Geologic Hazards in the Early Tertiary Sediments of the Sierra Foothills of California

Presentation Notes

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Abstract for the presentation

In 2009 the California Geological Survey issued a Geologic Hazard Notice to warn engineering and building departments in affected cities and counties over concern 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 and expansive soil behavior that leads to severe foundation distress.

The geologic unit in question has been variously mapped in the Sierra Nevada as the upper part of the legendary "Early Tertiary auriferous gravels," while in the Sierra foothills and adjacent lowland valley areas the smectite-rich detrital materials

superficially resemble, and are often mapped as the quartzose-kaolinitic Ione Formation sediments. Throughout the region, it has been mapped as the Valley Springs Formation where coherent rhyolitic tuffs are interbedded, yet recent age dates show most tuffs in the Sierra to be considerably older than those in Valley Springs type locality. Traditional reliance on the presence of rhyolite to mark the bottom of the Valley Springs has resulted in the mis-location of the contact between it and the underlying Ione Formation which is part of the reason some recent residential developments have been built on highly expansive smectitic clay without appropriate foundation design in the Sacramento region.

Another contributing factor is that despite careful scrutiny by numerous geotechnical professionals, the smectitic sediments are often classified as reasonably stable and suitable for use as engineered soils. ASTM soil tests often classify these sediments as having low or no expansion potential due to the occurrence of the smectite clay in a cemented granular form. The smectite clasts are stabilized largely by ephemeral amorphous silica as well as other pedogenic cements. Thus, the expansive behavior is latent, and significant soil heaving behavior can be delayed for years following its use as engineered soil. Recent investigations show that X-ray diffraction (XRD) and thin section petrography are other analytical techniques that can reliably assess the expansion potential of these sediments.

Introduction and Background

The data and conclusions presented here are the result of research and fieldwork conducted over the last 10 years by several of the co-authors listed. Much of the data collection came through geotechnical consulting projects dealing with adverse soil issues related to an unnamed problematic smectitic sedimentary unit that stratigraphically lies above the Ione Formation (Eocene) and below the Mehrten Formation (Miocene).

Surprising aspects of this smectitic sedimentary unit have led to considerable challenges for the geotechnical and construction industries. Until now, this fluvial sedimentary unit has not been officially recognized in the literature or on geologic maps as a distinct unit but has been classified as parts of various other units. Therefore, the areal distribution of this unit is not designated on any official geologic maps of the USGS or CGS. In addition, outcrops of this unit are not readily recognized in the field as smectitic (expansive) sediment because the smectite clay occurs in the form of cemented sand clasts. Thus, these sandy sediments resemble other sandstone units composed of durable sand. This unique occurrence of clay causes the expansive nature of the clay to go undetected in standard ASTM laboratory test methods customarily used by the geotechnical industry to characterize soil materials for their suitability as engineered soil. Consequently, many areas of suburban development in the Sacramento Valley region and adjacent Sierra Foothill areas have experienced significant and costly construction damage caused by unexpected soil heaving problems, sometimes many years after construction occurred.

The combination of these factors—unit previously unknown, unrecognized and unmapped; expansive potential undetectable in ASTM laboratory tests; and widespread

geotechnical problems—convinced the California Geological Survey to issue the *Geologic Hazard Notice for Smectite Clay Deposits in the Sierra Nevada Foothills* in 2009.

Area of Concern

The coarse grained portion of the problematic smectite sedimentary unit is the upper or bench gravel unit of the "Early Tertiary auriferous gravels" exposed in the upper section of most of the historic hydraulic mining pits throughout the Sierra Nevada foothills region. More information about the mineralogy of this smectitic unit is found in the GSA presentation *Early Tertiary Climate Change in its Impact on Matrix Mineralogy of the Auriferous Gravels in the Sierra Nevada Foothills*.

Early Oligocene rhyolitic tuff beds of various thicknesses are interbedded at the top of the problematic smectitic sedimentary section. The tuff beds perform as low angle bedding plane landslide slip surfaces. Therefore, the upper part of the Late Eocene to Early Oligocene sedimentary section is a focus of pervasive landslides and other low angle slope instabilities. Some known active and potentially active localities are plotted on the CGS Hazard Notice "Area of Concern" map. One prominent example of this style of landslide occurrence and general slope failure is in the vicinity of Alta, Placer County and noted on the map. Specific issues of this occurrence are discussed and profiled in the GSA presentation *Landslide Hazards Along the Interstate 80 Corridor Associated with the Early Oligocene Sedimentary and Volcanic Deposits in the Sierra Nevada.*

The other significant geotechnical hazard of concern and the subject of this presentation is the potential for expansive soil behavior that can cause foundation damage to building structures. The expansive behavior occurs in the finer grained downstream deposits of this geological unit in places such as Western Placer and Northern and Eastern Sacramento Counties. Other reported occurrences are in Amador County. Notable active examples are shown on the map.

Problem Unit Recognition and Historic Mapping

The coarse grained smectitic fluvial sediments in the Sierra Foothills (bench gravels of the Early Tertiary "auriferous gravels") are indistinguishable from the kaolinitic "lower gravels" also known as the Ione Formation. Early geologists such as Lindgren (1894) mapped the downstream equivalent finer grained smectitic sediments as either Neogene gravels (ie., pebbly quartzose sands) or Neogene Ione sandstone (finer grained sands). These are areas that have experienced expansive soil behavior discussed in this presentation.

One particular occurrence of Neogene gravels that Lindgren mapped in present day Loomis is currently undeveloped but has been subdivided for future building sites. A field check confirmed that this is an occurrence of problematic expansive smectitic sediment, hence, the justification of CGS issuing the Geohazard Notice to municipal building and planning agencies.

Again, because this Early Tertiary smectitic sedimentary unit was never defined or recognized, more recent mappers categorized this unit as various valley fill Quaternary units as shown on the lower map. Recent geotechnical investigations show that these "Quaternary" valley fill sediments of Helley and Harwood, 1985, actually underlie the intervening Mehrten (Miocene) ridge forming cap rocks. Thus, all the dense residential developments occupying the small valleys in present day Lincoln, Rocklin and Roseville are constructed on these heretofore unknown potentially expansive smectitic sediments.

Deficiencies of ASTM Standard Test Methods for the Characterization of Soil Materials

The ASTM test methods are the standard laboratory techniques used by the geotechnical industry to evaluate soil materials for their suitability as engineered soil. These methods include ASTM D422 Sieve and Hydrometer test; ASTM D4318 Liquid Limit and Plastic Limit test; and ASTM D4829 Expansive Index test. These test methods probably work correctly on 99% of the various soil materials found in nature. However, growing evidence indicates that these "standard of care" test methods do not correctly characterize these unique Early Tertiary smectitic sediments. The principal reason for this is because the smectite clay is in the unusual form of stabilized sand clasts and not as discrete clay particles.

The thin section photo shows that the sandstone from a locality in Orangevale, northern Sacramento County, is composed of 80% smectite clay in the form of sand clasts. The standard ASTM tests mentioned above classified this Orangevale sediment as having low or No expansion potential. The laboratory tests classified the bulk of the smectite clay largely as part of the sand fraction (>200mesh). The stabilization of the expansive clay by silica cement inhibited the clay from dispersing during the ASTM testing procedures. Thus, the conclusion of the geotechnical laboratory evaluation concludes that this potentially highly expansive soil is classified as a stable "granular" soil type that is most suitable to be placed with the use of conventional slab foundations with no concern for the prospect of soil heaving!

The absolute failure of the ASTM test methods in this case is because these standard tests are designed to detect, measure and analyze the expansive potential of clay in the form of disaggregated clay size particles, not in the form of cemented sand grains. The standard tests rely purely on the physical grain size of the potentially expansive clay fraction and do not accommodate the prospect of clay occurring in the sand or coarse particle fraction. In addition, the portion of clay and silt that is measured in the Sieve Test is also stabilized by silica cement and shows little expansion potential (low to moderate Expansion Potential in the testing of the Orangevale sediment).

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

The danger of relying on these results of the ASTM test methods for these unique smectitic sediments is shown in the illustration. The effect of cementation by silica is that the stabilization effect on the clay is ephemeral, ie., the cement will eventually dissolve with seasonal rainfall and repetitive irrigation. Thus, the soil may behave as a granular soil at the time of placement and compaction during construction but with time,

the clay will eventually become incrementally reactive and begin expansive behavior. This incremental process could develop over a long period of time and perhaps several years could pass before the soil clay becomes fully reactive.

X-Ray Diffraction (XRD) Analysis

In addition to the use of petrographic analysis to detect the amount of smectite clay in the soil and sediment, XRD clay mineral analysis is an quick, effective and relatively inexpensive analytical technique to characterize and quantify the amount of potentially expansive clay in these soils. While the standard ASTM tests classified this Orangevale soil as having low or no expansion potential, the XRD tests show that the sand fraction has as much smectite clay content as the fines fraction, both of which have substantial quantities of potentially expansive smectite clay.

These results indicate that the reliance of the standard ASTM laboratory test methods to characterize these Early Tertiary smectitic soils and sediments lead to significant errors in classification and use of those results for soil engineering design may lead to significant problems and structural failures at a later time.

The results of the soil analysis of the Orangevale case study reported here duplicates the results and data obtained by this consortium of co-authors from other locations where soil heaving behavior is active associated with this smectitic sedimentary unit. These other localities include Lincoln, Placer County; Nevada City, Nevada County; and Rancho Murieta, Sacramento County shown on the CGS "Area of Concern" map.

Geologic Mapping Efforts by CGS

Acknowledging that historic mapping efforts failed to correctly map localities of the problematic smectitic sediment, the staff of CGS has begun a program to evaluate historic geologic maps, identify likely localities where this smectitic sediment has been mapped but mis-identified and labeled as some other rock unit; and prepare new digital maps incorporating the re-evaluated historic efforts. An informal group of geologists including the co-authors is systematically field checking potential occurrences of the smectitic sediment to corroborate the results of the digital mapping efforts.