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September 27, 2002
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U.S. Nuclear Regulatory Commission
ATTN: Mrs. Deborah A. DeMarco
Two White Flint North
11545 Rockville Pike
Mail Stop T8A23
Washington, DC 20555

Subject: Programmatic Review of Presentations

Dear Mrs. DeMarco:

The enclosed presentations are being submitted for programmatic review. These materials will be presented as posters at the Geological Society of America 2002 Annual Meeting and Exposition on October 28 and 29, 2002, in Denver, Colorado. The titles of the presentations are:

> "Laboratory and Modeling Studies of Np-237 Uptake on Calcite" by P. Bertetti and B. Werling
>
> "Matrix Permeabilities of Faulted Nonwelded Tuffs" by C.L. Dinwiddie, R.W. Fedors, D.A. Ferrill, and K.K. Bradbury

NRC has previously reviewed and approved the abstracts for these presentations and the associated NRC Forms 390A. Please advise me of the results of your programmatic review. Your cooperation in this matter is appreciated.

Sincerely,

Budhi Sagar
Technical Director

/ph
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Laboratory and Modeling Studies of Np-237 Uptake on Calcite

F. Paul Bertetti and Bradley A. Werling
Center for Nuclear Waste Regulatory Analyses, Southwest Research Institute, San Antonio, Texas

BACKGROUND

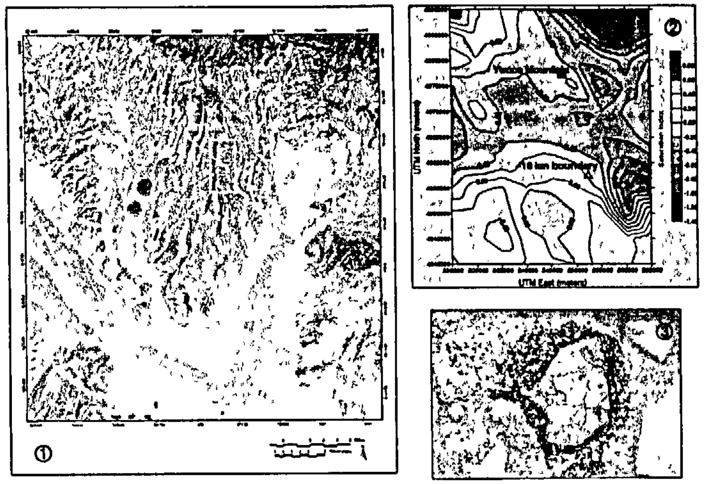
The U.S. Department of Energy is currently investigating Yucca Mountain, Nevada as a potential site for geologic disposal of high-level nuclear waste. Current conceptual models indicate that groundwater from the proposed repository will travel southeast then southward beneath Fortymile Wash to the compliance boundary approximately 18 km [11 mi] from the proposed repository.

Performance assessment models indicate that sorption of Np-237 is important to estimating dose to the reasonably maximally exposed individual located at the compliance boundary. Similarly, modeled radionuclide transport times in the saturated alluvium are sensitive to the retardation coefficient used for Np-237. Studies have suggested that Np-237 sorption on calcite, a mineral with widespread occurrence at Yucca Mountain, may be enhanced relative to sorption on other common mineral phases.

Geologically, Fortymile Wash is a complex mix of alluvial sediments, paleosols, volcanic tuff sequences, and early basinal sediments. Groundwater in the alluvial aquifer is generally undersaturated with respect to calcite, but calcite is observed in well cuttings from several wells drilled in Fortymile Wash. Calcite abundance increases with depth.

The objectives of this study are to examine the sorption of Np-237 on calcite under geochemical conditions relevant to Fortymile Wash and to develop an appropriate modeling interpretation of the sorption behavior. Model results can then be combined with similar results for other common minerals in Fortymile wash sediments to produce a composite model of Np-237 transport.

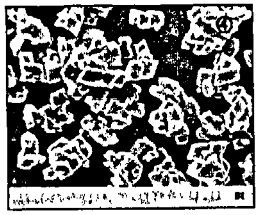
DISCLAIMER: This poster was prepared to document work performed for the U.S. Nuclear Regulatory Commission (NRC) under Contract No. NRC-02-97-009. This work is an independent product of the Center for Nuclear Waste Regulatory Analyses and does not necessarily reflect the views or regulatory position of the NRC.



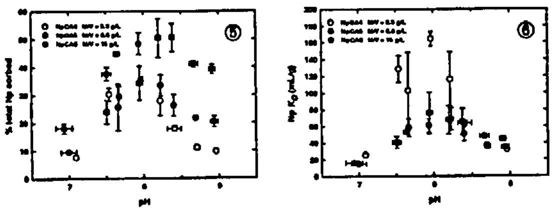
[1] TM-Landsat image of the Yucca Mountain region. [2] Calculated calcite saturation indices for groundwater in the Yucca Mountain region. [3] Thin section photomicrograph of well cuttings showing calcite replacement of feldspar. The sample was collected ~1,195 feet below the ground surface from well NC-EWDP-02D Thin section image is 1 0 mm [0 039 in] wide.

EXPERIMENTAL STUDIES AND RESULTS

- **Batch sorption experiments were conducted at equilibrium with atmospheric $CO_2(g)$. pH and solid mass to solution volume ratio were varied. Np concentrations were approximately 1.5 to 2.5×10^{-6} M. Ionic strength was maintained at 0.1 M $NaClO_4$.**
- **Experiments were conducted by adding aged calcite to previously prepared solutions at equilibrium with respect to calcite at desired pH. Np was then added as a spike.**
- **Results show that Np-237 sorption on calcite is significant and dependent on pH.**



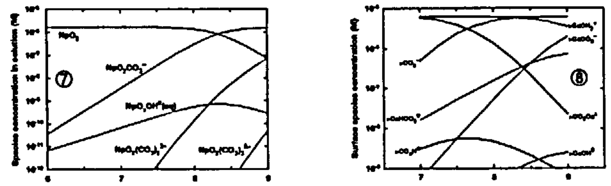
[4] SEM image of aged calcite used in the batch sorption experiments. Reagent-grade calcite was aged for 30 days in 0 02 M $NaHCO_3$ solution.



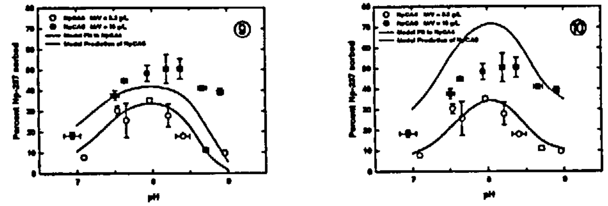
Results of sorption experiments in terms of percent Np-237 sorbed [5] and K_D (mL/g) [6]. M/V refers to the solid mass to solution volume ratio of the experiment. Replicate experiments indicate that experimental uncertainty for solutions with the least amount of calcite is high. Reasons for the uncertainty are being evaluated.

MODELING STUDIES AND RESULTS

- **Comparison of experimental results and Np speciation in solution indicates that Np speciation plays a significant role in sorption behavior..**
- **Two sorption models, one postulating exchange of NpO_2^+ for Ca^{2+} and the other postulating sorption of NpO_2^+ and $NpO_2CO_3^-$, were used to interpret the data.**
- **Both models fit the data reasonably, but the surface complexation model better reproduces the enhanced sorption at high end of the pH range studied.**



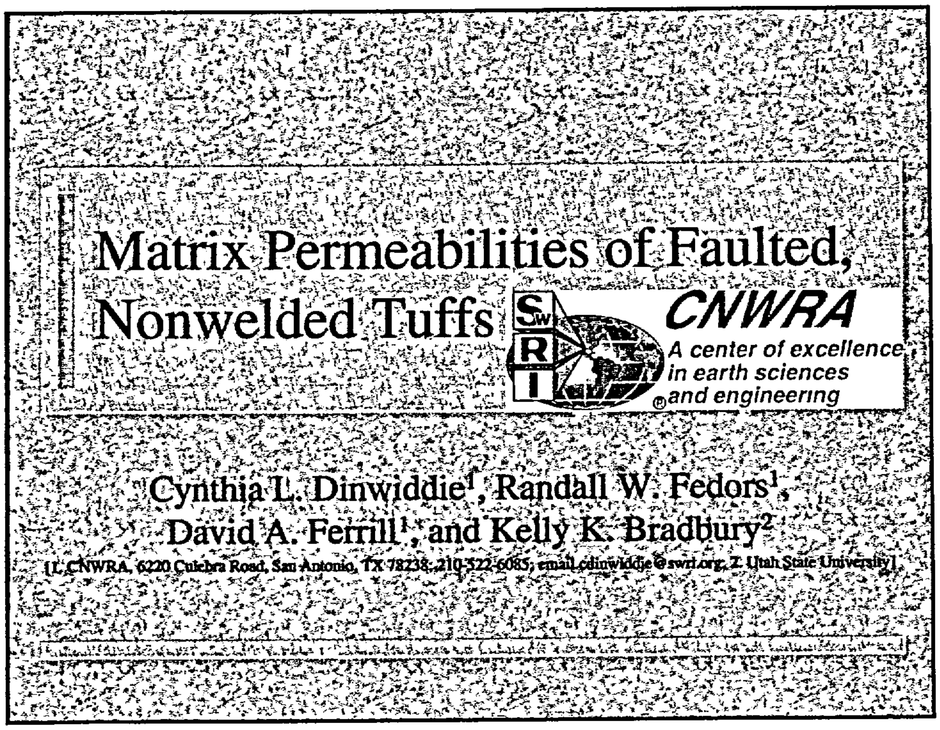
[7] Calculated speciation of 1.6×10^{-6} M Np in 0.1 M $NaClO_4$ and at equilibrium with atmospheric $CO_2(g)$. [8] Calculated calcite surface speciation under the same solution conditions. Surface speciation calculated using a constant capacitance model and the parameters of Van Cappellen et al (1993)



[9] Model fit and prediction results using an ion exchange model similar to that employed by Zachara et al. (1991) for sorption of divalent metals on calcite. [10] Model fit and prediction results using the constant capacitance surface complexation model of Van Capellen et al. (1993) and an assumption of NpO_2^+ and $NpO_2CO_3^-$ sorption.

CONCLUSIONS

- **Under the conditions studied, calcite is an effective sorber of Np. The magnitude of sorption is dependent on pH.**
- **The pH dependency of Np sorption onto calcite suggests that Np speciation in solution plays an important role in sorption behavior.**
- **An ion exchange model and a surface complexation model can be used to describe the sorption of Np-237 onto calcite.**
- **A surface complexation model approach appears to be more effective than an ion exchange model at reproducing the observed behavior over the entire range of pH studied.**
- **Additional experiments are required to address uncertainties (such as significant variation on sorption magnitude between replicate experimental solutions) in experimental data.**



Matrix Permeabilities of Faulted, Nonwelded Tuffs

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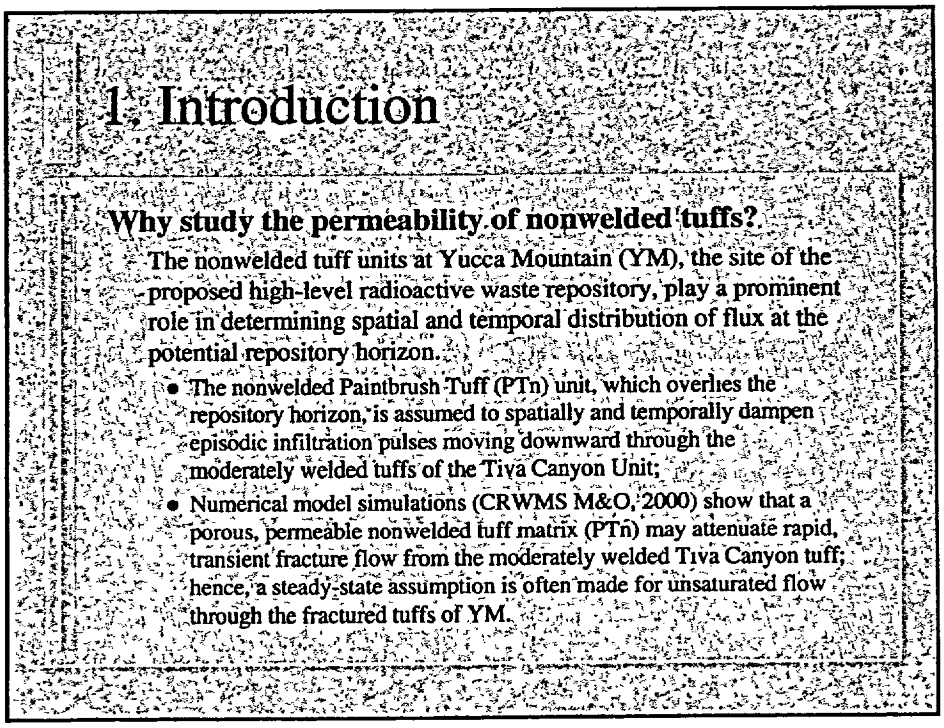
Cynthia L. Dinwiddie[1], Randall W. Fedors[1],
David A. Ferrill[1], and Kelly K. Bradbury[2]
[1. CNWRA, 6220 Culebra Road, San Antonio, TX 78238, 210-522-6085, email.cdinwiddie@swri.org, 2. Utah State University]



1. Introduction

Why study the permeability of nonwelded tuffs?

The nonwelded tuff units at Yucca Mountain (YM), the site of the proposed high-level radioactive waste repository, play a prominent role in determining spatial and temporal distribution of flux at the potential repository horizon.

- The nonwelded Paintbrush Tuff (PTn) unit, which overlies the repository horizon, is assumed to spatially and temporally dampen episodic infiltration pulses moving downward through the moderately welded tuffs of the Tiva Canyon Unit;
- Numerical model simulations (CRWMS M&O, 2000) show that a porous, permeable nonwelded tuff matrix (PTn) may attenuate rapid, transient fracture flow from the moderately welded Tiva Canyon tuff; hence, a steady-state assumption is often made for unsaturated flow through the fractured tuffs of YM.

1. Introduction

The Lateral Flow Theory

Formation of capillary or permeability barriers at lithologic contacts within the PTn unit has been suggested as a possible mechanism that could divert flow laterally away from repository drifts [Wu et al., 2000].

Available data on the heterogeneity of rock properties are currently limited for the PTn—a unit known to be highly variable. There is inadequate basis for modelers to assume ideal lateral flow diversion conditions. The conditions for vertical flow barriers include (1) coarse-grained units with homogeneous hydraulic properties overlain by fine-grained units with homogeneous hydraulic properties; (2) separation of all pertinent units by linear contacts; and (3) low flux rates. Thus, the effect of heterogeneity on potential capillary barrier-induced lateral flow diversion in the vicinity of the PTn requires evaluation.

1. Introduction

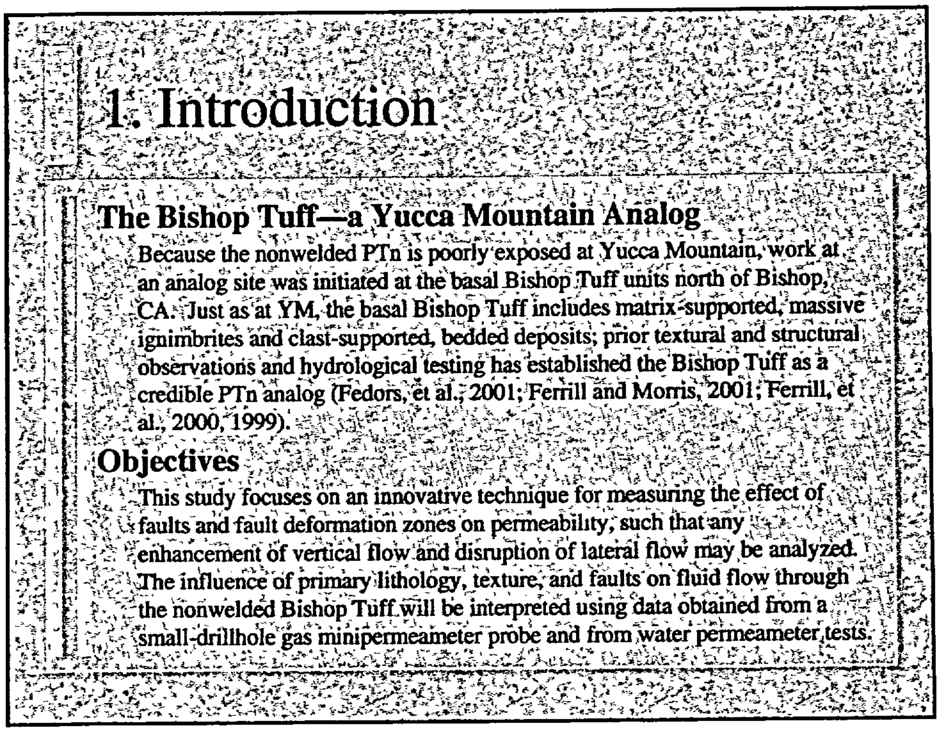
Evidence against the Lateral Flow Theory

Evidence for nonuniform flow, either spatially or temporally as focused episodic percolation, suggests that some episodic infiltration follows fast pathways through the PTn:

- Dilute chemical composition of the perched water below the proposed repository
- Presence of bomb-pulse Cl-36 below the PTn (still controversial)

What is the mechanism for fast flow at YM?

- Large faults likely participate, but these cover a relatively small area
- Primary heterogeneity or secondary discontinuities (e.g. fractures and faults) could serve as preferential flow paths through the PTn and into the underlying welded Topopah Spring Tuff (TSw), thus disrupting the potential for capillary or permeability barriers to divert water laterally away from the repository.



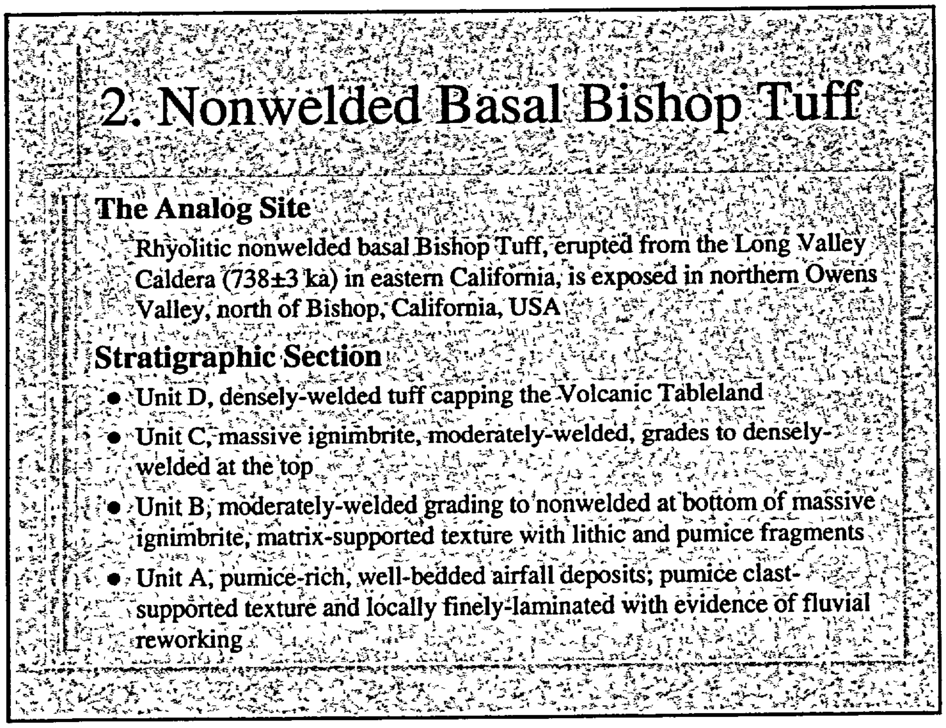
1. Introduction

The Bishop Tuff—a Yucca Mountain Analog

Because the nonwelded PTn is poorly exposed at Yucca Mountain, work at an analog site was initiated at the basal Bishop Tuff units north of Bishop, CA. Just as at YM, the basal Bishop Tuff includes matrix-supported, massive ignimbrites and clast-supported, bedded deposits; prior textural and structural observations and hydrological testing has established the Bishop Tuff as a credible PTn analog (Fedors, et al., 2001; Ferrill and Morris, 2001; Ferrill, et al., 2000, 1999).

Objectives

This study focuses on an innovative technique for measuring the effect of faults and fault deformation zones on permeability, such that any enhancement of vertical flow and disruption of lateral flow may be analyzed. The influence of primary lithology, texture, and faults on fluid flow through the nonwelded Bishop Tuff will be interpreted using data obtained from a small-drillhole gas minipermeameter probe and from water permeameter tests.



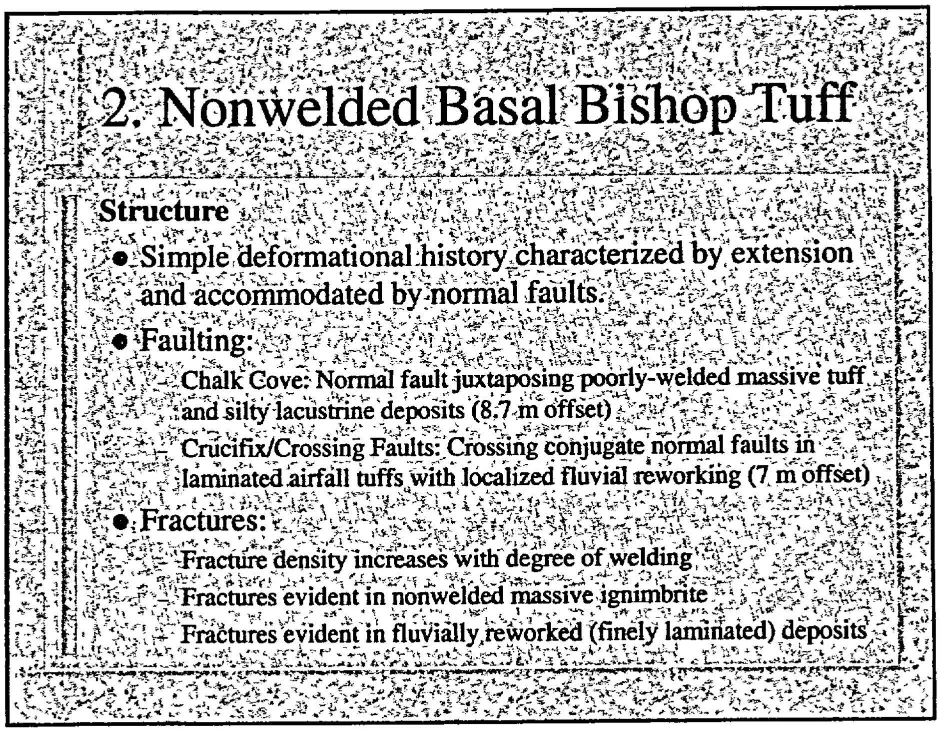
2. Nonwelded Basal Bishop Tuff

The Analog Site

Rhyolitic nonwelded basal Bishop Tuff, erupted from the Long Valley Caldera (738±3 ka) in eastern California, is exposed in northern Owens Valley, north of Bishop, California, USA

Stratigraphic Section

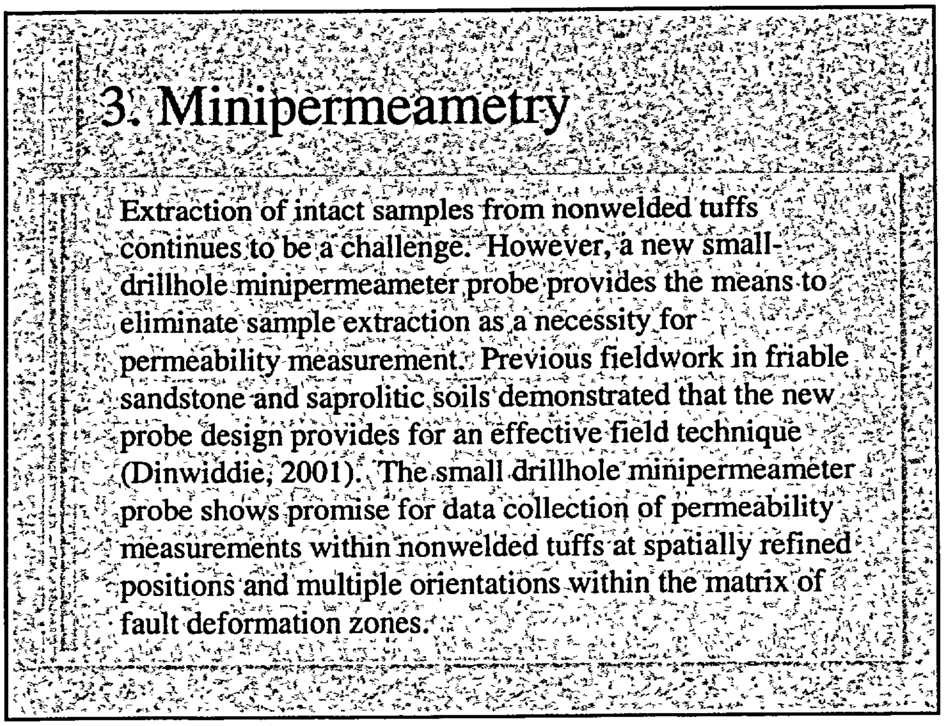
- Unit D, densely-welded tuff capping the Volcanic Tableland
- Unit C, massive ignimbrite, moderately-welded, grades to densely-welded at the top
- Unit B, moderately-welded grading to nonwelded at bottom of massive ignimbrite, matrix-supported texture with lithic and pumice fragments
- Unit A, pumice-rich, well-bedded airfall deposits; pumice clast-supported texture and locally finely-laminated with evidence of fluvial reworking



2. Nonwelded Basal Bishop Tuff

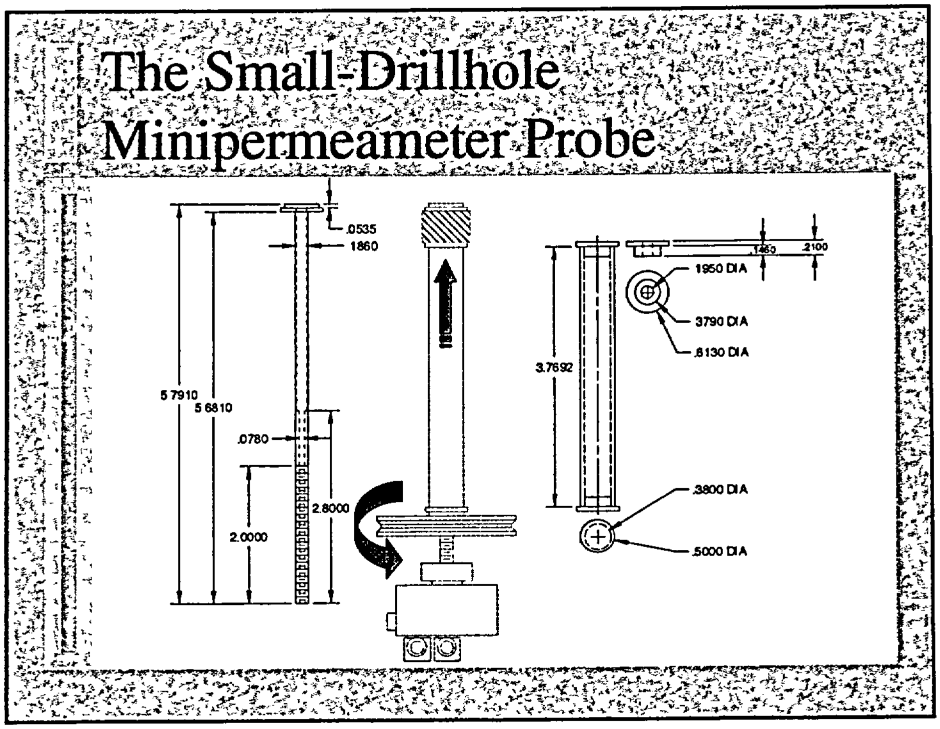
Structure

- Simple deformational history characterized by extension and accommodated by normal faults.
- Faulting:
  - Chalk Cove: Normal fault juxtaposing poorly-welded massive tuff and silty lacustrine deposits (8.7 m offset)
  - Crucifix/Crossing Faults: Crossing conjugate normal faults in laminated airfall tuffs with localized fluvial reworking (7 m offset)
- Fractures:
  - Fracture density increases with degree of welding
  - Fractures evident in nonwelded massive ignimbrite
  - Fractures evident in fluvially reworked (finely laminated) deposits

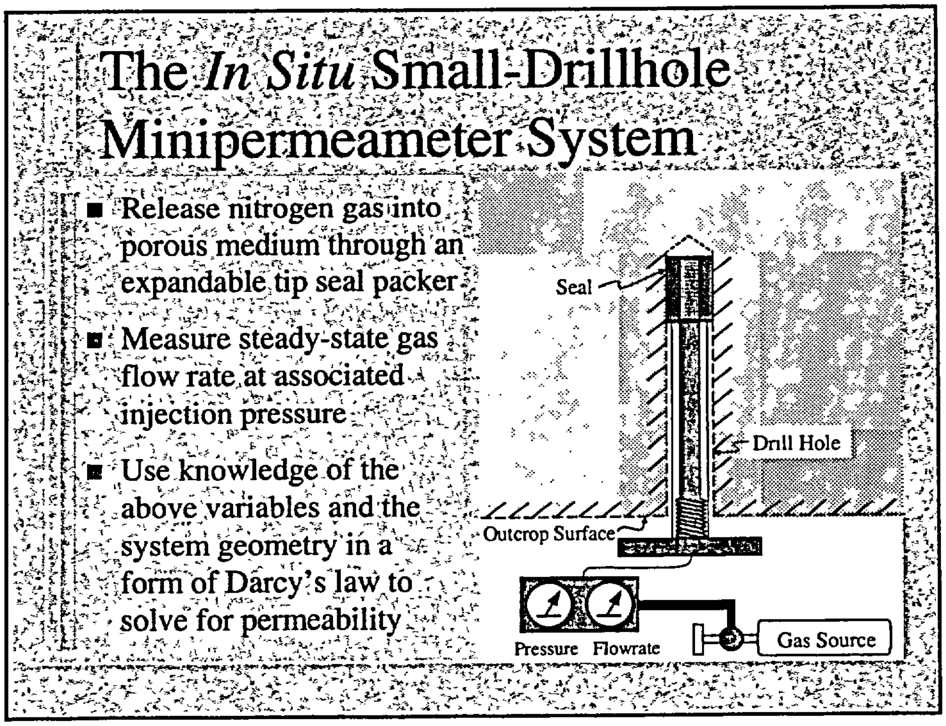


3. Minipermeametry

Extraction of intact samples from nonwelded tuffs continues to be a challenge. However, a new small-drillhole minipermeameter probe provides the means to eliminate sample extraction as a necessity for permeability measurement. Previous fieldwork in friable sandstone and saprolitic soils demonstrated that the new probe design provides for an effective field technique (Dinwiddie, 2001). The small drillhole minipermeameter probe shows promise for data collection of permeability measurements within nonwelded tuffs at spatially refined positions and multiple orientations within the matrix of fault deformation zones.



The Small-Drillhole Minipermeameter Probe



The *In Situ* Small-Drillhole Minipermeameter System

- Release nitrogen gas into porous medium through an expandable tip seal packer
- Measure steady-state gas flow rate at associated injection pressure
- Use knowledge of the above variables and the system geometry in a form of Darcy's law to solve for permeability

Calculation of Apparent Permeability, k_g

- For 2-D flow from a minipermeameter, Darcy's law is:

$$k_g = \frac{\mu_g q_1 P_1}{B G_o \left[\frac{P_1^2 - P_0^2}{2} \right]}$$

- where
  μ_g = viscosity of N_2 gas at P_1 and $T_{ambient}$, known
  q_1 = volumetric flow rate, measured
  B = drillhole radius (0.9 cm)
  G_o = geometrical factor, from a numerical solution
  P_1 = injection pressure, measured
  P_0 = atmospheric pressure, known

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4. *In situ* Permeability Measurements

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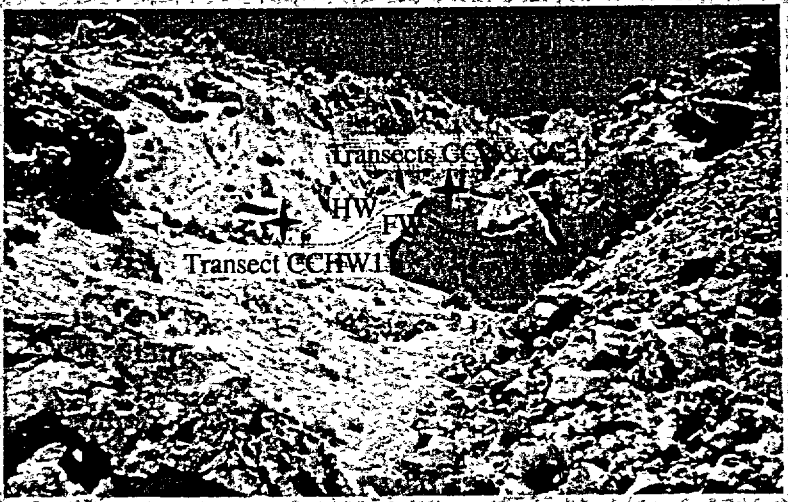
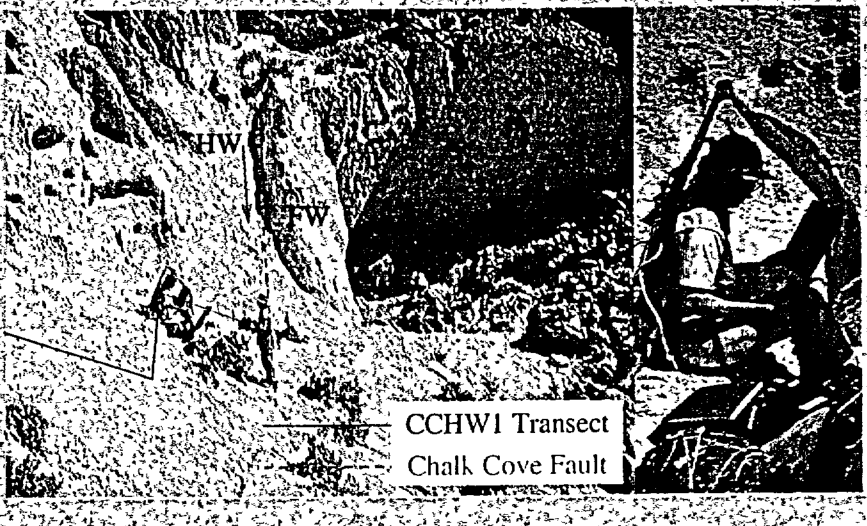
CLD, 10/27/11

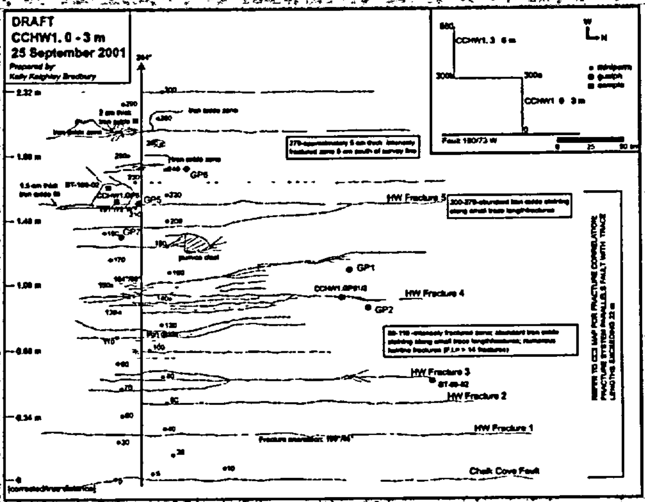
Chalk Cove Fault, Bishop, CA



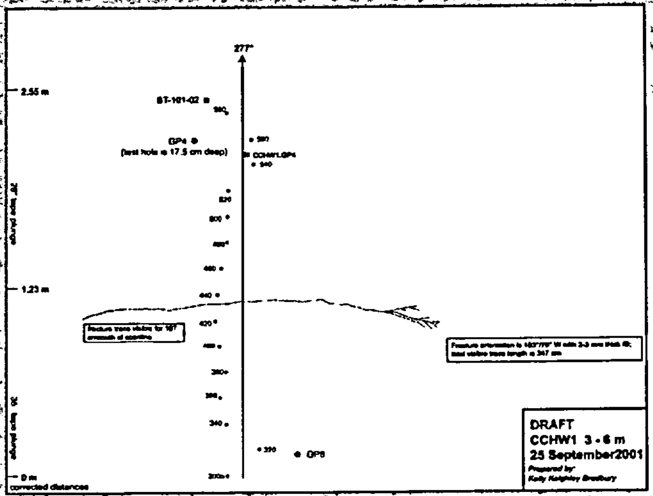
Chalk Cove Fault:
Lower Bench—Transect CCHW1

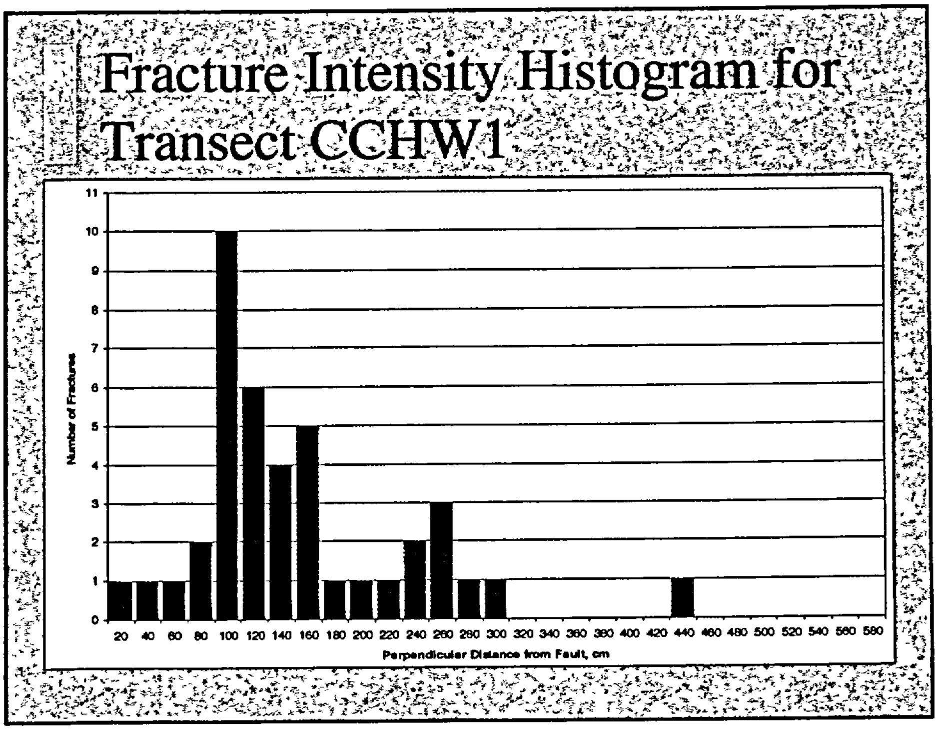


Fracture Map of Transect CCHW1.0-3 m

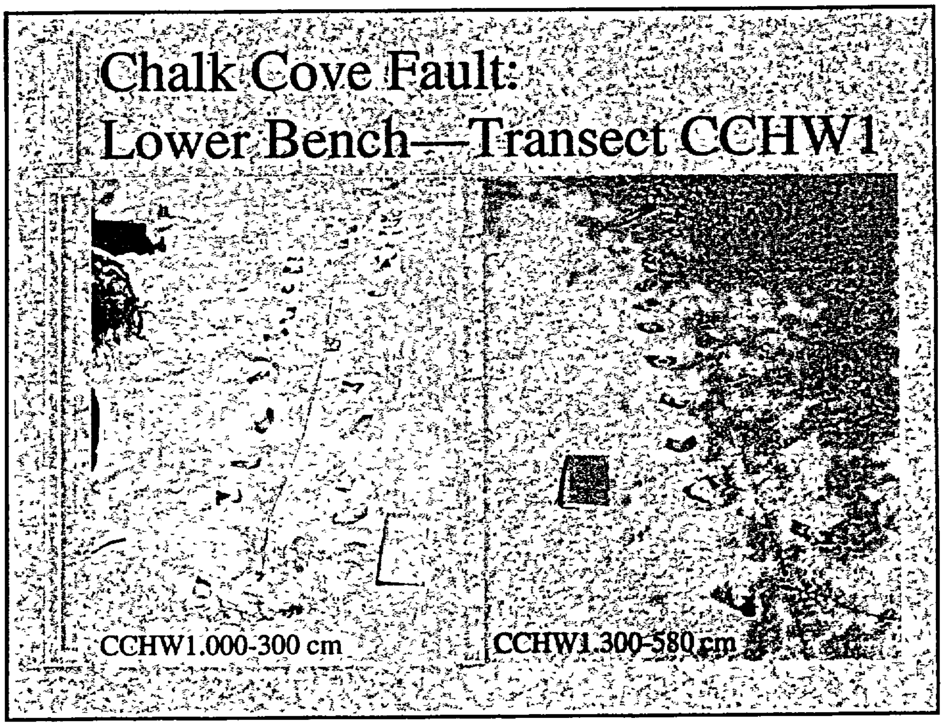


Fracture Map of Transect CCHW1.3-6 m





Fracture Intensity Histogram for Transect CCHW1

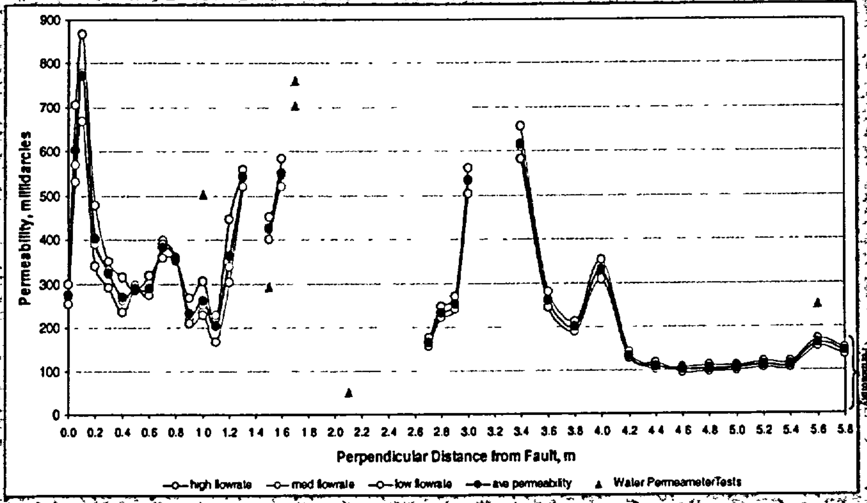


Chalk Cove Fault: Lower Bench—Transect CCHW1

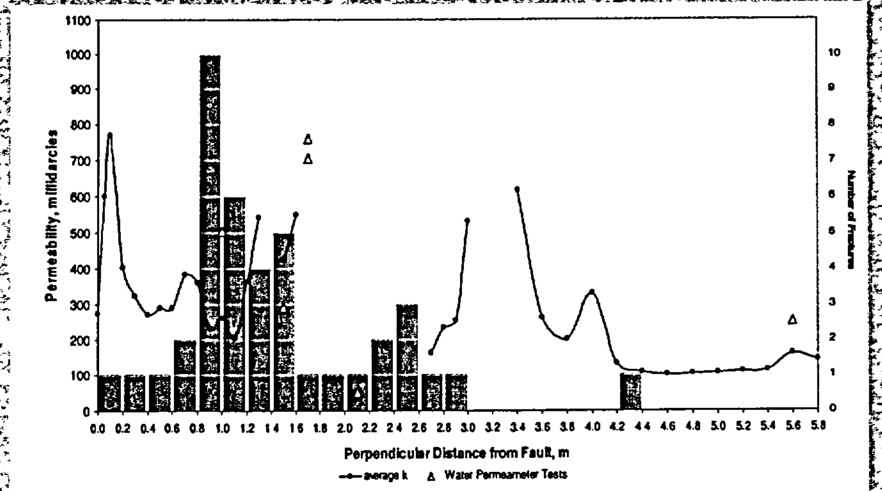
CCHW1.000-300 cm

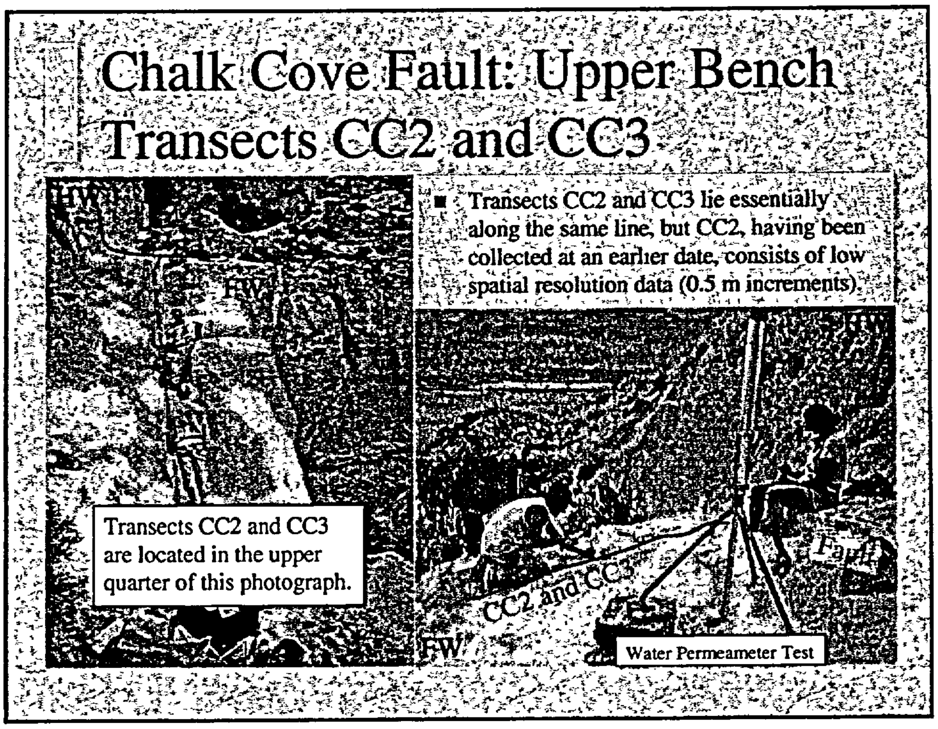
CCHW1.300-580 cm

Permeability of the Chalk Cove Hanging Wall—Transect CCHW1



Fracture Intensity and Permeability—Transect CCHW1



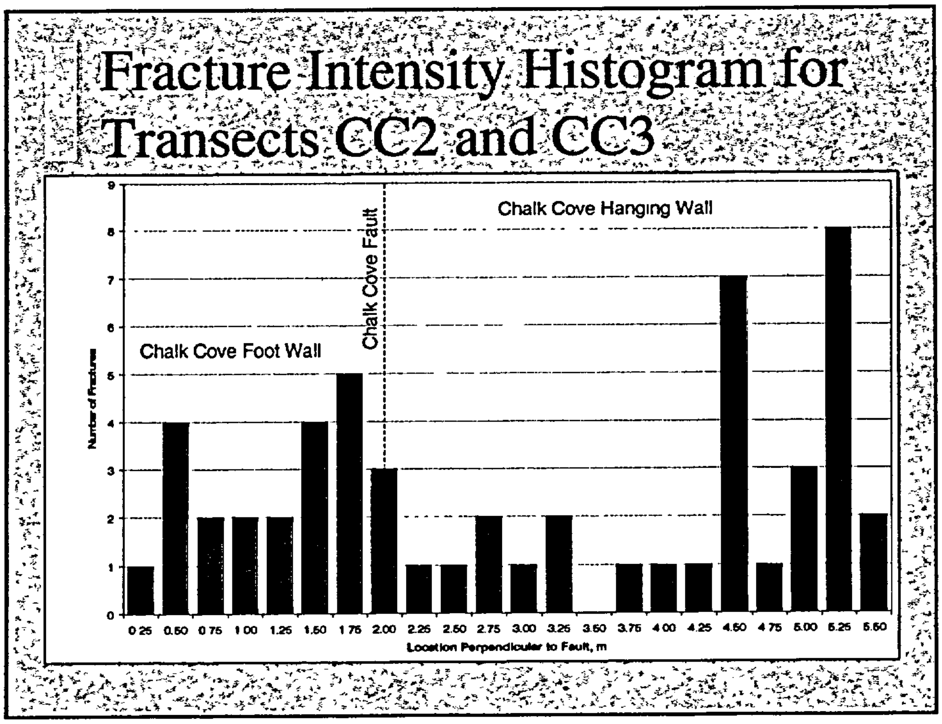


Chalk Cove Fault: Upper Bench Transects CC2 and CC3

- Transects CC2 and CC3 lie essentially along the same line, but CC2, having been collected at an earlier date, consists of low spatial resolution data (0.5 m increments).

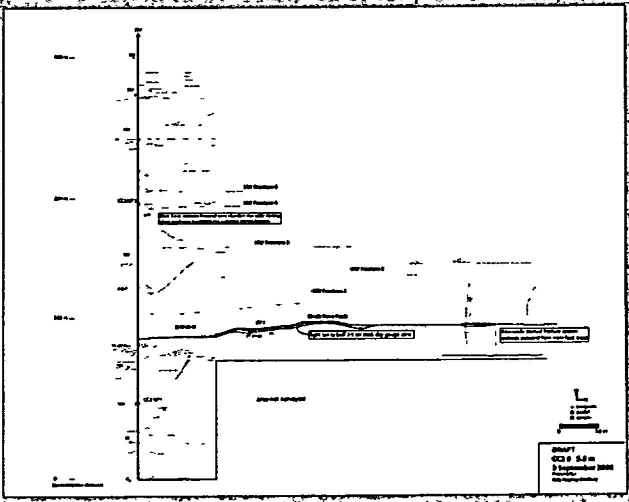
Transects CC2 and CC3 are located in the upper quarter of this photograph.

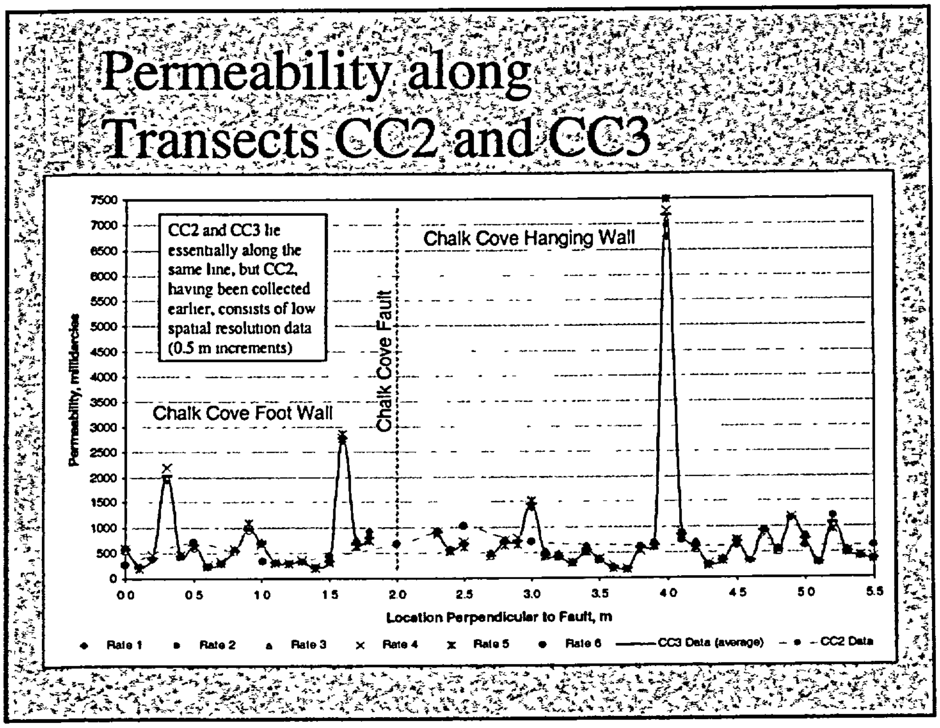
Water Permeameter Test



Fracture Intensity Histogram for Transects CC2 and CC3

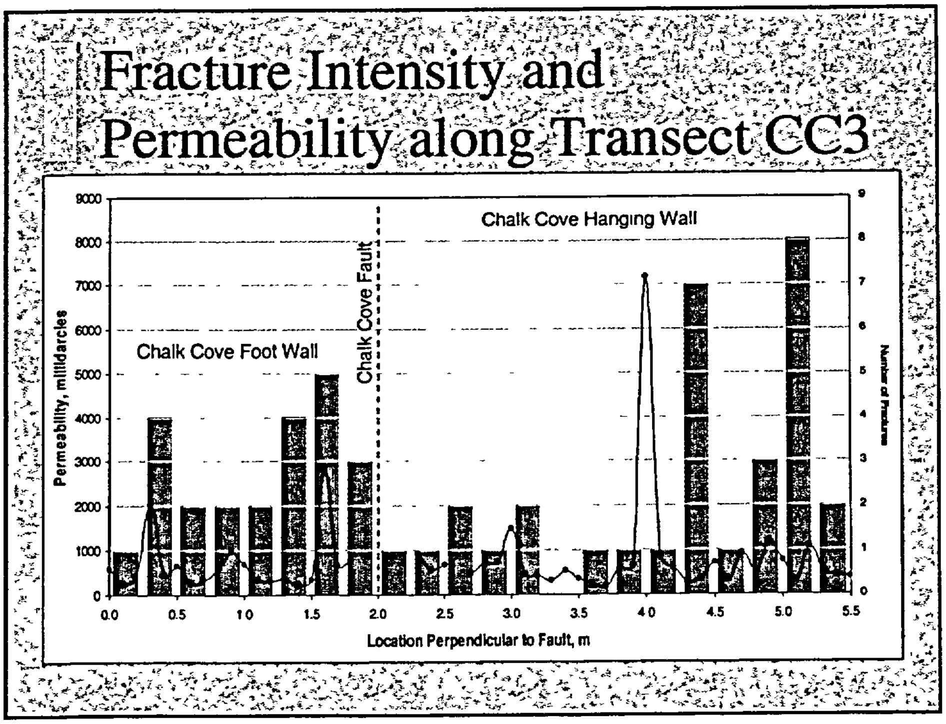
Fracture Map, Transect CC2





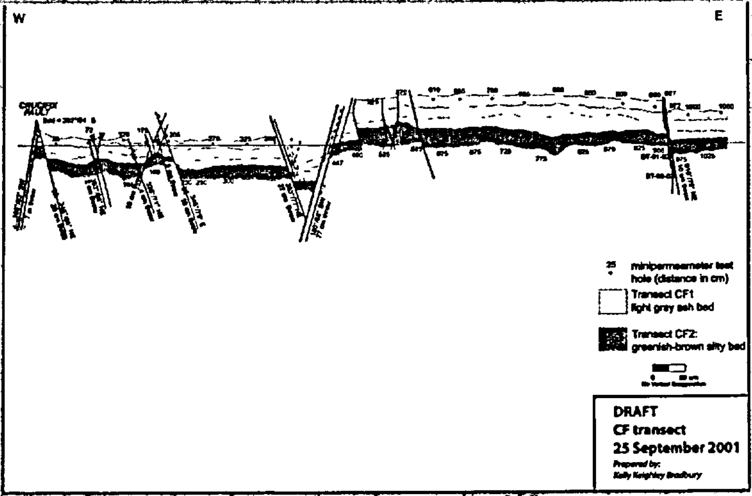
Permeability along Transects CC2 and CC3

CC2 and CC3 lie essentially along the same line, but CC2, having been collected earlier, consists of low spatial resolution data (0.5 m increments)

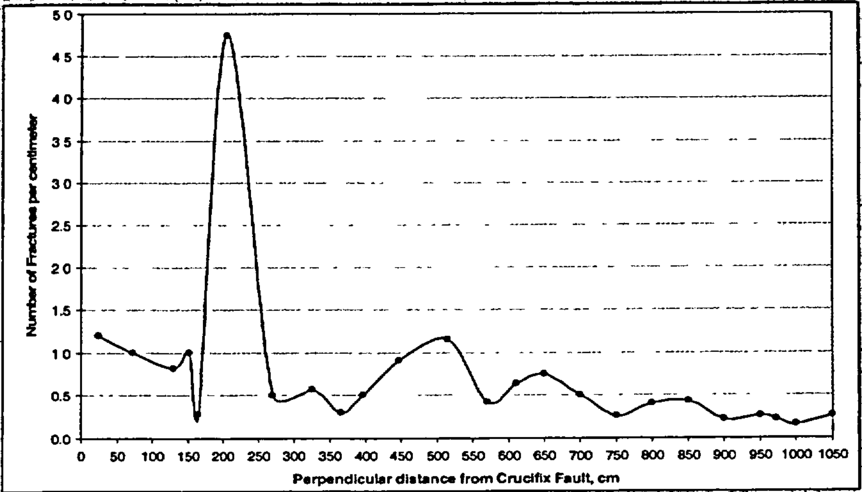


Fracture Intensity and Permeability along Transect CC3

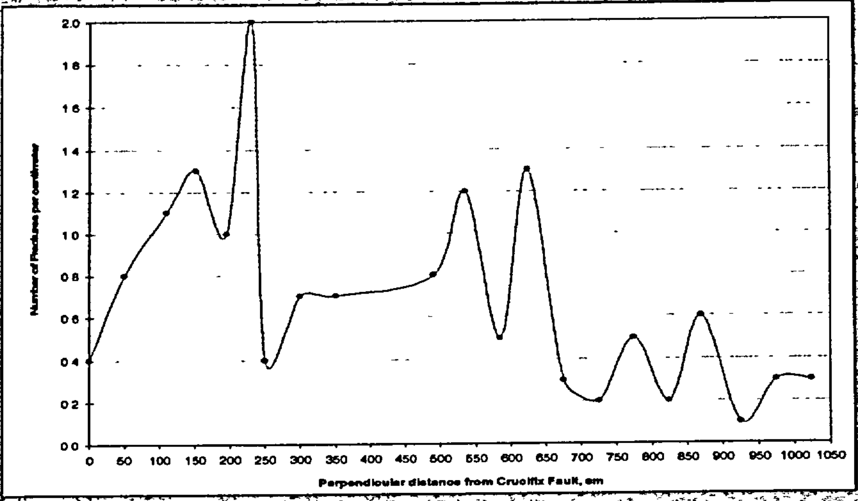
Crucifix/Crossing Faults Site



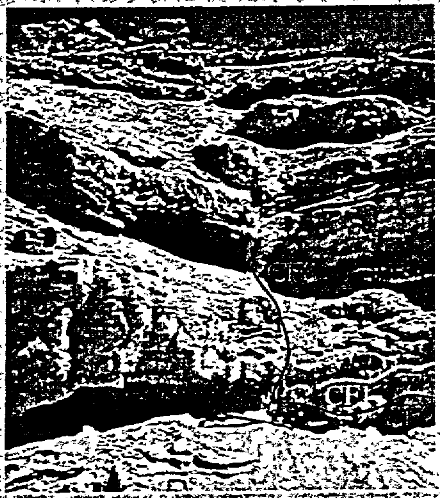
Fracture Frequency, Transect CF1

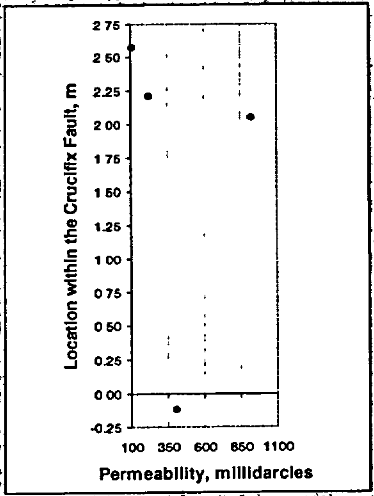


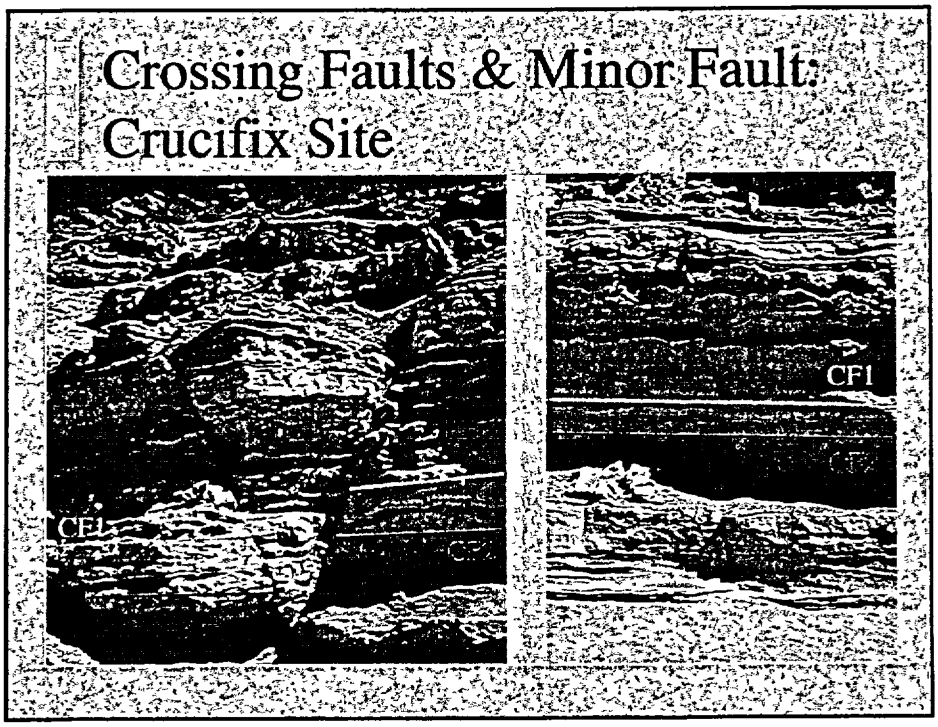
Fracture Frequency, Transect CF2



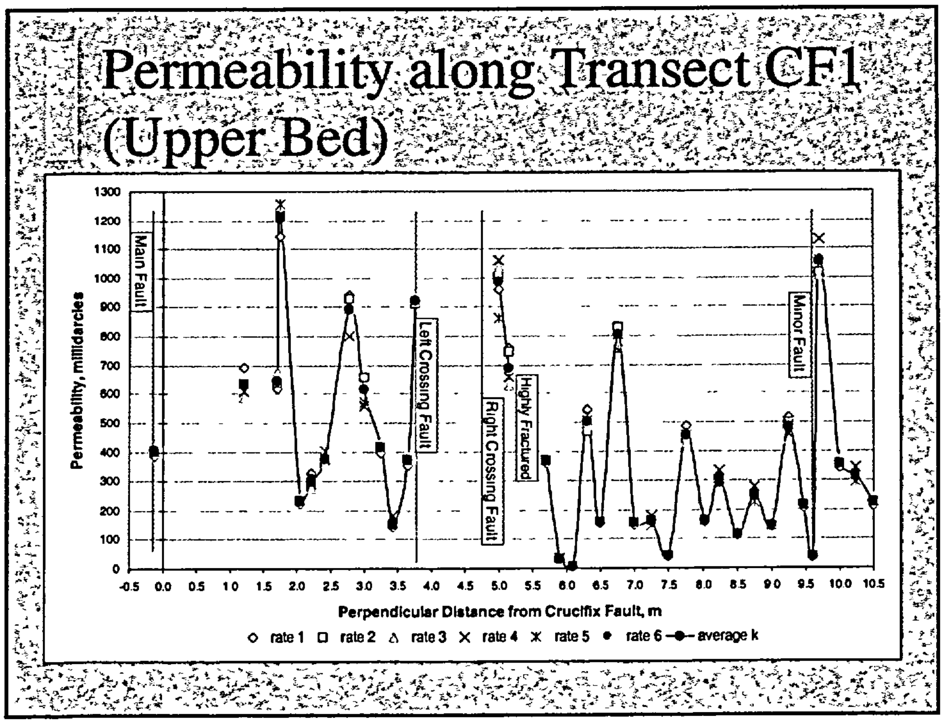
Permeability within Gouge of the Crucifix Fault (Profile CF3)



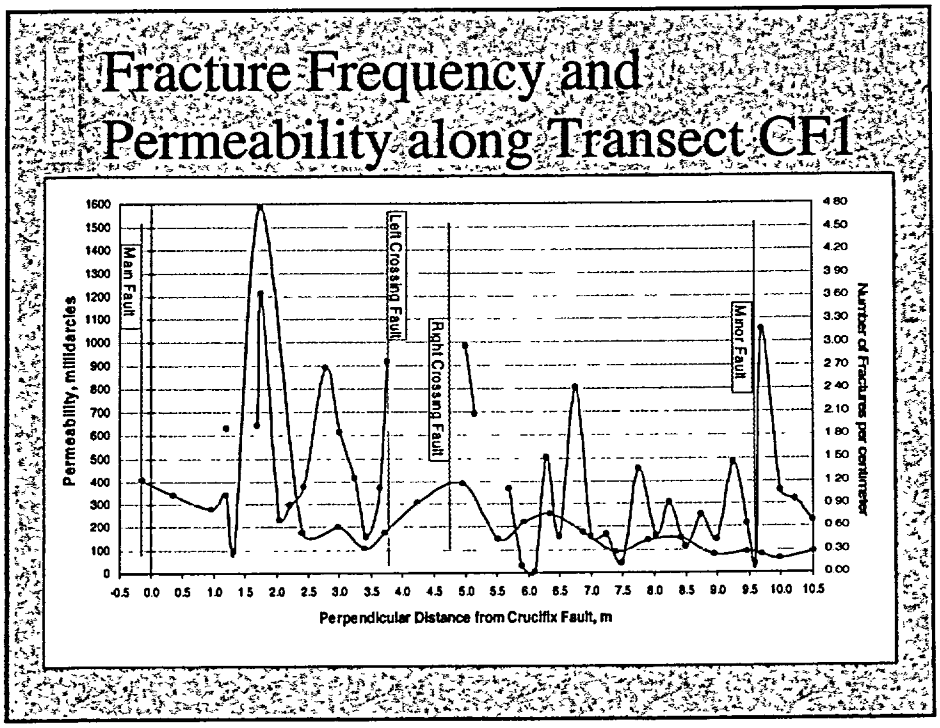




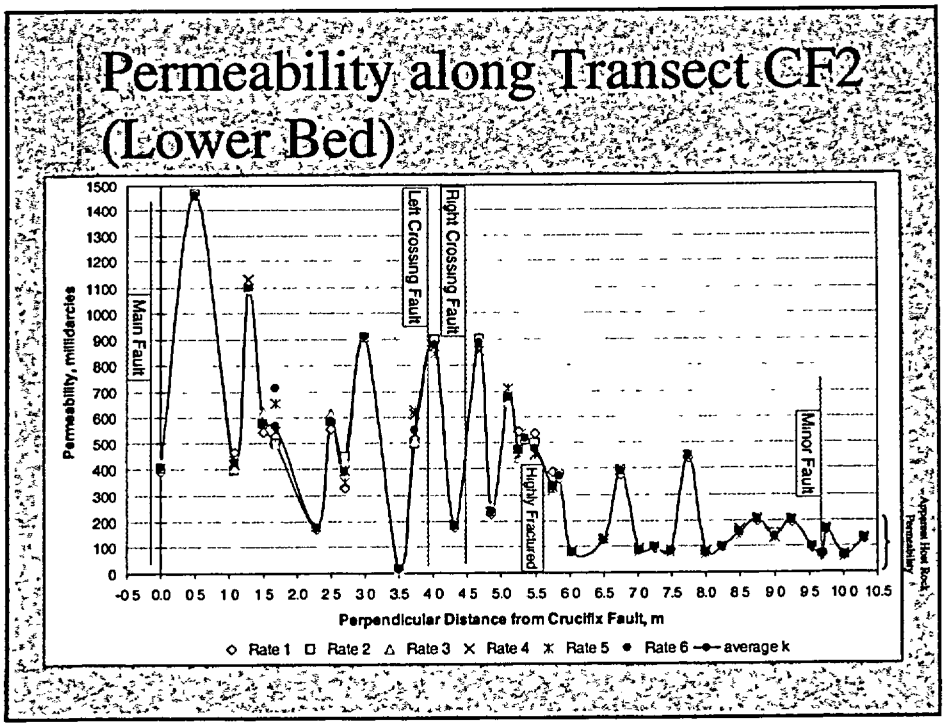
Crossing Faults & Minor Fault: Crucifix Site



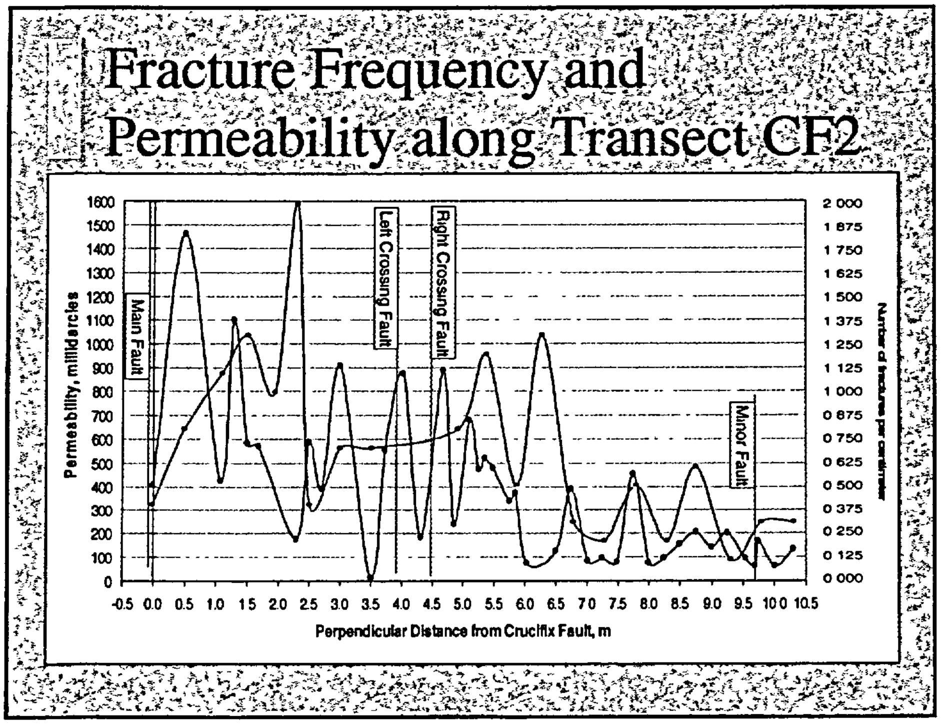
Permeability along Transect CF1 (Upper Bed)



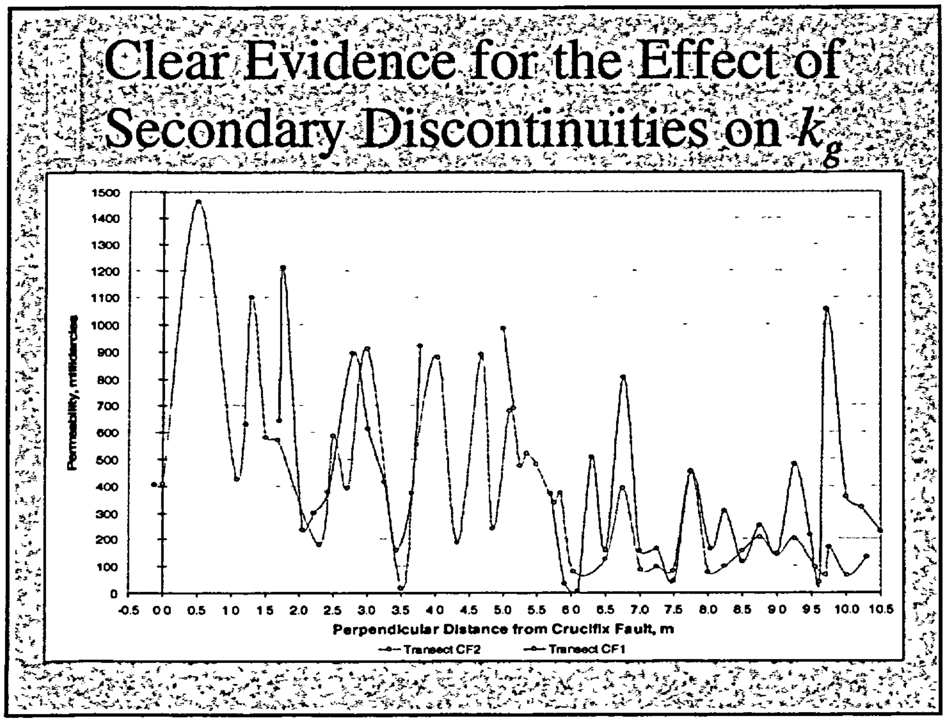
Fracture Frequency and Permeability along Transect CF1



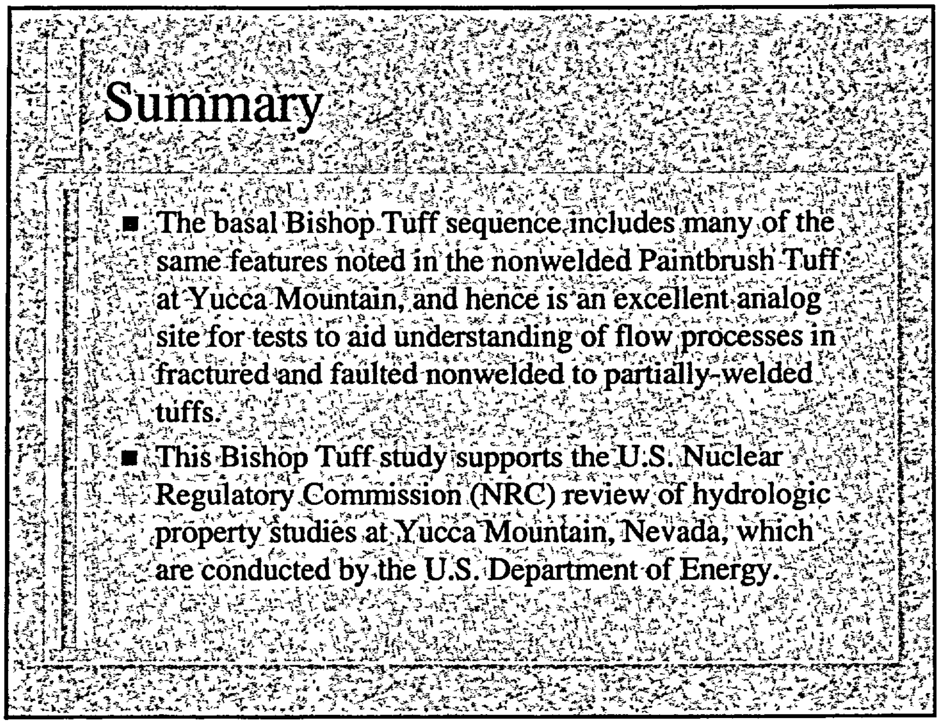
Permeability along Transect CF2 (Lower Bed)



Fracture Frequency and Permeability along Transect CF2

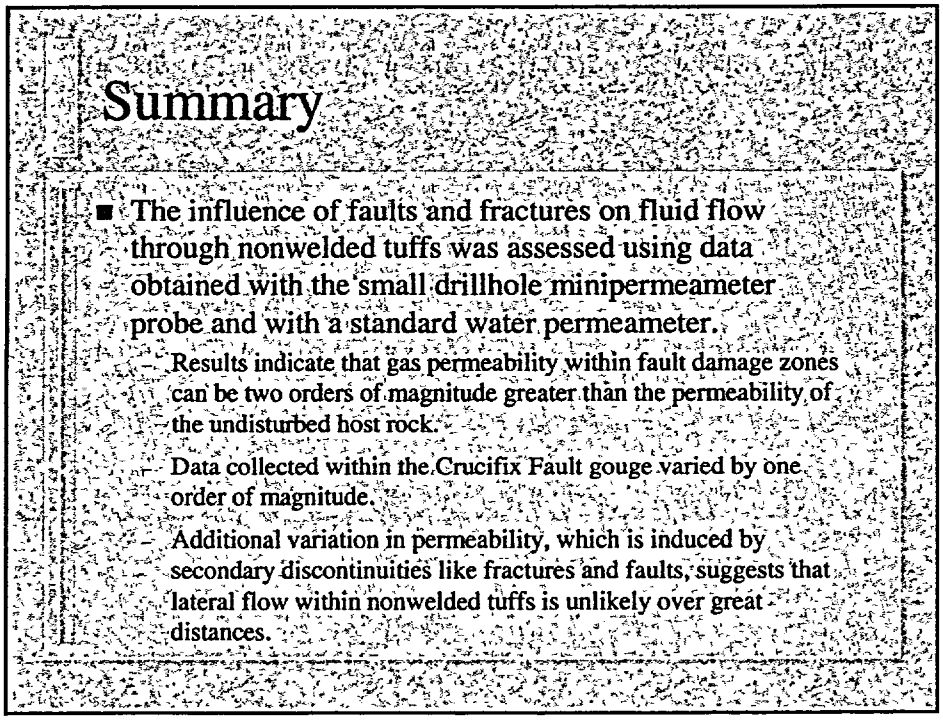


Clear Evidence for the Effect of Secondary Discontinuities on k_g



Summary

- The basal Bishop Tuff sequence includes many of the same features noted in the nonwelded Paintbrush Tuff at Yucca Mountain, and hence is an excellent analog site for tests to aid understanding of flow processes in fractured and faulted nonwelded to partially-welded tuffs.
- This Bishop Tuff study supports the U.S. Nuclear Regulatory Commission (NRC) review of hydrologic property studies at Yucca Mountain, Nevada, which are conducted by the U.S. Department of Energy.



Summary

- The influence of faults and fractures on fluid flow through nonwelded tuffs was assessed using data obtained with the small drillhole minipermeameter probe and with a standard water permeameter.
  - Results indicate that gas permeability within fault damage zones can be two orders of magnitude greater than the permeability of the undisturbed host rock.
  - Data collected within the Crucifix Fault gouge varied by one order of magnitude.
  - Additional variation in permeability, which is induced by secondary discontinuities like fractures and faults, suggests that lateral flow within nonwelded tuffs is unlikely over great distances.

Unit Conversions

$1\ \text{m} = 3.28\ \text{ft}$

$1\ \text{cm} = 0.39\ \text{in}$

$1\ \text{m}^2 = 1.013\times10^{12}$ Darcies

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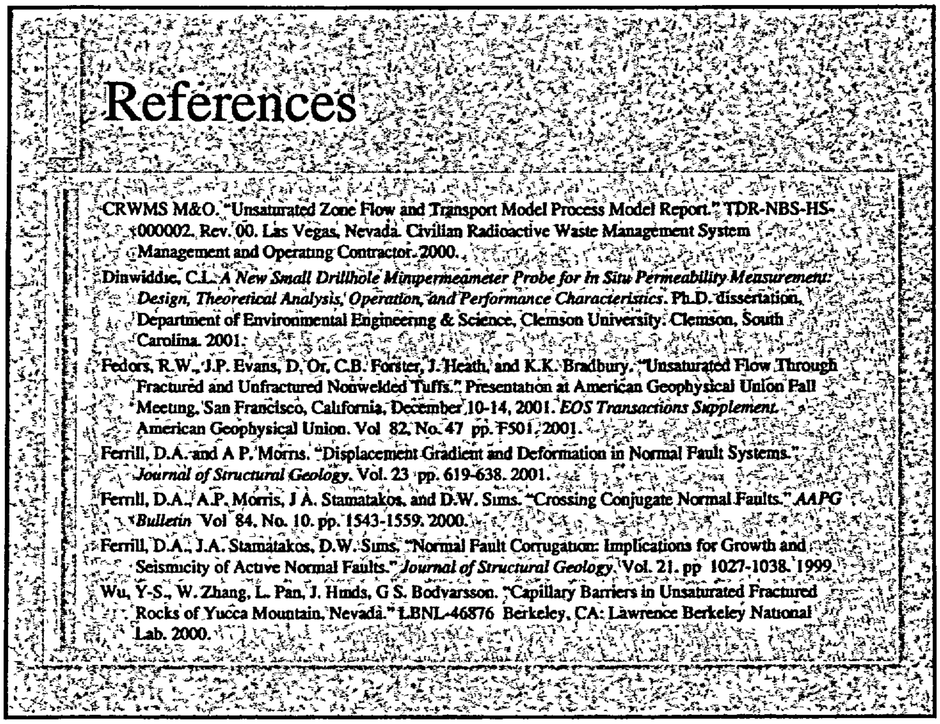

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