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## Introduction

In 2009 the California Geological Survey (CGS) issued a Geological Hazard Notice to warn engineering and building departments in affected cities and counties of problematic fluvial smectitic clay sediments occurring in the Sierra Nevada foothills and adjacent areas of the Sacramento and San Joaquin Valleys. The Geohazard Notice was warranted based on preliminary data and on-going investigations that show the potential for serious engineering problems associated with this fluvial unit including landsliding (this topic discussed in another poster presentation in this session) and expansive soil behavior that leads to severe foundation distress (the subject of this poster presentation).

## Problematic Unit Recognition

Geologic mapping has historically portrayed the hazardous clayey materials as part of, or as the “upper” member of the Ione Formation or the “auriferous gravels” in the Sierra foothills. The Ione Formation is well known for producing non-expansive kaolinite clay for the ceramic industry. The smectitic clay deposits stratigraphically lie above the Ione kaolinitic units, but have rarely been differentiated on geologic maps. This sequence of smectitic sandy sediments are best exhibited at Chalk Bluff in Nevada County. Geologic investigations to date have demonstrated that the unusual form of these expansive clay deposits has caused geologists to variably assign them to other geologic units besides the Ione Formation, including the Valley Springs, Mehrten, Riverbank, and Turlock Lake Formations, as well as Quaternary surficial deposits. Such confusion suggests that the geologic map units listed above should be considered suspect and receive careful scrutiny when they appear on geologic maps and soil logs included in geotechnical reports.

## Deficiencies of ASTM Standard Test Methods for Characterization

- **Sieve and hydrometer test (ASTM D422)**  
determines sand vs fines (silt & clay) — granular vs cohesive soil
- **Liquid limit (LL) & Plastic limit (PL) tests (ASTM D4318)**  
— aka Atterberg Indices  
determines Plasticity Index (PI) ≈ related to expansion potential
- **Expansion index (EI) test (ASTM D4829)**  
determines expansion or swell potential

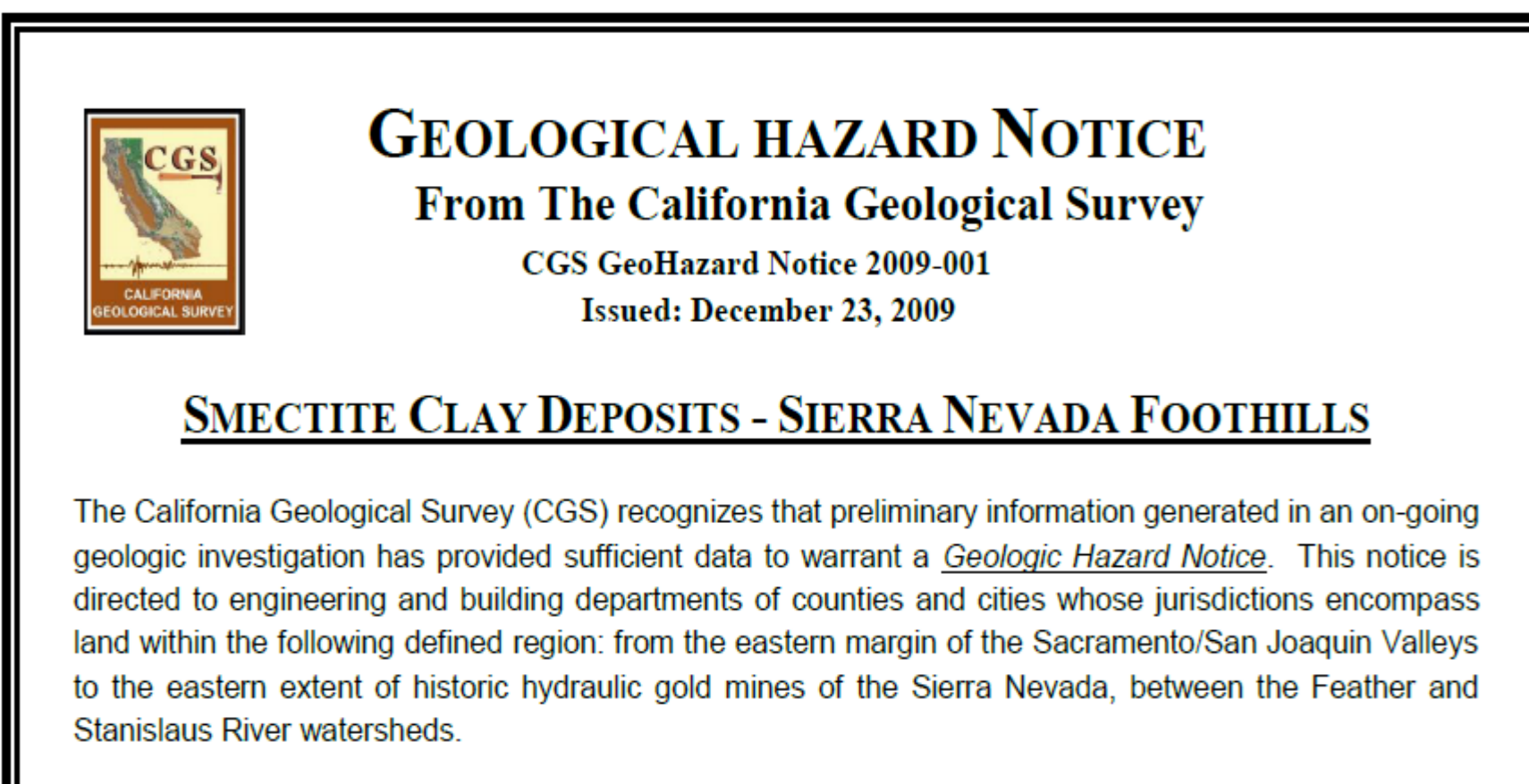
- Tests rely on the physical grain size of the sediment
- Tests the reactivity of clay only in the fines fraction (ie., <200 mesh)
- Ignores the mineralogy or chemistry of the sediment

## Supplemental Soil Test Methods

It is apparent that conventional ASTM soil tests often fail to provide results that reflect the true engineering properties of the subject smectite clay. Some local consultants have been successful using petrographic techniques, including optical microscope and X-Ray Diffraction (XRD), to identify and characterize the smectite clay content of these problem soils.

## Conclusions from XRD Analysis

- Analysis performed on <200 mesh and >200 mesh sieve separates (ASTM D422)
- XRD analysis showed that substantial amounts of smectite were found in the sand fraction (>200 mesh) after the sieve analysis
- Clay was difficult to disperse and large amounts of smectite clay remained undispersed as stabilized sand clasts
- **Results clearly show that standard ASTM procedures can result in significant errors in the characterization of soil grain size and potential soil activity”**



## Hazard Description

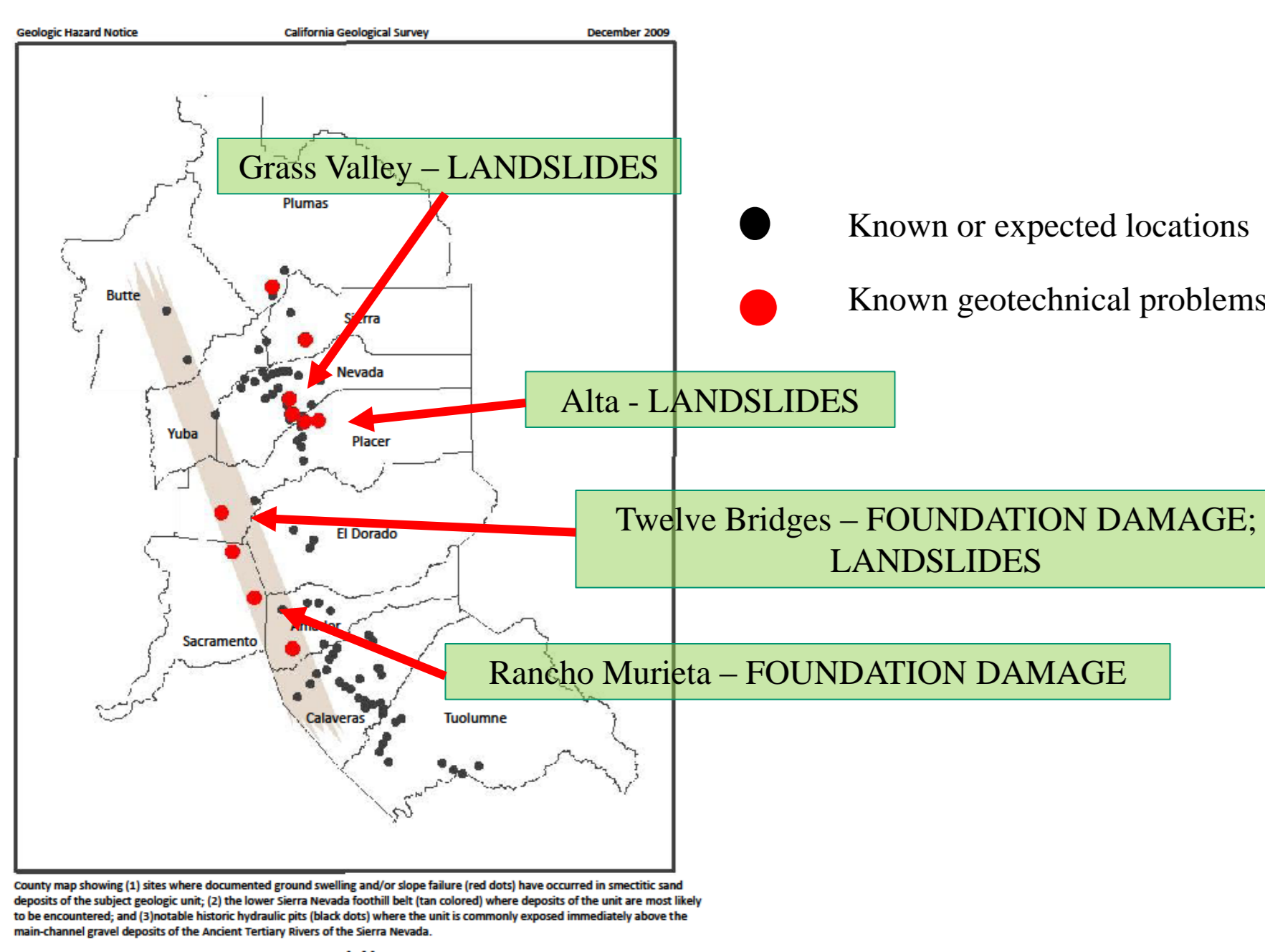
Exposed in patchy, often isolated, localities within the defined region is a particular geologic unit composed of varying mixtures of durable sand and an unusual form of expansive smectite clay. Despite geologic field observations, geotechnical site investigations, and laboratory soil testing performed by experienced professionals, the recognition of these deposits and the characterization of the expansive clay component have proven problematical.

As a consequence, a significant number of dwellings and other structures located in several foothill community developments have experienced severe foundation cracking and other significant structural damage resulting from unanticipated latent ground swelling.

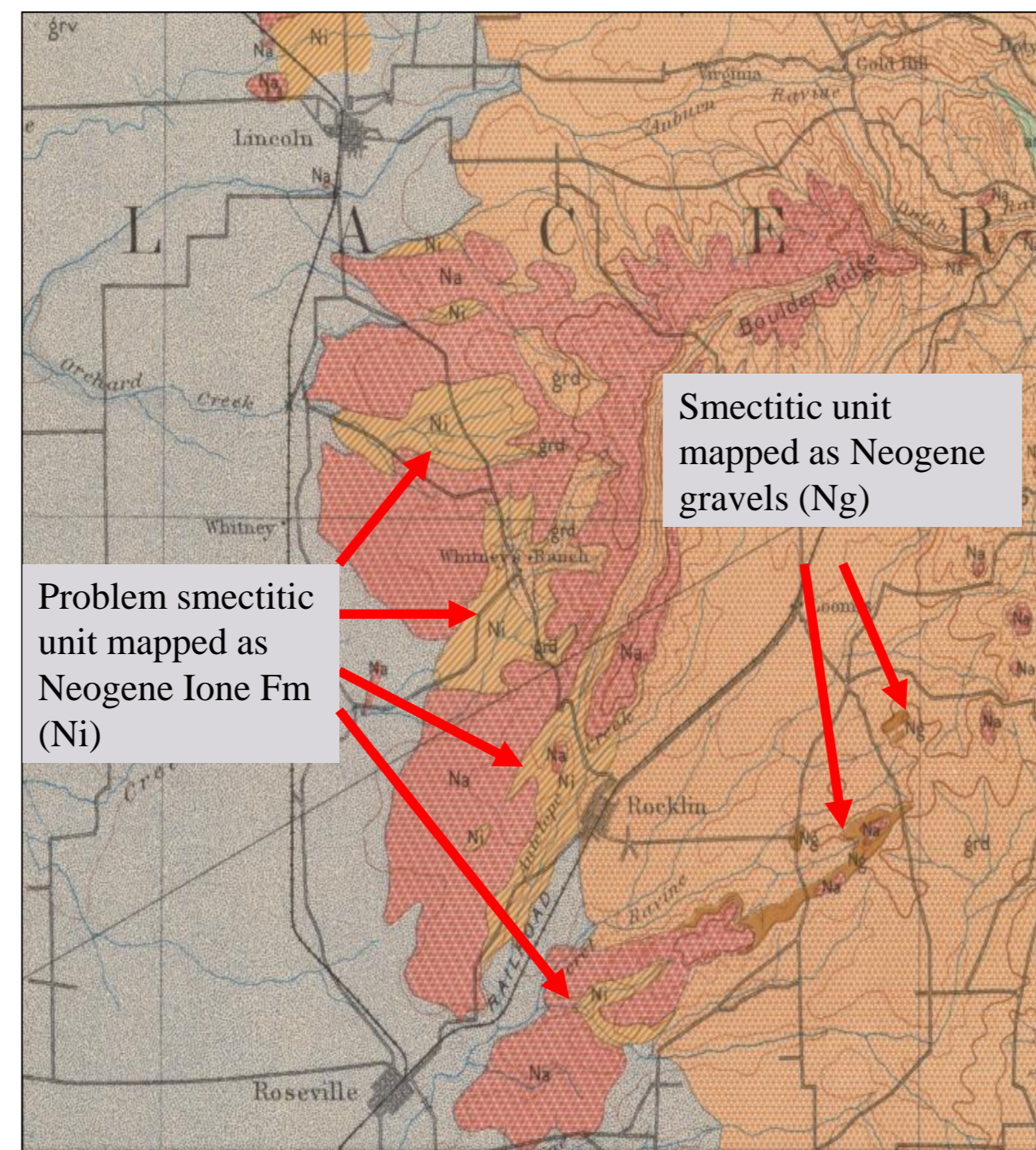
Damage to structures due to expansive clay has been documented in Sacramento and Placer counties, and slope instability in this geologic horizon is known to have occurred in Placer, Nevada, Sierra, and Plumas counties. This geologic unit is also likely to be exposed in Butte, Yuba, El Dorado, Amador, Calaveras and Tuolumne counties.

## Area of Concern

From the Hazard Notice

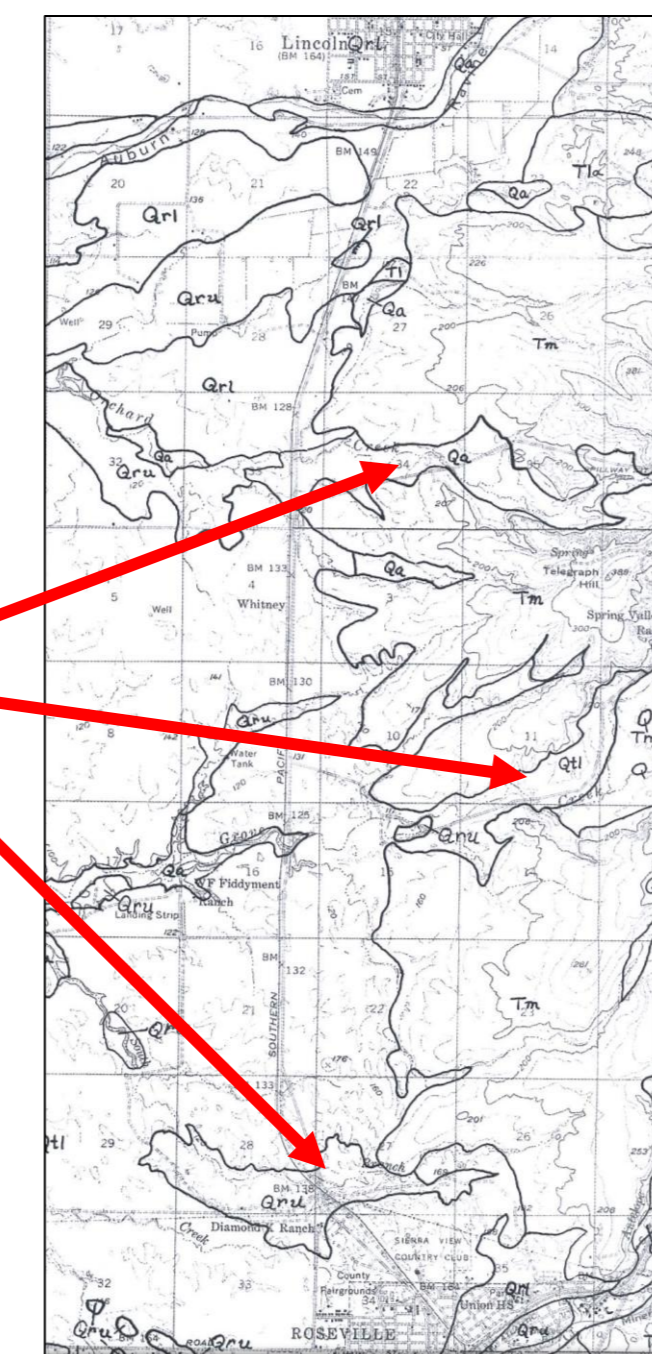


## Lincoln to Roseville — Lindgren, USGS Sacramento Folio



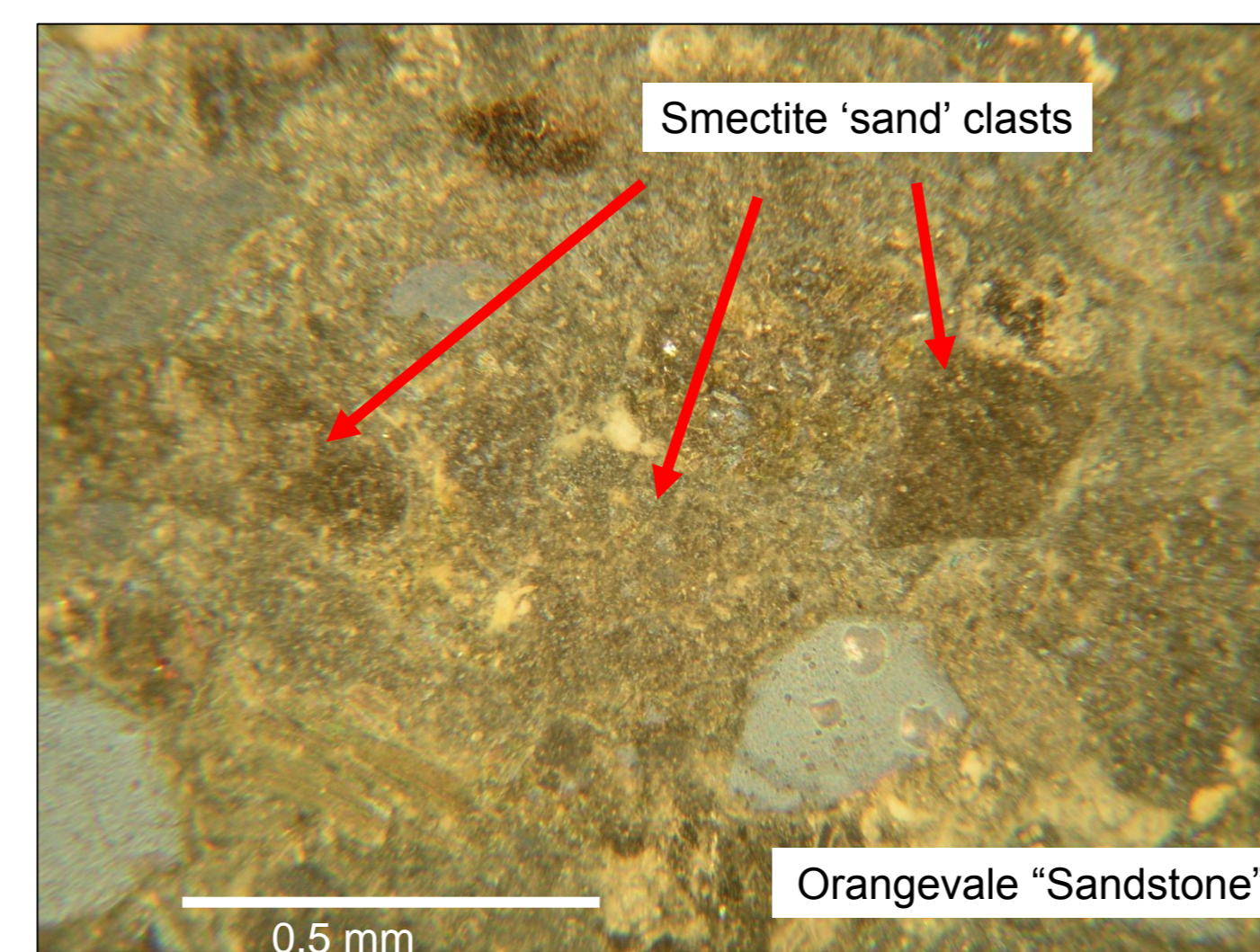
## Lincoln to Roseville - Helley and Harwood, USGS 1985

Problem smectitic unit mapped as various Quaternary units: River Bank (Qru) Turlock Lake (Qtl) and alluvium (Qa)



## Petrographic Analysis

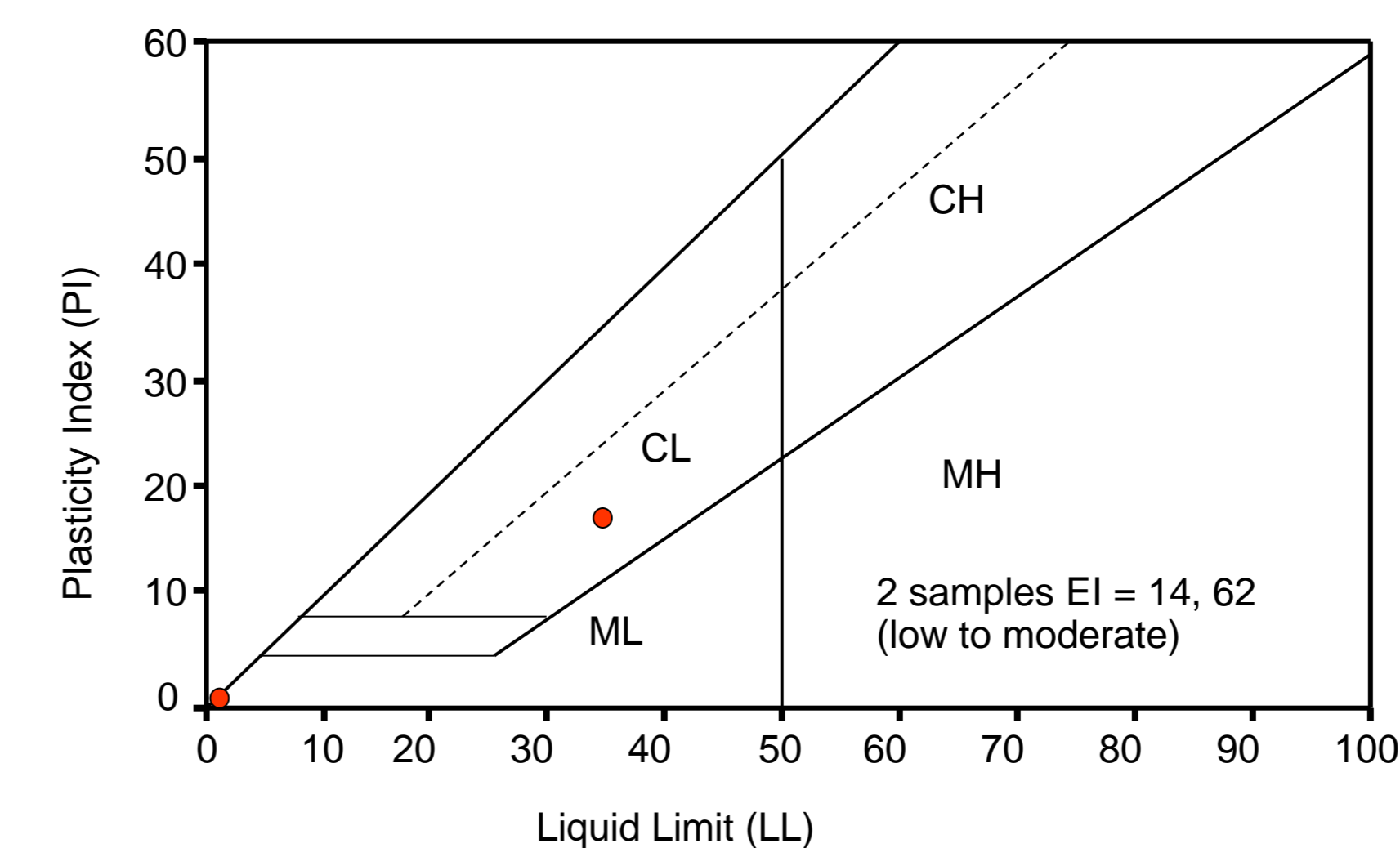
Expansive smectite clay in the form of cemented sand-size grains



Reflected Light View

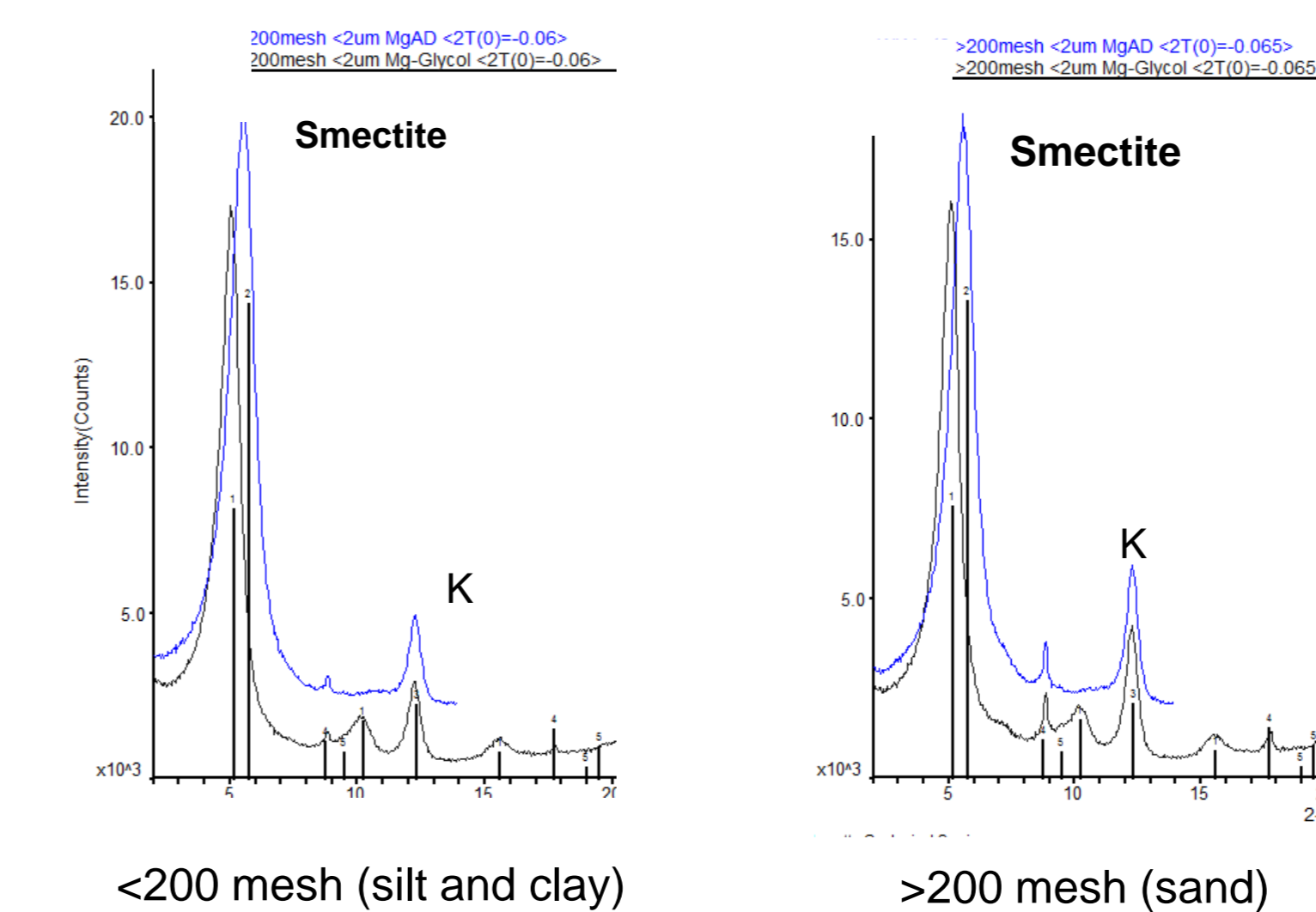
## Orangevale “Sandstone” Case Study

### PI and EI ASTM Test Results Orangevale Sandstone

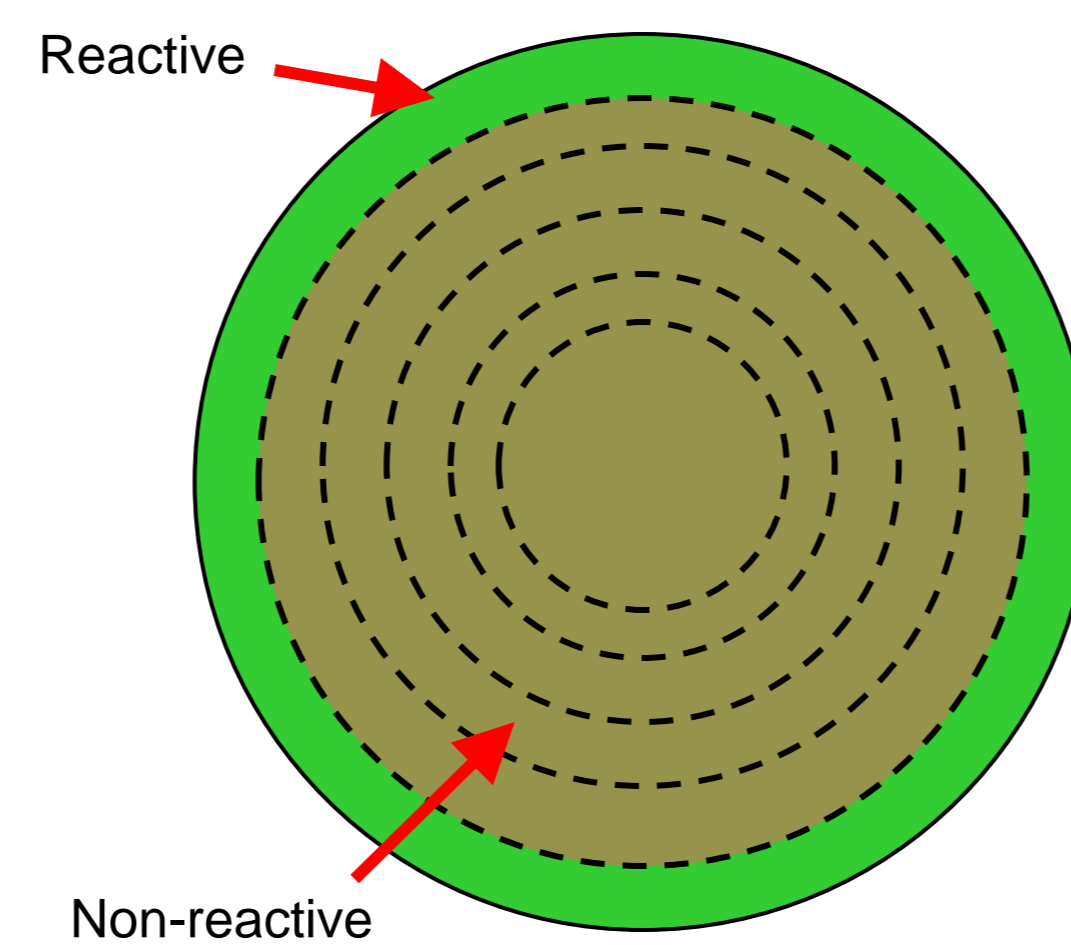


ASTM tests characterized soil as having low or no expansion potential!

## X-Ray Diffraction Analysis (XRD)



## Effect of cementation on the dispersion and reactivity of smectite clay clasts



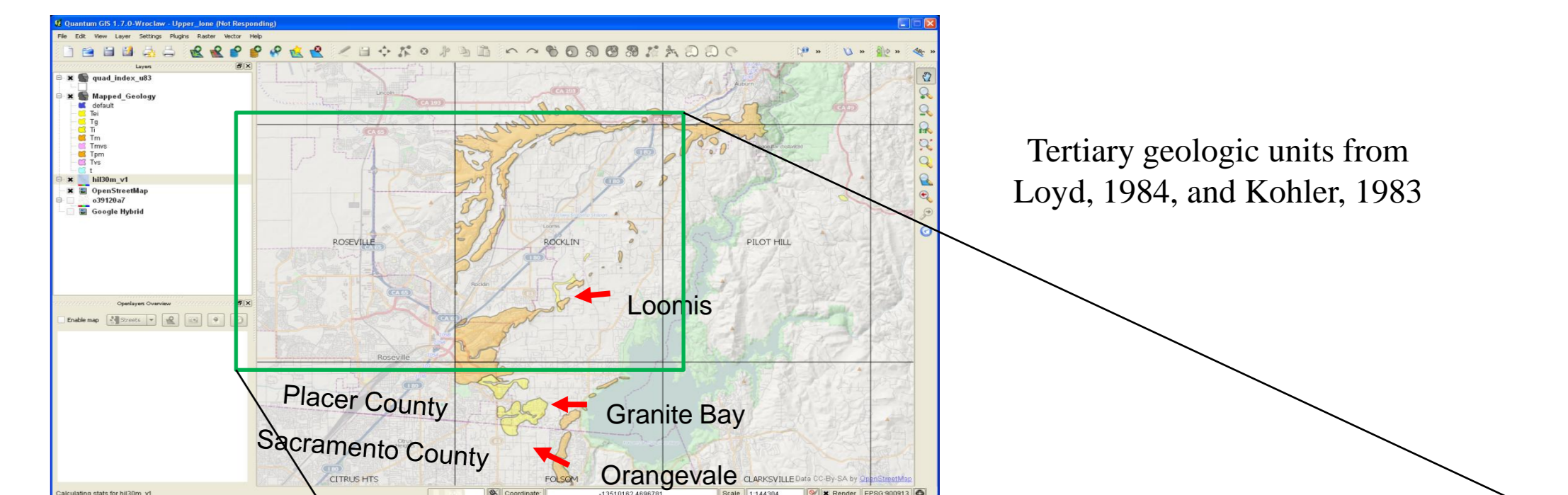
Cementation of clay clasts in soil dissolves incrementally. Thus, the clay reactivity or expansive behavior is similarly incremental.

Full expansive behavior of the clay is delayed or “latent”, sometimes for years

## Geologic Mapping Efforts by CGS

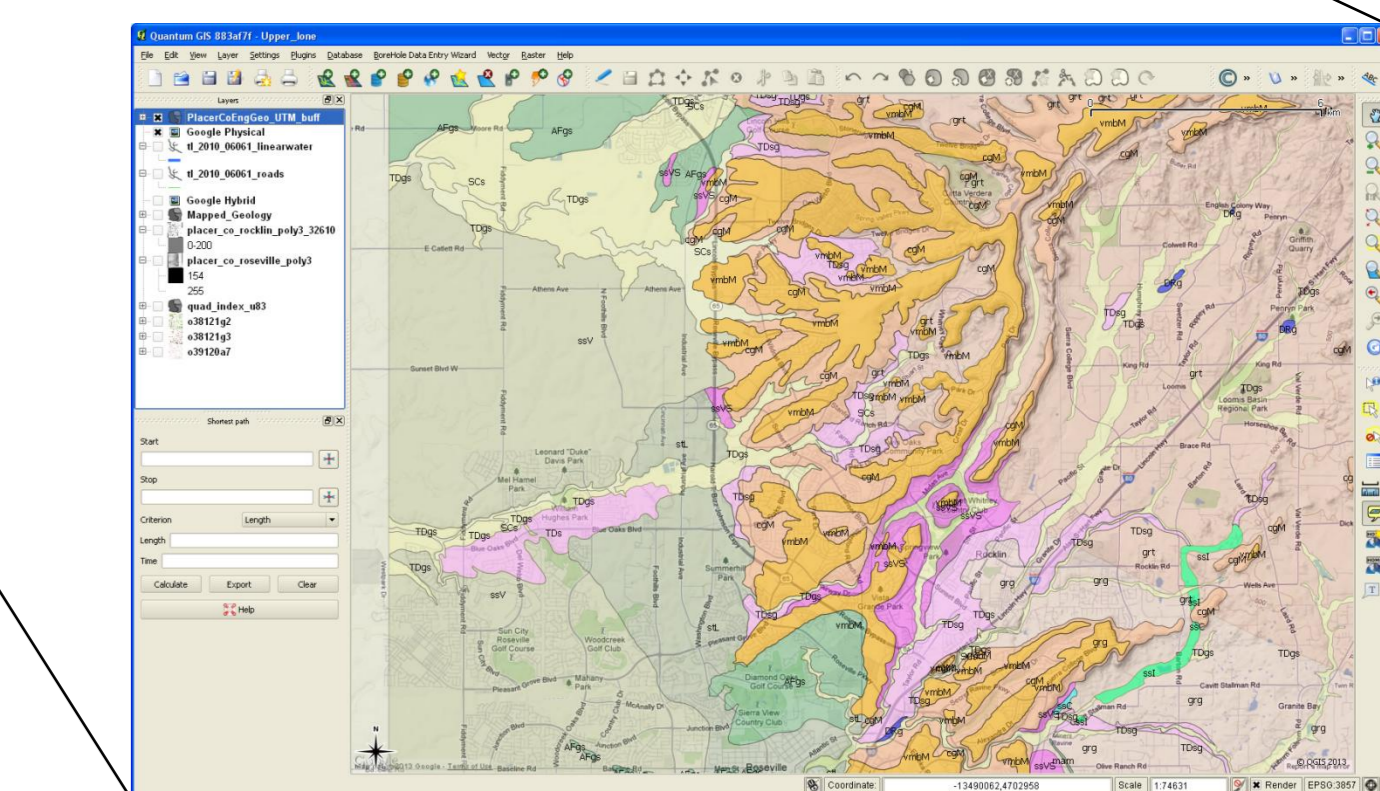
A preliminary effort is being conducted by the California Geological Survey to review previous geologic maps and digitize relevant mapping into modern data bases.

Previous mapping in Placer and Sacramento counties prepared by CDMG for mineral resource assessments shows Ione Formation (Ti; yellow color in the upper map below) in areas now known to contain the smectitic “sand” previously described. Engineering geologic mapping by Livingston (lower map) recognized rhyolitic volcanoclastic sediments but did not note enhanced expansion potential or numerous landslides in the Twelve Bridges area.



Tertiary geologic units from Loyd, 1984, and Kohler, 1983

Engineering Geologic Maps of Placer County, Livingston, 1975



## Ongoing Work

An informal group of engineers and geologists from consulting, academic, and state and county government organizations has been working to better understand the distribution and characteristics of this smectite sedimentary unit. Geologic maps that more accurately depict the areal distribution of the problematic clay materials are in progress. New foundation designs are being developed to accommodate the latent expansion potential of these soils, and if recognized beforehand, landslide-prone areas can be avoided or remediated prior to development.