the eastern half of the Santa Barbara 30'x60' Quadrangle in a future update. Strata of this age have a complex history of nomenclature: conflicting terminologies have developed due to a combination of complex depositional conditions (such as facies changes and local unconformities near the basin margins, and the time-transgressive nature of contacts due to westward migration of the paleoshoreline during basin infilling), and inconsistent methodologies used to define formations (such as the use of fauna rather than lithology, the use of formation names defined in other basins, and differing techniques used in surface mapping vs. subsurface exploration for oil). The basic stratigraphic sequence is regressive, ranging up section from bathyal hemipelagic and submarine fan turbidite deposits to granular shallow marine, local transitional/paralic, and granular continental deposits.

The definitions of the marine Pico Fm. and Towsley Fm. and the nonmarine Saugus Fm. published by Winterer and Durham (1962) for the type sections in the eastern Ventura basin are adopted and extended to the western portion of the basin. Marine strata formerly assigned by some workers to the Saugus Fm. in the southern Santa Susana Mountains are reassigned as an informal member of the upper Pico Fm. Strata formerly assigned to the San Pedro Fm. near South Mountain are reassigned to the Saugus Fm., if nonmarine, or to the Las Posas Fm. if marine. The informally defined term Mudpit shale member of the upper Pico Fm. is adopted in preference to Santa Barbara Fm. for strata west of Fillmore. The term "Repetto" is defined by Repettian Stage microfauna rather than lithology and is therefore considered a biozone rather than a formation. The Sunshine Ranch and Camarillo members of the Saugus Fm. are adopted, and the terms Elsmere Canyon delta-plain facies of the Saugus Fm. and Grimes Canyon deltaic facies of the Pico Fm. are also informally defined. The formational terms Santa Barbara, San Pedro, and Fernando are excluded to areas outside of the Ventura basin.

SANTA BARBARA SHEET – EAST HALF



LOS ANGELES SHEET

SCALE 1:100,000

Geology from Geologic Map of the East Half of the Santa Barbara 30x60' Quadrangle: Compiled by Gutierrez and Others (2008)

Geology from Preliminary Geologic Map of the Los Angeles 30x60' Quadrangle: Campbell and Others (2014)