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GEOLOGIC MAP AND DIGITAL DATABASE OF THE REDLANDS 7.5' QUADRANGLE, SAN BERNARDINO AND RIVERSIDE COUNTIES, CALIFORNIA, v. 1.0

Summary Pamphlet

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[This Summary Pamphlet accompanies the geologic map and digital database of the Redlands 7.5' quadrangle, San Bernardino and Riverside Counties, California, version 1.0]

INTRODUCTION

This geologic database of the Redlands 7.5' quadrangle (Fig. 1) was prepared by the Southern California Areal Mapping Project (SCAMP), a regional geologic-mapping project sponsored jointly by the U.S. Geological Survey and the California Geological Survey. The database was developed as a contribution to the National Cooperative Geologic Mapping Program's National Geologic Map Database, and is intended to provide a general geologic setting of the Redlands quadrangle. The database and map provide information about earth materials and geologic structures, including faults and folds that have developed in the quadrangle due to complexities in the San Andreas Fault system.

The Redlands 7.5' quadrangle contains earth materials and structures that provide insight into the late Cenozoic geologic evolution of the southern California Inland Empire region. Important stratigraphic and structural elements include (1) the modern trace of the San Andreas and San Jacinto faults and (2) late Tertiary and Quaternary sedimentary materials and geologic structures that formed during the last million years or so and that record complex geologic interactions within the San Andreas Fault system. These materials and the structures that deform them provide the geologic framework for investigations of earthquake hazards and ground-water recharge and subsurface flow.

Geologic information contained in the Redlands database is general-purpose data that is applicable to land-related investigations in the earth and biological sciences. The term "general-purpose" means that all geologic-feature classes have minimal information content adequate to characterize their general geologic characteristics and to interpret their general geologic history. However, no single feature class has enough information to definitively characterize its properties and origin. For this reason the database cannot be used for site-specific geologic evaluations, although it can be used to plan and guide investigations at the site-specific level.

This summary pamphlet discusses major categories of surficial materials in the Redlands quadrangle, and provides a conceptual framework and basis for how geologic-map units containing such materials are recognized and correlated.

QUATERNARY SURFICIAL MATERIALS

Quaternary surficial materials—geologic materials that have accumulated at the land surface over the last 750,000 years or so—are widespread throughout the Redlands quadrangle. These are mainly unconsolidated materials that mantle the ground surface of valleys and hillslopes, or that form the uppermost fillings of alluvial fans and valleys.

The transition between "unconsolidated" and "consolidated" (lithified) is not easy to define. In general, sedimentary materials that have begun to consolidate (lithify) will have some degree of compaction and (or) cementation that yields a stiff, firm, or coherent mass that resists breakage. This consolidation process leads to decreased pore space and increased relative density. The consolidation (lithification) process is influenced by sediment grain size, sorting, cohesiveness (cohesionless materials *versus* cohesive materials), overburden load, and circulating fluids. With increased consolidation, lithification and progressive hardening (induration) results. For the Redlands quadrangle, we used the criteria listed in Table 1 to describe the consolidation state of surficial materials. In general, consolidation increases with increasing age of the sedimentary material.

	Lithification State	Field Criterion	Relative Density (D_r)[1]
Unconsolidated	Very slightly consolidated	Easily indented with fingers	0.00—0.20
	Slightly consolidated	Somewhat less easily indented with fingers. Easily shoveled	0.20—0.40
	Moderately consolidated	Shoveled with difficulty	0.40—0.70
Consolidated	Well consolidated	Requires pick to loosen for shoveling	0.70—0.90
	Lithified	Requires blasting or heavy equipment to loosen	0.90—1.00
	Indurated	Rings to the blow of a hammer	1.00

Table 1: Criteria for the recognition of consolidation state in surficial materials (modified from Bowles, 1984, Table 5-2)

We classified surficial materials in the Redlands quadrangle into various map units using three kinds of information:

- physical properties and lithologic features (including consolidation, depositional fabric, particle size and particle sorting, particle composition, matrix support versus grain support);
- genesis and geomorphic setting (physiographic setting) and mode of origin (alluvial-fan, colluvial, slope failure, etc.);
- age (as interpreted mainly from pedogenic-soil characteristics, but also by degree of erosional dissection).

Our inclusion of genesis as a factor in mapping surficial materials runs counter to the way map units of other materials in the quadrangle are classified. According to the North American Stratigraphic Code (North American Commission on Stratigraphic Nomenclature, 1983), surficial geologic-map units—like map units of consolidated materials—are lithostratigraphic and (or) allostratigraphic units that should be defined on the basis of descriptive lithologic and stratigraphic features alone; highly interpretive and

[1]As translated by Bowles (1984, p. 151-152), relative density is an engineering parameter that relates void space determined in the laboratory to a ratio involving index values of minimum and maximum void space for specified materials under specified conditions. Void space in turn is related to *in situ* dry unit weight. The *Glossary of Geology* definition of relative density is: "The ratio of the difference between the void ratio of a cohesionless soil in the loosest state and any given void ratio to the difference between its void ratios in the loosest and in the densest states (ASCE, 1958, term 296)" (Jackson, 1997, p. 540).

derivative criteria such as genesis typically should be avoided. Despite these guidelines, use of genetic criteria as a basis for classifying and mapping surficial materials seems intuitive because they are forming right before our eyes: we can observe how the physiographic setting and geologic origin of the materials determines their physical properties and contributes to the overall characterization of a map unit. Thus, it is useful to include genetic factors in the mapping of these materials, and in the Redlands quadrangle surficial materials that have the same genesis are candidates for inclusion within the same geologic-map unit—assuming they are about the same age (discussed below).

Figure 3 illustrates the hierarchical framework for classifying surficial geologic-map units in the Redlands quadrangle, showing how physiographic setting and genesis figure into identifying and naming the units. Most surficial units in the quadrangle are classified into two major alluvial categories: *axial-valley materials* deposited in lowlands by through-going rivers and streams that flow down valley axes (units Qvya, Qya, Qoa, and Qvoa) and *alluvial-fan materials* deposited in cone-shaped aprons that flank the margins of hills and mountains or that build down onto through-going axial-valley plains from lateral tributaries (units Qvyf, Qyf, Qof, and Qvof).

Both *axial-valley* and *alluvial-fan* deposits are categories of alluvium: that is, they consist of sediment deposited mainly by stream flows (although alluvial-fan deposits locally include sediment-gravity-flow deposits). For this reason, the two alluvial deposit types generally have similar lithologic characteristics and physical properties. For example, axial-valley deposits have physical properties that are very similar to those of distal alluvial-fan deposits. How, then, can the two deposit types be distinguished by other than original physiographic setting and genesis, especially for older materials where information about such factors may have become obscured by erosion, deformation, and burial by younger units? Materials in *axial-valley* and *alluvial-fan* categories differ in the following general ways:

- alluvial-fan deposits typically are coarser grained and more poorly sorted than axial-valley deposits, being gravel-rich in comparison with sand-rich axial-valley deposits;
- axial-valley deposits typically have more layers of clay, silt, and organic-rich material (peat) associated with sand-and-gravel layers than do alluvial-fan deposits;
- where axial-valley and alluvial-fan deposits at the surface or in the subsurface are traced in a known or inferred upstream direction, alluvial-fan deposits tend to coarsen in grain size and lose fine-grained interbeds more rapidly than do their axial-valley counterparts.

Our classification of surficial geologic-map units also incorporates geologic age as a basis for assigning a map-unit name. This is because relative age position among bodies of surficial earth material is an obvious aspect that has an immediate impact on the observer. For example, during the Quaternary Epoch Southern California witnessed the cyclic development of multiple generations of surficial deposits:

- Mountain canyons display flights of alluvial terraces, each formed by different pulses of canyon-filling alluvium or down-cutting stream events;

- Alluvial fans flanking the mountains consist of different-aged units nested one into another;
- The coastal strip has flights of marine terraces that march upslope from present sea level.

These cycles developed because geologic and climatic conditions vary with the passage of time, and such changes trigger responses in the geologic and geomorphic processes that operate at the earth's surface. As a result, one package (map unit) of surficial materials can give way abruptly to another. If these packages have not been stripped away by erosion or concealed by younger materials, a succession of surficial units will be preserved.

This succession is age-sequenced: that is, the succession of alluvial map units on hillslopes or in canyons or on valley bottoms is arrayed in a chronologic sequence. As part of the geologic-mapping process, the geologist confirms how the sequence of deposits in one area relates temporally to the sequence in another area. Geologic age thus is a critical criterion in the classification and mapping of surficial geologic materials, and surficial deposits of the same age are candidates for inclusion within the same geologic-map unit—as long as they have the same origin and generally similar physical properties.

Figure 4 illustrates regional and global chronologies within which surficial materials of the Redlands quadrangle can be compared. Figures 5 and 6 indicate where we think surficial map units in the Redlands quadrangle fit within this chronology, especially in comparison with the succession of alluvial-terrace fills recognized by Bull (1991) in the San Gabriel Mountains and in the desert regions of southern California. Our classification scheme breaks out four major age-based surficial families:

- *Very young* surficial deposits (Qvy units; these are the most recent surficial deposits spanning the last few hundred years or so of Holocene time);
- *Young* surficial deposits (Qy units; these are Holocene and latest Pleistocene deposits that formed since the last major glacial period—since the late Wisconsin of Figures 4 and 5);
- *Old* surficial deposits (Qo units; these are surficial deposits that formed during the last few hundred thousand years. We currently do not have good age control on these units);
- *Very old* surficial deposits (Qvo units; these are the oldest surficial deposits that accumulated in the Redlands quadrangle since the deposition of the San Timoteo beds of Frick, 1921);

Currently, we cannot correlate very confidently surficial geologic-map units in the Redlands quadrangle with the global climatically-driven chronology. For one reason, our only way to estimate geologic age is the textural and mineralogic maturity of the pedogenic-soil profile that caps each surficial deposit. In general, this allows us to compare the age of the surficial units relative to each other, and allows us to speculate about where each unit falls relative to the provisional chronology developed by Bull (1991). Unfortunately, soil profiles in the Redlands quadrangle have only been studied carefully in a few areas (Woodruff and Brock, 1980; Kendrick, 1999). Moreover, during our geologic mapping we were able to examine soil profiles only in a perfunctory way. Until more careful investigations of the pedogenic soils are conducted, or until numerical geochronologic data are obtained using radiometric-age determinations (see the work by and Kendrick and others, 2002), our classification and correlation of surficial materials in the Redlands quadrangle is provisional and subject to modification and revision.

Although the general character of the surficial map units persists throughout the map area, in detail their character varies both horizontally and vertically. Thus, details of sediment interlayering, consolidation, grain-size variation, and permeability for a given map unit may change markedly between localities only a few tens of meters apart. Similar variations also occur vertically at a specific site: physical properties observed in the upper meter or two of a unit may not persist very far into the subsurface, and the surface unit may be underlain in the subsurface by an older unit (Qya_5 at the surface may be underlain within a few meters by units Qya_4, and Qya_3). Finally, because stream channels migrate from season to season and year to year and because the interface between alluvial-fan and axial-valley environments changes in location with the passage of geologic time, alluvial-fan and axial-valley deposits interfinger in the subsurface throughout the map area. These factors all contribute to lithologic variability both laterally and vertically within and between surficial geologic units.

Because the Redlands quadrangle has only some of the units recognized regionally, and because the dataset authors have attempted to correlate these units within the region-wide classification scheme, surficial units recognized in the quadrangle appear to be identified out of context: for example, unit $Qvoa_3$ is recognized even though older units $Qvoa_2$ and $Qvoa_1$ are not. Figures 4-6 illustrate the main region-wide surficial units.

From younger to older, we recognize the following categories of surficial deposits in the Redlands quadrangle:

Very young deposits (Qvyw, Qvyf, Qvyc, Qvyls)

These are the youngest surficial units in the Redlands quadrangle. They generally lack pedogenic-soil profiles, and are not dissected. These map units represent deposits formed essentially in equilibrium with modern climatic and landscape conditions.

Young deposits (Qya, Qyf, Qyls)

Sand-and-gravel deposits of this family are characterized by pedogenic-soil profiles having minimal soil-profile development: the $A/C_{ox}/C$ profiles are no thicker than 1 or 2 m, with the most mature profiles having Bcambic horizons that lack illuvial clay. These soils are Holocene to latest Pleistocene in age, coincide with soil-stages S6 and S7 of McFadden (1982) and Bull (1991), and are between 15,000 and 1,000 years old (Figures 5, 6).

Old deposits (Qoa, Qof, Qols)

Alluvial deposits of this age are characterized by pedogenic-soil profiles having red B horizons as thick as 2 m; soils having this degree of rubification are comparable to soil-stages S3, S4, and S5 of McFadden (1982) and Bull (1991), and probably are between 500,000 and 50,000 years old (Figures 5, 6). They represent the "older alluvium" of Burnham and Dutcher (1960, p. 77-78).

Very old deposits (Qvoa, Qvof)

Very old Quaternary deposits are characterized by pedogenic-soil profiles having very red B horizons as thick as 3 m. Soils of this maturity are comparable to soil-stage S2 of McFadden (1982) and Bull (1991), and probably are greater than 500,000 years old. These deposits coincide with the "old red gravel" of Burnham and Dutcher (1960, p. 72-77).

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Figure 1.--Index map showing location of Redlands quadrangle (red rectangle)

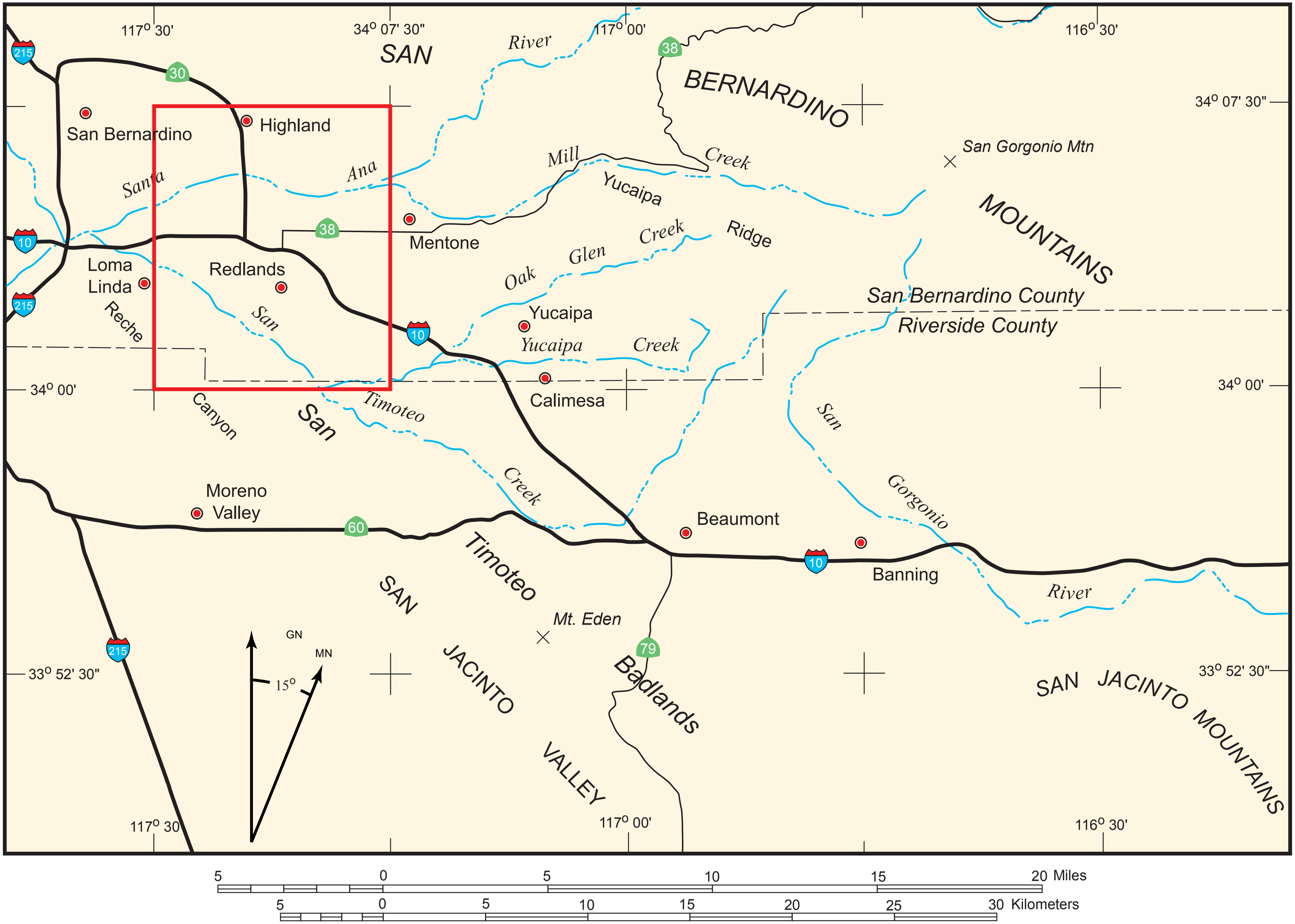
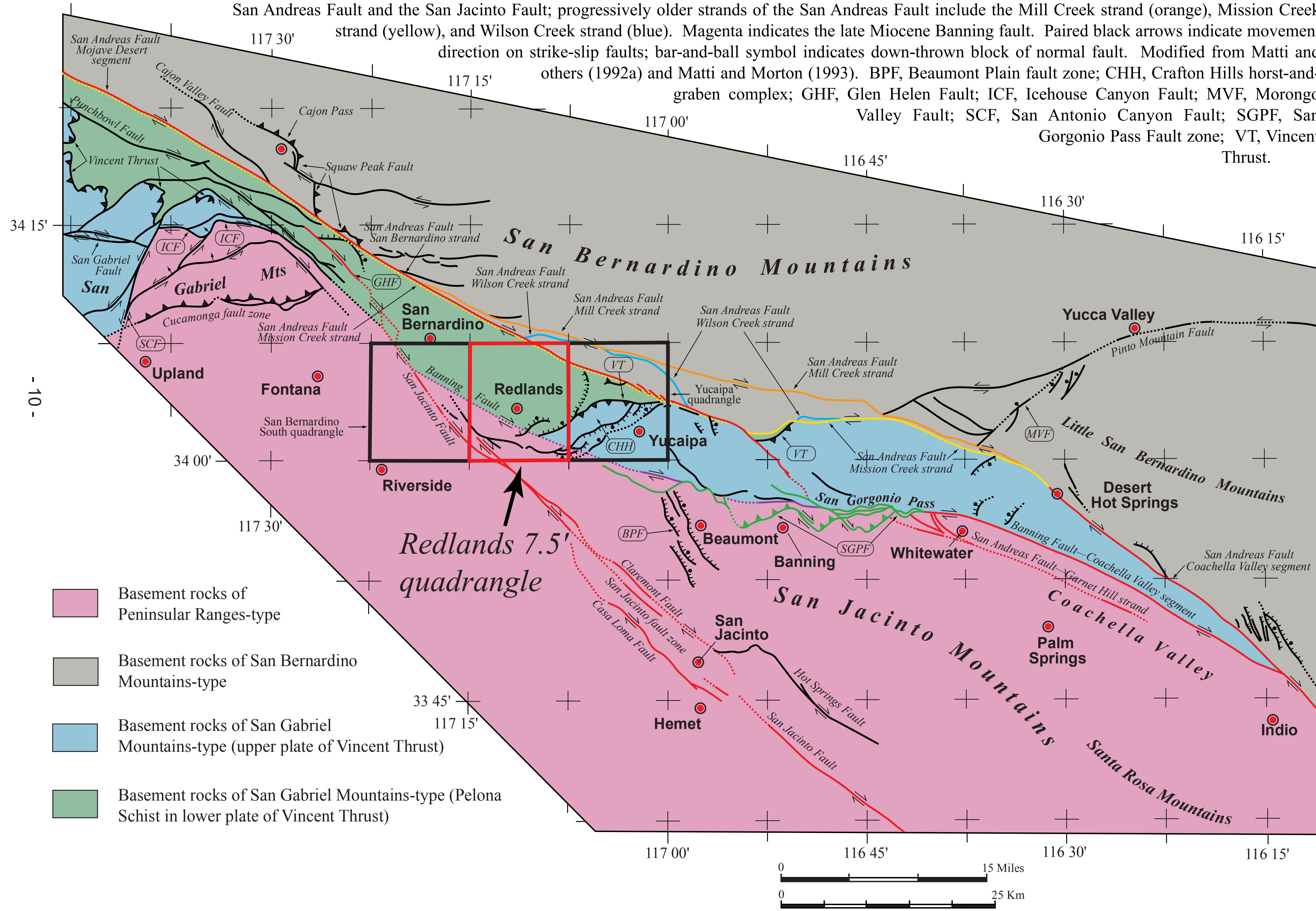


Figure 2.—Map showing location of Redlands 7.5' quadrangle relative to faults and basement-rock terranes in the region. Faults in red are modern strands of the San Andreas Fault and the San Jacinto Fault; progressively older strands of the San Andreas Fault include the Mill Creek strand (orange), Mission Creek strand (yellow), and Wilson Creek strand (blue). Magenta indicates the late Miocene Banning fault. Paired black arrows indicate movement direction on strike-slip faults; bar-and-ball symbol indicates down-thrown block of normal fault. Modified from Matti and others (1992a) and Matti and Morton (1993). BPF, Beaumont Plain fault zone; CHH, Crafton Hills horst-and-graben complex; GHF, Glen Helen Fault; ICF, Icehouse Canyon Fault; MVF, Morongo Valley Fault; SCF, San Antonio Canyon Fault; SGPF, San Gorgonio Pass Fault zone; VT, Vincent Thrust.



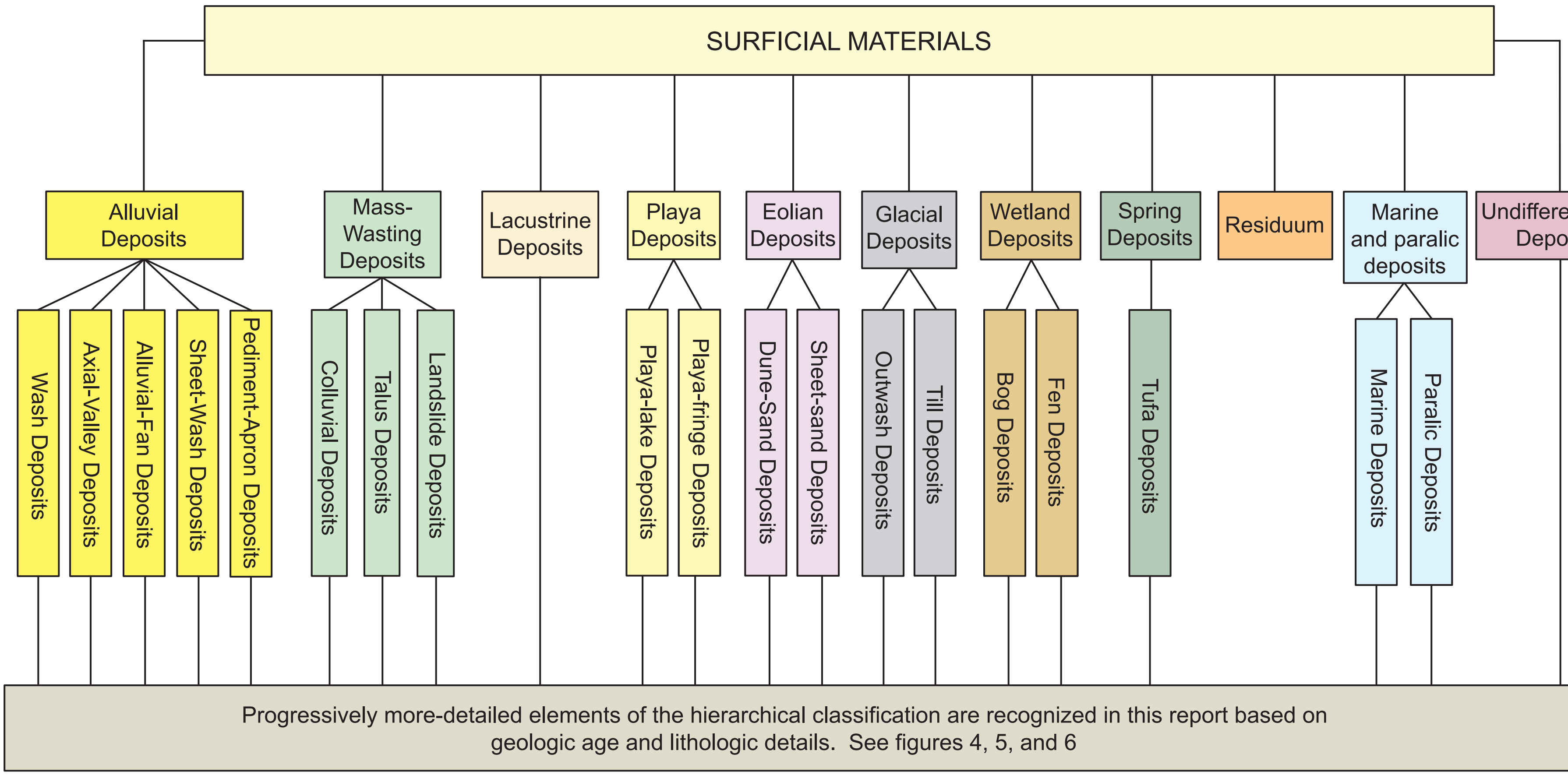


Figure 3.--Diagram illustrating hierarchical classification structure of surficial geologic-map units in the Redlands quadrangle, showing how physiographic setting and genesis figure into classifying and naming the units.

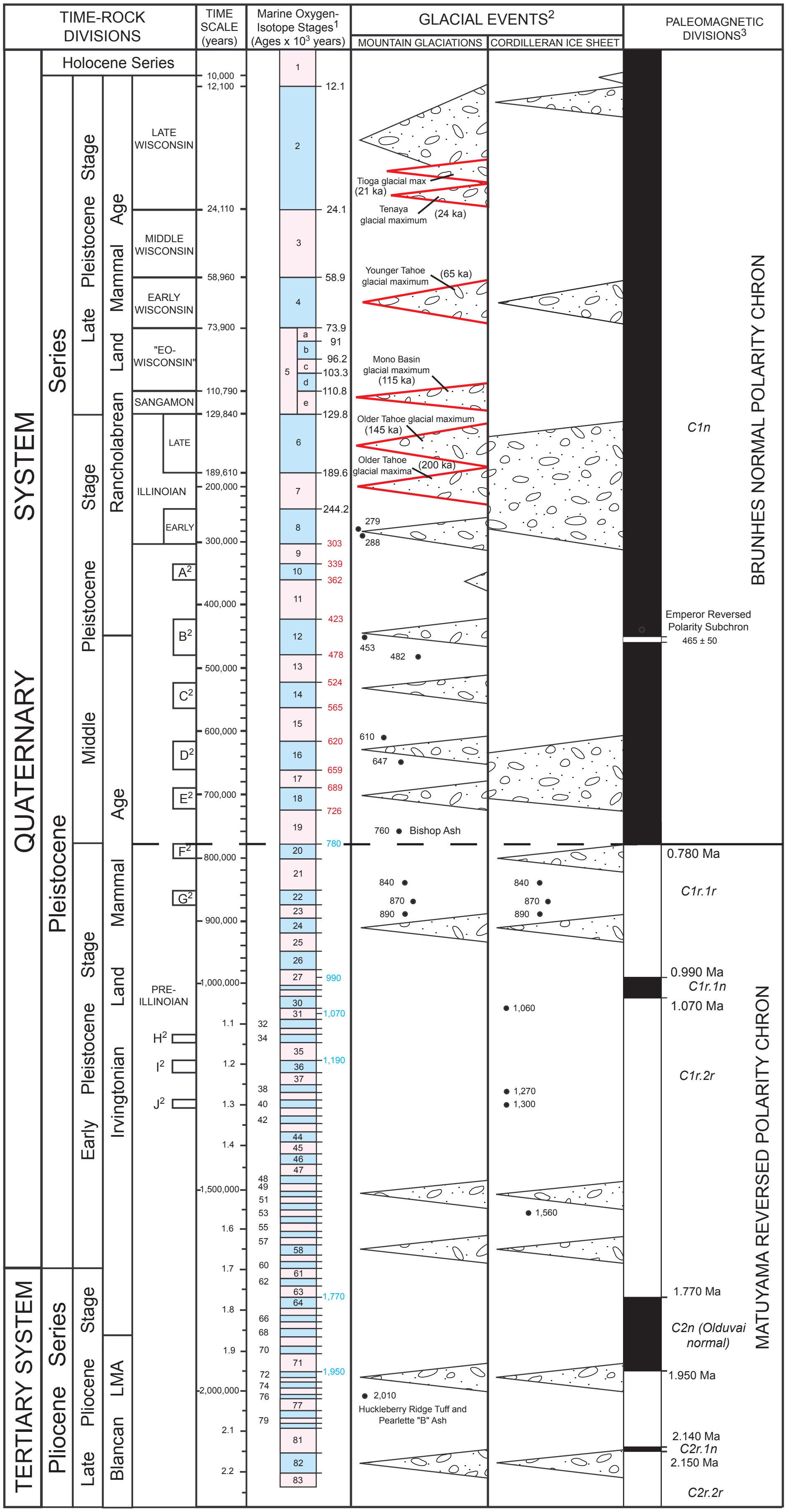


Figure 4.—Chart showing relations among Quaternary time-rock divisions, marine oxygen-isotope stages, glacial events, and paleomagnetic chronology. Figures 5 and 6 show how surficial materials in the Redlands quadrangle are correlated with the chronologies in this figure.

North American Land Mammal Ages adapted from Repenning (1987) and Lundelius and others (1987). North American glacial stages adapted from Bowen and others (1986). Time-rock divisions for Pleistocene Series from Berggren and others (1995a,b). Timescale is not linear: (a) for the interval dating from the present to 200,000 years before present (ybp), the span of time increments is adjusted to accommodate other information on the chart; (b) for the interval between 200,000 ybp to 1,000,000 ybp, the time increments are equal; (c) for the interval between 1,000,000 ybp and 2,300,000 ybp the time increments are equal, but not the same as (b).

[1]Marine oxygen-isotope stages adapted from several sources. (a) Stages 1 through base of 7, from Martinson and others, 1987 (black age annotations) based on orbital-tuning of results by Pisias and others (1984); (b) base of Stage 8 through base of Stage 18 from Imbrie and others, 1984 (red age annotations); (c) base of Stage 19 through base of Stage 83 interpolated by us from Figure 2 and Tables 3 and 4 of Shackleton and others, 1990 (blue age annotations from their Table 4).

[2]Sequencing of glacial events (gravel pattern) adapted from two sources. (a) Cordilleran Ice Sheet events and most mountain glaciations (including selected geochronologic age determinations) adapted and modified from Bowen and others (1986, Figure 1); (b) glaciations in the eastern Sierra Nevada Mountains along the southeast boundary of Yosemite National Park adapted from Phillips and others (1990; red outlines and geochronologic dates in parentheses).

[3]Paleomagnetic divisions adapted from Cande and Kent (1995), with age of Bruhnes-Matuyama boundary and selected Matuyama events determined by Shackleton and others (1990). Age of Emperor Reversed-polarity Subchron from Bowen and others (1986, Figure 1).

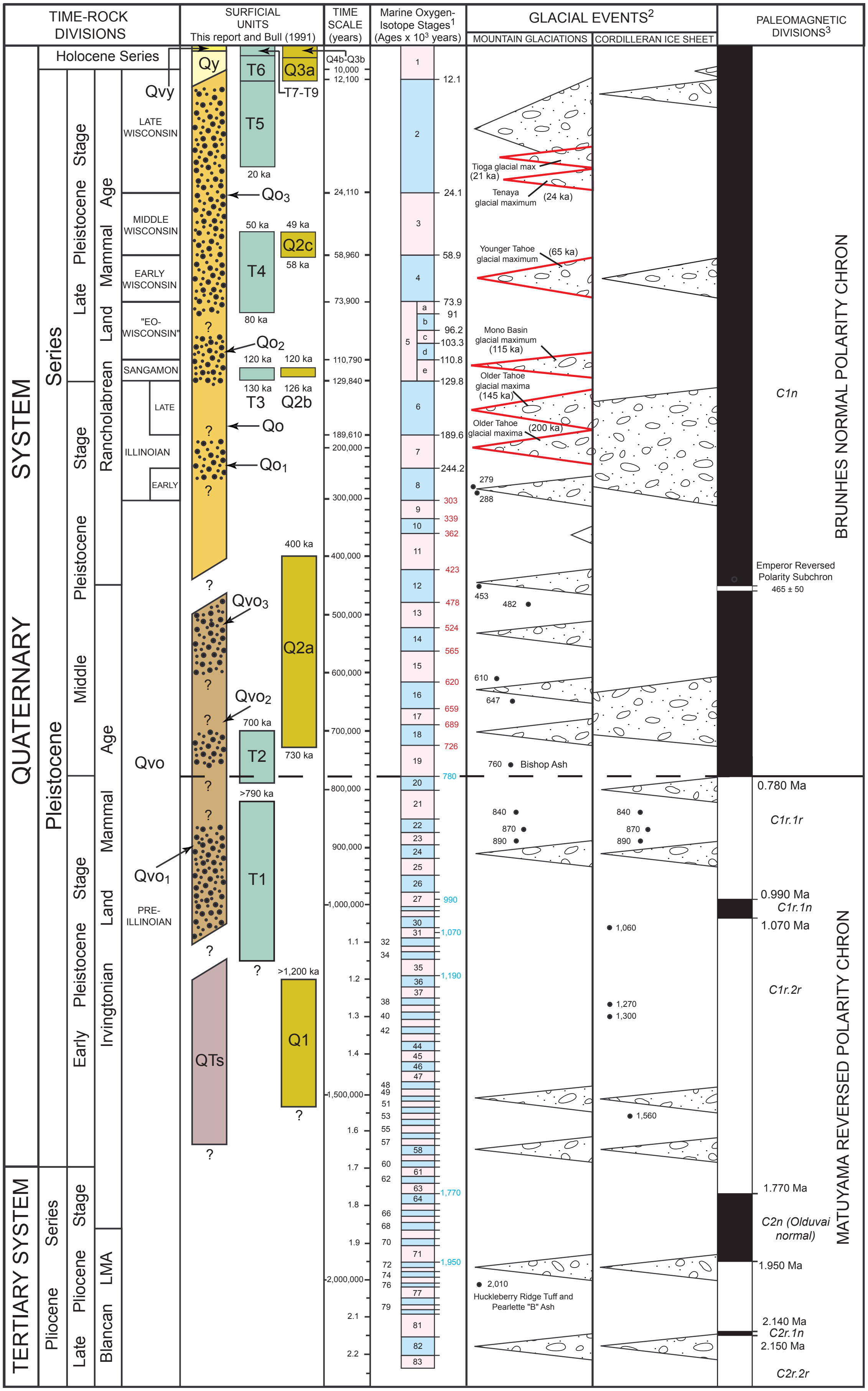


Figure 5.--Chart showing stratigraphic position of surficial geologic-map units mapped in this report (Qvy, Qy, Qo, Qvo) compared to alluvial-terrace units (T1-T9) and alluvial surfaces Q1-Q4b) defined by Bull (1991). Diagonal boundaries between Redlands map units indicate (a) time-transgressive nature of unit boundaries and (b) our uncertainty about the exact age of these boundaries locally.

Age ranges for alluvial-terrace units T1-T9 in the San Gabriel Mountains interpreted by us from Bull's Tables 4-1 and 6-2 and from our reading of his text (Bull, 1991, p. 232-254). Age ranges for alluvial-surfaces Q1-Q4b in the Mojave and Sonoran Deserts interpreted by us from Bull's Tables 4-1 and 6-2 and from our reading of his text (Bull, 1991, p. 232-254). See Figure 4 for explanation of Quaternary time-rock divisions, marine oxygen-isotope stages, glacial events, and paleomagnetic chronology.

Gravelly patterns within map categories of this report indicate where we currently interpret the stratigraphic position of subunits based on our mapping in the Inland Empire region. Future investigations might show the stratigraphic position of these subunits to be different than indicated in the figure; moreover, additional subunits might be recognized within the parent categories at positions for which map units currently are not identified. See Figure 6 for detailed map units within the Qy and Qvy Series.

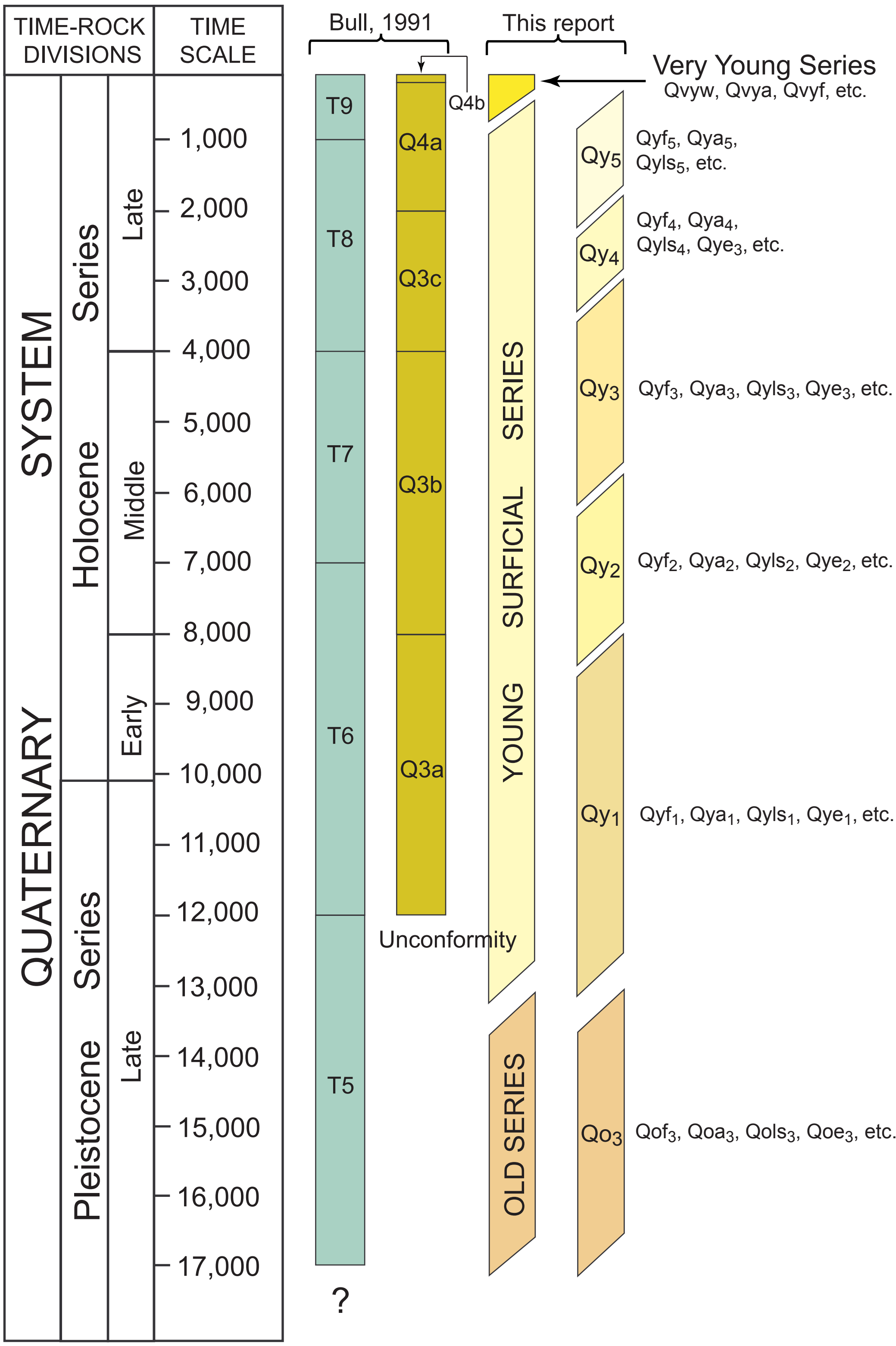


Figure 6.--Chart showing stratigraphic position of surficial geologic-map units for the latest Pleistocene and Holocene Series in the Redlands quadrangle; also shown are alluvial-terrace units T5-T9 and alluvial surfaces Q3a-Q4b defined by Bull (1991) in the San Gabriel Mountains and Mojave-Sonoran Deserts, respectively. Age ranges for alluvial-terrace units T5-T9 interpreted by us from Bull's Tables 4-1 and 6-2 and from our reading of his text (Bull, 1991, p. 232-254). Age ranges for alluvial-surfaces Q3a-Q4b interpreted by us from Bull's Tables 4-1 and 6-2 and from our reading of his text (Bull, 1991, p. 232-254). Time-rock divisions for Holocene Series from Hopkins (1975). Geologic timescale is linear. Diagonal boundaries between Redlands map units indicate (a) time-transgressive nature of unit boundaries and (b) our uncertainty about the exact age of these boundaries locally. Future investigations might show the stratigraphic position of subunits to be different than indicated in the figure; moreover, additional subunits might be recognized within the parent categories at positions for which map units currently are not identified.