LABORATORY NOTEBOOK

CNWRA/SwRI

NOTEBOOK NO. 620

ISSUED TO ____________________

ON ____________________ **20**____

DEPARTMENT ____________________

RETURNED ____________________ **20**____

Continuation of Sci. Ntbk #515 and #583 issued to Cynthia Dinwiddie for consultant Kelly K. Bradbury.

KKB ⇒ Kelly Keighley Bradbury

CLD ⇒ Cynthia L. Dinwiddie

SCIENTIFIC NOTEBOOK COMPANY
2831 LAWRENCE AVENUE
STEVENSVILLE, MICHIGAN 49127
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Project Summary - Continuation of fieldwork, labwork, and interpretation ~~of~~ CLD, 09/17/04 related to the study of fractures and faults in the poorly to nonwelded Bishop Tuff.

Work conducted with by Kelly Keighley-Bradbury
Cynthia Dinwiddie
Randy Fedors
David Ferrill
Don Bannon
Dick Heermance
Ronny McGinnis

of CNWRA to interpret structural architecture and fracture characteristics with permeability tests at the outcrop scale (cm's to m's)

Note that some pages have a second xerox taped over the original xerox. None of the informational content of the original xerox was changed in the overlying xerox, which can be verified by the reader because both copies Remain in the scientific notebook. The overlying copy is more readable than the original copy.

This is a continuation of CNWRA Scientific Notebook #583

CLD, 09/17/04

Witnessed & Understood by me, CLD
Date 10/13/03
Recorded by Better copy, CLD
Date 11/13/03

USU LAB KKB 6/17/03

BT-103 - TS3 -
- faultrock/gouge frac mosaics
- 47 pics
- sevel mosaics
- all @ 4x mag

BT-91-TS2 -
Direction of mosaic
. 4x mag.
. 44 pics of frac mosaics

BT-91-TS1 -
. 1st frac mosaic series @ 4x mag
. 2nd frac mosaic series @ 10x mag
(series start w/ micro frac @ edge of slide w/ Qtz xl to the upper left)
• 42 pics total

CLD 10/13/03
KKB 6/18/03

Chalk Cove outline - + review of relevant files
Bishop > papers 2 submit >
. CC outline . doc
. CC paper
Bishop > chalk cove sit
maps → CC2_CC3
Ccflt map.ai
Cchwla
Cchwlb
+ microstruc samples from CC site
• BASED ON outline for paper w/ 1st author C. Dinwiddie after email correspondance she would like me to write for sections →
I. A. i, iii, iv B. i - method
II. A. Lith & Deform - Meso Sc.
B. i Lith & Deform enviro.
III. microscale / Lab an
V. B. Discussion
6/24/03 KKB

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GTD 11/18/03

USW~~[illegible]~~ ~~p68~~ CLD 11/13/03 KKB 6/17/03

BT-103-TS3 —
- fault rock / gouge frac mosaics
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BT-91-TS2 —

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CLD 11/13/03

KKB ~~6/18~~ 6/18/03

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- CC outline .doc
- CC paper

Bishop > chalk cove site > maps → CC2_CC3
CCflt map.ai
CChwla
CChwlb

+ microstruce samples from CC site

- BASED ON outline for paper w/ 1st author C. Dinwiddie after email correspondance she would like me to write for sections →
  I. A. i, iii, iv $\overset{B.\,C}{}$ methods
  II. A. Lith & Deform - Meso Scale
  B. i. Lith & Deform enviro.
  III. microscale / Lab analys
  V. B. Discussion

L 6/24/03 KKB

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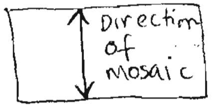
USW

KKB 6/17/03

BT-103-TS3 –
- fault rock / gouge frac mosaics
- 47 pics
- sevel mosaics
- all @ 4x mag

BT-91-TS2 –



· 4x mag.
· 44 pics of frac mosaics

BT-91-TS1 –
· 1st frac mosaic series @ 4x mag
· 2nd frac mosaic series @ 10x mag
(series start w/ micro frac @ edge of slide w/ Qtz xl to the upper left)
· 42 pics total

CLD 10/13/03

KKB 6/18

Chalk Cave outline –
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CCflt map.ai
CChwla
CChwlb
+ microstruc samples from CCS
· BASED ON outline for paper w/ 1st author C. Dinwidc after email correspanda she would like me to write for sections → B. i
I. A. i, iii, iv
II A. Lith & Deform – Meso. metr
B. i Lith & Deform envir
III. microscale / Lab
V. B. Discussion

6/24/03 KKB

Witnessed & Understood by me, CLD
Date 10/13/03
Invented by
Recorded by
repeat of page 1, this SN
Date CLD 11/13/03

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CLD 10/13/03 KKB 6/19-6/20/03

* Pack up samples for sieve & thin section @ USU -
- Box cut rocks - id
- Box sieved + unused grain size samples

- Boxes stored @ USU room 115 Geol Dept for temporary storage

CLD 10/13/03
KKB 6/23/0

contract renewal -
- Forms
- email correspondance w/ Shirlee Garcia
- CoI letter -> cnura coilett
(above rewritten below by CLD, 7/22/10)
- Forms
- email correspondance w/ Shirlee Garcia
- CoI letter -> cnura coilett

CLD 10/13/03

Witnessed & Understood by me, CLD

Date 10/13/03

Invented by

Recorded by Better copy, CLD

Date 11/13/03

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BOOK NO. GTF 11/13/03

3

CLD 11/13/03
~~070~~

KKB 6/19-6/20/03

* Pack up samples for sieve & thin section @ USU –
  - Box cut rocks – id
  - Box sieved + unused grain size samples
  - Boxes stored @ USU room 115 Geol Dept for temporary storage

CLD 11/13/03

CLD, 11/13/03
~~071~~

KKB 6/23/03

contract renewal –
- Forms
- email correspondence w/ Shirlee Garcia
- C.o.I. letter – ? ceiling

CLD, 11/13/03

CLD 10/13/03
* Pack up samples for sieve & thin section @ USU
  - Box cut rocks
  - Box sieved + unused grain size samples
  - Boxes stored @ USU room 115 Geol Dept for temporary storage

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CLD	10/13/03	Recorded by: Better copy, CLD	11/13/03

CLD 10/13/03

KKB 6/24/03

sieve analysis

Enter Data from CF1 sieve sample Spreadsheet onto ibook -
filepath >
Bishop > grainsize analysis
> CF grainsize analysis
> CF1grszdata

- update personal copy of cc outline
highlight in red text ideas for pg 105
Bishop > papers to 2 submit > ccoutline.doc
~12 figures total - assume from outline responsible for 10 of these figures (Fig 1-10)

C Dinwiddie possibly has better photos for Fig 1 & 3 Check w/ her KKB 6/25/03

CLD 10/13/03

CLD 10/13/03

KKB 6/25/03

cc paper

- Review updated outline emailed from C. Dinwiddie

- Review paper submitted by JP Evans & KK Bradb
- highlight relevant topics for this new paper to avoid repeat in material

rewritten here by CLD 7/22/10

- update personal copy of cc outline
highlight in red text ideas for pg 105
Bishop > papers 2 submit > ccoutline.doc
~12 figures total
assume from outline responsible for 10 of these figures
(Fig 1-10)

C Dinwiddie possibly has better photos for Fig 1 & 3 Check w/ her KKB

Witnessed & Understood by me, CLD Date 10/13/03

Invented by

Recorded by Better copy, CLD Date 11/13/03

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BOOK NO. GTD 11/13/03

TITLE GTD 11/13/03

Project No.

CLD 11/13/03

~~072~~

KKB 6/24/03

Sieve analysis

Enter Data from Cf 1
Sieve sample Spreadsheet
onto ibook –
filepath >
Bishop > grainsize analysis
> CF grainsize analysis
> CF 1grSZdata

CLD, 11/13/03

~~072~~

KKB 6/25/03

cc paper

- Review updated outline emailed from C. Dinwiddie
- Review paper submitted by JPEvans & KKBradbury
  - highlight relevant topics for this new paper to avoid repeat in material
- update personal copy of cc outline
  highlight in red text ideas for paper
  Bishop > papers2submit > CCoutline.doc
  ~12 figures total –
  assume from outline responsible for 10 of these figures
  (Fig 1-10)

C.Dinwidde possibly has better photos for Fig 1 3 ~~&~~ (Check w/ her!) KKB 6/25/03

CLD 10/13/03
Sieve analysis
KKB
Enter Data from Cf 1
Sieve sample Spreadsh
onto ibook –
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better photos for Fig 1 & 3
Check w/ her KKB 6/25
CLD 10/13/03

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CLD 10/13/03

USU LAB KRB 6/26/03

microstructure analysis
photomicrograph pictures (continued)

BT-92 – TS1 –
- Lithologic photograph focus
- 14 pics @ 4x mag

BT-93 · TS1 –
- Lithology focus – strat
- @ 4x mag (10 pics)

BT-94 – TS1 –
- Lithology focus
- @ 4x mag (15 pics)

BT-96 – TS1 –
- Lithology

TOP (Label ID) | mosaic Direction → | BOTTOM

- (12 pics) @ 4x mag

CLD 10/13/03

USU LAB KKB ~~6/26/0~~

BT-97 – TS1 –
- Lithology focus
- 1 pic @ 4x mag
- 3 pics @ 10x mag

orientation of pics taken in this dir → | combination photos // to long axis of

BT-98 – TS1
- Flattened pumice cl[...] suggest higher degr[...] of welding
- matrix/lithology
- 5 pics @ 4x mag

←→ pics taken // to [...] axis

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Date

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Date 11/13/03

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USU LAB #4 CLD, 11/13/03 KRB 6/26/03

microstructure analysis

photomicrograph pictures (continued)

BT-92 – TS1 –
- Lithologic photograph focus
- 14 pics @ 4x mag

BT-93 · TS1 –
- Lithology focus – strat
- @ 4x mag (10 pics)

BT-94 – TS1 –
- Lithology focus
- @ 4x mag (15 pics)

BT-96 – TS1 –
- Lithology

TOP (Label ID) mosaic Direction BOTTOM

- (12 pics) @ 4x mag

CLD, 11/13/03

USU LAB KKB 6/26/03

BT-97 – TS1 –
- Lithology focus
- 1 pic @ 4x mag
- 3 pics @ 10x mag

Orientation of pics taken in mosaic — combination of photos // to long axis of slide

BT-98 – TS1
- Flattened pumice clasts suggest higher degree of welding
- matrix / lithology focus
- 5 pics @ 4x mag

pics taken // to long axis

USU LAB CLD 10/13/03 KRB
microstructure analysis
photomicrograph pictures (con
BT-92 – TS1 –
- Lithologic photo
- 14 pics @ 4x
BT-93 · TS1 –
Lithology focus –
@ 4x mag (10 pi
BT-94 – TS1 –
Lithology focu
- @ 4x mag (1
BT-96 – TS1 –
Lithology
TOP (Label ID) mosaic Direction BOT
- (12 pics) @ 4

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CLD 10/13/03

USU LAB

KKB 6/26/03

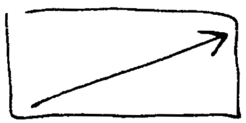
From Blenkinsop, 2000

→ Microfaults – see a great variety of colors of rk fragments in the matrix under the sensitive (gypsum) tint plate ~ this suggests clasts have been rotated & possibly derived from grains outside field of view ~ equant & subang. shear defined by

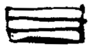
KKB 6/27/03

BT104AB1 –

- mosaic of fracture system
- includes 24 pics @ 4x mag taken in direction ↓ diaganol across slide



* • Also, in this folder include scale pic @ mm ruler for Ref

3 pics  ← most common scale  ← Full MAG w/ CAM. ZOOM

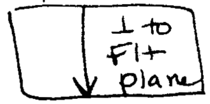
CLD 10/13/03

USU LAB

KKB 6/27/03

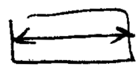
BT104AB2 –

pic mosaic dir.

- 

– 14 pics @ 4x r fracture mosai
- 10 pics w/ xpol ligh gypsum plate inserte
  – trying to capture micro fractures & catacl through discoloration
  – 24 pics total

BT105B1 –

-  several pics taken // to long direction

then  in area between fractures

- 51 pics total @ 4x mag.

Witnessed & Understood by me, CLD Date 10/13/03

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GTD' 11/13/03

GTD' 11/13/03

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CLD, 11/13/03

~~76~~

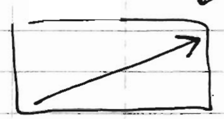
USU LAB KKB 6/26/03

From Blenkinsop, 2000
→ Microfaults – see a great variety of colors of rk fragments in the matrix under the sensitive (gypsum) tint plate ~ this suggests clasts have been rotated & possibly derived from grains outside field of view ~ shear defined by equant & subang.

KKB 6/27/03

BT104ATB1 –

- mosaic of fracture system
- includes 24 pics @ 4x mag taken in direction ↓ diaganol across slide



✱ • Also, in this folder include scale pic @ mm ruler for Ref ← Full MAG w/CAM ZOOM
3 pics ← most comm scale

CLD, 11/13/03

~~77~~

USU LAB KKB 6/27/03

BT104ATB2 –

pic mosaic dir.

- ⊥ to Flt plane – 14 pics @ 4x mag fracture mosaic
- 10 pics w/ x pol light gypsum plate inserted
  - trying to capture micro fractures & cataclasis through discoloration
  - 24 pics ~~total~~

BT105TB1 –

- several pics taken // to long direction
- then in area between fractures
- 51 pics total @ 4x mag.

CLD 10/13/03
USU LAB
From Blenkinsop, 2000
→ Microfaults – see a great variety of colo... rk fragments in the under the sensitive tint plate ~ this su... clasts have been rotated derived from grains shear ~ equa... field of view
BT104ATB1 –
• mosaic of fra... system
• includes 24 4x mag ta... direction ↓ a
✱ • Also, in this include sca... mm ruler for 3 pics ← most comm sc...

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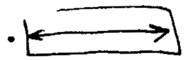
Witnessed & Understood by me, CLD | Date 10/13/03 | Invented by | Date
Recorded by Better copy, CLD | Date 11/13/03

CLD 10/13/03

USU LAB: ~~USU LAB~~ CLD 10/13/03 KKB 6/27/03

BT105TS2 -



- photos oriented parallel to long slide axis
- take a total of 59 pics
- several frac. mosaics

BT106 ~~TS1~~ KKB 6/27/03

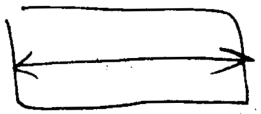
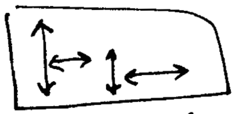


photo direction

- 46 pics @ 4x mag

BT107aTS1

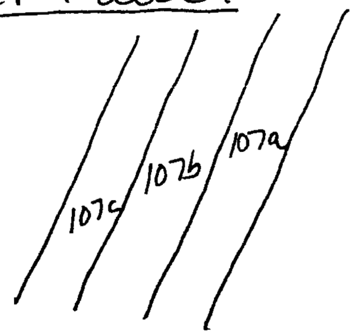


Fracture mosaic

- 48 pics @ 4x mag (1 @ 10x mag)

USU Lab KKB 6/27 + 7/9

CF Fault



BT107bTS1

- fracture mosaics

both // & ⊥ to long axis

- 28 pics @ 4x mag

BT107aTS2

- 25 pics @ 4x mag (10 w/ xpol & gypsum plate inserted)

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Invented by

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USULAB ~~78~~ CLD 11/13/03 KKB 6/27/03

BT105TS2 —

· photos oriented parallel to long slide axis
· take a total of 59 pics
· several frac. mosaics

BT106 ~~TS1~~ KKB 6/27/03

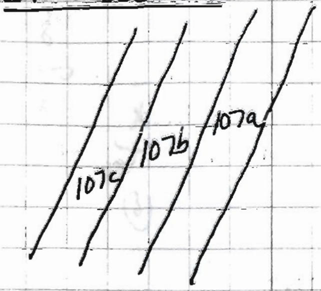
· photo direction
· 46 pics @ 4x mag

BT107a TS1

Fracture mosaic
· 48 pics @ 4x mag
(1 @ 10x mag)

CLD, 11/13/03
USU Lab ~~U79~~ KKB 6/27/03 + 7/9/03

CF Fault



BT107b TS1

· fracture mosaics both // & ⊥ to long axis
· 28 pics @ 4x mag

BT107a TS2

· 25 pics @ 4x mag
(·10 w/ x pol & gypsum plate inserted)

USULAB ~~CLD~~ 10/13/03 KK
BT105TS2 —
photos orien... parallel to ... axis
· take a total of 5...
pics
· several frac. ...
BT106 ~~TS1~~ KKB 6/27/0...
photo di...
· 46 pics @ 4x m...
BT107a TS1
Fracture m...
· 48 pics @ ...
(1@10X mag

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Date 10/13/03
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Date 11/13/03

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Date
11/13/03

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~~USU LAB~~ CLD 10/13/03 KKB 6/27/03
\+ 7/9/03

BT107bTS2 —

- Fracture mosaics
- take 41 pics @ 4x mag

BT107cTS1 —

- fracture mosaics
- 22 pics @ 4x mag

BT107cTS2 —

- frac mosaics
- 24 pics @ 4x mag

UPDATE → 8/7/03 KKB
* originally apply w/ intent (of) combining work efforts with Cynthia Dinwidd(ie) ~ conf. coordinators post(ed) title w/ JP Evans name on it ~ therefore, create) poster from JP Evans) paper) as formal presentation) and create file w/ n(ew) data for C. Dinwidd(ie) referenc(e)

CLD 10/13/03

CLD 10/13/03

KKB 6/30/03

APPILATION DUE 7/1/03
GHOSTRANCH CONFERENCE —
APPLY TO —
CLAUDIA [illegible], [illegible]
JEN [illegible]

FILEPATH →
GHOSTRANCH> KKbghostranch.doc

UPDATE → 8/7/03 K
* originally apply w/ intent
combining work efforts
with Cynthia Dinwidd
~ conf coordinators post
title w/ JP [illegible]
[illegible]
[illegible] from JP [illegible]
as formal present[illegible]
and create file w/
data for C. Dinwidd
Ref → (Ghost Ranch
Ghost Ranch > Ghost Ranch - a

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USULAB30 ~~P80~~ CLD 11/13/03 KKB 6/27/03 + 7/9/03

BT107bTS2 –

- Fracture mosaics
- take 41 pics @ 4x mag

BT107cTS1 –

- fracture mosaics
- 22 pics @ 4x mag

BT107cTS2 –

- frac mosaics
- 24 pics @ 4x mag

CLD, 11/13/03

KKB 6/30/03

APPLICATION DUE 7/1/03
GHOST RANCH CONFERENCE –
APPLY TO –
CLAUDIA LEWIS, LAUREL GOODWIN, JEN WILSON

FILEPATH →
GHOSTRANCH KKbghostranch.doc

UPDATE → 8/7/03 KKB
4 originally apply w/ intent on combining work efforts with Cynthia Dinwiddie ~ conf coordinators posted title w/ JPEvans name on it ~ therefore, create poster from JPE paper as formal presentation and create file w/ new data for C.Dinwiddie's
Ref → (Ghost Ranch 2)
Ghost Ranch > Ghost Ranch 1 - a.i. file

USULAB CLD 10/13/03
BT107bTS2 –
• Fracture mosaics
• take 41 pics
BT107cTS1 –
• fracture mosaics
• 22 pics @
BT107cTS2 –
• frac mosaics
• 24 pics
UPDATE → 8/7/03
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~ conf. coordinators posted title w/ JP Evans name on it ~ therefore, create poster from JP Evans paper pres. file
CLD 10/13/03
Ref → (Ghost Ranch 2)
Ghost Ranch → Ghost Ranch 1.ai

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~~p02~~ CLD 10/13/03

P

KKB 7/7/03

KKB

Grain Size / Seive Analysis

Continue to enter
CF sieve data table
into
filepath –

Bishop > Grsz analysis >
CF grsz analysis
> CF 1 grsz data

Start to create plots
for cumulative wt %
for each sample

Grain Size / Sieve Analysis –
continue analysis using
ibook > Bishop > Grsz analysis > CF grain analysis > Figs
create cumulative % plots

(Above rewritten by CLD, 7/22/10)

Grain Size / Sieve Analysis –
continue analysis using
ibook > Bishop > Grszanalysis >
CFgrainszanalysis > ~~Fig~~ CLD 7/22/10
CF1 grszdata
create cumulative %
plots

CLD 10/13/03

Witnessed & Understood by me,
CLD

Date
10/13/03

Invented by

Recorded by
Better copy, CLD

Date
11/13/03

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GRS 11/13/03

GRS 11/13/03

CLD 11/13/03 ~~p82~~

KKB 7/7/03

Grain Size / Seive analysis

Continue to enter
CF sieve data table
into
filePath -

Bishop > Gr sz analysis >
CF grsz analysis
> CF1 grszdata

Start to create plots
for cumulative wt %
for each sample

CLD, 11/13/03

CLD 11/13/03 ~~p83~~

KKB 7/8/03

Grain Size / Sieve analysis
Continue analysis -
Bishop > Grsz analysis >
CF grsz analysis > CF1 grszdata

create cumulative % graphs
to determine grain
size statistics

KKB
10/31/03

CLD 11/13/03

KKB

Grain Size / Seive

Continue to ent
CF sieve dat
into
filePath -

Bishop > Gr sz an
CF grsz ana
> CF1 grsz

Start to create
for cumulative
for each sam

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CLD	10/13/03	Better copy, CLD	11/13/03

Witnessed & Understood by me, CLD

Date 10/13/03

Invented by

Recorded by Better copy, CLD

Date 11/13/03

~~P84~~ CLD 10/13/03

KKB 7/15/03

UPDATE SAMPLE INVENTORY LOG

Filepath

BISHOP> sampleinventory7-03.doc

P

KKB 7/1

GrainSize/Sieve Analysis

Begin to enter data from Data Table CF2 Sieve data

Filepath—

Bishop > GrainSizeAnal CF grszanalysis > CF2 grsz data

CLD 10/13/03

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CLD, 11/13/03 ~~p84~~

KKB 7/15/03

UPDATE SAMPLE INVENTORY LOG

Filepath

BISHOP> sampleinventory7-03.doc

CLD, 11/13/03

CLD 11/13/03 ~~p85~~

KKB 7/16/03

Grain Size / Sieve Analysis:

Begin to enter data from Data Table CF2 Sieve data

Filepath –

Bishop > GrainSizeAnalysis >

CF grszanalysis >

CF2 grsz data

CLD, 11/13/03

KK
UPDATE SAMPLE INVE
Filepath
BISHOP> sampleinventory

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~~p86~~ CLD 10/13/03

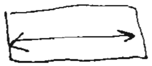
USU LAB — KKB 7/17/03

stratcolumn photomicrograph pic. LOG
on ibook
in iphoto

BTA1TS1 –

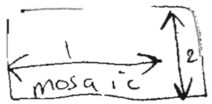
- Lithology focus
  - 8 pics @ 4 mag
  - 1 is scale for this series of photos

BTA1TS2 –



- Lithology
- 9 pics @ 4x mag

BTA2 –TS1 →



- Lithology
- frac mosaics
- 25 pics @ 4x mag

BTB-TS1 →

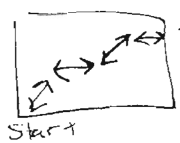
photo dir.

- Lith
- open frac
- 18 pics

USU LAB – KKB 7/17/03

CLD 11/11/03

BTBTS2 –



take across slide
12 pics in this orientation
@ 4x mag.

CLD 10/13/03

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Recorded by

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~~p 88~~ CLD 10/13/03 CLD 10/13/03

KKB 7/23/03

Grain Size / Sieve Analysis

Continue to enter data & create cumulative % plots for CF2 sieve data

Filepath
Bishop > GrainSZ Analysis >
CFGrainSZAnalysis > CF2 grsz data

KKB 7/23/03

Grain Size / Sieve Analysis
Continue to enter data & create cumulative % plots for CF2 sieve data

Filepath
Bishop > GrainSZ Analysis >
CFGrainSZ Analysis >
CF2 grsz data

Rewritten from above by CLD, 7/22/10

CLD 10/13/03

USU LAB -

KKB 7/24 - 7/25

microstructure photomicrograph picture log continues →
photos on ibook > iphoto

BT-C-TS1
· Lithology
· 18 pics @ 4x mag

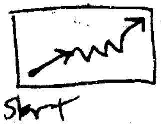

photo mosaic direction

BTC1aaTS1 -
· Lith. near fault zone
· Fracture mosaics
· 59 pics total
(last 3 are in polarized view w/ gypsum plate inserted @ 10x m

BTC1aaTS2 -
· Fracture mosaics
· 1 pic w/ gypsum plate of Deformation Band Cataclasis Zone
· 29 pics @ 4x mag.

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~~p 88~~ ~~CL~~ CLD, 11/18/03

KKB 7/23/03

Grain Size / Sieve Analysis

Continue to enter data & create cumulative % plots for CF2 sieve data

Filepath

Biohp > GrainSz Analysis > CFGrainSzAnalysis > CF2grsz data.

CLD, 11/13/03

CLD, 11/13/03 ~~p 89~~

USU LAB

KKB 7/24/03 - 7/25/03

microstructure photomicrograph picture log continues →

photos on ibook > iphoto

BT-C - TS1

· Lithology

· 18 pics @ 4x mag

start → end photo mosaic direction

BTC1aaTS1 -

· Lith. near fault zone

· Fracture mosaic

· 59 pics total (last 3 are in polarized view with gypsum plate inserted @ 10x mag)

BTC1aaTS2 -

· Fracture mosaic

· 29 pics @ 4x mag.

· 1 pic w/ gypsum plate of Deformation Band? Cataclasis Zone

Grain Size / Sieve Analysis

Continue to enter data & cumulative % plots CF2 sieve data

Filepath Biohp > GrainSz Analysis CFGrainSzAnalysis data.

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~~p90~~ CLD 10/13/03

USU lab — KKB — 7/24/03 7/25/03

BTC1 ccTS1 —

- frac. mosaics near Fault zone
- Cataclasis
- 33 pics @ 4x mag

BT C1d – TS1

matrix focus = welded!

- 11 pics @ 4x mag

BT C1e TS1 —

- matrix

photo direction

- 12 photos @ 4x mag

CLD 10/13/03 ~~p91~~

USU LAB — KKB 7/28

BTBCTS1 —

- Strat column sample
- 12 pics @ 4x mag

BTBC-TS2 —

11 pics @ 4x mag.

* UPDATE SAMPLE LOG to include notifi. of samples that have been photographed using the microsc.

Biohop > Samples > Sample inventory 7-03.doc

import/
ALSO — ADD OUTCROP PHOTOGRAPHS FROM CC site (for ease of review for CC paper) in iphoto — ADD —
602 cc site
902 cc site
+ 602 cf site

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CS 11/13/03

~~p90~~ CLD, 11/13/03 ~~p91~~

USU lab — KKB — 7/24/03 7/25/03

BT C1 ccTS1 —

· frac. mosaics near Fault zone
· Cataclasis
· 33 pics @ 4x mag

BT C1d – TS1

matrix focus — welded!
- 11 pics @ 4x mag

BT C1eTS1 —

· matrix
photo direction
· 12 photos @ 4x mag

USULAB — KKB 7/28/03

BTBCTS1 —

- Strat column sample
- 12 pics @ 4x mag

BTBC-TS2 —

11 pics @ 4x mag.

* UPDATE SAMPLE LOG to include notification of samples that have been photographed using the microscope

Biohop > Samples > Sample inventory 7-03.doc

ALSO – ADD/import OUTCROP PHOTOGRAPHS FROM CC Site (for ease of review for CC paper) into iphoto – ADD –
602 cc site
902 cc site
+ 602 cf site

USU lab — KKB
BT C1 ccTS1 —
· frac. mosaics near Fault zone
· Cataclasis
· 33 pics @ 4x
BT C1d – TS1
matrix focus welded!
· 11 pics @ 4x
BT C1eTS1 —
· matrix
pho
· 12 photos @

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CKB 8/6/03

microstructural analysis / Digital microphotography -

See also:

BT 74TS1 – ibook > BisHop > microstructures > micro data table

- open fractures filled w/ blue dye
- slighty / partially welded ? w/ angular clasts w/in glassy matrix
- blue dye infills pumice pore space
- sections of slide - gouge zones? -

banded by fract. → recrystallization of glassy matrix

- intra & inter granular fractures
- series of fractures around grain boundaries dave infilling (evid of mult phase fluid flow)
- fracturing of grains ~ first phase cataclasis → fractures

banding surfaces are wavy & rough

- fractures are curvilinear

Summary

- conjugate fractures w/in grains - hairline fr w/ sevl extending into matrix

Detailed characterization & pics in sample Log & notebook (unofficial) these data will be presented / entered in text format w/ Data table in future

KKB 8/6/03

BT 74TS2

- mosaics of open to hairline frac -
- see BT 74TS1 summary

BT82TS1 –

- fractured plagioclase clast infilled w/ mineralization due to alteration (sericite?)
- microbends - undul extinct. - Deformed
- Dissolution around edges of clast
- microfaults - sevl thru at clast (>5)
- edge of clast - broken by frac - extend into matrix (indication of clast movement - Deformation)

BT82TS2 –

- micro frac mosaic
- central fault gouge
- fine gr matrix - some flattening of clasts &/or alignment
- micro frac - interconnected
- curvilinear frac follow grain boundaries & open

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KKB 8/6/03

BT 85TS1

- blue dye in porespace of pumice clast
- fused text
- microflt - hairline w/in clasts of quartz
- open frac - rough surface
- most travel around grain boundaries

Sample - FeOx stained block - matrix between HW1 & 2 fractures near CC fault

- minor FeOx lining on frac planes also some FeOx growth w/in pore of pumice clast

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KKB 8/7/03

* see Micro Data Table - file path p. 92

BT 87TS1

- HW Frac 3 block @14m along CC Pit transect
- FeOx stain w/in matrix
- Frac travel thru grain & continue into matrix
- hairline frac w/in grain extend into open dyed filled frac
- clasts entrained / falling off? into frac surf from wall of matrix
- FeOx filled portions of frac w/ zones of thicker (>1μm) FeOx mink

Deform Feature → lineations w/in Qtz fragments
. Dissolution of grain bdry

BT 99TS1 - cataclasis process

- VOID - small fissure frac w/ clasts
- "Suevite" like clast
- 75-85cm from CCf lt contact
- zones of frac .. open frac w/ paralleling FeOx stained
- Fused matrix // frac

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BT100 BI – see file path p. 92

- Lg frac clast – likely frac result of initial eruption
- frac are infilled w/ minl ~ recrystall as result of qtz dissolution [qtz precip/dissol episodes]
- pumice clast boundaries coated w/ FeOx
{FeOx zone along CCHW1}
- Same fusion or recrystall appearance as previous CC samples
- grains/clasts appear to be rotated in some zones

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KKB 8/7/03

BT101 BI –

- w/in Hanging wall ~5 m from fault near outcrop test #4
- pretty well xllized or partially welded lith
- FeOx stained xl bdries
- FeOx frac system
→ See some flattening of pumice xls pore space
- inter + intragran frac
- frac linear → short TL to curvilinear – long TL
- Dissolution @ grain tips

BT101 BZ –

- close ups of intragran frac systems

* Dissolution Textures w/in indiv grains

* Pot'l rel to Deform – refer to Bleb[illegible] for Term

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~~p 40~~ CLD 06/04/04

KKB 8/20/03

microstructural analysis (continued)

PHOTOS - in iMac - iphoto photogallery and in hard copy in large sample Log folder

Text/descriptions - see also ibook > bishop > microstructures > micro data table

BT102TS1 -

- intragrain fractures (hairline) extend into matrix @ μm scale but hard to see (i.e. they die out into matrix) these are post depositional
- angular & rotated clasts "swim" in finer gr matrix
- connected system of open, blue dyed filled - wavy & rough walled frac thruout
- zones of (several μm thick) of open frac - + breccia clasts have coated outer perimeter ~ rexL / dissolution more rounded in these open micro cavities

· Footwall of fault

CLD 06/04/04 ~~p 99~~

KKB 8/20/03

BT103B1

- Discrete fracs xcut fine gr gouge and are filled w/ blue dye
- very fine grain ash gouge ~ altered to clay mineral
- intense frac
- multiple episodes of flow suggest by layering parallel to frac wall
- grains/clasts rotated + broken
- cataclasis processes & brittle microfrac
- frac terminate w/ horse tail splay style
- void space in pumice clasts retain blue dye
- open (blue dye stained) fracture system is highly connective across entire slide
- gouge appears somewhat "fused"
- dissolution/rexl of clasts

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11/13/03

Top copy replaces bottom illegible copy - CLD

06/04/04

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KKB 8/20/03

BT103TS2

- intra/inter frac systems
- Dissolution/reprecip of Qtz
- see BT103TS1

BT103TS3

- frac mosaics
- deform of pumice clasts indicated by flattening, rotation of grains
[in fusion/welding/grain compaction process w/in fault core]
- clasts appear to fall of frac wall into open frac (dyed blue) ~ cataclasis
- zones of brittle frac

BT90TS1 –

- non welded tuff
- very porous – blue dye fills pore space
- non-deformed (essentially) w/ few fractures

pot'l rel. to compaction frac – see dissol/reprecip of QTz

KKB 8/21/03

Microstructural analysis (cont.)

BT91TS1 –

- "Classic" non-welded tuff
  Airfall deposit
  very porous – resembles nonconsolidated sands
- thin, open wavy fractures penetrate matrix
- fractures extend through grains in some cases see pattern of frac along grain body that has first been opened – dissolving grain/clast then being closed by reprecipitation of minl
- hairline frac extend out of clast into matrix
- en echelon suites of hairline frac
- genl frac travel around grains pervasive
- Some frac lined w/ FeOx fill
- zones of compaction? (Deform Band processes?) ↓where band/frac becomes finer grs
  Check on this @
- FeOx stain/lined frac & pores

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KKB 8/21/03

BT 91 TS2
- mosaic of open frac filled w/ blue dye
(pot'l that this frac is filled w/ finer grain matrix yet is masked by blue dye - DBZ?)
'see also description BT 91 TS1
Note * clasts "fallen" into frac & entrained w/in frac surf suggest above may be the case

BT92 TS1 -
• see BT 91 TS1
• also - lineations w/in clast - possible plagioclase?
• grain boundaries are dissolved into irregular boundaries - reprecip of min'l in frac surfaces - see suturing around boundaries: pot'l to dec K thru matrix yet inc in frac?

KKB 8/22/03

microstructural analysis (cont.)

Samples from strat column site (LITHOLOGY) ↳ BT 94 - 98 * emphasis

*SAMPLES FOR POTENTIAL POINT COUNTS → XL %
Glass %
pumice %
ASH %

BT93 TS1 -
• very fine grain matrix clay, ash, glass shards
- fusion of glassy particles

BT94 TS1 -
• glassy matrix w/ some flattening of pumice - indicates some degree of welding
• clasts of Qtz xl, pumice, lithic fragments (rounded) suspended in matrix
• micro faults w/in Qtz xls (pot'l rel to compaction/deposition) & later cooling of tuff
• fluids dep's/in grains along gr boundaries may indicate fluids passing thru - postdep.

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see also —
microstrux – ibook > Bishop > microstructures
> microdatatable

BT96TS1 –

- same flattening of pumice clasts
- gen'l finer grain matrix than BT 94 TS1

estimate ~15% pumice ; 25% Qtz xl ; 15% clasts ; 55% glass + ash

BT 97 TS1 –

compaction related?? rotation of clasts ~+ glassy shards – rexl?

- see some collapse of pumice vesicles

~40% pumice ; 15–20% qtz ; 40% glassy matrix

BT98TS1 –

- Glassy shard matrix
- rexl of Qtz xls & possible redistribution &/or devitrification of glass shards
- rounded pumice clasts – very little evidence for welded / compaction
- concentric fractures in some Qtz xls likely rel. to eruption phase

~ 10% pumice ; 25-30% qtz xls ; 5% lithics ; 755% glassy matrix

KKB 8/22/03

For Future Note / work to be done:
BT – strat column samples – for comparison purposes to tuffaceous deposits @ yucca mountain we will most likely need to do a point count analysis on these stratigraphic samples + the BT A1 – BT C series collected @ the same stratigraphic study site along chalk Bluffs.
I think it is important to quantify the host rock lithology relative to fault rock resp. for porosity changes and how these different lithologies & various degree's of welding affect the deformation processes & resultant structures.

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KKB 8/25/03

microstrux – summary of thin sections reviewed (cont.)

File path: ibook > Bishop > microstructures > microdatatable
also pics in iphoto

BT104ATS1:

* File in iphoto contains photos of scale for T.S. Scale is in mm
1mm – for 3 views

- very fine gr gauge – Clay & ash
very little pumice (<5%)
- clasts are mm size or less
- comminution processes or/& cataclasis
- Hairline frac system filled w/ calcite & connected to more open 0.5 mm aperture frac system
- fluid appears to have entered thru frac – mult-phase

KKB 8/25/03

BT104ATS1 (cont.)

- FeOx partially lines some of the 0.5 mm frac
- frac term in horsetail splay geometry & dis. intermittent

BT104TS2

- Frac can change propagation direction as travel thru matrix of finer flt gauge & then go around a clast rather than cut right thru
- layering of fine gouge extends parallel away from frac.
layering is compositional – gray, more clast rich layer alternating w/ brown more clay rich
random & discontinuous
each typically bounded by frac –

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BT104TS2

- in polarized light — clasts are varied in color & rotated indicative of cataclasis processes of deform.

BT105TS1

- very fine gr matrix of ash & clay & some lithics
- ~~open~~ 0.25 mm scale frac cuts thru sample — fr filled (partially) w/calcite &/or FeOx

KKB 8/25/03

- some gas w/in frac? or air from epoxy
- curvilinear, rough frac trace
- FeOx appears to grow outward from frac walls to mid frac — suggest post fr fluid flow

KKB 8/25/03

BT105TS1

- as frac cuts ⊥ to layer of brown fine gr clay gouge thru to more glass rich, lithic rich layer the frac surf curves — again, suggest frac shape/geom rel. to lith. even @ micro scale
- sevl frac splay off main frac — these splays tend to be shorter T & die out quickly but may also connect to another short T splay

BT105TS2

- sevl of hairline frac appear to "bleach" slightly surrounding matrix
- These hairline frac cut thru gouge layered around the larger aperture frac → i.e. the more

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open frac that cut (or $CaCO_3$ filled) thru the gouge (which is v fine gr & impermeable) are connected to a system of hairline frac that extend outward away from central gouge - thereby potentially affecting to overall perm of fault core - may end up w/ fault core w/ very variable 'K' along strike & dip - in some cases fault may be barrier whereas may be able to transmit some fluid in other

{Heterogeneous fault core @ microscopic level}

Scaling evidence

KKB 8/26/03

microstructure analysis (cont.)
see filepath p. 106
BT 106 — 8/26/03 KKB → fallout tephra dep.

- classic nonwelded tuff sample
- see also Suevite ~glassy texture indicative of HiT/P &/or deform
- in zones around fracture Qtz & glass have fused together ~ irregular grain boundaries thereby increasing strength of overall rock so that could explain presence of brittle fracture &/or Deform Band features
- fractures still typically are curvilinear & travel around grain boundary
  → some frac surrounded by more broken &/or finer clasts
  → comp. &/or deform band
- some FeOx filling in frac

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KRB 8/26/03

BT107ATS1 –

- fine gr matrix ~ brownish clay, glass shards, some lithics
- – edge of slide – large frac w/ zone of cataclasis &/or Deform Band?? Small hairline fracs extend ⊥ away from frac wall into finer gr matrix –
- in Band of cataclasis? – clasts appear suspended in a finer grain matrix – very early phase cataclasis
- zones several mm wide of bleached halos surround hairline frac system – alter bandiny of these irregularly shaped zigzag halos is a darker FeOx mine

KRB 8/26/03

BT107ATS2 –

- see 107ATS1 –
- also note some hairline fracs are curvilinear – others in conjugate array

BT107BTS1

- see pinch & swell type geom w/ hairline frac filled w/ $CaCO_3$
- clast (Qtz) between 2 fracs dissolved & slightly smeared appearance
- rexl/redeposited? just <1mm from clast – parallel to frac system

BT107BTS2

- FeOx filled frac w/ pods or zones of white mine
- well devl zones of cataclasis w/ in fine gr fault gouge – layering ‖ to frac system
- multi phase flow – minl in layers

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BT107CTS1
- clast rich - non welded tuff
- zones of finer grain clasts ~ pot'l compaction or Deform Band?
- fracs die out into matrix slowly
- fracs are wavy + irregular
- "irregular blobs" of Qtz - suggest dissolution then redeposition

BT107CTS2
- cataclasis process → or DBZ?
- see above
- frac (even hairline) + pores fill w/ blue dye

CLD, 11/13/03

KKB [redacted]/28/03

Microstructures (cont)
see also photos (currently in iphoto on imac) & ibook (imac) > Bishop > Micro structures > Microdatatable

* SAMPLES FROM STRAT COL SITE
BTA1 KKB 8/28/03
→ These samples would also be quite useful for point counts

BTA1 TS1
1st slide • 40% Qtz xls; 5-10% lithics; 50-60% glassy matrix
2nd slide • 50% pumice; 50% matrix — <5% Qtz
3rd slide • 40% pumice; 15% Qtz; ~20% 45-50% matrix (glassy)
• some frac in this sample — zone of cataclasis — sample very near flt w/ outer surface of original sample being a major slip surface near bottom of TUFF section

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Micro Summary 8/28/03

BTA1TS1 – see previous w/ > pumice

BTA2 TS1 –

- FeOx rinds surround pumice clasts
- Hairline fractures intermittently filled w/ FeOx minl.

Qual! → overall > pumice than A1 (but need to do pt counts to determine)

- 20–40% pumice; 40–60% matrix; ~20% Qtz xls

BTBTS1 –

~~35~~ 30% pumice; 20%–30% Qtz; 40–45 ~~55~~% matrix; if less matrix ~ 5% lithics KKB

- hairline fracs present curvilinear & rough – connect together

BTBTS2 –

- 25% pumice; 5% lithics; 20% qtz; 50% matrix
- sevl FeOx minls ~xls ~ LOOK like 2ndry minl not Lithics

Micro Summary 8/28/03

BTC TS1 –

- pumice clasts have FeOx rinds appears to be some rexl of Qtz KKB ~~vitrification~~ w/in 8/28/03 pumice clasts to give texture of fused glass
- some of this text may be result of compaction & pressure w/ addition of hot fluids
- pumice clasts are aligned & flattened indicated much more welding in this unit – matrix is dense – unit is welded tuff
- pumice ~15%; matrix 40%; Qtz ±5%–20%; lithics ~5%

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KKB 8/28/03

BTBCTS1
- some flattening of pumice pores but not entire clasts
- FeOx rinds around pumice
- rexl of Qtz near & w/in some pumice clasts
– or pumice is devitrified as it appears some of pumice is replaced by FeOx or Qtz minl & pore space of clasts is not open & gas bubbles are located outside of individual pores w/in the pumice clast

~15% pumice; 60% matrix + glass; 20% Qtz xls; 5% lithics

BTBCTS2 — 30% pumice; 50% matrix; 15% Qtz; 5% Lithics
- in this cut see some flattening of pumice – indicated of ? welding
- FeOx rinds on pumice
- radiating frac w/in Qtz xls – rel to eruption

Here see ?? gas bubbles

KKB 8/29/03

Microanalysis

BTC1 Series of samples – from small fault ~5m N of strat column transect

ClaaTS1 –
- Flt surf composed of compacted band of Qtz xls & fibrous minl that grew outward from frac surf
  Band of Deform resembles Deform Band? or Low grade cataclasis w/in very thin rx
- Band stained w/ FeOx minl & clasts are rotated & align // to frac surf

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KKB 8/29/03

BTC1aaTS2

- more open frac surf observed
- host rk wall - Qtz + lithics entrained w/in predom open frac surf
- frac curvilinear & rough, jagged
- FeOx rinds on frac & extend into matrix + follow pumice & coat clasts
- frac splay from main flt surf & terminate @ surf connecting flt to matrix - > 2 layers of minl // FH

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BTC1ccTS1

- most intense deform w/in frac w/in this series
- Abundant FeOx stain fracs - sevl layers // frac surf. (FamH)
- frac are much more brecciated & typical cataclasis properties
- clasts adjacent to frac surf & intensely fractured

BTC1dTS1

- adjacent host rx to FH
- partial flatten of pum.
- 30% pumice; 20% Qtz ~45-50% matrix; 5% lithics

To Page No.

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BTC1e TS1 -

- >> welding than BTC1d
- much less pumice
- 5-10% pumice; 10% lithics; 20% Qtz; 50-60% matrix
- No fracs observed
- pumice & clasts appear flattened & aligned // to deposition

~~p123~~

CLD, 11/13/03

Note that pages 1, 3-10, and 12-13 have a second xerox taped over the original xerox. The second xerox is more readable than the first xerox. None of the original informational content of the first xerox was changed in the second xerox, which can be verified because both xeroxes remain in this notebook. CLD.

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Whole-rock Sampling and Analysis Method

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CLD, 11/14/03

Bishop Tuff Sampling and Analysis Methods

Prepared by:
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205 W 100 S
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In-situ Sample Collection

Whole-rock Sampling

Thin-section samples and large blocks (for potential hydrologic tests) were collected in one of four ways, depending on the degree of welding and/or deformation:

1. Several slightly to moderately welded samples had enough cohesive strength to be extracted directly from the outcrop using rock hammers and masonry tools and were then wrapped in tissue paper and/or bubble wrap for protection.
2. A few loose and/or non-welded deposits were gathered by creating semi-circular depressions 3–6 cm deep at the top of a scraped outcrop surface, and pouring a slow-acting epoxy resin into the depression. The resin was allowed to seep into the tuff, and the hardened sample was collected the next day. A negative pressure (cardboard surface) was sometimes applied to scraped surfaces next to the depression.
3. Many non-welded samples were collected by chipping and prying rock from the outcrop with small chisels or a rock hammer and were immediately immersed in a fast-acting epoxy resin.
4. Some of the larger samples were collected by cutting blocks up to 40 cm on a side with a portable saw, and lifting the sample out of the outcrop and placing it on a wood or cardboard platform. The sample was then immediately stabilized by pressing wood or cardboard coated with fast-acting foam insulation against all sides of the sample and allowing the foam to compress the sample slightly.
5. Deformed and/or fragile samples were collected in one of two ways. Some samples could be carefully excavated from the outcrop by carving with a knife or chisel, and stabilized with foam insulation (e.g. Great Stuff brand), or by pouring epoxy resin into fractures and along fault surfaces. These samples or peels were then cut out of the rock face, and stabilized by placing the sample into a small plastic re-sealable bag. This bag was then set into spray-foam insulation in an outer re-sealable bag. This provided lateral support for the sample during transport but keeps the insulation material from penetrating the sample.

Whole-rock Sampling and Analysis Method

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Grain-size sampling

Samples for grain-size analysis were collected in one of three ways:

1. Representative host-rock samples collected for depositional grain size data were extracted from an outcrop window at least several meters from the fault contact and outside of the fault damage zone. Samples were gathered from a chosen outcrop point or depositional layer and then bagged from top to bottom. Masonry tools or a circular drill bit were used to collect the samples that were then placed into ziploc bags and labeled.
2. Grain-size samples collected along permeability survey lines were taken starting with the outermost circumference of the air-permeability test-hole site. Tools including small chisels, masonry trowels, and rock hammer picks were used to delicately gather and push the sample material into ziploc bags.
3. Mineralized fault slip surfaces were collected by slowly peeling the surface or coating of the fault and placing sheet into a ziploc bag. Fault gouge materials were collected by first scraping away the exposed weathered surface of the gouge to obtain a fresh sample face and then a rock hammer pick and trowel were used to collect sample.

Guelph sampling

Samples were collected by first carving out a rectangle block with a rock hammer pick into the outcrop face within the same lithologic unit as the corresponding Guelph test site. A total of 6 measurements (2 in each dimension) in centimeters were taken for each block. Samples are then wrapped airtight in plastic bags and then duct taped and labeled.

XRD-sampling

A small amount of sample (enough to crush a representative portion of sample keeping in mind we needed to fill at least 0.5 dram bottles for testing) was carefully extracted from the outcrop and immediately bagged and labeled. For example, if a fault zone was comprised of a mineralized slip surface, fault gouge, and filled-fractures and veins, each sub-sample and the corresponding host-rock were bagged individually for testing. Sketches of the sample/sub-sample locations and/or map locations were identified in a notebook. Tools used to gather the samples include a knife, a rock hammer pick, and a trowel. Any attached organic matter was carefully removed prior to bagging.

Laboratory Analysis Techniques

Grain-size and Sieve Analysis
The following USU Sedimentary Research Laboratory equipment was used for sieve analyses:

1. OHAUS Brainwave™ B1500D scale calibrated each month using the OHAUS Fractional Scale Weights kit to a ±0.01 g average precision (measures total weight in grams of each sample measured and the weight of sediment within each screen interval).
2. Tyler Standard Screen Scale and U.S.A. Standard Testing Sieves. Screens are composed of brass and stainless steel and measure particle diameter.

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The following grain-size scales were used: 4 mm (-2 phi; i.e. fine pebbles), 2 mm (-1 phi; i.e. very fine pebbles), 1 mm (0 phi; i.e. very coarse sand), 0.5 mm (1 phi; i.e. coarse sand), 0.25 mm (2 phi; i.e. medium sand), 0.125 mm (3 phi; i.e. fine sand), 0.063 mm (4 phi; i.e. very fine sand) and 0.037 mm (4.75 phi; i.e. silt and clay size fraction).

The specific steps of the Sieve Analysis Method employed on the Bishop Tuff grain-size samples is outlined below (see also Blatt et al. 2nd edition, 1980):

1. clean equipment (brush screens with toothbrush to remove particles or remove larger particles by hand then wash between samples)
2. dry sieves with blow-dryer if necessary to remove dust/particles
3. tare scale
4. weigh empty sample bag
5. tare scale again
6. weigh total sample with bag
7. empty sample into sieves
8. shake all sieves 5–10 min
9. tare sample bowl
10. place sample from each sieve size into bowl and weigh
11. enter weight of sample into spreadsheet
12. return sub-sample to sample bag
13. sieve fines for another 5 min (only for sieve sizes 3–8 phi due to abundance of fine ash clinging to the screens after initial shaking)
14. weigh fines as described in steps 9–12 above

The data-entry format sheet constructed for the sieve samples is shown below and is from the Excel spreadsheet file grszdatasheet.xls (Microsoft Excel 98 on personal ibook).

sample	total weight (g)	>4 mm (-2 phi)	2–4 mm (-1 phi)	1–2 mm (0 phi)	0.5–1 mm (1 phi)	0.25–0.5 mm (2 phi)	0.125–0.25 mm (3 phi)	0.0625–0.125 mm (4 phi)	0.0037–0.063 mm (>4 phi to 8 phi)	measured total

From the paper copies, an electronic Excel file copy is created for further statistical analysis and graphing of the data. The data may then also be imported into an Excel Spreadsheet application called GRANPLOTS.xls for statistical analysis and plotting the sieve data (Balsillie, et al., 2002). Note: use of this last procedure is still pending.

Thin-section Blank Preparation

To prepare blanks for thin-section, samples were carefully opened (if wrapped) or handled in such a way that a small free face of interest was exposed. Faces were cleaned with a small steel pick or toothbrush to remove any excess dirt, foam, or paper. Palhouse Petro Products, Pullman, WA (makers Petropoxy 154™ epoxy) recommends baking very friable samples prior to epoxy impregnation for thin-section blanks. Therefore, most samples were baked prior to epoxy for several hours at 100–110 °C . To epoxy impregnate the hand samples, slow-acting thermally activated petrographic epoxy (Petropoxy 154™,) was mixed with curing agent using the recommended ratio of 5.0 ml resin to 0.5 ml curing agent. Resin was poured into a plastic beaker to the 15 ml level and then a plastic 1 cc syringe was used to fill 1.5 ml of curing agent to add to the epoxy.

Whole-rock Sampling and Analysis Method

About 1/16 tsp. of powdered blue dye was added (allows qualitative porosity and permeability estimates) the entire mixture is then stirred for 1 minute with a wooden stirring rod. The mixture was then poured on a clean sample face. A high vacuum was applied to the sample (3–10 vacuum cycles ranging from 1 to 4 hours depending on sample size and permeability/porosity). Between each cycle the sample was rotated to a clean face and another dose of epoxy mixture is applied. Successive exposure and vacuum cycles ensure that the entire sample is stabilized with an inert epoxy. The sample was then heated to 125 °C for 8 hours to set the epoxy. Thin section blanks were then cut from the impregnated samples with cuts no larger than 24×40 mm and 1–1.5 cm thick, and when necessary, the blanks or sample faces were re-epoxied. Blanks are typically cut to this size per recommendations to receive maximum discount on further slide preparations. Thin-section slabs were mailed to either Spectrum Petrographics or to Burnham Petrographics for the final slide preparation.

Digital Photomicrographs and Analysis of Thin-sections

An Olympus BH-2 Petrographic Microscope was used to view the thin-section slabs. Analysis of the slides was completed using 10×, 20×, or 40× magnification lenses. Slides were reviewed in both normal and cross-polarized light (gypsum plate inserted).

Photomicrographs were taken with a Nikon COOLPIX 5000 Digital Camera attached to the top of the petrographic microscope. Once the pictures are taken, the digital files are downloaded onto the desktop with Nikon View 5 on an Apple G4 (Mac OS 9.2). Nikon View 5 automatically saves the files as TIFFS. The TIFF files are then opened in Adobe Photoshop 5.5 and saved as .PSD files onto a zip disk.

Terminology from Blenkinsop (2000), Davis (1984), Schulz and Evans (1998), and Snoke et al. (1998) was used to describe the microstructures and deformation mechanisms observed during petrographic analysis of the Bishop Tuff.

X-Ray Diffraction Techniques

Equipment used for X-ray diffraction analysis includes a water cooled Norelco X-Ray Diffraction Unit #12045, Philips Electronic Instruments. This particular instrument is run with a copper x-ray tube with K-alpha radiation set at 35KV and 15 mA, a crystal monochrometer. Steps in X-ray sample prep:

1. Crush fingertip size (about 2.54 cm diameter) sample with mortar and pestle, time varies per sample depending on degree of welding with longer crush times associated with more welding; with a minimum of 5 minutes of crushing for all samples.
2. Sieve crushed sample using a Tyler Standard Screen Scale testing sieve size opening of 0.0049 inch or 115 meshes to the inch (U.S.A. Series equivalent 120).
3. Use small funnel to pour sample into 1-dram glass bottles and label.
4. Enter USU X-ray lab with sample(s) and immediately obtain dosimeter badge and adjust to zero hairline with Dosimeter Charger model #909 by Dosimeter Corp.
5. Turn on the cooling water supply.
6. Check that the kV knob and mA are fully counterclockwise and off prior to start.

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7. Press the START button firmly.
8. After about 20 seconds, push the "ON" button. After a click noise, the kV and mA meters should register approximately 8–10 kV and 5–6 mA, respectively.
9. Slowly advance the kV switch to 36 kV.
10. Slowly advance the mA switch to 15 mA (after this step the kV meter should read 35 kV).
11. Turn on computer, the DIFFTECH XRD AUTOMATION black box, and the zip drive.
12. Place powdered sample into aluminum rectangular sample plate, level and pack sample.
13. To load or change samples: a) close the X-ray shutter tube by pushing the small black button for window #2 on the shutter control box; b) remove radiation protection cap; c) insert or change sample; d) replace radiation protection cap; and e) open the X-ray shutter by pushing the small red button for window #2 on the shutter control box.
14. On computer, click "Run_XRD" icon on the desktop. Confirm the goniometer setting in the computer with the actual goniometer reading on the instrument, type in the correct value and press "ok".
15. Type in the name for the file; define the starting and ending 2θ values (4° and 62° were used); define the step interval and scan speed (0.05° and 2°/min were used); click on start, wait for scan (30 minutes).
16. Repeat steps 12–15 for additional samples.

Data from X-ray Diffraction instrument is sent to a Caliber PC via DIFFTECH XRD AUTOMATION Model 122. The program Visual XRD (licensed to USU) scans the data and creates an ASCII import data file (or .CPI file) that is then opened in an XRD pattern-processing program (Jade 3.1, Materials Data Inc.). Jade 3.1 runs a first-pass of the data with a search and match function. Once complete, the resulting signature data is analyzed by user to find the mineral PDF signatures that match the data obtained from scanning a particular sample. Note, the aluminum sampling plate produces an anomalous signature from 38–39 (2θ) degrees (i.e., the signature is not included in the search and match picks). The plot of the picked mineral PDF's is saved as a TIFF or JPEG file onto a zip disk, then transferred over to a personal ibook.

The X-ray instruments are calibrated once per semester by Pete Kolesar, Geology Dept., USU. Calibration is completed using a silicon powder sample. Calibration ensures correct alignment of the diffractometer and also inspects the intensities leaving the X-ray tube. The silicon powder used in the USU laboratory is the North American Philips Company X-Ray Standard Type No. 52131 Serial Number 57-213.

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CLD, 11/14/03

CCHW1MeanGrainSize.xls

sample loci (cm)	mean avg grain size (mm)
0	0.2836
20	0.3136
40	0.4404
60	0.3152
80	0.3030
100	0.3357
120	0.3269
140	0.4079
160	0.3622
180	0.3897
200	0.4446
220	0.3404
240	0.2731
260	0.5659
280	0.3327
300	0.4724
305	0.3925
320	0.4779
340	0.4241
360	0.4364
380	0.3839
400	0.3359
420	0.3983
440	0.4176
460	0.3624
480	0.4828
500	0.3660
520	0.4369
540	0.3008
560	0.2872
580	0.3515

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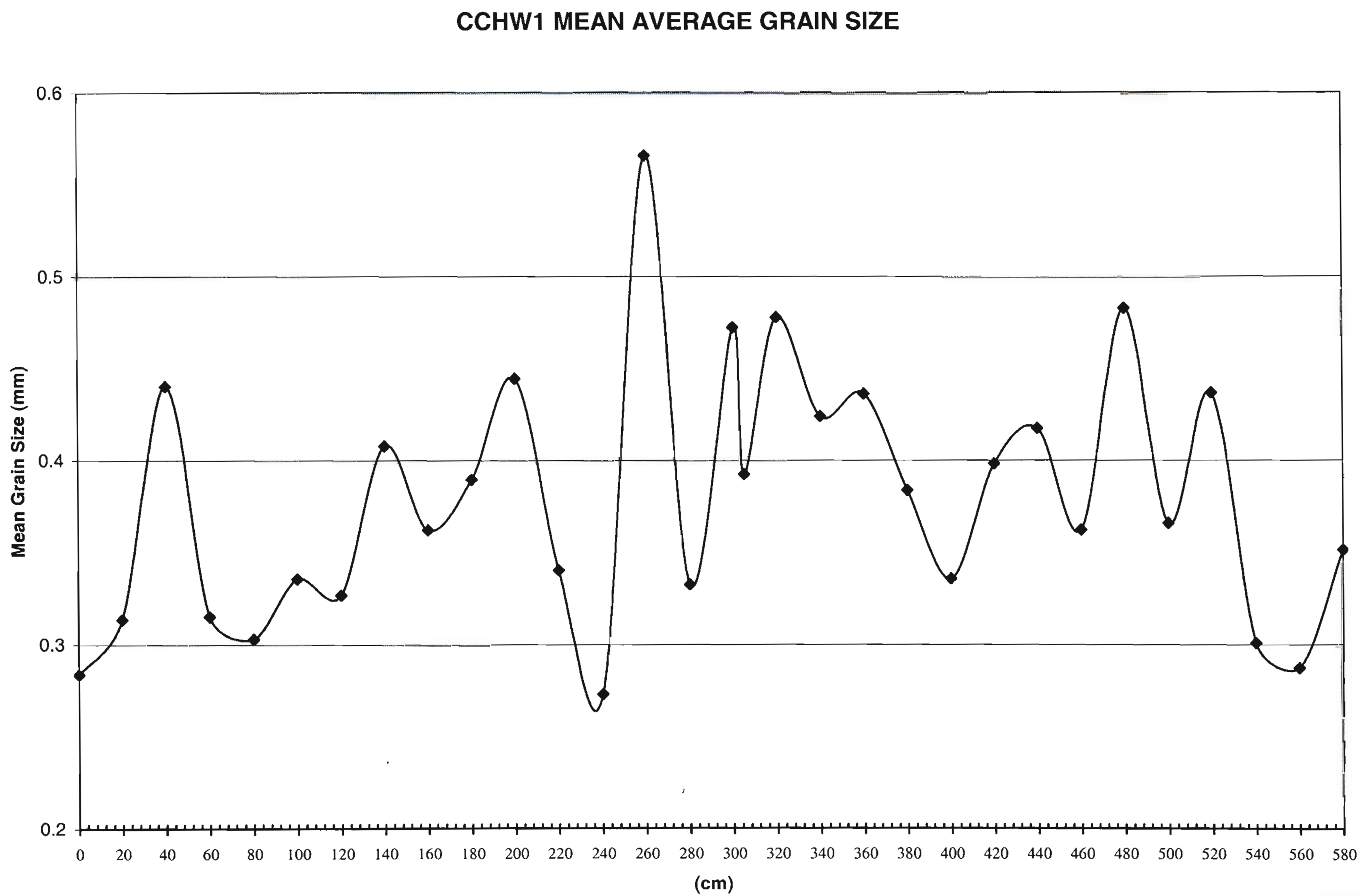
Date 06/04/04

Invented by

Recorded by

Date

Project No.
Book No.
TITLE



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CLD, 06/04/04

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CC3MeanGrainSize.xls

sample loci (cm)	mean avg grain size (mm)
0	0.3788
20	0.3337
40	0.3148
60	0.4697
80	0.4333
100	0.4675
120	0.361
140	0.5056
160	0.3451
180	0.3605
230	0.4715
240	0.4455
250	0.4587
280	0.3192
300	0.3991
320	0.4351
340	0.3775
360	0.3009
380	0.4558
400	0.6676
420	0.4463
440	0.4007
460	0.3514
480	0.4094
500	0.3874
520	0.3695
540	0.3582

	k data
0.00	571.3588
0.10	234.6380
0.20	443.9178
0.30	2260.1810
0.40	443.2225
0.50	655.0715
0.60	246.6477
0.70	304.6191
0.80	551.8919
0.90	918.6257
1.00	689.5546
1.10	316.4401
1.20	296.0223
1.30	339.2876
1.40	212.7207
1.50	330.0576
1.60	2672.5506
1.70	668.8989
1.80	790.2000
2.30	878.6732
2.40	542.1534
2.50	671.3682
2.70	443.4036
2.80	711.0301
2.90	768.0630
3.00	1490.0596
3.10	450.8842924
3.20	429.4359
3.30	294.3267
3.40	540.0463
3.50	367.7506
3.60	208.0538
3.70	168.1708
3.80	583.8286
3.90	643.7817
4.00	704.1122
4.10	847.3822
4.20	606.4663
4.30	260.3586
4.40	331.7447
4.50	709.1969
4.60	333.5972
4.70	912.4170
4.80	538.0486
4.90	1131.8273
5.00	767.8197
5.10	309.2212
5.20	1135.8565
5.30	501.7099
5.40	413.8574
5.50	365.5432

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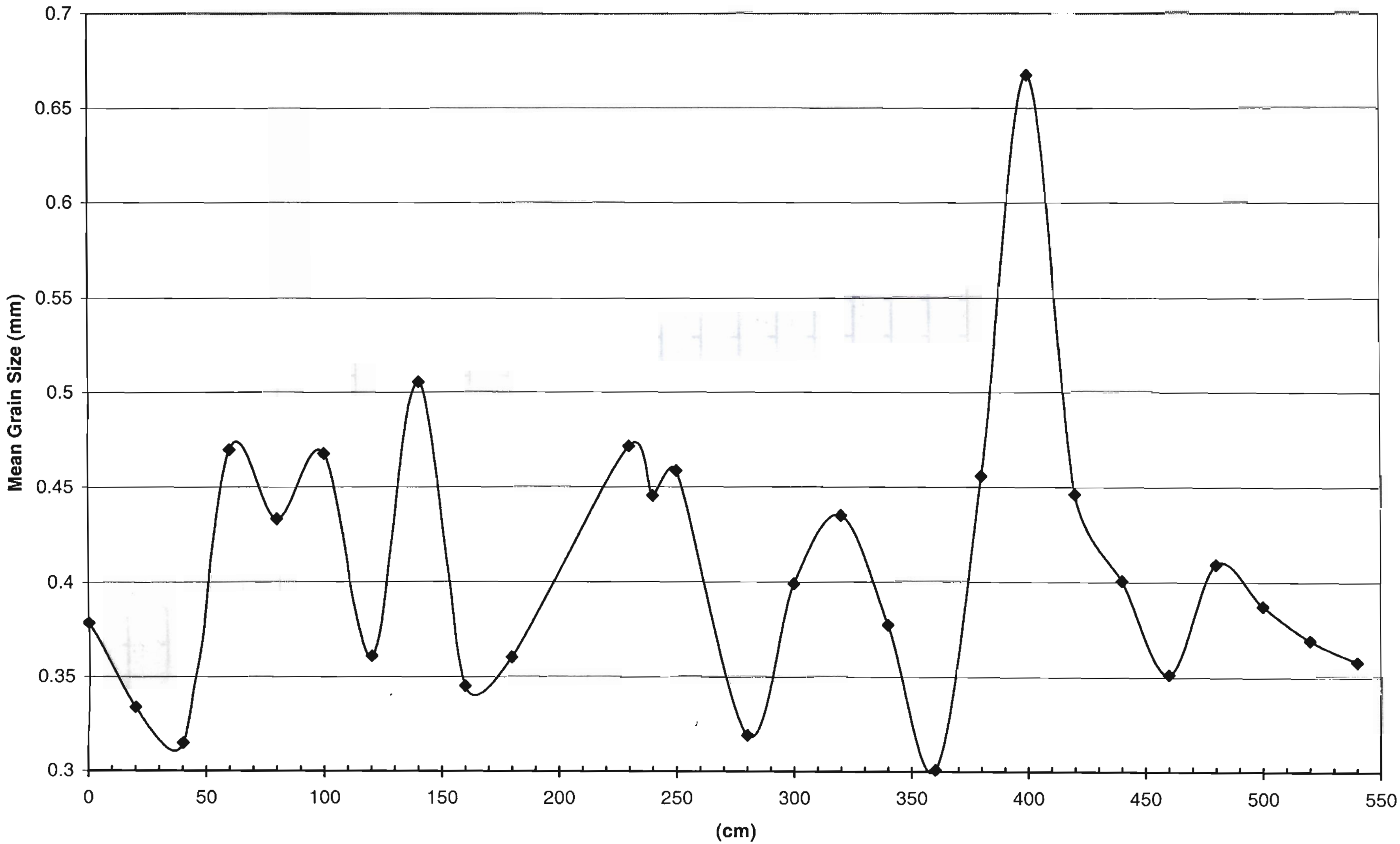
TITLE

CCH3 MEAN AVERAGE GRAIN SIZE



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06/04/04 @ CJ

Novemer 15, 2003

Notes on the IGPP-sponsored workshop: Fluid Flow and Transport through Faulted Ignimbrites and other Porous Media

by Kelly Keighley Bradbury (kellykb@cc.usu.edu)

The geology, deformation mechanisms, and hydrologic properties of fractured porous media were the major topics discussed at this fall meeting. Field observations and potential field strategies for studying these types of rocks were reviewed utilizing outcrops of Bandelier Tuff at the Bandelier National Monument, New Mexico.

Discussions and presentations from several scientists of various geologic disciplines were insightful and helped aid in our understanding of faulted porous media. This information is significant in that it may be applied toward our current study of the Bishop Tuff, Bishop, CA as an analog to the Paintbrush Tuff, Yucca Mountain, Nevada. Relevant findings include the following topics discussed below.

LITHOLOGIC CHARACTERISTICS OF POROUS MEDIA

Ignimbrites are typically heterogeneous with respect to a variety of petrophysical characteristics. They comprise variable amounts of glass in the form of pumice, ash, phenocrysts, and lithic fragments. The relative amounts of these different compositions within a particular deposit can influence both mechanical and hydrologic characterisitics.

The mechanical stratigraphy of ignimbrites may be controlled by variations in degree of welding, post-depositional crystallization, and alteration, and therefore may largely correspond to cooling units identified by previous workers. Structurally, the transition of sonic waves through variably welded ignimbrites may produce different damage zone elements which are a function of the degree of welding. In general these mechanical units correspond to hydrologic units.

The process of welding destroys some porosity and produces a pronounced horizontal anisotropy in the rock. Crystallization of minerals from vapor trapped in pores and/or the devitrification of glass in ash particles (determined through microscopic analysis) and pumice shards (pumice at the outcrop scale apppears sugary in texture with little to no integrity) may occur shortly after deposition (Stimac et al., 1996). These processes affect the overall mechanical and hydrologic properties of the rock.

For example, a sequence of non-welded but crystallized ignimbrite within a formation may be identified as a mechanical or hydrologic unit. The formation may be resistant to weathering and form cliff exposures but detailed analysis may reveal the pumice fragements are not compacted or elongated (characterisitcs of welded ignimbrite). Also, very fine glassy fragments are abundant thorughout the pore space, fusing many shards together. Overall this will increase the mechanical strength of the rock and decrease permeability within the matrix.

DEFORMATION OF POROUS MEDIA

Two end-member models are presented for mechanisms of failure in porous media (Laurel Goodwin, pers.comm. 2003):

1. Low porosity sandstones fail by formation of fractures (loss of rock cohesion). The resultant structures increase the overall permeability since previously there was a lack of pore connectivity within the matrix because there was a high grain contact area. Increasing grain contact area increases the strength of the rock.

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2. High porosity sandstones (low grain contact area, rock is weaker) fail by zones of cataclasis and deformation bands (here there is very little loss of cohesion). The grain size and porosity is reduced and therefore, permeability within these zones may be reduced.

The primary controls on mode of failure in porous media are the grain contact area and strength which are directly related to degree of welding and crystallization and inversely proportional to porosity.

In Ignmibrites, low porosity welded units form by transgranular fracture whereas high porosity, glassy, non-welded units deform by cataclasis with shear deformation bands. Moderately high porosity, non-welded units that have undergone devitrification or vapor-phase crystallization form either shear bands or fractures, depending on local variations in the degree and nature of crystallization.

Microscopic analysis allows distinction between phases of deformation such as cataclasis and deformation band processes. Under magnification observations suggest with cataclasis there tends to be discrete boundary of deformation whereas deformation bands have wavy, non-linear boundaries.

Several cases of deformation band faults (defined by pore collapse, grain crushing, particulate flow to cataclasis) have been observed in non-welded ignimbrites. Although typically these features occur at the mm-cm scale they are important because they may affect the overall hydrology of a particular fault zone at the m-scale.

Non-welded crystallized tuffs form both fractures and deformation band zones possibly due to:

1. Lateral variations in degree of crystallization – welding decreases as increase distance from calderas

2. Lateral variations in mineralogy phases, magnitude of crystallization, and vapor phase devitrification

3. Variations in regional and localized strain rates

Clay zones have been documented in several fault cores within porous media. The presence of a clay rich fault core is significant because it will dominate the hydrologic behavior of a specific fault. Geoffrey Rawling, pers.comm, 2003 observed alteration and variability of clays and carbonates within fault zones in poorly consolidated sands. His work suggested the clay comes from either:

1. Alteration of material in the fault zone due to water retention (e.g. hydrolosis of feldspars creates opal). Water retention in the unsaturated zone would suggest preferential fracture flow.

2. Infiltration from the surface. This also implies a preferential flow path. Characteristic textures observed using microstructural SEM images would suggest deposition of these clays

Most deformation within fault zones in porous media are consist of hetergeneous zones including mixed zones (very wide range of K), damage zones with deformation bands, and possibly a central core comprised of breccia and/or clay.

The Bandeler Tuff has a definable mechanical stratigraphy based on deformational features related to dgree of welding. The more welded units deform by fracturing whereas the less

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welded units typically deform with deformation banding. Increased grain contacts related to cyrstallization will also allow fractures to propagate. At the Bandelier National Monument we observed deformation band zones within the Bandelier Tuff that were hardened relative to the surrounding host rock and stained with a reddish color but studies had shown there was no geochemical signatures to suggest a different composition than the host rock. In thin section, iron and tin oxides grow outward from the deformation band surface towards the slip surface (indicating post -fluid deposition)

The following characteristics of the Bishop Tuff are included for comparison:

1. Brittle deformation features occur within non-welded deposits with ≥ 30% porosity
2. Two types of faulting were identified: a) deformation band faults with narrow damage zones and b) 1-30 cm thick fault cores comprised of clay gouge with distributed damage zones from 1-8 m wide
3. Localized decrease in grain size/grain comminution occurs within the central fault core gouge
4. Deformation at fracture tips appears to die out into a diffuse zone of small grain boundary fractures
5. Localized mineralization occurs within fractures while open fractures are smooth, discrete surfaces
6. Fracture apertures are much greater than pore apertures adjacent to the fracture surface
7. Deformation occurred at or near surface conditions under very small confining pressures

In general the faults within these deposits do not fit well to current conceptual hydrogeological models for faults in brittle rocks (Caine et al., 1993) and have very little macroscopic fracturing.

HYDROGEOLOGY OF POROUS MEDIA

Several similarities exist between the deformation behavior of non-welded tuffs and unconsolidated sands. The potential impact of faults on fluid flow and transport in ignimbrite sequences depends on the nature of fault zone deformation and the present-day hydrologic conditions (i.e. saturated or unsaturated).

Of particular interest is the potential hydrologic impacts deformation features in these deposits may have within the vadose zone. In the vadose zone we are above the water table where air and water fill the pore space and water is almost always wetting. The capillary forces become important and finer grain material has a greater affinity for water. Therefore, gravity becomes more important as well due to the large densities in the air within the pore spac (i.e. deformation bands do influence fluid transport in the vadose zone).

Faults may act as conduits in vadose zone. Under dry conditions this is a narrow zone whereas under wet conditions the fault may act as a catchment to flow since gravity pulls the water downwards (John Sigda, pers.comm, 2003).

Multiphase flow is still poorly understood in the vadose zone. However, bulk hydrological characteristics depend on and may be defined by (John Wilson, pers. comm., 2003):

1. Strong permeability contrasts of the fault zone and related host rock properties

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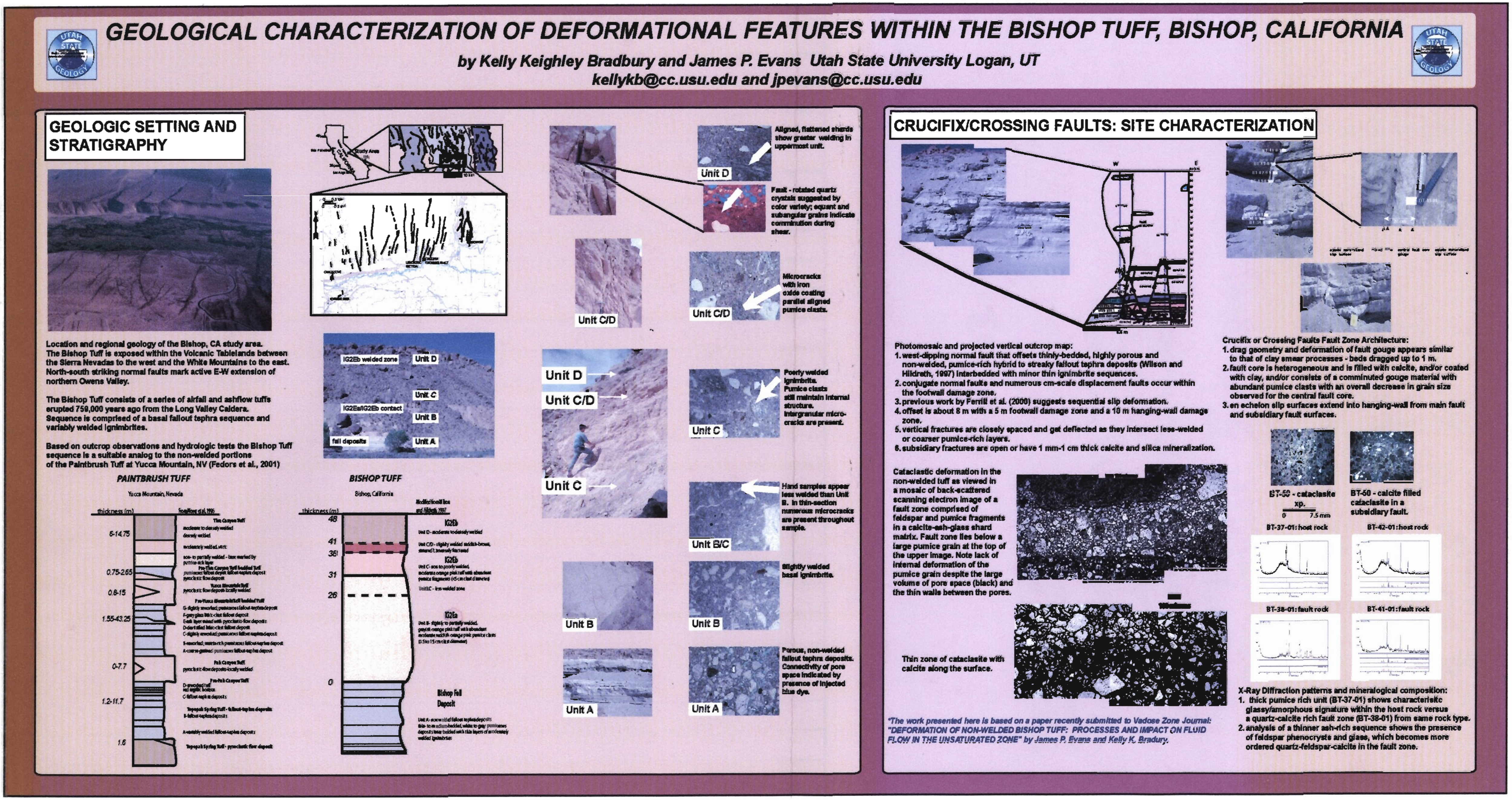
2. Rearrangement of lithologies influencing connections of high and low permeability materials

3. Interactions and linkages amongst faults

4. Setting within the flow system

The consequences of barrier type features are seals, compartments, and permability anisotropy whereas the consequences of conduit features are redistribution of fluids between lithologies, leakages of fluids, and springs.



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BTC1e TS1 –

- >> welding than BTC1d
- much less pumice
- 5-10% pumice; 10% lithics; 20% Qtz; 50-60% matrix
- No fracs observed
- pumice & clasts appear flattened & aligned // to deposition

Review prev photos* – 8/30/03 – 9/2/03
BT 1-10
BT 55
BT 56-62
BT 69
BT 65-68

* import all to iphoto now to create albums

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KKB 9/2/03

① Microanalysis (cont.) – 9/3/03
insert sample microphotomosaics into
Filepath GHOSTRANCH FOLDER > GHOSTRANCH2.ai
② CC2 fitcare.tif → insert into GHOSTRANCH2.ai
(poster for GHOSTRANCH / CDINW.DDIF)

KKB 9/4/03

① update ccf it-zone map – 9/6/03
Filepath GHOSTRANCH > GHOSTRANCH2.AI

② Work on insert of photomicrographs / photomicro mosaics / pics / figs into:
Filepath GHOSTRANCH > GHOSTRANCH2.AI
GHOSTRANCH > GHOSTRANCH1.AI

Witnessed & Understood by me, CLD
Date 06/04/04
Invented by
Recorded by
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Witnessed & Understood by me, CLD Date 06/04/04

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~~P124~~ CLD, 06/04/04

KKB 9/17/03
to 9/19/03

GRAIN SIZE ANALYSIS FOR
CHALK COVE PAPER / CF PAPER
CREATE CF2 DATA PLOTS
IN GRANPLOTS. XLS
SAVED AS:
BISHOP > GRAINSIZEANALYSIS >
CF GRAIN SIZE ANALYSIS >
cf2/cf1

KKB 9/22/03
- 9/23/03

* NOTEBOOK Q/A REQUESTS
THRU AUGUST 2003

KKB 9/29/03
- 9/30/03

* NOTEBOOK Q/A REQUESTS
THRU AUGUST 2003

CLD 06/04/04 ~~P125~~

KKB 10/1/03

NOTEBOOK Q/A REQUESTS -
MAILING

KKB 10/14/03

Continue microanalysis -
see "photomicrograph photos"
{CD enclosed}

Review KKB 10/15/03
Papers MAILED BY TONG-FANG LONG
per GHOST RANCH DISCUSSIONS
WANG et al 2001
WANG et al 2003

10/20/03
KKB 10/21/03

Continue cataloging
① photomicrograph slides
w/ photos {on CD}

* ② Prepare GHOST RANCH
TRIP Report notes

file path: GHOST RANCH >
GRtripnotes, GRtripprep.doc
GRtripprep

~~PR20~~ CLD, 06/04/04

KKB
10/23/03

file path
GHOSTRANCH > GHOSTRANCH
tripReport = GRtriprep

KKB 10/24/03

1. Q/A - Burn files to CD
photocopies
file path
2. GHOSTRANCH >
GRtriprep + GRtriprep.doc

KKB 10/30/03

1. Q/A - Notebook

2. file path GHOSTRANCH >
GRtriprep.doc
+ GRtriprep

~~PR27~~

KKB 11/03 CLD 06/04/04

1. print sieve plots ~ BISHOP >
file path GrainsizeANALYSIS

2. Final GHOSTRANCH KKB 11/17/03
TRIP Report
GRTRipnotes +
GRTRip notes.doc

3. update formulas for
BT sieve data

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~~p128~~ CLD, 06/04/04

KKB
12/10/03
- 12/12/03

① Grain size DATA
Fix Formula for spreadsheets - modified due to type error found in CC & CF spreadsheets
original data sheets BT 18 through BT 29 contain correct formula
- copy and paste to all CF & CC files
✓

② GRAIN SIZE STATISTICAL ANALYSIS CALCULATED W/ GRAN PLOTS FOR FOLLOWING FACTORS -
Measure: FOR CC & CF DATA
Mean ø, mm
Standard Deviation
Skewness
Kurtosis
Median
Relative Dispersion

~~p129~~ CLD, 06/04/04

KKB
12/16/03

① PHOTO micrographs FOR PHOTOMICROMOSAICS specifically for samples to be potentially used for CC paper
[see PHOTOMICROGRAPH CD FOR LIBRARY]

KKB 12/17 - 12/18/03

Chalk Cove paper
Lit review & library research
TUFF properties + Gr sz + %oclasts -
MOON, 1993
Winograd, 1971
WILSON & Hildreth, 1997, 1998
Ragan & Sheridan - 1972

Ptn -
Moyer, 1996

KKB 12/29/03

Review Thinsection slides & PHOTOMICROGRAPHS - CC Samples

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KKB 12/30/03

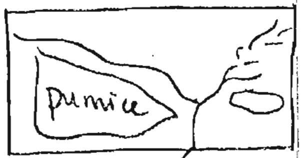
UPDATE Microdata table –
filepath – Bishop > Microstructures > microdata table

KKB 12/31/03

* Q/A notebook duties – re-copy requested per C. Dinwiddie

KKB 1/1/04

USU – Microscope
CC micro –
BT-3-01 (original sample from jpevans)



open micro frax
· abundant air bubbles in pumice clasts
- Glassy, shard matrix but not devitrified or welded
- Ksper xls, Qtz clasts
- Deformation lamellae in Feldspar xls + Qtz
- Some (minor) flattening of smaller pumice shards or beg phase of alignment
pic1 – multicolor clasts 10x
pic2 – Scale pic
pic series – mosaics
[see PHOTOMICROGRAPH CD]

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~~p132~~ CLD, 06/04/04

KKB 1/1/04

- CC samples in general do not resemble any material ive studied before or reported in the literature
  - need to try to track down any photomicrographs that may be published
- wavy fractures ↓
- observe deformation band-like micro structures in thin section & apparent in outcrop - but don't quite fit definition due to lack of significant decrease in grain size
- there is a decrease in grain size in several of the fH surfaces but also associated w/ open fractures - may represent an initial phase of a deform band structure

CLD, 06/04/04 ~~p133~~

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KKB 1/5/04

Lit review pertaining to CC micro structures —

- Moon, 1993
- Main et al., 2001
- Blenkinsop, 1991, 1992
- Mitra & Ismat, 2001

↓

Suture zones & Sintered

- Blenkinsop, 2000

KKB 1/15/04 - 1/16/04

file path - work file Bishop > GrainSize Analysis > CC HW1 gr sz analysis + CF grainsize analysis

"Continue work in Above files" 1/21/04 + KKB 1/25/04

KKB + 1/28/04

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~~p134~~ CLD, 06/04/04

KKB 1/26/04

litreview – CCpaper
- Boggs, 1995 – grain contacts
- Schulz & Evans, 1998
- Heynekamp et al, 1999

KKB 1/29/04

Generate mean grain size plots vs. initial air K files obtained from C DINWIDDIE

Filepaths:
Bishop > Grain Size analysis > CCHW1
grszanalysis > CCHW1 mean

and > CC3 grszanalysis > CC3 mean

KKB 1/30/04

– CCpaper
Bishop > CCmanuscript

CLD, 06/04/04 ~~p135~~

CC manuscript >
KKB 2/4/04
↓ manuscript w/ HJ template 2-3 doc from C. Dinwiddie

KKB 2/13/04
cc manuscript >
CC paper insert A

KKB 2/16/04
- fig xrd data
- fig strat
- fig strat pics

working CC paper figs

KKB 2/19/04 – 2/20/04
cc manuscript >
- KKb2.17.cctxt.doc
- manuscript 2.19
- ccmanuscript KKb.doc
- completed CC2, CC3, CCHW1. Data.xls
- ronsetting.doc

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~~p136~~ CLD, 06/04/04

KKB 3/3/04 - 3/6/04

ccpaper - ① cc micro
newpics for samples
BT 85
BT 74
BT 82 TS1, TS2
BT 99

② Gr sz analysis - Review of plot trends
- zones of fair Homogeneity
(relative dispersion 1 > x < 1.33)
occur where intense FeOx
alteration occurs & also
K tends to be higher &/or
spike &/or data is
lacking in these same zones
@ 3 sites:
CCHW1 - @ 220 & 240 cm
CC3 - @ 400 cm

idea?
matrix supported fabric
similar to conglomerate in
fluid flows

③ BT is glassy, nonwelded ! xlized?
NOT vapor phase xlized but
sintered zones near top CC3

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~~p137~~

CLD, 06/04/04

KKB 3/7/04 - 3/8/04

from -
Moon, 1993

① porosity / bulk density ✓ less accurate
- measures packing in ignimbrite
lo n but Hi p = Hi comp. strength

② soft, devitrified pumice
clasts deform much more
readily than surrounding
groundmass - providing
regions of stress
concentrations & microfrac
development

ignimbrite char w/ Hi tensile
strength & brittle failure
1. Shards aligned
2. dense, glassy pumice
3. Low proportion of pumice
[Ignimbrites w/ opposite char - plastic deform]

- Luddecke et al, 1998 - ±757 ka
- Wilson & Hildreth, 1997; 2003; review

BT = Glassy, nonwelded to sintered

- Ferrill et al 2000
- Bates, 1965
- Pinter, 1994
- Moyer, 1996.

~~P138~~ CLD, 06/04/04

KKB 3/9/04

Trip to U of U Library, Salt Lake City

Search for Refs not found at Utah State Univ -

① Schmincke & Swanson, 1967

"Some workers hand-sieve samples that contain abundant pumice fragments mixed w/ abrasive lithic & mineral clasts to avoid excessive breakage"

method applied to CC/CF samples

② Krumbein & Tisdel, 1940

Rosin's Law Dist / frequency is more suitable than normal distribution to describe volcanic mat'l (see cc data / granplots.xls)

③ Sheridan, 1971

④ Sun et al, 2003

⑤ pyroclastic rocks, 1984

⑥ Smith, 1960(b)

~~P139~~

CLD, 06/04/04

KKB 3/10/04 - 3/12/04

- cc manuscript >

KKBccinsert A.doc

+ working figs

KKB 3/15/04 - 3/19/04

cc manuscript >

Background

KKBinsert C.doc

KKBinsert D.doc

KKBinsert D2.doc

KKBinsert B.doc

KKB 3/22/04

KKB 3/23/04 - 3/25/04

- receive update K data

- KKB insert E1.doc

- " " E2.doc

KKB 3/29/04

KKB 3/30/04

CC xrd files -

run Search & match to look for cristobalite & trydimite -

save as .doc files

BT71 → BT89

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~~p140~~ CLD, 06/04/04

KKB 3/31/04

cc manuscript >
update → CC3mean
- CCHW1 mean
- KKb insert E3
- XRD documents printed

KKB 4/1/04

ccmanuscript >
Working Figs: ccatzropp pics.ai
FeOx.ai
bt 99.jpg
fig11a.ai
bt 74.jpg
fig11b.ai
bt 82tsl.jpg
bt 82clast.jpg
~~fuzzy~~ 85.jpg
fig5atzrop.ai
fig11d.ai
fig11e.ai
fig11c.ai
bt 99.100.ai
fig8cchw1 map.ai
bt 102 .103.ai
Fig 9 cc3map.ai

CLD, 06/04/04

~~p141~~

KKB 4/2/04

ccmanuscript >
working: Fig7ccf1+map.ai
KKb insert E4
Struct Discussion

KKB 4/4/04 - 4/9/04

cc manuscript >
- manuscript w/ HJ template.doc - ↓ load latest version
- xrdmethods.doc
- KKB insert B.doc
- F1 insert.doc

KKB 4/12-4/14/04

wrapping up final edits of ccpaper & requests for C. Dinwiddie

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06/04/04

Recorded by

December, 2003
Thin -section Inventory and analysis Summary Sheet
Kelly Keighley Bradbury
Geologic Consultant for CNWRA/SWRI
Bishop Project

Site Loci	Sample	Lithology	XRD	Physical Characteristics and Microstructures
Bishop—HC	BT-01-01	nonwelded glassy unit - sample from the fault/coating surface with attached pumice fragments in a poorly lithified volcaniclastic deposit ; thick feox coating; fault strikes 10E/70NE 1a -? 1b?	Q, Feld	intragranular fracture - fractures soley within grains are likely related to initial eruption while secondary fractures cutting between grains show evidence for quartz dissolution and recrystallization after deposition; 1b possibly some contact metamorphism related to faulting
Bishop—CC	BT-03-01	Hanging wall tuff; thin section	Q	Pumic clast bounded by open fracs; frac surf are irregular; appears to be some rotation of q xls
	BT-04-01	Sample – loci uncertain check jpevans notebook	?	Fine grained frac fill with calcite? Veining to open frac as observed by entrance of blue dye
	BT-05-01	Sample	CaCo3; Phyllite clays	Glassy q xls; feox stained frac surface with fine gr fill
Bishop—HC	BT-06-01	Upper fault surface	Q/Na,/ Ca spars	Intergranular and intergranular fracturing; feox stained fracture surface bounded by fine grained/crushed frac fill and breccia with some cataclastiic grain flow
Bishop—HC	BT-07-01	At fault contact between lacustrine and ignimbrite sequence; 301° blue line indicates sample orientation; fault orientation: 002°/70°N;		
Bishop—HC	BT-08-01	Slightly cemented wall in immediate hangingwall of fault;		
Bishop—HC	BT-09-01	Fault: N-15/70°--face opposite sample orientation line		
Bishop—HC	BT-10-01	Dip arrow on red surface (outer surface)--⊥ to fault; sample: Thin section		
Bishop—BP	BT-16-01	Fault surface epoxied west of pit 3; 16B-thin section; 16C-thin section ⊥ and		
Bishop—CC	BT-31-01	Moderately welded tuff;		
Bishop—BP	BT-32-01	Left of pit 1;		
Bishop—CF	BT-51-01	Fractured ash—green ash 1;		
Bishop—HC	BT-52-01	Fracture near fault zone epoxied;		
Bishop—HC	BT-53-01	Bedded pumice		

Site Loci	Sample	Lithology	XRD	Physical Characteristics and Microstructures
Bishop—CF	BT-54-01	1 m west of dye test;		
Bishop—CC	BT-55-01	Fault zone= 195/74W (on hanging wall), 196/73W; (sketch of rake—Kelly's notes p. 18) rake is 65°or 80°from south (65°rake is more commonly seen);		
Yucca Mtn.	YM-1-01			
Yucca Mtn.	YM-2-01			
Bishop—BP	BT-56-02	Pit sample of caliche fracture—2 m east of pit 2; small sample from along one of the small fractures with dye;		
Bishop—BP	BT-57-02	Cs(?) above; sample: thin section		
Bishop—BP	BT-58-02	Large sample from fracture, with dye;		
Bishop—BP	BT-60-02	Face at 005°/84°;		
Bishop—BP	BT-61-02	005°/76°;		
Bishop—CF	BT-62-02	Poorly welded tuff with 1-2 mm pumice fragments, with fractures 1-3 cm apart; yellow thin pumice layer at the top; collected 9 m east of the biggest fault at this site;		
Bishop—CF	BT-63-02	Collected 1.5 m east of the main fault at this site—similar stratigraphic level as BT62; fractured tuff with pumice; thin yellow pumice-rich layer at top of sample;		
Bishop—CF	BT-64-02	Collected from gray-green ash layer 2.5 m in hangingwall of the largest fault;		
Bishop-BP	BT-65-02			
Bishop-BP	BT-66-02			
Bishop—CF	BT-67-02	Very nice sample of fault on east edge of Crucifix Site; sample from white ash bed; 015°/67°E;		
Bishop—CF	BT-68A-02	From east edge of fault; thin gouge zone and slip surface;		
Bishop—CF	BT-68B-02	From east edge of fault; thin gouge zone and slip surface		
Bishop—CF	BT-68C-02	About 5 cm thick gouge		
Bishop—CF	BT-68D-02	From east edge of fault; thin gouge zone and slip surface;		
Bishop—CF	BT-69-02	Small fractured sample from top of white tuff;		
Bishop—CF	BT-70-02	Large fractured sample from white tuff bed		

Witn

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Site Loci	Sample	Lithology	XRD	Physical Characteristics and Microstructures
Bishop—CC	BT-74-02	Fault gouge immed?? foot wall in white, friable material		
Bishop—CC	BT-82-02	central fault gouge – TS1-ii to strike; TS2- +to strike		
Bishop—CC	BT-85-02	FeOx stained block between hanging wall fracture 1 and 2; 11-11.15m;		
Bishop—CC	BT-86-02	Fault core gouge; 2 cm thick @ 13.7m;		
Bishop—CC	BT-87-02	@ 14m; in fracture block west of fault core; ~ hanging wall fracture 3		
Bishop—CC	BT-88-02	Zone between hanging wall fracture 1 (on cc2?);		
Bishop—CC	BT-89-02	Clay gouge from fault core; 5 cm thick; CC2;		
Bishop—CF	BT-90-02	Crucifix; 9.6m on scan; fault gouge;		
Bishop—CF	BT-91-02	Fault gouge @ 9.6m		
Bishop—CF	BT-92-02	Green bed CF lower/CF 2; ~10cm from Crucifix fault; lithologic sample;		
Bishop—CF	BT-93-02	5.1m white bedding CF prer??/CF 1;		
Bishop—Strat	BT-94-02	Strat column site (BT94-98); unit A;		
Bishop—Strat	BT-96-02	Unit B/C		
Bishop—Strat	BT-97-02	Unit C—less welded (unit Ca);		
Bishop—Strat	BT-98-02	Unit C—densely welded (unit Cb);		
Bishop—Strat	BT-A1-02	@ 0m; fracture surface appears similar to discrete fault surfaces observed at Chalk Cove site; S25W 70NW fracture,		
Bishop—Strat	BT-A2-02	~46m; ⊥ to layering; near transition to B; lesser degree of welding;		
Bishop—Strat	BT-B-02	~53m; South side of tape; collected by D.H.; O°/78°W;		
Bishop—Strat	BT-BC-02	~63m; transition zone between units B and C		
Bishop—Strat	BT-C-02	@75.0m; welded tuff; N20W 2NE		
Bishop—Strat	BT-C1aa-02	Hanging wall rock and gouge;		
Bishop—Strat	BT-C1cc-02	Footwall rock and gouge;		
Bishop—Strat	BT-C1d-02	Footwall rock; 3cm;		

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Site Loci	Sample	Lithology	XRD	Physical Characteristics and Microstructures
Bishop—Strat	BT-C1e-02	Hanging wall rock; N5W 83E		
Bishop—CC	BT-99-02	Between hangingwall fracture 2 and hangingwall fracture 3; 2.5m N of transect line75-85 cm away from fault;		
Bishop—CC	BT-100-02	20cm south @ 270cm on transect CCHW1; in FeOx zone;		
Bishop—CC	BT-101-02	Near 580 cm; 13cm from midpoint of 580cm and 15cm west of 580cm near Guelph Test Site #4;		
Bishop—CC	BT-102-02	CC2 transect map; footwall of fault; .5m north from 65cm station on transect CC2;		
Bishop—CC	BT-103-02	Fault core gouge of Chalk Cove fault;		
Bishop—CF	BT-104a-02	CF fault; fault core gouge; runs parallel to fault surfaces;		
Bishop—CF	BT-105-02	Fault core parallel to previous two samples		
Bishop—CF	BT-106-02	From CF2; loci @ 465-470 cm and 25cm above tape; fault surface on E wedge fault;		
Bishop—CF	BT-107a-02	Fault core; east most layer; TS1-II to strike; TS2-+to strike XRD1 and XRD2	Q/Feldspar	
Bishop—CF	BT-107b-02	Fault core near K test 205 cm; central layer; TS1-II to strike; TS2-+to strike XRD1 and XRD2	Q/ Anorthite	
Bishop—CF	BT-107c-02	Fault core; west most layer; TS1-II to strike; TS2-+to strike	Q/Kspar /Naspar	

CLD 04/04/04

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Sample #	Total Weight (g)	4.00	4.75	5.00	%fines
cchw1-0	263	57.800	30.500	9.100	37.0342205
cchw1-20	186.9	15.7	22.3	13.2	27.3943285
cchw1-40	302.9	19.5	2.9	2.3	8.15450644
cchw1-60	303.3	40.5	6.5	2.4	16.2875041
cchw1-80	272.4	66.2	19	5.3	33.2232012
cchw1-100	207.8	43.3	12	3.5	28.2964389
cchw1-120	221.8	45.7	8.9	1.4	25.2479711
cchw-140	212	19.1	6	1.1	12.3584906
cchw1-160	165.8	41.9	9	2.2	32.026538
cchw1-180	207.4	37.5	10.2	3.5	24.6865959
cchw1-200	268.6	36.4	8.3	2.4	17.5353686
chw1-220	190.8	39.4	5.8	1.5	24.475891
cchw1-240	337.8	36.7	6.3	2.2	13.3806986
cchw1-260	214.7	28.6	9.5	5	20.0745226
cchw1-280	300	51.7	8.3	1.9	20.6333333
cchw1-300b	564.6	93	18.9	3.4	20.4215374
cchw1-300a	231	41.5	5.8	1.6	21.1688312
cchw1-320	691	55	6.4	1.4	9.08827786
cchw1-340	606.8	91.8	18	2.5	18.5069216
cchw1-360	564.2	61.9	2.6	0.4	11.5030131
cchw1-380	493.3	67.7	10.9	0.9	16.1159538
cchw1-400	355.4	66.6	11.3	2.1	22.5098481
cchw1-420	422.7	34	2.1	0.6	8.68228058
cchw1-440	584.4	32.3	2.3	0.1	5.93771389
cchw1-460	502.7	36.5	3.3	0.8	8.07638751
cchw1-480	474.6	33.1	6.1	2.2	8.72313527
cchw1-500	465.9	82.7	9.7	1.9	20.2403949
cchw1-520	426	49.6	10.3	1.7	14.4600939
cchw1-540	303.6	75.4	15.5	2.4	30.7312253
cchw1-560	173.5	31.9	12.4	2.8	27.1469741
cchw1-580	145	22.1	8	2.8	22.6896552

Sample #	Total Weight (g)	4.00	4.75	5.00	%fines
cc3-0	322.6	49.5	7	2.1	18.1649101
cc3-20	288.7	57.4	13.6	3.1	25.6667821
cc3-40	281.9	72.8	21.6	2.1	34.2319972
cc3-60	365.4	76.2	17.1	3	26.3546798
cc3-80	371.9	55.5	15.8	3.5	20.1129336
cc3-100	311.1	30	5.2	2.2	12.0218579
cc3-120	351	75.8	18.3	3.8	27.8917379
cc3-140	404.9	45.7	5.6	0.8	12.8673747
cc3-160	258.8	58.6	8.4	0.6	26.1205564
cc3-180	249.3	79.7	4.4	0.8	34.055355
cc3-230	422.5	22	2.8	0.7	6.03550296
cc3-240	55.1	38.3	5.9	1	82.0326679
cc3-250	519.9	72.9	12.5	1.2	16.6570494
cc3-280	384.2	82.6	13.9	0.8	25.3253514
cc3-300	586.8	72.9	9.9	1.1	14.2978868
cc3-320	408.4	52.8	10.3	1.2	15.7443683
cc3-340	378.7	67	14.4	1.4	21.8642725
cc3-360	320.8	78.9	16.1	1.4	30.0498753
cc3-380	326.4	44.9	9.9	2.1	17.432598
cc3-400	571.5	21.3	2.2	0.2	4.14698163
cc3-420	367.9	26.6	3.5	0.8	8.39902147
cc3-440	515.2	73.1	10.7	0.8	16.4208075
cc3-460	580.1	76.3	14.3	1.9	15.9455266
cc3-480	596	66.8	12.4	2.5	13.7080537
cc3-500	676	101.4	13.8	1.9	17.3224852
cc3-520	488	92.6	21.2	3	23.9344262
cc3-540	528.3	97.4	20.1	3.1	22.8279387

Witnessed & Understood by me,

CLD

06/04/04

Recorded by

SUMMARY CHARACTERISTICS FOR CRUCIFIX SITE SAMPLES

Sample ID	lithology/structure	location	Microanalysis summary	X-Ray Minl	Porosity
BT-34	white ash bed?	cf fault - 40 cm into footwall from flt	-	Qtz, feldspars	.59
BT-37	green bed?	cf fault - 10 cm into footwall from flt	-	Qtz, feldspars, glassy	.60
BT-39	green bed?	cf fault	-	Qtz, feldspars, glassy	.63
BT-41	fault surface/white ash	cf fault	-	Qtz, feldspars	.57
BT-43	fault core	cf fault	-	Qtz, feldspars, calcite	.39
BT-44	fault core	cf fault - footwall	-	Qtz, feldspars	.49
BT-46	fault core	cf fault - footwall	-	Qtz, feldspars	.69
BT-47	fault core/green ash 1	cf fault - hanging-wall	-	Qtz, feldspars	.42
BT-50	fault core	small FW fault	Evans and Bradbury, 2004	Qtz, feldspars, calcite	--
BT-51	green ash 1	footwall	Evans and Bradbury, 2004	Qtz, feldspars	--

**above samples from previous study with James P. Evans and are located in Figure 6 of Evans and Bradbury (2004)

BT-62	bedded fallout tephra host rock	9 m east of crucifix fault		--	--
BT-63	bedded fallout tephra host rock	1.5 m east of Crucifix fault		Qtz, feldspars	.51
BT-64	green ash fallout tephra host rock- hanging-wall	2.5 m west of Crucifix fault		--	.38

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BT-68	fault core	crucifix fault core - near 257 cm of fault perm tests of 9/18/02	fine to medium grain; irregular (sylolitic nature) hairline frac follow grain boundaries connect to larger open frac; cataclastic deformation; some frac with calcite fill; also iron oxides; evidence of healed frac; and recrystallization along some grain contactss	--	--
BT-69	white ash layer host rock	above survey areas but within similar white ash bed as CF1	very fine to clay size groundmass with open frac	--	--
BT-70	hanging-wall host rock - bedded fallout tephra	above line at -12 cm location	--	Qtz, feldspars	.62
BT-90	fault core	smalll fw flt core 9.6 m upper; 9.7 lower survey	poorly consolidated fine grains of pumice, quartz, and glass, blue dye fills pore spaces; dissolution and redeposition of qtz	Qtz, glass	.61
BT-91	fault core	small fw flt core 9.6 m upper; 9.7 lower survey	fine to medium grain poorly consolidated, irregluar hairline fraccompaction to dilation followed by dissolution and recrystallization of qtz and/or mineralization related to fluid flow along frac; some frac filled with finer goundmass indicating cataclasis	Qtz, feldspars	--
BT-92	green-gray fallout tephra-host rock	10 cm east of crucifix fault on CF2 or lower transect	medium to coarse grained poorly consolidated with finer matrix; grain boundary migration - recrystallization; efromation lamallae in qtz xls	Qtz	--
BT-93	white-ash host rock	about 5.2 m on CF1 or upper transect - sample just east of 5.15 m perm test hole	very fine grain to clay size; glassy; pores are interconnected as inidcated by spread of blue dye throughout	Qtz, glass	--
BT-104A	fault core gouge - lower outcrop	-12 cm - fault core was taken from below the survey lines	compaction; cataclasis; dilation; clay to ash size zones of banding alternate with fines; with open to filled fracs; migration of blue dye dependent on zones and fracturing	Qtz, glass	.70

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BT-105	fault core gouge- lower outcrop	-12 cm - fault core was taken from below the survey line	clay to ash size; compaction and cataclasis followed by dilation indicate at least two phases of deformation along microfaults; fluid properties vary along these microfracs as blue dye penetrates pods and zones then stops or follows open frac;	Qtz, glass	--
BT-106	east wedge or crossing faults fault surface and core	465-470 cm and 25 cm above fault perm survey CF2	fine to coarse grained; open pore space; pirmarily dilation mechanism potl for minor cataclasis prior; dark brown glassy material found within some fracs - possibly suevite related to the hydration of glass during faulting	Qtz, feldspars glass	.70
BT-107A	footwall side fault core - upper outcrop	crucifix fault at 221 cm of fault perm survey of 9/18/02	catalcastic deformation in frac surfaces; open microfrac within fine grained to ashy groundmass cut cataclastic bands of deformation - again suggesting dilation follows cataclastic phase of deformation	Qtz, feldspars	.29
BT-107B	central fault core - upper outcrop	crucifix fault at 205 cm of fault perm survey of 9/18/02	heterogeneous gouge; complex deformation - multi layering of gouge; fracturing - dissolution, healing, filled to open	Qtz, feldspars	.29
BT-107C	hanging wall side fault core - from dragged footwall bed - upper outcrop	crucifix fault at 257 cm of fault perm survey of 9/18/02	coarsest sample out of fault core suite 107; fine to medium grained; quartz ; cataclastic deformation to dilation; microstylolitic pattern again - see others - with iron oxides - concentrated as a result of removal of quarts (EXPLORE FURTHER).	Qtz, feldspars	.29

WHEN ONLY DISTANCES ARE LISTED THESE SAMPLES ARE REFERENCED TO HOLE LOCATIONS AS IDENTIFIED ON R. MCGINNIS MAP SENT TO ME ON 10/23/04 - CFMOSAIC.PDF

Other distances are referenced to survey lines for Cf1 and Cf2 completed in September 2002 by C. Dinwiddie

For CF1 or upper white ash bed - Mean average grain size: 0.12 mm Median: 0.0815 Max: 0.03128 Min: 0.0.0499

For CF2 or lower green gray fallout tephra bed - Mean average grain size: 0.25 mm Median: 0.2265 Max: 0.5926 Min: 0.1701

check this???if possible: do hanging wall rocks have lower porosity????? would make sense since as a result of less microfracs

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Electronic Notebook – Notes October 2005-April 2006
Kelly Keighley Bradbury
April 14, 2006

October - December 2005:

- Print R. McGinnis Figures and locate postion of thin-section samples from Crucifix site on large PDF file mosaic. Samples located include BT62, BT67, BT68, BT69, BT90, BT91, BT93, BT104a, BT105, BT106, BT107a, b, c. Using photographic mosaic contained within files supplied by R. McGinnis: CFmosaic.pdf; Crucifix.pdf
- Data to review and code out possibly?? Will want to create appendices which should include grain size data, porosity data, microstructural and mineralogical thin section analysis, X-Ray diffraction data, and 10 cm bin fracture data – compile this data and compare to R. McGinnis data for final Crucifix journal article. Ideal to somehow include data with symbols on the large photomosaic created by R. McGinnis for this site (to be contained within a summary figure for paper) – maybe use box, circles in different colors/patterns. As combine this might be able to incorporate in cfsurveyoutline.ai file (field mapping of site) and include portions of photomosaic which are appropriate.
- GSA – attendance at relevant research related talks/abstracts/posters includes Evans (2005); Shipton (2005); Vrolijk (2005); Bense (2005); Rawling et al. (2005); Wilson et al. (2005); Vaniman et al. (2005); Sternlof et al. (2005); Caine (2005); McGinnis et al. (2005).
- Internet search on poorly consolidated sediments, volcanic deposits, glass mountain rhyolite. Literature review/internet search pertaining to cfmanuscript.doc – Lee and Kim, JSG v27 (2005) p. 2099-2112; also - http://earthweb.ess.washington.edu/cowan; www.msm.cam.ac.uk/phase-trans/abtracts/recrystallise.grain.size.html; www.msm.cam.ac.uk/phase-trans/2005/Zener/index.html; http:/erp-web.er.usgs.gov/reports/annsum/vol41/pt/g0004/g0004.htm
- Review sample inventory and characteristics for cf site: cfsamples.doc
- Continue importing text and rearranging within master document for writing purposes in newcfmanuscript.doc
- Read reviewer responses from CC paper obtained from Vadose Zone Journal. Conference call with Cynthia Dinwiddie, David Ferrill, and Randy Fedors wrt to Chalk Cove final paper revisions for submittal to Vadose Zone Journal. Complete paper revisions.

January 2006:

- BT photomicrograph update at USU. Photographs contained within kkbmicrophoto folder.
- Add notes within newcfmanuscript.doc

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February 2006:

- Lit search and review – download articles from internet from Journal of Structural Geology and Vadose Zone Journal.

March 2006:

- Point count analysis on thin section slides: cfpointcounts.xls
- Review perm data supplied by C. Dinwiddie: CF1.SmartPerm and Fracture Data.xls and CF2.SmartPerm and Fracture Data.xls (see SN 639)
- Grain size analysis continued: BT71to80grszanalysis.xls; cfwholerkgrsz.xls; CF1.Mean.xls; CF2.CFlMean.xls; cf1.wtfines.xls; cf2.wtfines.xls
- Google Earth Bishop area: crucifix.jpg; bishop.jpg
- Review fracture intensity data: crfi.xls

April 2006:

- Continue data analysis for CF paper: CFKvsGRSZ.xls; cf1grsizedata.xls; Cf k data and outcrop.tiff (see Dinwiddie SN 639); integrated data.xls (see Dinwiddie SN 639); cf1.cfugrszdata.xls; cf2.cflgrszdata.xls; cf2.wtfines.xls; cf1.wtfines.xls
- Input standard deviation and skewness data for test hole sites – CFKvsGRSZ.xls
- Writing thoughts/ideas within cf paper: kkbCFINTRO.doc; newcfmanuscript.doc; kkboutline.doc
- Lit review of Glass et al. (2005); Flint et al. (2006); Wong et al. (2001); Wolf et al. (2003); Shipton and Cowie (2003); www.odp.tam.edu/ - values and definitions for volcaniclastic sands; see also Fisher and Schmincke (1984) – values for ash <2mm; silty to fine sands range very coarse sand is 1 mm to very fine sand is <125µm to silt is <62µm. Boggs (1992) – review section on volcaniclastic deposits
- Teleconference call with C.Dinwiddie, R.McGinnis, and D. Ferrill 4/6/06.
- Teleconference call with C.Dinwiddie, R.McGinnis, and D. Ferrill 4/13/06.

See attached CD for access to electronic files by K. Bradbury

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Reconciliation of Location Names: Data collected at the Crossing Faults/Crucifix Site

Scientific Notebook Entry

April 24, 2006

Grain Size and Fracture Intensity data and Thin Section samples were associated with numeric identifiers along transects CF1 and CF2 by Bradbury and Heermance. Permeability and Fracture Density data were associated with numeric identifiers along transects CF1 and CF2 (Dinwiddie, Bannon, and McGinnis). At some locations, the identifiers were slightly different because of the different technical staff reading off the distance of a specific location along a measuring tape in a different way. On this day, April 24, 2006, McGinnis, Bradbury, and Dinwiddie met to reconcile the differing location names based upon observations from the highly detailed outcrop photomosaics that are available in the McGinnis et al. paper. The following two tables summarize the location reconciliation:

CF1

Bradbury and Heermance (cm)	Dinwiddie, Bannon, McGinnis (m)	**Reconciled Location Name (m)**
No Bradbury data ~~585~~	CLD, 5/10/06 5.90	**5.90**
No Bradbury data ~~675~~	CLD, 5/10/06 6.76	**6.76**
800	8.03	**8.03**
950	9.48	**9.48**
967	9.61	**9.61**
972	9.71	**9.71**
1025	10.23	**10.23**

CF2

Bradbury and Heermance (cm)	Dinwiddie, Bannon, McGinnis (m)	**Reconciled Location Name (m)**
109	1.08	**1.08**
870	8.75	**8.70**
1025	10.30	**10.25**

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Reconciliation of Location Names:
Data collected at the Crossing Faults/Crucifix Site

Scientific Notebook Entry

May 3, 2006

Grain Size and Fracture Intensity data and Thin Section samples were associated with numeric identifiers along transects CF1 and CF2 by Bradbury and Heermance. Permeability and Fracture Density data were associated with numeric identifiers along transects CF1 and CF2 (Dinwiddie, Bannon, and McGinnis). At some locations, the identifiers were slightly different because of the different technical staff reading off the distance of a specific location along a measuring tape in a different way (and tapes were draped on three different site visits). On May 2, 2006, McGinnis, Bradbury, Ferrill, and Dinwiddie met to reconcile additional differing location names (beyond those identified on April 24, 2006) based upon observations from the highly detailed outcrop photomosaics that are available in the McGinnis et al. paper, and also on sample collection data, structural maps, and photographs under the control of K. Bradbury. A few identifiers on the highly detailed outcrop mosaics of McGinnis et al. were also found to need reconciliation with the data of Bradbury and Dinwiddie, given these additional sources of information. The following two tables summarize the location reconciliation:

CF1

Bradbury & Heermance (cm)	Dinwiddie & Bannon (m)	McGinnis et al. (ID label, only)	**Reconciled Location Name (m)**
165	1.75	1.75	**1.65**
no data	1.70	1.70	**1.60**
0	0.00	no data	**0.00**

CF2

Bradbury and Heermance (cm)	Dinwiddie and Bannon (m)	McGinnis et al. (ID label, only)	**Reconciled Location Name (m)**
no data	no data	0	**0**
152*	1.50	no data	**1.50**
168	1.68	1.50	**1.62**
195*	no data	1.68	**1.95**

*In Bradbury's notebook, sometimes the CF1 designation was written as cfu for upper bed, and CF2 was written as cfl for lower bed. This led to a transcription error where cfl for lower bed was recognized incorrectly to mean cf1. This issue led to the grain size sample for location CF2.152 (Bradbury's original location name) being put inadvertently in lists of data for CF1. This issue also partially led to the grain size sample for location CF2.195 being put inadvertently in the CF1 lists as being CF1.155. Going back to the original sample collection sheets helped us to identify and here-correct this mislabeling issue.

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Scientific Notebook Entry

May 10, 2006

Grain Size and Fracture Intensity data and Thin Section samples were associated with numeric identifiers along transects CF1 and CF2 by Bradbury and Heermance. Permeability and Fracture Density data were associated with numeric identifiers along transects CF1 and CF2 (Dinwiddie, Bannon, and McGinnis). At some locations, the identifiers were slightly different because of the different technical staff reading off the distance of a specific location along a measuring tape in a different way (and tapes were draped on three different site visits). On May 10, 2006, McGinnis, Bradbury, and Dinwiddie met to reconcile additional differing location names (beyond those identified on April 24 and May 2, 2006) based upon observations from the highly detailed outcrop photomosaics that are available in the McGinnis et al. paper, and also on sample collection data under the control of K. Bradbury. The following two tables summarize the location reconciliation:

CF1

Bradbury & Heermance (cm)	Dinwiddie & Bannon (m)	McGinnis et al. (ID label, only)	**Reconciled Location Name (m)**
923	9.25	9.25	**9.23**

CF2

Bradbury and Heermance (cm)	Dinwiddie and Bannon (m)	McGinnis et al. (ID label, only)	**Reconciled Location Name (m)**
490	no data	4.85	**4.85**
625	6.21	6.27	**6.25**
825	8.24	8.24	**8.24**

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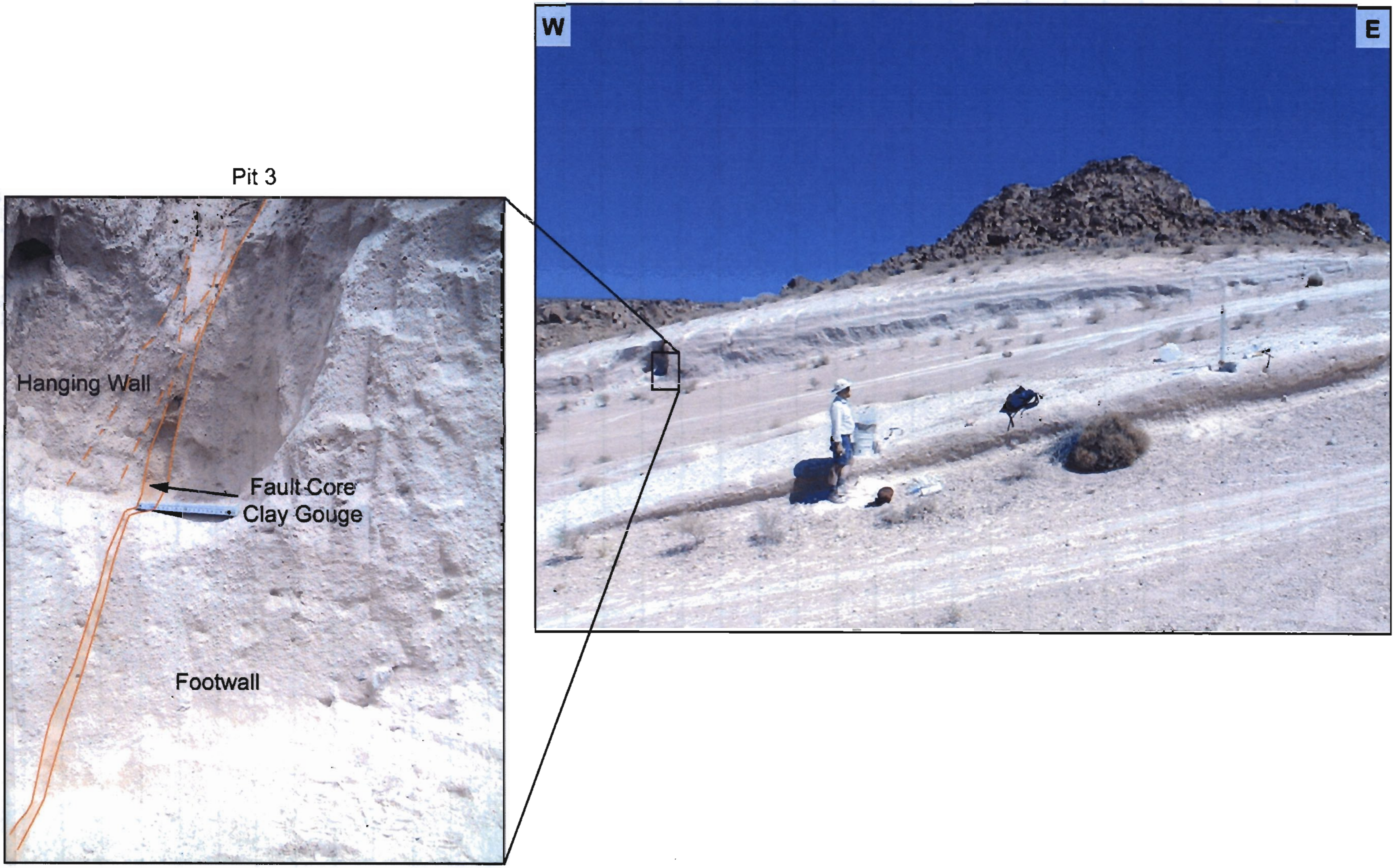

Figure 3.1-4. Context Image of Borrow Pit Excavation and Small Fault (Inset) Located at Test Pit 3 (Photographs Courtesy of Randall W. Fedors). See Figure 4 of Evans and Bradbury (2004) for Site Area Map.

From 2006 PTn Letter Report. Developed from images supplied by R. Fedors. –CLD, July 6, 2006

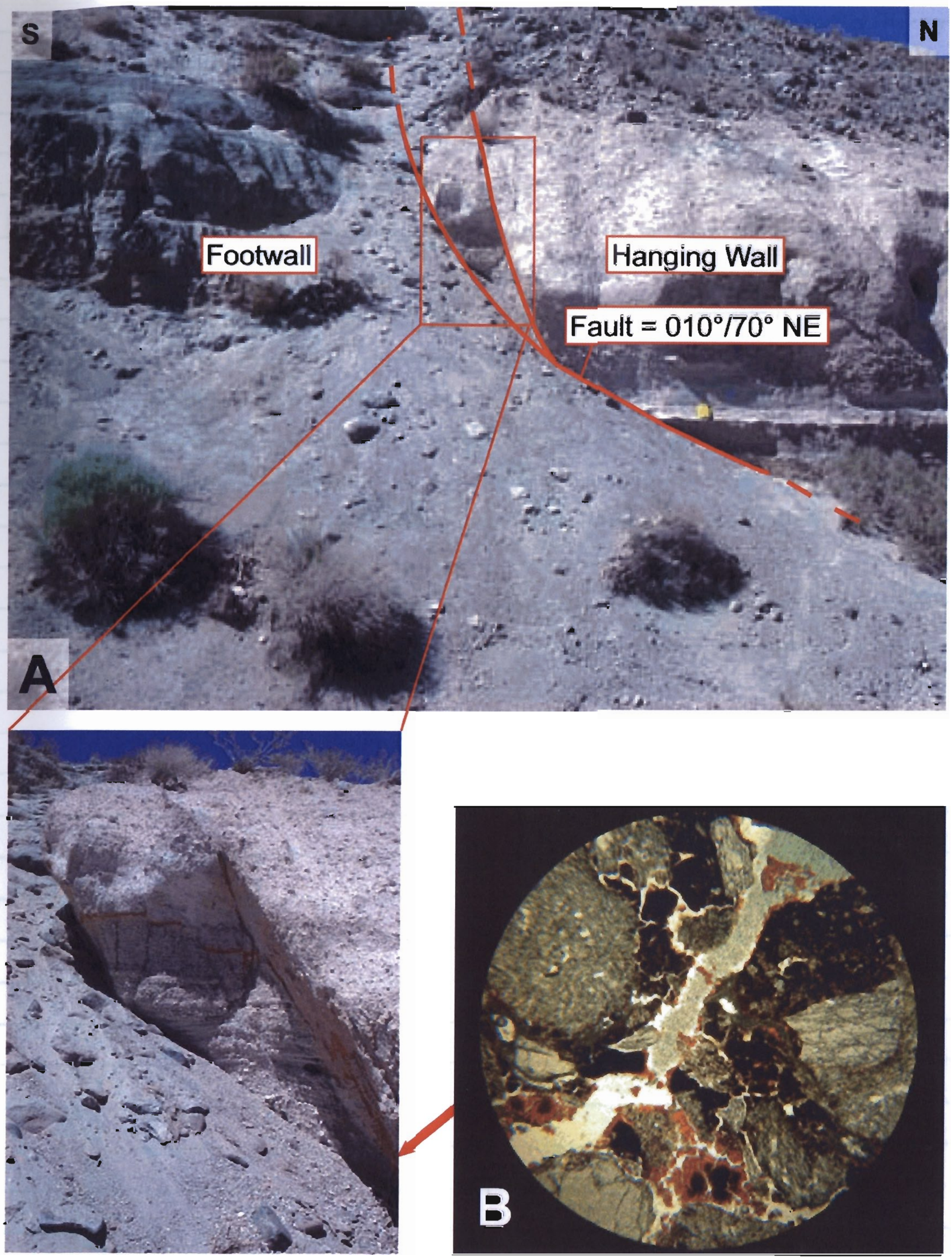

Figure 3.1-3. Horton Creek Fault: (A) Faulted Pumice-fall Deposits. North-East Trending Fault Offsets Bedded Pumice Fall Deposits. Throw Measured Along fault is 18 m [59 ft]. (B) Fault is Marked by Iron-oxide Staining, Curvilinear Fractures, and Fine Grain Matrix. Thin-sections Illustrate Brittle Deformation Mechanisms Such as Cataclasis and Microfractures Within the Nonwelded Fall Deposits Adjacent the Fault. Iron-Oxides Suggest a Preferential Flow Pathway Through this Irregular and Anastomosing Micro-Fracture System.

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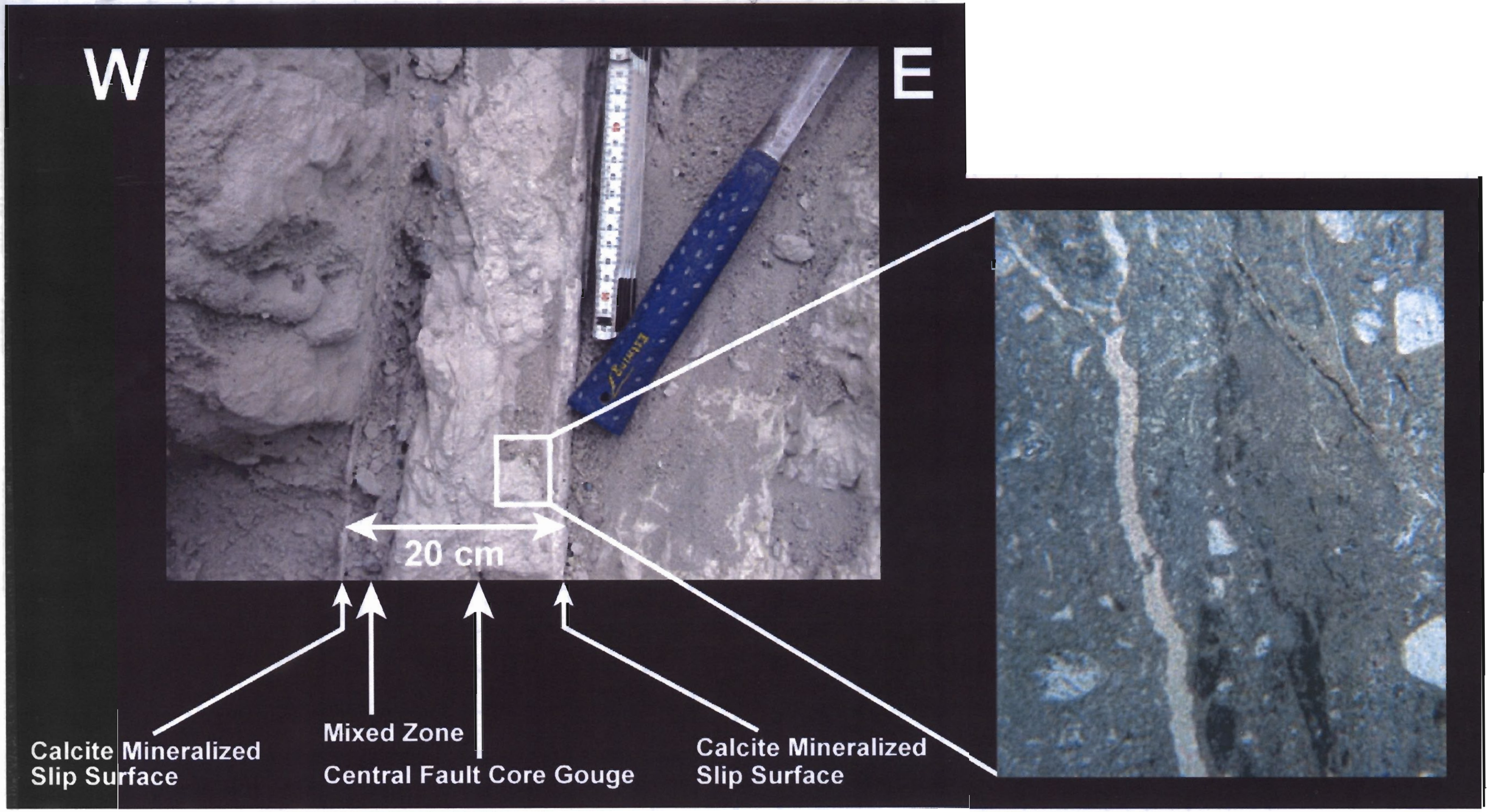

Figure 3.1-10. Western Bounding Fault at the Crucifix Site. (A) Beds of Reworked Volcaniclastic Deposits are Entrained Within the Fault Zone, Producing a Multi-Layered Fault Core. The Average Thickness of the Fault Core is ~20 cm [~8 in]. The Fault Core is Bounded by 1–3 mm [0.04–0.12-in]-Thick Slip Surfaces Coated with White Calcite. (B) A Thin-section Sample from the Eastern Edge of the Fault Core Consists of a Complex Assemblage of Fine-Grained Clays, Quartz, and Iron Oxides. Open Hairline Fractures Extend Both Parallel and Oblique to the Fault Core Layers.

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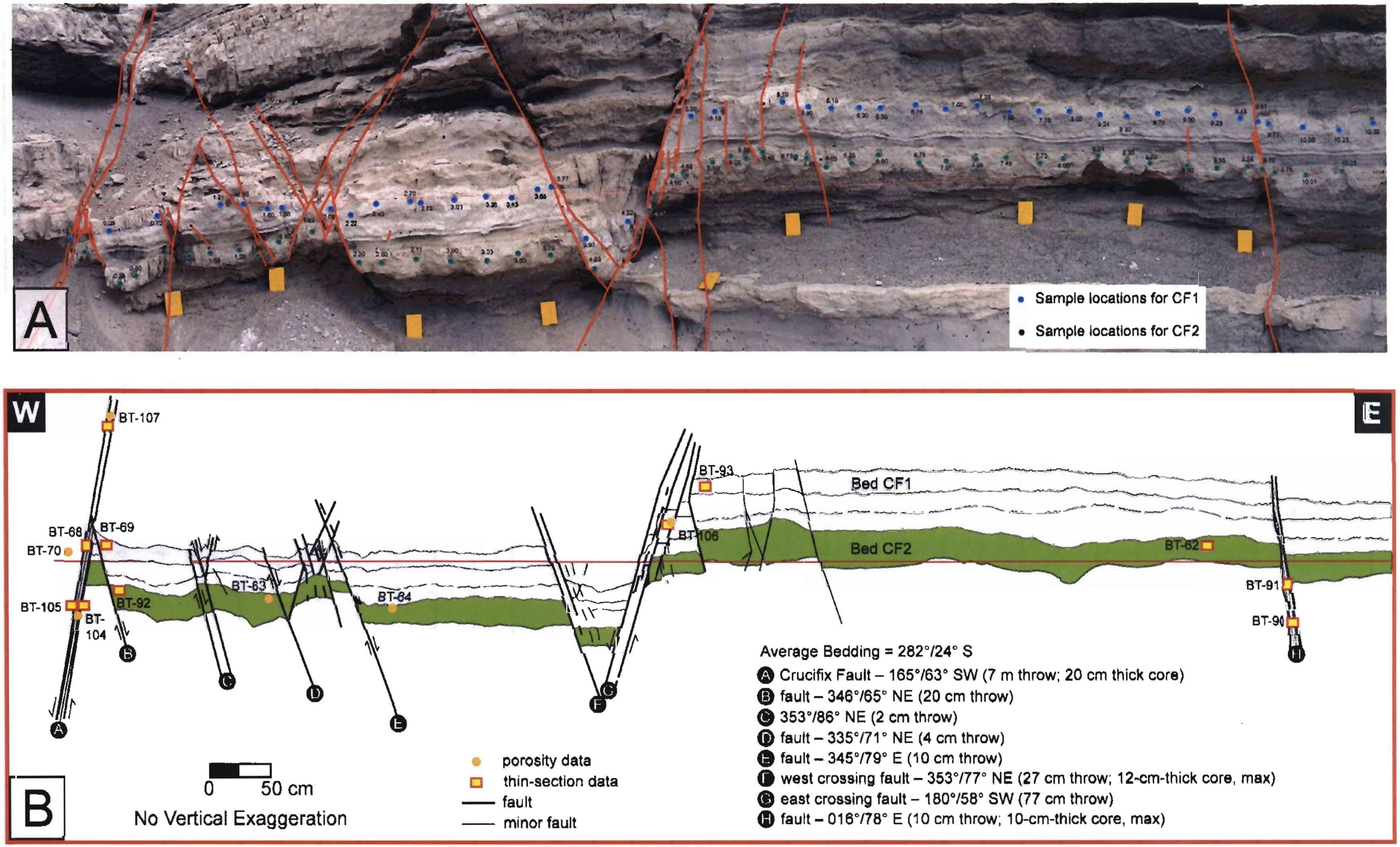

Figure 3.1-9. Crucifix Site Exposure: Western Bounding Fault and 10.5 m of Outcrop to the East. (A) Photomosaic with Grain Size and Permeability Locations Identified (After McGinnis, et al., 2005). (B) Simplified Geologic Map Emphasizing Two Beds Studied in Detail and Lithologic Data Collected along Eight of the Primary Fault Systems. Throughgoing Faults are Labeled A – H and Their Features are Briefly Described. [Note 1 inch = 2.54 centimeters]

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Quartz and glass are the primary constituents all outcrop samples from the Crucifix Site, with minor amounts of feldspars and lithic fragments (predominately pumice). Results from microscopic and X-Ray Diffraction analyses suggest a minor amount of the glass is beginning to alter to clay within the host rocks, while calcite coatings and infillings are commonly found along fracture surfaces. Alteration or devitrication of glass to form silica, cristobolite, trydimite, and trace amounts of zeolites occurs within the fault zone of the western bounding fault and related subsidiary faults. Development of clays and discontinous iron-oxide fillings and weathering of feldspars to fine-grained clays and sericite was also observed within samples from the intensely fractured regions or along the faults. This type of alteration suggests the migration of water may occur during various stages of sequential tectonic movement along the fault. The presence of glass within ash-rich layers or lenses may contribute to the brittle deformation style observed at the Crucifix Site. Similar to the behavior of fly ash as a concrete additive (Muhunthan et al., 2004; Copeland, 2003), the abundant volcanic ash within these reworked deposits may have behaved as a lubricant when hydrated, meaning less energy would have been required to deform material within these fault zones. As tectonic movement subsided and water left the system, the volcanic ash may have chemically reacted with calcium and oxides to produce a less permeable and more cohesive material.

Centimeter- and sub-centimeter-scale displacement faults at the Crucifix Site contain distinct slip surfaces, sometimes marked by white calcite or silica mineralization, but have no discernible core or damage zone [i.e., similar to Class A faults observed at Yucca Mountain (c.f., Gray, et al., 2005)]. Decimeter-scale displacement faults at the Crucifix Site have distinct slip surfaces, but unlike smaller faults, they have a small fault core and damage zone. Cataclasis and post-depositional mineralization are observed along the fracture planes of some of these faults [i.e., similar to Class C faults observed at Yucca Mountain (c.f., Gray, et al., 2005)]. Meter-scale displacement faults at the Crucifix Site have a measurable central fault core, a distinct damage zone, and an undeformed protolith (Caine, et al., 1996; Evans and Bradbury, 2004, McGinnis, et al., 2005) [i.e., similar to Class D faults observed at Yucca Mountain (c.f., Gray, et al., 2005)]. The fault core of the western bounding fault has discrete, bounding slip surfaces marked by mineralization and transitioning to layers of ash and sand to mixed-grain sizes with the central-most portion of the core composed of a very fine-grained comminuted material and clay gouge.

Observations by KKB for inclusion in the PTn Letter Report (2006) – CLD, 07/06/06

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Table 3.1-2. Bishop, California, Field Sites and Rock Properties				
Site Designation (Lithology)	*Horton Creek* (Pumice Fall)	*Borrow Pit* (Non- to Partially Welded Tuff)	*Chalk Cove* (Non- to Partially Welded Tuff Offsets Pumice Fall)	*Crucifix Site* (Reworked Tuffaceous Rock)
Comparable PTn Units[‡]	Tpbt4 Unit B Tpbt3 Units A, C–D Tpbt2 Units A–C	pv1 Tpc Tpy nonwelded; Tpbt4 Unit A Tpbt3 Unit E Tpp	pv1 Tpc Tpy nonwelded; Tpbt4 Unit A Tpbt3 Unit E Tpp	Tpbt3 Unit B Tpbt2 Unit D
Structural Setting	Normal Fault 18 m [60 ft] Offset	Damage Zone Between Two Bounding Faults	Normal Fault 6–8 m [20–26 ft] Offset	Normal Fault 4.38 m[†] [14 ft] Offset
Porosity	0.43 to 0.65	0.60	0.20 to 0.60	0.29 to 0.69
Bulk Density (g/cm^3)	0.88 to 1.42	1.0	0.98 to 1.60	0.75 to 1.50
Fracture Intensity (fr/m)	No Data	1 to 15	7 to 50	< 70
Intrinsic Permeability (m^2)	9×10^{-12}[¶]	6×10^{-13}[¶]	1×10^{-13}[§]	3×10^{-13}[*]

[‡]Moyer, et al. (1996)
[†]McGinnis, et al. (2005)
[¶]Fedors, et al. (2001, 2002)
[§]Dinwiddie, et al. (2006)
*Dinwiddie, et al. (in preparation)

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Table 3.1-1. PTn Rock Properties—Comparable Units From Moyer, et al. (1996)				
PTn Unit	**Lithologic Characteristics**	**Porosity***	**Bulk Density* (g/cm^3)**	**$k^{\ddagger}$ (m^2)**
Tiva Canyon Tuff (Tpcpv1)	Non- to moderately welded, vitric	0.13 to 0.55	1.02 to 1.94	1×10^{-13}
Pre-Tiva Canyon Bedded Tuff (Tpbt4)	Non-welded pumice-fall to pyroclastic flow; 90 to 95 percent light-gray pumice clasts; < 5.4 m thick for all subunits	0.31 to 0.56	0.99 to 1.52	1×10^{-13}
Yucca Mountain Tuff (Tpy)	Non- to moderately welded	0.04 to 0.45	1.39 to 1.78	$3 \times 10^{-14\dagger}$
Pre-Yucca Mountain Tuff bedded tuff (Tpbt3)	Weathered pyroclastic to pyroclastic fall, ash-fall, pumice-fall, and locally reworked deposits; light brown to light gray, 40 to 85 percent pumice clasts; moderately to poorly sorted. < 52.5 m thick for all subunits	0.12 to 0.53	1.11 to 2.16	1×10^{-13}
Pah Canyon Tuff (Tpp)	Non- to moderately welded	0.40 to 0.61	0.88 to 1.34	1×10^{-13}
Pre-Pah Canyon Tuff bedded tuff (Tpbt2)	Pumice-fall to locally reworked deposits; < 15.8 m thick for all subunits	0.03 to 0.60	0.90 to 2.38	5×10^{-12}

*Moyer et al. (1996), ranges as given in Table 3
‡Moyer, et al. (1996), Table 2
†Geometric Mean of Model Parameter *k* for Tpy

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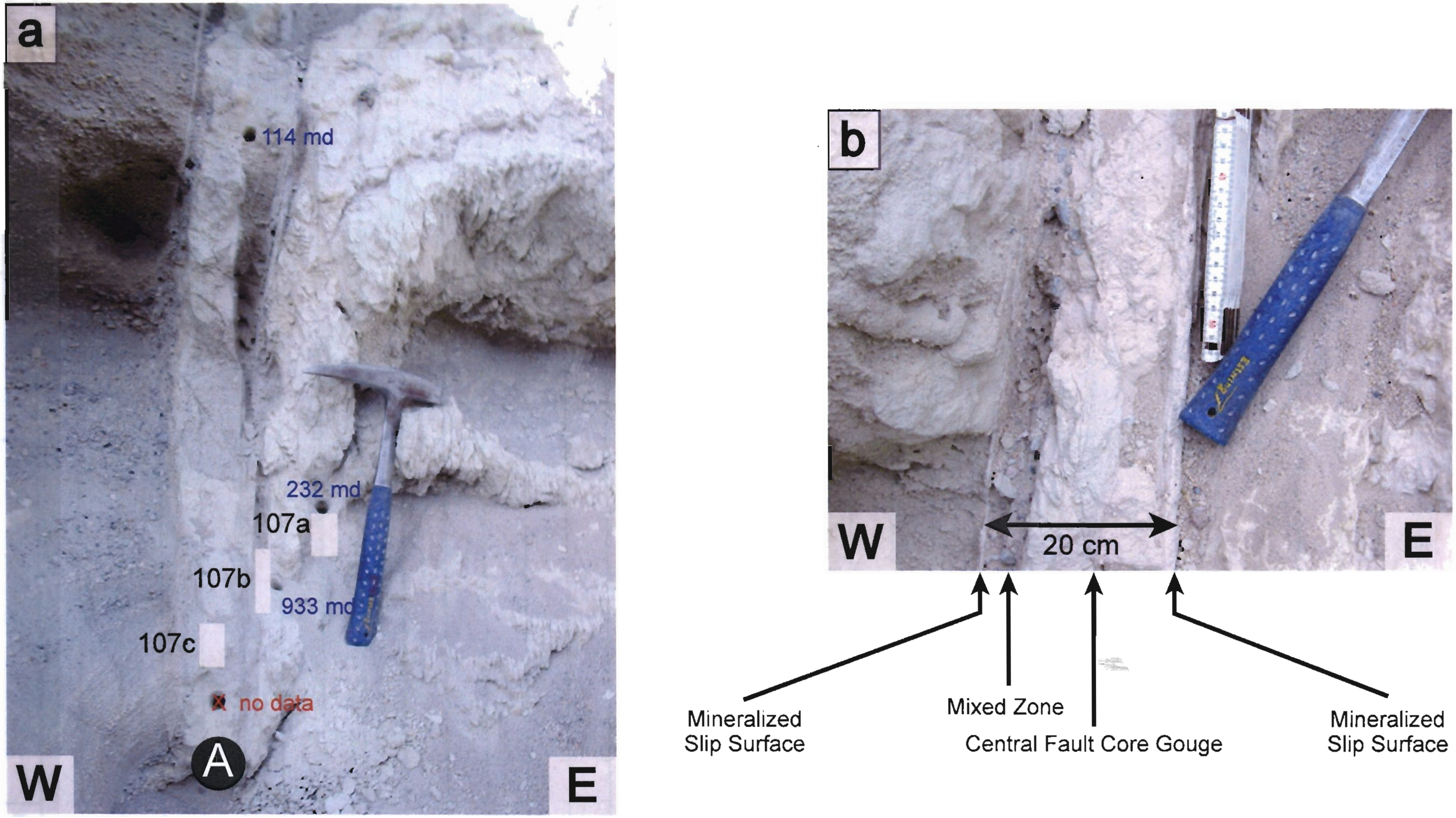

Fig. 5. (a) Crucifix Fault, A, as shown in Figure 4b. Sample collection locations for three thin sections and permeability as measured in three drill holes are indicated. (b) Fault zone properties change both vertically and horizontally within the main fault core, producing a multilayered fault core. Beds of reworked volcaniclastics are entrained within the mixed outer zones of the Crucifix Fault core, whereas clay gouge occurs within the central zone. The outer millimeter-thick bounding slip surfaces of the fault are mineralized by calcite, suggesting fluid flow interactions along the fault [after Fig. 7 of Evans and Bradbury (2004)].

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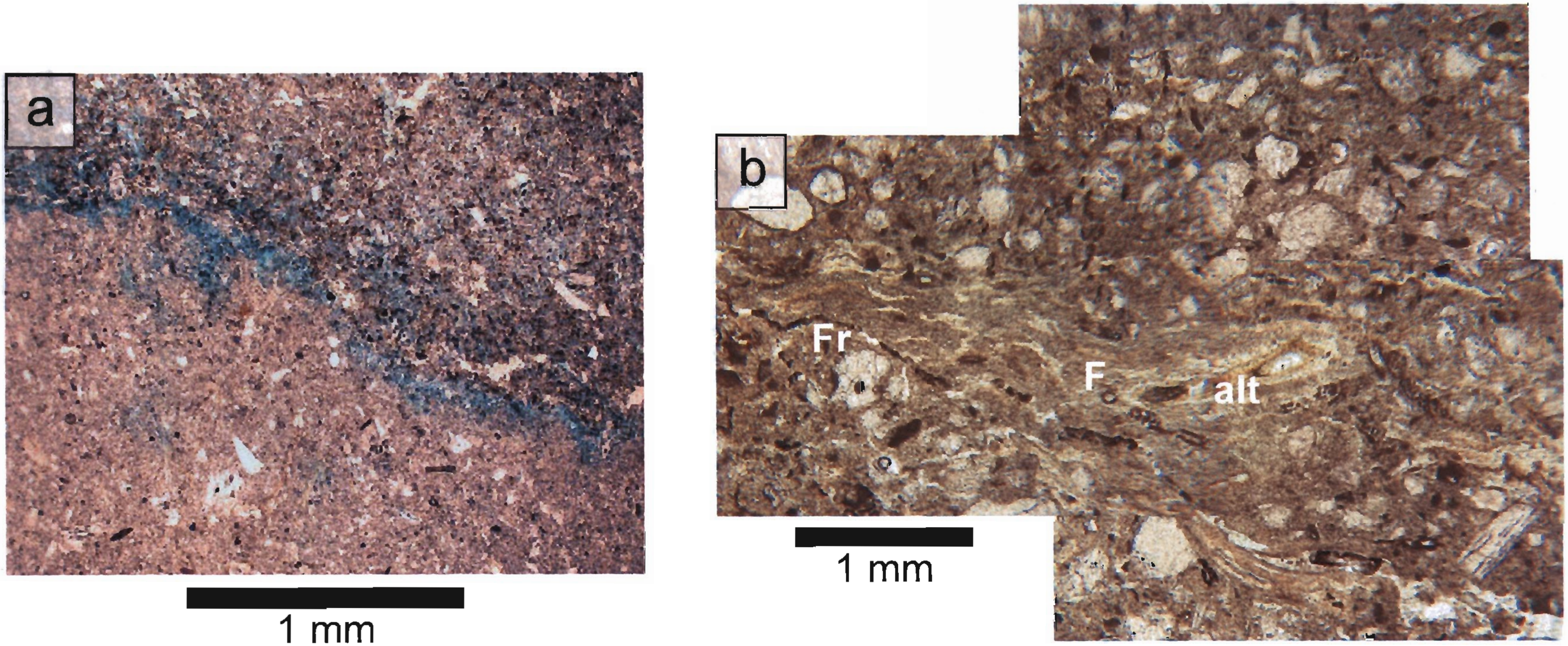

Fig. 9. Photomicrographs illustrating host rock composition. (a) Sample BT-93 from Bed CF1 (see Figure 4b for location). Dark-colored material near a fracture surface likely results from iron-oxide or clay alteration. Blue dye infiltrates into the matrix from the wall of a hairline fracture surface. (b) Sample BT-62 from Bed CF2. A dark-brown coating around several grains indicates alteration and formation of clay rims. Alteration of glass within a flattened pumice clast or fiamma (F) also suggests the initial stages of clay formation (alt). Microfracturing (Fr), such as that near the fiamma boundary, is commonly observed in this material. This microfracture is partially filled with dark-brown clay and iron oxides alternating with silica.

Consider reducing image size given resolution.

Figure 4 is on p. 79

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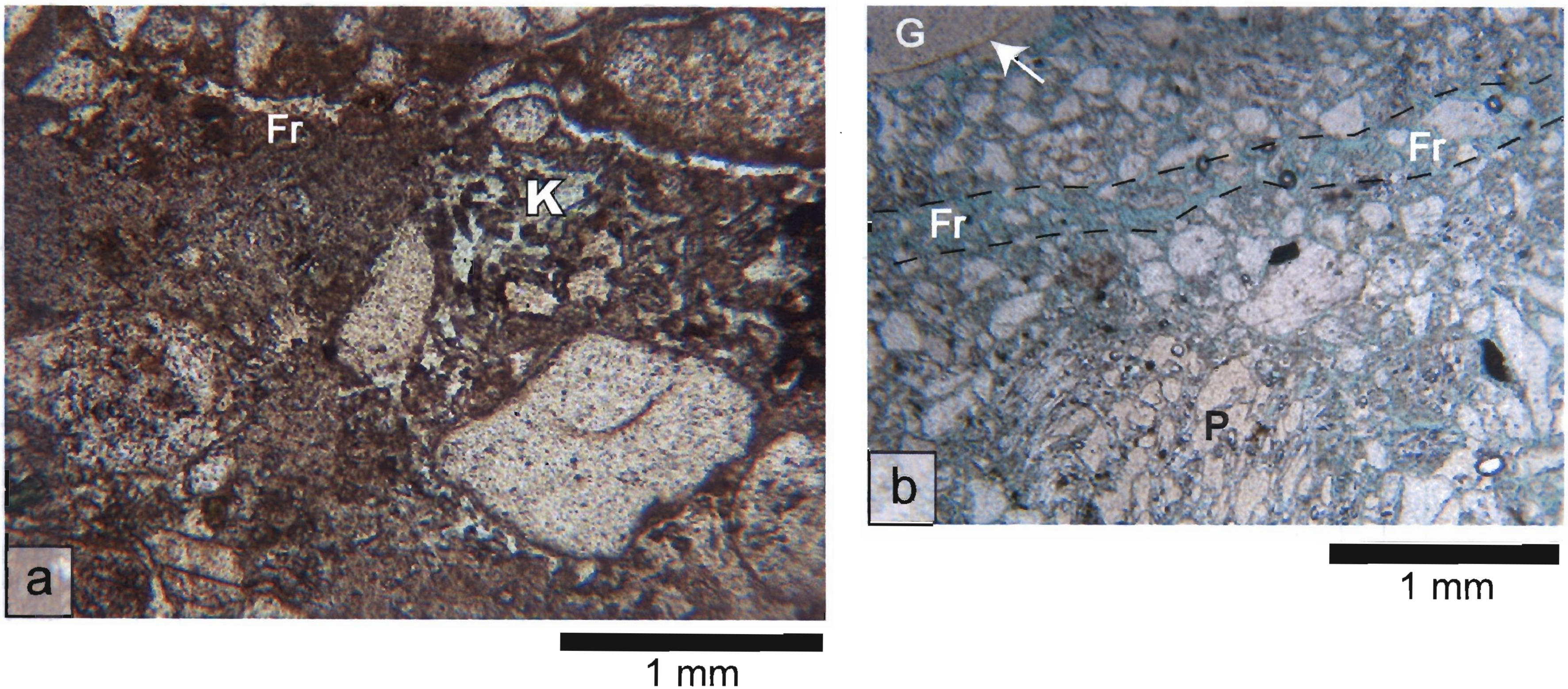

Fig. 10. Photomicrographs of fault labeled H in Figure 4b. (a) Sample BT-91 was collected from the contact of the 1-cm-thick fault surface and Bed CF2. Crystal fragments and glass shards are supported by a fine-grained matrix of glass and clay. A zone of fine-grained clay surrounds the outer walls of open hairline fracture surfaces (Fr). These microfeatures represent a mixed zone of deformation, including cataclasis and dilation, associated with faulting. The worm-like texture labeled K is vermicular kaolinite. The well-developed vermicular texture suggests the clay is an authigenic pore-filling cement that formed in situ, likely a result of diagenesis. (b) Sample BT-90 exhibits an amorphous silicic glassy fragment (G) with overgrowth textures, as indicated by an arrow that points to the original grain boundary. P = pumice clast; Fr = fracture and dilation band. Porous zones indicated by blue dye.

Consider reducing image size given resolution.

Figure 4 is on p. 79

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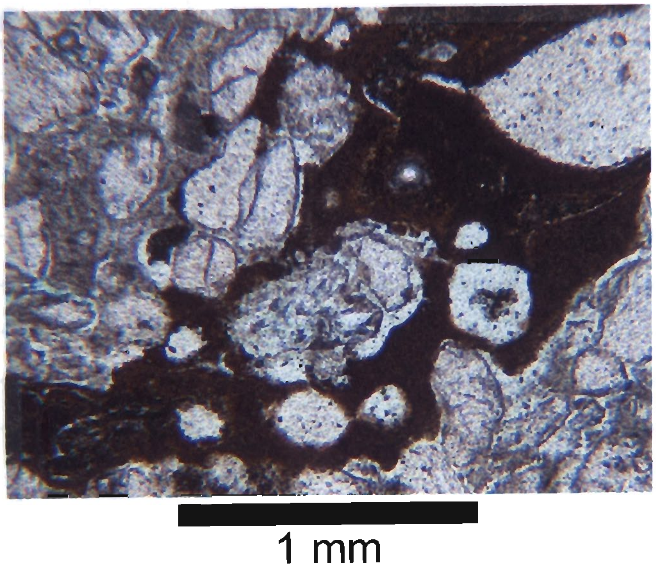

Fig. 11. Sample BT-106 was collected adjacent to the east wedge fault at ~4.7 m as shown in Figure 4b. A curvilinear fracture is filled with iron-oxides, clay, and glass altering to zeolite. Grains from wall boundaries are entrained within the fracture, suggesting deformation by cataclastic mechanisms. Blue dye fills microfractures oblique to the main fracture.

Figure 4 is on p. 79

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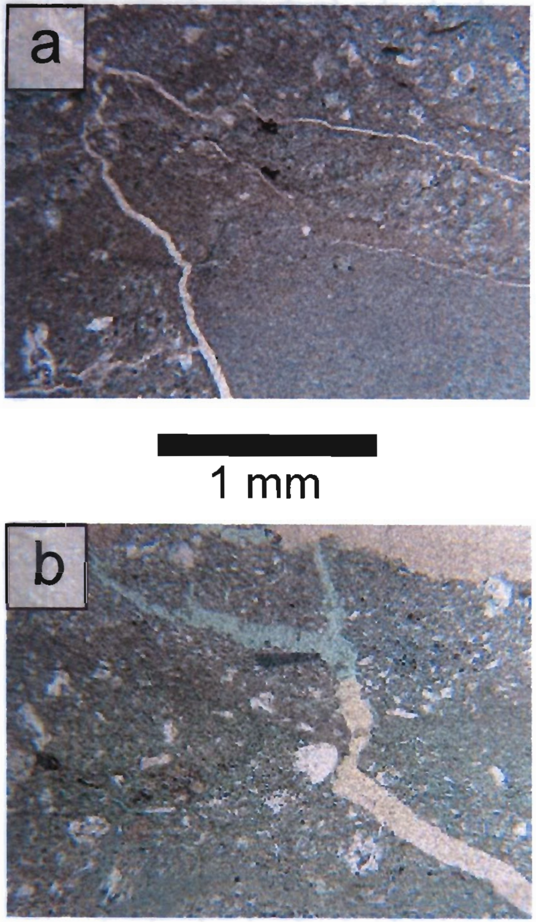

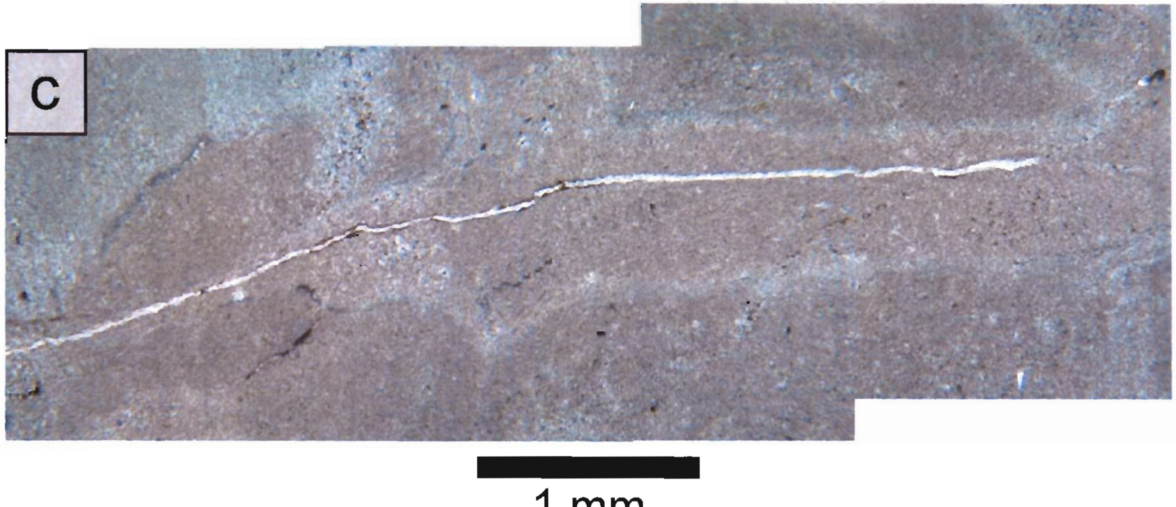

Fig. 12. Crucifix Fault core thin sections. (a) Sample BT-104a was collected from the east-most layer inside the Crucifix Fault core (as shown in Figure 4b). Abrasion, mixing, and dragging of adjacent beds, which is observed at the outcrop scale, results in abundant crystal and glass fragments seen in thin section. (b) Anastomosing fracture patterns in Sample BT-104. Partial fracture filling is evident in the blue dye pattern. (c) Sample BT-105 was collected perpendicular to fault strike on west edge of Crucifix Fault. A halo of light-colored convoluted clay and glassy ash surround an intra-core microfracture which is then surrounded by another halo of micrometer-thick bleached material. The interior of the microfracture does not absorb blue dye, unlike the surrounding clay layer.

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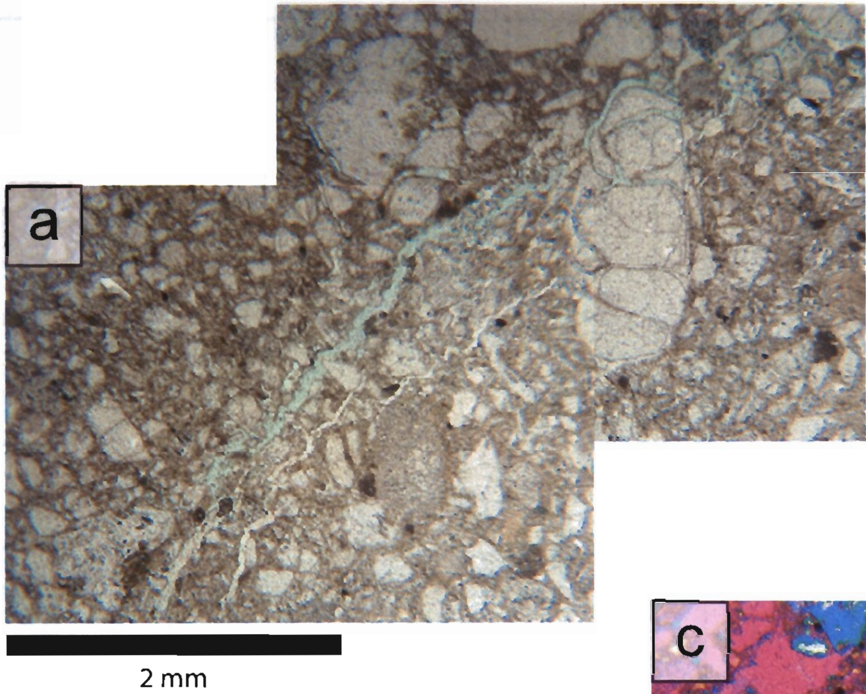

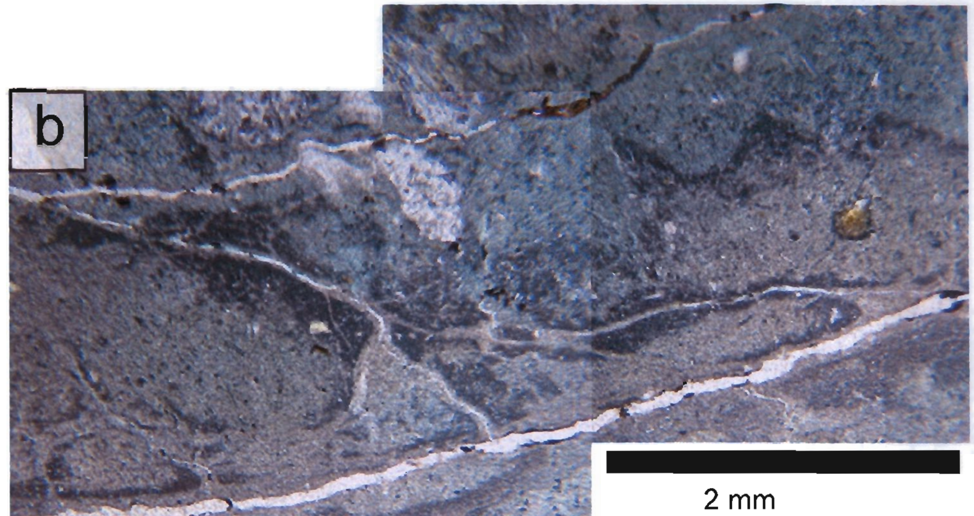

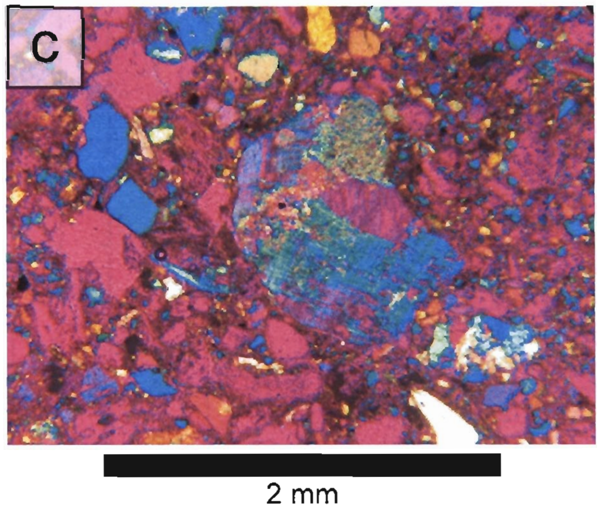

Fig. 5 is on p. 73
Fig 4 is on facing page.

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Fig. 13. Crucifix Fault deformation microstructures illustrate layered heterogeneity with varying textural and lithological characteristics. (a) Sample BT-107a was collected from the west portion of gouge as shown in Figures 4b and 5a. Perlitic fracturing is observed in a glassy fragment. Open microfractures transmit blue dye, while adjacent filled fractures do not. A brownish matrix of clay, volcanic ash, and glass is observed and crystal fragments are abundant througout this section. (b) Sample BT-107b was collected from the central fault core gouge zone (Figures 4b and 5a). This gouge is characterized by a layered and locally convoluted, fine-grained clay and ash having multiple fractures filled with silica and bounded by layers of clay—shown in alternating light and dark colors. Iron-oxide rich clays are present in the upper microfracture and in an altered glassy fragment. The presence of blue dye locally in the upper half of the photograph does not extend below the fracture oblique to the sections. (c) Sample BT-107c. View is in cross polarized light with the gypsum plate inserted. A deformed feldspar clast with sericitic alteration is surrounded by a zone of fine-grained cataclasis that is characterized by rotated grains and microfractures, pumice and glass fragments, quartz clast, and fine-grained clay.

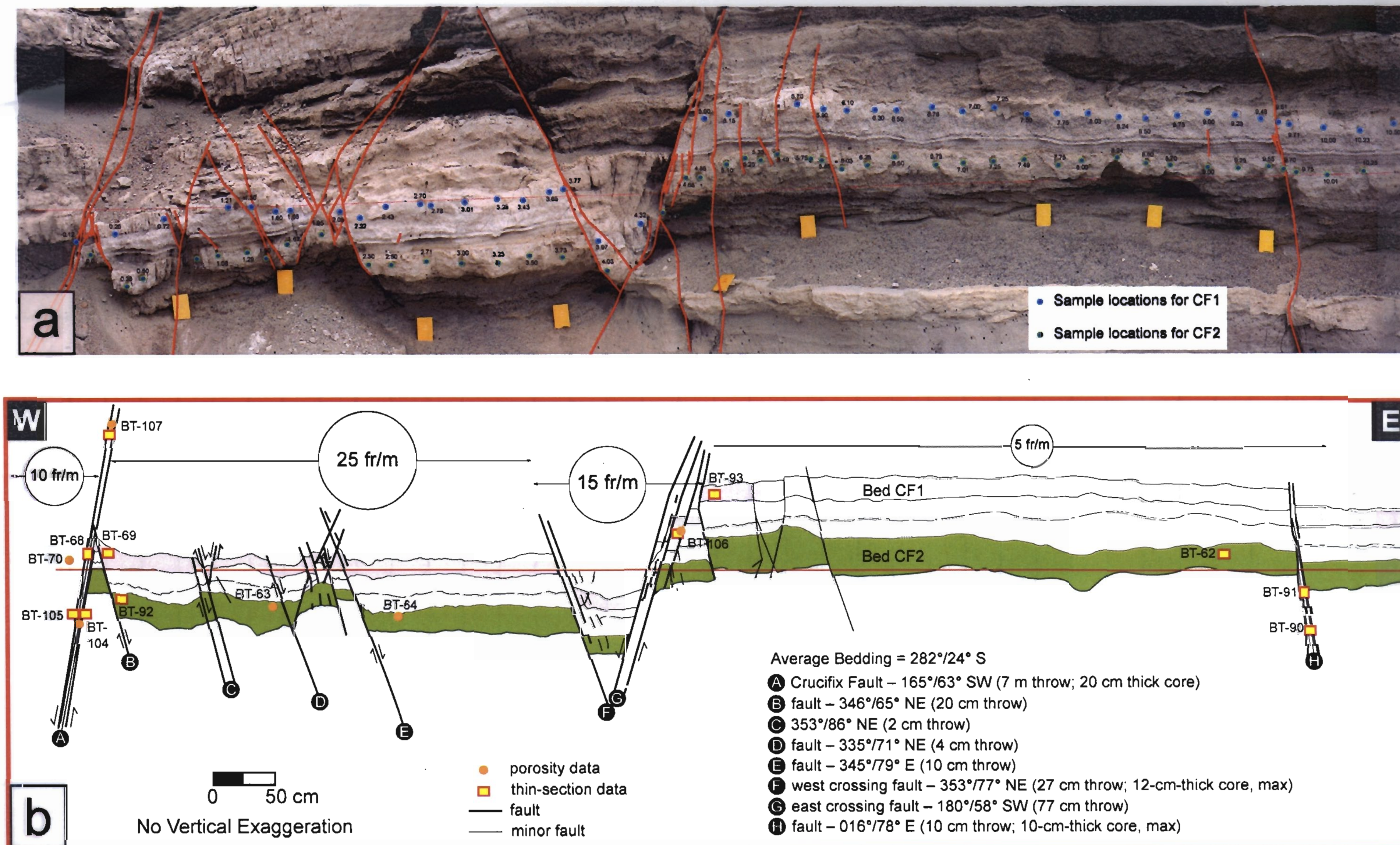

Figure 4. Crucifix Fault and 10.5 m of footwall block to the east. (a) Photomosaic (after McGinnis et al., in revision) with grain size and permeability sample locations identified. (b) Simplified geologic map emphasizing Beds CF1 and CF2 and lithologic data collected along eight primary fault systems. Through-going faults are labeled A – H.

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Consider simplifying 4b by removing sample location identifiers for samples not discussed in Crucifix Site Journal Article.

Note: Other figures drafted for article are found in Scientific Notebook 639.

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kkb
cf site
porosity data

samples highlighted in yellow were used for averages reported in table 2
all samples were used for fault core to give range of average found

sample	total mass	bag mass	sample mass	water vol disp	γ sample	γ constituents	n		
BT34	48.8	2.7	46.1	45	1.02	2.5	0.590	cf flt	Evans and Bradbury (2004)
BT37	73.9	3.2	70.7	70	1.01	2.5	0.596	cf flt	Evans and Bradbury (2004)
BT39	30.9	3.4	27.5	30	0.92	2.5	0.633	cf flt	Evans and Bradbury (2004)
BT41	24.3	2.6	21.7	20	1.09	2.5	0.566	cf1 proxy	Dinwiddie et al. (west of BT-70)
BT43	94.4	2.5	91.9	60	1.53	2.5	0.387	cf flt core	Dinwiddie et al.
BT44	48.2	3.2	45.0	35	1.29	2.5	0.486	cf flt core	Dinwiddie et al.
BT46	26.0	2.4	23.6	30	0.79	2.5	0.685	cf flt	Evans and Bradbury (2004)
BT47	82.2	3.0	79.2	55	1.44	2.5	0.424	cf2 gr ash	Dinwiddie et al.
BT63	63.7	2.6	61.1	50	1.22	2.5	0.511	cf2 fw	Dinwiddie et al.
BT64	64.0	2.3	61.7	40	1.54	2.5	0.383	cf hw	Evans and Bradbury (2004)
BT70	31.3	2.7	28.6	30	0.95	2.5	0.619	cf2 proxy	Dinwiddie et al.
BT104a	21.7	2.7	19.0	25	0.76	2.5	0.696	cf flt core	Dinwiddie et al.
BT106	36.2	2.5	33.7	45	0.75	2.5	0.700	cf1-wedge	
BT107	359.2	5.4	353.8	200	1.77	2.5	0.292	cf flt core	Dinwiddie et al.

calculation
n = 1 - (specific gravity of sample/specific gravity of constituents)
constituents taken at 2.5 g/cc - which may be too high for these sediments but standard in calculations

average for bed cf1		
BT41	1.085	0.566
BT106	0.749	0.700
	0.917	*0.633*
	density	**n**

average for bed cf2		
BT47	1.44	0.424
BT63	1.22	0.511
BT70	0.95	0.619
	1.21	*0.518*
	density	**n**

fault (ranges)	
0.76-1.77	*29-70%*
density	**n**

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No additional entries; Notebook closed.

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