U.S. DEPARTMENT OF ENERGY
OFFICE OF CIVILIAN RADIOACTIVE WASTE MANAGEMENT

NUCLEAR WASTE TECHNICAL REVIEW BOARD
PANEL ON STRUCTURAL GEOLOGY & GEOENGINEERING

SUBJECT: SOILS AND GEOMORPHIC STUDIES - PART II

PRESENTER: DR. STEPHEN G. WELLS

PRESENTER'S TITLE AND ORGANIZATION: PROFESSOR OF GEOMORPHOLOGY
UNIVERSITY OF CALIFORNIA - RIVERSIDE
RIVERSIDE, CALIFORNIA

PRESENTER'S TELEPHONE NUMBER: (714) 787-4367

ALEXIS PARK HOTEL
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Outline

- **Geomorphic processes on cone slopes**
  - Regional survey of slope geomorphology, results of types of mass wasting and fluvial processes
  - Review of criteria for distinguishing between sedimentologic and volcanic deposits
  - Sequence of geomorphic processes modifying cone slopes
    - * Sequence based on Cima volcanic field studies published by Dohrenwend, Wells, and Turrin (1985); Dohrenwend, Abrahams, and Turrin (1987) as well as independent studies
- **Results of studies at Black Tank volcanic center, Cima Volcanic Field, California**
  - Mapping and trenching results: new stratigraphy
  - Age estimates for stratigraphic units
  - Additional evidence for polycyclic volcanism
  - Significance of comparing Black Tank with Lathrop Wells volcanic center
- **Conclusions**

Survey of the Geomorphic Features Associated with Selected Late Quaternary Scoria Cone Slopes*

Primary Geomorphic features observed:

- Garlands, talus deposits formed during eruption (McGetchin et al., 1974)
- Agglutinate mounds and/or outcrops
- Unmodified cone slopes with slope angles typically >27 degrees

* Lathrop Wells Center, Cima Volcanic Field, Zuni-Bandera Volcanic Field, San Francisco Volcanic Field

Survey of the Geomorphic Features Associated with Selected Late Quaternary Scoria Cone Slopes

(Continued)

Secondary (erosional/mass wasting) features observed:

- Debris flow channels and debris flow deposits
- Fluvial channels: rills, gullies, incised drainages
- Cone aprons below debris flow levees and fluvial channels
- Rock falls (minor)

Secondary (erosional/mass wasting) features <u>not</u> observed:

- Rotational slumps, block slides, block glides, earthflows, debris avalanches, debris slides

Survey of the Geomorphic Features Associated with Selected Late Quaternary Scoria Cone Slopes Cima Volcanic Field, CA

Cone	Total Area (km^2)	Apron Area (km^2)	Area of Fluvial Incision (%)	Garland Area (%)	Agglutinate Area (%)
		Black Tank, A, Volcanic Center			
Qv1	0.12	0.48	74	0	23
Qv3	0.12	0.01	40	59	1
		U Volcanic Center			
U1	0.22	0.24	58	38	0.5
U2	0.16	0.08	16	80	0
		G Volcanic Center			
	0.49	0.76	93	5	2

(From Renault & Wells, in prep.)

Criteria for Distinguishing between Sedimentary and Volcanic Deposits on Strombolian Basaltic Cinder Cones

Clast	Texture/Stratification	Depositional Morphology
Volcanic Tephra Flow/Fall		
- Aligned bombs with flattened bases parallel to bedding	- Coarsening upward, some cross strata	- Bounding surfaces (unit contacts) parallel to constructional slopes
- Grain/framework supported	- Composite beds of moderately to well sorted angular to subangular scoria	- Low relief along bedding planes and bounding surfaces
Viscous Slurry (Debris) Flows		
- Lack of aligned volc. bombs; bombs not parallel to bedding *-a-b* planes of clasts dip away from and/or parallel to boundaries	- Matrix support scoria with poor sorting and stratification; little grain support	- Bedding and bounding surfaces not parallel to constructional slopes
	- Coarsening upward clasts with heterogeneous mixture of clasts with reworked pedogenic $CaCO_3$ coatings	- High depositional relief along bedding planes and bounding surfaces; debris flow channels filled with scoria

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Criteria for Distinguishing between Sedimentary and Volcanic Deposits on Strombolian Basaltic Cinder Cones

Clast	Texture/Stratification	Depositional Morphology
Stream and Hyperconcentrated Flows		
- collapse packing and imbrication of grains *-a-b* planes of clasts parallel to flow or slope direction	- Heterogeneous or reworked clast lithologies from different positions on vent - Cross laminae/cross strata	- Erosional relief on bedding planes and bounding surfaces - Fluvial channels filled with scoria

Sequence of Surficial Processes Related to Scoria Cone Degradation*

- Cessation of eruption, downslope movement by gravity sliding of scoria, forming garlands and attaining angle of repose between 31 and 38 degrees (McGetchin et al., 1974)

- Cone slope stabilization and trapping of eolian fines in voids of cinder; increasing soil plasma and decreasing net permeability of cone slope

- Small discontinuous debris-flows and rills with low width-to-depth ratios are initiated across garlands in response to decrease in permeability in scoria <u>or</u> in response to runoff below impermeable bedrock exposures, such as the agglutinate or proto-agglutinate areas

** [assumption: substitution of space for time; different cones of progressively older age are compared to established sequence, from Renault and Wells, in prep.]*

Sequence of Surficial Processes Related to Scoria Cone Degradation*

(Continued)

- **Debris flows and channel incision continue to develop as soils form on cone slope; debris flow activity and runoff generation increases, resulting in sediment transport to base of cone and cone apron formation**
- **As more sediment is transported from scoria cone:**
  - agglutinate is exposed, causing more runoff
  - soils are stripped from eroded cone slope area
  - cone slope angle decreases
  - area of cone apron increases
- **As runoff generating capacity is increased, channels integrate and incise through cone apron, resulting in abandonment of deposition on cone apron and development of inset aprons**

** [assumption: substitution of space for time; different cones of progressively older age are compared to established sequence, from Renault and Wells, in prep.]*

Experimental Rainfall - Runoff Results and Conclusions, Israel and New Mexico Studies (From Yair and Wells, 1989, in prep.)

- Experimental rainfall-runoff plot results

- Rocky plots, 1988-89:	site 12D	=	2,357 (liters)
	site 2C	=	958 (liters)
- Colluvial cover plots, 1988-89		=	20 (liters)

- Conclusions
  - Significantly more measurable runoff from those regions with lower permeability (rocky) surfaces
  - In semi arid and arid regions, rocky surfaces behave like saturated areas in humid regions and fit the concept of partial-area contribution to runoff development in humid regions
  - Channel runoff is affected by the spatial distribution of bedrock surfaces and permeable surface cover

Experimental Rainfall - Runoff Results and Conclusions, Israel and New Mexico Studies (From Yair and Wells, 1989, in prep.)

(Continued)

- Applications for volcanic cone slopes
  - Areas with agglutinate and proto-agglutinate (bomb concentration) will result in channelized runoff and debris flow activity (Renault, 1989)
  - With time the development of soils in scoria and the reduction in permeability due to soil plasma will enhance runoff and debris flow activity

New Stratigraphic Studies at Black Tank (A) Volcanic Center Cima Volcanic Field, CA

- Nine backhoe trenches excavated at Black Tank volcanic center
- Three vents and their associated flows, tephra, and apron deposits have been mapped at Black Tank cone
  - Stratigraphic evidence for three major phases of eruptions at same center
  - Stratigraphic, soil, geomorphic, and age estimate evidence for hiatus between eruptive events, which vary in time from 1,000 to 100,000 yrs.

New Stratigraphic Studies at Black Tank (A) Volcanic Center Cima Volcanic Field, CA

(Continued)

- New age estimates for three eruptive phases:

unit Qv3la = 8.5 +/- 0.7; 9.0 +/-0.8 ka (TL, Forman)

12 +/- 3.8 ka ($^{3}He_{C}$, Stone)

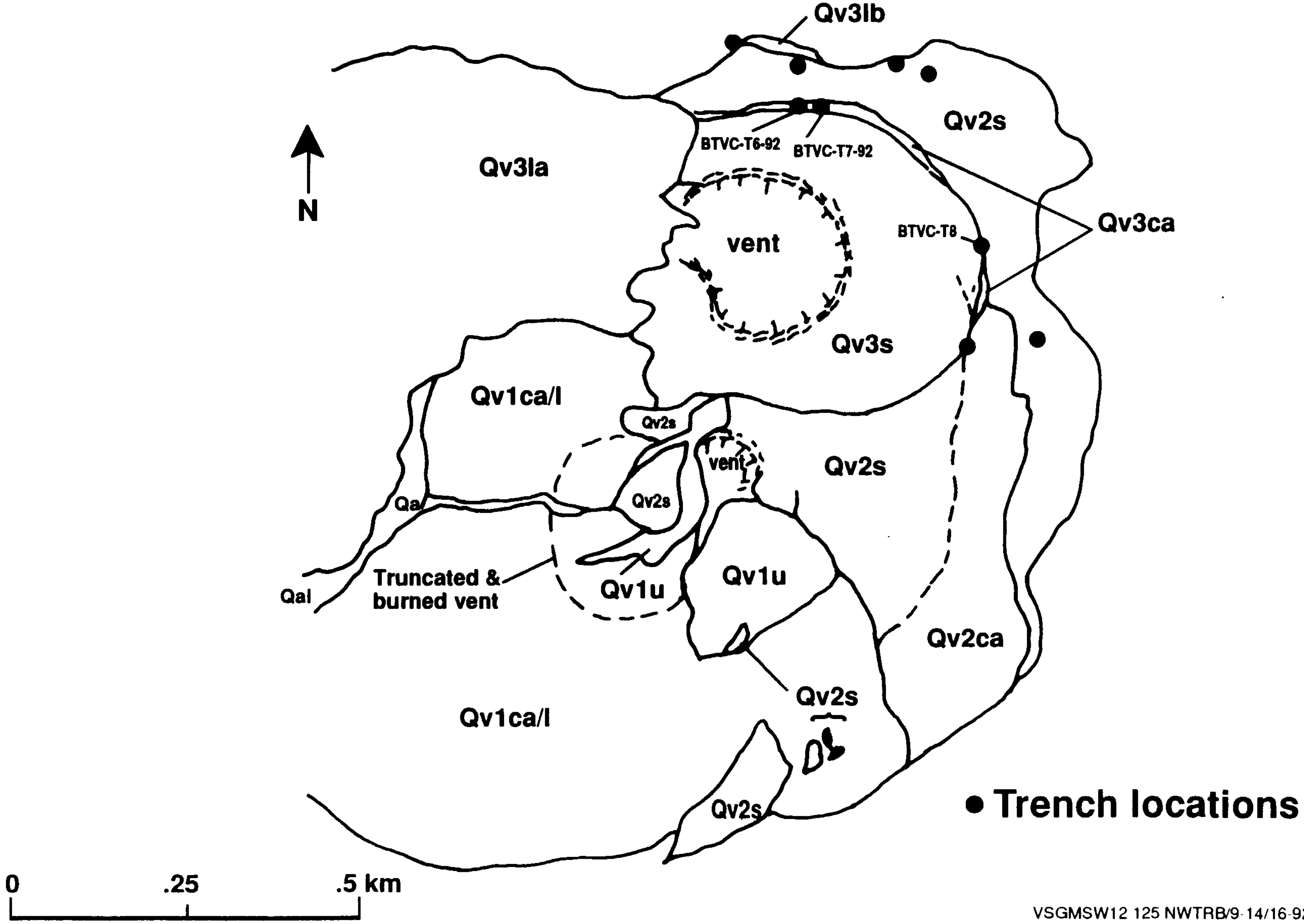
[bounding unconformity: buried stone pavement & buried soil]

unit Qv2s = 22 +/-8 ka ($^{3}He_{C}$, Olinger)

[bounding unconformity: buried stone pavement & buried soil]

unit Qvl1 = undated; estimated > 500 ka on basis of geomorphology and soil development

Generalized Geologic Map of Black Tank Volcanic Center



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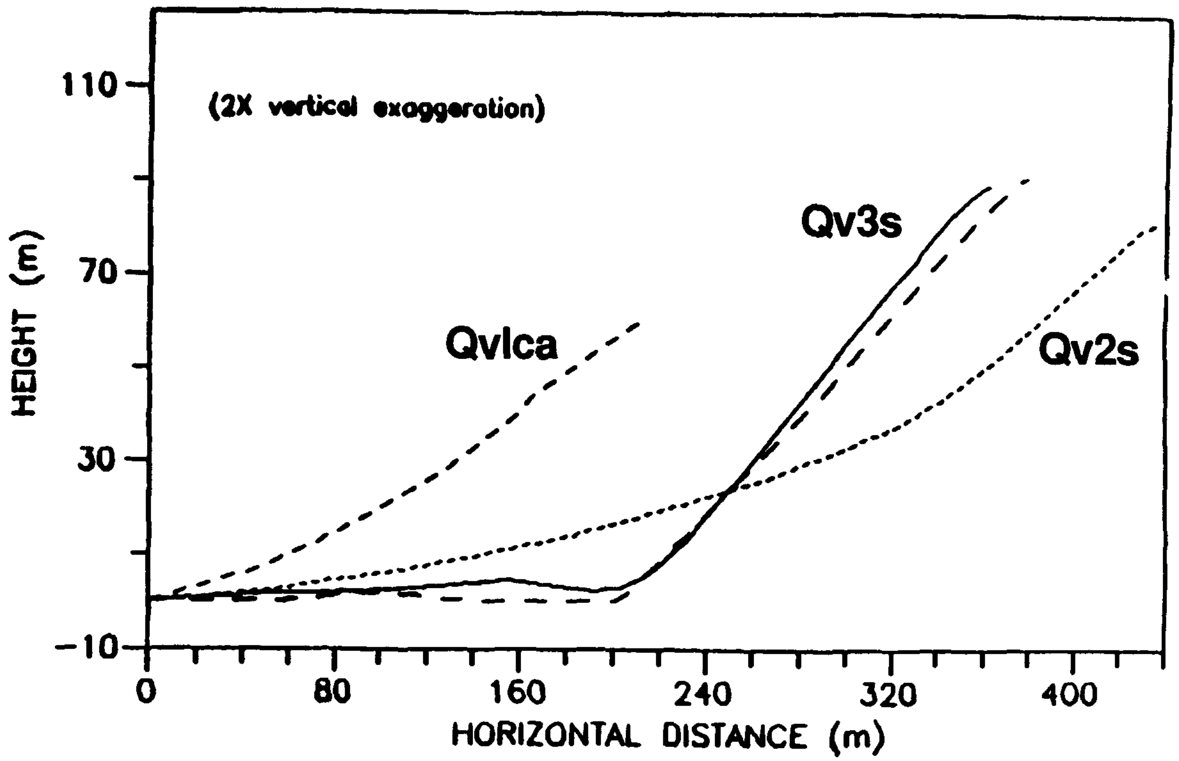
A Cone, Composite Topographic Profile



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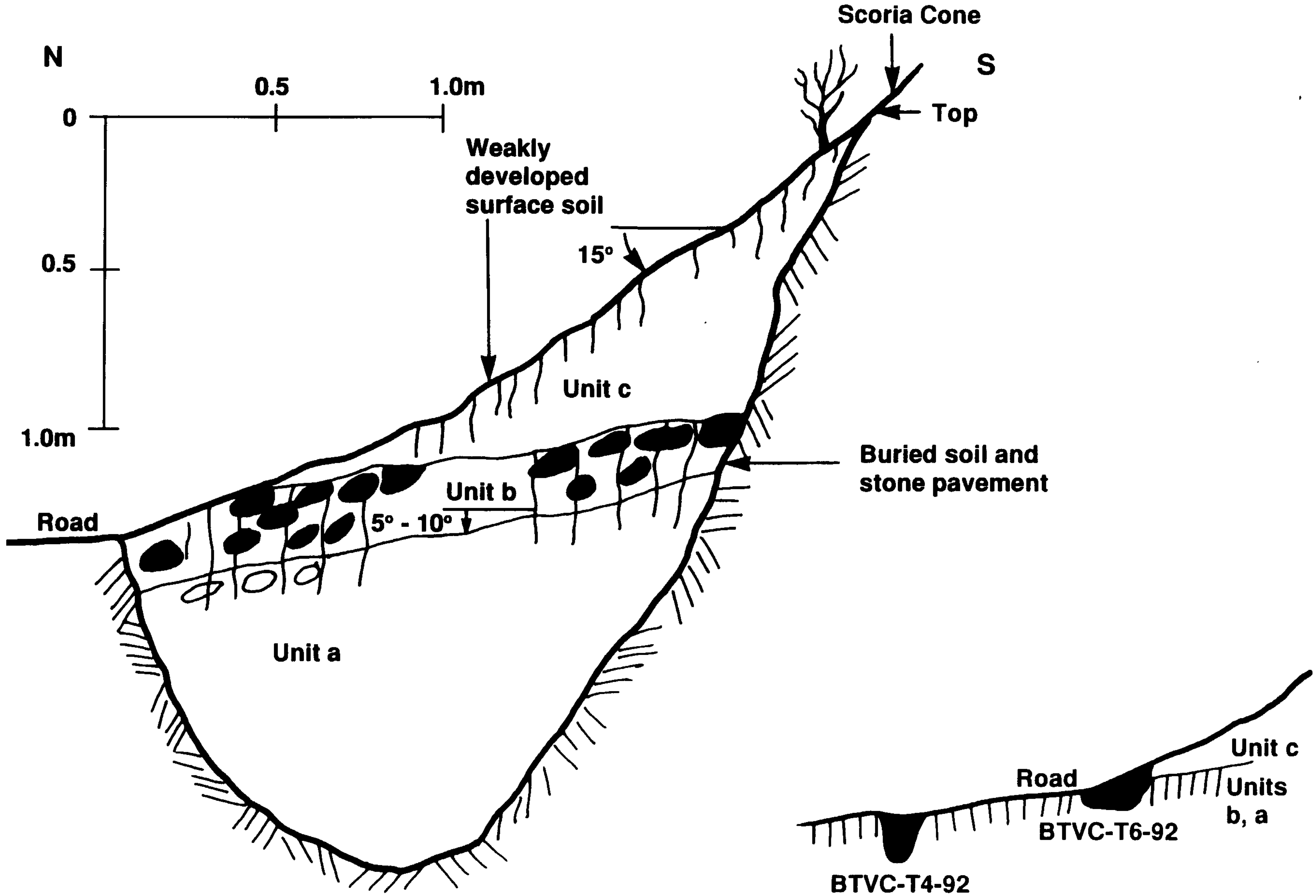
Log of Trench BTVC-T6-92



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Generalized Stratigraphy of Trench BTVC-T6-92

- **Land surface** - average slope of 12^0, varies from 10^0 - 15^0
- **Unit c** - Accretionary cone apron with scoria derived from scoria cone (Qv3s) and eolian fines forming matrix in voids; weakly developed surface soil

[bounding pavement/soil unconformity]

- **Unit b** - 0.3 thick layer of dense bombs with eolian sand matrix; basal contact slopes approximately 8^0 away from scoria cone (Qv3s); stone line is buried pavement as indicated by varnish on buried bombs, pedogenic calcium carbonate rinds on clasts, and a weakly developed soil below pavement and underlying soil exposed in trench BTVC-T4-92; unit is upper part of unit Qv2s
- **Unit a** - 1.5 m of scoria and bombs with weak planar parallel stratification, dipping > 10^0 away from unit Qv3s cone center, eolian matrix decreases with depth; unit Qv2s

Significance of Studies of Black Tank (A) Volcanic Center, Cima Volcanic Field, CA

Comparison to Lathrop Wells Volcanic Center

- Both volcanic centers display geomorphic processes on cone slopes which are consistent with regional survey
- Both volcanic centers display unconformities (buried soil or stone pavements) between volcanic deposits and associated landforms, indicating complex volcanic history
- A soil- or pavement-bounded unconformity indicates long-duration hiatus between eruptive events and supports interpretation that polycyclic volcanism as well as monogenetic volcanism can be observed regionally
- Experimental numerical age estimates (such as TL and cosmogenic ^{3}He) are relatively compatible but yield significantly younger ages than that of K-Ar or $^{40}Ar/^{39}Ar$ age estimates

Conclusions

- Hillslope processes on scoria cones dominantly involve the modification of constructional slopes by debris and stream flow modifications not by large scale rotation, flowage, gliding or sliding processess
- Field criteria for distinguishing such features was applied to Lathrop Wells volcanic center, indicating "quarry site" stratigraphic sequence stands as published by Wells et al. (1990)
  - Published inferences by USGS personnel that "mass flowage" and "slumping" phenomena have produced such features are unsound. Such studies fail to incorporate
    * Understanding of soils stratigraphic pedogenic features in the field
    * Standard particle-size analyses techniques
    * Understanding of geomorphic and sedimentologic processes on volcanic vents
    * Geochemical testing of sources of stratigraphic units in question

Conclusions

(Continued)

- Geomorphic process-response models (involving soil formation, time-dependent permeability changes, and hillslope runoff) demonstrate that eruptive hiatus of long-duration are required to pedogenically and geomorphically modify cone slope and to produce features recognized in rock record
- Soil and stone pavement bounded unconformities are observed at Black Tank vent in the Cima volcanic field and at Lathrop Wells volcanic center, thus rock record at two different sites indicate polycyclic volcanism is a viable interpretation