CGS SPECIAL REPORT 217

Geologic Compilation of Quaternary Surficial Deposits in Southern California

Compiled by
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Digital Preparation by
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July 2010

A Project for the Department of Water Resources
by the California Geological Survey

ARNOLD SCHWARZENEGGER, Governor **STATE OF CALIFORNIA**	LESTER SNOW, Secretary **THE RESOURCES AGENCY**	BRIDGETT LUTHER, Director **DEPARTMENT OF CONSERVATION**	JOHN G. PARRISH, Ph.D., State Geologist **CALIFORNIA GEOLOGICAL SURVEY**

CALIFORNIA GEOLOGICAL SURVEY
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BACKGROUND

Since November 2007, the Department of Conservation's California Geological Survey (CGS) has been a technical consultant to the Department of Water Resources (DWR) and its Alluvial Fan Task Force (AFTF) for a 10-county southern California area including San Bernardino, Riverside, Los Angeles, Ventura, Santa Barbara, San Luis Obispo, Kern, Orange, Imperial, and San Diego. In this capacity, CGS has assisted in identifying geologic hazards and natural resources that could affect or be affected by development on alluvial fans, and in preparing guidance for alluvial fan floodplain management.

CGS has also conducted original research on how geologic maps may be used to help identify where flooding and other hazards may occur on alluvial fans in southern California. Older geologic maps of California typically lump recent alluvial deposits into a single unit identified as Qal, Quaternary age alluvium (less than about 1.8 million years). Many modern geologic maps, including those that focus on urbanizing areas within southern California, show additional details of Quaternary age deposits on alluvial fans and floodplains such as depositional environment, relative age, and grain size. These deposits can be related to a number of geologic hazards including amplification of seismic shaking, liquefaction, and collapsible soils. They can also be used to show where sediment has been deposited on alluvial fans in the geologically recent past. Because areas of most recent deposition during Late Holocene time (within the last 500 years) are the most likely to be areas of flooding and deposition in the future, they are a high priority for evaluating the potential for alluvial fan flooding. Conversely, areas underlain by older alluvial fan deposits are less likely to be prone to alluvial fan flooding.

The CGS Compilation of Quaternary Surficial Deposits in Southern California (CGS Compilation) was designed as a regional-scale planning tool to assist DWR, the AFTF, and local communities in evaluating future development on alluvial fans. A detailed Geographic Information System (GIS)-based data set (Source GIS Database) presents a compilation of recent high-resolution geologic maps of Quaternary age and older deposits that cover portions of southern California from Santa Barbara to San Diego. A second data set (Derivative GIS Database) merges geologic mapping from various authors, and at different scales, into a common seamless format that normalizes and differentiates the various alluvial fan and related Quaternary deposits into four main age categories (Late Holocene=most recent, Holocene to Late Pleistocene=young, Late to Middle Pleistocene=old, and Middle to Early Pleistocene=very old) for the entire area at a scale of 1:100,000. The primary delivery format of the data is intended to be both a GIS-based data set and an interactive online web map viewer. A Portable Document File (PDF) version of the 1:100,000 scale derivative maps is also provided to assist elected officials, local floodplain managers, developers, environmental groups, representatives from various governmental agencies, and the public in the rapid identification of areas subject to previous and potential future flooding and other geologic hazards on alluvial fans and floodplains.

SCOPE OF WORK

Area Mapped

The CGS Compilation covers approximately 35,000 square miles between Santa Barbara and San Diego, including portions of the following counties in southern California: Imperial, Inyo, Kern, Los Angeles, Orange, Riverside, San Bernardino, San Diego, San Luis Obispo, Santa Barbara, and Ventura. Geologic maps were compiled from areas within the following 30'x 60' quadrangles (1:100,000 scale): Amboy, Blythe, Cuddeback Lake, Cuyama, El Cajon, Long Beach, Los Angeles, Mesquite Lake, Oceanside, Santa Barbara, San Bernardino, San Diego, Santa Ana, and Sheep Hole Mountains (Figure 1). In addition, CGS compiled 1:100,000 scale derivative data for Orange County and the San Gabriel River Hydrologic Unit to illustrate how the database can be used to depict information on a jurisdictional or watershed basis.

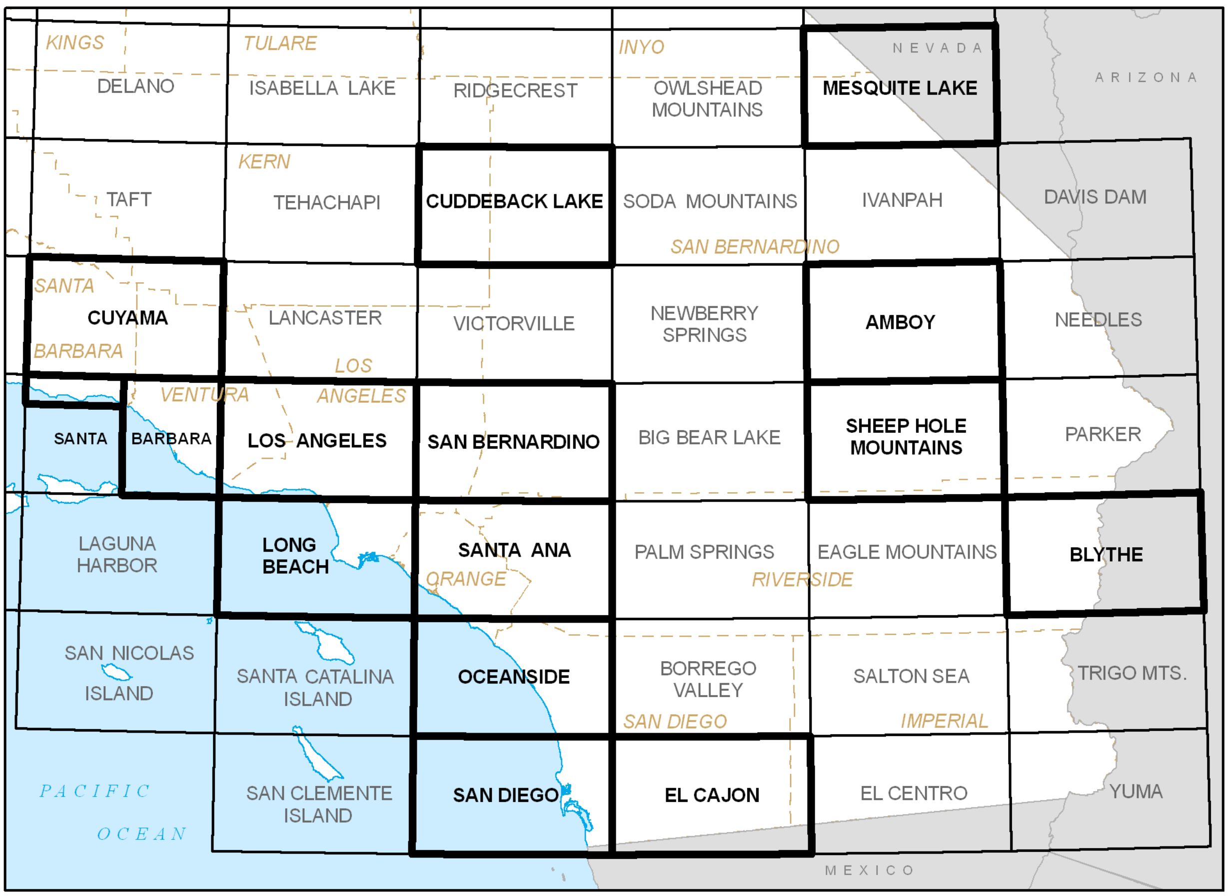

Figure 1: Simplified Index Map of Quadrangles Included in the CGS Compilation. Mapped areas in bold.

Tasks

The focus of the CGS Compilation was to collect available geologic mapping of alluvial deposits within the southern California region and compile them into a more generalized, seamless GIS database. To complete the project, CGS was asked by DWR to:

1. Collect digital files and hard copies of geologic maps. For this task, CGS compiled available published and unpublished geological maps, primarily from the U.S. Geological Survey (USGS) and CGS. The digital source maps used by CGS in the Source GIS Database are listed in Appendix A. The Source and Derivative GIS Database layers contain attribute hyperlinks to additional references used by CGS to verify geologic information within each quadrangle.

2. Reassign surficial units following the methodology of Matti and Cossette (2007). To accomplish this, CGS reviewed geologic units contained on the various source maps and compared them with the methodology of Matti and Cossette (2007). CGS also consulted previous versions of the Matti and Cossette methodology developed under the Southern California Areal Mapping Project (SCAMP, 2000, and 2002) and the USGS and California Division of Mines and Geology (DMG, 2000, Appendix B). A Description of Derivative Geologic Map Units (Appendix C) and Correlation of Derivative Geologic Map Units (Appendix D) were developed for the Derivative GIS Database based on modifications of these methodologies (see below).

3. Rectify any inconsistencies between maps/map boundaries and document all changes. CGS matched geologic units along the edges of map boundaries within the Derivative GIS Database. Where discrepancies existed, CGS adjusted the geologic unit boundaries to provide seamless and consistent mapping units. The units as originally mapped are retained for reference in the Source GIS Database.

4. Create a seamless ArcGIS database of the geologic map with the associated metadata, Project Index Map with references, a stratigraphic Correlation of Derivative Geologic Map Units, and a brief geologic report that describes the geologic units. In addition, CGS prepared a Geologic Labels spreadsheet for each quadrangle showing how geologic units in the Source GIS Database are correlated with categories used in the Derivative GIS Database. A correlation of equivalent deposits across the whole southern California CGS Compilation area is presented in the GIS-based table entitled Correlation of Derivative and Source Geologic Map Units.

5. Prepare a PDF version of the geologic map that may be accessed by the public in a user-friendly format. The CGS Compilation is to be published as an official CGS publication, with CGS and DWR logos, and be available on the CGS and DWR websites, and as a DVD from CGS. It will also be distributed to libraries and referenced to the geologic community. All available data will be provided in a format that can be placed on AFTF-related servers.

COMPILATION OF THE SOURCE GIS DATABASE

In preparing the Source GIS Database, CGS used basic geologic data, including geology polygons, faults and other line work, compiled in digital format at a scale of 1:100,000 for each 30'x 60' quadrangle mapped by the USGS and CGS (Appendix A). To maintain integrity of the GIS data in both the Source GIS Database and the Derivative GIS Database, CGS performed topology reconciliation to prevent gaps and overlaps in the geologic polygons. In addition, CGS used the following base layers across the entire mapped area:

- Springs and Wet Areas - GNIS layer of geographic names from the USGS
- Streams and Lakes - "NHD_HighRes" and "compiled_lakes2" from the National Hydrography Dataset Plus (NHDPlus) and the California Department of Fish and Game
- Counties – "cnty24k09_1" from CAL FIRE
- Hydrologic Units – "CalWater, Version 2.2.1" from the California Interagency Watershed Mapping Committee (IWMC)

To provide additional consistency, CGS also derived contour base maps throughout the entire mapped area at a 50-meter interval from the USGS National Elevation Dataset (NED) and performed base layer annotations to accentuate the clarity of mapped Quaternary surficial deposits.

Data files used in the Source GIS Database are listed in the project metadata and ReadMe files.

COMPILATION OF THE DERIVATIVE GIS DATABASE

The goal of the CGS Compilation was to represent southern California's complex geology in a user-friendly format that depicts alluvial deposits and bedrock in several generalized categories. More than 2100 geologic units, found on the digital maps published primarily by the USGS and CGS, are retained in the Source GIS Database. To assist in identifying areas where flooding and sediment deposition occurred in the geologically recent past, CGS reassigned these geologic units into a Derivative GIS Database consisting of 40 categories based on age, rock type, and nature of deposits (Figure 2, Appendices C and D).

Quaternary surficial deposits in the Description of Derivative Geologic Map Units (Appendix C) are divided into 28 categories modified from the methodology of Matti and Cossette (2007), SCAMP (2000), and the USGS and DMG (2000, Appendix B). The CGS Correlation of Derivative Geologic Map Units chart (Appendix D) represents a hybrid of the Matti and Cossette (2007), SCAMP (2000), and USGS and DMG (2000) nomenclature to account for variations in rock types and age ranges used in prior geologic mapping between the coastal and inland areas of southern California. The various types of surficial deposits in the CGS Compilation include: artificial fill; undifferentiated surficial deposits; landslide deposits; beach deposits; alluvial wash deposits; alluvial fan deposits; alluvial valley deposits; terrace deposits; lacustrine, playa, and estuarine deposits; and eolian and dune deposits. While specific variations in age and physical properties exist within units on each source map, CGS retained the basic premise of Matti and Cossette (2007) that surficial deposits within each of the Quaternary derivative map units formed during a particular range of geologic time, have a similar depositional origin, and have generally similar physical properties. Within the 28 derivative units, progressively older surficial deposits are typically better consolidated and more highly dissected by erosion, have more developed and/or eroded soil profiles with stronger degrees of weathering and surface armoring, and occupy a higher topographic position within alluvial fan and floodplain terrains.

Geologic bedrock formations from the source geologic maps are divided into 12 categories on the CGS derivative maps, based on age and rock type. Bedrock units in the derivative version of the maps were combined to include: coarse-grained sedimentary bedrock; fine-grained sedimentary bedrock; bedrock of volcanic origin; metamorphic formations of sedimentary and volcanic origin; serpentinite; and granitic and other intrusive crystalline rocks.

Figure 2: Abbreviated List of Derivative Geologic Map Units

Late Holocene: (Surficial Deposits)	af	Artificial Fill
	Qsu	Undifferentiated Surficial Deposits
	Qls	Landslide Deposits
	Qb	Beach Deposits
	Qw	Alluvial Wash Deposits
	Qf	Alluvial Fan Deposits
	Qa	Alluvial Valley Deposits
	Qt	Terrace Deposits
	Ql	Lacustrine, Playa, and Estuarine (Paralic) Deposits
	Qe	Eolian and Dune Deposits
Holocene to Late Pleistocene: (Surficial Deposits)	Qyw	Young Alluvial Wash Deposits
	Qyf	Young Alluvial Fan Deposits
	Qya	Young Alluvial Valley Deposits
	Qyt	Young Terrace Deposits
	Qyl	Young Lacustrine, Playa, and Estuarine (Paralic) Deposits
	Qye	Young Eolian and Dune Deposits
Late to Middle Pleistocene: (Surficial Deposits)	Qow	Old Alluvial Wash Deposits
	Qof	Old Alluvial Fan Deposits
	Qoa	Old Alluvial Valley Deposits
	Qot	Old Terrace Deposits
	Qol	Old Lacustrine, Playa, and Estuarine Deposits
	Qoe	Old Eolian and Dune Deposits
Middle to Early Pleistocene: (Surficial Deposits)	Qvow	Very Old Alluvial Wash Deposits
	Qvof	Very Old Alluvial Fan Deposits
	Qvoa	Very Old Alluvial Valley Deposits
	Qvot	Very Old Terrace Deposits
	Qvol	Very Old Lacustrine, Playa, and Estuarine Deposits
	Qvoe	Very Old Eolian and Dune Deposits
Quaternary Units: (Bedrock)	Qss	Coarse-grained formations of Pleistocene age and younger
	Qsh	Fine-grained formations of Pleistocene age and younger
	Qv	Pleistocene age and younger formations of volcanic origin
Tertiary Units: (Bedrock)	Tss	Coarse-grained Tertiary age formations
	Tsh	Fine-grained Tertiary age formations
	Tv	Tertiary age formations of volcanic origin
Mesozoic and Older Units (Bedrock)	Kss	Coarse-grained Cretaceous age formations of sedimentary origin
	Ksh	Fine-grained Cretaceous age formations of sedimentary origin
	Kv	Cretaceous age formations of volcanic origin
	pKm	Cretaceous and pre-Cretaceous metamorphic formations of sedimentary and volcanic origin
	sp	Serpentinite of all ages
	gr	Granitic and other intrusive crystalline rocks of all ages

<u>Note</u>: See Appendix C for definitions.

Colors selected for the various surficial deposits and bedrock units shown on the maps and in the Correlation of Derivative Geologic Map Units (Appendix D) are based on a combination of colors and Patterns used by Matti and Cossette (2007) and current USGS geologic mapping standards (Federal Geographic Data Committee, 2006; USGS, 2007). Artificial fill and other deposits generated by human activities are designated with a darker gray tone. Quaternary surficial deposits are depicted in a range of lighter gray, yellow, and tan hues that generally intensify with age. Quaternary (Qss, Qsh, Qv), Tertiary (Tss, Tsh, Qv) and Mesozoic and older bedrock units (Kss, Ksh, Kv) of sedimentary and volcanic origin are represented by various shades of orange, brown, and green respectively. Cretaceous and pre-Cretaceous age metamorphic rocks (pKm) are blue; serpentinite of all ages (sp) is purple; and granitic and other intrusive crystalline rocks of all ages (gr) are pink.

Quaternary surficial units and geologic formational names compiled in the original geologic source data are correlated with derivative categories used by CGS in the Geologic Labels spreadsheet for each quadrangle. In general, CGS retained the original geologic source data name, description, and age of surficial deposits and geologic formations listed in the Geologic Labels spreadsheets. However, CGS changed age categories, designated as “upper” and “lower” in the source data, to “late” and “early” on the derivative data for purposes of correlating the age of geologic units across the derivative compilation. In addition, original descriptions in the source data explanations were abbreviated in some cases to indicate the basis on which the derivative correlations were made. Because there is a lack of consistency in terminology, map units, and age designations among the source data quadrangles used for the CGS Compilation, inconsistencies in formational names, ages, and capitalization exist throughout the individual Geologic Labels spreadsheets prepared by CGS. The same inconsistencies are retained within the correlation of equivalent deposits across the whole southern California project as presented in the GIS-based table entitled Correlation of Derivative and Source Geologic Map Units.

In preparing the derivative geologic maps, CGS retained the boundaries of the Quaternary age surficial deposits shown on the source maps with very few revisions. Boundaries of more detailed Quaternary age source map unit subdivisions are shown without label within the generalized derivative map unit. This indicates more detailed geologic information is available in the Source GIS Database. For example, an area designated Qyf (young alluvial fan deposits) on the derivative geologic map may have been subdivided on the source geologic map into several units (Qyf1, Qyf2, Qyf3, etc.) to distinguish different depositional surfaces and compositions. If local jurisdictions require more detailed mapping in these areas, the original source data can be retrieved and further evaluated by qualified professionals.

CGS rectified inconsistencies along the boundaries of the various mapped areas to create a seamless Derivative GIS Database, but retained links to the original mapping in the Source GIS Database so that the more detailed geologic information can be retrieved. Where differences in the mapping of geologic units along quadrangle boundaries were severe, CGS consulted other geologic references listed in the reference documents and various types of aerial photography to resolve rock type, location, and age discrepancies. Because field review was limited, CGS made some edge match judgments solely on the basis of age and/or areal extent of the mapped units along the borders of each quadrangle. For example, if geologic rock type boundaries matched on adjacent quadrangles, but there was a discrepancy in the age (e.g., Qoa vs Qvoa), CGS considered the stratigraphic position of the unit in relationship to other geologic units mapped in the overall area, as well as the extent of the mapped units on both quadrangles. In most cases, CGS designated the younger age (i.e., Qoa) along the mapped boundaries. However, if selection of the Qoa designation would result in more extensive areal changes on one derivative map than the other, then the Qvoa designation was selected for purposes of the edge match only.

CGS also developed the Project Index Map to depict areas contained in the CGS Compilation. The Source and Derivative GIS Database layers contain attributes that enable feature-based hyperlinks to reference documents that list the digital geologic source maps used in the compilation and other geologic references pertinent to each 100,000 scale quadrangle mapped. To assist local planning agencies and other interested parties in accessing information within a given area, CGS added a county overlay from CAL FIRE and hydrologic unit overlay from CalWater. These can be used to excerpt geologic information on a jurisdictional basis, similar to the Orange County and San Gabriel Hydrologic Unit demonstration maps in the PDF version of the derivative maps (see below).

Data files used in the Derivative GIS Database are listed in the project metadata and ReadMe files.

PDF VERSION OF THE DERIVATIVE MAPS

As requested by DWR, CGS prepared a PDF version of the derivative geologic maps in the CGS Compilation for those who do not have GIS capabilities. The following 100,000 scale 30' x 60' quadrangles are included in the PDF files: Amboy (Plate 3), Blythe (Plate 4), Cuddeback Lake (Plate 5), Cuyama (Plate 6), El Cajon (Plate 7), Long Beach (Plate 8), Los Angeles (Plate 9), Mesquite Lake (Plate 10), Oceanside (Plate 11), San Bernardino (Plate 13), San Diego (Plate 14), Santa Ana (Plate 16), Santa Barbara (Plate 17) and Sheep Hole Mountains (Plate 18). In addition, CGS included PDF versions of the derivative maps for Orange County (Plate 12) and the San Gabriel Hydrologic Unit (Plate 15) to demonstrate how the seamless derivative map can be used to excerpt specific areas. The PDF versions of the maps, viewable in Adobe Reader, are available on the CGS website (www.conservation.ca.gov/cgs); as links through the DWR (www.water.ca.gov) and AFTF (http://aftf.csusb.edu/) websites; and as CGS Special Report 217, Geologic Compilation of Quaternary Surficial Deposits in Southern California.

Information on the PDF maps includes:

- The mapped derivative geologic units imposed on a shaded relief base with 50-meter contours.
- An Index to USGS 7.5' Quadrangles (1:24,000 scale) covered within each map.
- An abbreviated Map Explanation that focuses on the general type and location of Quaternary and other units found in each quadrangle.
- References that refer to the digital geologic source used in compilation of the derivative geologic map, references used in developing the map units, and other references used specifically in developing the Map Explanation for each quadrangle.
- Map Units and the Correlation of Map Units specific to each map.

Other information contained in the PDF files includes:

- The Project Index Map (Plate 1). This map is linked to accompanying reference documents.
- Legend and Correlation of Derivative Geologic Map Units (Plate 2). These define the 40 derivative geologic units developed for the entire project.
- A Geologic Labels spreadsheet for each quadrangle. Each spreadsheet shows how the geologic units in the source data were correlated to the derivative map units and presents an abbreviated description of each geologic unit. Original source data maps and pamphlets must be consulted for more detailed descriptions of the source geologic units within each quadrangle.

- References. These documents reflect additional references consulted in verifying the derivative geologic data on each of the 100,000 scale maps.
- Correlation of Derivative and Source Geologic Map Units. This table correlates the original source geologic data from each quadrangle mapped to the 40 derivative map units across the entire project area. More than 2100 original geologic map units are represented.

The ReadMe file provided on the DVD includes information on the structure of the folders, listing of the GIS files used in preparation of the maps, and a discussion of printing issues that may be encountered.

USE OF MAPS

Southern California includes some of the most complex and varied geology in the western United States. Topographic relief ranges from sub-sea level to rugged mountains. Large areas of low relief along coastal and desert regions are densely populated and/or rapidly urbanizing. Low-lying drainage basins, adjacent to steep fault-bounded and landslide-prone mountain ranges, are subject to periodic debris laden floods and debris flows. In some areas, both the magnitude and areal extent of devastating landslides, flooding, and debris flows increase when seasonal wildfires are followed by heavy rainfall. For this reason, information contained in the CGS Compilation should not be used as a substitute for detailed geologic studies in any specific area. The database is intended only for rapid regional identification of areas subject to previous and potential future flooding and other geologic hazards on alluvial fans and floodplains. Local jurisdictions may require a more detailed analysis by professionals where such areas are identified.

ACKNOWLEDGEMENTS

The GIS Compilation was funded by DWR under Interagency Agreement DWR 4600008323/DOC1008-016R. Although the original agreement was to include only those areas where digital mapping already exists, it is the intent of both CGS and DWR to include additional areas within southern California as 100,000 scale maps and funding become available.

The development of 100,000 scale databases for the CGS Compilation was truly a cooperative, and interactive, effort on behalf of CGS geologists and GIS staff. The original concept for the project was proposed to DWR by CGS Alluvial Fan Task Force members Bill Short, Jeremy Lancaster, and Tom Spittler. Work for the project was done primarily within the Forest and Watershed Geology (FWG) Program under Supervising Engineering Geologist Bill Short. However, FWG geologists consulted early in the process with Supervising Engineering Geologist Chris Wills and staff in the Regional Geologic Hazards Mapping (RGHM) Program to ensure consistency in format and terminology with other Quaternary and Alluvial Fan Task Force-related mapping projects being conducted by CGS. These include alluvial fan “footprint” mapping at the 100,000 scale and more detailed mapping of the Quaternary age alluvial deposits in the Lancaster, Palm Springs, east half of Taft, and Tehachapi 30’ x 60’ quadrangles (Interagency Agreement DWR460008540/DOC1008-022R).

Senior Engineering Geologist Trinda Bedrossian coordinated the CGS Compilation and developed the 40 derivative geologic map units used in the compilation, as modified from the work of Matti and Cossette (2007), SCAMP (2000), and the USGS and DMG (2000). Peter Roffers and Solomon McCrea created the Project Index Map and directed the compilation of source maps within the Source GIS Database, as well as the development of the derivative map colors and the Geologic Labels spreadsheets for each quadrangle. Solomon McCrea developed the GIS table entitled Correlation of Derivative and Source

Geologic Map Units. Barbara Wanish, Jim Thompson, John Carotta, Shannon Utley, and Milind Patel provided assistance with annotations and other layers within the Source GIS Database. CGS geologists Trinda Bedrossian, Cheryl Hayhurst, and Peter Roffers compiled the Derivative GIS Database maps, including geologic unit conversions on the Geologic Labels spreadsheets, references, edge-matching of quadrangle boundaries, and the PDF map explanations for each quadrangle. At various stages throughout the project, CGS geologists Bill Bryant, Clif Davenport, Tim Dawson, Carlos Gutierrez, Will Harris, Wayne Haydon, Pam Irvine, Jeremy Lancaster, Brian Olson, George Saucedo, John Schlosser, Bill Short, Tom Spittler, Shannon Utley, Dave Wagner, and Chris Wills provided input on geologic details. CGS Los Angeles Office geologists Pam Irvine, Jeremy Lancaster, and Brian Olson also provided review of the PDF map explanations and the Santa Ana, Orange County, and San Gabriel River Hydrologic Unit demonstration maps. Anita Carney and Lee Wallinder also assisted with DVD production.

Last but not least, the project would not have been feasible without funding from DWR and the availability of 100,000 scale digital files of quadrangles mapped by both the USGS and CGS (Appendix A).

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U.S. Geological Survey, 2007, Divisions of geologic time – major chronostratigraphic and geochronologic units: USGS Fact Sheet 2007-3015, 2 p.

U.S. Geological Survey and California Division of Mines and Geology, 2000b, Classification of Quaternary deposits, Southern California Areal Mapping Project (SCAMP), a working model, version 1.0: (09/10/2000).

APPENDIX A: DIGITAL GEOLOGIC SOURCE DATA FILES USED IN CGS COMPILATION

Amboy

Bedford, D.R., Miller, D.M., and Phelps, G.A., 2006, Preliminary surficial geologic map database of the Amboy 30x60 minute quadrangle, California, http://ngmdb.usgs.gov/Prodesc/proddesc_77605.htm: U.S. Geological Survey, Open-File Report 2006-1165, scale 1:100,000.

Blythe

Stone, P., 2006, Geologic map of the west half of the Blythe 30' by 60' quadrangle, Riverside County, California and La Paz County, Arizona, http://ngmdb.usgs.gov/Prodesc/proddesc_76909.htm: U.S. Geological Survey, Scientific Investigations Map 2922, scale 1:100,000.

Cuddeback Lake

Amoroso, L., and Miller, D.M., 2006, Surficial geologic map and geodatabase of the Cuddeback Lake 30'x 60' quadrangle, San Bernardino and Kern counties, California, http://pubs.usgs.gov/of/2006/1276: U.S. Geological Survey, Open-File Report 2006-1276, scale 1:100,000.

Cuyama

Kellogg, K.S., Minor, S.A., and Cossette, P.M., 2008, Geologic map of the eastern three-quarters of the Cuyama 30' by 60' quadrangle, California, http://pubs.usgs.gov/sim/3002/: U.S. Geological Survey, Scientific Investigations Map 3002, scale 1:100,000.

El Cajon

Todd, V.R., 2004, Preliminary geologic map of the El Cajon 30' x 60' quadrangle, southern California, http://pubs.usgs.gov/of/2004/1361: U.S. Geological Survey, Open-File Report 2004-1361, scale 1:100,000.

Long Beach

Saucedo, G.J., Greene, H.G., Kennedy, M.P., and Bezore, S.P., 2009 (in progress), Geologic map of the Long Beach 30' by 60' quadrangle, California: A digital database, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Preliminary Geologic Map, scale 1:100,000.

Los Angeles

California Geological Survey, 2009 (in progress), Preliminary geologic map of the Los Angeles 30' by 60' quadrangle, California: A digital database: California Geological Survey, Preliminary Geologic Map, version 12/22/09, scale 1:100,000.

Mesquite Lake

Schmidt, K.M., and McMackin, M., 2006, Preliminary surficial geologic map database of the Mesquite Lake 30' x 60' quadrangle, California and Nevada, http://pubs.er.usgs.gov/usgspubs/ofr/ofr20061035: U.S. Geological Survey, Open-File Report 2006-1035, scale 1:100,000.

Oceanside

Kennedy, M.P., and Tan, S.S., 2007, Geologic map of the Oceanside 30' by 60' quadrangle, California: A digital database, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Regional Geologic Map No. 2, scale 1:100,000.

Orange County

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Morton D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California, http://ngmdb.usgs.gov/Prodesc/proddesc_78686.htm: U.S. Geological Survey, Open-File Report 2006-1217, scale 1:100,000.

Saucedo, G.J., Greene, H.G., Kennedy, M.P., and Bezore, S.P., 2009 (in progress), Geologic map of the Long Beach 30' by 60' quadrangle, California: A digital database, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Preliminary Geologic Map, scale 1:100,000.

San Bernardino

Morton D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California, http://ngmdb.usgs.gov/Prodesc/proddesc_78686.htm: U.S. Geological Survey, Open-File Report 2006-1217, scale 1:100,000.

San Diego

Kennedy, M.P., and Tan, S.S., 2008, Geologic map of the San Diego 30' by 60' quadrangle, California, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Regional Geologic Map No. 3, scale 1:100,000.

San Gabriel River Hydrologic Unit

California Geological Survey, 2009 (in progress), Preliminary geologic map of the Los Angeles 30' by 60' quadrangle, California: A digital database, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Preliminary Geologic Map, version 12/22/09, scale 1:100,000.

Morton D.M., and Miller, F.K., 2006, Geologic map of the San Bernardino and Santa Ana 30' x 60' quadrangles, California, http://ngmdb.usgs.gov/Prodesc/proddesc_78686.htm: U.S. Geological Survey, Open-File Report 2006-1217, scale 1:100,000.

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Santa Ana

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Gutierrez, C.I., Tan, S.S., and Clahan, K.B., 2008 (in progress), Geologic map of the east half Santa Barbara 30’ x 60’ quadrangle, California, http://conservation.ca.gov/cgs/rghm/rgm/Pages/preliminary_geologic_maps.aspx: California Geological Survey, Preliminary Geologic Map, scale 1:100,000.

Minor, S.A., Kellogg, K.S., Stanley, R.G., Gurrola, L.D., Keller, E.A., and Brandt, T.R., 2009, Geologic map of the Santa Barbara coastal plain area, Santa Barbara county, California, http://pubs.usgs.gov/sim/3001: U.S. Geological Survey, Scientific Investigations Map 3001, scale 1:100,000.

Sheep Hole Mountains

Howard, K.A., 2002, Geologic map of the Sheep Hole Mountains 30’ x 60’ quadrangle, San Bernardino and Riverside counties, California, http://ngmdb.usgs.gov/Prodesc/proddesc_51545.htm: U.S. Geological Survey, Miscellaneous Field Studies, Map MF-2344, scale 1:100,000.

APPENDIX B: SCAMP CLASSIFICATION OF QUATERNARY DEPOSITS (2000)

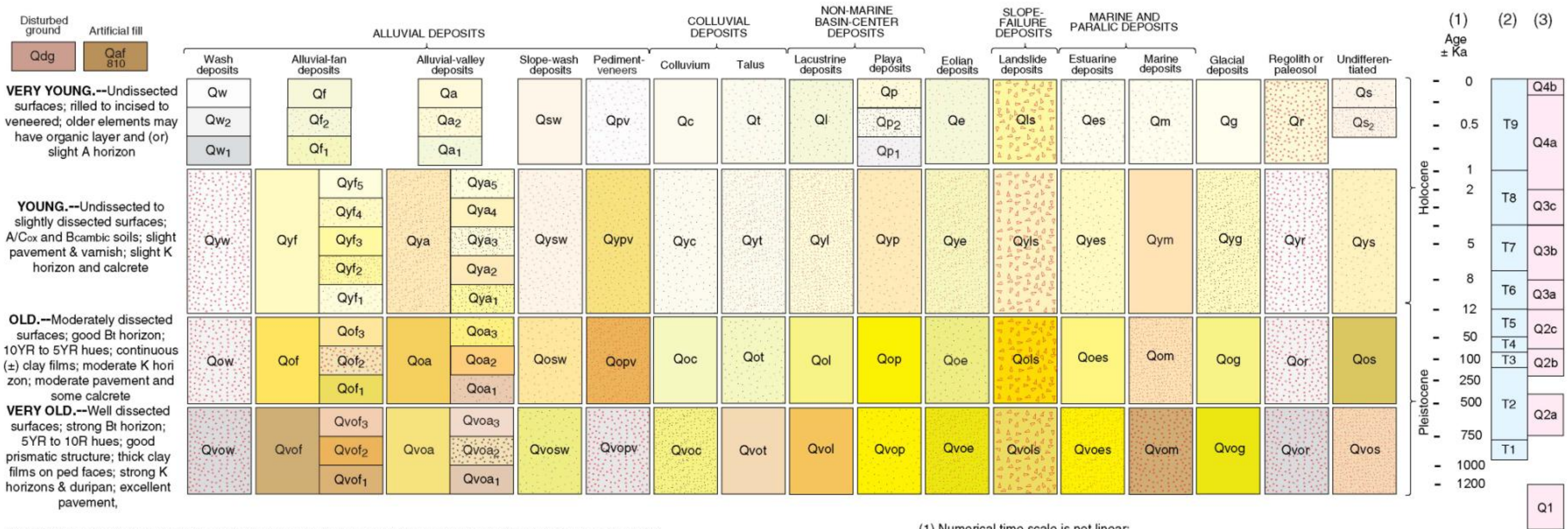
USGS science for a changing world — U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY

DIVISION OF MINES AND GEOLOGY

CLASSIFICATION OF QUATERNARY DEPOSITS, SOUTHERN CALIFORNIA AREAL MAPPING PROJECT (SCAMP)

A working model

Version 1.0 09/10/2000



For SCAMP geologic-map products, grain-size and physical-property information for surficial units is stored in digital data bases through the use of coded attributes (Matti and others, 1997). At the option of the geologic-map author, characteristic grain size information can be displayed in plot files through the use of alpha characters (e.g. Qyf_b, Qoa_{2a}), where the characters conform to the following definitions:

a - arenaceous (very coarse sand through very fine sand)
b - boulder gravel (25mm)
g - gravel (cobble through granule gravel)
s - silty
c - clayey
m- marl
p - peat

(1) Numerical time scale is not linear;
(2)Terrace-age designations proposed by McFadden (1982) and by Bull (1991, Figure 4.11) for alluvial deposits in Mediterranean-climate regimes of southern California;
(3) Geomorphic-surface designations proposed by Bull (1991, Table 2-13) in arid climatic regimes of southern California

Bull, W.R., 1991, Geomorphic responses to climatic change: New York, Oxford University Press, 326 p.

Matti, J.C., Miller, F.K., Powell, R.E., Kennedy, S.A., and Cossette, P.M., 1997a, Geologic-polygon attributes for digital geologic-map data bases produced by the Southern California Areal Mapping Project, version 1.0: U.S. Geological Survey Open-File Report 97-860, 248 p.

McFadden, L.D., 1982, The impacts of temporal and spatial climatic changes on alluvial soils genesis in southern California: Tucson, University of Arizona, unpublished Ph.D. thesis, 430 p.

APPENDIX C: DESCRIPTION OF DERIVATIVE GEOLOGIC MAP UNITS

Late Holocene: (Surficial Deposits)	af	Artificial Fill; deposits of fill resulting from human construction, mining, or quarrying activities; includes engineered fill for buildings, roads, dams, airport runways, harbor facilities, and waste landfills
	Qsu	Undifferentiated Surficial Deposits; includes colluvium, slope wash, talus deposits, and other surface deposits of all ages; generally unconsolidated but locally may contain consolidated layers
	Qls	Landslide Deposits; may include debris flows and older landslides of various earth material and movement types; unconsolidated to moderately well-consolidated
	Qb	Beach Deposits; unconsolidated marine beach sediments consisting mostly of fine- and medium-grained, well-sorted sand
	Qw	Alluvial Wash Deposits; unconsolidated sandy and gravelly sediment deposited in recently active channels of streams and rivers; may contain loose to moderately loose sand and silty sand
	Qf	Alluvial Fan Deposits; unconsolidated boulders, cobbles, gravel, sand, and silt recently deposited where a river or stream issues from a confined valley or canyon; sediment typically deposited in a fan-shaped cone; gravelly sediment generally more dominant than sandy sediment
	Qa	Alluvial Valley Deposits; unconsolidated clay, silt, sand, and gravel recently deposited parallel to localized stream valleys and/or spread more regionally onto alluvial flats of larger river valleys; sandy sediment generally more dominant than gravelly sediment
	Qt	Terrace Deposits; includes marine and stream terrace deposits; marine deposits include slightly to moderately consolidated and bedded gravel and conglomerate, sand and sandstone, and silt and siltstone; river terrace deposits consist of unconsolidated thin- to thick-bedded gravel
	Ql	Lacustrine, Playa, and Estuarine (Paralic) Deposits; mostly unconsolidated fine-grained sand, silt, mud, and clay from fresh water (lacustrine) lakes , saline (playa) dry lakes that are periodically flooded, and estuaries; deposits may contain salt and other evaporites
	Qe	Eolian and Dune Deposits; unconsolidated, generally well-sorted wind-blown sand; may occur as dune forms or sheet sand

Holocene to Late Pleistocene: (Surficial Deposits)	Qyw	Young Alluvial Wash Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected sandy and gravelly stream bed sediments in marginal parts of active and recently active washes and river channels
	Qyf	Young Alluvial Fan Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected boulder, cobble, gravel, sand, and silt deposits issued from a confined valley or canyon
	Qya	Young Alluvial Valley Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected clay, silt, sand, and gravel along stream valleys and alluvial flats of larger rivers
	Qyt	Young Terrace Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected marine and stream terrace deposits
	Qyl	Young Lacustrine, Playa, and Estuarine (Paralic) Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected fine-grained sand, silt, mud, and clay from lake, playa, and estuarine deposits of various types
	Qye	Young Eolian and Dune Deposits; unconsolidated to slightly consolidated, undissected to slightly dissected wind-blown sands
Late to Middle Pleistocene: (Surficial Deposits)	Qow	Old Alluvial Wash Deposits; slightly to moderately consolidated, moderately dissected sand and gravel; typically elevated above modern washes
	Qof	Old Alluvial Fan Deposits; slightly to moderately consolidated, moderately dissected boulder, cobble, gravel, sand, and silt deposits issued from a confined valley or canyon
	Qoa	Old Alluvial Valley Deposits; slightly to moderately consolidated, moderately dissected clay, silt, sand, and gravel along stream valleys and alluvial flats of larger rivers
	Qot	Old Terrace Deposits; slightly to moderately consolidated, moderately dissected marine and stream terrace deposits
	Qol	Old Lacustrine, Playa, and Estuarine (Paralic) Deposits; slightly to moderately consolidated, moderately dissected fine-grained sand, silt, mud, and clay from lake, playa, and estuarine deposits of various types
	Qoe	Old Eolian and Dune Deposits; slightly to moderately consolidated, moderately dissected wind-blown sands

Middle to Early Pleistocene: (Surficial Deposits)	Qvow	Very Old Alluvial Wash Deposits; moderately to well-consolidated, highly dissected sand and gravel; typically elevated above modern washes
	Qvof	Very Old Alluvial Fan Deposits; moderately to well-consolidated, highly dissected boulder, cobble, gravel, sand, and silt deposits issued from a confined valley or canyon
	Qvoa	Very Old Alluvial Valley Deposits; moderately to well-consolidated, highly dissected clay, silt, sand, and gravel along stream valleys and alluvial flats of larger rivers; generally uplifted and deformed
	Qvot	Very Old Terrace Deposits; moderately to well-consolidated, highly dissected marine and stream terrace deposits
	Qvol	Very Old Lacustrine, Playa, and Estuarine (Paralic) Deposits; moderately to well-consolidated, highly dissected fine-grained sand, silt, mud, and clay from lake, playa, and estuarine deposits of various types
	Qvoe	Very Old Eolian and Dune Deposits; moderately to well-consolidated, highly dissected wind-blown sands
Quaternary Units: (Bedrock)	Qss	Coarse-grained formations of Pleistocene age and younger; primarily sandstone and conglomerate
	Qsh	Fine-grained formations of Pleistocene age and younger; includes fine-grained sandstone, siltstone, mudstone, shale, siliceous and calcareous sediments
	Qv	Pleistocene age and younger formations of volcanic origin
Tertiary Units: (Bedrock)	Tss	Coarse-grained Tertiary age formations; primarily sandstone and conglomerate
	Tsh	Fine-grained Tertiary age formations; includes fine-grained sandstone, siltstone, mudstone, shale, siliceous and calcareous sediments
	Tv	Tertiary age formations of volcanic origin
Mesozoic and Older Units: (Bedrock)	Kss	Coarse-grained Cretaceous age formations of sedimentary origin
	Ksh	Fine-grained Cretaceous age formations of sedimentary origin
	Kv	Cretaceous age formations of volcanic origin
	pKm	Cretaceous and pre-Cretaceous metamorphic formations of sedimentary and volcanic origin
	sp	Serpentinite of all ages
	gr	Granitic and other intrusive crystalline rocks of all ages

APPENDIX D: CORRELATION OF DERIVATIVE GEOLOGIC MAP UNITS*

Quaternary Surficial Deposits

	Artificial Fill	Undiff. Surficial Deposits	Landslide Deposits	Beach Deposits	Alluvial Deposits: Alluvial Wash Deposits	Alluvial Deposits: Alluvial Fan Deposits	Alluvial Deposits: Alluvial Valley Deposits	Terrace Deposits	Lacustrine, Playa, and Estuarine Deposits	Eolian and Dune Deposits
Late Holocene	af	Qsu	Qls	Qb	Qw	Qf	Qa	Qt	Ql	Qe
Holocene to Late Pleistocene					Qyw	Qyf	Qya	Qyt	Qyl	Qye
Late to Middle Pleistocene					Qow	Qof	Qoa	Qot	Qol	Qoe
Middle to Early Pleistocene					Qvow	Qvof	Qvoa	Qvot	Qvol	Qvoe

	Coarse-grained	Fine-grained	Volcanic	Cretaceous and Pre-Cretaceous Metamorphic (sedimentary and volcanic)	Serpentinite (all ages)	Granitic Rocks (all ages)
Quaternary (Bedrock)	Qss	Qsh	Qv			
Tertiary (Bedrock)	Tss	Tsh	Tv			
Mesozoic and Older (Bedrock)	Kss	Ksh	Kv	pKm	sp	gr

* Boundaries of Quaternary units are gradational and time transgressive in a regional sense.