# Statewide Mapping of Mineral Hazards in California – A Model for Multiple Applications

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[1]California Geological Survey

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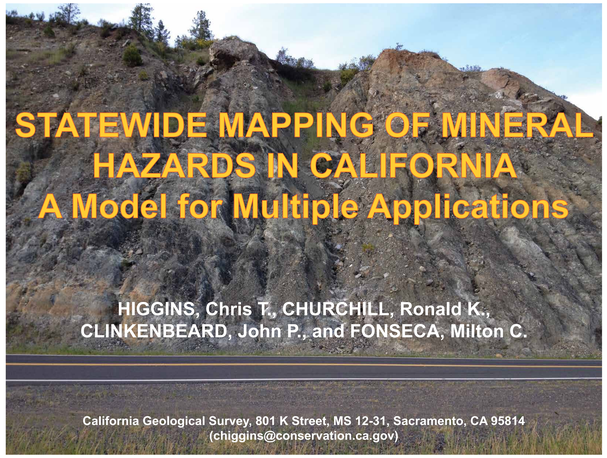
**Abstract**

Mineral hazards are a common, yet often less-recognized group of features compared to other types of natural and man-made hazards. We define "mineral hazards" in part as minerals and elements that occur naturally in elevated, potentially harmful, concentrations in rocks, soils, and certain fluids. Also included are features from human activities related to extraction of mineral and energy resources. Along with its large human population, extensive development, and diverse natural environment, California is very complex geologically, thus it contains many areas of mineral hazards that make it appropriate for such a study. Although mineral hazards have been investigated over several decades by the California Geological Survey (CGS), no systematic statewide assessment had been accomplished until recently when, at the request of the California Department of Transportation (Caltrans), the CGS completed a preliminary assessment of potential mineral hazards over the entire state. This work focused on natural and man-made minerals-related features that might adversely affect construction, use, and maintenance of state and federal highways under Caltrans jurisdiction. The features evaluated include: 1) geologic units that may contain naturally-occurring asbestos (NOA), fibrous erionite, or elevated concentrations of regulated metals (Ag, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Tl, V, Zn) and metalloids (As, Sb, Se); 2) faults, which can be sites of increased potential for certain types of mineralization; 3) mines and prospects, which can be sources of anomalous concentrations of metals and ore-processing chemicals; 4) oil and natural-gas seeps; 5) thermal springs and fumaroles; and 6) oil, natural-gas, and geothermal wells. The methods and products developed during the Caltrans study can be applied worldwide to many other uses besides highways where there are obligations to protect public health and safety and the environment. The products include maps that highlight types and locations of potential mineral hazards, digital data in GIS format, and accompanying reports that provide details and additional information. Although they do not indicate risk or probability, these products can be applied by users from many backgrounds as screening tools to assess potential for the presence of mineral hazards.



# STATEWIDE MAPPING OF MINERAL HAZARDS IN CALIFORNIA
## A Model for Multiple Applications

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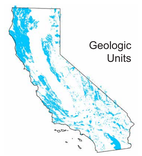
## OVERVIEW

Mineral hazards are a common yet often less-recognized group of features compared to other types of natural and man-made hazards. We define "mineral hazards" in part as minerals and elements that occur naturally in elevated, potentially harmful, concentrations in rocks, soils, and certain fluids. Also included are features from human activities related to extraction of mineral and energy resources. Along with its large human population, extensive development, and diverse natural environment, California is very complex geologically, thus it contains many areas of mineral hazards that make it appropriate for such a study. Although mineral hazards have been investigated over several decades by the California Geological Survey (CGS), no systematic statewide assessment had been accomplished until recently when, at the request of the California Department of Transportation (Caltrans), the CGS completed a preliminary assessment of potential mineral hazards over the entire state. This work focused on natural and man-made minerals-related features that might adversely affect construction, use, and maintenance of state and federal highways under Caltrans jurisdiction. The features evaluated include: 1) geologic units that may contain naturally-occurring asbestos (NOA), fibrous erionite, or elevated concentrations of regulated metals (Ag, Ba, Be, Cd, Co, Cr, Cu, Hg, Mo, Ni, Pb, Tl, V, Zn) and metalloids (As, Sb, Se); 2) faults, which can be sites of increased potential for certain types of mineralization; 3) mines and prospects, which can be sources of anomalous concentrations of metals and ore-processing chemicals; 4) oil and natural-gas seeps; 5) thermal springs and fumaroles; and 6) oil, natural-gas, and geothermal wells. The methods and products developed during the Caltrans study can be applied worldwide to many other uses besides highways where there are obligations to protect public health and safety and the environment. The products include maps that highlight types and locations of potential mineral hazards, digital data in GIS format, and accompanying reports that provide details and additional information. Although they do not indicate risk or probability, these products can be applied by users from many backgrounds as screening tools to assess potential for the presence of mineral hazards.

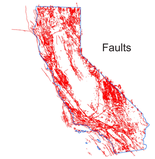


## FEATURES OF PRINCIPAL INTEREST



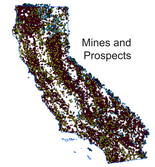


Sheared metasedimentary rock – SH70



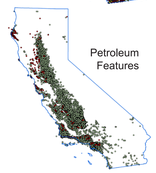


Cataclastic fault plane – SH299



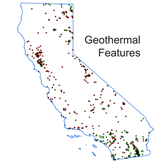


Metal-sulfide mine waste – SH299





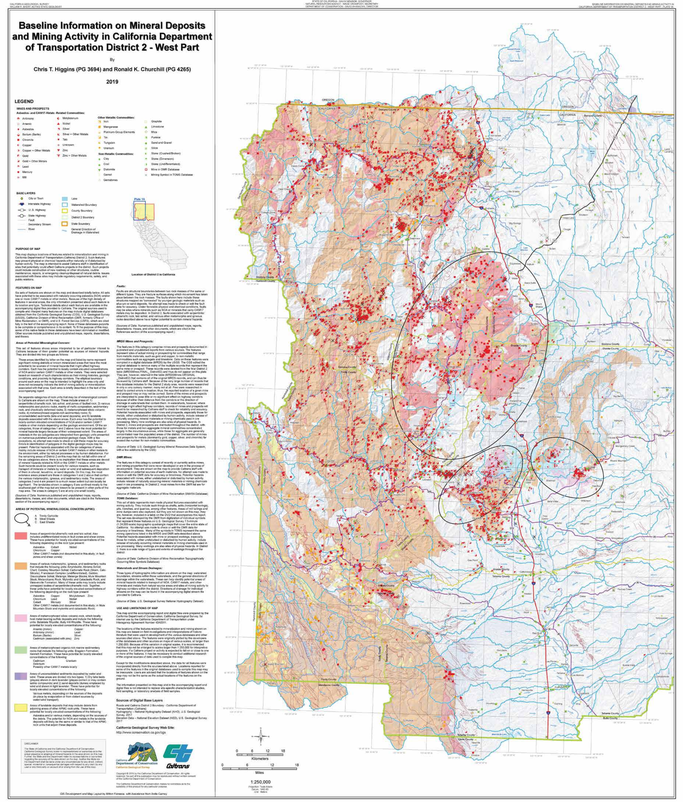
Natural oil seep – SH150

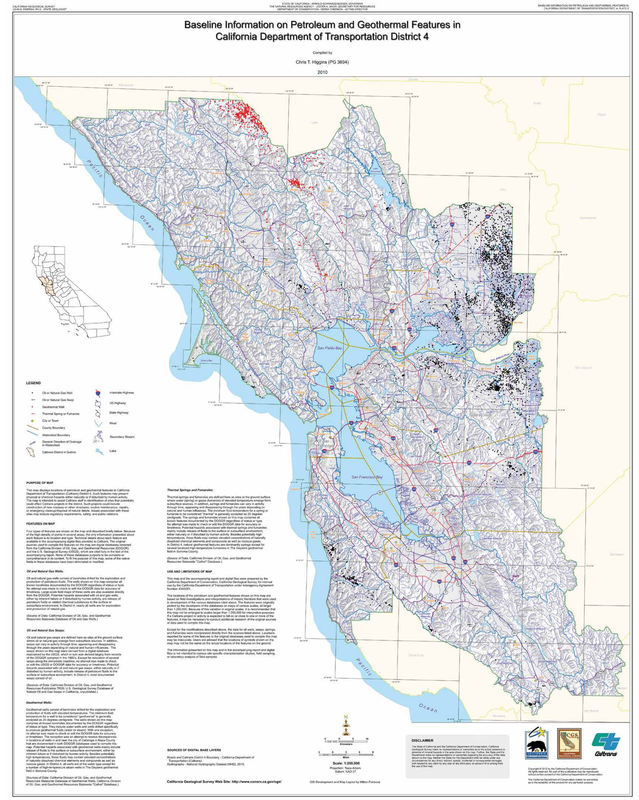




Geothermal well – US395

## EXAMPLES OF 1:250,000-SCALE CALTRANS DISTRICT MAPS



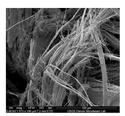

## Naturally-Occurring Asbestos* and Other Fibrous Minerals

**SERPENTINE**
**Chrysotile***

**AMPHIBOLES**
**Tremolite***
**Actinolite***
**Anthophyllite***
**Crocidolite***
**Amosite***
**Glaucophane?**

**ZEOLITES**
**Erionite**
**Mordenite?**


Tremolite Asbestos


Erionite

## DEVELOPMENT OF THE MAPS

Two primary sets of thematic maps have been prepared for each Caltrans district. One set displays areas and features of potential mineralogical concern, which comprise significant mining districts, localities of known mines and mineralization, certain types of geologic units, and faults, all of which may be of interest to Caltrans for further investigation. Selection of geologic units is based on their likelihood to contain NOA/fibrous minerals or elevated concentrations of the regulated metals/metalloids listed. The second set displays oil and natural-gas seeps, thermal springs and fumaroles, and wells drilled for petroleum and geothermal resources. Watersheds, streams, and the overall directions of flow of the streams in the watersheds are shown because of their potential to transport contaminants to highway corridors.

We have developed the maps from many sources of data. The highlighted geologic units (see table) and faults are interpreted and compiled from basic geologic maps, geochemical data, and fieldwork. The data on mines and mineralization are compiled from technical reports and several digital databases; the U.S. Geological Survey's Mineral Resources Data System (MRDS) is the primary source of data, which we have edited to some degree to improve its utility. The petroleum and geothermal features are compiled from data prepared by the California Division of Oil, Gas, and Geothermal Resources.

The process of developing the maps has evolved as new (and sometimes unanticipated) phenomena, conditions, and sources of data have been discovered. All compilation, analysis, and interpretation of mineral-hazard data are done with GIS tools, which are used to develop products that range from paper maps to digital files for use by Caltrans staff. This range assures that users with different levels of computer experience or available computer resources can access the information.

## California-Regulated Threshold Values for Metals/Metalloids

| METAL/METALLOID | STLC (mg/l)[1] | TTLC (mg/kg)[2] |
|---|---|---|
| **Antimony (Sb)** | **15** | **500** |
| **Arsenic (As)** | **5** | **500** |
| **Barium (Ba)** | **100** | **10,000** |
| **Beryllium (Be)** | **0.75** | **75** |
| **Cadmium (Cd)** | **1** | **100** |
| **Chromium (Cr)** | **560** $Cr^{+3}$=560; $Cr^{+6}$=5 | **None*** $Cr^{+3}$=2,500; $Cr^{+6}$=500 |
| **Cobalt (Co)** | **80** | **8,000** |
| **Copper (Cu)** | **25** | **2,500** |
| **Lead (Pb)** | **5** | **1,000** |
| **Mercury (Hg)** | **0.2** | **20** |
| **Molybdenum (Mo)** | **350** | **3,500** |
| **Nickel (Ni)** | **20** | **2,000** |
| **Selenium (Se)** | **1** | **100** |
| **Silver (Ag)** | **5** | **500** |
| **Thallium (Tl)** | **7** | **700** |
| **Vanadium (V)** | **24** | **2,400** |
| **Zinc (Zn)** | **250** | **5,000** |

**Those shown in red are of particular interest because of their distribution in California**
[1] Soluble Threshold Limit Concentration
[2] Total Threshold Limit Concentration
*Not established

## GEOLOGIC UNITS HIGHLIGHTED ON MAPS

| UNIT | POTENTIAL | COMMENTS |
|---|---|---|
| Alkalic Intrusive Complex | NOA, Ba, (other CAM17?), Radioactive Elements | Mountain Pass area; crocidolite; rare-earth elements |
| Amphibolite | NOA, Co, Cr, Cu, Ni | Mafic protoliths; some ultramafic bodies |
| Anorthosite Complex | NOA, Be, Co, Cr, Cu, Mn, Ni, V | Bodies of ultramafic, gabbro, actinolite-tremolite schist |
| Anthophyllite Schist | NOA | Bodies within metavolcanic rock |
| Balaklala Rhyolite | Cu, Pb, Zn, Ag, Cd, Sb, As | Volcanogenic metal-sulfide deposits |
| Big Blue Formation | NOA, Co, Cr, Cu, Hg, Ni | Derived from New Idria serpentinite body |
| Carbonate Rock | NOA, Cu, Mo, Pb, Ag, Zn | Metamorphic terranes with skarn, calc-silicate rock |
| Catalina Schist | NOA, Co, Cr, Cu, Mn, Ni | Contains serpentinite and actinolite |
| Chert | NOA | Includes metachert; crocidolite |
| Fault-Zone Rock | NOA, Co, Cr, Cu, Ni | Undifferentiated; serpentinite, gabbro, metavolcanic |
| Franciscan Complex | NOA, Co, Cr, Cu, Hg, Mn, Ni | Undifferentiated; many rock types; mélange belts |
| Gabbro | NOA, Co, Cr, Cu, Ni (As) | Includes metagabbro and diabase; As in Sierra |
| Glaucophane Schist | NOA, Hg | Includes blueschist; crocidolite; fibrous glaucophane |
| Great Valley Complex | NOA, Co, Cr, Cu, Hg, Mn, Ni | Basal mélange and Coast Range Ophiolite |
| Hydrothermally Altered Rock | Hg, Ag, As, Cu, Pb, Sb, Zn | Typically silicic and/or argillic; metal sulfides |
| Kennett Formation | Se, Cd, U (other CAM17 metals locally?) | Shasta area; contains organic-rich siliceous shales |
| La Panza Pluton | U | U in shear zones and metamorphic inclusions |
| Landslide Deposits | NOA, fibrous zeolites, and/or various metals | Associated only with the other units on this list |
| Los Banos Formation | NOA, Co, Cr, Cu, Hg, Mn, Ni | Contains Franciscan Complex, serpentinite detritus |
| Mariposite-Rock Complex | NOA, Co, Cr, Cu, Ni, Pb, Ag, Zn, As | Altered serpentinite; complex hydrothermal alteration |
| Melange | NOA, Co, Cr, Cu, Hg, Mn, Mo, Ni, Pb, Ag, Zn (As) | Non-serpentinite matrix only; complex unit |
| Merced Falls Slate | NOA, Co, Cr, Cu, Ni | Local mafic and ultramafic bodies |
| Metavolcanic Rock | NOA, Cu, Pb, Zn (As) | Undifferentiated; dominantly mafic; actinolite common |
| Monterey Formation + Similar Units | Cd, Se, U (other CAM17 metals locally?) | Organic-rich siliceous/phosphatic marine shales |
| Mylonitic and Cataclastic Rock | NOA | Local sheared zones may be favorable |
| Oro Loma Formation | NOA, Co, Cr, Cu, Hg, Mn, Ni | Detritus from Franciscan Complex and serpentinite |
| Orocopia Schist | NOA, Co, Cr, Cu, Mn, Ni | Correlative with Franciscan Complex |
| Paso Robles Formation | Cd, Se, U (other CAM17 metals locally?) | Abundant detritus from Monterey Formation |
| Plutonic Rock | NOA | "Fibrous" actinolite in granitic rock |
| Rand Schist | NOA, Co, Cr, Cu, Mn, Ni | Correlative with Franciscan Complex |
| Saline Lake Evaporite Deposits | Possible but unspecified CAM17 and other metals | Windblown dust from playas |
| San Onofre Breccia | NOA, Co, Cr, Cu, Mn, Ni | Detritus from Catalina Schist |
| Sand Deposits | NOA, fibrous zeolites, and/or various metals | Windblown; dunes, sheets, ramps |
| Sedimentary Rock | Fibrous zeolites | Erionite in altered lacustrine glass-rich tuffs |
| Serpentinite/Ultramafic Rock | NOA, Co, Cr, Cu, Hg, Ni | Includes serpentinite-matrix mélange and talc schist |
| Shear-Zone Rock | NOA, Co, Cr, Cu, Ni | Undifferentiated; sheared and disrupted belts of rock |
| Shoo Fly Complex | NOA, Cu, Mo, Pb, Ag, Zn, Ba | Local bodies of skarn and calc-silicate rock |
| Sierra Buttes (Elwell) Formation | Cd, Se, U (other CAM17 metals locally?) | Horizons of phosphate-bearing chert |
| Silica-Carbonate Rock | NOA, Co, Cr, Cu, Hg, Ni | Alteration product of serpentinite |
| Spring Deposits | Possible but unspecified CAM17 and other metals | Siliceous and calcareous sinter |
| Tulare Formation | NOA, Co, Cr, Cu, Hg, Mn, Ni, Cd, Se, U | Franciscan Complex and Monterey Formation detritus |

In addition to the individual district maps prepared during the project, the CGS is integrating the features from each of the districts into several thematic layers that cover the entire state. For example, all of the geologic units will be combined into one single seamless map layer.

## EXAMPLES OF OTHER POTENTIAL USERS AND APPLICATIONS OF MINERAL-HAZARD MAPS

| Users | Applications |
|---|---|
| Agricultural Industry | Crop-uptake of metals from soils derived from underlying or surrounding bedrock |
| Air Pollution Specialists | Establish regulations on control of dust emissions where fibrous minerals may be present |
| Construction Firms | Employee health at construction sites that may contain mineral hazards |
| Consultants (Engineers/Geoscientists) | Technical-project investigations (planning, design, construction) |
| Consultants (Environmental Firms) | Environmental studies, preparation of required environmental documents |
| Elected Officials | Awareness to aid decision-making (all levels of government) |
| Emergency Responders | Potential hazards from dust related to wildfires, floods, landslides, etc. |
| General Public | Awareness of potential hazards (e.g., for property sale/purchase or ownership) |
| Hazardous-Waste Specialists | Remediation of mine sites, particularly those that produced metals |
| Highway Departments | Maintenance, new construction, emergency cleanup, employee and public health |
| Land-Use Managers and Planners | Improve land-management to protect public and environment |
| Military Facilities | Remediation of sites; protection of personnel during training exercises |
| Public-Health Community | Medical geology; epidemiological studies of sites with high occurrences of disease |
| Real Estate Community | Awareness of conditions related to sale and purchase of real property |
| Recreational-Site Officials | Protection of public where generation of dust may occur (hiking, biking, camping, etc.) |
| Timber Industry | Harvesting of timber; employee health |
| Utility Operators | Siting and maintenance of transmission structures |
| Water Specialists | Watershed studies related to water quality, pollutants |

Caltrans

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California Geological Survey

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