Early Tertiary Climate Change and its Impact on Matrix Mineralogy of the “auriferous gravels” in the Sierra Nevada Foothills

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Slide Notes

Slide 1
This is an oral slide presentation prepared and delivered at the GSA Cordilleran Conference (Session T5: Critical Zone: Where Rock Meets Water and Life at Earth’s Surface) in Fresno CA on May 20, 2013.

Slide 2
Abstract for the presentation

Slide 3
General description of the principle or prevailing thoughts about the characterization of this Early Tertiary sedimentary system in the Sierra foothills.

Slide 4
The classification nomenclature was, and still is, defined by the early miners’ terms.

Slide 5
Basic configuration of units. The lower gravels backfilled a stream cut canyon. The upper gravels spilled out over the channel margins and backfilled a stream cut bedrock terrace(s).

Slide 6
The continued use of a non-descript term to refer to this important geologic unit has perpetuated an attitude among geoscientists that it is acceptable to rely on oversimplified and often erroneous data and assumptions about the characterization of this unit that originated in the first half of the 20th Century. Further, this sedimentary unit(s) is/are far more complex than previously thought. An understanding of the mineralogical distinctions and contrasts between these units (including the paleosoils associated with them) have implications to better understand other important aspects of Sierran geohistory and paleo-environments.

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The co-authors’ involvement with research on this sedimentary system was spawned through a research program at the Unocal Research Center where both were employed. In addition, they were introduced to the Ione Formation in California in the course of preparing a fieldtrip for the 1989 Annual Meeting of the Clay Minerals Society in Sacramento. Updated research was incorporated into a subsequent fieldtrip for the

Annual Meeting of the Association of Engineering Geologists held in Sacramento in 1995. See the AEG Ione Formation Fieldtrip Guide posted at sierrageology.org.

Slide 8
This is one of the earliest geologic maps of the Sierra foothills. This early map was purposed to show the distribution of the economic placer gold deposits before topographic contour mapping methods matured. The map shows the location of several "auriferous gravel" deposits that were hydraulicked in Placer and Nevada Counties (shown in yellow; Mehrten sedimentary cap rocks shown in pink). Locations of proximal sediment samples discussed in this presentation are labeled.

Slide 9
Next few slides reiterate the fundamentals of chemical weathering in warm and humid climates and its role in the determination of the degree of mineral dissolution in rock as well as the formation of secondary clays in soils.

Slide 10
The role of water in chemical weathering is under-appreciated. While other acids play a role in chemical weathering such as carbonic acid, the shear volume of water moving through the soil column in warm/wet tropical/subtropical climates is the principle chemical weathering agent.

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The order of mineral weathering or dissolution in response to hydrolysis is determined by both the type of chemical bonding and silica structure complexity in the various minerals. The order of ionically bonded elements susceptibility to dissolution is generally first the alkali and alkali earth elements with +1 and +2 charges, then the transition elements that form +2, and +3 cations, with the elements that form covalent bonding most resistant. The most susceptible silica structure to dissolution is that in which the silica tetrahedra are isolated from one another (nesosilicates) as in olivine. Most resistant structure is the framework (tectosilicates) such as that of quartz.

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With these concepts combined, the order of mineral weathering follows Bowen's Reaction Series.

Slide 13
With greater hydrolytic intensity, cations are increasingly depleted or become unavailable to form mineral structures.

Slide 14
With low hydrolytic intensity such as in the weathering front in soils (ie., incipient mineral weathering at the soil/rock contact), various cations are available to form clay minerals (phyllosilicates) with elements such as Fe, Na, Mg, Ca, etc. in their structure.

Plus, sufficient silica is available to form 2 tetrahedral layers in the clay structure ie, two silica tetrahedral layers to one aluminum octahedral layer (2:1 clays). With increasing hydrolyitc intensity such as in higher levels of a mature tropical soil profile, the various cations including silicon are depleted and only clay minerals with one silica layer can form such as kaolinite and halloysite (1:1 clays). With even greater hydrolytic intensity, clay with no silica forms (gibbsite).

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The climate curve shown here is based on oxygen isotope studies of benthic foraminifera. This curve only tracks temperature trends through time. Implicit in the paleo-temperature trend is an accompanying hydrologic regimen that corresponds to the change in climate. The age of Ione sediment is roughly mid-Eocene or about 50 Ma during a time when globally, kaolinite was spilling into the ocean sediments at very high latitudes and in North America, kaolinitic river systems were flowing from Late Cretaceous through the middle Eocene. An abrupt global climate crash occurred about the mid-Eocene to late Eocene boundary and into early Oligocene or beginning about 45 Ma (+/-). Permanent polar ice caps appeared at the beginning of the Oligocene. With this significant climate change and corresponding decrease in hydrolytic intensity, a corresponding change in climax clay mineral assemblages should have appeared in soils and sediments during this transition time.

Slide 16
The bottom of the main channel sediments usually rests on unweathered bedrock for the most part where the channel thalweg scoured down to fresh rock material. Paleosols that co-existed at the time of the active stream systems had the chance of being preserved when the aggrading river sediment buried the soils at the time of deposition. Some of these contemporary paleosols preserved below the Early Tertiary sediments are located in both proximal areas in the Sierra foothills and in distal areas such as in Ione.

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The general description of the paleosols buried below the Ione sediments both in proximal and distal areas follow the characteristics of Oxisols. Allen (1929) described these soils as either “laterites” (the upper oxic horizon of Oxisols) or as “lithomarge” — the pale, white kaolinitic soil material where rock structure is preserved but all weatherable minerals are altered to clay. The modern term for this latter soil material is “saprolite”.

Slide 18
X-ray diffraction patterns show the clay mineralogy of the weathering front (kaolinite, smectite, and illite) and the kaolinitic soil in the mature saprolite of the soil. These are data from the paleoOxisol at Nevada City. The bedrock at this location is described as a biotite hornblend granodiorite.

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This is a fundamental tenet of sedimentology.

Slide 20
This XRD analysis of a channel sediment sample from an "auriferous" channel near the town of Washington (Nevada County) shows that kaolinite is the dominant clay specie with traces of vermiculite, illite and gibbsite present in the assemblage. This assemblage reflects the upstream regional soils dominated by kaolinite with some of the minor clay minerals occurring in the weathering front also present. Some soils in the region also contained gibbsite reflecting slight variations of hydrolytic intensity. Such variations can be produced by variations in topography, ie, soils on flat-lying topography would endure greater hydrolytic intensity.

Slide 21
The sediments occurring at Ione and Lincoln are composed of nearly 100% kaolinite with only traces of illite.

Slide 22
The top of the clay sediment section at both Ione and Lincoln record an interesting (ominous?) change in the clay mineral assemblage. Shown here is the last 10 meters of claystone in the Bacon Pit in Ione. Smectite appears in the assemblage at about -10m with about 5% smectite at -7m (c). Smectite continues to increase with elevation until it comprises 30% of the assemblage at the top of the Ione claystone section (a). The sedimentary record of this increasing smectite component at both Ione and Lincoln signifies a change in the clay mineral assemblage of regional soils that were shedding debris to the river systems. This was a preview of coming attractions!

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Slide 24
Insight into this smectite clay mineral phenomenon is gained by looking at the changes that occurred at the transition from the channel sediments to the terrace deposits and their underlying paleosols.

Slide 25
This photo shows the hydraulic mining pit at You Bet of kaolinitic channel deposits (foreground) with the planar fluvial terrace visible in the distance. Chalk Bluff (in shadow) and the overlying Mehrten andesitic capping sediments are seen in the far distance. This sedimentary sequence exhumed by hydraulic mining is probably the most complete section or locality of the "bench gravels" (ie., terrace deposits) of any of the hydraulic mining areas in the region.

Slide 26
This clay mineral assemblage in the weathered soil material close to unaltered bedrock shows a similar assemblage to the weathering front of the paleoOxisol at Nevada City developed on granitic rock.

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In striking contrast to the Oxisol kaolinitic climax clay mineralogy, the paleosol at Chalk Bluff that developed on the planed-off terrace bedrock surface shows the alteration of weatherable minerals to an assemblage with smectite dominant and kaolinite subordinate with roughly a 70/30% ratio. No residual mica (illite) is present from the original slate rock. The sample from La Porte is of a paleosol from a similar terrace bedrock surface. These paleosols possess nearly identical smectite to kaolinite ratios.

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In another example, a paleosol developed on a granitic knoll at Donner Summit was buried by an ignimbrite of about 30Ma in age (pers com Chris Henry). What is significant about this setting is that it shows the soil mineralogy at the time of burial at about 30Ma. Here, the paleosol hasn't lost too much of its former self through scouring by overlying stream action as on the fluvial terraces. The upper surface of soil here shows evidence of ablation by the overlying ash flow but it retains significant thickness (roughly 30 feet thick at the core of the knoll). Again, the clay mineral assemblage has a similar S/K ratio as the previous two examples.

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The striking similarity of clay assemblages from the two terrace bedrock paleosols and the later Oligocene soil suggests a new climax assemblage due to decreased hydrolytic intensity associated with significant climate change. If this is the case, then the matrix mineralogy of fluvial sediments overlying these terrace bedrock paleosols should mimic the new climax clay mineral assemblage of those later soils from which they were eroded.

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This sandstone is within about 10 to 15 feet above the paleosol on the terrace bedrock surface at Chalk Bluff (previous slide) but demonstrates that the sediments don't exactly mimic the mineralogy of the underlying soils at this location. However, this should be anticipated because the river sediment would have an amalgamation of sediment derived from the scouring of the underlying kaolinitic sediments all along the river course as far upstream as the area of Nevada. (see next slide illustration).

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Thus, reworking of underlying Ione kaolinitic sediment upstream would have diluted the influence of the new regional soil clay mineral assemblage with smectite dominant and probably accounts for this "clay mineral lag" observed in the initial terrace sediments.

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Indeed, with increasing stratigraphic elevation of terrace sediments, the smectite content increases accordingly as the underlying kaolinitic sediment is buried in upstream reaches of the river system.

Slide 33
With increasing elevation above the terrace bedrock paleosols, smectite continues to increase in the sediment matrix clay assemblage…here at about 50/50 in some adjacent

hydraulic mining pits. A thorough clay mineral analysis of each hydraulic pit plotting S vs K with elevation could provide accurate means to correlate specific sediment horizons from pit to pit. Stream gradients could be calculated.

Slide 34
Well into the Chalk Bluff fluvial sediment section, the matrix clay assemblage approximates the secondary clay assemblage of the terrace bedrock and regional paleosols as should be expected.

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Distal area Ione sediments also mimic this soil clay mineralogy.

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If this climax clay mineral response between the sediments and regional soils is truly a regional phenomenon due to global climate change, then similar sediment matrix response should be observed in other disparate locations. Here is an example from sandstones in the San Diego area collected on a 1992 Clay Minerals Society fieldtrip. In the XRD pattern on the left, a climax assemblage identical to the Ione sediments is evident. At the top of that sandstone outcrop, smectite appears. Above a disconformity, the overlying sediment shows a clay mineral assemblage nearly identical to soils and sediments more than 500 miles north in the Sierra foothills.

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The BIG question is about the age constraints of the postulated climate change that is recorded by mineralogy in this Chalk Bluff sedimentary section. Fortunately, the top of the Chalk Bluff section has rhyolitic tuff beds interbedded that date from 33Ma (La Porte) to 31.5Ma (Iowa Hill) to 30Ma (Chalk Bluff). The fact that another 50 to 100 feet of quartzose and gold bearing river sediment overlie the tuff beds at Iowa Hill indicates a post date of no earlier than 30 Ma and maybe a little younger. Examples of interbedded tuff beds in the uppermost smectitic Chalk Bluff sedimentary section can be seen at other hydraulic mining areas.

Slide 38
Gold mining is still occurring in the uppermost terrace sediments at Iowa Hill. In the wall of this drift mine, rhyolitic tuff pebbles and cobbles are among the coarse quartz clastic component. Right photo shows the contact of the quartzose smectitic section (bench or terrace gravels) with the basal Mehrten Fm andesitic river sediments (coarser boulders and pinkish sediments in photo).

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Conclusions

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The decrease in hydrolytic intensity that would have accompanied the global climate crash (late Eocene to Early Oligocene) would lead to the change in climax clay mineral assemblage from 1:1 clay (kaolinite) to 2:1 clay species dominant (smectite). This change is recorded in the paleosols and sediments of the kaolinitic Ione Fm (50Ma) and the later smectitic paleosols and Chalk Bluff section sediments in which the matrix mineralogy is dominated by smectite with kaolinite subordinate. We know the end of the Chalk Bluff sequence is approx 30Ma because of the interbedded tuff beds. The unknown factor is when the smectitic soils developed on the terrace bedrock surfaces and region. Was it the pause of the climate change trend that occurred about 45 Ma to 40 Ma—the middle Eocene to late Eocene boundary? Or was it during the Late Eocene from about 40Ma to about 37Ma when the climate was in rapid decline? Or was it the pause from about 37 Ma to 34 Ma? It was certainly before the Oligocene boundary at about 34Ma because the interbedded tuff beds at La Porte are dated independently at 33Ma and the bulk of the smectitic Chalk Bluff section is below that horizon.

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Its time to abandon the old 19th Century mining nomenclature that ignores the mineralogical distinctions of the various sedimentary units that comprise what is known as the Early Tertiary “auriferous gravels” and adopt new nomenclature that recognizes the Chalk Bluff sedimentary section not merely as an upper sequence of sediments in the “auriferous gravels” but as a unique and later river system that operated during a later time in the Early Tertiary…a time of much different global environmental conditions than those of the Middle Eocene.