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David Groeneveld

Yucca Mountain Project Documentation of Field Work and Laboratory Analyses

conducted for
Center for Nuclear Waste Regulatory Analyses

June 8, 2000

Prepared by David P. Groeneveld, Ph.D.
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This is the Second Scientific Notebook.
The First Scientific Notebook was Dated April 7, 1998.

Contents Page

This notebook was assembled over a 4 day period ending 5/8/00. Pages 1-3 are a table of contents. The seven sections of this notebook correspond with field work and follow-up laboratory work from seven field expeditions. Therefore pages 1 - 148 of this notebook are part of one continuous entry. My initials on this page, at David Groeneveld's request (telephone 9/13/00), are intended to take the place of initials and dates on each page.

RF 9/13/00

[Randall Fedors]

Field Trips and Laboratory Analyses Conducted from April 7, 1998 to Present

This Scientific notebook presents data collected on field trips and describes air photograph missions. Analyses of these data are presented with each data acquisition effort and are not necessarily reported in chronological order.

May 14 through May 18, 1998

This field trip had a series of objectives:

(1) Studies of watershed function in Split Wash on Yucca Mountain.
(2) Measurement of vegetation transects on north and south-facing slopes of Antler Ridge to serve as groundtruth to compare to vegetation cover measured on air photography.
(3) Obtain photographs for a field guide to the important plant species of Yucca Mountain.
(4) Visit a potential climate-change analog site, Phinney Canyon, in the Grapevine Mountains west of Beatty, Nevada.
(5) Collect shrub stem sections from Ephedra viridis on the north- and south-facing slopes of Antler Ridge.

The following report that was generated from this work is not included here:

Groeneveld, D.P. and R. W. Fedors. A brief guide to plant species in the Yucca Mountain region: A compilation to support infiltration studies. Undated and un-numbered CNWRA report.

June 26, 1998

A photographic mission was flown to obtain low (altitude 6,000 feet msl) and mid-level (altitude 10,000 feet) air photographs over Yucca Mountain. These photographs were used for measuring plant cover for (1) studies of the effect of elevation, aspect and slope on vegetation cover, (2) performing preliminary mapping of lineaments that may be fault traces, and (3) mapping landform features that may influence infiltration processes.

RF 9/13/00 White-out used on page 2 (bottom) does not reflect on the integrity of this notebook since it only refers to page numbers. Note that: pages 1,2,3 are a table of contents for this scientific notebook.

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May 14 through May 18, 1998

This field trip was carried out during the approximate peak of spring leafout following much wetter-than-normal winter rainy period. A general observation of the condition of the vegetation confirmed the hypothesis that the vegetation on Yucca Mountain was undergoing a pulsed conversion from a shrub-dominated to an annual grass dominated ecosystem in many locations. The primary agent responsible for this conversion is Bromus madritensis rubens also known as B. rubens. These observations prompted a report that was later developed through additional limited field work and library research.

A major focus of this field trip was to measure possible "hot spot" infiltration through rock fractures and joints in canyon bottoms. This and other watershed-level processes were examined.

The field trip had a series of objectives:

(1) Studies of watershed function in Split Wash on Yucca Mountain.
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(5) Collect shrub stem sections from Ephedra viridis on the north- and south-facing slopes of Antler Ridge.

Shrub ring analyses confirmed earlier work performed on Chrysothamus teretifolius which showed that the vegetation was "fitted" to a maximum level permitted by each microsite location. Thus, the vegetation forms "closed" communities where the root systems of perennial plants are interfingered and a member must first be lost in order to permit another to become established. This delicate balance underscores the serious disruption that an invasive species such as B. rubens can cause.

The following report that was generated from this work is not included here:

Groeneveld, D.P. and R. W. Fedors. A brief guide to plant species in the Yucca Mountain region: A compilation to support infiltration studies. Undated and un-numbered CNWRA report.

cross-out by Groeneveld intended to remove non-CNWRA project reference in his notebook RF 9/13/00

1998

~~5-11 Sao Paulo - Almir collected 18 leaves of P. v. var. cebocla these were separated into v. green and somewhat yellowish for later analysis~~

5-13 [Yucca Mtn: pack; purchase supplies for trip TT: SK, DO, RR 5.3]

5-14 [Yucca Mtn: drive B14 to YM sample Ephedra viridis on flanks of Antler Ridge.

vigor class	NF1 - 163 x 56 x 53 (tall)	near base of slope	
	NF2 - 104 x 77 x 73 "	" ≈20 m	
	NF3 - 133 x 100 x 63	" above	
@ 1/3 from base slope	NF4 - 113 x 102 x 80	somewhat decadent	
	NF5 - 92 x 65 x 60	part of v. old large clone isolated from main portion	
	NF6 - 94 x 63 x 59.		
@ 2/3 up slope	NF7 - 188 x 160 x 78	v. vigorous	
	NF8 - 219 x 152 x 77		

This is page 10 of D.P. Groeneveld field notebook for period 3-27-98 to 5-8-00

page 11

NF9 - 162 x 133 x 88	2/3 up slope
NF10 - 112 x 96 x 76	just below ≈20 m ridge top
NF11 151 x 111 x 52	
NF12 150 x 73 x 70	
//	
SF1 54 x 91 x 51	near slope base w/in 25 m.
SF2 82 x 76 x 42	
SF3 106 x 108 x 58	
SF4 130 x 98 x 61	1/3 up from slope base
SF5 81 x 54 x 38	
SF6 89 x 80 x 53	
SF7 90 x 65 x 51	2/3 up from slope base
SF8 96 x 55 x 55	
SF9 91 x 84 x 48	
SF10 135 x 97 x 38	near top - ca 20 m from
SF11 112 x 91 x 46	
SF12 95 x 91 x 43	

Slope is 53% (≈28°) on SF side of split wash

note: only 2 EPNI on S-facing side of Antler Ridge so this sample is different from S-facing CHTE 12.8]

5-15 [Yucca Mtn: botanical guide for CNWRA

Photo Log -

Position 1: cupola above split wash

Page 12

panorama 1: Salazaria, EPNE, EPVI
yellow Haplopappus, Eriogonum sp., CORA
Sitanion hystrix, Castilleja
these species shown in 2 closeup
shots on crest
panorama 2: ATCA, HACO (Ericameria)
CHVI with closeup of these w/
♀ & ♂ of ATCO on crest
panora 3: just off crest top
Yucca, weedy Amsinkia?, and
purple phacelia, Aster species (common
shrubby - familiar, needle & thread grass
Panorama 4: ATCO, CELA, spiny
hopsage ♀ & ♂
Composition 1: HACO and 4-O'clock
in bloom
Composition 2: Phacelia in bloom
w/ TEAX in bloom
Shots of Bromus Rubens on ridge w/
carcases of ATCO, other species includ
Grayia, HACO, CHVI, cover is
v. low ca 5-7% by perennial veg.
note v. few scattered but clumped
Bromus tectorum on ridge
Shot of wash just north of Highway
ridge - note diff between BRRU

dominated S-facing slope and north-facing
slope dominated by ARTR
Panorama 5: Galleta grass, ARTR, CHNA
closeup of these + Eriog. inflatum
Shot of cleared zone on Highway Ridge
w/ recruitment of Chrysothamnus nanus (rare)
viscidiflorus (dominant), teretifolius (common)
also Stephanomeria pauciflora
Swing Pan of wash between Abandoned
Wash & Highway Ridge showing Bromus r.
domination of deep soil zones and S-facing
slopes.
Swing Pan of Creosote/bursage w/
BRRU dominating @ bottom of
Abandoned wash
Panorama 6: Creosote/Bursage
w/ these species + Krameria? LYAN
and Indian rice grass in closeups
Panorama 7: Creosote/Bursage
closeups of Hymenoclea, Steph. panc.,
HACO in bloom & AMDU in bloom
also Lycium? (Menodora?)
Panorama 8: Lycium andersonii w/
AMDU & creosote bush
closeup of LYAN, Sphaeralcea, Salazaria,

101 – 1-FT INTERVALS

1. Plant transects S-facing side of Split Wash.

1.1 Scree [tally marks] 57
Rock [tally marks] 32
EPV 2/2
AMDU 1/1
CHTE 1/1 2/1
ERFA 5/3 2/1 2/1 1/1 10/6
Sphalc 1/1
EPNE 0/1
CHVI 0/1
TOTAL 17/14

1.2 SCREE [tally marks] 75
ROCK [tally marks]
AMDU 0/1 1/1 2/1 3/3
EPVI 3/2
CHTE 3/1 1/1 2/1 6/3
ERFA 0/1
TOTAL 12/9
50% SLOPE

1.3 SOIL [tally marks] ON POSSIBLE LINEATION
ROCK [tally marks] 31
CHVI 2/1 0/2 0/1 1/2 3/6
ERFA 0/1 2/3 0/1 2/2 4/6
EPVI 1/1 0/2 1/3 CELA 0/1
LSalaz 1/3 0/2 1/5 ATCO 2/1
CHTE 0/1
EPNE 2/2
AMDU 0/1 1/1
TOTAL 14/28

2. PLANT TRANSECTS N-FACING SIDE OF SPLIT WASH

2.1 SOIL ||
ROCK [tally marks] Scree = 86%
EPVI 1/2 rock = 12%
HACO 1/1
CHTE 2/2 4/2 6/3 4/2 16/9
ERFA 0/2
Spiny Polemoneum? 0/1 LEPU
LYAN 2/1
CHVI 2/2 3/4 0/2 5/8 25/24 24.8/23.8

2.2 SOIL |||
ROCK [tally marks]
CHVI 2/2 0/1 1/3 1/3 4/9
Spiny Polemonium? 0/1 1/1 0/1 (LEPU)
ATCO 0/1
EPVI 0/2 0/1
SIHY 0/1 6.9/21.8
CHNA 2/5
TOTAL 7/22

2.3 SOIL |||| ROCK [tally marks]
CHVI 2/2 3/4 scree = 80%
CHNA 0/1 0/3 2/4 1/5 rock = 16%
EPVI 3/5 0/3 0/1
SIHY 1/1 11.9/29.7
ATCO 0/1
TOTAL 12/30

16

57% N174°

3. PLANT TRANSECTS S-FACING SLOPE OF ANTER Ridge

3.1 SOIL ~~||||~~ ||| soil - 90%   rock - 7%
ROCK ~~||||~~ ||
AMDU 1/1 1/2
STPA 0/1 0/1
ATCO 1/1 2/1 0/1
CHTE 0/1 0/1
ERFA 2/1
NEEDLE AND THREAD GRASS 1/2 0/1 0/1   .178 / .158
ERIOG. INFL. 1/1
TOTAL 9/16

3.2 SOIL ||| soil - 94%   rock - 3%
ROCK |||
EPNE 1/1
ERFA 1/1
CHTE 0/2 1/3 1/1   .158 / .119
AMDU 1/1 3/2 0/1   TOTAL 8/12

3.3 SOIL ~~||||~~   soil - 69%   rock - 24%
ROCK ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||||
CHVI 0/1
ERFA 1/3 0/1 2/3   .079 / .099
AMDU 0/1
NEEDLE & THREAD GRASS 1/1
TOTAL 4/10

1.4 SOIL ~~||||~~ ~~||||~~
ROCK ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ |
AMDU 1/1 1/1 1/1 1/1
STPA 0/1
CELA 0/1
ERFA 1/2 0/1
CHTE 0/1
TOTAL 5/10
13.8]

5-16 [Yucca Mt.: visit analog site @ Phinney Canyon in Grapevine Mtns. PIMO show severe needle scale infestation that are killing plants, especially in lower elevation zones. Samples collected and pictures taken.
- Sites up canyon from mine: South. Prospective S-facing slope only assumed 110° and so was rejected 12.0]

15-17 [Yucca Mt.:
reading on ponded infiltration test in wash bottom. Site has initial reads
@ 35 min 7.1 cm
pond dimensions: EW: 24, 45, 43
NS 37, 41, 41
@ 1:25 6.2 cm EW: 23, 43, 43
NS 35, 30, 40

Lower wash #1 @ confluence of small
wash (2nd confl. from top)
wash top dimension 48 cm x (33.4+33.4+34.5)
Start @ 3:08:00 4.40 cm
3:20:00 4.40 cm
3:55:00 4.40 cm
5:04:00 4.20 cm 95% surf area
5:40 4.10 cm

Upper site Lower test plot
5:13. 52.35 cm (arbitrary piece of
95% surf. Area 5:34 51.20 cm tape)
5:50 51.00 cm this site held
6:06 50.07 cm water for 1.5 hrs. before test

refilled to 5.0 cm @ 5:42 pm
4.9 cm @ 6:13 pm 13.0

5-18 [Yucca Mtn: plant transects in watershed
WS1 192° bearing on S-facing slope
22° slope

S FACING - N BR SPLIT WASH

	SOIL 𝍸𝍸 11 12%	69% Scree	
	ROCK 𝍸𝍸𝍸 1111 19%		
	CHTE 3/2		
	AMDU 2/1 1/1 (3/2)		
	ERFA 1/1 0/1 0/1 1/1 0/1 0/2 2/2	(4/9)	
	STSP 1/1		
	TOTAL	11/14	
WS2	215° 21° Slope		
	Soil 𝍸 𝍸𝍸 10 1 27%	52% Scree	
	Rock 𝍸 𝍸𝍸𝍸 1 21%	mod. biome ca 20%	of interspace area
	STSP 0/1 1/1 0/1 (1/3)		
	EPNE 1/1 1/2 0/1 0/1 2/1 0/1	(4/7)	
	AMDU 0/1 0/1 0/1 1/1	(1/4)	
	ERFA 1/2 1/1	(2/3)	
	SAME 1/1		
	HACO 1/1		
	CELA 2/1 TOTAL	12/20	
WS3	193° 25° Slope Soil 𝍸𝍸𝍸𝍸𝍸𝍸	30%	
	LYPA 1/3 Rock 𝍸1	11%	
	STSP 1/1 Scree	59%	
	ATCO 0/1		
	AMDU 0/1 heavy biome ca	40% of interspace area	
	CHTE 2/1		
	EPNE 0/1 0/2 (0/3) TOTAL	4/10	

Tcpul Bearing Slope

WS4 179° 25° Rock ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ || 22%
Soil ~~||||~~ ~~||||~~ ~~||||~~ | 26%
EPVI 0/1 0/1 0/4 (0/6) 62% Sene
BRFA 1/0 0/1 0/1 (1/2) Bromus Heavy ~40% of interspaces not rock
CHTE 0/2
STSP 0/1 TOTAL 1/11

WS5 165° 25° Rock ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ || 27%
Tcpul
Soil ~~||||~~ |||| 9%
Stipa 0/1 1/1 1/1 0/1 0/1 (2/5) 64% Sene
ERFA 0/2 3/3 (3/5)
BPNS 0/2 0/1 1/1 (1/4)
CHTE 0/1 1/1 (1/2)
EPVI 1/1 0/2 (1/3)
ERFA 0/1 2/1 (2/2)
LYPA 0/1 TOTAL 10/22

WS6 93° 35° Soil ~~||||~~ ~~||||~~ 10%
ERFA 0/2 0/2 1/1 1/1 0/1 0/1 (2/8) Rock ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ (20) ~~||||~~ |||| 59%
CHTE 1/1
EPVI 0/2 21% Sene
LYPA 1/1 TOTAL 4/12

Bearing Slope 48%

WS7 84° 24° Soil ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ ||||
CHTE 2/1 1/1 (3/2) Rock || 2%
CELA 0/1 V. heavy brome infestation ca. 80% w/ location
ERFA 1/1 0/1 2/1 2/2 (5/5) Scree 50%
AMDU 0/1
HACO 2/4 0/2 (2/6) TOTAL 10/15

WS8 2° 26° Soil ~~||||~~ ~~||||~~ ~~||||~~ ||| 19%
Rock ~~||||~~ ||| 8%
POA 0/1 0/1 (0/2) Scree 73%
CHTE 1/4 1/1 (2/5)
ERFA 1/2 0/1 0/1 0/1 0/1 1/1 2/3 (4/10)
CHNA 1/2 0/1 3/3 (4/6)
SIHY 0/1
EPVI 2/1 TOTAL 12/25

WS9 354° 25° Soil ~~||||~~ (15) ~~||||~~ ~~||||~~ ~~||||~~ ~~||||~~ 40%
Rock ||| 3%
CHTE 1/1 3/2 0/1 (4/4) Scree 57%
ERFA 2/2 0/2 0/2 2/1 0/2 0/1 1/1 0/1 (5/12)
STSP 0/1 0/1 (0/2)
POA 1/1
CHVI 0/1
SIHY 2/1 12/21

Bearing Slope 60%

WS10 26° 20° Soil

Rock 0% 40% Scree

ERFA 1/1 2/1 1/1 0/1 1/2 1/1 3/2 (8/9)

SIHY 0/1

POA 0/1 0/1 v. heavy bromus infestation (0/2)

CELA 0/1 0/1 (0/2)

CHTE 1/1 TOTAL 10/15

Bromus infestation is proportional to soil depth up to, say, 50 cm.

WS11 15° 26° ROCK 12%

SCREE 19%

EPNE 1/1

CHTE 0/1 0/1 (0/2)

ERFA 2/2 2/1 1/1 1/2 1/1 1/3 (8/10)

SAME 0/1 TOTAL 9/14

WS12 92° 9° Old Burn

Scree 0%

Rock ||| 3%

HYSA 0/1 0/1 0/2 0/2 1/3 1/1 (2/10)

very heavy BRRU infestation

disregarded for analysis because on burn

Yucca Mountain Field Trip Report
5-14 through 5-18-98

May 26, 1998

David P. Groeneveld, Ph.D.
Resource Management Consulting, Inc
PO Box 3296 Telluride, Colorado 81435
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May 14, 1998:

The day began with the drive from Bishop, California to the Mercury Gate. While on this drive, several important factors were noted.
(1) the phenology of the vegetation was lagging by about 2 or more weeks behind "normal" conditions that I have observed over the course of decades of observation. This is directly attributable to the cool and wet conditions that have prevailed during the late Winter and Spring period of 1998.
(2) The wetter-than-normal Winter and Spring have influenced the growth of the parasitic plant dodder (probably *Cuscuta denticulata*). In areas where introduced weedy annuals have become established, the thick growth of this spring has permitted the dodder to bridge between to cover virtually all shrubs in patches that approach 10's to100's of hectares in areal extent, especially in creosote bush-dominated vegetation. Examples of this were particularly evident in the Amargosa Valley between Beatty and the divide with the Indian Springs watershed. Heavy infestation by these plants may cause widespread mortality of shrubs and, in the case of creosote bush, may kill off individuals that have reproduced clonally for thousands of years. The weedy species with the highest ground cover in these areas is an introduced Eurasian grass, *Vulpia octoflora*.
(3) On Lida Summit which is located just over the border into Nevada from California, many single leaf pines are showing a marked defoliation by an insect whose larval form resembles scale insects: some have been killed. This same defoliation has been noted on pines growing in the Grapevine Mountains, a climate analog study site. Thus, this infestation may be widespread enough to effect any of the climate analog. The nature of this infestation will be determined since it potentially effects the species especially at its lower growth limits where the defoliation and mortality have been noted.

The team assembled at Yucca Mountain by mid-day. My work for the day was to collect additional shrub stem samples, these from *Ephedra viridis*, to add to data from Yucca and Shoshone Mountains to develop a theoretical growth curve for use on north- and south- facing slopes at Yucca Mountain under present and climate-change conditions to (1) apportion evaporation versus transpiration and (2) apportion probable vegetation cover. These samples were collected from the north and south slopes of Split Wash.

May 15, 1998:

Color print photographs were obtained of the major common Yucca Mountain species in order to assemble a field guide to plants for CNWRA staff. At present count, this guide will contain 34 species, heavily weighted to perennial species, especially shrubs. The photographs contain both closeup views of foliage and views of plant groupings in which examples of the individual species will be identified.

The other activity for this day was to run vegetation transects on the north and south facing slopes (two south, one north) where shrub stem samples were collected for investigation of differential growth rates. Stu Stothoff assisted this effort.

May 16, 1998:

Phinney Canyon in the Grapevine Mountains was visited with the research team. Because of limited timing, the scale of the topography and the lack of paired north- and south-facing slopes, no core samples were collected of single-leaf pines for further work on the theoretical curve mentioned above. This curve requires excellent control on slope, slope alignment, vegetation cover The insect infestation of needles of this species were noted, photographed and collected for later identification. May of these pines are showing nearly complete defoliation, and thus, probable mortality at the lower limit of their growth.

A mine shaft located in Phinney Canyon and adjacent to the road was observed. This shaft shows that deep recharge and seepage is occurring under current climatic conditions on site. Moisture was observable as seepage on the rock faces at about 30 feet deep while at around 45 to 50 feet deep (all depths estimated) permanent seepage is marked by the presence of a green algal coating on the rocks.

May 17, 1998:

During this day my efforts were subsumed by infiltration tests. I cut and silicone-sealed plastic boxes to exposed rock overlying fractures. In another test, Stu Stothoff, Dani Or and I flooded a crack system in a naturally-sealed depression. The data I collected were copied by Stu. The data that I collected on infiltration using the boxes sealed to the rock surface are as follows:

Lowermost location at confluence of small wash: this site is a crack system adjacent to that measured by Dani on May 15. The dimensions of the plastic tub (opaque, green) was 48 cm by 33.8 cm (average cross dimension). These data are:

Time	Reading	
3:08:00	4.40 cm	95% surface area of water (box not filled because of greater potential for leakage)
3:28:00	4.40 cm	
3:55:00	4.40 cm	
5:40:00	4.10 cm	

The upper location, lower test box: this site was located up the right-hand channel of a small 1st order wash. The box used was the same clear plastic as that used by Dani on May 15.

Time	Reading	
5:13	52.35 cm	this box also had 95% surface area for same reason
5:34	51.20 cm	
5:50	51.00 cm	
6:06	50.07 cm	

The uppermost box at this upper location was abandoned after it was determined that effective sealing could not be accomplished using silicone sealant.

May 18, 1998:

Thirteen vegetation transects were run with the assistance of Stu Stothoff throughout the intensive-study watershed. These include lower elevation, higher elevation and north- and south-facing slopes. A report detailing the results of these transects with locations shown on vertical air photographs will be written and forwarded during the month of June.

During the return drive to Bishop from Yucca Mountain. Photographs were obtained of the dodder infestation and, for the plant guide, one of the important shrub regional shrub species that were not photographed on Yucca Mountain.

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June 8, 1998

Mr. Randy Fedors
Center for Nuclear Waste Repository Analysis
Post Office Drawer 28510
San Antonio, TX 78228-0510

RE: Addendum to Trip Report for May Field Trip

Dear Randy:

As a general observation, the region surrounding and including Yucca Mountain were dominated by intershrub growth of brome grasses. In most locations, this species has assumed equivalent or even dominant cover to the native species of shrubs. There are two species of brome grass, *Bromus tectorum*, and *Bromus rubens*. The latter species dominates in the region around Yucca Mountain and typically dominates on sites that are below about 5,000 feet. From observations made on this trip, it is apparent that on Yucca Mountain and the surrounding region, *B. rubens* is replacing shrub cover. This is particularly apparent on gentle slopes with deeper soils that generally face south, west and east but occasionally toward the north: in short, any place where intensive soil drought is expected without benefit of coupling with rock fractures, *B. rubens* is apparently taking over.

From casual observation dominance of *B. rubens* is a mechanism largely resulting from intense competition with seedlings of the native species. Where *B. rubens* dominates on southern aspects, there is evidence of shrub carcasses related to drought-induced die-off around 1989-1990. However, now that a relatively wet period has occurred, natural regeneration of the native species is to be expected. This regeneration was lacking in sites where *B. rubens* growth was most intensive. Lack of regeneration by native species apparently occurs because *B. rubens* germinates during early winter and grows during warm days in winter. Thus, when native species germinate as a result of the previous winter's precipitation, they face intensive and apparently fatal competition for water and nutrients by *B. rubens* which are already nearing maturity. The nutrient that generally tends to most limiting in desert environments is nitrogen. Nitrogen is generally locked up in the top 20 cm of the soil, within easy reach of intensely proliferating *B. rubens* roots.

Observations of large areas of *B. rubens* replacement of shrubs can be studied using historic air photographs, if they exist, or Landsat MSS data. These data cover a period back to the mid-1970's which largely predates the establishment of dominance by *B. rubens*. Change-detection procedures for comparison of paired scenes from wet years and obtained in mid-April (*B. rubens* and native shrubs are both green) and mid-June (*B. rubens* senesced and straw colored, native shrubs are green) would document where these changes have occurred in the region of Yucca Mountain. With this documentation in hand, the basis for prediction of the potential replacement of native species over the repository footprint of Yucca Mountain would be stronger. Analysis with satellite data for this purpose is currently beyond the scope of the present work.

I plan to provide an analysis of the potential for the two weedy *Bromus* species to replace deeper- rooted Yucca Mountain native perennial vegetation. This problem may have profound impact on the potential for deep percolation as has been found by other researchers in arid- to semi-arid environments: replacement of deep-rooted native vegetation greatly increases groundwater recharge. My analysis will combine field observation, specially-obtained air photos and a thorough literature review. For air photos, early- to mid-summer color-positive air photos will highlight those areas where *Bromus rubens* dominates vegetation cover because native shrubs will have green canopies while annual weedy species (including *Bromus*) will have turned a straw color. Additional air photos will need to be collected over Yucca Mountain again during late June or early July: this effort should be coordinated with obtaining photos of other targets over Yucca Mountain.

A major focus of my current field effort is to develop a numerical relationship for vegetation cover through any climatic regime. A theoretic curve describing this relationship is shown in Figure 1. In order to develop this curve we need to locate paired north and south facing slopes that have about the same slopes as exist along the east-west trending canyons of Yucca Mountain. Another factor that we should try to control for is parent material, preferentially choosing densely welded tuffs over other other rock types. The sites and species included in this analysis are two shrubs on Yucca Mountain in the vicinity of Split Wash and Antler Ridge (*Chrysothamnus teretifolius* and *Ephedra viridis*) and on Shoshone Mountain (*Pinus monophylla*). Candidate sites to add to the analysis include Timber Mountain (*Pinus monophylla* and *Pinus ponderosa*), Grapevine Mountain (*Pinus monophylla*) and Northern Pahroc Range (*Chrysothamnus nauseosus* and *Artemisia tridentata*).

The sites chosen must have relatively continuous vegetation cover, i.e., no large gaps due to fire scars, scree slopes, canopy die-off due to disease, etc. For development of the curve, shrub stem and tree core samples need to be collected from plants on north and south-facing. These will be and analyzed to determine differential growth rates. Vegetation cover will be established on vertical air photos and so, any location chosen for study must have clearance for an overflight. From work completed so far on *C. teretifolius* and *P. monophylla* support the theoretic curve of Figure 1: cover is significantly lower on the south facing slopes and lower at lower altitudes. Growth rates were found to be same for north- and south-facing slopes for both samples. These results indicate that the study sites are closed communities: competition among individuals is intensive and establishment of new plants is not possible without first losing members of the original vegetation cover.

Figure 1

Theoretic Curve for Vegetation Cover

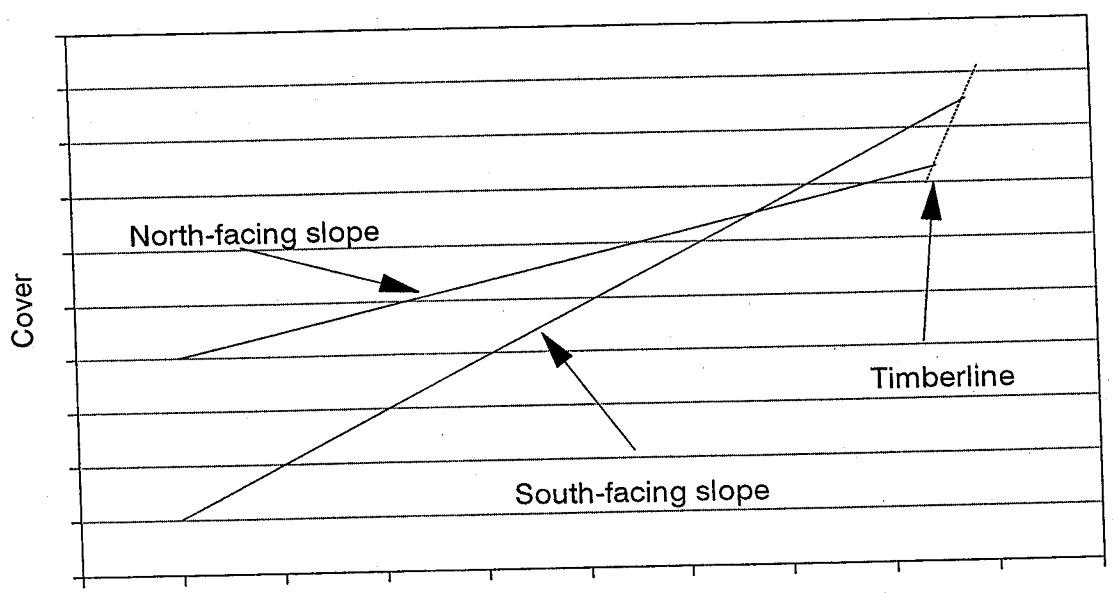

Figure 1. This theoretic curve describes vegetation cover according to elevation which is a surrogate for weather and, therefore, is an analog for climate change driven by cooler and wetter conditions. The curve describes maximal vegetation cover which can be moderated in infiltration models by using a stochastic driver to simulate the effects of fire, insects, blowdown, etc.

Please call if you have questions or need additional information.

Sincerely,

David P. Groeneveld, Ph.D.

Analysis of *Ephedra viridis*

3-18-00

~~NF1 - A) .10, .16, .07, .12, .16, .16~~
~~B) .10, .115, .06, .13, .13, .10~~
~~C) .115, .11, .07, .15, .16, .~~

NF1 - A)	.088	NF7 - A)	.079
B)	.075	B)	.073
C)	.089	C)	.073
NF2 - A)	.068	NF8 - A)	.146
B)	.070	B)	.160
C)	.071	C)	.116
NF3 - A)	.081	NF9 - A)	.104
B)	.101	B)	.081
C)	.099	C)	.107
NF4 - A)	.075	NF10 - A)	.125
B)	.075	B)	.118
C)	.072	C)	.106
NF5 - A)	.084	NF11 - A)	.130
B)	.090	B)	.119
C)	.099	C)	.131
NF6 A)	.071	NF12 - A)	.101
B)	.064	B)	.092
C)	.067	C)	.093

```
MTB > prin c1-c4

 ROW  SF-inT   SF-mm   NF-inT   NF-mm

   1   0.122   0.516   0.088   0.373
   2   0.133   0.563   0.075   0.318
   3   0.128   0.542   0.089   0.377
   4   0.087   0.368   0.068   0.288
   5   0.081   0.343   0.070   0.296
   6   0.101   0.428   0.071   0.301
   7   0.121   0.512   0.081   0.343
   8   0.114   0.483   0.101   0.428
   9   0.122   0.516   0.099   0.419
  10   0.142   0.601   0.075   0.318
  11   0.131   0.555   0.075   0.318
  12   0.148   0.627   0.072   0.305
  13   0.091   0.385   0.084   0.356
  14   0.089   0.377   0.090   0.381
  15   0.091   0.385   0.099   0.419
  16   0.081   0.343   0.071   0.301
  17   0.075   0.318   0.064   0.271
  18   0.082   0.347   0.067   0.284
  19   0.134   0.567   0.079   0.334
  20   0.135   0.572   0.073   0.309
  21   0.136   0.576   0.073   0.309
  22   0.086   0.364   0.146   0.618
  23   0.090   0.381   0.160   0.677
  24   0.096   0.406   0.116   0.491
  25   0.101   0.428   0.104   0.440
  26   0.091   0.385   0.081   0.343
  27   0.096   0.406   0.107   0.453
  28   0.064   0.271   0.125   0.529
  29   0.070   0.296   0.118   0.500
  30   0.073   0.309   0.106   0.449
  31   0.061   0.258   0.130   0.550
  32   0.062   0.262   0.119   0.504
  33   0.056   0.237   0.131   0.555
  34   0.080   0.339   0.101   0.428
  35   0.071   0.301   0.092   0.389
  36   0.069   0.292   0.093   0.394

MTB > mean c2
   MEAN    =      0.41275
MTB > stdev c2
   ST.DEV. =      0.11211
MTB > mean c4
   MEAN    =      0.39911
MTB > stdev c4
   ST.DEV. =      0.10127
MTB > nopaper
```

inches for 6 layers

mm per layer

Ephedra viridis

Yucca Mtn.

no statistical difference N Facing vs. S Facing

Excel: Plant transects - Book 2

Yucca Mt - Split Wash, Antler Ridge

Cover	AMDU	ATCO	CELA	CHNA	CHTE	CHVI	EPNE	EPVI	ERFA	GRSP	HACO	HYSA	LYPA	POA	SAME	SIHY	STSP	Totals
WS1	1.98				1.98				8.91								0.99	13.86
WS2	3.96		0.99				6.93		2.97		0.99				0.99		2.97	19.80
WS3	0.99	0.99			0.99		2.97						2.97				0.99	9.90
WS4					1.98			5.94	1.98								0.99	10.89
WS5					1.98		3.96	2.97	1.98				0.99				4.95	16.83
WS6					0.99			1.98	7.92				0.99					11.88
WS7	0.99		0.99		1.98				4.95		5.94							14.85
WS8				5.94	4.95				9.90					1.98		0.99		23.76
WS9					3.96	0.99			11.88					0.99		0.99	1.98	20.79
WS10			1.98		0.99				8.91					1.98		0.99		14.85
WS11					1.98				9.90						0.99			12.87
WS12												9.90						9.90
WS13							0.99	6.93	9.90	0.99							1.98	20.79

	Aspect	Class	Slope	Cover	LAI
WS1	192	S	40.4	13.86	0.218
WS2	215	S	38.4	19.80	0.238
WS3	193	S	46.6	9.90	0.079
WS4	174	S	46.6	10.89	0.020
WS5	165	SE	46.6	16.83	0.139
WS6	93	E	70.0	11.88	0.079
WS7	84	E	44.5	14.85	0.198
WS8	2	N	48.8	23.76	0.198
WS9	354	N	46.6	20.79	0.238
WS10	26	NNE	36.4	14.85	0.198
WS11	15	N	48.8	12.87	0.158
WS12	92	E	15.8	9.90	0.040
WS13	105	E	44.5	20.79	0.139

	North	South	asterly
Mean Cover	**18.07**	**13.61**	**14.85**
Mean LAI	**0.198**	**0.139**	**0.119**

Table ____. Results from Transects in Split Wash Catchment 5-18-98

LAI	AMDU	ATCO	CELA	CHNA	CHTE	CHVI	EPNE	EPVI	ERFA	GRSP	HACO	HYSA	LYPA	POA	SAME	SIHY	STSP	Total
WS1	0.059				0.059				0.079								0.020	0.218
WS2	0.020		0.040				0.079		0.040		0.020				0.020		0.020	0.238
WS3					0.040								0.020				0.020	0.079
WS4									0.020									0.020
WS5					0.020		0.020	0.020	0.040								0.040	0.139
WS6					0.020				0.040				0.020					0.079
WS7					0.059				0.099		0.040							0.198
WS8				0.079	0.040				0.079									0.198
WS9					0.079				0.099					0.020		0.040		0.238
WS10					0.020				0.178									0.198
WS11									0.158									0.158
WS12												0.040						0.040
WS13								0.040	0.079								0.020	0.139

Excel: Plant Transects – Book 1
Yucca Mt-Splitwash, Antler Ridge

Table ____. Transect Results 5-15-98

Plant Cover

Site #	AMDU	ATCO	CELA	CHNA	CHTE	CHVI	EPNE	EPVI	ERFA	HACO	LEPU	LYAN	SAME	SIHY	SPAM	STPA	STSP	Totals
1.1 SF Split Wash	0.99				1.98	0.99	0.99	1.98	5.94						0.99			13.86
1.2 SF Split Wash	2.97				2.97			1.98	0.99									8.91
1.3 SF Split Wash						5.94		2.97	5.94				4.95					19.80
2.1 NF Split Wash					8.91	7.92		1.98	1.98	0.99	0.99	0.99						23.76
2.2 NF Split Wash		0.99		4.95		8.91		2.97			2.97			0.99				21.78
2.3 NF Split Wash		0.99		12.87		5.94		8.91						0.99				29.70
3.1 SF Antler Ridge	2.97	2.97	1.98						0.99							1.98	3.96	14.85
3.2 SF Antler Ridge	3.96				5.94		0.99		0.99									11.88
3.3 SF Antler Ridge	0.99					0.99			6.93								0.99	9.90

Site #	Rock	Soil	Scree	Cover		LAI	
1.1 SF Split Wash	31.68	11.88	56.44	13.86	**Mean Cover**	0.337	**Mean LAI**
1.2 SF Split Wash	9.90	15.84	74.26	8.91		0.238	
1.3 SF Split Wash	30.69	4.95	64.36	19.80	**N-facing**	0.178	**N=facing**
2.1 NF Split Wash	6.93	1.98	91.09	23.76	**25.1 (n=3)**	0.495	**0.291 (n=3)**
2.2 NF Split Wash	6.93	2.97	90.10	21.78		0.139	
2.3 NF Split Wash	15.84	3.96	80.20	29.70	**S-facing**	0.238	**S-facing**
3.1 SF Antler Ridge	6.93	7.92	85.15	14.85	**13.20 (n=6)**	0.178	**0.195 (n=6)**
3.2 SF Antler Ridge	2.97	2.97	94.06	11.88		0.158	
3.3 SF Antler Ridge	4.95	23.76	71.29	9.90		0.079	

Leaf Area Index

Site #	AMDU	ATCO	CELA	CHNA	CHTE	CHVI	EPNE	EPVI	ERFA	HACO	LEPU	LYAN	SAME	SIHY	SPAM	STPA	STSP	Totals
1.1 SF Split Wash	0.02				0.059	0	0	0.0396	0.198						0.02			0.337
1.2 SF Split Wash	0.059				0.119			0.0594	0									0.238
1.3 SF Split Wash						0.059		0.0198	0.079				0.0198					0.178
2.1 NF Split Wash					0.317	0.099		0.0198	0	0.02	0	0.04						0.495
2.2 NF Split Wash		0		0.04		0.079		0			0.02			0				0.139
2.3 NF Split Wash		0		0.059		0.099		0.0594						0.02				0.238
3.1 SF Antler Ridge	0.059	0.059	0						0.04							0	0.02	0.178
3.2 SF Antler Ridge	0.079				0.04		0.02		0.02									0.158
3.3 SF Antler Ridge	0					0			0.059								0.02	0.079

Table _____. Key to Species Abbreviations for Perennial Plants Measured on Yucca Mountain.

Life forms are S-shrub, F-perennial forb, G-grass, T-tree; e-evergreen (deciduous unless noted), sp-stem photosynthesis, b-bunch forming (grass only), r-rhizomatous (grass only)

Abbreviation	Species	Authority	Life Form
AMDU	*Ambrosia dumosa*	A. Gray	S
ARTR	*Artemisia tridentata*	Nutt.	Se
ATCA	*Atriplex canescens*	Pursh	S
ATCO	*Atriplex confertifolia*	Torrey & Fremont	S
CACH	*Castilleja augustifolia*	Nutt.	F
CELA	*Krascheninnikovia lanata* (previously *Ceratoides lanata)*	Pursh	Se
CHNA	*Chrysothamnus nauseosus*	Pallas	Ssp
CHTE	*Chrysothamnus teretifolius*	Durand & Hilg.	Se
CHVI	*Chrysothamnus viscidiflorus*	A. Gray	Ssp
CORA	*Coleogyne ramoissima*	Torrey	S
ELEL	*Elymus elemoides*	Nutt.	Gb
EPNE	*Ephedra nevadensis*	S. Watson	Se,sp
EPVI	*Ephedra viridis*	Cov.	Se,sp
ERFA	*Eriogonum fasciculatum*	Benth.	S
GRSP	*Grayia spinosa*	Hook.	S
HACO	*Ericameria cooperi* (previously *Haplopappus cooperi)*	A. Gray	Se
HALI (yel)	*Ericameria linearifolia* (previously *Haplopappus linearifolia)*	DC.	Se
HIJA	*Pleuraphis jamesii* (Formerly *Hilaria jamesii*)	Torrey	Gb
HYSA	*Hymenoclea salsola*	A. Gray	S
KRPA	*Krameria parvifolia*	Benth.	S
LATR	*Larrea tridentata*	DC.	Se
LEPU	*Leptodactylon pungens*	Torrey	F
LYAN	*Lycium andersonii*	A. Gray	S
LYPA	*Lycium pallidum*	Miers	S
MESP	*Menodora spinescens*	A.Gray	Ssp
ORHY	*Achnatherum hymenoides* (previously *Oryzopsis hymenoides)*	Roemer & Schultes	G
Poa	*Poa* (bluegrass sp.)		Gr
SPAM	*Sphaeralcea ambigua*	A. Gray	F
STPA	*Stephanomeria pauciflora*	Torrey	F
STSP	*Achnatherum speciosa* (previously *Stipa speciosa)*	Trin. & Rupr.	Gb
TEAX	*Tetradymia axillaris*	Nelson	S
TEGL	*Tetradymia glabrata*	Torrey & A. Gray	S
UK	Unknown species (lacking characteristics for positive identification)		

Species climate change . wpd

Table _____. Potential Important Perennial Plant Species on Yucca Mountain Under Glacial Maximum

Species	Authority	Life Form
Amelanchier alnifolia	Nutt.	S
Artemisia tridentata	Nutt.	Se
Cercocarpus ledifolius	Jepson	Se
Chamaebatiaria millefolium	Torrey	S
Chrysothamnus nauseosus	Pallas	S
Ephedra viridis	Cov.	ES
Fallugia paradoxa	(D. Don) Endl.	DS
Holodiscus dumosus	S. Watson	S
Juniperus osteosperma	Torrey	Te
Leymus cinereus	Scribner & Merr.	Gb
Pinus flexilis	James	Te
Pinus monophylla	Torrey & Fremont	Te
Poa sp.		Gr
Purshia tridentata	(Pursh) DC	ES
Quercus gambelii	Nutt.	T
Rosa woodsii	Lindley	Sw
Salix exigua	Nutt.	Sw
Symphoricarpos sp.		S

Life Form:
- F - forb
- G - grass
- S - shrub
- T - tree

Life Form Modifiers:
- e - evergreen, (deciduous unless specified)
- w - wet locations, springs or drainage
- b - bunch (grass only)
- r - forming rhizome (grass only)

Species RootDepth . wpd

Table ____. Root-Depth Classes for Plants Under Present and Possible Future Climates on Yucca Mountain

Species that are not present currently on Yucca Mountain but may grow under future climates are indicated by "**". Three species, Symp, ROWO and SAEX will only be present in very restricted areas within wetted drainages in the event of cooler and wetter climates on Yucca Mountain.

Annual Species

BRTE, BRRU	*Bromus tectorum or rubens*
AMTE	*Amsinckia tesselata*

Perennial Grasses (< 1 m)

ELEL	*Elymus elemoides*	CACH	*Castilleja augustifolia*
HIJA	*Hilaria fasciculatum*	**ELCI	*Leymus cinereus*
ORHY	*Achnatherum hymenoides*	Poa	*Poa* (bluegrass sp.)
SPAM	*Sphaeralcea ambigua*	STPA	*Stephanomeria pauciflora*
STSP	*Achnatherum speciosa*		

Shallow Rooted Shrubs (< 2m)

AMDU	*Ambrosia dumosa*	CELA	*Kraschenninnikovia lanata*
CHVI	*Chrysothamnus viscidiflorus*	CORA	*Coleogyne ramoissima*
EPNE	*Ephedra nevadensis*	ERFA	*Eriogonum fasciculatum*
GRSP	*Grayia spinosa*	HYSA	*Hymenoclea salsola*
KRPA	*Krameria parvifolia*	LATR	*Larrea tridentata*
LEPU	*Leptodactylon pungens*	LYAN	*Lycium andersonii*
LYPA	*Lycium pallidum*	MESP	*Menodora spinescens*
TEAX	*Tetradymia axillaris*	TEGL	*Tetradymia glabrata*

Deep Rooted Shrub (< 4 m)

ARTR	*Artemisia tridentata*	**AMAL	*Amelanchier alnifolia*
ATCA	*Atriplex canescens*	ATCO	*Atriplex confertifolia*
***CELE	*Cercocarpus ledifolius*	**CHMI	*Chamaebatiaria millefolium*
CHNA	*Chrysothamnus nauseosus*	CHTE	*Chrysothamnus teretifolius*
EPVI	*Ephedra viridis*	HACO	*Ericameria cooperi*
HALI	*Ericameria linearifolia*	**HODU	*Holodiscus dumosus*
**ROWO	*Rosa woodsii*	**SAEX	*Salix exigua*
**Symp.	*Symphoricarpos* sp.		

Trees (< 6 m)

**JUOs	*Juniperus osteosperma*	**PIFL	*P. flexilis*
**PIMO	*Pinus monophylla*	***QUGA*	*Quercus gambellii*

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June 26, 1998

This photographic mission was prompted by analysis of a set of air photographs obtained on 3-10-98 which indicated that numerous lineaments could be seen on the large-scale air photographs. These earlier photos were obtained principally for mapping and measuring of vegetation.

During the photo mission, altitudes of the flightlines were controlled to low (ca. 1000 feet above the ground) over Yucca Mountain and nearby region. These photographs were later used for measuring plant cover for (1) studies of the effect of elevation, aspect and slope on vegetation cover, (2) performing preliminary mapping of lineaments that may be fault traces, and (3) mapping landform features that may influence infiltration processes.

The air photo products obtained during the overflight were a critical component which permitted analysis and discovery of phenomena that were overlooked by other researchers; for example the role of rock fissures in plant distribution and possible interplay for infiltration processes (published in J. Hydrology 218:169-190, S. Stothoff lead author).

Although the other uses made of this aerial photography is important, for example locating potential faulting and measurement of vegetation cover, perhaps the most important use made of this photography was for mapping of landforms that may give rise to non-distributed infiltration (flow focused into discrete zones; i.e. "hot spot"). Landforms were mapped from these air photographs and it appears that three slope-related and lithologic factors may be responsible for such focused flow: (1) an upslope catchment which provides a flow of water during precipitation events ; (2) a topographic break existing as ~~a~~ paleo-terrace that focuses the flow in a zone; and (3) fracturing and jointing of rock that receive the focused flow. Landform mapping was accomplished at the end of the this project and, though it remains incomplete, the very rough first draft map on page 40 provided relatively good correspondence with known rapid flowpaths in the ESF tunnel (determined by bomb-pulse ^{36}Cl levels) and possibly could be refined to be a tool that could be used to better design the repository to be safe from the effects of infiltration. An unfortunate factor in such fast paths for infiltration is that will probably increase in size and effectiveness under higher infiltration conditions resulting from a climate change to glacial maximum conditions.

RF for DWG 9/26/00

Resource Management Consulting Inc
PO Box 3296 Telluride, Colorado 81435
(970) 728-2033 Fax: (970) 728-1708

April 1, 1998

To: Randy Fedors, CNWRA
Copies: Stu Stothoff and Dani Or
From: David Groeneveld

Re: Recently-obtained Air Photos and Lineaments Mapped from Them

I completed an overflight of Yucca Mountain on March 10 in which I obtained a series of vertical- and oblique-view photos. The intent of this photo series was to provide higher-resolution views of the washes and vegetation than have been available from other sources. I've made a series of color copies of these air photos to assist analysis and cross checking of lineaments that I have mapped. I have sent two copies of these products each to you and Stu and one copy to Dani. In addition, I have enclosed the original air photos that appear in the color copies in the package to Stu. Stu can make these available to your structural geologists during his upcoming field trip.

You will find the following separate series of copies enclosed:
o 11 x 17 inch panoramic views with an 8.5 x 11 inch key to the view seen in each.
o 11 x 17 inch vertical-view photo-mosaic from a low altitude flightline taken parallel and just west of the position of the ESF. This is accompanied by an 8.5 x 11 inch key that shows the position of this and another similar low-altitude flightline.
o 8.5 x 11 inch key to mapped lineaments accompanied by an 8.5 x 11 inch key to mid altitude flightlines that cover the entire repository area and photo-mosaics of these photos with the mapped lineaments indicated.

The reason I analyzed the air photos for lineaments was threefold (1) we have been discussing the concept of "hotspot" infiltration and I wished to look at potential locations of hotspot infiltration, particularly lineaments that cross upper canyon washes, (2) once I began the analysis, I saw that there are large-scale lineaments that may influence deep percolation as well, and (3) to insure that this analysis was performed on the fresh look provided by these new air photos. As scientists what we learn is very often the direct result of the resolution provided by our view - in this case, air photos. Hopefully, these photos show things not visible on earlier sets.

With regard to small lineaments that cross washes, these are obviously very numerous but tend to be occluded by the presence of scree and are, thus, better predicted by overall jointing patterns rather than from air photos. Once I determined this, I focused on larger-scale lineaments that were identified by changes in coloration of the exposed rock/skeletal soil material, linear vegetation features, topographic depressions or offsets and linear alignment. I observed these features on the 4 x 6 inch color photos that have been forwarded to Stu under 2, 6 and 12x magnification with a mirror stereoscopic.

The ^{36}Cl hits correspond well with the placement of the lineaments which underscores their potential importance in transmission of infiltrated water to deep percolation. In some cases, these faults are pronounced, unmistakable and actually form the washes that they have given rise to (for example, lineaments mapped as D, I and J). As such, their role both in infiltration and deep percolation may be profound.

I would like to call to your attention to a number of additional features that may control infiltration:

1. On the low-altitude flightline which contains photos GL1-GL35, note that the jointing pattern of the tuff shows very little lineation toward the south end of the area of interest (say, GL1 through GL16), while at the north end the rock shows very pronounced linear patterns that are highlighted by vegetation (GL17 through GL35). These patterns suggest greater potential for infiltration, particularly on the north-facing slopes.
2. The lineaments that I have mapped tend to align with other features that may indicate that, if these features are indeed faults, they may have given rise to canyons and drainages beyond the points of visible fault traces. This is especially pronounced for both ends of "O", for the southern end of "H", and for the eastern end of "D".
3. The lineament "N" is especially interesting because it suggests an upthrusting of the northern end which is atypical of the remainder of the lineaments noted.

Obviously some of the lineations may not be faults, but all are good candidates for field checking. Please note that this mapping was made with me ignorant of all but the Ghostdance Fault (which, by far, was the most pronounced). Thus, this analysis is not biased by the findings of other researchers. After many hours of staring through a mirror stereoscope, I certainly hope that these analyses bear fruit: I'd hate to regret sending such a memo on April Fool's day!

I look forward to the potential field trip to Yucca Mountain and climate-change analog sites on or about May 15. I'll be in Brazil between April 16 and May 12 but I'll try to contact you by e-mail from there to firm up a field schedule.

Yucca Mt. Mapped Lineaments (Candidate Faults)
Resource Management Consulting for CNWRA/NRC

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July 7, 1998

Mr. James Hogan
Center for Nuclear Waste Regulatory Analyses
Post Office Drawer 28510
San Antonio, TX 78228-0510

Dear James:

Enclosed are the photographs that you requested over Yucca Mountain. Also enclosed is the flightline map that you prepared with the lines given an alphabetic code by me. Each of these flightlines is separated and numbered from the starting frame (1) to the ending frame (various). The following frames and the altitudes flown are:

6-28-98
air photos

Flightline	Altitude (msl)
AB	Start at 5,400 and end at 5,800 feet
C	"
D	"
E	"
F	"
G	"
H	"
I	"
J	"
L	5,400 feet
M	Start at 5,400 and end at 5,800 feet
N	"
O	"
P	"
Q	Start at 5,400 and end at 5,800 feet

The altitudes are good to about plus or minus 200 feet which was the best I could do given the complexity of the terrain, the close-in work and the thermal activity during the overflight. The lens used was 28mm. As we discussed, scale will be highly variable due to the complexity of the terrain (and therefore, distance from the camera platform).

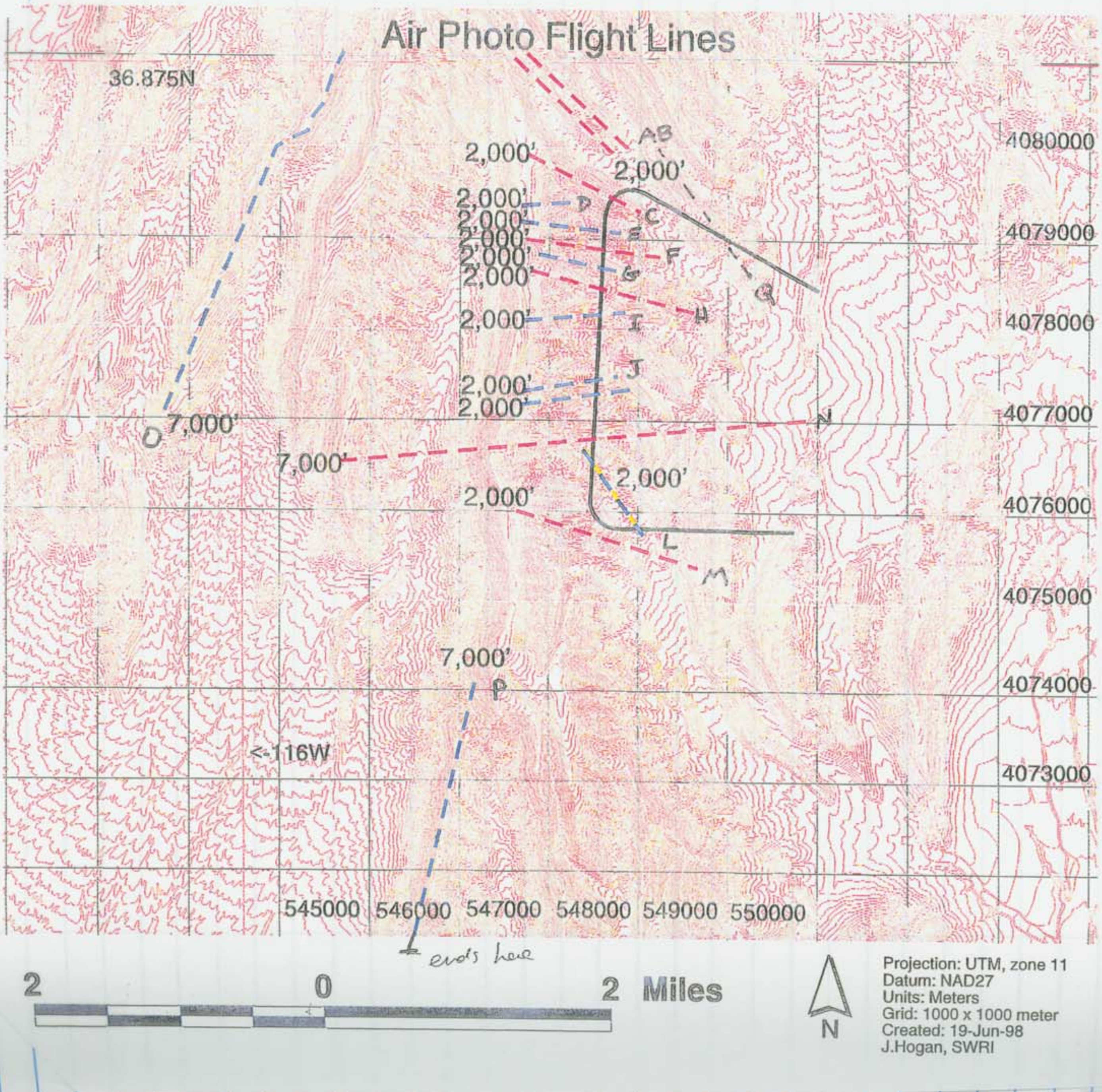
Please note that because of proximity, I combined flightlines A and B into one, AB. I tried this with J and K but, unfortunately, only acquired flightline J. I acquired several extra flightlines. These are flightline Q which crosses the northernmost of the eastern extensions of the ESF, and P' which is an extension to the north along the western scarpface of flightline P. Additionally, when I thought the mission completed, I reshot flightline L to use up the film and this is designated L'.

If you have any questions, please give me a call.

Sincerely,

David P. Groeneveld, Ph.D.

Copies: Randy Fedors
English Pearcy



Air Photo Flight Lines
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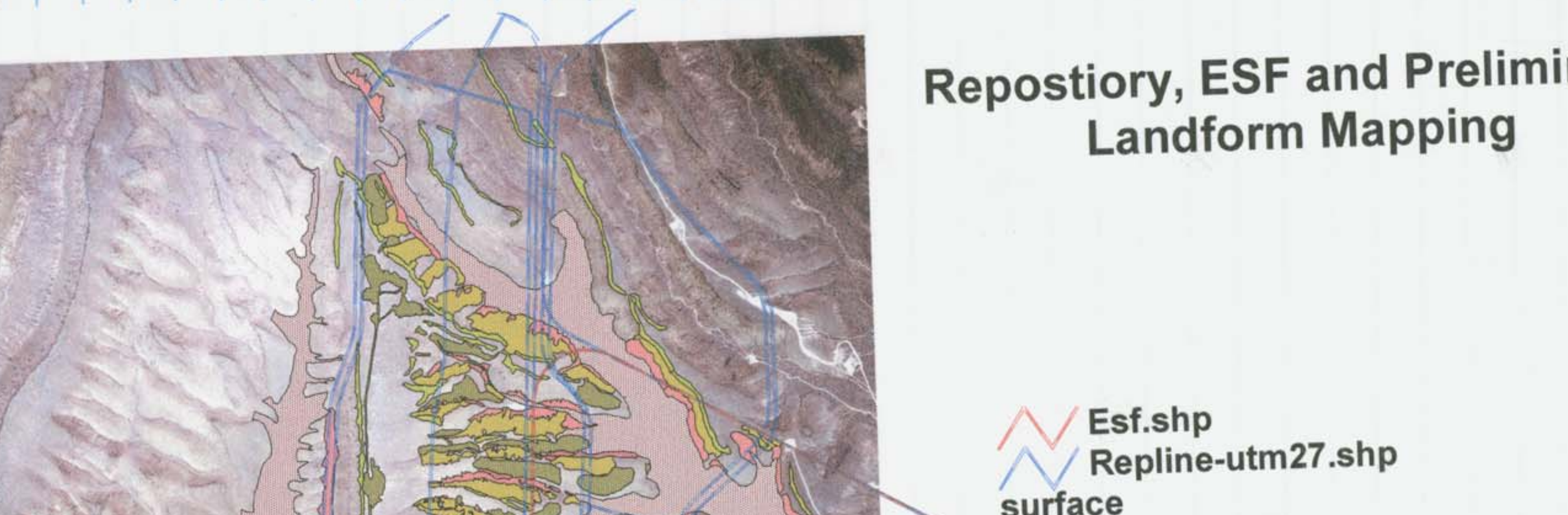
Projection: UTM, zone 11
Datum: NAD27
Units: Meters
Grid: 1000 x 1000 meter
Created: 19-Jun-98
J.Hogan, SWRI

Repostiory, ESF and Prelimi
Landform Mapping



Mapping of landforms that influence infiltration on Yucca Mountain

This activity began late in the project (late November- early December, 1999) even though the basic concepts were developed during 1997. This program could only be undertaken with the receipt of geo-corrected air photography from DOE which finally occurred within several months prior to the mapping. These photographs, imported into ArcView, served as the base upon which landforms were mapped after identification on the higher resolution air photographs (flown by myself on March 10, 1998 and June 26, 1998). Features observed on both the high resolution photographs and on the base air photograph were used to guide the mapping.

Landfrom Types Identified

Several types of landforms were identified:

Alluvium: This category generally consists of deep soils as valley fill. Where alluvium exists, virtually no infiltration can occur because the soil is sufficiently deep and supports shrubs rooted to depths that permit harvesting of all precipitation.

Terrace: This category exists on Yucca Mountain as remnants of previous valley fill. Terraces may provide sufficient damming effectto permit absorption of runon.

Cone: Terraces that have been highly dissected by erosion into a stable cone-like deposits that cling to valley sides were classified as "cones". Although smaller in extent and discontinuous, cones may also act in the same manner.

Bedrock 1: This category is poorly vegetated mostly exposed rock surfaces that may generate runoff that can concentrate water for infiltration.

Bedrock 2: This category consists of exposed crystal rich tuff which we have called "caprock". Bedrock 2 has exposed rock surfaces that may generate runoff and deep fissures that may receive this water, however, the effects of bedrock 2 on potential infiltration are far outweighed by Bedrock 1 that is more extensive.

Talus 1: This category consists of slopes that are mostly talus with vegetation obviously constrained to a level of cover much less than grows on slopes that do not have significant talus (i.e., about 40%, or less, of normal). Talus represents two promotional effects: impervious surfaces that give rise to significant runoff and "mulch" that reduces evaporation loss.

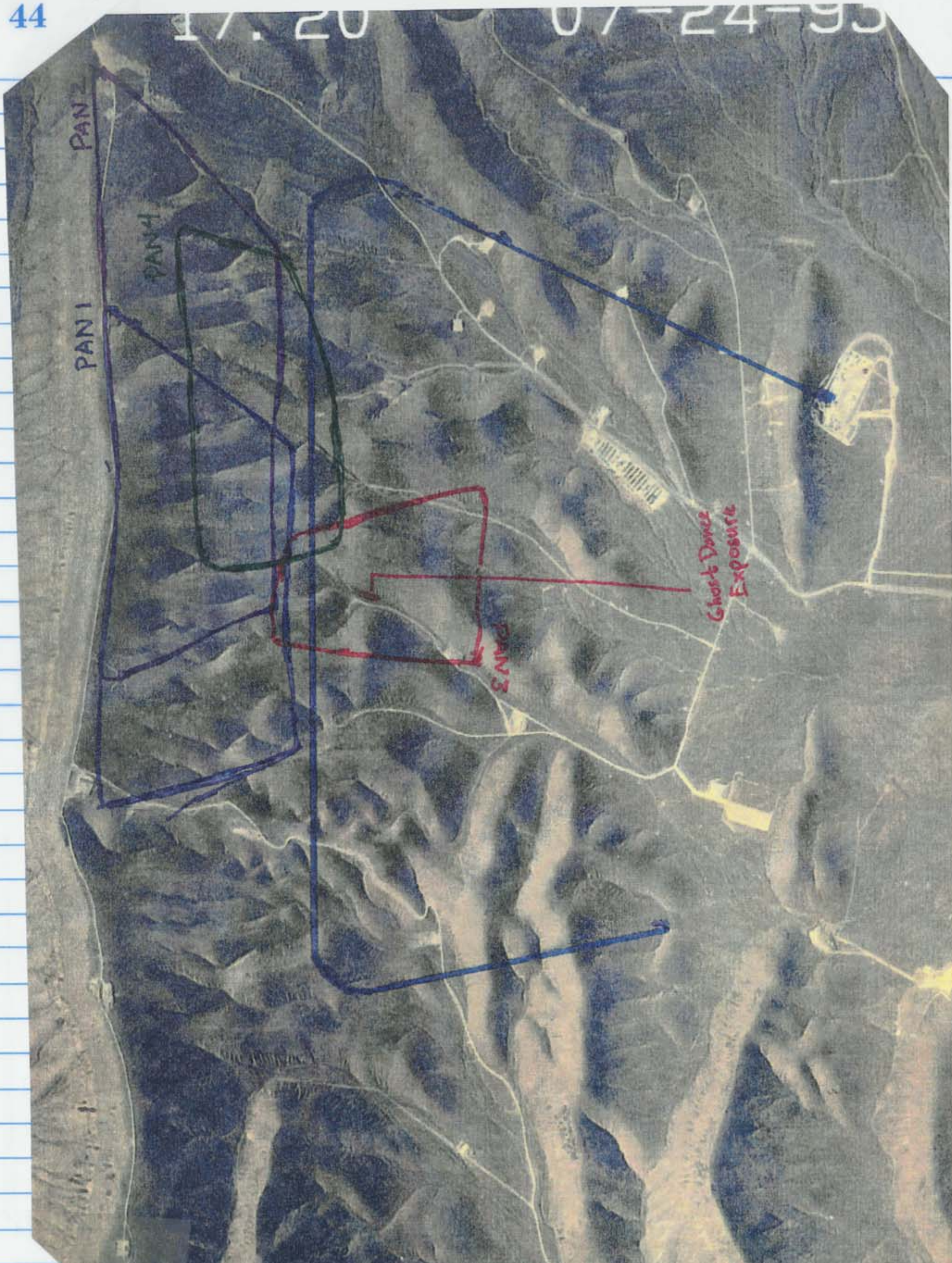
Talus 2: This category is talus of continuos cover where vegetation is largely excluded. Thus, this category is an intensification of Talus 1.

Preliminary Results:

The preliminary map is presented on the facing page. A comparison with the modern ^{36}Cl hits measured in the ESF shows good correspondence with locations that have (1) runoff generating areas--bedrock 1 and talus surfaces overying, (2) terrace zones. Faulting and fractures are hypothesized to (3) provide for a fast path of infiltration of the concentrated runon.


GL30
GL10


D15
C11
A10
B10
D10
A5
C5
D5
A1
C1
D1



Yucca Mt. Oblique Panoramas: 3-10-98
Resource Management Consulting for CNWRA/NRC

YM Shrub Cover

South Facing

	Site	Elev.	Aspect	Slope	Cover %
29	YM-T-SF	4340	174°	24.1°	14.1
30	YM-R-SF1	4250	182°	27.1°	20.0
31	YM-R-SF2	4400	182°	27.1°	20.4
32	YM-X-SF3	4450′	168	19.5°	16.5
33	YM-X-SF4	4440	176	25.3°	18.8
34	YM-X-SF5	4550	168	19.5°	23.1
35	YM-X-SF6	4520	188	25.3°	21.2

(data on this and next page used in vegetation cover model for elevation, slope & aspect

North Facing

	Site	Elev.	Aspect	Slope	Cover %
29	YM-T-NF	4400′	6°	22.1°	34.1
30	YM-R-NF1	4200	9°	24.4°	33.7
31	YM-R-NF2	4390	9°	24.4°	37.6
32	YM-X-NF3	4450	10°	20.8°	36.9
33	YM-X-NF4	4440	10°	21.4°	38.4
34	YM-X-NF5	4550	26°	20.8°	35.3
35	YM-X-NF6	4520	26°	21.4°	34.1

Shrub Cover on Yucca Mtn.

Site	Transect 1	2	3	4	5	Σ	Cover
YM-T-SF	9	10	4	7	6	36	14.1 %
YM-T-NF	19	16	22	13	17	87	34.1
YM-R-SF1	12	9	10	12	8	51	20.0 %
YM-R-SF2	10	10	12	8	12	52	20.4 %
YM-R-NF1	16	20	18	19	13	86	33.7 %
YM-R-NF2	23	14	20	21	18	96	37.6 %
YM-X-SF3	10	11	12	8	12	42	16.5 %
YM-X-NF3	18	16	22	17	21	94	36.9 %
YM-X-SF4	8	10	12	11	7	48	18.8 %
YM-X-NF4	18	20	22	23	15	98	38.4 %
YM-X-SF5	14	15	11	9	10	59	23.1 %
YM-X-NF5	18	16	23	15	18	90	35.3 %
YM-X-SF6	11	10	15	8	10	54	21.2 %
YM-X-NF6	20	17	15	14	21	87	34.1 %

June 27 through June 30, 1998

The intention for this field trip was twofold, (1) to study two climate-change analog sites and gather tree cores for later analysis and (2) to observe locations between 6,000 and 8,000 feet that have experienced invasion and takeover by Bromus tectorum. This early summer period followed a much wetter-than-normal winter which induced full expression of Bromus in many localities.

The work that resulted from this field trip confirmed that B. tectorum probably would replace shrub and possibly tree cover on Yucca Mountain under conditions of glacial maximum. More discussion is provided in the report which stemmed from this field trip and listed below.

Analyses of the tree cores obtained during this field trip confirmed a similar analysis on material collected on Shoshone Mountain: like shrub communities, forest communities comprised of pinyon and juniper are also effectively fitted to environmental limitation of each microsite.

The following report that was generated from this work is not included:
Groeneveld, D.P., R.W. Fedors and S.A. Stothoff. Weedy brome grasses and their potential effect on the infiltration and recharge rates in the vicinty of Yucca Mountain, Nevada. CNWRA report prepared for NRC under Contract NRC-02-97-009. August, 1999.

6-27 [Y.M. : East of Lida Pass
★ Hillside becoming over grown with BRTE ; ca 15-20% cover of domin.
near road → CHNA, ARTR, Gutierrezia
Position: N 37° 27.069' 6400' elev
W 117° 30.922' (car; GPS)
slope aligned to 180°
Slope: 12%
other plants present GRSP, W. Cedar,
2 soil horizons: 0-14 w/ lower Clay
certainly much less water
LP Terrace: BRTE patch
on BRTE dominated
@28 un large dead PUGL (purshia glandulosa) root
BRTE roots to 34 cm deep, few or none
below: Rocks $CaCO_3$ on both sides (diff-

page 38 in D.P. Groeneveld field notebook
3-27-98 through 5-8-00

ages as one side fresh white while other is weathered
0-32 [illegible] w/ roots of BRTE, top 8 cm
is recent colluviation. 32-38 seems
coarser (less fines) & definitely dryer
At ecotone BRTE to no BRTE
note carcasses of PIMO (ca 8 yrs), ARTR
and EPVI; BRTE roots to 33 cm;
rocks @ all depths have multiside
variable-aged caliche; ARTR dominated below
samples 0-30 (6 cm dead root of EPVI @ 32 cm)
30-40
Below ecotone: ARTR dominated, PIMO,
EPVI, Chrysothamnus sp., Penstemon sp.,
ORHY, Viguiera sp.
Soil;
horizon: 0-7 cm recent colluviation
0-44 massive
living roots of PIMO 188 cm to N & on Contour
@ 23 8 mm
35 11 mm
45 6 mm
Many (≥ 40% of BRTE, where dominant)
in top 30 cm
Base of slope has colluvial lobes of
coarser particles 1-10 cm diam rocks,
well rounded & w/ caliche mostly on
one side
slope is 25° & aligned to 330°

40

° drive to Phinney Canyon, set up equip. and camp, prep for Phinney Pk climb 8 hrs.]

6-28 [Y.M: @ Phinney Cyn area
South Peak: position on ridge is 36° 56.526' N

PC-SP 117° 06.185' W 8700' per GPS
NF Slope 28° slope to 340°
of tree cover, ca 75% is PIFL
PIFL remainder is PIMO
NF1 dbh 22 cm w/ 3 branches from base; Box 1 posit. 1, etc
PIFL NF2 dbh 27 cm Box 1-2
PIMO NF3 dbh 40 cm all trees are ca 12-18' tall
PIMO NF4 dbh 46 cm
PIMO NF5 dbh 26 cm
PIMO NF6 dbh 24 cm
PIFL NF7 dbh 28 cm
Soil pit: 0-45 cm massive w/ rock fragments & fine sandy matrix
1 sample V. moist
sampled stand is NW through N from pink mark pt.
other plant species: spiny phlox sp., Ribes inerme, Chrysothamnus sp., ARTR
Lupine, senecio sp.

PC-SP
SF Slope 24° slope to 165°
PIMO dominated w/ Chrysoth. Nause, Ribes inerme, ARTR

				Box	Pos.
PIMO	SF1	dbh	38 cm	2	1
PIMO	SF2	dbh	25 cm	"	2
PIMO	SF3	dbh	31 cm	"	3
"	SF4	dbh	34 cm	"	4
"	SF5	dbh	43 cm; large main branches near base; cored @ 2.3 m above gnd		5
"	SF6	dbh	35 cm	"	6
	SF7	dbh	26 cm	"	7

note: trees on S-F slope are generally < 15' tall are pyramidal and tend to be multi-trunked while on N-F slope PIMO tend to be taller w/ flat-topped crowns & single trunk.
soil pit: v. moist (like N-F slope)
v. sandy - cosa w/ rock fragments
sample 0-35
Sample stand is S to E of mark
evidence of fire but that is not responsible for standing dead PIMO

PIMO	NF8	dbh	34 cm	Box 2	8
"	NF9	dbh	22 cm	"	9
"	NF10	dbh	28 cm	"	10

42

Grapevine Mtns:
North Peak   Position 36° 59.825' N
8733 ft.   117° 08.023' W
GM NP SF
South facing slope PIMO, ARTR, EPVI
Gutierrezia
all PIMO are ≤ 12 ft height
PIMO SF1 forks @ 1 m largest is 26 cm dbh
SF2 dbh 33 cm   BOX 1: 1-7
SF3 dbh 26 cm
SF4 dbh 33 cm (largest fork; forks 0.6 m)
SF5 dbh 34 cm (largest; forks @ 1.0 m)
SF6 dbh 21 cm (largest fork; forks @ 1.2)
SF7 dbh 23 cm
Soil pit 0-12 cm roll erosion over flow
12-35+ cm massive w/ rock fragments
large pine root @ 18 cm deep
167° true; 25° slope
Stand sampled is S. of mark
North facing slope 330° 25° slope
PIMO NF1 dbh 40 cm
NF2 dbh 26 cm
NF3 dbh 38 cm
NF4 dbh 22 cm
NF5 dbh 37 cm
NF6 dbh 23 cm
NF7 dbh 27 cm
Soil pit - 0-12 cm recent alluvial

(roll) deposit; 12-37 cm+
large roots of PIMO @ 26 cm
☆ note: all 4 soil pits from S Peak & N. Peak had large PIMO roots ca 25 cm deep
sampled stand is N & NW of mark
General Note: Cercocarpus (Sierran sp.) growing on NE slope of N peak
bare area on NP is old fire scar - dead carcasses of PIMO scattered about now vegetated w/ ARTR & Chrysothamnus [illegible]
14.4]

6-29 [YM: pack up & break camp @ Phinney Cyn - drive to S. Quinn Cyn Range
- stop enroute to Quinn Cyn Range
6590 ft (GPS) 38° 06.832' N
116° 54.250' W
pt. where patches of BRTE is taking over,
note Phinney Cyn was clear where BRRU gives way to BRTE
Quinn Canyon Site 1 Position: 38° 06.838' N, 115° 34.935' W
SF slope 18° to 180°
PIMO & JUOS are codominant ca 50-50, ARTR, EPVI
also Yucca Baccata
[Site 1 is just SW from turnoff to Penoyer Valley

QK1 only core PIMO all 16-20' tall
SF1 dbh 24 cm
SF2 dbh 19 cm
Box 1 SF3 dbh 23 cm
SF4 dbh 16 cm
SF5 dbh 24 cm
SF6 dbh 26 cm
SF7 dbh 20 cm
soil pit 0-13 alluvial colluvial horizon, nil evident
13-35 horizon enriched w/ clay
appearance of soil is weathered in place

(around trunk but mostly N)

NF 19° to 355° trees 16-22' tall forked, core middle
NF1 dbh 25 cm, 21 cm, 12 cm
NF2 dbh 25 cm
NF3 dbh *19, 15, 22, 15 cm (cored *)
Box 2 NF4 dbh *20, 14 (forked)
NF5 dbh *20, 15 "
NF6 dbh *25, 25 "
NF7 dbh *28, 18

(around trunk but mostly N)

(note: some porky scars evident on trees, both slopes)
soil pit (3rd try in 10 feet)
0-12, colluvial/alluvial, 12-22 silt

developed in situ; 22 cm + decomposed rock; tuffaceous
Sampling design:
2 shrub species / same site: YM
5 PIMO sites, 7 each NF & SF
each with soil data, veg data, x.s. or tree cores
question to ask is whether growth rates are same on NF & SF slopes, if so, is indicator that all resources, especially water are exploited
PIMO sites ~6,000 Quinn Cyn Range
~6,500 " "
~6,800 Shoshone Mtn.
~8,300 Grapevine Mtns. SP
~8,400 " " NP
needs 1-2 sites between 6,800 & 8,300
ca 7500-7600 feet
Stratify up to 20-30 sites w/
- Known elevation, slope, slope alignment w/in 30° of true N & S
- Choose sites w/ uniform expression of cover, few, if any, carcasses of other trees
- choose slopes lacking rock outcrops or surface expressions of worn rock etc.
- photograph first as panorama which

shows location, then in flightline
@ 750-1000' AGL,
- position, note on GPS
- from air photos & topo maps interpret
1. slope
2. alignment
3. elevation
4. species comp.
5. cover
13.5]

6-30 [Yucca Mtn: up dry fork from
Cherry Creek - South- & North-facing
slopes in canyon bottom
Position: 38° 09.148' N
115° 38.451' W
7033 ft elev. (GPS)
170 to 190° (lobate slope form)
28° slope
PIMO is dominant but with ARTR
Ribes inerme, EPVI

QK2 SF1 27 cm dbh Box 1 1
SF2 21 cm
SF3 28 cm
SF4 20 cm
SF5 23 cm
SF6 *28 cm, 14, 10 cm (fork @ 0.5 m)
SF7 26 cm

Soil pit: 0-9 cm colluvial material
9-38 cm clay enriched zone
in situ
around work, line marked on roadway
QK2 NF across from QK2 SF but ~300 m
to East 38° 09.066' N
115° 38.329' W
7005 '(GPS) Slope 34°, 352° true

NF1 19 cm dbh Box 2 1
NF2 10, 14, *28, 16 cm (forked @ 0.5 m)
NF3 dbh 20 cm
NF4 22 cm
NF5 23 cm
NF6 *25 cm, 11 cm
NF7 26 cm

Soil pit - 0-10 colluvial material
10-35 high org. matter loam
NF slope has Symphoricarpos oreophilus
ARTR as understory, whole slope
dominated by Poa sp. sod. ca 40%
of ground cover is poa.
return BIH, unpack, clean & store
equip. 10.0]

7-1 [Yucca Mtn: purchase topo maps
fly air photos of 7 overlap sites in
Grapevine Mtns, drop off & pick up

Yucca Mountain Project Trip Report: Analog Sites in Western Nevada and *Bromus tectorum* Observations, 6-27-98 through 6-30-98

David P. Groeneveld, Ph.D.
Resource Management Consulting
Telluride, Colorado

Trip Purpose:

The trip was undertaken with two objectives:
(1) Collect tree cores from north and south-facing slopes of climate-change analog sites; and
(2) Observe the growth of cheatgrass (*Bromus tectorum)*.

Climate change analog sites are locations with parent material, slopes and aspects that are similar to Yucca Mountain but at a higher elevation. At higher elevations, precipitation is greater and temperatures are cooler than currently exit at Yucca Mountain, hence, forming an analogy to cooler and wetter climate that existed during the glacial cycle. The climate analog sites that have been and are being chosen for Yucca Mountain are at higher elevations and contain various coniferous vegetation dominated by single leaf pine (*Pinus monophylla*). The elevation that may be applicable as an analog for full glaciation is between 6,500 to 8,500 feet. Tree cores obtained from single leaf pine will used to determine whether trees from north- and south-facing slopes have the same growth rates.

From earlier cores taken at Shoshone Mountain in the Nevada Test Site, there was no discernible difference in growth rates between north- and south-facing slopes, a result that is counter intuitive because overall growth, expressed as plant cover, is much greater on north-facing slopes owing to larger portions of incident precipitation cycled through plants rather than evaporation. This result with further confirmation is important because it tells us that the vegetation cover on north- and south-facing slopes is distributed so as to optimize itself to the available water source. Growth rates then become constrained by competition because water is limited by neighboring trees whose density is selected for during the gradual process that achieved a mature stand. This conceptualization, if sustained by this present work, may help apportion realistic parameters for water uptake on north- versus south-facing slopes for Yucca Mountain under glacial conditions.

Cheatgrass (*Bromus tectorum*) is an aggressive introduced Eurasian grass species that has invaded many locations in Nevada. Evidence exists that cheatgrass is replacing native shrubs and grasses over large areas of Nevada at the elevations that are appropriate as the present climate analogy for Yucca Mountain during a glacial cycle: between 6,500 and 8,000 feet. Another species of brome grass, foxtail chess (*Bromus rubens*), is currently dominating the annual vegetation and apparently replacing native shrub species on portions of Yucca Mountain. This species has been noted to largely be replaced by cheatgrass above about 5,000 feet and, thus, may not be of concern under cooler and wetter conditions.

Day 1 - June 27:

Lida Pass, at an elevation of 7,000 feet, is located on the route between Bishop, California, the start point of the trip and Phinney Canyon, a climate analog site located west of Beatty, Nevada. This location has the same parent material as Yucca Mountain, welded and non-welded silicic ash flow tuff, according to USGS, Stewart and Carlson, 1978, Geologic Map of Nevada. Cheatgrass was observed to dominate south-facing slopes on the north side of State Route 266 to the probable eventual exclusion of recruitment of the shrub species. These shrubs, rabbitbrush (*Chrysothamnus nausesosus*) and big sagebrush (*Artemisia tridentata*) were all mature and no young plants were found. In contrast to this cheatgrass dominance, a north facing terrace slope to the south of the road largely lacks cheatgrass cover except for a small area of cheatgrass cover.

The ecotone (boundary between dominant forms of vegetation) between the cheatgrass-dominated cover and the cheatgrass-absent vegetation on this terrace was studied. Soil pits were dug (1) in the cheatgrass cover on the north side of State Route 266, (2) within cheatgrass cover above the ecotone, (3) at the ecotone between cheatgrass/cheatgrass-absent vegetation, and (4) below the ecotone where cheatgrass was absent. Soil samples were collected and sent to Utah State University soil lab for analysis. These are the results:

(1) In cheatgrass-dominated vegetation north of State Route 266: slope ca. 7° to about 180° true. Vegetation is scattered rabbitbrush and sagebrush with lesser amounts of *Gutierriezia* (an aster family shrub), and *Grayia spinosa*.

Horizon	≥2mm	Sand	Silt	Clay	Texture
0-14 cm:	67.1	57	35	8	sandy loam
14-40 cm:	73.6	59	29	12	sandy loam

(2) North-facing slope of a terrace, within cheatgrass cover above ecotone (slope ca 25° facing to 330°).

Horizon	≥2mm	Sand	Silt	Clay	Texture
0-30 cm:	68.9	69	20	11	sandy loam
30-50 cm:	71.9	64	22	14	sandy loam

(3) North-facing slope of a terrace, at ecotone between cheatgrass/non-cheatgrass cover (slope ca 25° facing to 330°).

Horizon	≥2mm	Sand	Silt	Clay	Texture
0-30 cm:	60.0	69	22	9	sandy loam
30-60 cm:	75.5	67	19	14	sandy loam

(4) North-facing slope of a terrace, below ecotone and cheatgrass absent (slope ca 25° to 330°).

Horizon	≥2mm	Sand	Silt	Clay	Texture
0-7 cm:	68.9	69	21	10	sandy loam
7-44 cm:	59.2	69	20	11	sandy loam

Roots of the cheatgrass were found to 32 cm deep in the pits dug for (1), (2) and (3). The same perennial native species were found above and below the ecotone: single leaf pine, big sagebrush, green ephedra. Native herbaceous species were largely absent above the ecotone but existed below: *Caulanthus, Viguera, Penstemon,* and Indian ricegrass. No apparent differences existed between the perennial vegetation and soils above and below the ecotone. Thus, it is the process of replacement of native vegetation with cheatgrass is probably ongoing and will, in time, extend beyond the ecotone to encompass the entire site.

Phinney Canyon was reached during the evening and camp was made preparatory to performing field work the next day.

Day 2 - June 28:

The objective for visiting the analog sites was to obtain tree cores on paired north- and south-facing slopes in order to evaluate the growth rate of trees on these sites. The cover by trees and other vegetation was not to be measured in the field as this exercise was most easily accomplished using low-altitude high-resolution color-positive photographs taken specifically for this purpose. The first site visited was a peak south of Phinney Canyon in the Grapevine Mountains west of Beatty, Nevada named Wahguyhe Peak.

The Wahguye Peak has a ridgeline that produces broad slopes that are almost north- and south-facing. The elevation of this ridge is 8,400 feet (interpreted from the Wahguyhe Peak 7.5' quadrangle) and the rock type is listed as welded and non-welded silicic ash flow tuff on the Geologic Map of Nevada.

The paired sample site chosen is as follows:
GPS position: 36° 56.526' N by 117° 06.185' W on ridge between north- and south-facing sites.
The north-facing site had a 28° slope to 340° true at an elevation of 8,300 feet.

A soil pit was dug to 45 cm deep with soil found to be massive with rock fragments and fine sandy matrix. One sample was obtained, designated PC-SP-NF:

horizon	>2mm	sand	silt	clay	texture
0-45 cm	61.6	54	34	12	sandy loam

On this north-facing slope the vegetation was dominated (about 75%) by limber pine (*Pinus flexilis*), with 25% single leaf pine, and with all mature trees between 12 and 18 feet tall. Other species included *Leptodactylon pungens*, currant *(Ribes inerme)*, big sagebrush and unknown species of the following: rabbitbrush, lupine and *Senecio*.

Cores were obtained from the east side (parallel to the contour) of seven trees with species designated by abbreviations PIFL or PIMO. Diameter at breast height is abbreviated "dbh". Breast height was taken to be four feet above the base of the tree.

designation	species	dbh (cm)
SP-NF1	PIFL	22
SP-NF2	PIFL	27
SP-NF3	PIMO	40
SP-NF4	PIMO	46
SP-NF5	PIMO	26
SP-NF6	PIMO	24
SP-NF7	PIFL	28
SP-NF8	PIMO	34
SP-NF9	PIMO	22
SP-NF10	PIMO	28

A sample location was chosen on the south-facing slope facing 165° at an angle of 24°. The vegetation Is dominated by rubber rabbitbrush, single-leaf pine, currant, and big sagebrush. One soil pit was dug to 35 cm deep through the same type of soil as on the north slope yielding a sandy loam texture.

horizon	>2mm	sand	silt	clay	texture
0-35 cm	60.4	74	18	8	sandy loam

Cores were obtained from the east side of seven trees (parallel to the contour). All specimens were from single leaf pine. Mature trees were generally less than 15 feet tall with pyramidal shape and multiple trunks. In contrast, on the north-facing slope this species tended to be flat topped.

designation	dbh (cm)
SP-SF1	28
SP-SF2	25
SP-SF3	31
SP-SF4	34
SP-SF5	43
SP-SF6	35
SP-SF7	26

The approximately 3 miles and 2,000 of Wagugyhe Peak was then descended and preparation was made to collect tree cores and data at another site, Coyote Peak which is located about 5 miles north of Phinney Canyon. The ridge of this peak, at 8,500 feet (interpreted from the 7.5' Grapevine Peak quadrangle) and a GPS position of 38° 59.825'N and 117° 08.023'W was ascended in the afternoon. A site was selected on the north-facing slope that had an angle of 25° facing to 330° true. A soil pit was dug to 37 cm yielding the following:

horizon	>2mm	sand	silt	clay	texture
0-12 cm	35.4	40	45	15	loam
12-37	80.3	53	31	16	sandy loam

The vegetation on the north slope was single leaf pine but with mountain mahogany also present. Cores were obtained from the east side of seven single leaf pine (parallel to the contour).

designation	dbh (cm)
NP-NF1	40
NP-NF2	26
NP-NF3	38
NP-NF4	22
NP-NF5	37
NP-NF6	23
NP-NF7	27

The south-facing slope was faced to 167° true at an angle of 25° and vegetated with *Guterrezia*, big sagebrush, green ephedra and dominated by single leaf pine. A soil pit was dug to 35 cm and a large pine root was located at 18 cm deep. In all four soil pits of the Phinney Canyon study sites, roots of pines were numerous. In the soil pits from both north- and south-facing slopes the upper horizon represents colluvial drift of finer soil possible frost heaved from the rocky matrix. These two pits yielded relatively fine soil textures that possibly indicate strong in situ weathering or, possibly, parent material that has greater weathering potential.

horizon	>2mm	sand	silt	clay	texture
0-12 cm	47.6	48	45	7	loam
12-35 cm	72.3	30	52	18	silt loam

Cores were obtained from the east sides of seven single leaf pines parallel to the contour:

designation	dbh (cm)	
NP-SF1	26	(forked, largest fork cored)
NP-SF2	33	
NP-SF3	26	
NP-SF4	33	
NP-SF5	34	
NP-SF6	21	
NP-SF7	23	

The 3,000 feet and 6-mile descent back to the car were hiked and camp was made for the night. Observations made earlier in the day were confirmed on the hike out: the elevation of Phinney Canyon represents a transition point between foxtail chess and cheatgrass, with cheatgrass existing in relatively pure stands above but potentially mixed below. At Yucca Mountain, foxtail chess is dominant.

Day 3 - June 29:

The vehicle was packed and the road was driven through Tonopah, Nevada en route to the Quinn Canyon Range in central Nevada. Extensive stands of cheatgrass were observed east of Tonopah at elevations between 6,000 and 7,000 feet. A site was visited near Saulsbury Summit, Nevada

(GPS position 38° 06.832' N, 115° 54.250' W) where cheatgrass has apparently been established for several years and where the native shrub species are being replaced by this annual grass.

Like the Lida Pass terrace site observed on June 27, locations where cheatgrass is invading near Tonopah have definite ecotones between vegetation where cheatgrass dominates and where it is absent. As an example, viewed from a distance of 10 miles, the purple-brown of the cheatgrass-dominated vegetation in Stone Cabin Valley resembled burns from wildfire in extent and contrast to the surrounding green vegetation. In other locations in adjacent valleys observed from the air, some patches of cheatgrass are apparently just becoming established (less than 0.5 square mile in extent) while, in other valleys, virtually the entire valley floor has become cheatgrass dominated. This pattern of cheatgrass invasion underscores the potential for eventual replacement of the present shrub steppe vegetation with an annual grass cover. The mechanisms for this phenomenon and the potential impact on regional hydrology are discussed in a separate report to CNWRA by this author.

We reached the Quinn Canyon during the afternoon and selected a site for sampling. This site is just SW of the turnoff to Garden Valley from the main road, which is marked "Cherry" on the Wadsworth Ranch 7.5' quadrangle though no cherry trees were visible (GPS position 38° 06.838' N, 115° 34.935' W). The actual site is located at 6,400 feet elevation (interpreted from the quadrangle) and the slope is 18° facing to 180° true and the parent material, like that in the region of Phinney Canyon is welded and non-welded silicic ash-flow tuff (according to the Map of Nevada). The soil pit, dug on the south-facing slope yielded the following very fine textured soils, which, as at Coyote Peak in the Grapevine Mountains, is unclear whether increased weathering or parent material is causal:

horizon	>2mm	sand	silt	clay	texture
0-13 cm	37.5	52	26	22	sandy clay loam
13-35 cm	35.2	49	22	29	sandy clay loam

The tree cover on both north and south-facing slopes is about 50% each of single leaf pine and *Juniperus osteosperma* with an understory of big sagebrush, green ephedra and *Yucca baccata*. Porcupine scars were visible on the single leaf pine of both north- and south-facing slopes.

A soil pit was dug to 22 cm through the stony ground of the north facing slope (third try: others failed due to rocks) with deeper than 22 cm being decomposed tuffaceous rock. The soil, again, was quite fine textured when compared to the uniform sandy loams of Yucca Mountain.

horizon	>2mm	sand	silt	clay	texture
0-12 cm	35.8	50	26	24	sandy clay loam
12-22 cm	40.7	49	21	31	sandy clay loam

Cores were obtained from seven trees each on the north- and south-facing slopes, all cored from the east side parallel to the contour.

South-facing designation	dbh (cm)	North-facing designation	dbh (cm)
QK1-SF1	24	QK1-NF1	25, 21, 12 (forked, largest cored)
QK1-SF2	19	QK1-NF2	25
QK1-SF3	23	QK1-NF3	19, 15, 22, 15 (forked, cored 19 cm branch)
QK1-SF4	16	QK1-NF4	20, 14 (forked, largest cored)
QK1-SF5	24	QK1-NF5	20,15 (forked, largest cored)
QK1-SF6	26	QK1-NF6	25, 25 (forked, largest cored)
QK1-SF7	20	QK1-NF7	28, 18 (forked, largest cored)

Camp was made for the night along the little Cherry Creek which, at that time of year, was moderately infested with no see-ums (*Simulium* sp.) that provided the evening's entertainment.

Day 4 - June 30:

A site was selected on the north- and south-facing sides of Little Cherry Creek Canyon at GPS position 38° 19.148' N, 115° 38.451' W and at 6,900 feet elevation (interpreted on Nyala 7.5' quadrangle). The south facing slope was dominated by single leaf pine with big sagebrush, currant, and green ephedra. This slope was lobate in form between 170° and 190° true with a slope of 28°. A soil pit dug on the south-facing slope yielded:

horizon	≥2mm	sand	silt	clay	texture
0-9 cm	51.7	45	39	16	loam
9-35 cm	52.1	35	35	30	clay loam

On the north-facing slope, the vegetation was also dominated with single leaf pine with an understory of snowberry (*Symphoricarpos oreophilus*), sagebrush and a thick sod of bluegrass (*Poa* sp.) which covered about 40% of the ground area. A soil pit was excavated through a thick matrix of pine roots (typical for all soil pits from the Quinn Canyon Range) yielding:

horizon	≥2mm	sand	silt	clay	texture
0-10 cm	32.5	39	38	23	loam
10-35 cm	67.3	39	35	26	loam

Cores were obtained from seven each single leaf pines on the north- and south-facing slopes, all taken from the east parallel to the slope contour.

South-facing designation	dbh (cm)	North-facing designation	dbh (cm)
QK2-SF1	29	QK2-NF1	19
QK2-SF2	21	QK2-NF2	10, 14*, 28, 16
QK2-SF3	28	QK2-NF3	20
QK2-SF4	20	QK2-NF4	22 (multiple limbs from a fork are given
QK2-SF5	23	QK2-NF5	23 with '*' designating the limb cored)
QK2-SF6	26 28*, 14, 10	QK2-NF6	25*, 11
QK2-SF7	26	QK2-NF7	26

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10-Aug-98

David Groeneveld
Resource Management
P.O. Box 3296
Telluride, CO 81435

☆ = Bromus 1.dat

Soil samples received 13 July 1998

USU #	Ident.	>2mm ---%---	Sand ---%---	Silt ---%---	Clay ---%---	Texture
5740	QK1 NF 0-12cm	35.8	50	26	24	Sandy Clay Loam
5741	QK NF 12-22 cm	40.7	49	21	31	Sandy Clay Loam
5742	QK2 NF 0-10 cm	32.5	39	38	23	Loam
5743	QK2 NF10-35cm	67.3	39	35	26	Loam
5744	QK1 SF 0-13 cm	37.5	52	26	22	Sandy Clay Loam
5745	QK1 SF13-35cm	35.2	49	22	29	Sandy Clay Loam
5746	QK2 SF 0-9 cm	51.7	45	39	16	Loam
5747	QK2 SF 9-35cm	52.1	35	35	30	Clay Loam
BELOW ECOTONE						
5748	LP Terrace 0-7 CM	68.9	69	21	10	Sandy Loam
5749	LP Terrace7-44 CM	59.2	69	20	11	Sandy Loam
5750	LP Terrace 0-30 cm	68.9	69	20	11	Sandy Loam
5751	LP Terrace 30-50	71.9	64	22	14	Sandy Loam
5752	GM NP SF 0-12cm	47.6	48	45	7	Loam
5753	GM NP 12-35 cm	72.3	30	52	18	Silt Loam
5754	Ecotone LP Terrace 0-30 cm	60.0	69	22	9	Sandy Loam
5755	Ecotone LP Terrace32-40cm	75.5	67	19	14	Sandy Loam
5756	PC SP SF 0-35cm	60.4	74	18	8	Sandy Loam
5757	PC SP 0-45 cm	61.6	54	34	12	Sandy Loam
5758	GM NP NF 0-12cm	35.4	40	45	15	Loam
5759	GM NP NF12-37cm	80.3	53	31	16	Sandy Loam
5760	LIDA Pass 0-14	67.1	57	35	8	Sandy Loam
5761	LIDA Pass14-40 cm	73.6	59	29	12	Sandy Loam

analog.dat 12.8 (497)

If you have any questions, please contact the lab

Tree rings YM2.wpd

Table ___. Growth rates of trees growing in the Grapevine Mountains. Two species were collected, *P. monophylla* (PIMO) and *P. flexilis* (PIFL). Samples from the flanks of Wahguyhe Peak were designated PC-SP. Samples collected on the flanks of Coyote peak, also at 8,400 feet were designated GM-NP. Plant cover, slope angle and bearing, and elevation were interpreted from air photos and topographic maps.

Sample	Species	DBH (at 4 feet)	100yr (mm)	200yr (mm)	Total years and length (mm)	Average Growth Rate (mm)
PC - SP: Stand GV-1-1-NF2: Slope 30.2°, Bearing 327°, Elevation 8,400', Cover = 52.2%						
NF1	PIFL	22 cm	33.30	60.33	271y - 89.92	(0.332)
NF2	PIFL	27 cm	31.12	80.12	302y - 109.14	(0.361)
NF3	PIMO	40 cm	49.070	104.67	249y - 134.31	[0.539]
NF4	PIMO	46 cm	34.290	75.89	329y - 139.42	[0.424] mean = 0.844
NF5	PIMO	26 cm	99.00	---	110y - 123.49	1.123 s.d.= 0.302
NF6	PIMO	24 cm	54.53	99.52	212y - 105.79	[0.499] n = 4
NF8	PIMO	34 cm	93.09	---	120y - 121.69	1.104 (samples in
NF9	PIMO	22 cm	89.13	---	124y - 120.04	0.968 parentheses
NF10	PIMO	28 cm	---	---	90y - 93.35	1.037 not included)
PC - SP: Stand GV-1-1-SF2; Slope 31.4°, Bearing 159°; Elevation 8,320', Cover = 58.8%						
SF1	PIMO	38 cm	91.69	---	100y - 91.69	0.917
SF2	PIMO	25 cm	---	---	80y - 81.92	1.024
SF3	PIMO	31 cm	---	---	80y - 125.52	1.569
SF4	PIMO	34 cm	62.23	---	135y - 111.86	0.829 mean = 1.107
SF5	PIMO	43 cm	117.50	---	100y - 117.50	1.175 s.d. = 0.259
SF6	PIMO	35 cm	---	---	70y - 90.88	1.298 n = 7
SF7	PIMO	26 cm	86.23	---	120y - 112.42	0.937
GM - NP: Stand GV-1-2-NF1; Slope 29.9°, Bearing 331°, Elevation 8,320', Cover = 63.5%						
NF1	PIMO	40 cm	42.44	86.51	250y - 118.57	
NF2	PIMO	26 cm	22.91	55.22	317y - 130.61	
NF3	PIMO	38 cm	41.55	86.08	290y - 133.83	
NF4	PIMO	22 cm	19.73	46.74	244y - 82.42	mean = 0.486
NF5	PIMO	37 cm	65.51	---	180y - 117.60	s.d. = 0.101
NF6	PIMO	23 cm	26.26	96.77	220y - 112.78	n = 7
NF7	PIMO	27 cm	49.33	109.22	210y - 115.21	
GM - NP: Stand GV-1-2-SF2; Slope 26.4°, Bearing 172°, Elevation 8,400', Cover = 59.2%						
SF1	PIMO	26 cm	73.66	---	190y - 137.59	
SF2	PIMO	33 cm	60.88	119.89	230y - 141.43	
SF3	PIMO	26 cm	37.87	81.03	250y - 106.43	
SF4	PIMO	33 cm	43.18	104.49	250y - 144.37	mean = 0.582
SF5	PIMO	34 cm	70.15	---	180y - 130.94	s.d. = 0.120
SF6	PIMO	21 cm	43.46	112.40	202y - 114.25	n = 7
SF7	PIMO	23 cm	44.58	---	150y - 66.04	

July 1, 1998 and July 2, 1998

Air photographs were obtained over the Grapevine Mountains during the first day and over the Quinn Canyon Range on the second day. These photographs were obtained over sites chosen for the following properties:

(1) Welded tuff as exists on Yucca Mountain.
(2) Heavy and even vegetation cover that was not obviously influenced by runon from the slope above.
(3) paired north- and south-facing slopes (within about 30° of true, as are slopes at Yucca Mountain) and at about the same slope (mostly between 20 and 30°).
(4) lack of outcropping within the patches evaluated.

The photos were used as the base for measurement of vegetation cover at locations identified on topographic maps. The interest for this data stemmed from the desire to produce a vegetation model that could predict plant cover at any given aspect, slope and elevation. The results from these analyses combined with the results from analyses of the products from the air photo mission of September 15, 1999 were used by S. Stothoff to successfully model plant cover using incident solar radiation, that changes due to slope and aspect, and precipitation, that changes due to elevation. The physical data necessary for these analyses were interpreted from the topo maps: slope, aspect and elevation. Vegetation cover was measured by counting the number of contacts by points in a grid of 255 points.

Although extensive work was performed on sites in the Quinn Canyon Range, this site was dropped from the analysis when it was determined that the vegetation cover there is much higher than in the Grapevine Mountains–probably as a result of greater monsoonal flow which the Grapevine Mountains and nearby Yucca Mountain lack.

Pages 68-71 : A memorandum of April 2, 1999 explaining the method.

Pages 72-78 : Copies of topographic maps with flightlines and interpolated physical data for points evaluated for tree/shrub cover. Photographic prints and negatives are maintained in "Hydro-Biological Archives under Climate Analog Sites (1)". Individual plots evaluated are indicated on the photographic prints.

Pages 79-85 : Copies of analysis results.
Pages 86-89 : Testing of results and analyses discarding Quinn Canyon Range.

[by FAX, 4 pages]

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April 2, 1999

----------------**MEMORANDUM**--------------

TO: Stuart Stothoff, Randy Fedors
From : David Groeneveld

RE: Input on Vegetation Cover For Climate Change at Yucca Mountain

As an advanced look at the results from my analyses, I've attached three graphs that show elevational relationships for vegetation cover on north and south-facing slopes. For Yucca Mountain, we have a general understanding about how the vegetation is distributed on north- and south-facing slopes. The analysis that I have completed now gives us the curves to anticipate potential vegetation cover on Yucca Mountain under climate change to cooler and wetter conditions. I still need to double check some of the air photo-interpretation and underlying assumptions so the attached will allow you to provide me with your comments prior to my final assessment..

The method I use to assemble this data occurred in the following steps:

(1) obtain a geologic map of Nevada and determine mountain ranges with the same general lithology as Yucca Mountain: welded and non-welded silicic ash-flow tuff.

(2) observe candidate areas from the air to locate and observe ridges that were steep, composed of the right lithology and covered with regularly spaced plant canopies. (This operation was accomplished during other flights, mainly for transportation to-from work in California.) Three locations were chosen for this effort: Yucca Mountain, Quinn Canyon Range and Grapevine Mountains.

(3) All three locations were visited on the ground and plant samples were collected on north- and south-facing slopes--cores from single-leaf pines and stems sections from shrubs. (These specimens have been mounted and polished but have not yet been analyzed).

(4) Soil samples were collected and analyzed for texture on all sites where tree cores were collected.

(5) Air photos were taken over fifteen separate flightlines that crossed north- to south-facing ridges . Thirty five locations, each, on north- and south-facing slopes, were selected on the air photos that showed regular-spaced relatively continuous canopy cover. Canopy cover was evaluated using a stereo binocular microscope and a grid field with 255 points in five transects (percent cover = canopy-grid point intersection /255 * 100).

(6) Each of the 70 sites was located on a topographic map and the elevation, slope, and aspect were determined, measured or calculated.

As a summary of these analyses, you will find attached two graphs that show the results displayed for south- and north-facing slopes. On each graph, two lines are presented: one which is fitted from all of the data represents an average, and the second, drawn from the highest values obtained represents the "peak cover possible". I believe the average cover line to be the relationship we want but I need to think, communicate and double check.

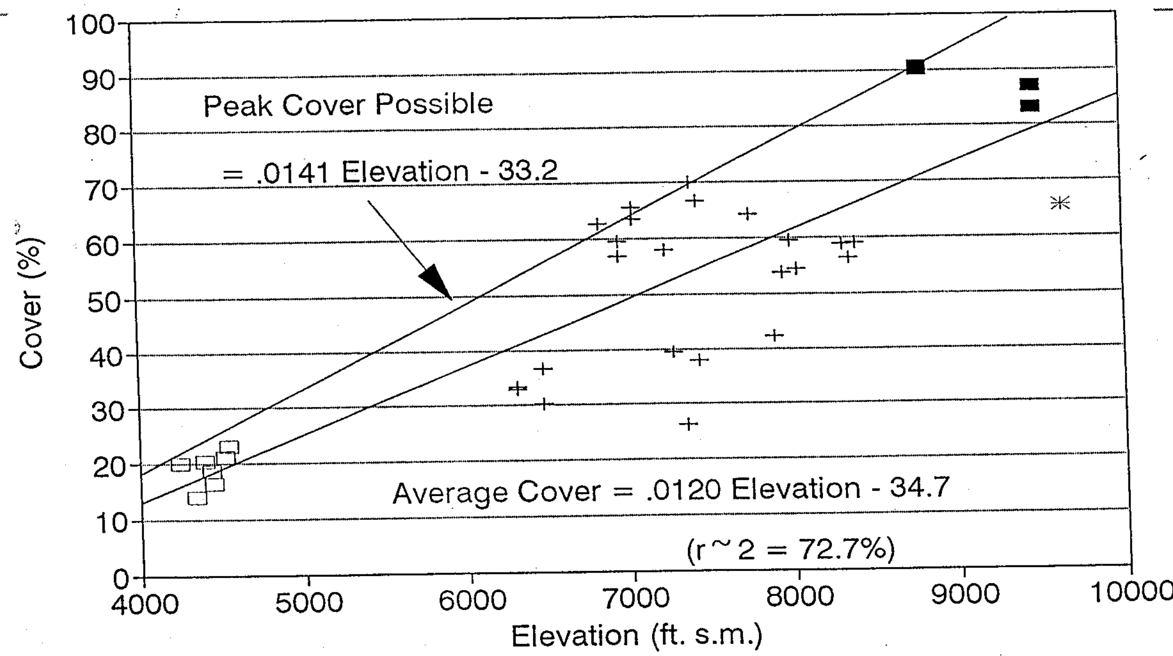
There are two areas in which I will concentrate when I re-evaluate these data: (i) the data obtained contains error induced by shadow and I need to check outliers under mirror stereoscope to ensure that this error is not severe nor skewing the results in any one direction; and (ii) I need to cross check the data to ensure that the location of the site, e.g., Quinn Canyon Range vs. Grapevine Mountains has not greatly influenced the results (it appears to me that the Grapevine region has a fairly profound rain shadow effect). I will try to get these analyses completed in the next several weeks.

I have data from the USGS that was sent to me by a colleague at the Las Vegas Valley Water District that I need to download and analyze to determine the expected increase in precipitation with elevation. The USGS study is a cooperative program with LVVWD and the State of Nevada intended to determine this relationship for the region north of Las Vegas. If you have a climatologist on staff at CNWRA, perhaps this person should do the analysis, otherwise, I'll make the effort myself.

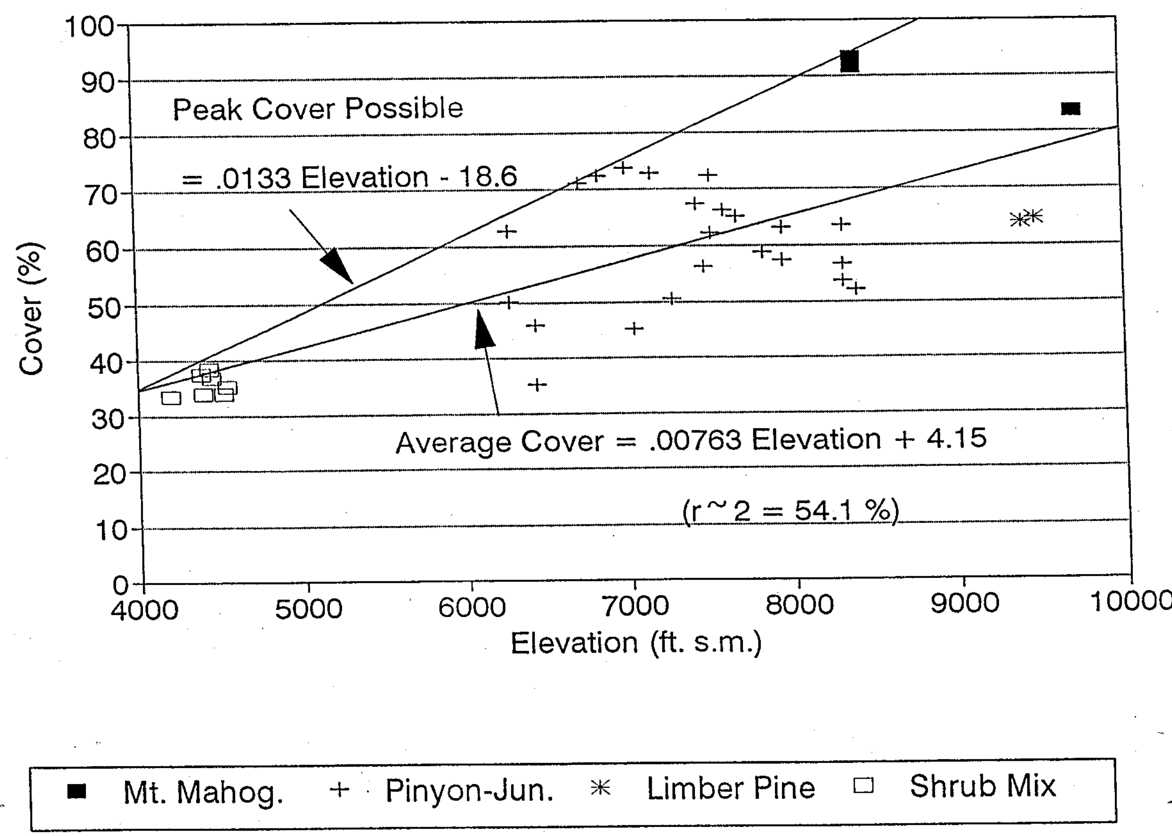
Based on your feedback, I'll produce a report that will address these results as well as the growth ring and soil data. I expect that these data will assist us to place reasonable constraints on vegetation cover and its relationship to soil formation under climatic change..

I look forward to discussion of these data during our meeting on April 8.

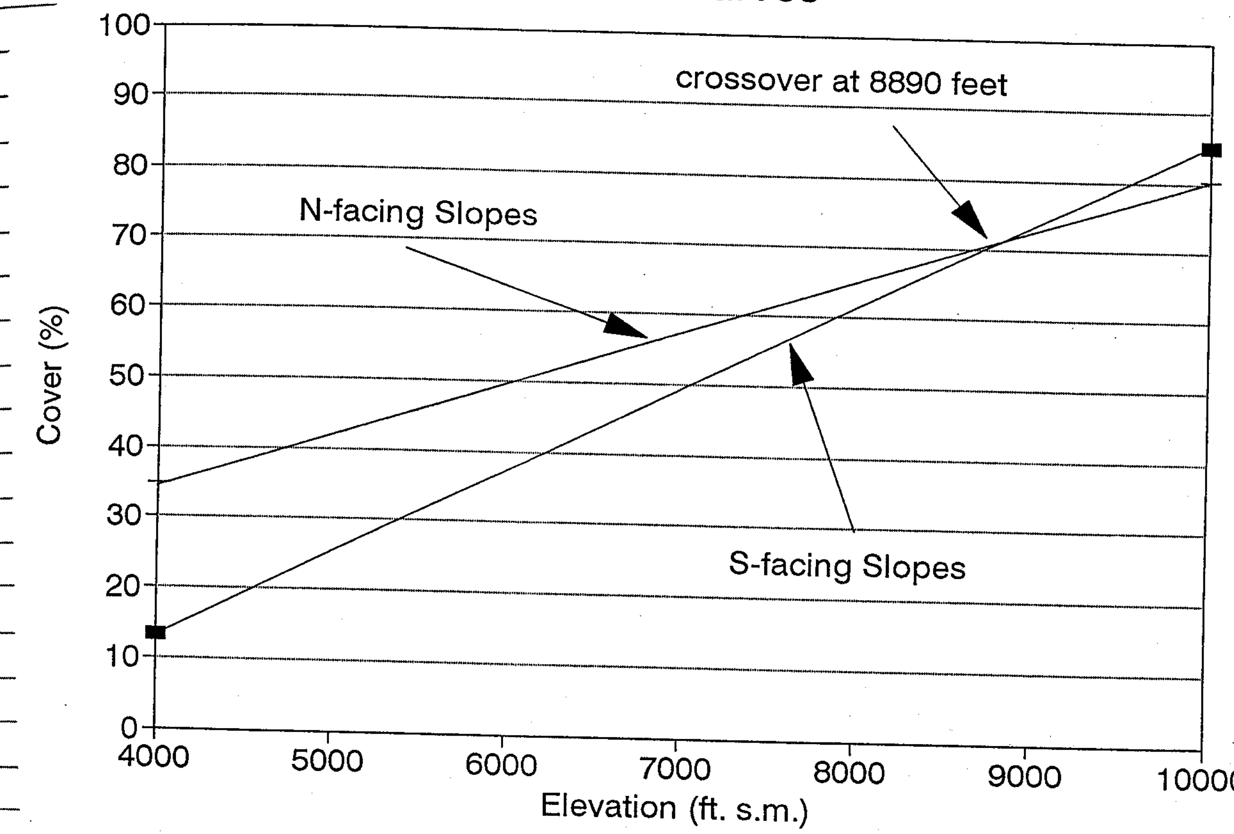
South-Facing Slope

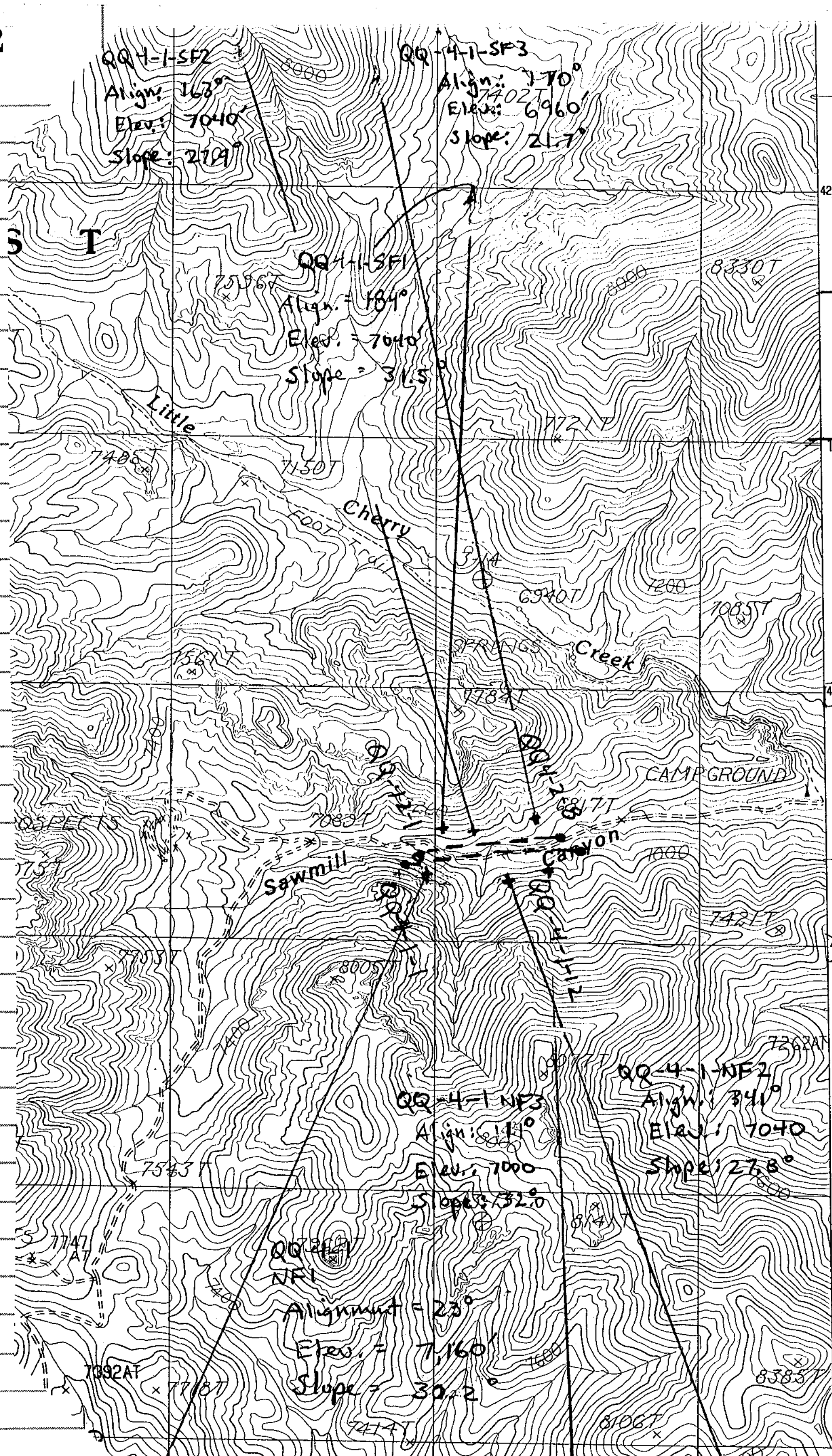


North-Facing Slopes

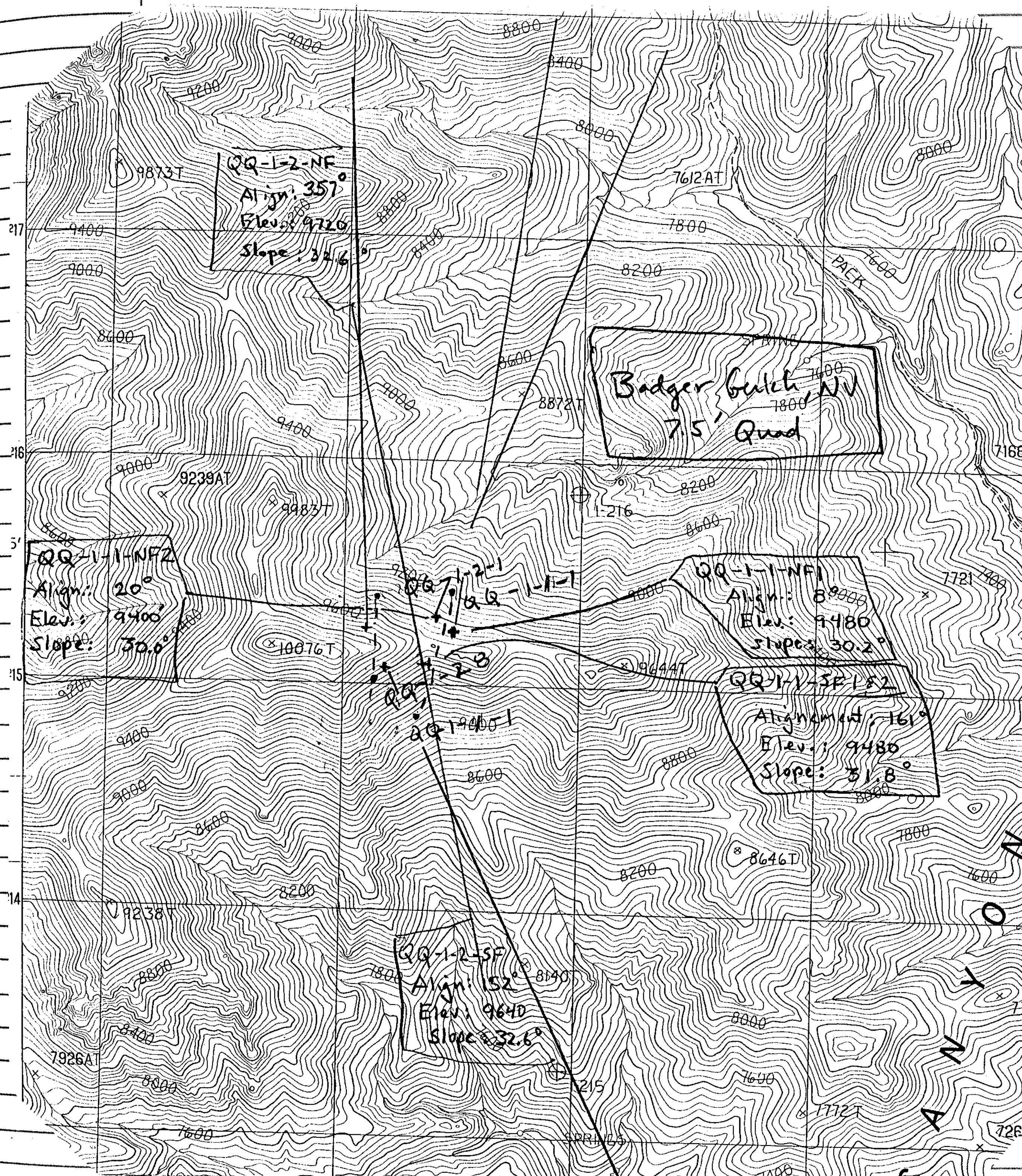


Theoretic Curves





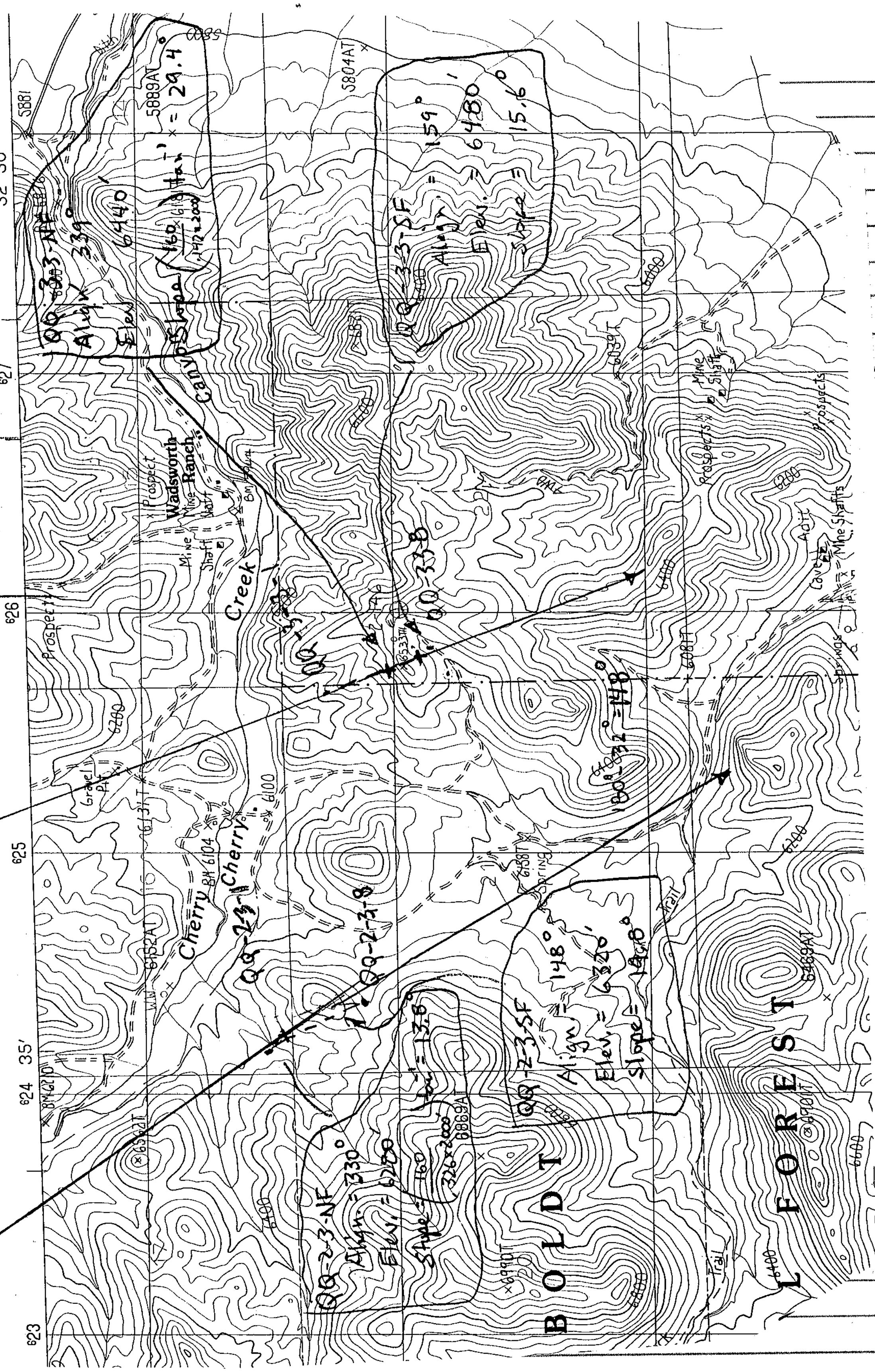
Nyala, NV
7.5' Quad

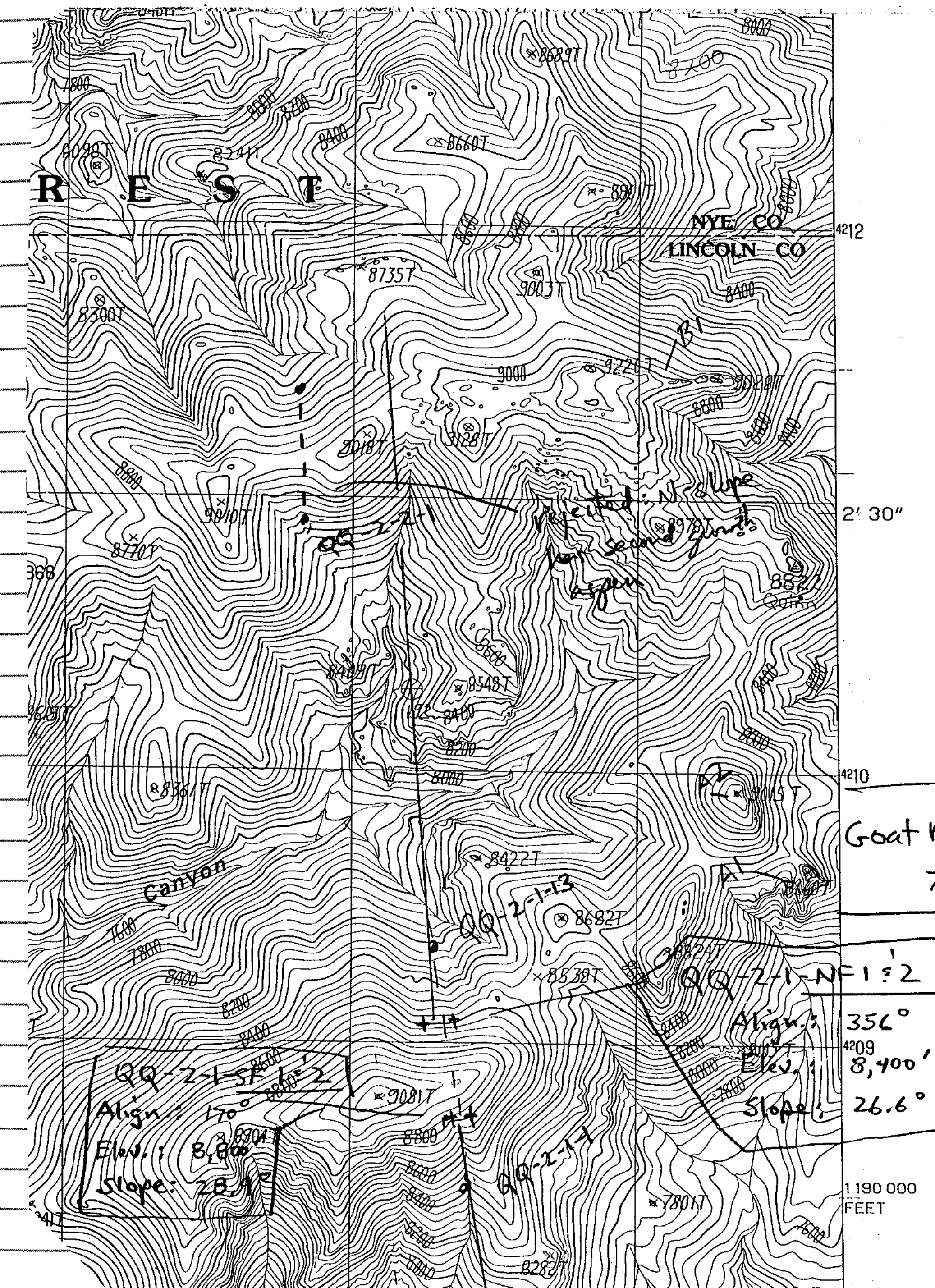


Wadsworth Springs, NV 7.5' Quad

21° elevation

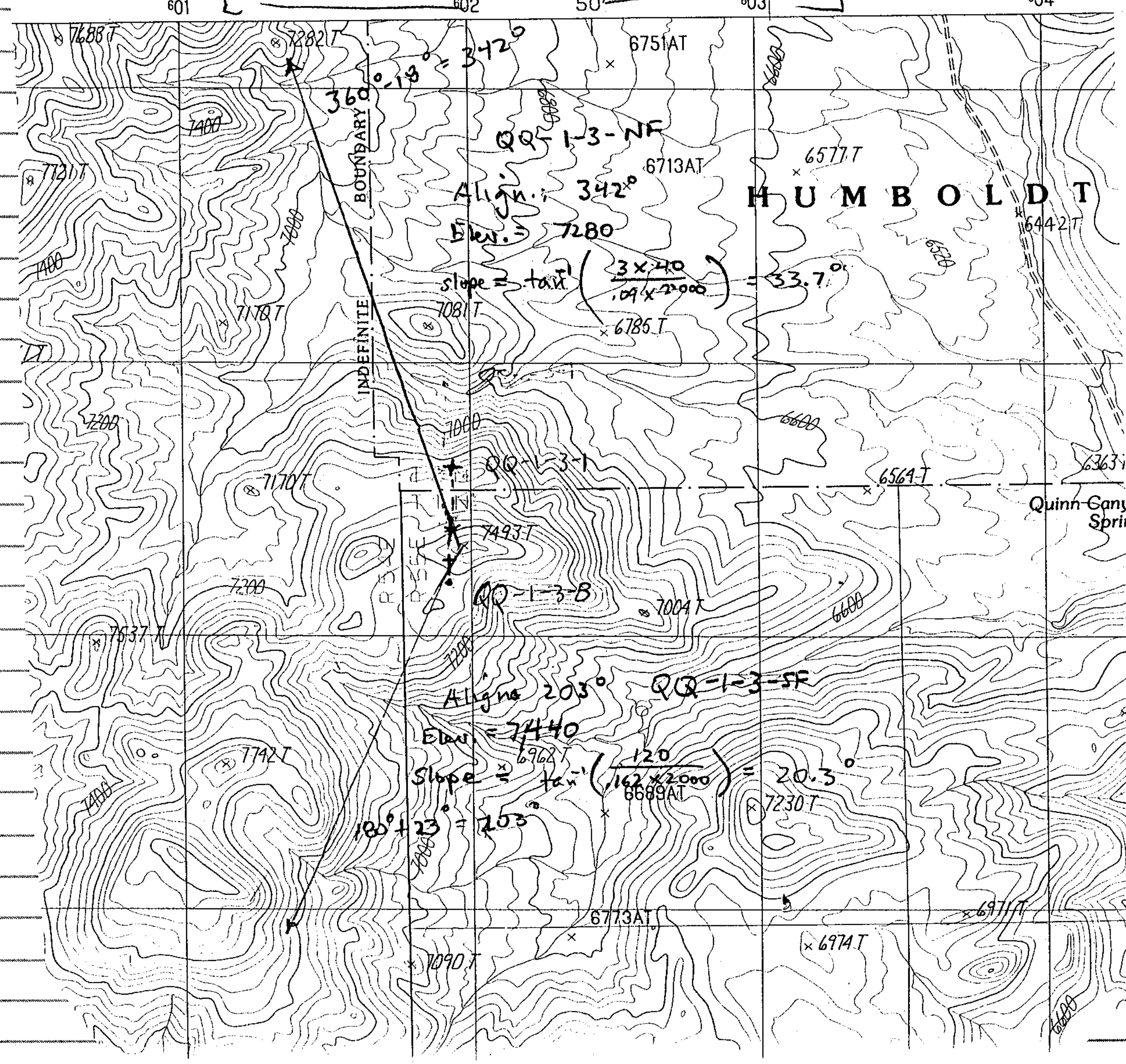
360°-30°
330°



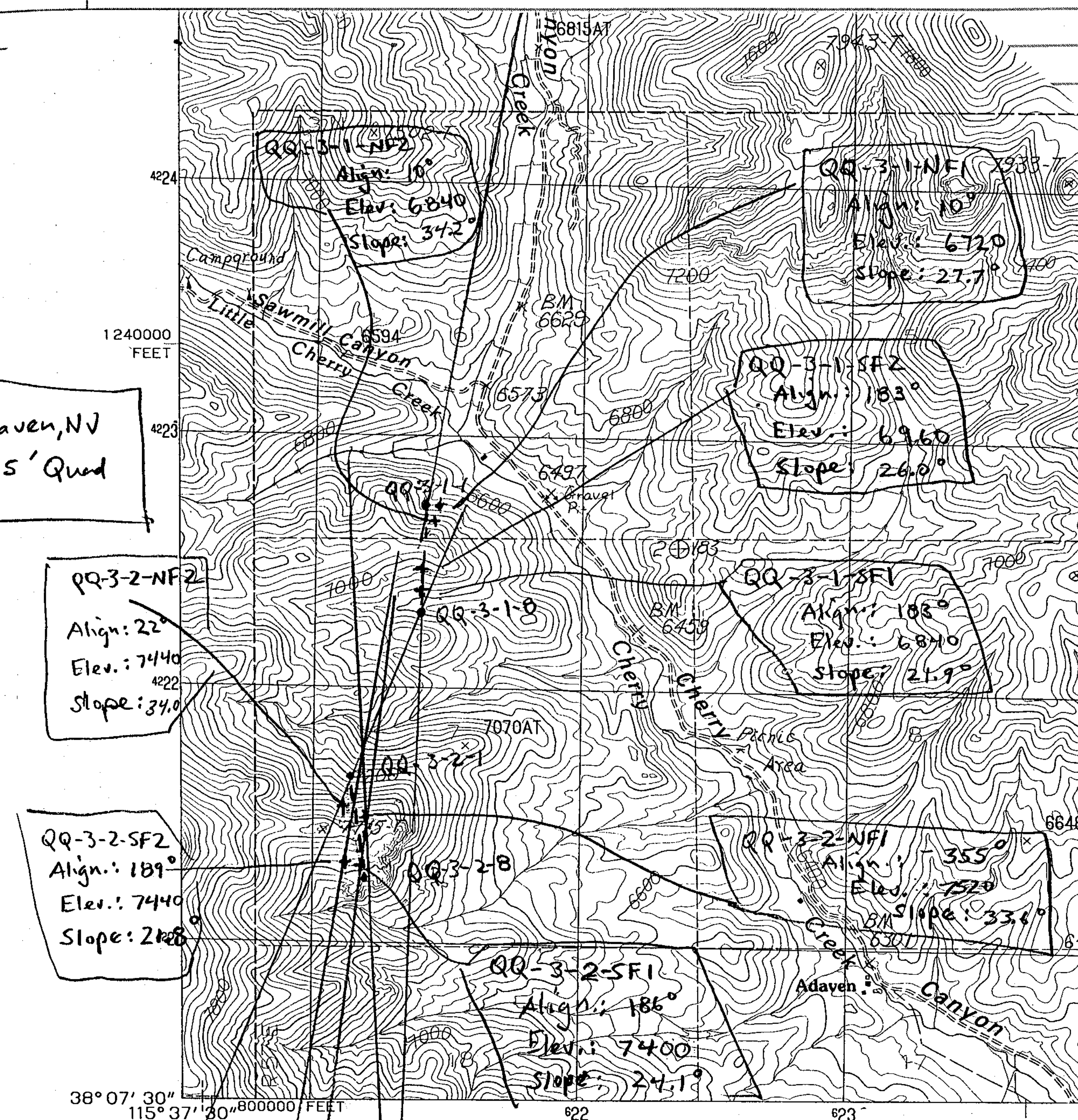


Goat Ranch Spgs, NV 7.5' Quad

Quinn Canyon Springs, NV 7.5' Quad

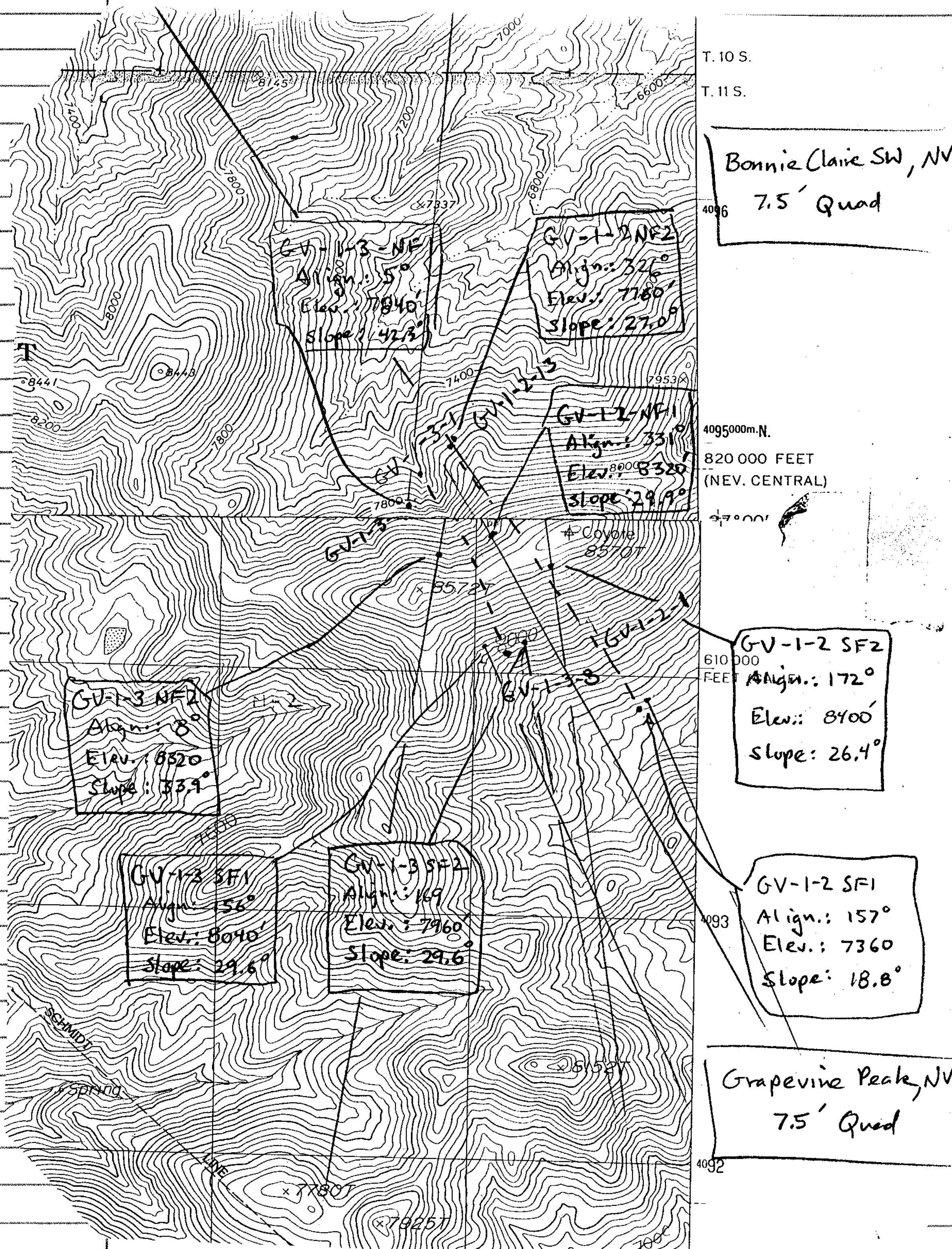


Adaven, NV 7.5' Quad



PRODUCED BY THE UNITED STATES GEOLOGICAL SURVEY
CONTROL BY .... USGS, NOS/NOAA
COMPILED FROM AERIAL PHOTOGRAPHS TAKEN 1980
FIELD CHECKED .... 1981 MAP EDITED 1985
PROJECTION .... TRANSVERSE MERCATOR
GRID: 1000-METER UNIVERSAL TRANSVERSE MERCATOR .... ZONE 11
10,000-FOOT STATE GRID TICKS .... NEVADA, CENTRAL ZONE
UTM GRID DECLINATION .... 0°53' EAST
1985 MAGNETIC NORTH DECLINATION .... 14°30' EAST
VERTICAL DATUM .... NATIONAL GEODETIC VERTICAL DATUM OF 1929

NORTH



South Facing

Contained in File "S-facing"

#	Site Designator	Elev.	Aspect	Slope	Cover %	Species Tree	Species Shrub
1	QQ-1-1-SF2	9480	161°	31.8°	87.1	3	0
2	QQ-1-1-SF1	9480	161°	31.8°	83.1	3	0
3	QQ-1-2-SF	9640	152°	32.6°	65.5	4	0
4	QQ-4-1-SF1	7040	184°	31.5°	63.5	1	0
5	QQ-4-1-SF2	7040	163°	27.9	65.5	1	0
6	QQ-4-1-SF3	6960	170°	21.7	59.6	1	0
7	QQ-3-1-SF1	6840	183°	21.9°	62.7	1	0
8	QQ-3-1-SF2	6960	183°	26.0°	56.9	1	0
9	QQ-3-2-SF1	7400	186°	24.1°	70.0	1	0
10	QQ-3-2-SF2	7440´	189°	21.8°	66.7	1	0
11	QQ-2-3-SF1	6320	148°	19.8°	33.3	1	0
12	QQ-2-3-SF2	6320	148°	19.8°	32.9	1	0
13	QQ-3-3-SF1	6480	159°	15.6°	36.8	2	1
14	QQ-3-3-SF2	6480	159°	15.6°	30.2	2	1
15	QQ-1-3-SF	7440	203°	20.3°	38.0	2	1
16	QQ-2-1-SF1	8,800	170°	28.9°	90.6	3	0
17	QQ-2-1-SF2	8,800	170°	28.9°	90.2	3	0
18	GV-1-3-SF1	8040´	156°	29.6°	54.4	1	0
19	GV-1-3-SF2	7960´	169	29.6°	53.7	1	0
20	GV-1-2-SF1	7360´	157	18.8°	26.3	1	0
21	GV-1-2-SF2	8400´	172°	26.4°	59.2	1	0
22	GV-1-1-SF1	7600´	156°	25.5°	42.4	1	0
23	GV-1-1-SF2	8320´	159°	31.4°	58.8	1	0
24	GV-2-4-SF	7280´	179°	37.8°	39.6	1	0
25	GV-2-1-SF1	8000´	142°	40°	59.6	1	0
26	GV-2-1-SF2	8360´	141°	23.4°	56.5	1	0
27	GV-2-3-SF1	7240´	179°	25.4°	58.0	1	0
28	GV-2-3-SF2	7760´	175°	27.0°	64.3	1	0

new

Shrub = 1
PJ = 2
CELE = 3
PIFL = 4

old

Key to veg:

Tree		Shrub
1	PIMO	0 - none
2	PIMO/JUOC	1 - ARTR/CHNA
3	CELE	
4	PIFL	

North Facing

Contained in Files "N-facing"

#	Site Designator	Elev.	Aspect	Slope	Cover %	Species Code Tree	Species Code Shrub
1	QQ-2-1-NF1	8,400′	356°	26.6°	91.4	3	0
2	QQ-2-1-NF2	8,400′	356°	26.6°	93.3	3	0
3	QQ-1-1-NF1	9480′	8°	30.2°	64.7	4	0
4	QQ-1-1-NF2	9400′	20°	30.0°	63.9	4	0
5	QQ-1-2-NF	9720	326°	32.6°	83.5	3	0
6	QQ-4-1-NF1	7160	23°	30.2°	72.9	1	0
7	QQ-4-1-NF2	7040	341°	27.8°	75.3	1	0
8	QQ-4-1-NF3	7000	1°	32.0°	73.7	1	0
9	QQ-3-1-NF1	6720	10°	27.7°	71.0	1	0
10	QQ-3-1-NF2	6840	10°	34.2°	72.5	1	0
11	QQ-3-2-NF2	7440	22°	34.0	67.4	1	0
12	QQ-3-2-NF1	7520	355°	33.6°	72.5	1	0
13	QQ-2-3-NF2	6280′	330°	13.8°	50.2	1	0
14	QQ-2-3-NF1	6280′	330°	13.8°	62.7	1	1
15	QQ-3-3-NF1	6440′	339°	29.4°	35.3	1	1
16	QQ-3-3-NF2	6440′	339°	29.4°	45.9	2	1
17	QQ-1-3-NF	7280′	342°	33.7°	50.6	2	1
18	GV-1-3-NF1	7840′	5°	42.3°	58.8	2	1
19	GV-1-3-NF2	8320′	8°	33.9°	56.9	1	0
20	GV-1-2-NF1	8320′	331°	29.9°	63.5	1	0
21	GV-1-2-NF2	8320′	331°	29.9°	53.7	1	0
22	GV-1-1-NF1	7600	342°	27.4°	66.2	1	0
23	GV-1-1-NF2	8400	327°	30.2	52.2	1	0
24	GV-2-4-NF	7520	328°	24.4°	62.3	1	0
25	GV-2-1-NF1	7960	316°	40.0°	57.6	1	1
26	GV-2-1-NF2	7960	316°	40.0°	63.1	1	0
27	GV-2-3-NF1	7480	357°	28.3°	56.5	1	0
28	GV-2-3-NF2	7680	354°	32.0°	65.4	1	1

Site	transect 1	2	3	4	5	Σ	Species	Cover
QQ-2-1-NF1 (poor focus)	47	45	48	46	47	233	CELE	91.4%
QQ-2-1-NF2 (poor focus)	47	47	48	49	47	238	CELE	93.3%
QQ-1-1-SF2 (poor focus)	46	41	47	45	43	222	CELE	87.1%
QQ-1-1-SF1 (poor focus)	39	41	44	43	45	212	CELE	83.1%
QQ-1-1-NF1	31	26	36	39	33	165	PIFL	64.7%
QQ-1-1-NF2	32	32	38	29	32	163	PIFL	63.9%
QQ-1-2-NF	38	45	45	40	45	213	CELE	83.5%
QQ-1-2-SF	37	32	39	37	22	167	PIFL	65.5%
QQ-4-1-SF1	37	32	31	30	32	162	PIMO	63.5%
QQ-4-1-NF1	32	42	38	37	37	186	PIMO	72.9%
QQ-4-1-SF2	32	30	37	35	33	167	PIMO	65.5%
QQ-4-1-NF2	40	32	37	42	41	192	PIMO	75.3%

Site	Transect 1	2	3	4	5	Σ	Species	Cover
QQ-4-1-SF3	29	29	23	33	38	152	PIMO	59.6 %
QQ-4-1-NF3	39	39	39	35	36	188	PIMO	73.7 %
QQ-3-1-SF1	31	30	36	32	31	160	PIMO	62.7 %
QQ-3-1-NF1	40	32	37	31	41	181	PIMO	71.0 %
QQ-3-1-SF-2	28	37	19	16	45	145	PIMO	56.9 %
QQ-3-1-NF2	38	37	42	32	36	185	PIMO	72.5 %
QQ-3-2-SF1	40	35	29	34	41	179	PIMO JUOC	70.0 %
QQ-3-2-SF2	31	33	39	32	35	170	PIMO JUOC	66.7 %
QQ-3-2-NF 2	50	34	36	15	37	172	PIMO	67.4 %
QQ-3-2-NF1	39	33	30	43	40	185	PIMO	72.5 %
QQ-2-3-SF1	25	21	15	10	14	85	PIMO	33.3 %
QQ-2-3-SF2	16 1	21 1	15 2	13	14 1	79 5	PIMO ARTR/CHNA	32.9 %

Site	Transect 1	2	3	4	5	Σ	Species	Cover
QQ-2-3-NF2	19 3	34	18 6	14	33 1	118 10	PIMO ARTR/CHNA	50.2 %
QQ-2-3-NF1	32 4	29 3	33 2	34	23	151 9	PIMO ARTR/CHNA	62.7 %
QQ-3-3-SF1	4 5	23 2	15 7	28 1	9	79 15	PIMO/JUOC ARTR/CHNA	36.8 %
QQ-3-3-SF2	9	23	19	12	9 5	72 5	PIMO/JUOC ARTR/CHNA	30.2 %
QQ-3-3-NF1	16	23 2	14 3	16 1	17	84 6	PIMO/JUOC ARTR/CHNA	35.3 %
QQ-3-3-NF2	14 3	23 2	24	23 4	22 2	106 11	PIMO/JUOC ARTR/CHNA	45.9 %
QQ-1-3-SF	12	20 1	22 3	17	22	93 4	PIMO/JUOC ARTR/CHNA	38.0 %
QQ-1-3-NF (focus)	20	31	20 5	24	29	124 5	PIMO/JUOC ARTR/CHNA	50.6 %

	1	2	3	4	5	Σ	Species	Cover
GV-1-3-SF1	24	26	17	21	41	139	PIMO	54.4 %
GV-1-3-SF2	23	25	23	34	32	137	PIMO	53.7 %
GV-1-3-NF1	24	34	34	25	33	150	PIMO	58.8 %
GV-1-3-NF2	33	26	27	28	31	145	PIMO	56.9 %
GV-1-2-SF1	15	19	14	13	16	67	PIMO	26.3 %
GV-1-2-SF2	28	34	30	27	32	151	PIMO	59.2 %
GV-1-2-NF1	37	25	37	34	29	162	PIMO	63.5 %
GV-1-2-NF2	28	36	18	25	24	131	PIMO	53.7 %
	1	0	1	1	2	5	Shrub	
GV-1-1-SF1	17	21	19	26	25	108	PIMO	42.4 %
GV-1-1-SF-2	28	20	39	35	25	147	PIMO	58.8 %
					3	3	shrub	
GV-1-1-NF1	33	39	33	35	29	169	PIMO	66.2 %
GV-1-1-NF2	24	27	27	24	31	133	PIMO	52.2 %

Site	Transect 1	2	3	4	5	Σ	Species	Cover
GV-2-4-SF	20	30	12	27	12	101	PIMO	39.6 %
GV-2-4-NF	32	30	35	26	36	159	PIMO/ARTR	62.3 %
GV-2-1-SF1	34	26	26	36	30	152	PIMO	59.6 %
GV-2-1-SF2	36	21	32	24	31	144	PIMO	56.5 %
GV-2-1-NF1	26	30	26	33	32	147	PIMO	57.6 %
GV-2-1-NF2 (poor focus)	31	33	36	30	31	161	PIMO	63.1 %
GV-2-3 SF1	34	28	31	35	20	148	PIMO	58.0 %
GV-2-3-SF2	22	41	34	36	31	164	PIMO	64.3 %
GV-2-3-NF1	25	25	31	30	33	144	PIMO	56.5 %
GV-2-3-NF2	30	28	18	18	20	114	PIMO	65.4 %
	5	7	14	14	13	53	Shrub.	
QQ-2-1-SF1 (poor focus)	46	44	46	47	48	231	CELE Cercocarpus ledifolius	90.6 %
QQ-2-1-SF2 (poor focus)	44	48	49	47	42	230	CELE	90.2 %

Testing of Vegetation Cover Results

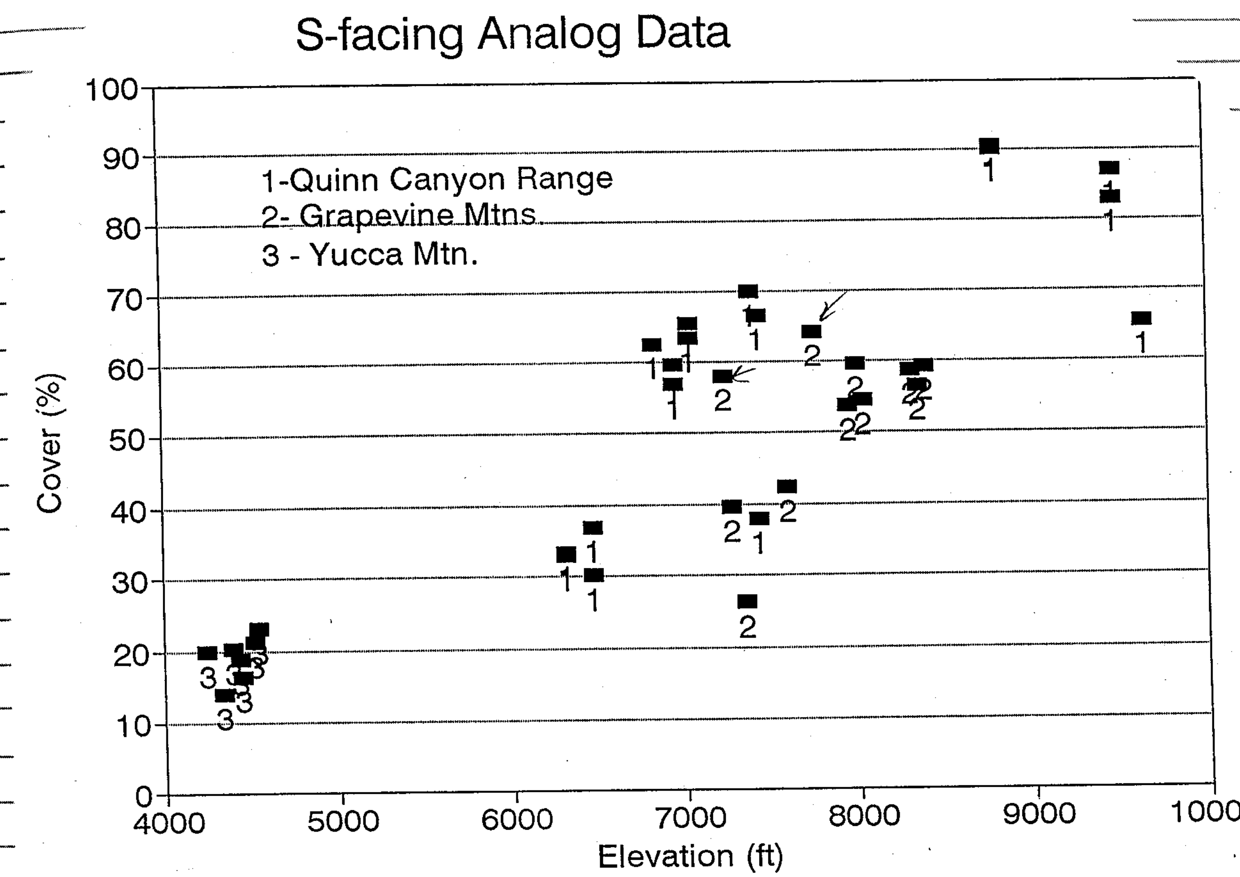
1. Note poor fit for relationships - need investigate
2. Test - are data scattered because of error in air photo interp. techniques? Test for shadow effects on Grapevine Mtn. data w/ mirror stereoscope. Conclude data are not skewed.
3. Plot data for Quinn Canyon vs. other sites - significant upward skewing due to high elevation sites.
4. Separate data for Q. Cyn. out of data set resultant n is 18 for both S- & N-facing Grapevine Mtns & Yucca Mtn.
5. Regression relationships boosted to r^2 of > 83%

Re-analysis of Select Sites under Mirror Stereoscope

	1	2	3	4	5	Σ	%
GV-2-3-SF-1	31	42	32	20	22	147	57.6%
GV-2-3-SF-2	35	33	38	44	29	179	70.2%

initial measurements were SF-1 = 58.0%
SF-2 = 64.3%

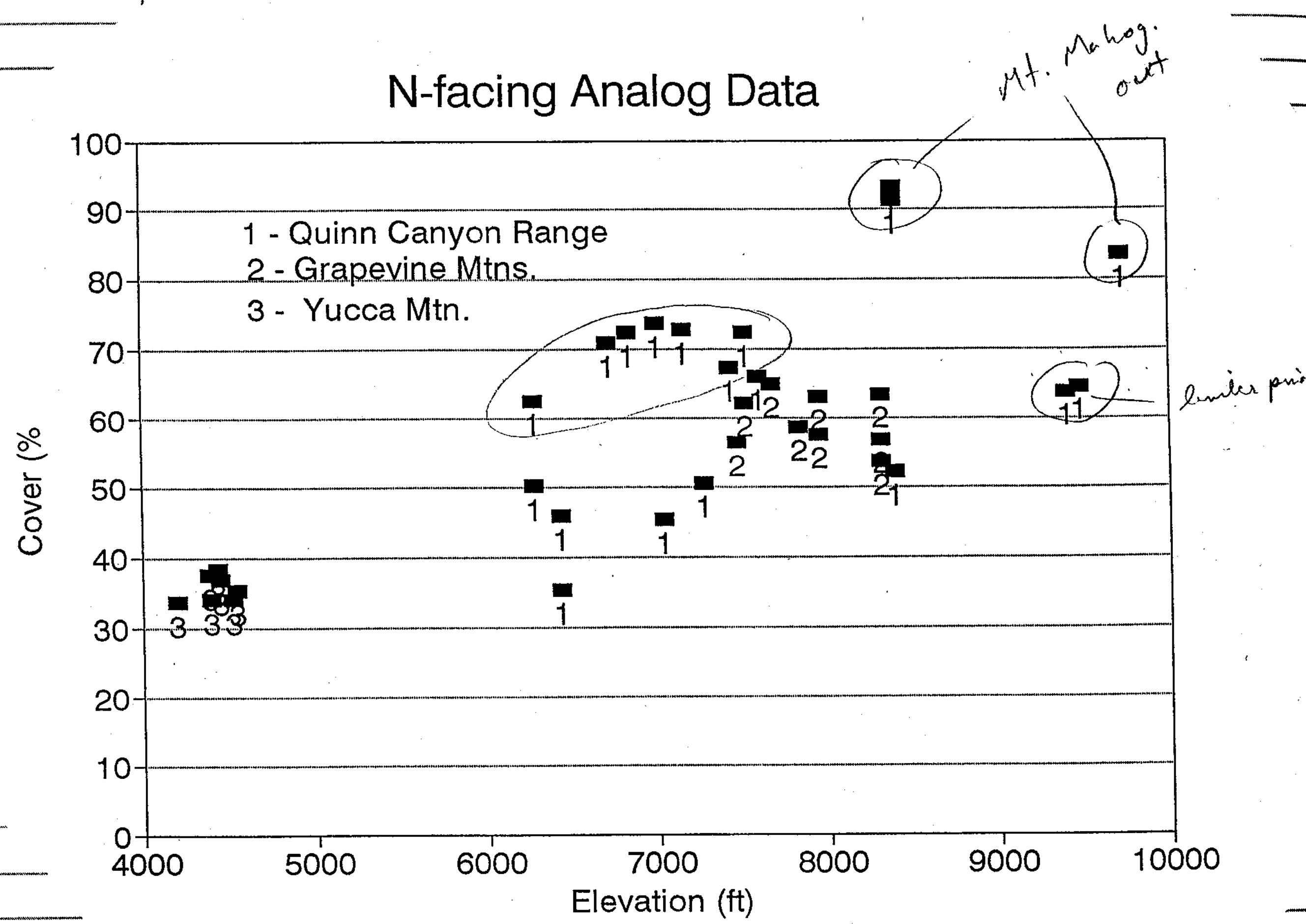
These two chosen to test whether shadow influenced result. So, conclude that shadow did not have a significant effect. Both SF-1 & SF-2 were unusually high



Check sites marked by arrows

GV-2-3-SF1

GV-2-3-SF2



Regression: S-facing Cover = .0120 Elev. − 34.7
4,000' Ĉover = 13.3 %
10,000' Ĉover = 85.3 %
N-facing Cover = .00763 Elev + 4.15
4,000' Ĉover = 34.7 %
10,000' Ĉover = 80.4

.0120 Elev. − 34.7 = .00763 Elev. + 4.15
(.0120 − .00763) Elev. = 4.15 + 34.7
.00437 Elev. = 38.85
Elev. = 8890'

Hybrid Cover line for S-facing
23.1 % @ 4,000' ; 90.6 % @ 8,800
.0141 Elev. − 33.15

Highest Cover Relationships.

	4,000	Y = 100 %
N-facing	34.6 %	8920'
S-facing	23.2 %	9443'

Intentionally Blank

July 22 through July 24, 1999

A field trip to the area east of Tonopah was conducted in order to map and measure the infestation of Bromus tectorum preparatory to perform a satellite mapping program that was not completed. This work grew out of observations and a report concerning the importance of weedy Brome grasses in infiltration. With a change of vegetation cover from deep-rooted shrubs to shallow rooted annual grasses, infiltration may increase by over an order of magnitude. Since the invasion and replacement process is at the scale of entire valleys, this process will probably greatly affect regional water table levels. Unfortunately, this work remains incomplete.

Pages 97 - 102: Memorandum proposing work to investigate the invasion and establishment of annual grasslands replacing native shrubs.

Pages 92 - 96: Field notes.

Pages 103 - 120: Trip report (sent as a draft to be included in a trip report that was not completed).

Pages 119 - 120: Air photographic overview (negatives and photographic prints sent to CNWRA under separate cover).

Page 121: Soil sample results showing no overt physico-chemical influence promoting BRTE

7-21 [Yucca Mtn: e-mail R. Feders,
prep, pack, fly to SQL → TPH
check in study species info - 12.0]
7-22 [YM: TPH area field
- stop 1 WP 004 on ecotone near solstice summit
BRTE - 16:38 z (004)
ecotone - no difference between
above & below
no fire above in BRTE visual 3-8 % shrubs
BR=5 GRSP, EPNE, ARTR, CELA, ATCA
below in shrubs 20-30% (closer to 30%)
ARTR, GRSP, EPNE, CELA
- 005 large triangular piece of BRTE
dominated veg. in Stone Cabin Valley
BR=5 ATCO, CHGR greasewood, CELA, ARSP
< 3% cover - no fire here
dead shrub carcasses numerous
- 006 transitional area shrub cover ~15%
HIJA c ca 5% cover; adj.
BR=2 area shrubs are ca 20%
shrub species are CHGR, CELA, ARSP
ATCO w/ v. sparse BRTE

page 133 of D.P. Greenwald
3-27-98 through 5-8-00

007 - ecotone w/ PJ: ARTR w/ some
BRTE EPNE: ORHY; ARTK v/ short stature
ca 20-30 cm (no BRTE)
008 - ecotone again patchy fuel
heavy BRTE cover on way
down from this due patchy; ca
(prob. 50% cover of BRTE in wet year) 10% cover, overall is ca 20-25
: CHGR, EPNE, HIJA, ARSP
also patches of these species w/ ARTR
dominant
009 - no Bromus but bald patches
of altered tuff; ARTK, EPNE
CHGR ORHY
010 - BRTE mixed w/ CHGR, ORHY
HIJA, TEAX, ATCO but dom. by
ORHY & HIJA, no new growth
this year - prob. 30-40% in wet
011 - BRTE dom. very little new
growth this year, CELA w/ some
sage which is dying out; some
remaining in stranded islands.
Hypotheses:
- finer soil in runoff channels promotes
BRTE
- parent material matters for
perennial natives not for BRTE

- BRTE first dormant @ higher elevations
- BRTE will always dominate
- fire not necessary nor a player
- BRTE takeover occurs in pulses tied to water year
- BRTE takeover is recent phenomena 20-30 years and is in progress
- Slope and aspect are initially important for establishment then for spreading rel. unimportant
- Indian rice grass & winterfat are part water-controlled dominants 12,0]

7-23 [YM: air force, spectro operation [10 pics]

Site 012: no BRTE ORHY Dom. w/ HIJA

ORHY - 0/1 1/1 0/1 0/1 0/1 1/1 0/1 0/1 1/1 (no BRTE) 3/9

HIJA 1/1 1/1 0/1 0/1 0/1 0/1 0/1 1/1 0/1 3/9

CELA 20% cover

ARSP 0/1 LAI = .119 0/1

STPA 0/1 0/1

Site 013: Hillslope HIJA dom. heavy BRTE remnants from WY 1998 = 3

HIJA 0/1 1/1 0/1 0/1 1/1 0/1 1/1 0/1 0/1 0/1 6/10

CHGR 0/1 0/1 1/1 0/1 0/1 0/1 (BRTE = 3) 1/6

EPNE 1/1 0/1 0/1 0/1 : 1/4 ORNY 0/1 0/1 : 0/2 BRTE

ATCO 0/1 >90% of pics in remnant

014: N. heavy BRTE w/ this yrs growth < 50% as high & prob. 1/4 prev. expression? BRTE = 4

ARSP 0/1 0/1 0/1 0/1 0/1 0/1 : 0/6

HIJA 0/1 0/1 0/1 1/1 0/1 0/1 : 1/6

ATCO 1/1 2/1 0/1 : 3/3

EPNE 0/1

015: V.V. Heavy BRTE = 5

EPVI - 2/1 0/1 0/1

GRSP - 0/2 0/2 0/1 0/1 0/1 0/1 0/1 0/2 0/1 : 0/14

Cutinneous smoothrue - 0/1 0/2

CHNA - 0/1

→ BLM 482-7800 (775)

UN Coop Ext. 482-6794 12.0]

7-24 [YM:

016: Base of Basalt hill w/ rocks highly rounded and varnished. digging ATCO & GRSP no recruitment BRTE mostly from last year with some growth this year HIJA dom. note BLM marker 200 range trend site?

direct point of basalt

HIJA - 2/1 0/1 0/1 2/1 (BRTE 4)

ATCO - 0/1 0/1 1/1

138.

[020 - BRTE1 w/ occasional
patches HIJA, SPCR, ATCO
CELA @ ca 15-20% - no diff
[021 - BRTE0 ST [illegible] is
dominant CELA, TEAX, ARTR ≈15%
[022 - BRTE-0 ARTR, HIJA
& desert pavement and vesiculated ca 20%
[023 - BRTE-0,
GHNA (v. short ca 40 cm),
HIJA, ARSP w/ bald ca 15%
patches, desert pvmt., vesiculated soil
- prep. camera equip. for flight
- pack samples & equip. 11.0]
7-25 [YM - prep plane, fly aerials
of Bromus sites, return TEX
airport & store field equip. 8.0]
(13.8 hrs, ac)

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Memorandum

May 5, 1999

TO: Randy Fedors and Amit Armstrong
FROM: David Groeneveld

RE: Attached proposal to use satellite data to study *Bromus* invasion

As we discussed, I researched available satellite data that can be used for the study of *Bromus* invasion. I then constructed a proposal that would approach the problem in 4 discrete steps that gain in complexity and build from the results of the previous step. To my knowledge, nothing like this has been attempted by other researchers. Importantly, all 4 steps could be accomplished in one year and would yield some valuable and exciting additions to the literature--particularly as a support to other hydrologic study.

To recap my telephone call with Dr. Robin Tausch, USFS, of Reno, Nevada, who is an expert on *Bromus* invasion and replacement by native vegetation:

- o this issue is not receiving serious study, especially in the Nevada region of interest for Yucca Mountain.
- o the problem is easily of the magnitude for hydrologic effects as we have postulated.
- o although there will probably be elevational limits for *Bromus* dominance (hence limited by wet/cold climate scenario), there are other species that are set up for invasion and establishment by *Bromus* dominance. These species (e.g., Russian knapweed, medusa-head wildrye) are shallow rooted, are likely hydrologic equivalents to *Bromus* and apparently have greater tolerance to cold/wet limitations.

I asked Dr. Tausch to send me his most recent papers dealing with *Bromus*. He agreed to this and to writing a cover letter affirming that our course of study, especially dealing with the hydrologic implications, is timely and important. I'll forward both to you when received.

Proposal to Use Satellite Data to Document the Invasion of *Bromus* into Regional Groundwater Catchments Near Yucca Mountain

Prepared by D.P. Groeneveld, Ph.D., Resource Management Consulting, Inc.
May 5, 1999

Introduction:

The invasion of two species of the grass genus *Bromus*, cheatgrass and foxtail chess, within Nevada rangelands may have an important promotional effect upon groundwater recharge, especially under climate conditions that someday are cooler and wetter than at present.

This proposal seeks to document the process of regional invasion and dominance of *Bromus* using historic satellite data. Although, theoretically, heavy *Bromus* canopies should be easy to discriminate on satellite imagery, this proposal has been constructed so that each step can only be undertaken with the successful completion of the previous step.

Step 1. Proof of concept that *Bromus* can be identified on satellite data. (Can be accomplished within 3 weeks of receiving satellite data.)

This step would determine whether *Bromus* can be identified on satellite data in 1998, a year that we have acceptable ground-truth information in the form of oblique air photos and that we can also reconstruct, as needed, for conditions during summer, 1999. The analysis would be performed on one late-summer Landsat TM scene--a period that offers the greatest potential for discrimination of *Bromus* canopies. The spectral signature of *Bromus* is expected to be highly reflective and emitting mostly within the yellow and infrared region of the visible spectrum. Dr. Christopher Elvidge (presently at NOAA), who pioneered measurements of spectral signatures of non-living vegetation cover, confirmed that senesced *Bromus* canopies are highly distinctive from living native vegetation but can be confused with generally small areas of hydrothermally altered, iron-rich clays. This aspect would be explored during Step 2.

The proposed study area for steps 1 and 2 is Reveille and Southern Railroad Valleys that is 50-60 miles north of Yucca Mountain, located at an elevation of between 5,000 and 7,000 feet, and undergoing recent active invasion by cheatgrass. This area is of special interest because of (1) the discrete pattern of cheatgrass invasion against the intact shrub cover, (2) invasion has occurred during the period of satellite record (mostly over the 10 years by direct observation by D. Groeneveld), (3) the site contains an elevational range that would likely have a climate similar to Yucca Mountain under full glacial cycle, (4) the pattern of cheatgrass invasion and establishment offers excellent study of patterns of takeover and the potential dominance on various soil types, and (5) we have existing oblique photography of the site that can be used to confirm the initial pattern of cheatgrass takeover for comparison to ground truth and satellite data. A view of the discernable patterning of cheatgrass in Southern Railroad and ReveilleValleys is shown on attached (A).

Step 2. Mapping distribution of *Bromus* canopies, determining their spectral characteristics and performing a site visit to gather data. (Can be completed in 1-2 months after Step 1)

This step would use the satellite data purchased for Step 1, obtained on August 17, 1998. One field trip would be necessary that would encompass 3-4 days. Prior to field work, the study area would be overflown with 35 mm camera to obtain a series of air photographs upon which to base field observation and documentation of *Bromus* invasion. Photos taken during the previous year, 1998, would be used to confirm that the invading front of *Bromus* is in approximately the same location during 1999 as in 1998. Thus, with this confirmation, 1999 photos could be used as surrogates for 1998, when combined with ground truth measurements.

The Reveille and Southern Railroad Valleys would be visited on the ground to gather observational data, to confirm the distribution visible on air photos and to obtain evidence for or against the role of wildfire in the invasion/replacement of the native shrub cover. A number of other hypotheses could be checked at the same time, e.g., initial aggressive invasion and replacement by *Bromus* occurs due to shallow distribution of soil moisture from either shallow soils or impeded infiltration due to high clay content. Also of major interest is the potential for replacement of tree species by *Bromus*, probably in concert with wildfire.

The Yucca Mountain area was not chosen for the analyses of Steps 1 and 2 because the study site needed for these initial steps must have *Bromus* in the invasion process with clear boundaries between shrubs with *Bromus*, *Bromus* without shrubs, and shrubs without *Bromus*. This patterning permits unequivocal identification and documentation of unique spectral characteristics of this vegetation on satellite imagery. Within the Yucca Mountain region *Bromus* has already invaded and become heavily established. Since we lack contemporal documentation of *Bromus* distribution during invasion when appropriate patterning would have existed on and near Yucca Mountain, this region is, therefore, a poor choice for such initial study. An additional degree of complication is the complex topography and exposed rock and soil of Yucca Mountain--additional complexity that does not exist in the flat to gently sloping terrain within Reveille and South Railroad Valleys.

3. Determination of the best time of year for identification of *Bromus* canopies. (Can be completed in 2-3 months following completion of Step 2)

Bromus undergoes a transition from full crown expression and seed set in May when it assumes a purple-green color to a bright straw color in the late-summer-to-fall period. Within the library of available satellite data, acquisition dates are available throughout the year which would allow detection at any time. This step would determine how to identify *Bromus* canopies during the spring and summer and would determine which time of year is best for this purpose. Additional dates of imagery from 1998, probably the one from 6-30-98, would be selected from the scenes listed on attachment (C). This date corresponds to the time of a field trip through this region of Nevada that documented that regional cheatgrass canopies had reached full growth and

had turned purple prior to senescence. The image would be analyzed to determine whether the purple color would better pinpoint the location of cheatgrass cover than the late summer straw color.

4. Determine the rate at which brome invasion and replacement is occurring. (Can be completed within 6 months following completion of Step 3)

Regional precipitation records would be consulted to identify which years had growing seasons that followed wet winters when maximal expression of *Bromus* canopies would be expected. A library of 5-8 Landsat Scenes would be purchased for the best time of year during such years. These would then be co-registered and analyzed for the presence of *Bromus* to document the invasion and takeover during the past 25 years. This activity would be performed for the Reveille and South Railroad Valleys study area and for the regional groundwater catchment basin north of Yucca Mountain and Yucca Mountain and its surrounding region.

Available Satellite Data of the Area of Interest:

Landsat has the most extensive broad band data available. There are two types of images available, Thematic Mapper (TM) and Multispectral Scanner (MSS). The spectral information of interest for identification of *Bromus* is roughly equivalent for the two image types although the image resolution is higher for TM, 1 pixel = about 29m than MSS, 1 pixel = about 79 m. For our initial research, TM would be much better because of its higher resolution because it would allow us to better resolve the minimum degree of cover by *Bromus* within varying mixes of shrub cover detectable using satellite data. If we are successful in determining the spectral signature and issues surrounding detection, we can apply the data to a library of multiple images back in time to track invasion and takeover by *Bromus*.

Using the Global Land Information System (GLIS: www.cr.usgs.gov/Webglis), I reviewed the available Landsat Images. Depending upon (1) the exact location of the area of interest around Yucca Mountain, and (2) the particular image, one image may cover the entire study area from the potential Reveille Valley study area through the Yucca Mountain region. The location of scenes varies and sometimes lops off the lowermost location that includes Yucca Mountain (but generally includes most of what I believe is the catchment for groundwater flow to Yucca Mountain. For the entire library of Landsat images with 10%, or less, cloud cover, the following are available:

Landsat Satellite	Years Available	Number of Images
TM	1982-1998	150
MSS 4 and 5	1982-1992	65
MSS 1, 2, and 3	1972-1983	137

There is detailed data available for each scene and sometimes a "browse" image that allows you to see the area of coverage, cloud cover, vegetation phenology, etc. before choosing the data. Detailed written data is entitled "Meta Data" and importantly provide corner points. Before purchasing any image, these corner points should be plotted in order to determine whether the image covers the Yucca Mountain region--it would be cheaper if we only order one scene to cover both areas of interest rather than one at a time. An example of a probable scene that we will wish to buy (LT5040034009822910 obtained for 40/34 on August 17, 1998) is attached with a map showing the location, a browse image and meta data (B). Other scenes available with no cloud cover during 1998 are listed and attached (C).

Landsat TM and MSS 4 and 5 are all co-registered to path/row 40/34. Landsat MSS 1, 2, and 3 are co-registered to path/row 43/34 which covers the same area as 40/34 on the later images. Not all of the images are perfectly registered within the path/row indicated, however, and this applies to Landsat images in the early 1980's. This is another reason why the coordinates of the image need to be carefully checked prior to purchase. As a safeguard, especially for scenes that lack a browse image, if the data aren't as specified, for example location, cloud cover or data integrity, the scene can be returned for a full refund within 60 days.

Cost of Satellite Images:

There are a number of products that are available from USGS/EROS Data Center for both TM and MSS. The cheapest is raw digital data with no processing to correct for actual map location, terrain or skewing that naturally occurs due to satellite travel and Earth rotation. Correction of the data for these aspects by USGS/EROS Data Center, although more expensive initially, is highly recommended because it saves some potentially lengthy steps that would need to occur before the data could be analyzed. The cost of the map- and terrain-corrected TM data is $900 per scene and for map- and terrain-corrected MSS data is $675 per scene.

Southern Reveille Range from over Reveille Valley Looking SE

All straw-colored vegetation is cheatgrass (*B. tectorum*) growing within shrub cover. The cheatgrass cover has aggressively colonized and dominated part of the bajada below Reveille Peak. Form similar patterns identified in nearby Owens Valley, California, the soil on this site is probably ancient alluvial fan deposits with higher clay contents.

Southern Railroad Valley, Nevada, Looking SE

The pattern of cheatgrass growth clearly follows swales where finer textured soils accumulate. Other observations, for example, the entire bajada in the background of the photo above, indicate that cheatgrass eventually takes over all soils in these valleys, even very coarse bajadas.

Draft Report for field trip sent to Dr. A. Armstrong CNWRA

Field Trip Purpose:

Recent Center field work and analysis has discovered that the invasion of Nevada rangelands by weedy species of the grass genus *Bromus* has the potential to profoundly alter regional infiltration and groundwater levels. This mechanism is due to the replacement of deep-rooted (generally 2-3 m) shrub species by these shallow-rooted (ca. 0.5 m) annual grasses: water that has infiltrated below root zones is essentially available for groundwater recharge. This field work and other investigations have examined this question to confirm that *Bromus* will replace native shrub vegetation in the regional catchment to Yucca Mountain and to determine how where and why limitation to this replacement will be imposed by the environment. The persistence of *Bromus* under cooler and wetter conditions associated with climatic change is of direct interest and can be examined by the performance of *Bromus* under higher elevations where the existing climate is indicative of cooler and wetter conditions that would enhance the potential for infiltration.

One means of tracking and documenting the rate of the invasion and takeover by *Bromus* is to use comparison of a time series of satellite images since these data may offer the only historical record to permit tracking the invasion. Evaluating *Bromus* cover on satellite data should be relatively simple because this species exhibits a straw color that contrasts with, and is easily distinguishable from, the surrounding native shrubs.

Field work was undertaken in the Reveille Valley and Southern Railroad Valleys of Nevada to gather data to (1) confirm that conversion to annual grasslands from formerly stable native shrub cover is occurring, (2) determine mechanisms for this invasion and conversion, and (3) to determine how best to identify areas with *Bromus* cover unequivocally on satellite images. The study area was chosen because it is an area where *Bromus* has invaded and is establishing dominance in recognizable patterns. This condition is unlike Yucca Mountain, where *Bromus* invasion is relatively complete, covers virtually all areas and, thus, probably predates the invasion in Southern Railroad and Reveille Valleys by several decades. The *Bromus* species in the study area is *B. tectorum* L., while in the Yucca Mountain area, *B. tectorum* is present but greatly dominated by another *Bromus* species, *B. madritensis* ssp. *rubens*. These species are comparable in their physical appearance, physiologic requirements and ecological niches but apparently have different elevational optima, *B. tectorum* being favored at higher elevations (and thus, probably of greater interest for climate-change conditions). For brevity *B. tectorum* will be referred to in this report by the symbol BRTE.

This trip report will detail and interpret ground and airborne data gathered over the study area. The final section to the trip report will examine the three goals stated above.

Field Trip Timing:

The field work on the ground was accomplished in three days, from July 22 through July 24, 1999. Additional observations were made during an overflight of July 21 and again on July 25, when air photographs were obtained for training computer-recognition of BRTE on satellite data.

For conclusively documenting aspects of *Bromus* infestation, timing is critical. A preceding wet winter period is highly desirable because this assists establishing heavy *Bromus* cover that can be directly measured. Though providing valuable input, the period of the field visit unfortunately occurred following a relatively dry winter and consequently, minimal expression of BRTE canopies. Another time-wise aspect of this field work is that it was conducted after senescence (entering inactivity; for annual species, this means the setting of seeds and death marked in *Bromus* by changing from green to a straw color). A better time for study of *Bromus* ecology would be during its active growth period, near its growth peak which occurs between the second week in May and the second week of June (weather dependent). Aspects of timing and BRTE expression not withstanding, because of the recent identification of the potential hydrologic influence presented by the replacement of native perennial, particularly shrubs by *Bromus*, this field trip represents the first opportunity to mobilize to obtain field documentation.

Ground Sites Visited:

Sites visited were named using a 3 digit numeric symbol for the GPS waypoint that was established. The majority of sites documented were located on the mid-to-lower portions of bajadas and valley floors in valleys east of Tonopah, Nevada. Particular emphasis was paid to Reveille and Railroad Valleys and to the bajadas and hills immediately east of the Kawich Range.

Two types of vegetation data were gathered at these sites: (1) visual estimation of cover (a rapid technique) was used on 13 sites; and (2) more detailed and time consuming line-point method was used on seven sites. The line-point method measures leaf area index (LAI) and cover by sampling with a vertically dropped pin along a transect line sampled according to set intervals along a stretched tape (described in Groeneveld. 1987. Vertical point quadrat sampling and an extinction factor to calculate leaf area index. *Journal of Arid Environments* **36**:475-485). Sampling intervals were every 0.5 m along a 50 m tape for a total of 101 points evaluated. The frequency of pins passing through the canopy of each perennial plant species was used to establish canopy cover. Only perennial plants were recorded because of the relatively low cover of BRTE and other annual species during the 1999 growing season.

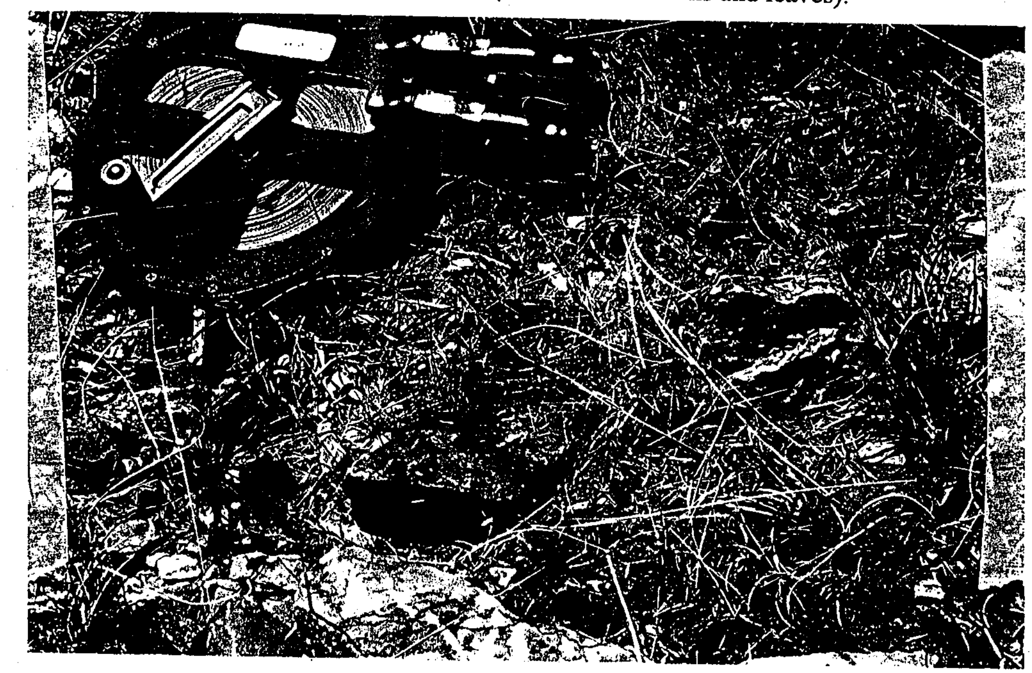
Measurement of diffuse annual species such as BRTE are not well suited to transect-based techniques. Because it is an annual species dependent upon precipitation during the previous winter, BRTE also tends to fluctuate greatly from year to year. This is apparent in the comparison of the size of the senesced BRTE material from this and last year shown in Figure A. Visual observation of BRTE dominance was made using the following key, with judgment based on the presence of both this and last year's growth.

Data are presented with adjoining photographs for all 20 sites, 004 through 023. Each site is rated for BRTE infestation (0-5) and where measured by line point transect, LAI and percent cover of perennial species, and a count of these species is given; where estimated, only cover by perennial species is given.

<u>*Bromus* infestation key</u>:

0 - BRTE not present
1 - BRTE present but only as isolated individual plants
2 - BRTE present as isolated individual plants but also in patches of heavier cover.
3 - BRTE found throughout the site but of generally equal dominance to native species
4 - BRTE found throughout the site and with patches clearly dominating native species
5 - BRTE dominant over native species throughout the site

Figure A. Close up of duff at Site 013 from BRTE growth last year; relatively wet and good growing conditions (remnant long stems bleached straw or gray color), with BRTE growth from the relatively dry growing season this year; (short reddish stems and leaves).



(drafting tape: easy removal)

Study Site Soils

In general, soils were fine-grained loams and sandy loam textures with weak to moderate development with textures becoming finer toward the valley floors. A component of caliche was observed in most soils with the percentage also increasing valleyward. Ground srufaces on fans were commonly covered by a thin veneer of pebble-sized clasts derived from surrounding hills. Desert pavement was common and was often accompanied by vesicular soil. Soil samples were obtained from a variety conditions represented on six sites (Sites 012, 013, 014, 015, 017, 018. These have been sent to the Utah State University soil test lab for analysis of pH, electrical conductivity, $CaCO_3$ activity, texture and percent rock composition.

The following accompanied photos not reproduced here

Site 004: N 38 06.295, W 116 53.737 Estimated cover = 3-8% BRTE=5
Visited July 22

A point on an ecotone between BRTE dominated and shrub dominated vegetation in the hills of Salisbury Summit. There was no evidence of fire in this location. Above the ecotone in the BRTE dominated zone, visual inspection indicated the perennial vegetation cover was between 3-8 % with shrub species represented in decreasing order of importance by spiny hopsage, Nevada ephedra, big sagebrush, winterfat and fourwing saltbush. On the other side of the ecotone BRTE growth was sparse (rated 1) and shrub cover was 20-30%, by order of importance, big sage, spiny hopsage, Nevada ephedra, and winterfat. BRTE infestation was rated as 5 inside the BRTE dominated area.

This site is located on a rhyolite knoll. The soil developed here is on ignimbrite and, thus, is probably rather alkaline. Outcrops of in-situ rhyolite are common and float is relatively coarse grained. This is a weakly developed soil

Site 005: N 38 05.878, W 116 30.263 Estimated cover = <3 % BRTE = 5
Visited on July 22

This site is a large triangular (about 1 mile sides) parcel dominated by BRTE in eastern Stone Cabin Valley. The cover here is less than 3% by native shrub vegetation in order of decreasing importance: shadscale, Greene's rabbitbrush, winterfat and budsage. Dead shrub carcasses were numerous. BRTE infestation was rated as 5.

This site is located on the bajada on the west side of the Kawich Range. The soil parent material is alluvial outwash of ignimbrite origin and probably rhyolite composition.

Site 006: N 38 05.848, W 116 30.396 Estimated cover = 20% BRTE = 2
Visited on July 22

A transitional area from the much heavier infestation of BRTE to the east at Site 005. Shrub cover is variable but about 15% with native galleta grass forming about 5% cover. Ranked shrub species are Greene's rabbitbrush, winterfat, budsage, and shadscale. BRTE infestation was judged to be 2.

This site is located on the bajada adjacent to Site 005 and similarly the soil parent material is alluvial outwash of ignimbrite origin and probably rhyolite composition.

Site 007: N 37 51.281, W 116 09.223 Estimated cover = 20% BRTE = 0
Visited on July 22

This site is located at the break in slope between the Reveille Range and the Reveille Valley and is an ecotone between big sagebrush and pinyon-juniper forest. BRTE is absent here.

This site is located at the uppermost portion of a fan where ignimbrite outcrops are abundant. The soil is weakly developed and is derived from ignimbrite. Regolith is abundant in the near surface portion of the soil.

Site 008: N 37 50.968, W 116 10.790' Estimated cover = 20% BRTE = 1-2
Visited July 22

This is an ecotone with patchy cover where BRTE is heavier downslope and light upslope. Overall cover is about 20 cover with Greene's rabbitbrush, Nevada ephedra, galleta grass, budsage, and with patches where big sagebrush is dominant. BRTE infestation of 2, especially downslope, less up slope (1).

This site is located at the bajada base from the southwestern Reveille Range. Ignimbrite clasts (2-6 cm length) are abundant on the surface of the alluvial fan. Compared to site 007 which lies above, more calliche is more abundant.

Site 009: N 37 49.139', W 116 15.008' Estimated cover = 15% BRTE = 0
Visited on July 22

Altered tuff bedrock is exposed here for an overall highly reflective ground surface. BRTE is absent here (infestation of 0). Perennial native Shrub species are big sagebrush, Nevada ephedra, Greene's rabbitbrush and Indian ricegrass.

This site is on the west side of the Reveille Valley on the bajada at the base of the Kawich Range. The soil is particularly light-colored and appears to consist of proplylitically (??DPG note--is this spelled correctly) altered ignimbrite as chemically altered tuffs. This soil is weakly developed.

Site 010: N 37 45.989, W 115 58.823' Estimated cover = 15% BRTE = 4
Visited on July 22

BRTE infestation judged to be very heavy (4) but no new growth was noted for this dry year. Perennial native species were Indian ricegrass, galleta grass, Greene's rabbitbrush, spiny horsebush and shadscale.

This site is located south of the intersection of Highway 375 and the dirt road that passes through Reveille Valley. The soil is weakly developed and contains clasts of volcanic tuff, carbonate and chert. Clasts range in size from silt to coarse pebbles.

Site 011: N 37° 45.786', W 115° 59.138' Estimated cover = 10% BRTE = 5
Visited on July 22

BRTE infestation is very heavy (5) but with little new growth this year. Perennial cover is winterfat with some patches of big sage at about 10 % cover.

This site is in Southern Railroad Valley near the Junction of 375 and the Reveille Valley Road. This soil constains clasts of carbonate rock and caliche and is probably derived from weathering of carbonates.

Site 012: N 38° 04.558', W 117° 00.325' LAI = 0.118 Cover = 19.8% BRTE = 0
Visited July 23
Very light straw colored vegetation cover dominated by Indian ricegrass (LAI= .059, cover=8.9%), galleta grass (LAI=.059, cover=8.9%), budsage (LAI=0, cover=1.0%), needlegrass (LAI=0, cover=1.0%) as measured by the line point technique. BRTE was absent (0).

This site is located southeast of the junction of Highway 6 and the road to the Tonopah test site. The soil is sandy with fragments (1 to 3 cm) clasts of slate, carbonate, rhyolite, and chert. The dominant parent material for this mostly alluvial soil was unclear. Soil samples were collected for analysis.

Site 013: N 38° 01.591', W 116° 42.356' LAI = 0.159 Cover = 22.8% BRTE = 4
Visited July 23
Hillslope with remnants of heavy BRTE infestation from 1998, estimated to be a rating of 4. The site was dominated by galleta grass (LAI=.119, cover=9.9%), Greene's rabbitbrush (LAI= .020, cover=5.9%), Nevada ephedra (LAI= .020, cover=4.0%), Indian ricegrass (LAI=0, cover=2.0%), shadscale (LAI=0, cover=1.0%). BRTE infestation judged to be 3 and >90% of pins from the line-point technique intercepted remnants from the 1998 growing season.

This south-facing slope is blanketed with quartzite pebbles and regolith. The soil is very weakly developed and outcrops of quartzite were observed. The slope is underlain by a carbonated rock that is exposed in drainages about the base of the hill. Soil samples were collected for analysis.

Site 014: N 38° 05.857', W 116° 30.537' LAI = 0.079 Cover = 15.8% BRTE = 4
Visited July 23
Very heavy BRTE growth (infestation of 4) with this years stalks less than half as tall as remnants from last year. Perennial vegetation present is galleta grass (LAI=.020, cover=5.9%), budsage (LAI=0, cover=5.9%), shadscale (LAI=5.9%, cover=3.0%), Nevada ephedra (LAI=0, cover=1.0%).

This site is located on the bajada immediately NW of a large triangle of BRTE (see site 005) at the north end of the Kawich Range. Patches of desert pavement are common and pebbles show well-developed desert varnish. This suggests deflation of fines from the surface. Rhyolite cobbles (volcanic tuff) to 15 cm + and sand sized grains are abundant. Soil samples were collected for analysis.

Site 015: N 38° 07.565', W 116° 21.916' LAI = 0.040 Cover = 19.9% BRTE = 5
Visited July 23
Extremely heavy BRTE infestation (5) and no trace of fire. Perennial native vegetation consisted of spiny hopsage (LAI=0, cover=13.9%), green ephedra (LAI=.040, cover=2.0%), snakeweed (LAI=0, cover=3.0%), and rubber rabbitbrush (LAI=0, cover=1.0%).

This site is near the base of an alluvial fan with fine-grained soil that is moderately well developed. Rhyolite clasts are common but it is uncertain what the dominant parent material is. Soil samples were collected for analysis.

Site 016: N 38° 08.019', W 116° 05.306' LAI = 0.099 Cover = 7.0% BRTE = 4
Visited on July 24
The two shrub species shadscale and spiny hopsage (not represented on transect) have many dead branches (>50%) and no recruitment of young were found. The perennial vegetation measured was galleta grass (LAI=.079, cover=4.0%) and shadscale (LAI=.020, cover=3.0%). BRTE judged to be 4, mostly represented by last years growth.

This site is at the north end of Southern Railroad Valley on a debris lope below basaltic outcrop. The basalt clasts are rounded, strongly covered with desert varnish, and make up about 40% of the ground surface. The soil between the basaltic clasts is very light colored with a loam or silt loam texture from aeolian deposition.

Site 017: N 37° 52.332', W 116° 03.349' LAI = 0.218 Cover = 21.8% BRTE = 0
Visited on July 24
This site is in a grassland area where shrubs appear to be in poor shape and possibly decreasing, disrupted by the hoof action of heavily stocked cattle. Comparatively high species diversity was recorded here with seven perennial species--galleta grass (LAI=.099, cover=8.9%), sand dropseed (LAI=.079, cover=5.9), three-awn (LAI=0, cover=2.0%), apricot mallow (LAI=.020, cover=1.0%), shadscale (LAI=0, cover=2.0%), needle grass (LAI = .020, cover=1.0%), winterfat (LAI=0, cover=1.0%). BRTE infestation was 0, although 2 BRTE plants were found in the about 1 hectare observed.

This site is on the west side of the Southern Railroad Valley. Desert pavement here indicates deflation of fines and vesicular soil is common. Rhyolite is the dominant pebble-sized material with minor amounts of basalt clasts. Caliche is a minor component. Soil samples were collected for analysis.

Site 018: N 37° 51.616', W 116° 04.344' LAI = 0.120 Cover = 12.9% BRTE = 2
Visited July 24
Grassland undergoing probable conversion to BRTE which is migrating downslope. Zones of heavy growth of BRTE were associated with bioturbation probably by ground squirrel. The line-point transect again recorded seven perennial species for this site: sand dropseed (LAI=.020, cover=6.9%), Nevada ephedra (LAI=.040, cover=3.0%), galleta grass (LAI=.040, cover=2.0%), ball cactus (LAI=.020, cover=1.0%), needlegrass (LAI=0, cover=2.0%), budsage (LAI=0, cover =1.0), desert milk aster (LAI=0, cover=1.0%). BRTE infestation was judged to be 2, light infestation with patches of BRTE dominance.

This site is located midway up an alluvial fan of 3-5 degree slope. Clasts in the soil are rhyolite (volcanic tuff) suggesting that this is the major parent material. Rhyolite is altered and oxidized. Samples were collected for analysis.

Site 019: N 37° 47.902', W 116° 06.570' Estimated Cover = 15% BRTE = 2
Visited July 24
Grassland transitional to upslope shrubland. Like in 018, heavy patches of BRTE coincided with mounds of rodent bioturbation. Visual estimates of perennials by decreasing order of importance is sand dropseed, galleta grass, snakeweed, big sagebrush. Overall BRTE infestation judged at 2.

This site is on a bajada from the southeastern flank of the Kawich Range. The soil contains clasts of rhyolite and is moderately well developed. A desert pavement is moderately well developed and comprised of volcanic tuff. Vesiculated soil was present.

Site 020: N 37° 47.365', W 116° 05.867' Estimated Cover = 15-20% BRTE = 1
Visited July 24.
Perennial vegetation on this site in order of importance was galleta grass, sand dropseed, shadscale, and winterfat forming 15-20% cover. No duff (dead mulch-like material, much like thatch in a cultivated lawn) was visible, whereas in all sites noted above where BRTE is present at an infestation of 2 or more, duff generated over the past three growing seasons was visible. BRTE infestation was judged to be 1.

This site contains soils that are like those of site 019 except, being located on a shallower slope nearer the valley floor contains generally smaller clasts. A desert pavement is more strongly represented than on site 019 and derived from volcanic tuff.

Site 021: N 37° 48.455', W 116° 11.330' Estimated Cover = 15% BRTE = 0
Visited July 24.
Needlegrass was dominant with winterfat, spiny horsebush, and big sagebrush also present. No BRTE was found. Total cover was about 15 %.

This site is located in small hills derived from tuff that are southwest of the Southern rampart of the Reveille Range. The soil contains pebbles and sand-sized grains of rhyolite that are weakly developed into a desert pavement.

Site 022: N 37° 51.110', W 116° 13.681' Estimated Cover = 20% BRTE = 0
Visited July 24.
Total cover was estimated to be about 20% dominated by big sagebrush, galleta grass with occasional Greene's rabbitbrush. No BRTE was found.

This site is on the floor of Reveille Valley and has a strongly developed desert pavement of volcanic tuff pebbles. . Bald patches between shrubs covered desert pavement were highly vesiculated. The soil is moderately well developed and probably of volcanic tuff origin.

Site 023: N 37° 52.233', W 116° 14.292' Estimated Cover = 15% BRTE = 0
Visited July 24
Total cover was estimated at about 15% with perennial species in order of importance: galleta grass, rubber rabbitbrush (very short, ca. 40 cm) and budsage. BRTE was absent.

Patches of vesiculated desert pavement were present. The desert pavement clasts are of volcanic tuff origin that suggests that this is a dominant parent material.

List of Plant Species Recorded on Field Trip:

The plant species that were measured or observed on the field trip are presented in the following table. Nomenclature and authorities are from Hickman, J.C. 1993. *The Jepson Manual: Higher plants of California*. University of California Press.

Common Name	Scientific name	Species Abbreviation
grasses:		
desert needlegrass	*Achnatherum speciosum* Trin. And Rupr. Barkworth	STSP
galleta grass	*Pleuraphic jamesii* Torrey	HIJA
Indian ricegrass	*Achnatherum hymenoides* (Roemer & Schultes)	ACHY
sand dropseed	*Sporobolus cryptandrus* (Torrey) A. Gray	SPCR
three awn	*Aristida* sp.	ARIS
forbs:		
globemallow	*Sphaeralcea ambigua* Gray	SPAM
shrubs:		
big sagebrush	*Artemisia tridentata* (Nutt.)	ARTR
budsage	*Artemisia spinescens* D. Eaton	ARSP
four-wing saltbush	*Atriplex canescens* (Pursh) Nutt.	ATCA
Green ephedra	*Ephedra viridis* Colville	EPVI
Greene's rabbitbrush	*Chrysothamnus greenei* (A. Gray) E. Greene	CHGR
Nevada ephedra	*Ephedra nevadensis* S. Watson	EPNE
rubber rabbitbrush	*Chrysothamnus nauseosus* (Pallas) Britton	CHNA
shadscale	*Atriplex confertifolia* (Torr. & Frem.) S. Wats.	ATCO
snakeweed	*Gutierrezia microcephala*	GUMI
spiny hopsage	*Grayia spinosa* (Hook.) Moq.	GRSP
spiny horsebush	*Tetradymia spinosa* Hook. & Arn.	TESP
winterfat	*Krascheninnikovia lanata* (Pursh) A.D.J. Meeuse & Smit	CELA
trees:		
single-leaf pine	*Pinus monophylla* Torrey and Fremont	PIMO
Utah juniper	*Juniperus osteosperma* (Torrey) Little	JUOR

Discussion of Vegetation Sampling Results:

The main goal of the measurement and estimation of vegetation cover and composition was to provide ground-truth information for training computer-aided recognition of BRTE infestation in satellite data. This was accomplished at 20 sites with the numerical rating from 0 to 5, described above.

The visual rating of *Bromus* infestation is somewhat subjective and inferior to actual measurement. However, given constraints of budget and time, measurement was not warranted during the 1999 growing season because preceding conditions were not conducive for BRTE

growth except in restricted locations probably reflecting the uneven spatial distribution of precipitation. Though more time consuming and costly, a superior method would be to measure *Bromus* biomass (oven-dry weight per area) determined by random plot sampling. This more intensive/expensive method should be reserved for periods following relatively wet winter when maximal expression of *Bromus* would be ensured. Such work is outside the scope of this exploratory-level study but would be required for publication that has as an objective testing whether *Bromus* is replacing shrubs.

A central hypothesis to test is that perennial vegetation, especially shrubs, are being replaced by *Bromus*. The secondary goal for this field work was to compare perennial vegetation cover to determine whether there are any clear trends that *Bromus* is replacing perennial plant cover. Figure B presents a graph that compares estimated/perennial cover versus BRTE infestation demonstrating that perennial vegetation cover decreases significantly ($p = 0.014$) as infestation increases. This was demonstrated even with a small survey-level sample (20) and measurement in areas at various stages of invasion and across many different soil parent material/geomorphic units: consequently variable chemistry and particle size distribution. Another factor concerns dynamic, pulse-driven timing: the reduction in native perennial vegetation due to BRTE probably has occurred over periods of tens of years in pulses governed by drought and wet years. As was hypothesized in Groeneveld, Fedors and Stothoff (1999; CNWRA report in final preparation phase), *Bromus* apparently replaces native shrubs when they are prevented from recruitment during wet years which is the sole time that these plants can germinate and establish. During such years, *Bromus* will germinate and grow as a basal rosette during the winter and, at seedling densities commonly reaching 10,000 or more per square meter, leave essentially no water or nutrients for the less robust and numerous seedlings of native species.

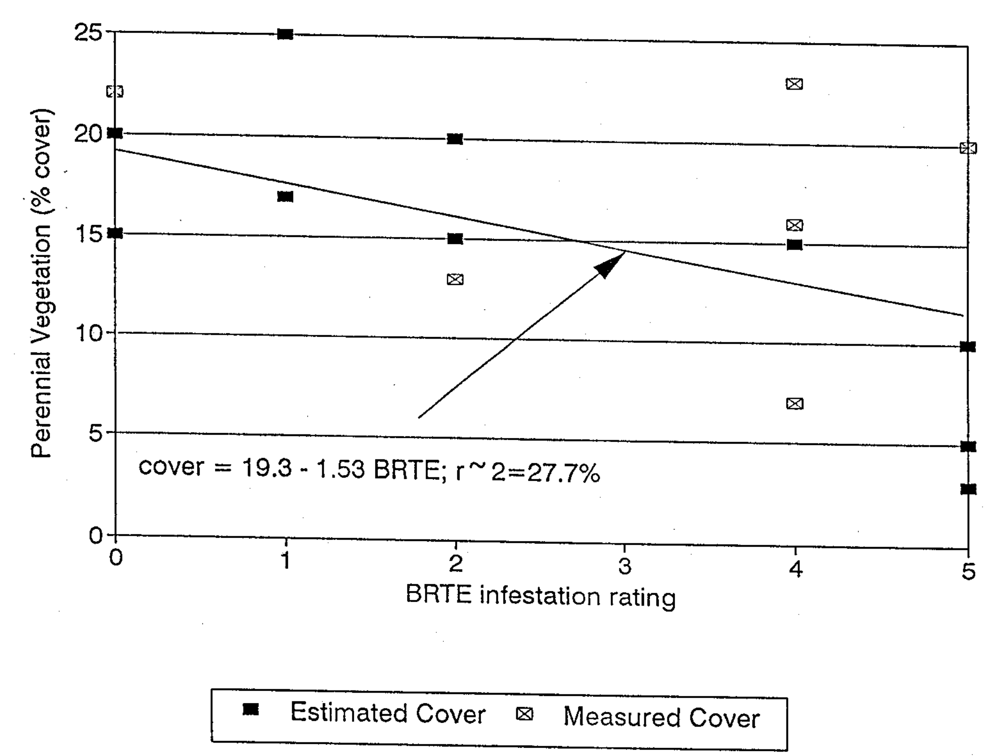
Within the study area, BRTE infestation has probably occurred relatively recently and, so, the sites sampled represent many different stages within this process. D. Groeneveld, one of the authors of this trip report, did not observe BRTE along US Highway 6 east of Tonopah (within the present study area) during 1981, 1982 and 1983, except on the floor of Stone Cabin Valley and around Warm Springs. This fact was corroborated by Valerie Metscher, BLM Range Specialist in Tonopah who noted that BRTE existed when she began working in the region in 1980.

These results are preliminary, and because of the use of field estimation and the small sample size should not be regarded as publishable results. However, if the *Bromus* issue grows beyond the exploratory stage which this field effort represents, such data could easily be developed within about 1-2 weeks of field effort. In addition, it is advisable for such follow-on studies to be conducted during a year of heavy *Bromus* growth.

The need for documentation that *Bromus* is replacing native shrubs is especially important for demonstration of the magnitude of this phenomenon to the scientific community. Although undisputedly, large areas throughout the region are dominated by BRTE, the trend of growth and dominance for this species on the native range is not generally clear. For example during the

telephone interview, V. Metscher, BLM, remained unconvinced that BRTE is actually increasing because of two factors: (i) "it's been in the area a long time" and (ii) "it's really only present during wet years". Of course, both statements are true and to the casual observer the pulse-driven decrease of native shrubs may not be obvious. Compounding this problem of conceptualization is the location of few range trend analysis plots in areas of *Bromus* infestation but that give a stilted viewpoint that *Bromus* is mainly a problem only in areas of heavy grazing. Such range trend plots also provide only a spotty record of measurement that occurs at "several year" intervals and that may not capture peaks of *Bromus* growth that are tied to the occasional wet year. Finally, this spotty record and the trend for choosing measurement sites probably tends toward the interpretation that "all areas of heavy *Bromus* infestation are the result of disturbance (over grazing). From our field aerial observation, this is simply not the case because many locations sporting heavy *Bromus* are outside of grazing pressure by cattle and receive only light pressure from wild horses.

Figure B. A graph comparing percent cover of perennial vegetation with the level of BRTE infestation. The predicted relationship indicates that perennial cover undergoes significant decrease as BRTE rating increases.



Comparison of Weather from a Year with Heavy *Bromus* (1998) versus a year with relatively Light Cover of *Bromus* (1999)

Field observations during 1998 and 1999 in the Tonopah region indicate that conditions were not conducive for heavy *Bromus* growth during 1999, even on patches of BRTE that were obviously very vigorous and dominant during 1998. Classification of *Bromus* on satellite images will require that sufficient signature is available to be distinguishable from light soil background in shrub cover. Thus, an understanding of the weather factors that drive *Bromus* growth is essential for reconstructing which years of historic satellite data should be purchased for tracking the growth and spread of *Bromus*.

Monthly precipitation totals for 1996, 1997, 1998 and 1999 through July were transcribed from the data sheets at the Tonopah Airport. These data are presented in Figure C. The 1997-1998 rainfall fostered heavy BRTE growth while during 1996-1997 and 1998-1999, regional BRTE growth was sparse.

Figure C. Graph of monthly total precipitation measured at Tonopah Airport. The total precipitation for September through March for three periods was calculated for three growing season. Total precipitation for the period of September through June was 1996-1997--3.8' inches, 1997-1998--8.91 inches, and 1998-1999--5.95 inches.

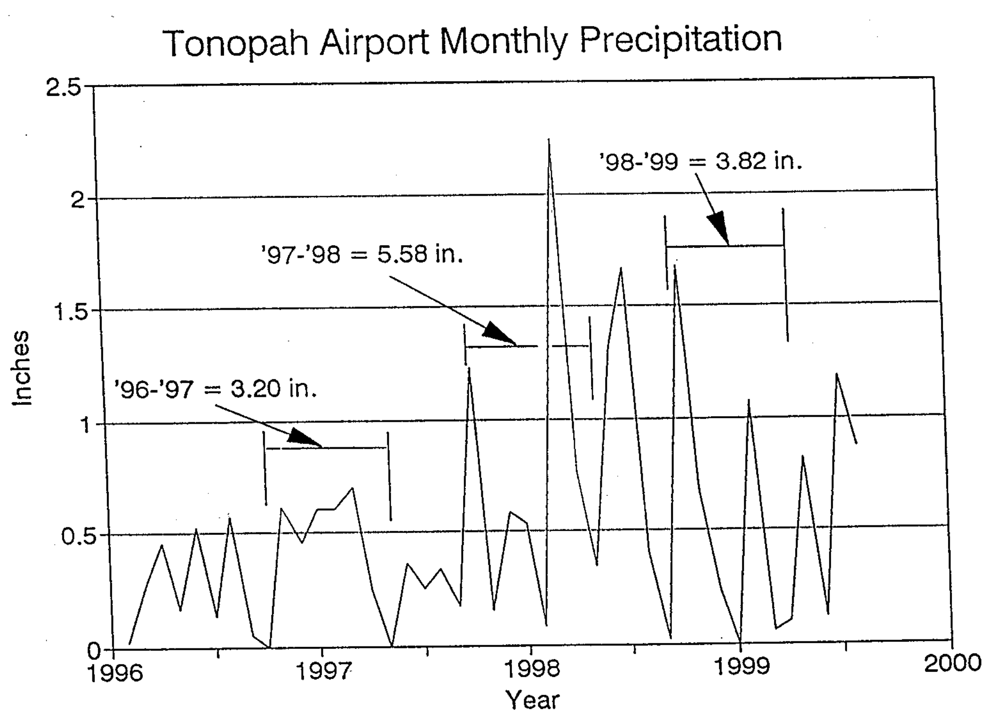


Table 1 presents the monthly precipitation data for further discussion. Because *Bromus* germinates in the fall, to then become established over winter, an analysis of the timing of precipitation is probably as important as the total amount. For example if the entire amount of precipitation received during 1997-1998 (which fostered regional heavy growth) had occurred at the end of March, probably conceivably little or no *Bromus* growth would have occurred.

Table 1. Tonopah Precipitation data in inches.

	1996	1997	1998	1999
January	0.02	0.60	0.08	1.08
February	0.26	0.70	2.25	0.06
March	0.45	0.24	0.76	0.10
April	0.16	0	0.34	0.82
May	1.52	0.36	1.32	0.12
June	0.13	0.25	1.67	1.19
July	0.57	0.33	0.40	0.87
August	0.05	0.17	0.02	N.A.
September	0	1.23	1.68	N.A.
October	0.61	0.15	0.67	N.A.
November	0.45	0.58	0.23	N.A.
December	0.60	0.53	0	N.A.

A number of distinct stages can be recognized in *Bromus* phenology. These stages are (i) germination, (ii) establishment and growth of a basal rosette through the winter, (iii) bolting (rapid growth of a stem and inflorescence), (iv) flowering and seed set and senescence. The water requirement for each of these is very different. Germination occurs in early to late fall with the onset of winter precipitation for germination to occur, the seeds need to remain wet for at least a week to provide for seed imbibition--a heavy precipitation event or a period of events is necessary for this process. The period of establishment and growth as a basal rosette probably requires occasional input of precipitation to permit for root and leaf growth but much less than at other times of the year because of the reduced winter ET demand. Sufficient precipitation must occur during the basal rosette stage to acquire stored energy sufficient for bolting. Finally, residual soil water or additional precipitation provides the needed stores to fund flowering and seed set. The last stage, characterized by the plant gradually drying out is accomplished with or without additional precipitation.

From Figure C and Table 1 it is apparent that very low precipitation during the late winter months may prevent the growth of *Bromus* for the season. Aborted BRTE as is visible in Figure 1 were particulary noticeable at many of the study sites. At other sites, lack of any remnants from the 1999 growing season suggests that either germination failed or that little or no growth had occurred following germination. If so, the significant precipitation measured at Tonopah (1.68 inch) which fell during early September of 1998 may have been too early and ET demand still too high (hot and dry) to foster and maintain a competent cover of BRTE. Likewise, even where germination did permit germination and initial growth, low precipitation during the 1998 and 1999 winter months, especially only 0.16 inch of precipitation for February and March, may have been responsible for the failure of the 1999 *Bromus* crop (see Figure A).

Field observations during 1998 disclosed one of the highest activities of *Bromus* in the region seen by the authors of this trip report. It is important to note that all periods of precipitation supply were met: perhaps first with germination following 1.23 inches in September, and maintenance by light precipitation during October, November and December. Although January precipitation was scant (0.08 in.) such low mid-winter levels may not be that important because of the low ET demand. In February, heavy events much of it in the form of snow that melts and recharges rather than running off, provided 2.25 inches of water that were followed by additional maintenance precipitation through April. May and June were then comparatively wet which provided for excellent bolting, flowering and seed set. A field trip to the region at the end of June showed that BRTE was active and at the peak of seed set before the onset of senescence.

Knowing the triggering precipitation for *Bromus* growth is important for an analysis of satellite data because the spread of this plant can best be tracked for years with weather that is conducive for its growth. The foregoing discussion and comparison can be used for choosing which years provide suitable growth to track within satellite data.

Aerial Reconnaissance and Stereo-Pair Nadir-look photographs

Stereo pair, nadir-look air photographs were obtained of select points within the study area to further assist training computer aided recognition of BRTE infestation. The photographs were taken over a variety of parent materials, perennial vegetation and levels of BRTE infestation. The points that were chosen for photography have obvious mosaic patterns of vegetation cover that provide several covertypes/soil types per photo pair to build the greatest utility for assisting training computer aided recognition.

A GPS waypoint was obtained for stereo pair of air photographs. The waypoint was taken between the two air photographs and so the center point represents the center of the overlap of the two air photographs. For comparing these photos with the satellite data the visible mosaic of vegetation can be used once the positioning of the photograph is projected onto the image.

The data for the air photographs is provided in an appendix to this report. The degree of BRTE infestation on the second photograph (always designated "b") of each pair was overlain with an

acetate template ruled in 2 x 2 inch squares. The degree of BRTE infestation was then estimated according to the *Bromus* infestation key presented in this report and by comparison to the texture and coloration of the vegetation observed within the entire set of photo pairs, within the particular photo evaluated and utilizing field notes from locations that were visited and documented on the ground.

Spectrometer Data of Senesced *Bromus* Canopies, Bare Soil and Other Surfaces

Michael to write this and to include the following:
(1) description of measurement technique and averaging algorithm for developing representative spectra representative of what a satellite would "see"
(2) spectra from heavy BRTE patch
(3) spectra from two (or so) bare soil patches, one highly reflective and one relatively dark
(4) spectra from heavy BRTE infestation area: e.g., site 15
(5) any other stuff that may be germane.

Observations About Bromus Infestation, Regional Soils and Remote Sensing

Within shrub communities, BRTE infested zones show up very well against the background of shrubs, especially when viewed at an oblique angle (Figure D-1). Because of the low cover of BRTE during the dry 1999 growing season, nadir views show very low signature of BRTE. (D-2 and -3). Oblique views provide better identification of BRTE canopies for two reasons that include upright stem remnants from the previous year and duff, mostly from last years growth that sits in the interstices of rocks to reflect light at low angles. This duff material was present on all sites that were highly infested with BRTE and consists principally of old stem and leaf fragments that are almost horizontal.

From observations of the patterns of BRTE growth as shown on Figure D it is evident that there tend to be soil-induced differences of growth at least in the initial stages of invasion. Ultimately, some promotional influence provided by this or that soil factor will probably eventually be unimportant as BRTE fills in and establishes dominance. This hypothesis arises from the observation that BRTE was found to dominate on virtually all soils encountered. As yet, why BRTE is initially favored in one location over another is poorly understood.

Figure E shows a portion of Reveille Valley which is undergoing invasion of BRTE from the north where it dominates the vegetation in the region around Warm Springs. Large areas of Reveille Valley remain free of BRTE and, like Southern Railroad Valley, appears to be subjected to two patterns of invasion. In shrub communities BRTE appears to invade and establish dominance to largely replace native shrubs. In native vegetation dominated by grasses, in particular galleta grass, this cycle of invasion, dominance and replacement may be different because the perennial grasses appear to be able to compete with, but not exclude BRTE. Galleta grass was found to be doing relatively well in areas of moderate BRTE invasion, for example at

Site 016, a colluvial slope of basalt site. Whether such coexistence of native grasses and BRTE can continue is not known, however, the effect upon infiltration by replacement of deep rooted shrubs with shallow rooted grasses is probably about the same, whether the grass is a native species or an introduced *Bromus*.

Observations were made of the vegetation along the bajada of the Reveille Range in Southern Railroad Valley. In this area, BRTE is just beginning to invade and has not established dominance except in small patches associated with bioturbation from rodent activity. In these locations rodents have created numerous burrows on shallow mounds that are between 5 and 10 meters in diameter. Like many invasive annual species, BRTE thrives in disturbed areas possibly because they provide a ready seedbed that is devoid of competition from established perennial plants. The pattern of BRTE growth on these sites suggests that it first establishes in these disturbed locations to then spread into the surrounding native vegetation community. If so, this suggests a mechanism where a closed plant community (i.e., there is no room or resources to support additional perennial plant cover) gradually gives way to BRTE, first a plant or two wherever a spot of bare ground exits or in a zone induced by rodent activity. This initial stage may then be followed by more and more BRTE as it competes for nutrients and water. This process continues until finally replacing the native species.

Although the exact mechanism for the replacement of native vegetation is not well understood, the fact that the replacement is occurring is fairly clear. There may be chemical as well as physical effects due to *Bromus*. Beyond simple competitive effects, the heavy duff observed where *Bromus* has become dominant suggests that allelopathic effects may exist from this material (allelopathy is where the exudate, leàchate or physical remnants from one plant may inhibit another. From field observations *Bromus* may also affect the soil structure. In areas where *Bromus* cover was absent or at low levels, vesiculated soil structure was prevalent while in other areas of heavy infestation, vesiculation was absent.

Appendix to Field Report: Data from Aerial Photo Mission

Site	Latitude (N)	Longitude (W)	BRTE rating	Notes
024	38° 04.479'	116° 59.717'	0 0 0 / 0 0 0	No BRTE, ORHY dominant; 024 contains ground truth Site 012
025	38° 03.835'	116° 56.837'	1 2 2 / 0 3 2	This clssification suspect, minimal minimal straw color for BRTE
026	38° 05.170'	116° 54.773'	2 3 3 / 4 5 5	BRTE dominates raised and weathered basalt
027	38° 06.256'	116° 53.375'	5 5 5 / 5 5 5	BRTE dominates in patches on rhyolite and basalt hills; 027 contains ground truth Site 004
028	38° 06.620'	116° 51.938'	3 5 4 / 4 5 3	Patterns of BRTE evident by low shrub cover
029	38° 05.071'	116° 47.308'	3 5 3 / 4 5 5	Note exclusion of shrubs in BRTE zones, poor BRTE signal (light straw color)
030	38° 02.051'	116° 43.133'	5 5 5 / 5 5 5	BRTE zones very smooth--(like like contrasting with shrub cover. 030 contains ground truth Site 013
031	38° 02.336'	116° 39.957	0 2 3 / 0 2 3	BRTE as buff-colored patches
032	38° 00.817 '	116° 36.942'	5 5 5 / 5 5 5	BRTE following drainages, v. heavy
033	38° 00.670'	116° 35.424'	4 5 5 / 3 4 4	BRTE is buff colored, very evident On basalt hill and terrace
034	38° 02.548'	116° 32.644'	2 2 5 / 2 4 5	BRTE v. heavy below break in slop (to right) and on small hill
035	38° 0.3839'	116° 30.237'	5 5 5 / 5 5 5	heavy BRTE growth this year in drainages, otherwise in patches
036	38° 04.665'	116° 28.708'	3 3 5 / 5 5 5	Intact ARTR in drainage of 1a and 2a, contrasts w/heavy BRTE cover
037	38° 05.863'	116° 29.916'	4 5 5 / 4 5 5	v. heavy BRTE on bajada, otherwise v. heavy in drainages, invading on hillslopes; 037 contains 005, 006 and 014
038	38° 06.102'	116° 26.839'	2 5 4 / 3 5 5	BRTE is patchy and appears to dominate zones of rock outcrop
039	38° 07.540'	116° 22.385'	3 3 4 / 4 5 5	BRTE patchy and dminating light-colored formation-- terrace/bajada; 039 contains ground truth Site 015

numbers refer to level of BRTE infestation as described on page 29-30 116-117 of Sci. Notebook

Site	Latitude (N)	Longitude (W)	BRTE rating	Notes
040	38° 06.364'	116° 21.360'	5 4 3 5 4 2	BRTE in large nearly pure patches
041	38° 02.987'	116° 21.183'	3 4 2 4 4 2	BRTE not dominant in drainages, V. light yellow color, suspect class.
042	37° 58.441'	116° 19.621'	0 0 0 0 0 0	BRTE known to be absent, grassy patches are HIJA; compare 041
043	37° 57.140'	116° 19.226'	2 2 2 3 4 5	BRTE invading basalt--heaviest on slopes
044	37° 57.879'	116° 16.056'	3 4 4 0 0 0	ridge in 21 and 31 and bowl in 3a, 3b and 2b have heaviest BRTE-basalt
045	37° 58.893'	116° 14.108'	2 3 3 1 3 3	BRTE distinguishable by yellow color
046	37° 59.167'	116° 19.188'	4 4 3 3 2 0	heaviest BRTE concentration on basalt butte
047	37° 55.604'	116° 15.285'	4 3 3 4 1 0	invasion appears to be from upper left
048	37° 56.065'	116° 10.692'	1 4 3 2 2 2	very patchy BRTE, purest patch at border of 2b and 3b
049	37° 55.635'	116° 12.130'	4 4 4 4 4 3	BRTE appears as yellow-brown patches w/ low shrub cover
050	37° 54.143'	116° 10.895'	2 2 1 1 2 1	BRTE is heaviest in drainages
051	37° 50.554'	116° 05.850'	4 4 2 2 2 1	BRTE "scalds" between drainges, probably mixed with HIJA
052	37° 50.274'	116° 04.168'	2 2 2 1 1 1	patchy BRTE appears to be spreading from loci
053	37° 48.395'	116° 06.195'	0 0 0 0 0 0	BRTE known to be present but uncommon; note wild horse herd
054	37° 45.873'	115° 59.415'	4 4 3 2 2 1	BRTE dominant in patches in 1a, 2a 054 contains ground truth Sites 010 and 011
055	37° 48.494'	115° 57.021'	5 5 4 3 3 2	BRTE visible as yellow-brown, smooth texture
056	37° 48.483'	115° 57.584'	5 5 5 5 5 4	BRTE very distinct as smooth yellow-brown
057	37° 48.113'	115° 57.584'	5 5 2 0 0 0	abupt transition on parent material

[by FAX, 2 pages]

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December 22, 1999

Memorandum

TO: Randy Fedors, CNWRA
FROM: David Groeneveld

RE: Attached Soils Data Analyzed for Samples Collected in July--Add to Complete Trip Report

The USU Soils Lab finally came through with the data for the soils we collected in July. Recall that we were interested in some rough indicators of soil properties to again determine whether there was a discernable difference between sites infested with Bromus and adjacent sites where this species had not yet invaded en masse. Recall that we developed a classification representing *Bromus*, where 0- none, 1- just a few, 2- heavier but patchy, 3- heavy but original vegetation doing well, 4- very heavy with patches of native vegetation giving way to *Bromus*, and 5- very heavy *Bromus* dominating native vegetation. See draft of Trip report sent earlier.

In quick overview, the sampling points were as follows:

Site	Depth (Cm)	Vegetation	pH	EC (dS/m)	Texture
012	0-5	no Bromus(0),	7.8	0.2	loamy sand
	10-20	20% cover, 0.119 LAI	8.2	0.3	sandy loam
013	0-5	heavy Bromus (3),	7.1	0.1	sandy loam
	10-20	22.8% cover, 0.159 LAI	7.1	0.25	sandy loam
014	0-5	very heavy Bromus (4),	7.1	0.1	loamy sand
	10-20	15.8% cover, 0.079 LAI	7.3	0.3	sandy loam
015	0-5	very very heavy *Bromus* (5),	7.3	0.5	sandy loam
	10-20	19.9% cover, 0.040 LAI	8.0	0.45	sandy loam
017	0-5	no *Bromus* (0),	7.7	0.35	loamy sand
	10-20	21.8% cover, 0.218 LAI	7.8	0.45	loamy sand
018	0-5	*Bromus* present (2)	7.0	0.3	sandy loam
	10-20	12.9% cover, 0.12 LAI	7.8	0.45	loam/sandy loam

These results test and support our hypothesis that there is no overt physico-chemical factor that favors *Bromus* infestation. Instead, *Bromus* is taking over in a wide variety of environments without much resistance, edaphic or vegetative. I'm available to finalize the trip report.

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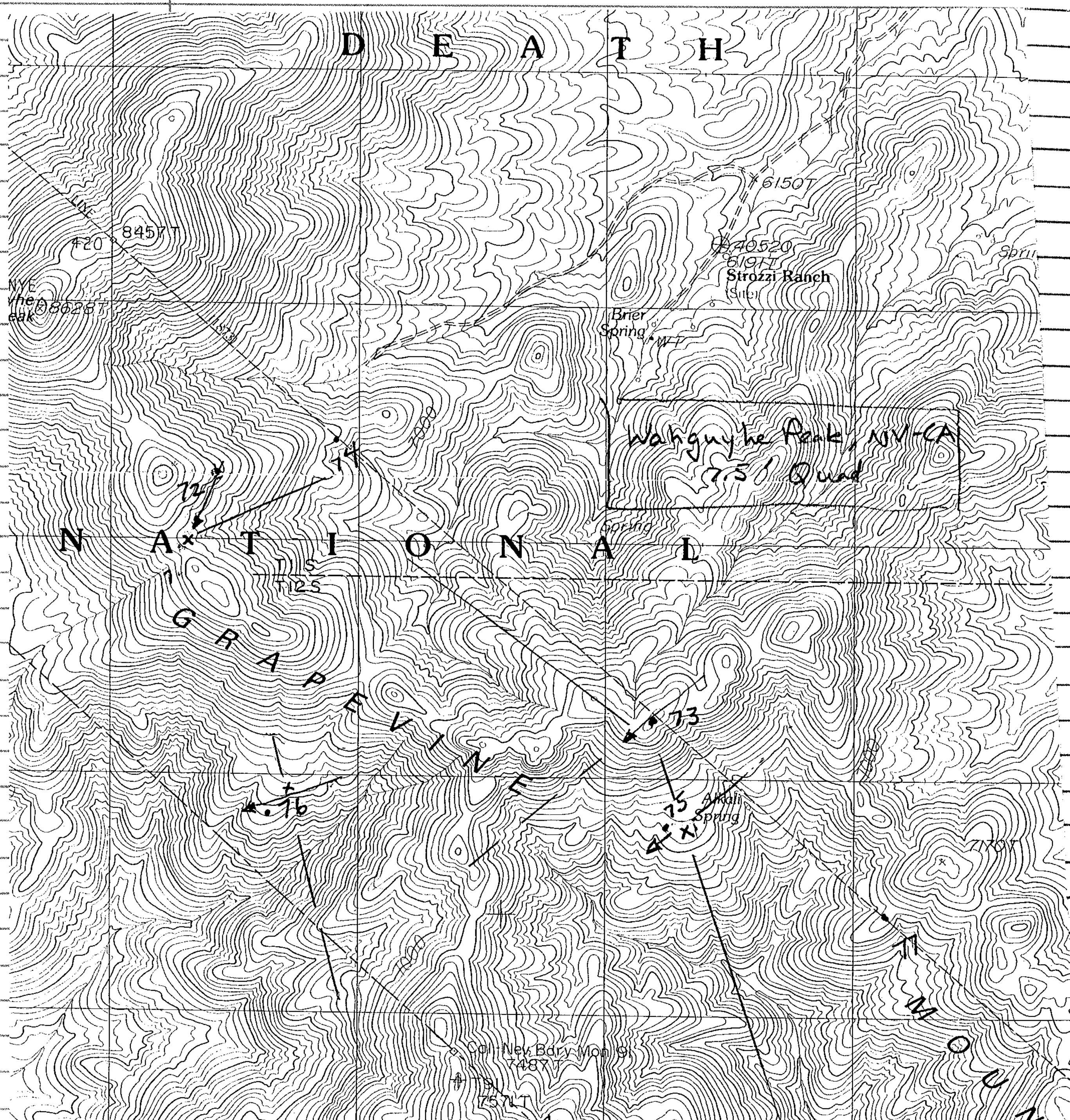
September 15, 1999

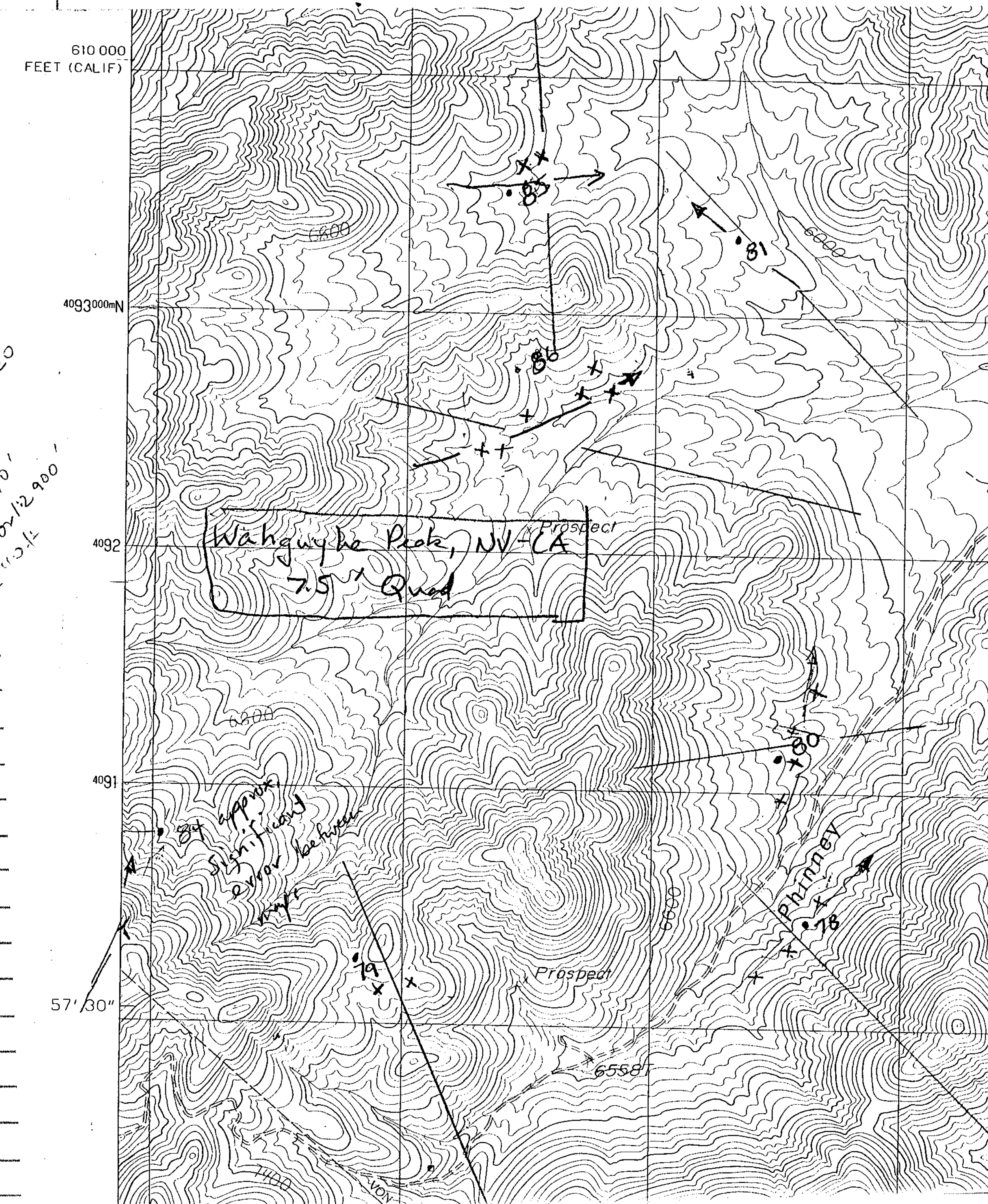
This final photo mission was flown over the Grapevine Mountains to add to the data base for analyzing forest cover versus elevation. The sites chosen were all relatively level, having slopes of less than about 5 °. The resulting photographs were analysed using the a stereological grid with 255 points to determine (1) the relative tradeoff between shrub and tree cover at a site with the same elevation and lithology but little slope (thus permitting combination of data from the Grapevine mountains and from Yucca Mountain , and (2) the relationship of vegetation cover with elevation, aspect and slope that were used in the model developed by S. Stothoff.

Pages 124-126 : Topographic maps showing the location of GPS waypoints and the air photo flightlines and direction flown that cross over the waypoint. Sites were selected along each flightline. Photographs and negatives are maintained in Hydro-Biological Archives entitled "Climate Analog Sites (2)". Individual plots that were evaluated are indicated on the photographic prints.

Pages 127-133 : Analysis results examining the tradeoff between shrubs and trees at the ecotone between all shrub cover and forest

Pages 134-142 : Analysis results for determining vegetation cover on level or gentle slopes.


D E A T H
N A T I O N A L
GRAPEVINE
MOUN
Strozzi Ranch
Brier Spring
Alkali Spring
6150T
8457T
Wahguyhe Peak, NV-CA
7.5' Quad
72
73
74
75
76


610 000
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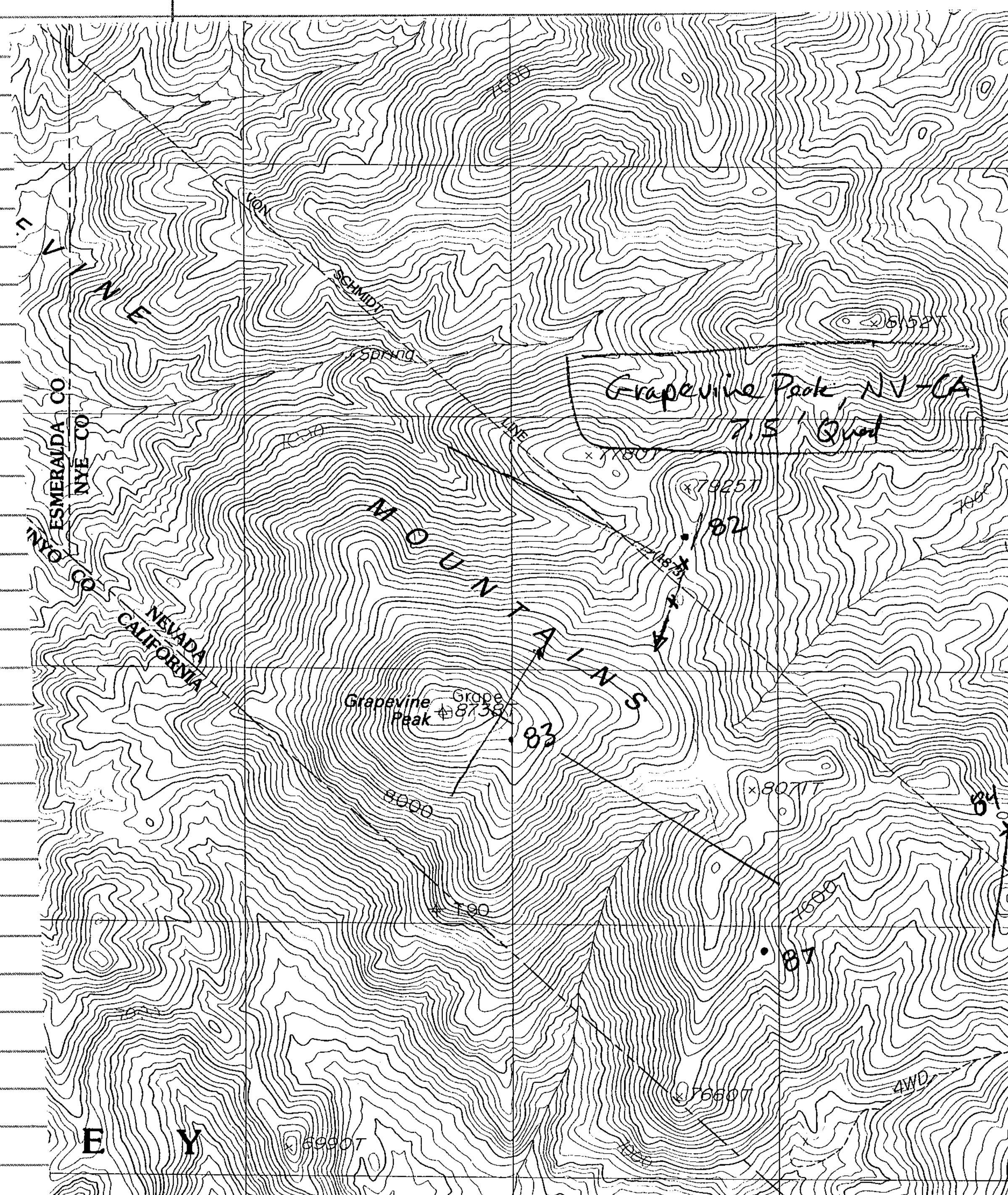
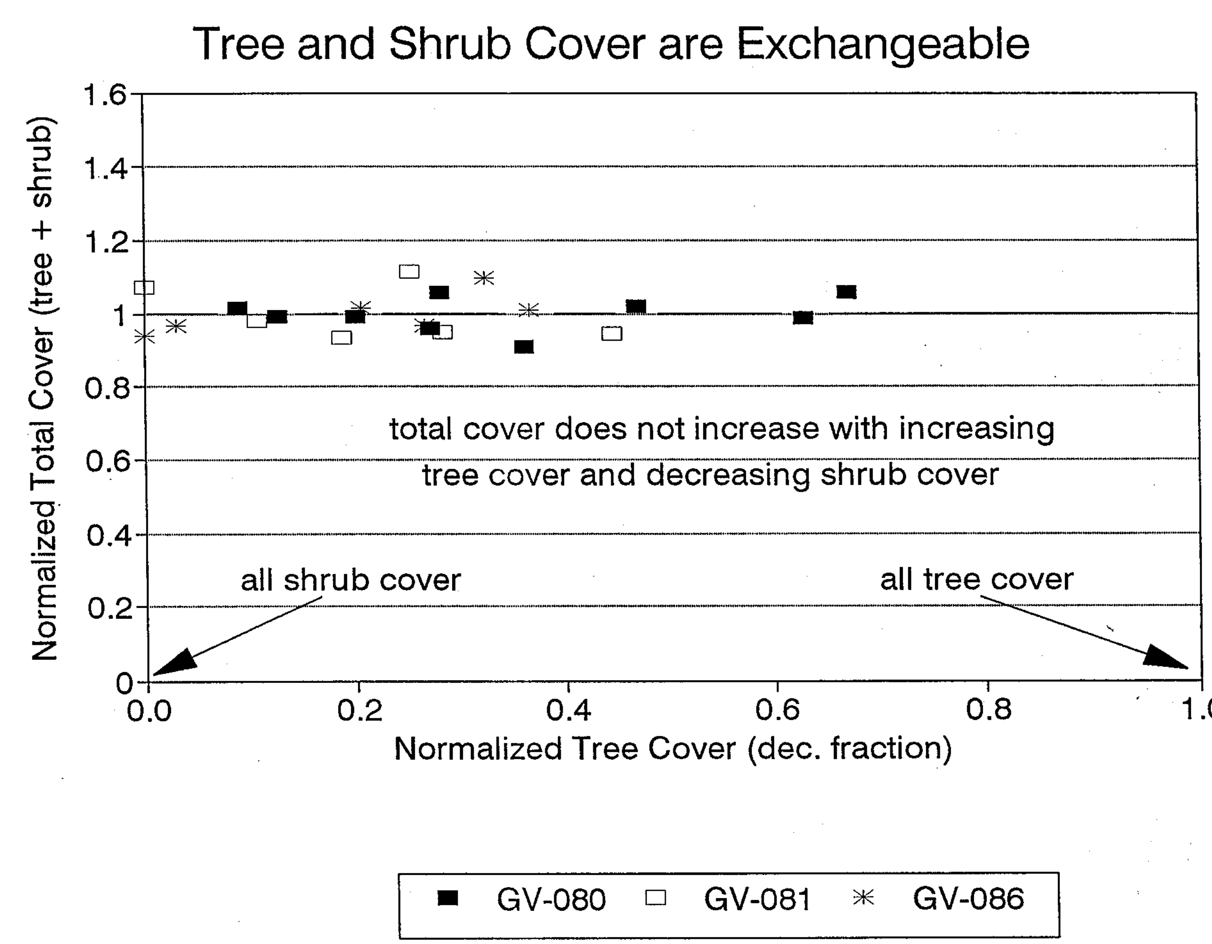


Figure 3 "TEST"



Test.. MTW

MTB > prin c1-c6

ROW	tree80	shrb80	tot80	tree81	shrb81	tot81
1	60	166	226	47	161	208
2	134	77	211	35	139	174
3	27	185	212	20	163	183
4	143	83	226	83	93	176
5	77	117	194	0	200	200
6	100	118	218	53	124	177
7	43	169	212			
8	58	147	205			
9	19	198	217			

Using data of Shrub vs. Tree Grapevine Mtns. 80 & 81 are waypts. plotted on Wahguyhe Pk. Quad.

MTB > prin c7-c12

ROW	Ntr80	Nshrb80	Ntot80	Ntr81	Nsh81	Ntot81
1	0.281	0.891	1.059	0.252	0.864	1.116
2	0.628	0.413	0.989	0.188	0.746	0.934
3	0.126	0.993	0.993	0.107	0.875	0.982
4	0.670	0.445	1.059	0.445	0.499	0.945
5	0.361	0.628	0.909	0.000	1.073	1.073
6	0.469	0.633	1.021	0.284	0.665	0.950
7	0.201	0.907	0.993			
8	0.272	0.789	0.960			
9	0.089	1.063	1.017			

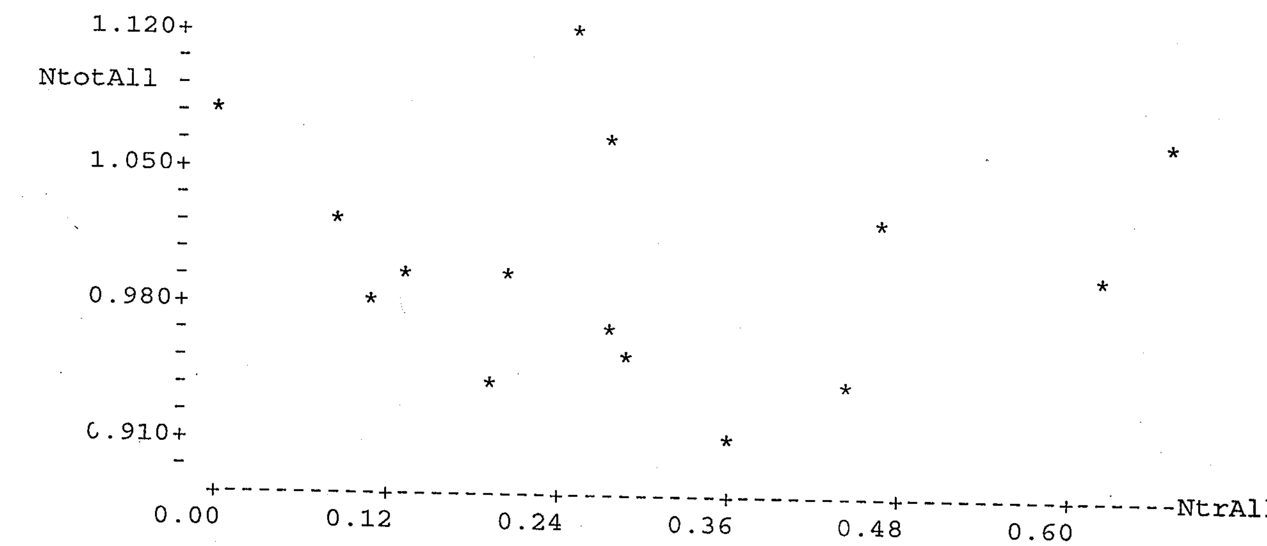
N... represents Normalized data divide by Mean total

3 > prin c13-c15

ROW	NtrAll	NshAll	NtotAll
1	0.281	0.891	1.059
2	0.628	0.413	0.989
3	0.126	0.993	0.993
4	0.670	0.445	1.059
5	0.361	0.628	0.909
6	0.469	0.633	1.021
7	0.201	0.907	0.993
8	0.272	0.789	0.960
9	0.089	1.063	1.017
10	0.252	0.864	1.116
11	0.188	0.746	0.934
12	0.107	0.875	0.982
13	0.445	0.499	0.945
14	0.000	1.073	1.073
15	0.284	0.665	0.950

N ... All

MTB > plot c15 c13



MTB > regr c15 1 c13

The regression equation is
NtotAll = 1.01 - 0.0176 NtrAll

Predictor	Coef	Stdev	t-ratio	p
ıstant	1.00513	0.02863	35.10	0.000
NcrAll	-0.01759	0.08266	-0.21	0.835

s = 0.05988 R-sq = 0.3% R-sq(adj) = 0.0%

Analysis of Variance

SOURCE	DF	SS	MS	F	p
Regression	1	0.000162	0.000162	0.05	0.835
Error	13	0.046620	0.003586		
Total	14	0.046782			

MTB > nopaper

MTB > prin c1-c3

ROW	TreeCov	ShrbCov	Cover
1	118	325	443
2	263	151	414
3	53	362	415
4	280	163	443
5	150	229	379
6	196	231	427
7	140	331	471
8	142	288	430
9	74	388	462

MTB > plot c3 c1

```
         -                         *
Cover    -
         -            *
         -
      450+
         -                    *                               *
         -
         -                         *
         -                                    *
      420+
         -        *                                         *
         -
         -
         -
      390+
         -
         -                           *
           ------+---------+---------+---------+---------+---------+TreeCov
               50       100       150       200       250       300
```

MTB > nopaper

MTB > prin c13-c15, c16-c18

ROW	NtrAll	NshAll	NtotAll	Ntr86	Nsh86	Ntot86
1	0.281	0.891	1.059	0.000	0.937	0.937
2	0.628	0.413	0.989	0.267	0.701	0.968
3	0.126	0.993	0.993	0.031	0.937	0.968
4	0.670	0.445	1.059	0.366	0.645	1.011
5	0.361	0.628	0.909	0.205	0.813	1.018
6	0.469	0.633	1.021	0.323	0.776	1.098
7	0.201	0.907	0.993			
8	0.272	0.789	0.960			
9	0.089	1.063	1.017			
10	0.252	0.864	1.116			
11	0.188	0.746	0.934			
12	0.107	0.875	0.982			
13	0.445	0.499	0.945			
14	0.000	1.073	1.073			
15	0.284	0.665	0.950			
16	0.000	0.937	0.937			
17	0.267	0.701	0.968			
18	0.031	0.937	0.968			
19	0.366	0.645	1.011			
20	0.205	0.813	1.018			
21	0.323	0.776	1.098			

MTB > nopaper

1/4

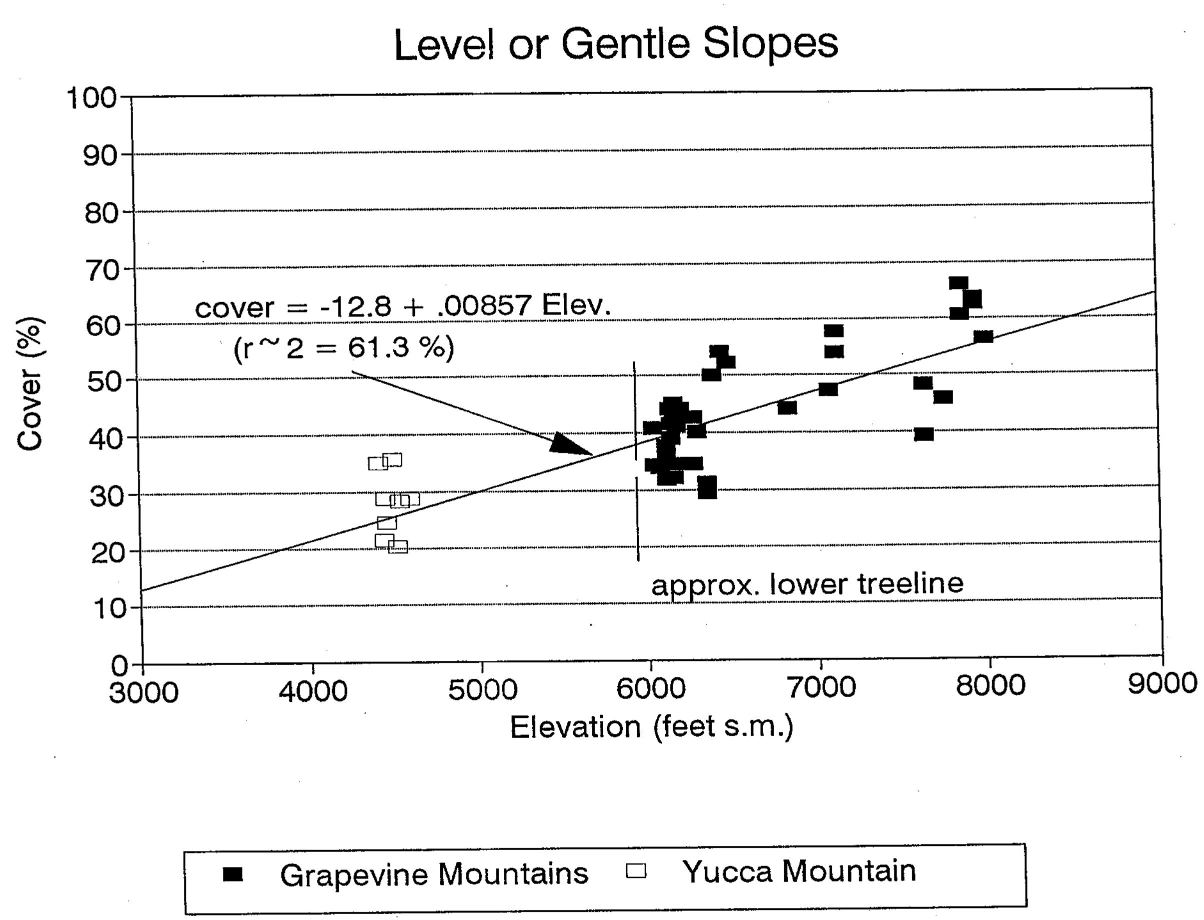
Special Study
tradeoff in cover between
shrubs & trees

	Pinyon / Juniper		Shrub		Σ
GV-080-8-1	0, 3, 13, 9, 12 0, 0, 9, 10, 4 (6.0)	11.8%	19, 21, 16, 15, 13 (16.6) 16, 23, 15, 12, 16	32.5%	44.3%
GV-080-8-2	18, 20, 9, 13, 18 8, 9, 12, 10, 17	26.3%	10, 5, 3, 7, 4 8, 13, 13, 10, 4	15.1%	41.4%
GV-080-8-3	0, 0, 3, 0, 10 4, 10, 0, 0, 0	5.3%	20, 20, 17, 22, 17 17, 14, 23, 19, 16	36.2%	41.5%
GV-080-8-4	23, 15, 9, 10, 18 12, 16, 16, 8, 16	28.0%	2, 5, 8, 8, 11 11, 9, 8, 11, 10	16.3%	44.3
GV-080-8-5	7, 8, 7, 14, 0 8, 3, 11, 9, 10	15.0%	11, 13, 12, 9, 18 9, 10, 14, 10, 11	22.9%	37.9
GV-080-4-1	14, 11, 15, 5, 7 5, 11, 18, 4, 10	19.6%	12, 7, 10, 19, 11 17, 13, 7, 18, 4	23.1%	42.7
GV-080-4-2	0, 7, 0, 0, 0 7, 6, 7, 6, 10	8.4%	23, 13, 20, 18, 23 16, 15, 14, 14, 13	33.1%	41.5
GV-080-1-1	8, 0, 6, 0, 3 5, 13, 9, 2, 12	11.4%	10, 22, 14, 17, 17 12, 11, 21, 15, 8	28.8%	40.2
GV-080-1-2	0, 5, 0, 0, 2 0, 3, 0, 6, 3	3.7	20, 20, 19, 21, 18 24, 18, 23, 19, 16	38.8%	42.5

1/2

	Σ		P/J	Shrub	
GV-081-3	(40.8)	9.2%	16, 7, 9, 0, 0 0, 9, 6, 0, 0	8, 7, 11, 20, 27 19, 14, 17, 28, 10	31.6%
GV-081-4	(34.1)	6.9%	0, 9, 0, 0, 9 0, 12, 0, 5, 0	20, 6, 15, 16, 15 16, 10, 15, 9, 17	27.2%
GV-081-6	(35.9)	3.9%	5, 0, 6, 0, 0 9, 0, 0, 0, 0	14, 18, 15, 14, 16 15, 18, 17, 20, 16	32.0%
GV-081-3-1	(34.5)	16.3%	8, 17, 16, 0, 0 23, 9, 10, 0, 0	9, 6, 9, 16, 13 2, 8, 4, 18, 8	18.2%
GV-081-6-1	(39.2)	0%	0, 0, 0, 0, 0 0, 0, 0, 0, 0	22, 20, 19, 19, 23 18, 19, 20, 25, 15	39.2%
GV-081-5	(34.7)	10.4%	3, 12, 8, 2, 4 12, 11, 0, 7, 4	13, 5, 15, 20, 8 10, 7, 20, 10, 14	24.3%

Figure 4 "Master"



Analysis of vegetation cover — Grapevine Mtns

	Data	$\bar{x}$	Cover	Notes
GV-072-4 PJ	20, 26, 21, 16, 25 30, 20, 30, 29, 16	23.3	45.7%	twice because of large scale
GV-073-2 PJ	29, 19, 19, 26, 9 14, 32, 28, 8, 17	20.1	39.4%	"
GV-073-4 PJ	17, 27, 25, 20, 23 21, 40, 29, 24, 20	24.6	48.2%	
GV-075-4	17, 24, 24, 10, 34 38, 30, 26, 22, 17	24.2	47.4%	
GV-076-3	35, 19, 9, 30, 31 23, 20, 32, 18, 9	22.6	44.3%	
GV-078-2	28, 25 29, 24, 25 25, 26, 30 31, 23	26.6	52.2%	
GV-078-4	32, 34, 19, 23, 25 26, 26, 33, 33 26	26.6 28.9 27.7	54.3%	
GV-078-6	27, 20, 22, 30, 19 36, 25, 28, 27, 21	25.5	50.0%	
GV-079-4	29, 28, 16, 31, 27 31, 25, 39, 25, 24	27.5	53.9%	
GV-079-6	22, 29, 31, 33, 25 32, 30, 25, 33, 35	29.5	57.8%	
GV-080-1	26, 24, 20, 15, 25 21, 21, 20, 17, 29	21.8	42.7%	
GV-080-4	18, 27, 20, 22, 30 25, 14, 22, 25, 23	22.6	44.3%	
GV-080-8	23, 27, 26, 19, 19 20, 31, 24, 21, 21	23.1	45.2%	

		x̄ hds	
GV-082-4-1	36, 38, 21, 25, 28 31, 44, 28, 27, 31	30.9	60.6 %
GV-082-4-2	31, 22, 35, 44, 42 31, 38, 33, 28, 33	33.7	66.1 %
GV-082-7-1	28, 36, 23, 37, 28 29, 32, 39, 40, 28	32.0	62.7
GV-082-7-2	33, 36, 44, 36, 30 38, 34, 40, 40, 39	32.5	63.7
GV-083-4	41, 28, 43, 36, 41 46, 38, 44, 29, 39	38.5	75.5
GV-083-6	41, 37, 36, 40, 42 42, 45, 35, 43, 38	39.9	78.2
GV-083-8	35, 48, 30, 40, 42 40, 45, 32, 42, 46	40.0	78.4
GV-083-9	46, 48, 32, 44, 41 45, 49, 45, 44, 41	43.5	85.3
GV-084-3	30, 30, 29, 24, 39 31, 28, 29, 32, 21	28.8	56.5
GV-085-3	12, 20, 17, 18, 17 15, 9, 29, 7, 16	16.0	31.4
GV-085-4	17, 17, 16, 20, 11 23, 16, 15, 14, 11	16.0	31.4

Precision Test Statistics
on 086 1/1

		tree	shrub		Σ
GV-086-1	0	0, 0, 0, 0, 0 0, 0, 0, 0, 0	17, 16, 12, 13, 12 16, 17, 21, 13, 14	15.1	29.6%
GV-086-3-1	4.3	12, 0, 0, 8, 0 12, 0, 0, 9, 2	5, 15, 8, 11, 11 14, 11, 14, 8, 13	11.3	30.6%
GV-086-3-2	0.5	0, 0, 0, 0, 0 5, 0, 0, 0, 0	13, 16, 18, 16, 15 14, 13, 16, 16, 14	15.1	30.5%
GV-086-9-1	5.9	0, 15, 0, 0, 0 15, 0, 5, 14, 10	7, 5, 15, 16, 15 0, 18, 14, 8, 6	10.4	32.0 %
GV-086-9-2	3.3	14, 5, 0, 5, 0 10, 1, 3, 0, 5	18, 6, 8, 23, 16 15, 13, 7, 13, 12	13.1	32.2%
GV-086-10	5.2	6, 0, 3, 9, 5 13, 10, 0, 0, 6	8, 12, 13, 14, 13 13, 7, 19, 11, 15	12.5	34.7%

mean total = 16.1

∴ conclude data are reasonably tight
using

Master . MTW

MTB > prin c1-c4

ROW	Elev	Aspect	slope	Cover
1	7760	64	7.2	45.7
2	7640	312	5.0	39.4
3	7640	312	5.0	48.2
4	7080	163	9.6	47.4
5	6840	160	9.6	44.3
6	6480	316	10.8	52.2
7	6440	316	10.8	54.3
8	6400	316	10.8	50.0
9	7120	158	5.8	53.9
10	7120	158	5.8	57.8
11	6280	100	6.7	42.7
12	6200	100	6.7	44.3
13	6160	100	6.7	45.2
14	6170	100	6.7	44.3
15	6180	100	6.7	41.4
16	6150	100	6.7	41.5
17	6140	100	6.7	44.3
18	6120	100	6.7	37.9
19	6240	100	6.7	42.7
20	6160	100	6.7	41.5
21	6300	100	6.7	40.2
22	6160	100	6.7	42.5
23	6040	133	3.8	40.8
24	6080	133	3.8	34.1
25	6120	133	3.8	35.9
26	6050	133	3.8	34.5
27	6150	133	3.8	39.2
28	6180	133	3.8	34.7
29	7860	297	9.6	60.6
30	7860	297	9.6	66.1
31	7940	297	9.6	62.7
32	7940	297	9.6	63.7
33	8520	120	9.6	75.5
34	8560	120	9.6	78.2
35	8600	120	9.6	78.4
36	8640	120	9.6	85.3
37	8000	197	5.0	56.5
38	6360	177	8.4	31.4
39	6360	177	8.4	31.4
40	6360	103	9.6	29.6
41	6360	103	9.6	30.6
42	6360	103	9.6	30.5
43	6120	103	9.6	32.0
44	6160	103	9.6	32.2
45	6280	103	9.6	34.7
46	4440	93	3.6	21.6
47	4460	93	3.6	24.7
48	4540	86	6.2	28.6
49	4520	274	7.5	20.4
50	4500	82	8.1	35.7
51	4450	97	11.1	29.0
52	4410	96	9.9	35.2
53	4600	259	6.0	29.0

↑ Grapevine Mtns

Yucca Mtn. ↓

MTB > plot c4 c1

```
        -
Cover   -
        -                                                         *
        -                                                        **
      75+                                                        *
        -
        -                                               *2
        -                                      *        *
        -                              *       *          *
      50+                             **              *
        -                          42*      *  *       *
        -                         *5 *                *
        -    **                   22 *
        -     ***                  2  5
      25+     *
        -     **
        -
          --------+---------+---------+---------+---------+--------Elev
               4800      5600      6400      7200      8000
```

MTB > regr c4 1 c1

	$\hat{\text{Cover}}$
3000 ft.	6.1
9000 ft.	71.5
11,000ft	93.3

```
The regression equation is
Cover = - 26.6 + 0.0109 Elev

Predictor        Coef         Stdev     t-ratio        p
Constant      -26.552         6.271       -4.23    0.000
Elev        0.0109243     0.0009584       11.40    0.000

s = 7.879       R-sq = 71.8%      R-sq(adj) = 71.3%

Analysis of Variance

SOURCE       DF          SS          MS          F        p
Regression    1      8065.9      8065.9     129.93    0.000
Error        51      3166.1        62.1
Total        52     11232.0

Unusual Observations
Obs.    Elev      Cover        Fit  Stdev.Fit   Residual   St.Resid
  2     7640      39.40      56.91       1.58     -17.51     -2.27R
 36     8640      85.30      67.83       2.37      17.47      2.32R
```

These Data Saved in GU.MTW

Site	Elevation	Aspect	Slope	Cover Fraction
72-4	7760	64°	7.2°	.457
73-2	7640	312°	5.0°	.399
73-4	7640	312°	5.0°	.482
75-4	7080	163	9.6	.474
76-3	6840	166°	9.6	.443
78-2	6480	316°	10.8°	.522
78-4	6440	↓	↓	.543
78-6	6400			.500
79-4	7120	158°	5.8°	.539
79-6	7120	158°	5.8°	.578
80-1	6280	100°	6.7°	.427
80-4	6200	↓	↓	.443
80-8	6160			.452
80-8-1	6170			.443
80-8-2	6180			.414
80-8-3	6150			.415
80-8-4	6140			.443
80-8-5	6120			.379
80-4-1	6240			.427
80-4-2	6160			.415
80-1-1	6300			.402
80-1-2	6160			.425
81-3	6040	133°	3.8°	.408
81-4	6080	133	3.8°	.341
81-6	6120	133	3.8°	.359
81-3-1	6050	133	3.8°	.345
81-6-1	6150	133	3.8°	.392
81-5	6080	133	3.8°	.347
82-4-1	7860	297°	9.6°	.606
82-4-2	7860	↓	↓	.661
82-7-1	7940			.627
82-7-2	7940			.637
83-4	8520	120°	9.6°	.755
83-6	8560	↓	↓	.782
83-8	8600			.784
83-9	8640			.85.3

	Elev.	Aspect	Slope	Cover Fraction
84-3	8000	197°	5.0°	.565
85-3	6360	177°	8.4°	.314
85-4	6360	177°	8.4°	.314
86-1	6360	103°	9.6°	.296
86-3-1	6360	↓	↓	.306
86-3-2	6360			.305
86-9-1	6120			.320
86-9-2	6160			.322
86-10	6280			.347

Yucca Mtn. Cover
Analysis - saddles

Site	Elevation	Aspect	Slope	Cover
C1	4440	93°	3.6°	21.6
C2	4460	93°	3.6°	24.7
C3	4540	86°	6.2°	28.6
C4	4520	274°	7.5°	20.4
C5	4500	82°	8.1°	35.7
C6	4450	97°	11.1°	29.0
C7	4410	96°	9.9°	35.2
C8	4600	259°	6.0	29.0

These Data added to "GV.MTW" to form "Make.MTW" and reported in Scientific notebook (1).

October 4 through 6, 1999

A series of field visits were made to climate change analog sites. These sites included Rainier Mesa, 3-Springs Canyon in the Kawich Range near Tonopah, and Timber Mountain east of the Pahroc Valley.

The most important observation made during this field trip was that these higher elevation sites, and particularly Rainier Mesa, have large amounts of internal drainage through fractures in the underlying tuff bedrock. This was particularly evident at Rainier Mesa where significant areas of the mesa top lacked discernable external drainage. Communication with DOE personnel prompted by this observation disclosed that much of the internal borings of Rainier lack calcite and significant amounts of water flux through the mountain. Compared to similar anecdotal observations within the ESF tunnel beneath Yucca Mountain discloses two hypotheses: (1) calcite deposition does not occur in cases of relatively heavy infiltration flux; (2) under conditions of climate-change induced higher infiltration, calcite which largely seals much of Yucca mountain could be dissolved; and (3) any existing fast flow paths for infiltration would expand greatly. Although this is cause for alarm, a systematic comparison of Yucca Mountain and Rainier Mesa was not been made because of the termination of the work reported here and because the extreme difficulty for access into either location as controlled by DOE.

Pages 144-147 : Field notes

10-4 [Yucca Mtn: Rainier mesa
top of Rainier mesa
Veg: PJ; Gambel Oak; sage, bitter brush; sedge UK, sticky r brush
long spined opuntia, [illegible] sp.

[redacted]

needle leaf r.b.

- soils have aeolian mixture sed. loess ?
- soil in pans w/ little evidence of surface drainage
- uncover a crack w/ soil of ca 8 cm expose cracks - and into crude 6-8 cm, is clay / silt w/ v. few fine roots [illegible] $CaCO_3$
- w/in streambed @ cable crossing some evidence (light deposition) of stream action thin fine sed: ca 4-5 cm deep over buried soil - this due to damming by excavated material pushed as a crossing to drainage ponding must have occurred upstream as downstream spill is highly eroded (deep hole 1.3 m deep) as plunge pool; much of the water for this appears to have come down cuts on either side

(another cut comes in ca 150 m upstream)

- channel is approx. trapezoidal in x.s. above second cut, 50 cm deep 80 cm wide at base & 300 cm wide @ top no appearance of flow bank full marking? suggest flows may of x.s of 40 by

Genus/Gung and Steel ? get
per Stu

10 cm deep in center area
no stones in channel are very rounded
and most are sub angular
DTRA: Larry Ashbaugh 295-7069
possible air photos
or Barbara Harris-Weil / or Gary Reynolds
RSL - ?
Darnel MacPherson OCC
is center point for this issue
drive to TPH 12.0]
10-5 [Yucca Mtn: TT: Pat Sanchez
confirm that air photos we have
are the only ones @ RSL w/ sufficient
detail to analyze veg. cover - all others
are from 16 K AGL or above
Kawich Range: 3 Spgs Basin
Hiked into approx middle of Basin:
soil mostly regolith w/ v. poor secondary
development -
veg. in drainage is willow - S. monticola?
and S. exigua, narrow leaf cottonwood,
Amelanchier alnifolia, Purshia tridentata,
Symphoricarpos sp., Prunus virginiana
- springs were located in 7 locations
- up slope veg. mostly PIMO &
JUOC with a poa with v. narrow

photos taken to write report
on species of plants in
linear leaves, Mtn. Mahogany   Cooler/wetter condition
- flow was absent in Creek in
all locations but was discharging
from canyon w/ larger catchment
to S.
- comparison of 3 spgs canyon w/
canyon to north of same size
& extent, 3 spgs. has much
greater extent of riparian veg.
- trees were seen that grow directly
from fissures,
- heavy pine nut set 11.0]
10-6 [Yucca Mtn.:
TT: J. Woodruff re: P. Sanchez's
confirmation: need cross check w/
OCC, then if still no photos,
try to obtain clearance.
- Visit Timber Mtn.: photos taken
finding: confirm trees can grow
out of rock fissures w/ little or no
soil,
- drive to LAS 10.5]
10-7 [Yucca Mtn.: fly LAS to TEX
total hours on trip were 9.1 3.5]
[Olancha: download & analyze pptn. 4.5]

End of D.P. Groeneveld
Scientific Notebook
RP for DPG 9/13/00

This Notebook [Although differently constructed] includes all essential requirements of QAP-001. Particularly, Adequate information is provided for another qualified person to reproduce the work.

E. C. P[illegible] 9/26/2000

SUPPLEMENT TO SCIENTIFIC NOTEBOOK #268

DAVID GROENEVELD
CONSULTANT

Project 20-01402-861 USFIC
Created February 1998
Closed Out September 2000

This notebook is a color copy of the notebook turned in by David Groeneveld. The copy, rather than the original, is being used for quality assurance records because the original notebook was assembled in a spiral bound notebook without consecutively numbered pages. By copying the spiral bound notebook, a permanent record has been created.

RF 9/14/00

Randall Fedors

Cross-outs initialed in red ink for DPG
RF 9/26/00

Yucca Mountain Project Documentation of Field Work and Laboratory Analyses

conducted for
Center For Nuclear Waste Repository Analysis

April 7, 1998

Prepared by David P. Groeneveld, Ph.D.
Resource Management Consulting, Inc
PO Box 3296 Telluride, Colorado 81435
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DPG 2-10-98

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2-10-98

Field Trips and Laboratory Analyses Conducted to Date

Field Trip, November 25, 1996: Familiarization.

The mountain ranges around Beatty and the portions of Yucca Mountain that lie outside (west) of the Nevada Test Site were visited with Stuart Stothoff of Center for Nuclear Waste Regulatory Analysis (CNWRA) for familiarization and conceptualization of the role of vegetation in infiltration.

Page 2: Field notes and field photos
Pages 3-8: field photos.

Field Trip, March 26 through 30, 1997: Infiltration, the role of fissures, vegetation cover and soils.

Yucca Mountain was visited with Stuart Stothoff of CNWRA and Dani Or of Utah State University (USU) for the purpose of (1) determining infiltration properties of the shallow soils and exposed rocks, (2) investigating linear vegetation features observable on air photos and their with rock fissures, (3) determining the species composition and cover of vegetation covering crystal-rich tuff caprock, and on north- and south-facing slopes and ridges composed of non-crystal-rich tuff , and (4) cursory examination (particularly texture) of soil properties from crystal rich and crystal poor sites.

Pages 9 and 10: field notes and description of plant cover. A pertinent publication is attached to the back of page 9.
Pages 11-12: data on soil samples collected during the field campaign.
Pages 13-15: summaries of field data, including graphs.
Pages 16-18: summary of point frame results.
Pages 19-20: key to species abbreviations used in point frame data.
Pages 21-31: raw field data collected using the point frame.

Laboratory Analyses, May 1997: Measurement of vegetation crown cover on low altitude, high-resolution air photos.

Plots of homogeneous vegetation were located on low altitude air photos taken over the southern end of the repository and crest of Yucca Mountain. These plots were chosen to represent crown cover on the crystal rich ruff of the caprock, and the crystal poor tuff divided into south- and north-facing slopes and the ridgelines in between.

Page 32: purpose, methods and summary of results of air photo analysis of cover.
Pages 33-35: data sheets from the air photo analysis.
Pages 35-51: copies of air photographs with locations indicated of plots evaluated for cover.

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Field Trip, June 5 through 9, 1997: Scree as an infiltration hotspot, root growth, calcite in fissures and Yucca Mountain Prow and Shoshone Mountain as a climate change analogs.

The potential role of scree on infiltration was examined by dissecting scree piles. Additional soil pits were dug to expose roots and calcite fillings at several random locations. Sample cross sections were gathered of a shrub species that is generally associated with fissures on Yucca Mountain (*Chrysothamnus teretifoius*). Two sites judged to have potential for serving as an analog for climate change were visited, Shoshone Mountain and the Prow of Yucca Mountain. This field trip was conducted in the company of Stuart Stothoff and Gordon Whittmeyer of CNWRA, Dani Or of USU, Neil Coleman of Nuclear Regulatory Commission (NRC), and David Woolhiser consulting specialist for stormflow runoff.

Pages 52-54: field notes.
Pages 54-58: field photos.

January 26 through 29, 1998: Soil depths, calcite in fissures, growth rates of shrubs and trees on south- and north-facing slopes on Yucca and Shoshone Mountains.

A series of soil pits were dug on north- and south-facing slopes on both sides of Antler Ridge to measure the depth of the soil and to confirm the presence of calcite in cracks. Soil pits were spaced 25-m apart up the slopes starting just above the zone of alluvial file in the wash bottoms. Samples of the crack-loving *Chrysothamnus teretifolius* were obtained around each of the soil pits. At the Ghost Dance Fault exposure (south-facing slope of Antler Ridge) I examined root penetration of shrubs, sub-shrubs and herbs into calcite crack fillings. On Shoshone Mountain, I obtained cores from single leaf pine (*Pinus monophylla*).

Pages 59-63: summary report.
Pages 63-68: field notes.
Pages 68-73: field photos.

February, 1998: Laboratory analysis of growth rates of *Chrysothamnus teretifolius* from Yucca Mountain and *Pinus monophylla* from Shoshone Mountain.

The tree cores and shrub stem cross sections obtained during the January, 1998 field work were analyzed. These samples showed now statistical difference in growth rate which indicates that the even within the climate-change analog sites (cooler and wetter), the vegetation is intensely water limited. These insights should assist development of realistic vegetation/hydrologic parameters for dynamic modeling of Yucca Mountain under present and climate-change conditions.

Page 74: purpose, methods and results.
Page 75: air photo and results from analysis of cover.
Page 76-77: data sheets from the analysis of tree cores.
Page 78: data sheets from the analysis of shrub cross sections.
Page 79: photos of shrub cross section and tree core.

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Initial Trip - Familiarization
November 25, 1996

Field Notes:

11-25 [Yucca Mtn: field tour w/ Sh... :
Stop plus photos in Cyn E of Beatty
reach by Flourspar Rd.: note veg.
in fissures.
- roots through caliche zone?? note channels
- could channels be due to pore flow?
- roots passing down @ ca 2m Larrea?
- Radio Carbon dating of caliche
- N probe calibr.
End field work + fly to LAS 12.5]

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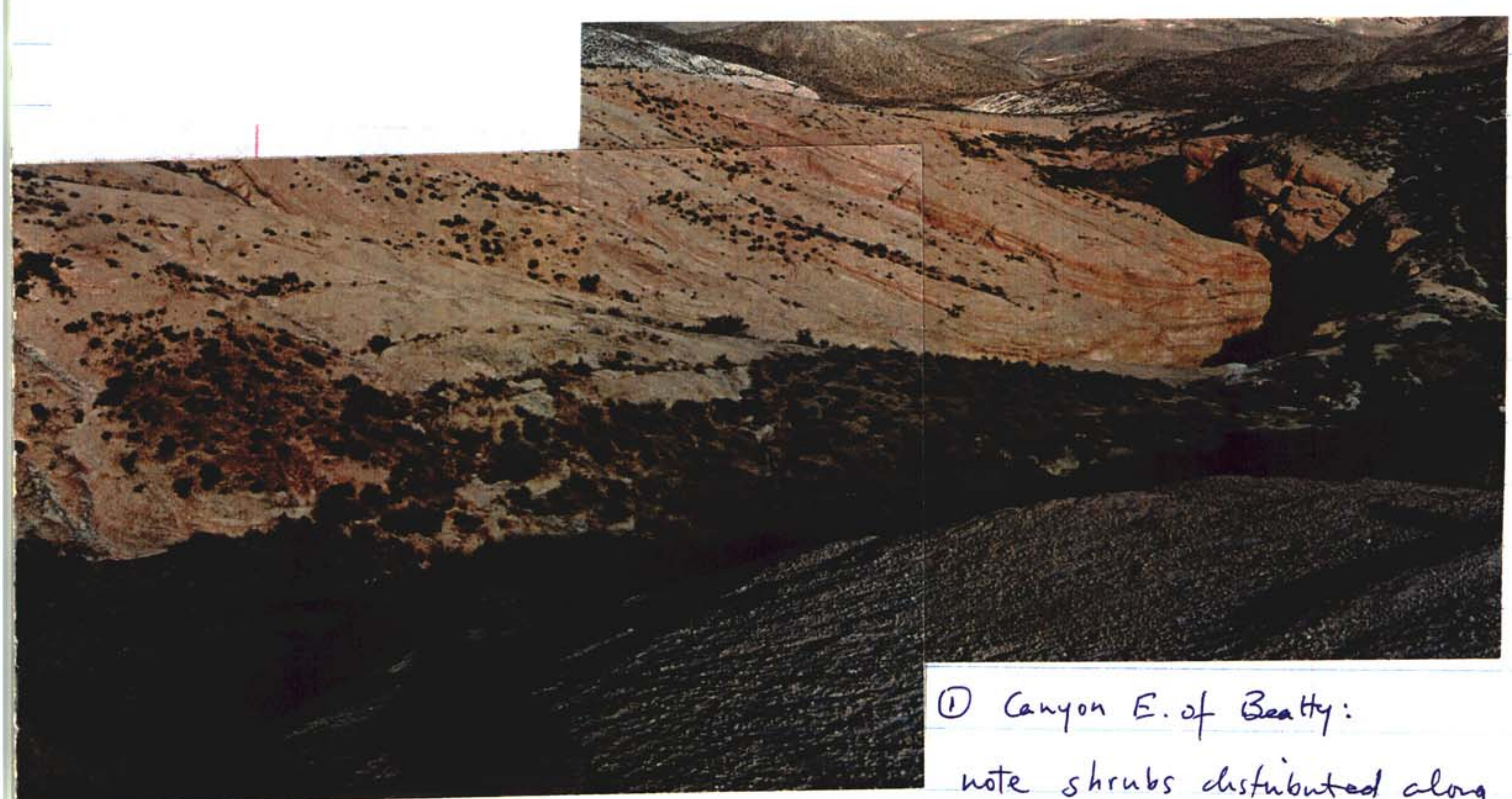
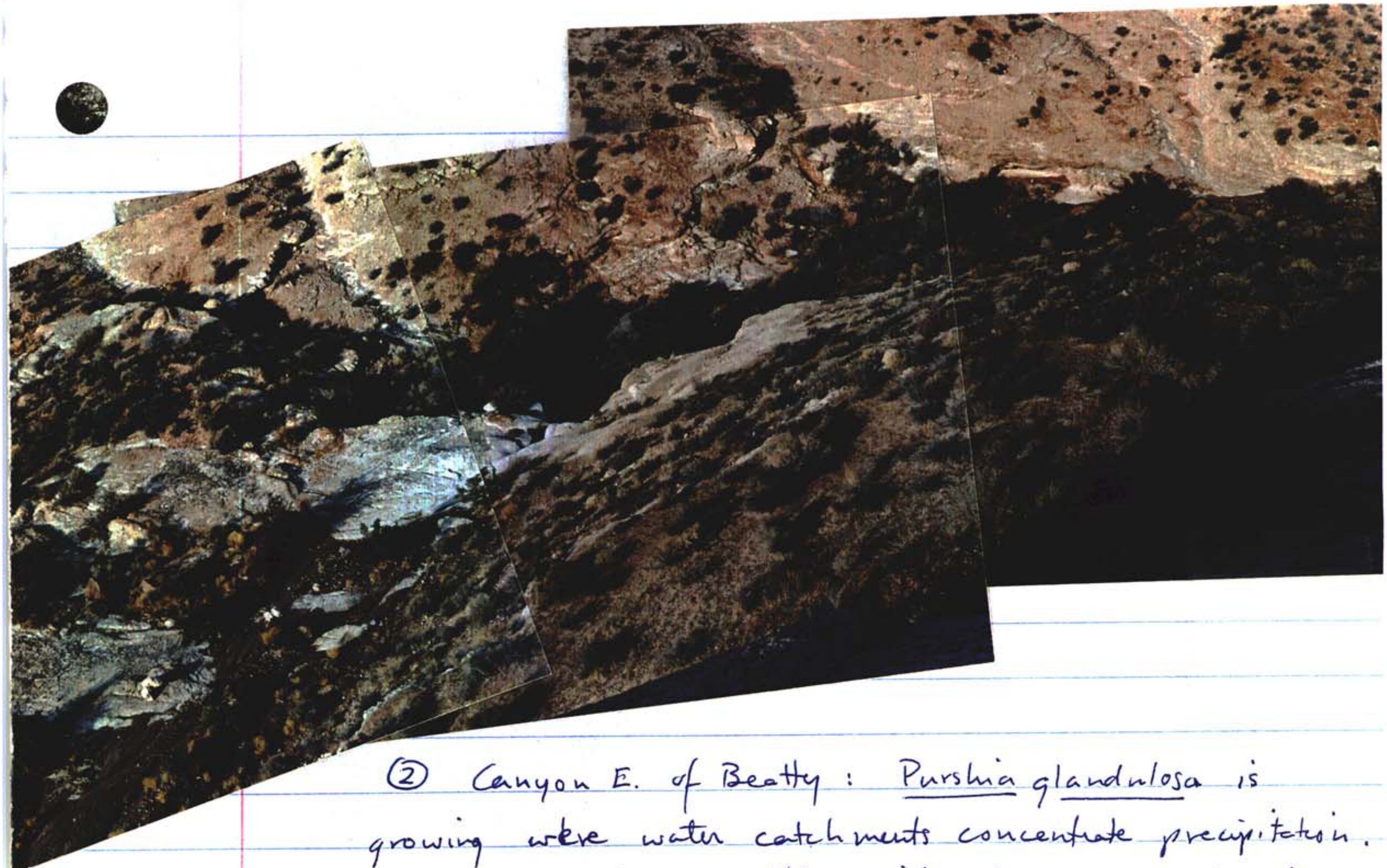
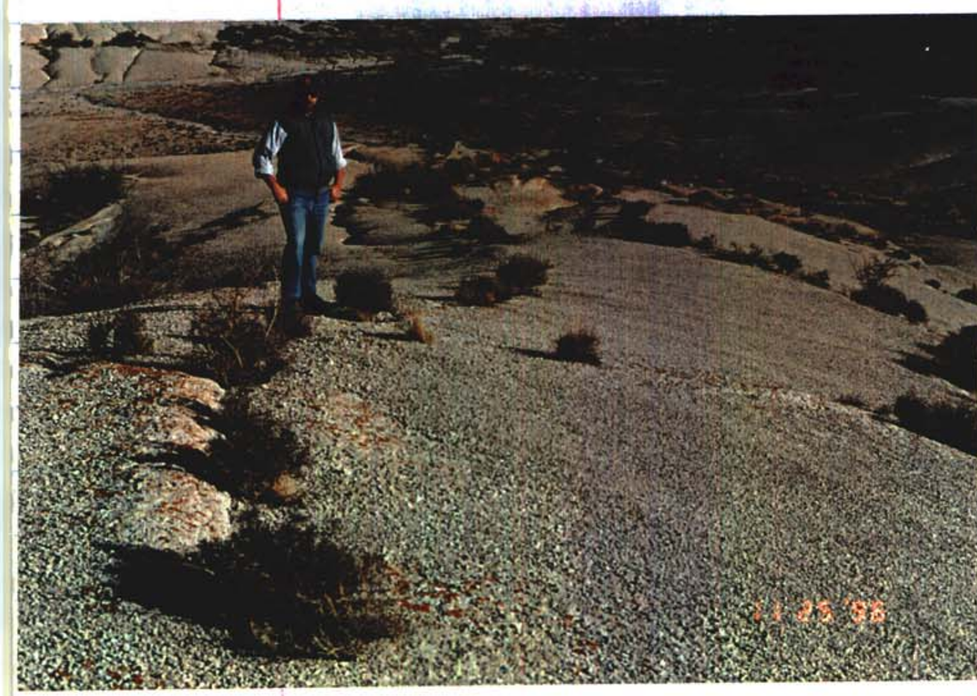
Results: (in photographic format)



① Canyon E. of Beatty: note shrubs distributed along cracks in poorly welded (non?) weathered tuff

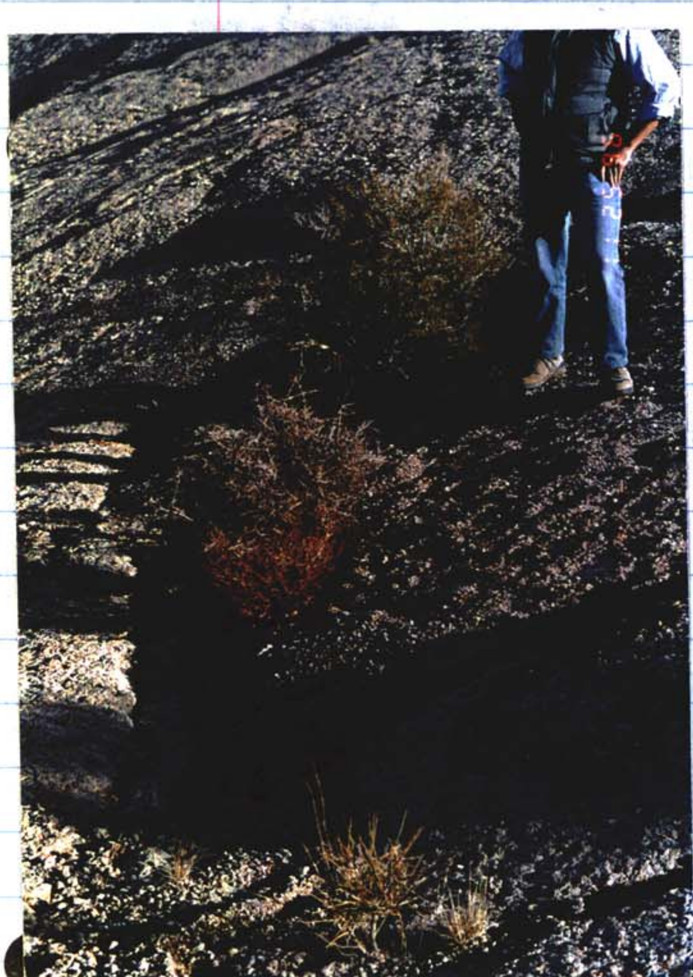


② Canyon E. of Beatty: Purshia glandulosa is growing were water catchments concentrate precipitation. This species is potential climate change vegetation for Yucca Mtn.



③ Plants growing in a fissure in non-welded tuff in canyon E. of Beatty

④ A dominant species of cracks, Chrysothamnus teretifolius, remains green through year while other plants are drought deciduous. (Canyon E. of Beatty)

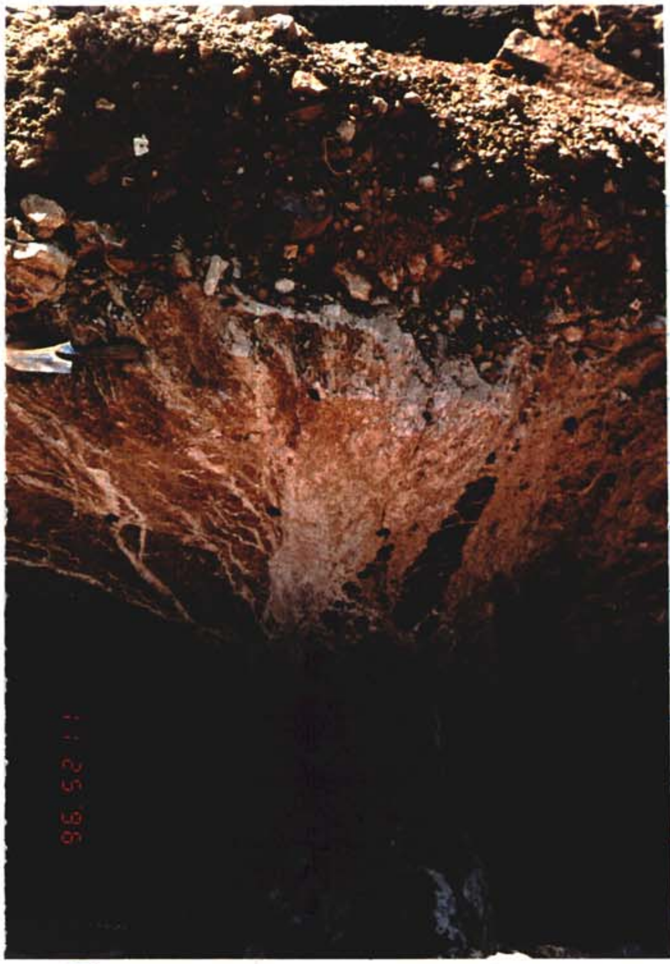


⑤ other species may also be associated with cracks, including Lycium, Encelia and Ephedra. (Canyon E. of Beatty)

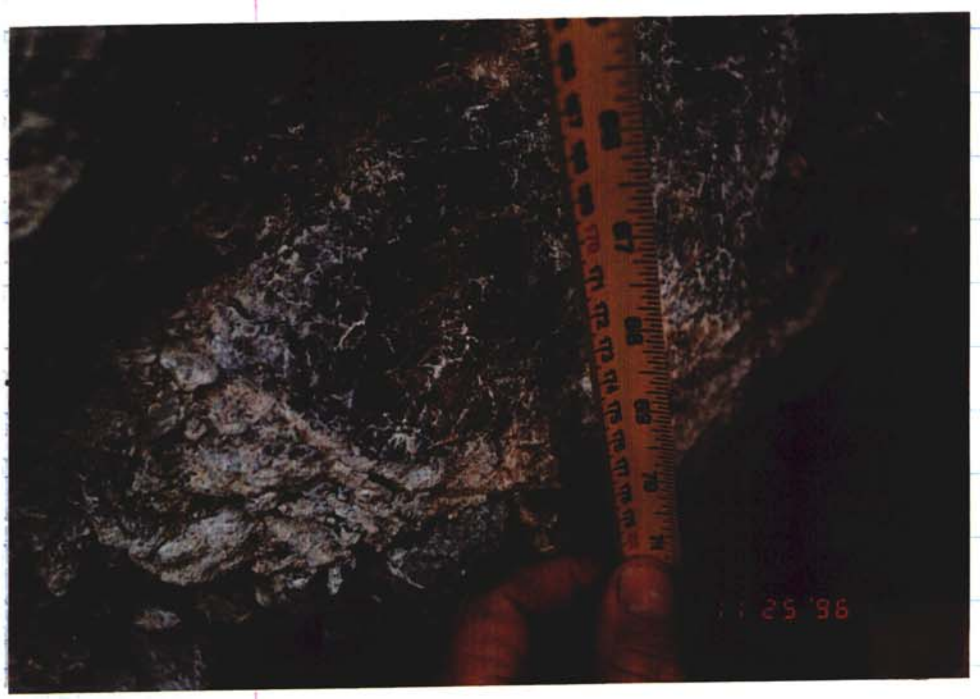
(6) Larrea ~~divaricarpa~~ tridentata associated w/ Ambrosia dumosa dominates areas of deep alluvium. (E. of Beatty and near previous photos.)

(7) Larrea tridentata killed by Cuscuta sp. In this region dodder (Cuscuta) may kill large areas of shrubs. Cheatgrass (Bromus rubens) helps bridge gaps between shrubs (near above)

(8) Bromus rubens dominates areas of greater soil development, particularly alluvial fans @ base of rocky slopes. Bromus may be causing reduction in shrub cover due to early spring competition for water and nutrients. (W. side of Solitario Wash)



(9) Solitario Canyon Fault exposure with fault plane region heavily calcified



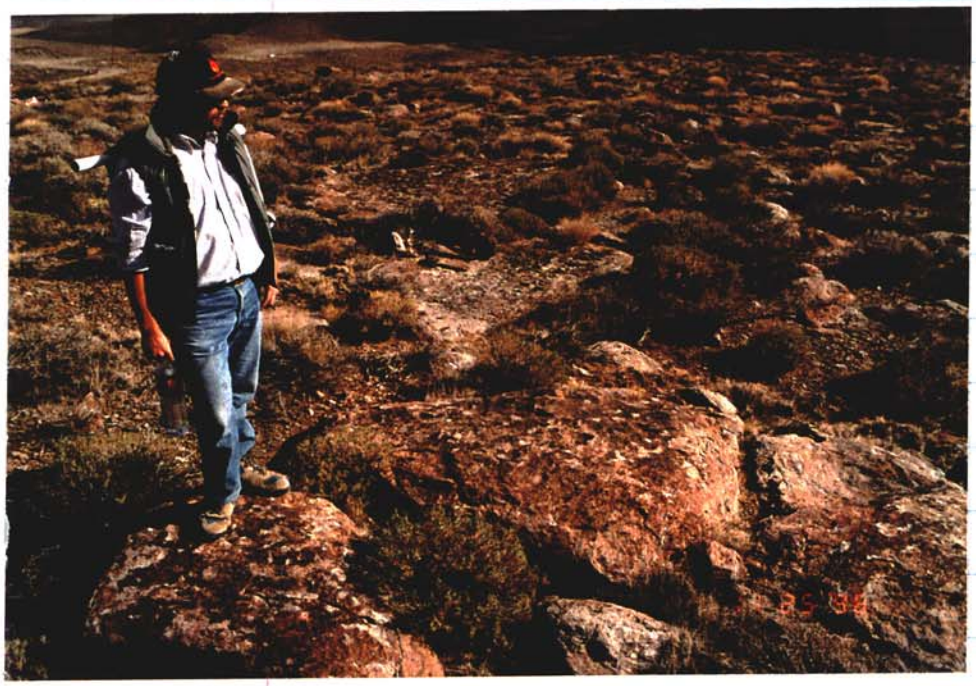
(10) Dendritic patterns calcified around old root channels on downhill side of Solitario Canyon Fault. Root material was recovered from within one of these channels.

(11) North- vs. south-facing slopes: different species and covers. In foreground, vegetation cover is much greater and dominated by big sagebrush (<u>Artemisia tridentata</u>) on north-facing slope. In background the slope is south facing and dominated by lower cover of <u>Ambrosia dumosa</u> and <u>Lycium</u>. Washes generally do not have higher vegetation cover suggesting that runoff must be rapid and provide poor opportunity for plant capture.

(12) Taken in vicinity of above (Yucca Mtn. @ bulldozer cut N. of Highway Ridge). Note scree associated w/ higher vegetation cover on right side of wash. This scree is very stable noting covering of desert varnish.

(13) Yucca Mt. Crest @ USGS neutron probe access tube, just South of Highway Ridge Rd. on Highway Ridge.

DPG
ok for DWG 9/26/00



(14) Yucca Mtn. Crest near above. Note flora associated with fissures (dominated by Chrysothamnus ~~[illegible]~~ teretifolius) Also note polygon patterns of vegetation forced by underlying rock. Soil is very thin.

(15) Yucca Mtn. scarp face in solitario canyon. Note Larrea and Ambrosia dominate on alluvium

DPG 2-10-98

1st Field Trip to Gather Data

March 26 through 30, 1997

Field Notes:

3-26 [Yucca Mtn. : Field Study
7 veg. study points + drive fm B1H
& drive to Lodging 14.0]
3-27 [Yucca Mtn. : Field 14.0]
3-28 [Yucca Mtn. Field (+ drive to LAS) 13.0]
3-29 [Yucca Mtn : wrap up w. Stu & Dave 1.0
drive to field site from LAS 8.5]
3-30 [Yucca Mtn. wrap up on field work 9.5]
3-31 [Return to B1H, 4.5 unpack, 0.5 key out unknowns
and go over field sheets 1.5]
4-1 [Yucca Mtn : Sieve & weigh soil samples 1.5 ;
clean, return borrowed equip. 2.0
Analysis 1.0]

DPG 2-10-98

pf for DWG
9/20/00

Plant Cover Data was developed using a line pt. transect technique. A 100-m tape was stretched along the contour of the study site and a sharpened pin was lowered at 0.5 m intervals to constitute 201 pins. Contacts with leaves were noted ~~as~~ (to calculate LAI) and ~~[illegible]~~ whether the pin passed through a living or dead canopy was noted

The substrate, whether rock (average dimension @ least ½ m), scree (loose rock fragments or soil (not as above) was noted.

The point frame technique was adopted from methods developed by the author of this report and published in <u>Journal of Arid Environments</u>.

Groeneveld 1997
J. of Arid Environ,
vol 36: 475-485
"Vertical point quadrature sampling and an extinction factor to calculate leaf area index"

Following are:

1. Summaries of soil texture for soil samples collected at each site. (2 pages)
2. A summary field data presenting slope, aspect, GPS positioning, vegetation cover LAI, % Rock, % Scree, % Rock (5 pages)
3. Copies of raw field data preceded by a table summarizing the vegetation findings (3 pages)

The raw field data comprises an additional 11 pages. 2 pages of species abbreviations are provided.

① Soil Samples and Rock Content prior to shipping for analysis:

WEIGHT IN GRAMS ROUNDED OFF

YUCCA MOUNTAIN SOIL SAMPLES

APRIL 1, 1997

DPG 9-10-98

SAMPLE #		RAW WT (includes tare)	− BAG WT	= TOTAL WT	ROCK (greater than 2mm) (includes tare)
FP	1.1	1409	13	1396	778
FP	1.2	1445	13	1432	321
FP	2.1	815	13	802	140
FP	3.1	1285	13	1272	579
FP	3.2	1508	13	1495	495
RS	1.1	1293	13	1280	252
RS	2.1	975	13	962	255
RS	2.2	949	13	936	171
RS	2.3	1129	13	1116	299
RS	16.1	1197	13	1184	520
RS	16.2	1532	13	1519	663 (mislabel)
RS	16.3	1080	13	1067	339
RS	16.4	1391	13	1378	423
RS	18.1	1571	13	1558	576
RS	19.1	1595	13	1582	774
RS	19.2	1617	13	1604	581
RS	20.1	1027	13	1014	396 (mislabeled as 22.1)
RS	20.2	1418	13	1405	582
RS	21.1	NO SAMPLE			
RS	21.2	1228	13	1215	299
RS	23.1	2116	13	2103	820
RS	23.2	1318	13	1305	492
RS	23.3	1611	13	1598	640
RS	23.4	NO SAMPLE			
RS	24.1	1938	13	1925	706
RS	24.2	1705	13	1692	531
RS	24.3	2007	13	1994	1213
RS	28	686.	5	681	256.
RS	29	473	5	468	19.
RS	30 (@ 50cm)	423	13	410	102
RS	30 (@ 10cm)	583.	13	570	117.

YUCCA surface transect #1 3/27/97
Transect #1 trench 3/27/97
Transect #1 trench crack ~30cm+ 3/27/97
Transect #2 surface sample adjacent to 2 perm. tests (1 w/rock)

Utah State UNIVERSITY

(① continued) Results from Analysis of soils sampled

USU ANALYTICAL LABORATORIES
Utah State University
Logan, UT 84322-4830
Telephone (801) 797-2217
Fax (801) 797-2117

17 April 1997

Results for:

Dani Or
PS&B 4820

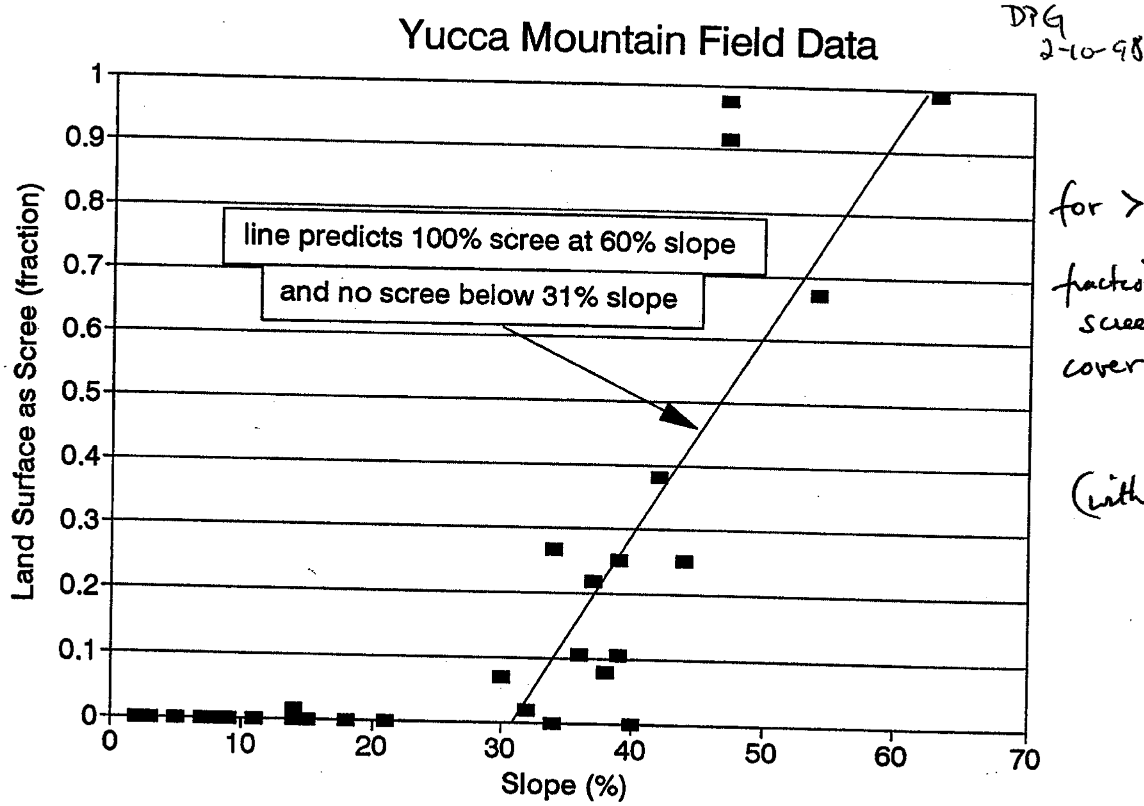
Soil samples received 4/7/97.

USU#	ID	EC mmhos/cm	% Hydrometer Sand	Silt	Clay	Texture	
2145	FP 1.1	0.4	77	16	7	LS	on Fan
2146	1.2	0.6	57	33	10	SL	
2147	2.1	0.3	57	30	13	SL	
2148	3.1	0.4	72	23	5	SL	
2149	3.2	0.2	69	24	7	SL	
2150	RS 1.1	0.3	61	25	14	SL	repository Block
2151	2.1	0.3	60	27	13	SL	
2152	2.2	0.3	65	24	11	SL	
2153	2.3	0.3	70	20	10	SL	
2154	16.1	0.3	66	26	8	SL	
2155	16.2	0.4	63	26	11	SL	
2156	16.3	0.4	63	29	8	SL	
2157	16.4	0.3	67	25	8	SL	
2158	18.1	0.3	62	30	8	SL	
2159	19.1	0.4	60	28	12	SL	
2160	19.2	0.3	70	22	8	SL	
2161	20.1	0.4	72	18	10	SL	
2162	20.2	0.3	64	25	11	SL	
2163	21.2	0.4	67	25	8	SL	
2164	23.1	0.4	63	23	14	SL	
2165	23.2	0.4	66	24	10	SL	
2166	23.3	0.3	64	27	9	SL	
2167	24.1	0.4	67	23	10	SL	
2168	24.2	0.3	75	18	7	SL	
2169	24.3	0.3	68	26	6	SL	
2170	28	0.3	71	24	5	SL	
2171	29	0.8	58	24	18	SL	
2172	30 (10cm)	0.2	73	22	5	SL	
2173	30 (50 cm)	0.4	64	25	11	SL	
2174	Yucca #1 surface	0.3	71	23	6	SL	
2175	Yucca trench 20	0.3	66	23	11	SL	
2176	Yucca trench 30	0.5	67	26	7	SL	
2177	Yucca #2 surface	0.5	76	17	7	SL	

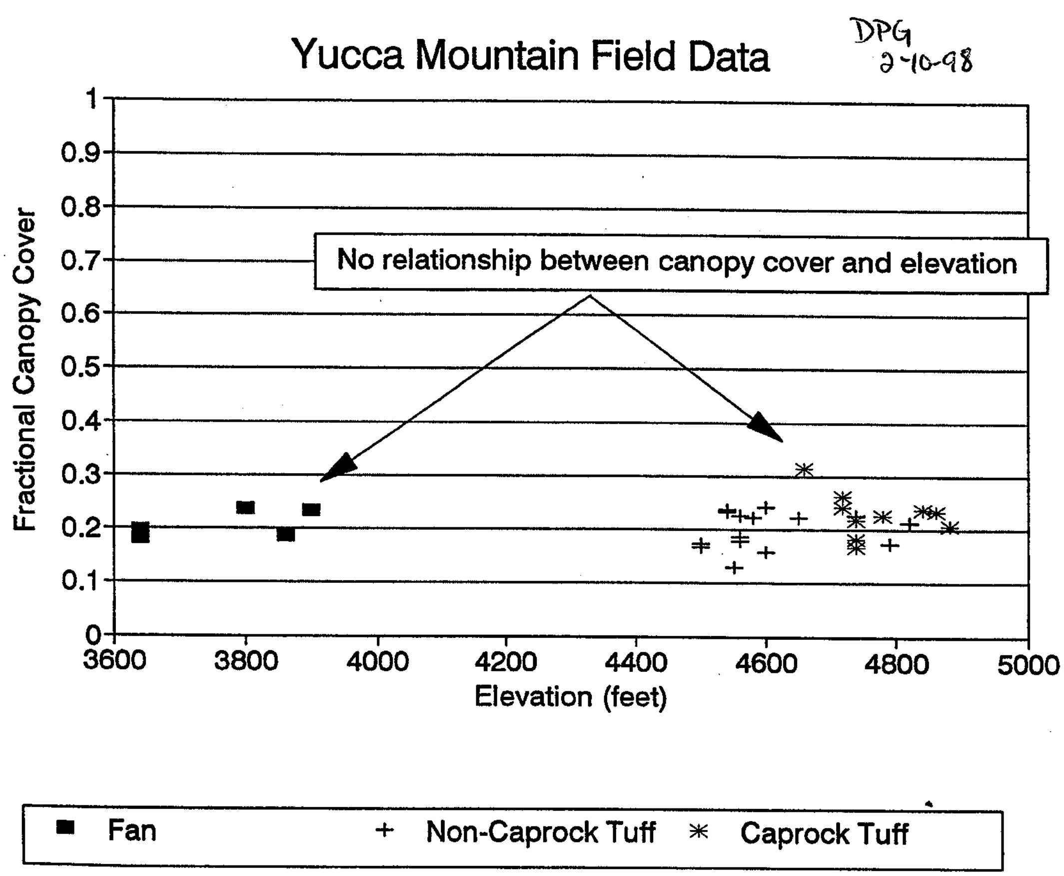
If you have any questions, please contact the lab

(2) Summary of Field Data

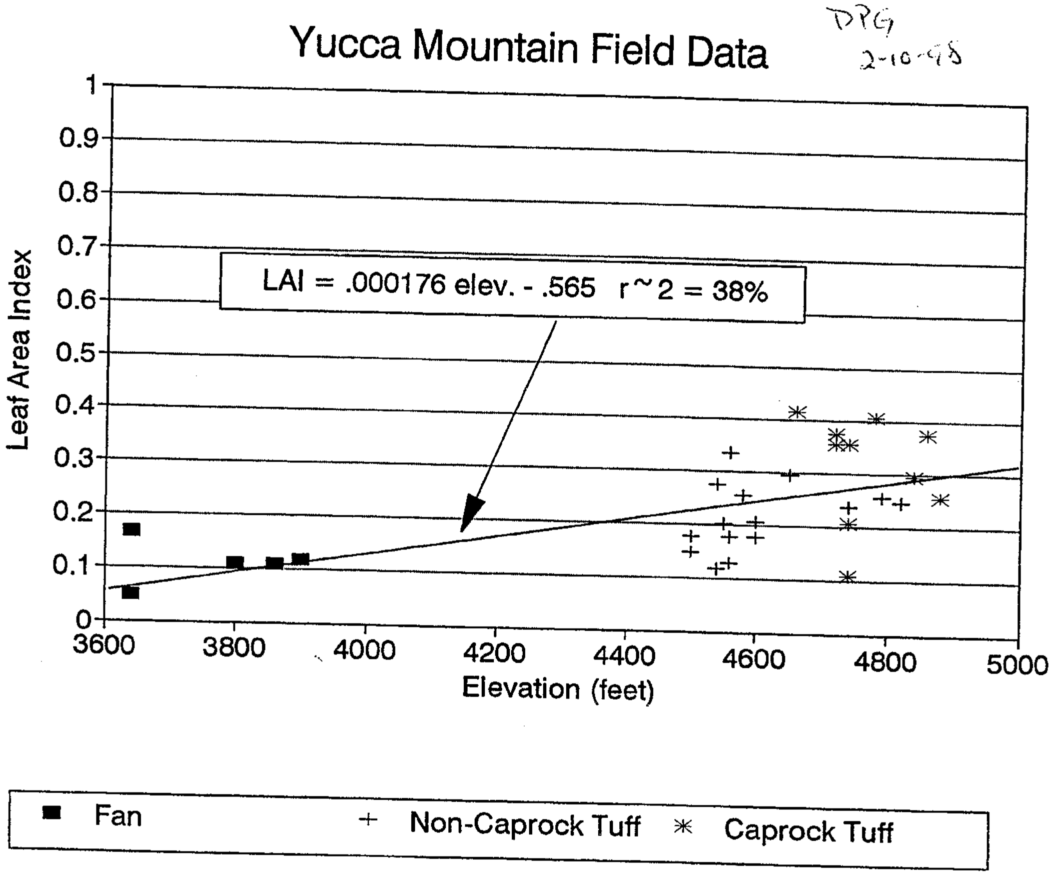
SITE		SLOPE	ASPECT	GPS POSITIONING		Σ dnum / 202 TOTAL COVER	Σ num / 101 LEAF AREA INDEX	/202 % ROCK	/202 % SCREE	/202 % DEAD	DPG 2-10-98		Aspect Code
FP 1.1	3640	2%	225°	36° 48' 116° 30'	5930N 1470W	0.183	0.050	0	0	.030		FAN(1)	8
FP 1.2	3640	2%	200°	36° 49' 116° 30'	016N 1331W	0.198	0.168	0	0	.025		"	9
FP 2.1	3800	7%	220°	36° 49' 116° 27'	1875N 3361W	0.238	0.109	0	0	.040		"	8
FP 3.1	3860	5%	133°	36° 50' 116° 26'	3656N 2309W	0.188	0.109	0	0	0		"	7
FP 3.2	3900	18%	52°	36° 50' 116° 26'	3407N 2252W	0.233	0.119	0	0	0.020		"	2
RS 16.3	4500	63%	8°	36° 50' 116° 27'	2962N 4140W	0.173	.178	0	.990	.015		tuff(2)	0
RS 16.4	4500	47%	180°	36° 50' 116° 27'	2947N 4148W	.168	.149	.010	.975	.050		"	10
RS 1.1	4820	2%	250°	36° 50' 116° 27'	2757N 5791W	.213	.248	0	0	.010		"	7
RS 2.1	4560	46.5%	10°	36° 51' 116° 27'	3188N 3658W	.178	.337	0	.916	.010		"	0
RS 2.2	4600	11%	88°	36° 51' 116° 27'	2847N ———	.243	.208	.257	0	.025		"	5
RS 2.3	4560	39%	163°	36° 51' 116° 27'	———N ———W	.228	.129	.644	.104	.035		"	8
RS 16.1	4600	2.5%	95°	36° 50' 116° 27'	2901N 4343W	.158	.178	.124	0	.050		"	5
RS 16.2	4640	39%	12°	36° 50' 116° 27'	2811N 4491W	.238	.119	0	.252	.054		"	0
RS 19.1	4550	32%	123°	36° 50' 116° 27'	1466N 4193W	.129	.203	0	.020	.045		"	6
RS 19.2	4560	37%	218°	36° 50' 116° 27'	1918N 3730W	.188	.178	0	.218	.035		"	8
RS 18.1	4540	42%	41°	36° 50' 116° 27'	1527N 3848W	.233	.277	.050	.381	.020		"	2
RS 21.1	4790	34%	194°	36° 50' 116° 28'	1086N 799W	.173	.257	.183	.267	.015		"	10
RS 21.2	4740	43.5%	157°	36° 50' 116° 27'	625N 5973W	.228	.238	.188	.252	.010		"	8
RS 20.1	4650	13.5%	17°	36° 50' 116° 27'	0984N 4956W	.223	.297	.109	.015	.015		"	1
RS 20.2	4580	30%	355°	36° 50' 116° 27'	1513N 4228W	.223	.257	.064	.069	.035		"	0
RS 23.1	4740	33.5%	178°			.168	.109	.030	0	.015		(3) caprock	10
RS			75°										
RS 23.2	4790	9%	98°			.218	.356	.332	0	.015		caprock	5
RS 23.3	4720	36.5%	28°			.243	.376	.030	.104	.030		"	1
RS 23.4	4860	53.5%	16°			.317	.416	0	.673	.025		"	1
RS 24.1	4780	21%	125°			.228	.406	0	0	—		"	7
RS 24.2	4740	14.5%	100°			.183	.208	.119	0	.025		"	5
RS 24.3	4720	37.5%	20°			.262	.356	.005	.079	.045		"	1
RS 30	4860	15%	87°	36° 49' 116° 27'	1468N 5950W	.233	.376	.045	0	.030		"	5
RS 29	4880	7.5%	83°	36° 49' 116° 28'	4852N 0524W	.208	.257	.307	0	.030		"	5
RS 28	4840	40%	82°	36° 50' 116° 28'	639N 856W	.238	.297	.074	0	.035		"	5



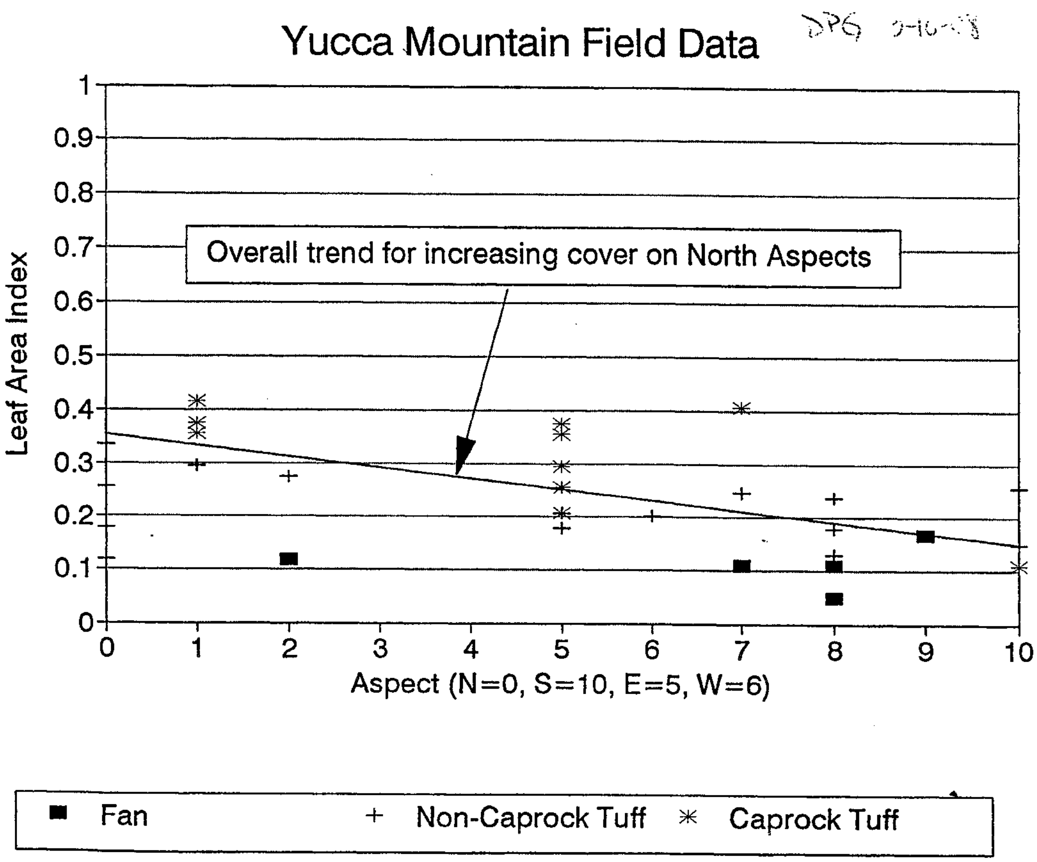
for > 31% slope fractional scree cover = .0346(slope) − 1.09 (with slope in %)



these data contain a mix of North and South-facing slopes that are much more important than elevation in determining cover.



Slight increase in LAI w/ elevation is to be expected, however, this is confounded by ① mixing of aspect in these data, and ② LAI not measured @ its peak but some 3 weeks before expected.



Weak trend is as expected but is confounded in these data by ① mixing of elevation ② LAI measured well before its expected peak

Summary Data From Point Frame (Total 201 pins)

numbers are: hits on leaves / pins through canopy (pins through dead canopy)

okay PK 9/13/00

DPG 2-10-98

SITE #	ERFA	LATR	GRSP	AMDU	LYPA	KRPA	MESP	EPNE	ATCO	HYSA	LYAN	CHNA	PGA
FP 1.1		2/20 (0)	0/3 (1)	2/8 (0)	1/1	0/5 (5)							
FP 1.2		2/4 (0)		1/15 (2)	6/7 (0)	2/5 (1)	5/8 (0)	1/1 (0)					
FP 2.1		4/9 (0)		0/7 (1)	0/3 (0)	1/10 (3)	4/10 (0)	2/6 (1)	0/3 (3)				
FP 3.1		9/33 (0)		2/5 (0)									
FP 3.2		6/27 (0)	0/4 (3)					1/4 (0)		4/11 (1)	1/1 (0)		
RS 16.3	1/10 (1)		3/4 (1)						1/1 (0)			5/6 (0)	1/1 (0)
RS 16.4	2/8 (3)		0/1 (0)	1/4 (0)			2/2 (0)	2/5 (0)	2/7 (5)		0/2 (2)		
RS 1.1									0/1 (0)				
RS 2.1	4/4 (0)											2/2 (0)	1/2 (0)
RS 2.2	0/8 (0)							1/7 (0)			1/3 (1)		
RS 2.3	1/4 (0)			3/7 (0)				0/7 (1)	0/3 (2)		0/2 (1)		
RS 19.1			0/4 (1)	1/1 (0)				9/12 (1)		3/16 (4)	1/6 (2)		
RS 19.2			0/4 (2)	1/3 (1)				1/5 (0)		2/3 (1)	0/1 (1)		
RS 18.1	21/31 (3)		1/2 (1)					0/2 (0)			2/2 (0)	0/1 (0)	1/5 (0)
RS 16.1	2/10 (5)							3/5 (0)					
RS 16.2	2/16 (6)		2/1 (0)					4/4 (0)	0/4 (1)				0/3 (0)
RS 21.1	3/6 (0)		6/7 (1)					3/6 (0)	0/1 (1)		0/5 (1)		
RS 21.2	3/8 (1)		4/10 (0)					4/10 (0)	1/1 (0)		3/5 (0)		
RS 20.1	4/5 (0)		1/3 (1)	0/1 (0)				2/1 (0)			0/1 (0)		0/3 (0)
RS 20.2	3/10 (0)							2/7 (1)				1/2 (0)	
RS 23.1			0/2 (1)	0/1 (0)			1/1 (0)	5/11 (0)		0/7 (0)	0/2 (1)		
RS 23.2	12/15 (3)		1/1 (0)					8/7 (0)					
RS 23.3	11/14 (2)		0/4 (3)					0/1 (0)			0/2 (0)		2/1 (0)
RS 23.4													
RS 24.1 (NOD used)			10/10 (0)						0/3 (0)	0/2 (0)	1/5 (0)		
RS 24.2	2/6 (2)		4/9 (0)				0/1 (1)	2/6 (0)			0/1 (0)		
RS 24.3	11/15 (5)		0/2 (1)					2/4 (0)				0/1 (0)	0/1 (0)
RS 30	2/2 (0)		13/12 (0)					5/10 (0)		4/4 (0)	1/5 (0)		
RS 29	7/9 (2)		1/3 (0)					1/2 (0)		0/1 (0)	0/1 (0)		
RS 28	8/17 (5)		9/8 (1)					2/6 (0)	0/1 (0)	1/1 (0)	0/1 (0)		

(Species abbreviations on page 19 & 20)

DPG 2-10-98

Summary Data from Pt. Frame Continued

DPG 2-10-98

SITE #	EPVI	CHTE	CACH	STSP	TEGL	HACO	LEPU	TEAX	CORA	ARTR	CELA	CHVI	UK	ATGI
FP 1.1														
FP 1.2														
FP 2.1													0/2 (2)	
FP 3.1														
FP. 3. 2														
RS 16.3	4/7 (0)	2/1 (0)		1/1 (0)	0/1 (0)									
RS 16.4		2/1 (0)		0/1 (0)		2/1 (0)	0/1 (0)	2/1 (0)					0/1 (1)	
RS 1.1	2/4 (0)	1/4 (1)				5/2 (0)			17/32 (0)					
RS 2.1	0/1 (0)	1/3 (1)		0/1 (0)						26/23 (1)				
RS 2.2		6/8 (0)		0/4 (0)		9/13 (4)			2/2 (0)		0/1 (1)	2/3 (0)		
RS 2.3	0/1 (0)	1/4 (1)		0/1 (0)		4/9 (0)					0/1 (1)	4/6 (0)		
RS 19.1						0/1 (0)					0/1 (0)		0/1 (1)	
RS 19.2		0/1 (0)		0/2 (0)		13/15 (2)					1/4 (0)			
RS 18.1		3/1 (0)		0/1 (1)							0/2 (0)			
RS 16.1		1/2 (1)		0/3 (2)		11/5 (0)					1/2 (0)	0/3 (0)	0/1 (1)	0/1 (1)
RS 16.2		4/8 (2)						0/1 (1)					0/5 (0) greso / 0/3 (3)	
RS 21.1		1/1 (0)		0/1 (0)		7/5 (0)					5/2 (0)	1/1 (0)		
RS 21.2				3/6 (0)		2/2 (0)					4/4 (1)			
RS 20.1		3/1 (0)				10/5 (0)								
RS 20.2										20/26 (6)				
RS 23.1				0/1 (0)	1/2 (0)						2/5 (1)			2/2 (0)
RS 23.2	1/2 (0)		2/1 (0)	1/1 (0)						1/2 (0)	1/1 (0)			2/3 (0)
RS 23.3	1/1 (0			1/2 (0)						22/20 (1)				
RS 23.4				2/2 (0)						40/62 (8)				
RS 24.1 (no D used well)	2/5 (0)	9/7 (0)				15/9 (0)				2/2 (0)	4/2 (0)			
RS 24.2	4/2 (0)	2/3 (1)				6/6 (1)					1/1 (0)			
RS 24.3	3/4 (0)	5/7 (1)		8/4 (0)		0/1 (1)				9/8 (0)				
RS 30		2/2 (1)				10/3 (0)		0/4 (A			1/2 (0)			
RS 29		1/1 (0)										0/1 (1)	0/1 (1)	0/3 (1)
RS 28	1/2 (0)	4/2 (0)		0/2 (0)		1/1 (0)							0/2 (2)	

Summary from Pt. Frame Continued

	HYIA	~~[illegible]~~	HALI (YEL)	~~[illegible]~~	ORHI	SP[illegible] (AM)	~~[illegible]~~	~~[illegible]~~	ELEL	STPA
FP1.1										
P1.2										
P2.1										
P3.1										
P3.2										
S16.3										
S16.4										
S1.1										
S2.1										
S2.2										
S2.3										
S19.1										
S19.2										
S18.1										
S16.1										
S16.2	0/3 (0)									
S21.1										
S21.2										
S20.1	0/6 (0)		11/19 (2)							
S20.2										
S23.1										
S23.2	0/3 (0)		7/8 (0)							
S23.3			1/4 (0)							
S23.4										
S24.1	NOP Used 0/1 (0)									
S24.2	0/1 (0)			~~[illegible]~~	0/1 (1)					
S24.3	0/1 (0)		4/4 (0)			0/1 (0)				
S30										
S29	0/4 (1)		6/7 (0)							
S28									0/1 (0)	0/1 (0)

Okay RF 9/13/00

RF 9/13/00

Key to Species Abbreviations :

ERFA	Eriogonum fasciculatum
LATR	Larrea tridentata
GRSP	Grayia spinosa
AMDU	Ambrosia dumosa
LYPA	Lycium pallidum
KRPA	Krameria pauciflora
MESP	Menodora spinescens
EPNE	Ephedra nevadensis
ATCO	~~Artemisia~~ Atriplex confertifolia
HYSA	Hymenoclea salsola
LYAN	Lycium andersonii
CHNA	Chrysothamnus nauseosus
Poa	genus Poa (bluegrass sp.)
EPVI	Ephedra viridis
CHTE	Chrysothamnus teretifolius
CACH	Castilleja angustifolia
STSP	Stipa speciosa (
TEGL	Tetradymia glabrata
HACO	Haplopappus cooperi (now Ericameria cooperi)
LEPU	Leptodactylon pungens
TEAX	Tetradymia axillaris
CORA	Coleogyne ramosissima
ARTR	Artemisia tridentata
CELA	Ceratoides lanata (now Krascheninnikovia lanata)
CHVI	Chrysothamnus viscidiflorus
UK	Unknown
ATCA	Atriplex canescens

PF 9/26/00

PF for DP/Gr 9/26/00

Key to Species abbreviations (continued)

HIJA	Hilaria Jamesii
HALI (YEL)	Haplopappus linearifolia
ORHY	Oryzopsis hymenoides
SPAM	Sphaeralcea ambigua
ELEL	Elemys elemoides
STPA	Stephanomeria pauciflora

3/30/97 Easter Sunday Yucca Mtn * 4/5/97

DPG 2-10-98

near LAGC

FP 1.1

Inactive Terrace in Wash - moderate varnish pavers — Adjacent to Roadway in Wash - Terrace — near ________ 400-600m from their site

2% to 225°; 36° 48' 59.30 N, 116° 30' 1470 W

no rock no scree

Cover (37) .283
Dead (6) .030
LAI (5) .050 × 2

LATR 2 (2/20)
AMDU (2/8)
KRPA (0/5) — pf 9/13/00 — (broken) GRSP (0/3)
(1/1) LYPA - (Tetradimia? poss. Krameria) very stout, thorny branchlets - sub-tending main stems @ angle - glabrous branches - sparse lanceolate leaves — 4-10 mm; 30-60 cm — up to 18 mm on more leafed plant

20-30 cm — short, dark grayish, whorled leaves @ nodes, branches at 120°, fine branchlets extending beyond canopy

LYPA - leafed out but failing for some
LATR - leafed; now senescent w/ small new leaves

adjacent to Roadway in Terrace has sig caliche deposit; very well developed desert pavement, mostly (65%) varnished —

near LAGC

FP 1.2

36° 49' 01.16 N; 116° 30' 1331 W

2% to 200°

MESP	5/8	AMDU	1/13	LATR	2/4		rock Ø	scree Ø
KRPA	2/5	LYPA	6/12	EPNE	1/1			
UK #?	0/2							

Cover (40) .198
Dead (5) .025
LAI (17) .168

NEAR LATI — Just off Roadway into Y.M.

FP 2.1

36° 49' 18.75 N; 116° 29' 33.01 W; 7° to 220°

transects buried to intersect 2 LATR

pf 9/13/00

KRPA	1/10	LATR	4/9	LYPA	0/3
AMDU	0/17	MESP	4/10	EPNE	2/6
ATCO	0/3				

no rock or scree

cover (48) = .238
dead (8) = .040
LAI (11) = .109

3/28/97 YUCCA MTN
FRI

* A1514 DPG & JJT

DPG 2-10-98

LLG IT

FP 3.1 ~~LLGA~~ (Duplication near TRW site)

5% to 133° / 36°50' 3656 N ; 116°26' 2309 W

LATR 212211 9/33

AMDU 11 2/5

no rock or scree
Cover (58) .1099
Dead (0) = 0
LAI (11) = .109

v. heavy annual flora Amsinckia & BRRU

Cross-outs this page okay, RK 9/13/00

rock : 0
scree : 0
Cover (47) = .233
Dead (4) = .020
LAI (12) = .119

~~LLGB~~ (As Above, near TRW)

FP 3.2 18% to 52° 36°50' 3407 N ; 116°26' 2252 W

EPNE 1 1/5 GRSP 0/4 LYAN 1 1/1

LATR 1113 6/27 HYSA 22 4/18

all scree unless otherwise noted

RS 16.3 ca 30 m below 16.2 N facing ridge down draw top 30, 30 (ca 30 due limb)

63% to 8° 36°50' 2962 W ; 116°27' 4140 W

CHNA 12 3/4 + 2/2 = 5/6 ~~SRK~~ 0/1 ERFA 1/10 STSP 1 1/1

GRSP 2 2/2 EPVI 111 4/7 SOIL 11 0/2 TEGL 1 0/1

POA 1 1/1 CHTE 2 2/1 CHNA 11 2/2 GRSP 1 1/2

ATCO 1 1/1

rock 0
scree (201) = .99
cover (35) = .173
Dead (..) = .015
LAI (18) .178

RS 16.4 47% to 180° S side of ridge

ALL SCREE UNLESS O.W. NOTED

36° 50' 2947 N ; 116° 27' 4148 W

TEAX 2/1 2/1

SOIL 111 0/3 AMDU 1 1/4

ERFA 11 2/8 ATCO 2 2/7 LYAN 0/2

ROCK 11 0/2 HAEO 2 2/1 MESP 11 2/2

EPNE 2 2/5 LEPU 1 0/1 STSP 1 0/1

GRSP 1 0/1 CHTE 2 2/1

v. Spiny leaves whorled on stem

~~Fetrodyumin~~ ?

Leptodactylon pungens

rock (2) = .010
scree (197) = .975
Cover (34) = .168
Dead (10) = .050
LAI (5) = .149

* 4/5/97 Yucca MTN 3/29/97 SAT
JJT & DPG
DPG 2-10-98

RS 1.1 Ridgeline

2% to 250°; 36°50' 2757 N; 116°27' 5791 W

17/32 CORA 1121312221 21 ; CHTE 1 1111⑩ 1/4 ; ATCO ⑩ 0/1
2/4 ERVI 2 1111 ; HACO 32 11 5/2

Rock 0
Scree 0
Cover (43) = .213
Dead (2) = .010
LAI (25) = .248

RS 2.1 N facing slope of [illegible] 40 m down from ridgetop

SCREE UNLESS OTHERWISE NOTED

46.5% to 10°; 36°51' 3188 N; 116°27' 3658 W

SOIL 17 tallies 0/17 ; ARTR 2132124222 1123 26/23 ; ERFA 22 1111 4/4
CHTE 11⑩1 1/3 ; POA 1 11 1/2 ; STSP 1 0/1
EPVI 1 0/1 ; CHNA 11 11 2/2

Rock (0) = 0
Scree (185) = .916
Cover (36) = .178
Dead (2) = .010
LAI (34) = .337

RS 2.2 Ridgetop

11% to 88°; 36°51' 2847 N; Battery Fault — Batteries on GPS lost

ERFA 8 tallies 0/8 ; HACO 21312 ⑩ ⑩ ⑩ ⑩ 111 1/13 ; LYAN 1 1⑩1 1/3 ; CHTE 222 1111 111 6/8
ROCK 52 tallies 0/52 ; CELA 1⑩ 0/1 ; EPNE 1 1111 11 1/7
STSP 1111 0/4 ; CHVI 2 111 2/3 ; CORA 2 11 2/2

Rock (52) = .257
Scree (0) = 0
Cover (49) = .243
Dead (5) = .025
LAI (21) = .208

RS 2.3 39% to 163°

south of above ridgetop 20 m down –

Rock unless otherwise stated

ATCO 11⑩⑩ 0/3 ; 0/51 SOIL 51 tallies ; SCREE 21 tallies 0/21
HACO 2 11 1111 1111 4/9 ; EPNE 1111 1⑩1 0/7 ; CHTE 1 111⑩ 1/4
ERFA 1 111 1/4 ; CHVI 22 1111 4/6 ; STSP 1 0/1
AMDU 111 1111 11 3/7 ; LYAN 11⑩ 0/2 ; CELA ⑩ 0/1
EPVI 1 0/1 ; KRGR ⑩ 0/1

Rock (130) = .644
Scree (21) = .104
Cover (46) = .228
Dead (7) = .035
LAI (13) = .129

*4/5/97 (UK=CRPA?) All rock unless marked soil

3-28-97 FRIDAY

RS 16.1 Ridge top no slope 2.5% to 85° DPG : JJT DPG 2-10-98

36° 50' 2901 N ; 116° 27' 4343 W

ROCK 0/25 SOIL 0/0

SCREE 0/0 CHVI ||| 0/3 STSP 0/3

HACO 3 2 3 0/4 ERFA 2/5 ATCA 0/1

EPNE | 0/1

rock (25) = .124
Scree (0) = 0
Cover (32) = .158
Dead (10) = .050
LAI (18) = .178

~~Rock (25) = .124~~
~~Scree (0) = 0~~
~~Cover (17) = .084~~
~~Dead (5) = .025~~
~~LAI (10) = .010~~

NORTH SIDE RS16.1

SCREE ERFA 0/5 CHTE 1/2

ROCK UK? ~~[illegible]~~ 0/1 EPNE 3/4

SOIL CHVI || 1/2 HACO 3/1

~~Rock (0) = 0~~
~~Scree (0) = 0~~
~~Dead (5) = .025~~
~~Cover (15) = .074~~
~~LAI (8) = .079~~

RF for DWG/DPG 9/26/01

RS 16.2 N slope edge of ridge 50 m from top

36° 50' 2811 N ; 116° 27' 4491 W 39% to 12°

ERFA 2/16 UK 0/3 POA ||| 0/3

SCREE 0/51 HIJA ||| 0/3 GRASS UK |||| 0/4

CHTE 4/8 ATCO 0/4 TEAX ~~TETRAYMA?~~ 0/1

UK GRASS | 0/1 GRSP 2/1 EPNE 4/4

ROCK = 0
SCREE (51) = .252
COVER (48) = .238
DEAD (11) = .054
LAI (12) = .119

Plants on Crack Excavated by D. A. : Stn

GRSP	HACO	EPNE	LYAN
12	1	6	1

15-17 m long

* 4/15/98 DPG 2-10-98

3/27/97 Thursday Yucca Mtn

RS-19.1 32% to 123° 36° 50' 1466 N ; 116° 27' 4193 W

LYAN 10 11 1/3
HYSA 12 ||||| 11 0 ||||0 10 11 10 3/16
EPNE ||||| 12 ||||| ||||| 1 0 1 9/12
SCREE |||| 0/4
GRSP 10 111 0/4
~~LYSA~~ LYAN 11 0 10 0/3 — okay DF 9/13/00
CELA 1 0/1
AMDU 1 1/1
HACO 1 0/1

SCREE (4) = .020
ROCK (0) = 0
COVER (41) = .203
DEAD (9) = .045
LAI (13) = .129

RS-19.2 37% to 218° 36° 50' 1568 N ; 116° 27' 3730 W

GRSP 10 11 0 0/4
SCREE ||||| ||||| ||||| ||||| 1 11 ||||| |||| ||||| |||| 0/44
EPNE 1 |||| 1/5
CHTE 1 0/1
HACO 3 2 2 1 3 2 ||||| 11 0 ||||0 111 13/15
AMDU 1 11 0 1 1/3
STSP 11 0/2
CELA 1 |||| 1/4
LYAN 1 0 0/1
HYSA 11 11 0 1 2/3

SCREE (44) = .218
ROCK 0 = 0
COVER (38) = .188
DEAD (7) = .035
LAI (18) = .178

RS-18.1 42% to 41° 36° 50' 1527 N ; 116° 27' 3848 W

SCREE ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| ||||| 11
ROCK ||||| ||||| 0/10
ERFA 1 3 1 1 2 2 1 2 1 1 2 2 ||||0 1 0 ||||0 |||| ||||| ||||| ||||| 21/31
CATE 3 1 3/1
POA 1 |||| 1/5
EPNE 11 0/2
LYAN 11 2/2
GRSP 1 0 1 1/2
CHVI 11 0/2
STSP 1 0/1
CHNA 1 0/1

SCREE (77) = .381
ROCK (10) = .050
COVER (47) = .233
DEAD (4) = .020
LAI (28) = .277

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*4519.88

3/27/97

Spray denotation before was moll GRSP

All CHVI before this should be YYE1

ALL LYPA before this in a ~~may be this~~ ? species

ERYA = 2 sous

RS-21.1

34% to 194° 36° 50' 1086 N 116° 28' 799 W

SCREE 0/54

EPNE 3/6 ATCO 0/1 CHTE 1/1

CELA 5/2 CHVI 1/1 HACO 7/5

ROCK 0/37 GRSP 6/7 ERFA 3/6

STSP 0/1 LYAN 0/5

Rock (37) = .183
SCREE (54) = .267
COVER (35) = .173
DEAD (3) = .015
LAI (26) = .257

RS-21.2

43.5% to 157° 36° 50' 625 N 116° 27' 5973 W

SCREE 0/51

ROCK 0/38 GRSP 4/10 ATCO 1/1

EPNE 4/10 CELA 4/4 HACO 2/2

LYAN 3/5 ST SP 3/6 ERFA 3/8

ROCK (38) = .188
SCREE (51) = .252
COVER (46) = .228
DEAD (2) = .010
LAI (24) = .238

ROCK (22) = .109
SCREE (3) = .015
COVER (45) = .223
DEAD (3) = .015
LAI (30) = .297

RS 20.1

13.5% to 17° 36° 50' 0984 N 116° 27' 4936 W

ROCK 0/22 POA 0/3 ~~ERFA~~ 4/5 SCREE 0/3

HALI 11/19 CHTE 2/1 HACO 10/5 GRSP 1/3

EPNE 2/1 HIJA 0/6 AMDU 0/1 LYAN 0/1

Haplopappus linearifolius

RS 20.2

30% to 355° | 36° 50' 1513 N | 116° 27' 4228 W

EPNE 3/7 ROCK 0/13

ARTR 20/26 SCREE 0/14

ERFA 3/10 CHNA 1/2

ROCK (13) = .064
SCREE (14) = .069
COVER (45) = .223
DEAD (7) = .035
LAI (20) = .257

4/26/97 YUCCA MTN WED P.M.

* 4/5/97
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RS-23.1

-33.5% to 128°

HYSA |||| 0/4 MESE | 1/1 HYSA ||| 0/3
AMDU | 0/1 LYAN ||⊚ 0/2 ATCA || 2/2
HACO CELA ||||⊚| 2/5 TEGL || 1/2
EPNE 1211 5/11 ROCK 0/6
STSP | 0/1 GRSP |⊚| 0/2

Rock (6) = .030
Scree (0) = 0
Dead (3) = .015
Cover (34) = .168
LAI (11) = .109

RS-23.2

HT / CROWN

-9% to 98°

EPNE 12113 8/7 HALI 21121 7/8 CELA | 1/1
ROCK 0/67 STSP | 1/1 EPVI || 1/2
ATCA ||| 2/3 HIJA ||| 0/3
ERFA 2212221 12/15 ARTR || 1/2
GRSP | 1/1 (cal'sha) CACH 2/1

Rock (67) = .332
Scree (0) = 0
Dead (3) = .015
Cover (44) = .218
LAI (36) = .356

RS-23.3

36.5° to 28°

ERFA 24112 11/14 EPNE | 0/1 Rock 0/6
STSP | 0/1 GRSP 0/4 STSP | 1/1
ARTR 133 7/4F → ARTR 11232222 15/16
SCREE 0/21 HALI 1/4 POA 2/1
EPVI | 1/1 LYAN || 0/2

Rock (6) = .030
Scree (21) = .104
Dead (6) = .030
Cover (49) = .243
LAI (38) = .376

RS-23.4

(just downslope 50 m (in saue) from 23.3)

-53.5% to 16°

0/136 SCREE 0/68
49/62 ARTR 20/31 a121211111 2112
2/2 STSP 1/1 |

* completed 1/2 transect due to time – multiply by 2 constraints – getting dark
– no soil sample v. rocky

Rock (0) = 0
Scree (136) = .673
Dead (5) = .025
Cover (64) = .317
LAI (42) = .416

estimating 16° of deviation

~~189~~ ~~125~~ leaf / crown

* 4/5/97 SSt

3/26/97 Yucca Mtn Cap rock DPG 2-10-98

SITE RS24.1 21% + Slopes towards ~~[illegible]~~ 125°

GRSP 4 4 2 10/10 ~~[illegible]~~
|||| | | | | | ||

CELA 1 3 4/2
| |

ARTR 2 2/2
| |

HACO ~~3~~ 3 3 3 4 2 15/9
| | | | | | | | |

HYSA 0/2
||

EPVI | | 2/5
~~3~~ | | | | | |

ROCK (0) = 0
SCREE (0) = 0
DEAD (0) = 0
COVER (46) = .228
LAI (41) = .406

CHTE ||| 3 | 7/7
||| | | | |

LYAN | 1/5
||| | |

cross-outs this page are okay
RJK
9/13/00

ATCO 0/3
| | |

HIJA 0/1
|

*" ~~88~~ need to make batches

3/26/97 Yucca Mtn

DPG 2-10-98
YELL = yellow flowered bush

RS-24.2 (off cap rock)

Rock = Rocks, Stones

14.5 % slope to 100% ca 100' below 24.1 vertically

GRSP ① IIII 4/7
~~IIII~~ IIII

CELA I 1/1
I

EPVI II II 4/2
II

CHTE II 2/3
II⑤I

~~YELL~~

Rock 0/24
~~IIII~~ ~~IIII~~ ~~IIII~~ ~~IIII~~ IIII

EPNE II 2/6
~~IIII~~I

ERMI II 2/6
I⑤I⑤III

HACO ~~IIII~~I 6/6
III⑤III

MESP 0/1
I

ORHI
INDIAN RICEGRASS 0/1
①

LYAN 0/1
I

~~[illegible]~~ DF 9/13/00

HIJA 0/1
I

Rock (24) = .119
SCREE (0) = 0
DEAD (5) = .025
COVER (37) = .183
LAI (21) = .208

3/26/97 Wed

DPG 2-10-98

* 4/5/97

RS 24-3

37.5 % to 20° N-facing slope

ERFA	3 1 3	8/5	EPNE 11	2/4
	1⑩ 1111		1111	
GRSP		0/2	CHTE 1	1/3
	1⑩1		1⑩11	
POA		0/1	HALI	0/1
	1		1	
STSP		0/1	EPVI 1	1/2
	1		11	
HAGO		0/1	SCREE	0/5
	1⑩		𝍸	
			CHNA	0/1
			1	

ROCK (1) = .005
SCREE (16) = .079
DEAD (9) = .045
COVER (53) = .262
LAI (36) = .356

~~RS 24-3~~ same site 9/1/00

ERFA	1 2	3/10	Spharalcea SPCO	0/1	ROCK	0/1
	1⑩11⑩ 1⑩11⑩11⑩		1		1	
EPVI	11	2/2	HIJA	0/1		
	11		1			
SCREE		0/11	ARTR 3 3 2 1	7/8		
	𝍸𝍸 1		𝍸111			
CHTE	2 2	4/4				
	1 111					
STSP	11	2/3				
	111					
HALI	2 1 1	4/3				
	1 11					

3/30/97 Easter Sunday Yucca Mtn UT 2 DPG * 4/5/97 DPG 2-10-98

Dan's Crack Site (also TRW study site?)

RS 30 — east side of road — cap rock
15% to 87°; 36° 49' 1468N; 116° 27' 5950W

LYAN	1 ~~||||~~	1/5	EPNE	1121 ~~|||| ||||~~	5/10	HAKO	334 ||| –	10/3
ROCK	~~||||~~ ||||	0/9	HYSA	22 ||||	4/4	ERFA	2 ||	2/2
GRSP	6133 ~~|||| ||||~~ ||	13/12	ATCA	⑩||	0/3	TEAX	1⑩⑩⑩⑩	0/4
CELA	||	1/2	CHTE	2 ||⑩	2/2			

SCREE (0) = 0
ROCK (9) = .045
DEAD (6) = .030
COVER (47) = .233
LAI (38) = .376

Took 2 soil samples here 1@ ~~15~~ 5-10cm deep and another at 45-50cm deep

~~Ages of soil, aeolian guality, ages of desert varnish~~ (stable surface)

RS29 — west side of road — cap rock (like samples from 3-25 = caprock)
additional site on ridge where Dave's site measured infiltration of rocks - Also site 8 USW-UZ-N62

ROCK (62) = .307
SCREE (0) = 0
DEAD (6) = .030
COVER (42) = .208
LAI (26) = .257

7.5° to 83°; 36° 49' 4852N; 116° 28' 052AW [4964 ft ALT]

GRSP	1 |||	1/3	ROCK	~~|||| |||| |||| |||| ||||~~ [illegible] ~~|||| |||| |||| |||| ||||~~ [illegible]	1/62	HAKO	2 13 121 [illegible] ||	10/12
HALI	1221 ~~||||~~ ||	6/7	CHTE	1	1/1	CHVI	⑩	0/1
ERFA	223 ~~||||~~⑩|||⑩	7/9	HIGA	|||⑩	0/4	LYAN	1	0/1
HYSA	1	0/1	EPNE	||	1/2	UK	1⑩	0/1

RS28 40% to 82°; 36° 50' 639 N; 116° 28' 856 W
(same unless otherwise)

0/50 SOIL	~~|||| |||| |||| |||| |||| |||| |||| |||| |||| ||||~~		ROCK	~~|||| |||| ||||~~	0/15	EPNE	2 ~~|||~~ 1	2/6	ATCO	1	0/1
~~GRYA~~	4 ||		ERFA	251 ~~||||~~⑩ ~~||||~~⑩||⑩|⑩||⑩||	8/17	HAKO	1	1/1	UK	||⑩⑩	0/2
GRSP	21132 ~~||||~~ ⑩ |||	13/9	EPVI	1 ||	1/2	LYAN	1	0/1	HYSA	1	1/1
STSP	||	0/2	ELEL	1	0/1	CHTE	1	1/1	STPA	1	0/1
CHTE	3 [illegible]	3/1									

elymus elymoides & STSP may be confused due to lack of floral parts on some transects

SOIL (50) = .248
ROCK (15) = .074
SCREE (0) = 0
DEAD (7) = .035
COVER (48) = .238
LAI (30) = .297

DPG 2-10-98

Laboratory Analyses, May 1997: Measurement of vegetation crown cover on low altitude, high-resolution air photos.

Purpose:
From the field work conducted in late March, it was evident that the analysis of vegetation made on the ground was too time consuming for the scope of this investigation. Instead, preliminary analyses of air photos indicated that use of low-altitude nadir-look air photos obtained by the author on 3-23-97 provided estimates of vegetation crown cover comparable to that measured on the ground. From the results of transects obtained in the field in late March, 1997, it was evident that four distinct environments exist in the zone above the repository zone, these formed out of crystal-rich tuff caprock with all slopes gently sloping toward the east and from crystal-poor tuff having north-and south-facing slopes and ridgelines.

Methods:
Patches of homogeneous vegetation of the four environments were delimited on the air photos using a permanent marking pen in approximately 30 x 30 m plots. A square grid field was then overlain over the air photo under 15x magnification. Points of the grid that intersected vegetation were counted and tallied. These tallies were divided by 500, the number of grid points used to yield fractional crown cover..

Summary of Results:

Landscape Position	Rock Type	No. of Plots	Crown Cover Mean and (St.Dev.)
Caprock	crystal rich tuff	25	0.296 (0.036)
north-facing slope	crystal-poor tuff	19	0.322 (0.086)
south-facing slope	crystal-poor tuff	19	0.142 (0.032)
ridgelines	crystal-poor tuff	8	0.184 (0.027)

Attached Pages:

3 pages of data generated during air photo analyses.
18 pages of copies of air photos with plots indicated.

Caprock Series

DPG
2-10-98

Plot	5 transects: Hits on Shrubs	$\bar{x}$
A.1	24, 25, 31, 36, 47	32.6
A.2	30, 27, 35, 36, 37	33.0
A.3	21, 19, 27, 32, 32	26.2
A.21	39, 22, 31, 28, 26	29.2
A.22	28, 29, 30, 39, 27	30.6
A.4	23, 26, 25, 28, 29	26.2
A.5	18, 37, 25, 27, 43	30.0
A.6	21, 34, 20, 24, 29	25.6
A.7	23, 24, 19, 16, 34	23.6
A.23	25, 25, 37, 31, 33	30.2
A.8	33, 22, 22, 25, 26	25.5
A.24	20, 22, 26, 25, 36	25.8
A.25	22, 26, 21, 31, 25	25.0
A.9	32, 39, 29, 26, 35	32.2
A.10	25, 35, 19, 25, 26	26.0
A.26	34, 36, 30, 21, 31	30.4
A.11	31, 27, 36, 30, 31	31.0
A.12	31, 33, 24, 33, 44	33.0
A.13	31, 29, 31, 22, 21	26.8
A.14	38, 37, 38, 35, 41	37.8
A.15	25, 32, 45, 38, 21	32.2
A.17	35, 31, 42, 29, 33	34.0
A.18	39, 32, 25, 42, 33	34.2
A.19	35, 31, 31, 39, 21	31.4
A.20	36, 27, 25, 21, 27	27.2

Mean Overall
0.288
sd = .0634

Mean Plotwise
0.296
sd = .0362
n = 25

Gridfield: 50 ticks across × 2 (each side of tick) × 5 transects = 500

divide total Hits / grid of 5 transects by 500

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2-10-98

Below Caprock: North- vs. South-Facing Slopes

Plot	Slope	5 transects Hits on shrubs	$\bar{X}$
B1	S	24, 18, 22, 13, 13	18.0
B2	S	22, 21, 18, 15, 18	16.8
B3	S	17, 14, 16, 22, 23	18.4
B4	S	21, 19, 20, 20, 20	20.0
B5	N	23, 28, 32, 25, 34	28.4
B6	N	42, 34, 36, 35, 27	34.8
B7	N	32, 29, 30, 40, 41	34.4
B9	S	16, 4, 13, 20, 11	12.8
B10	S	9, 14, 6, 16, 11	11.0
B11	S	17, 18, 12, 10, 13	14.0
B12	N	29, 27, 24, 21, 24	25.0
B13	N	21, 25, 21, 25, 24	23.2
B14	N	25, 21, 23, 22, 16	21.4
B15	N	25, 27, 25, 25, 23	25.0
B16	S	24, 12, 13, 16, 5	14.0
B17	S	10, 6, 10, 10, 14	10.0
B18	S	5, 15, 14, 7, 15	11.2
B19	N	22, 24, 30, 27, 23	25.2
B20	N	33, 24, 26, 39, 29	30.2
B21	S	14, 5, 9, 13, 9	10.0
B22	S	12, 12, 13, 22, 18	15.4
B23	N	34, 33, 33, 30, 31	32.2
B24	N	36, 39, 38, 42, 38	38.6
B25	S	11, 13, 10, 10, 10	10.8
B26	S	9, 13, 14, 14, 14	12.8
B27	N	38, 42, 55, 52, 55	48.4
B28	N	50, 52, 44, 50, 47	48.6
B29	N	43, 36, 51, 46, 54	46.0
B30	N	43, 49, 47, 36, 35	42.0
B31	S	13, 14, 14, 20, 14	15.0
B32	S	23, 15, 22, 17, 14	18.2
B33	N	34, 25, 27, 30, 32	29.6
B34	N	27, 21, 31, 37, 24	28.0
B35	S	20, 15, 16, 22, 20	18.6
B36	S	8, 10, 9, 16, 11	10.8
B37	S	10, 14, 13, 22, 15	14.8
B38	N	33, 33, 41, 29, 34	34.0

Overall:

S-facing:
$\bar{X}$ = .143
st dev. = .0488

N-facing:
$\bar{X}$ = .324
st dev. = .0972

Plotwise:

S-facing:
n = 19
$\bar{X}$ = .142
sd = .0323

N-facing:
n = 19
$\bar{X}$ = .322
sd = .0856

Below Caprock
Ridges between N & S-facing Slopes

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Plot	5 transects, Hits on Shrubs	$\bar{x}$
C1	15, 21, 17, 19, 22	18.8
C2	15, 14, 18, 19, 20	17.2
C3	10, 13, 15, 18, 21	15.4
C4	23, 14, 13, 12, 16	15.6
C5	19, 28, 24, 26, 15	22.4
C6	17, 15, 16, 22, 21	18.2
C7	12, 21, 24, 25, 30	22.4
C8	21, 22, 17, 12, 22	18.8

Overall: $\bar{x}$ = .184
Std ev = .0466

Plotwise: n = 8
$\bar{x}$ = .184
St. Dev = .0265

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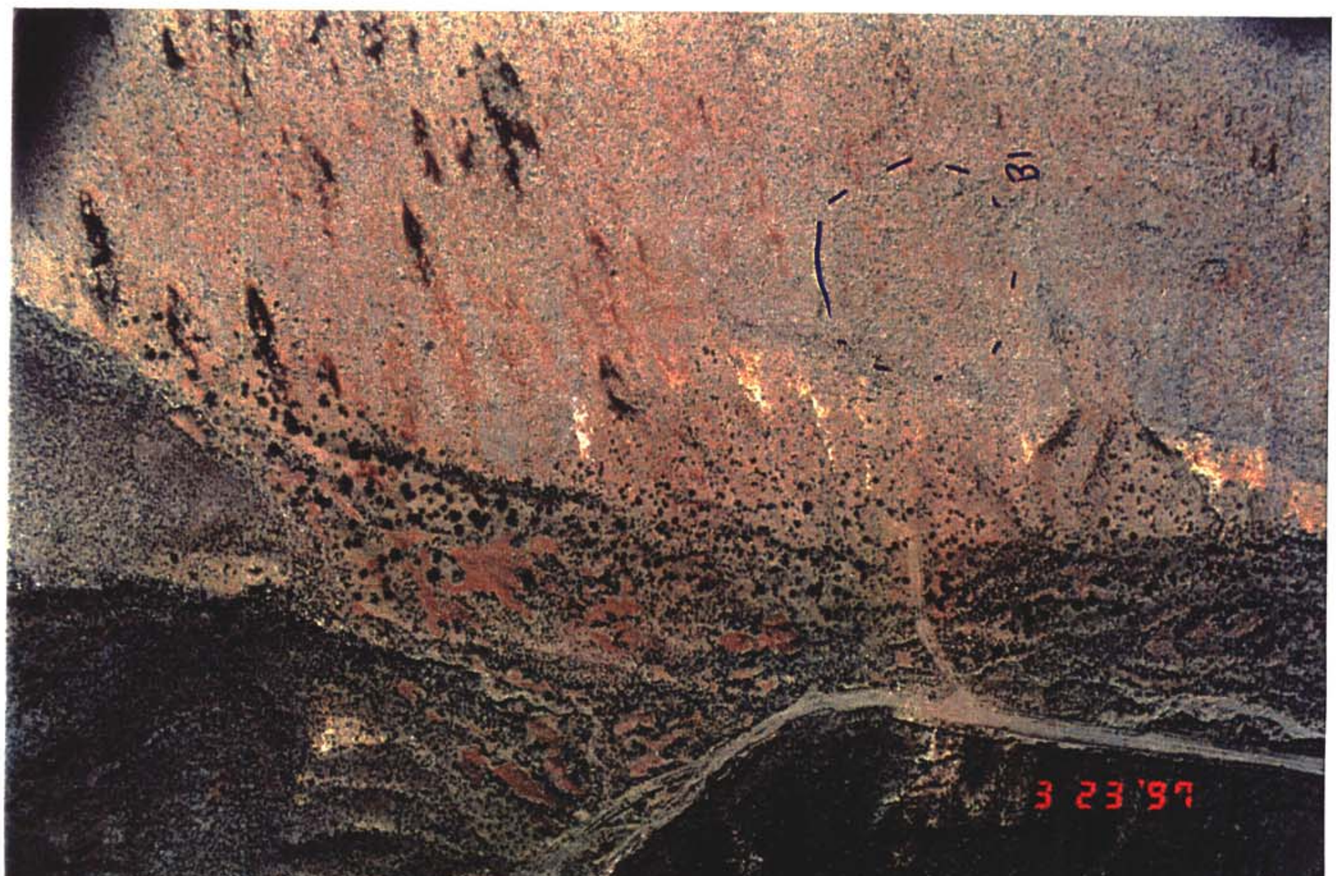

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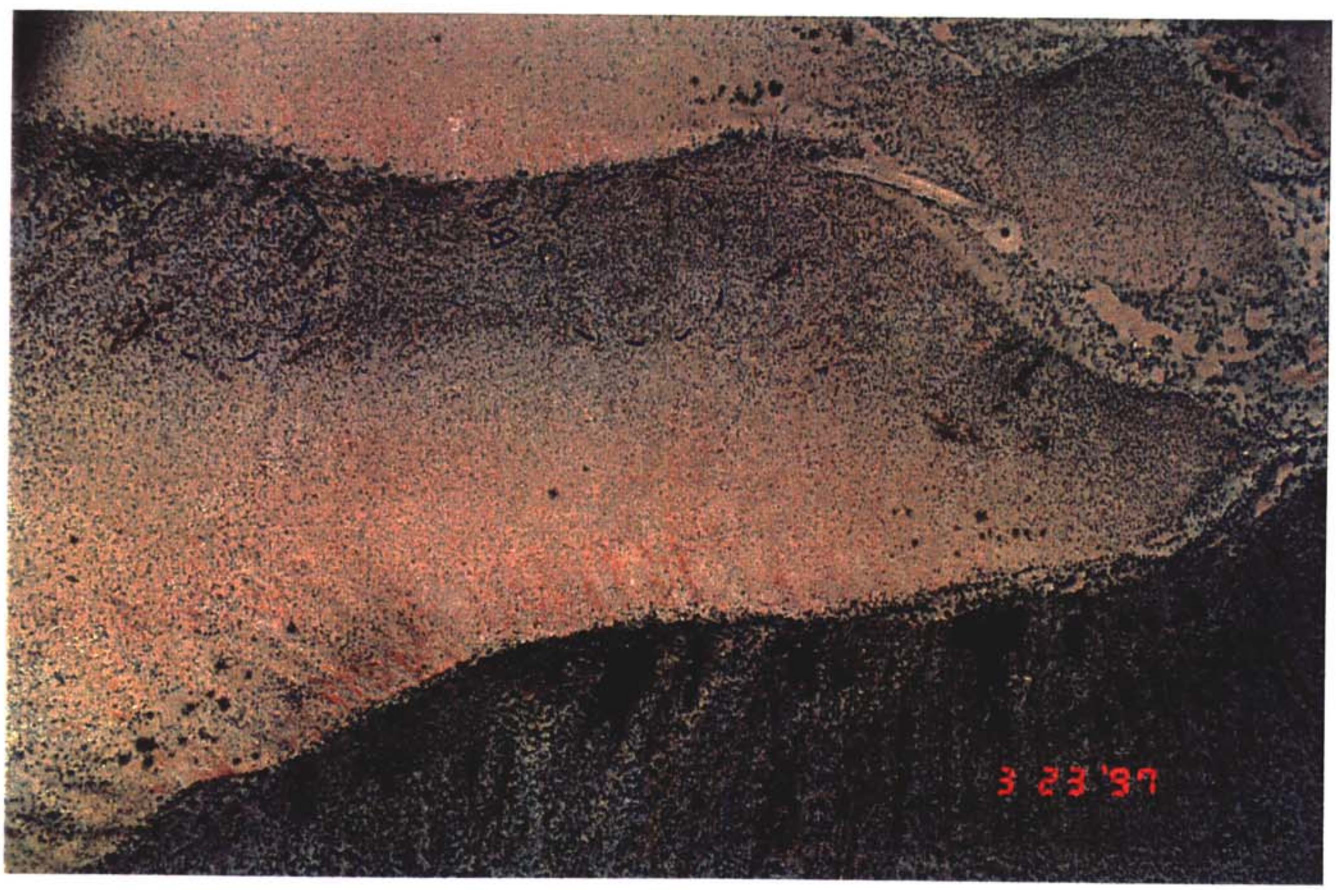

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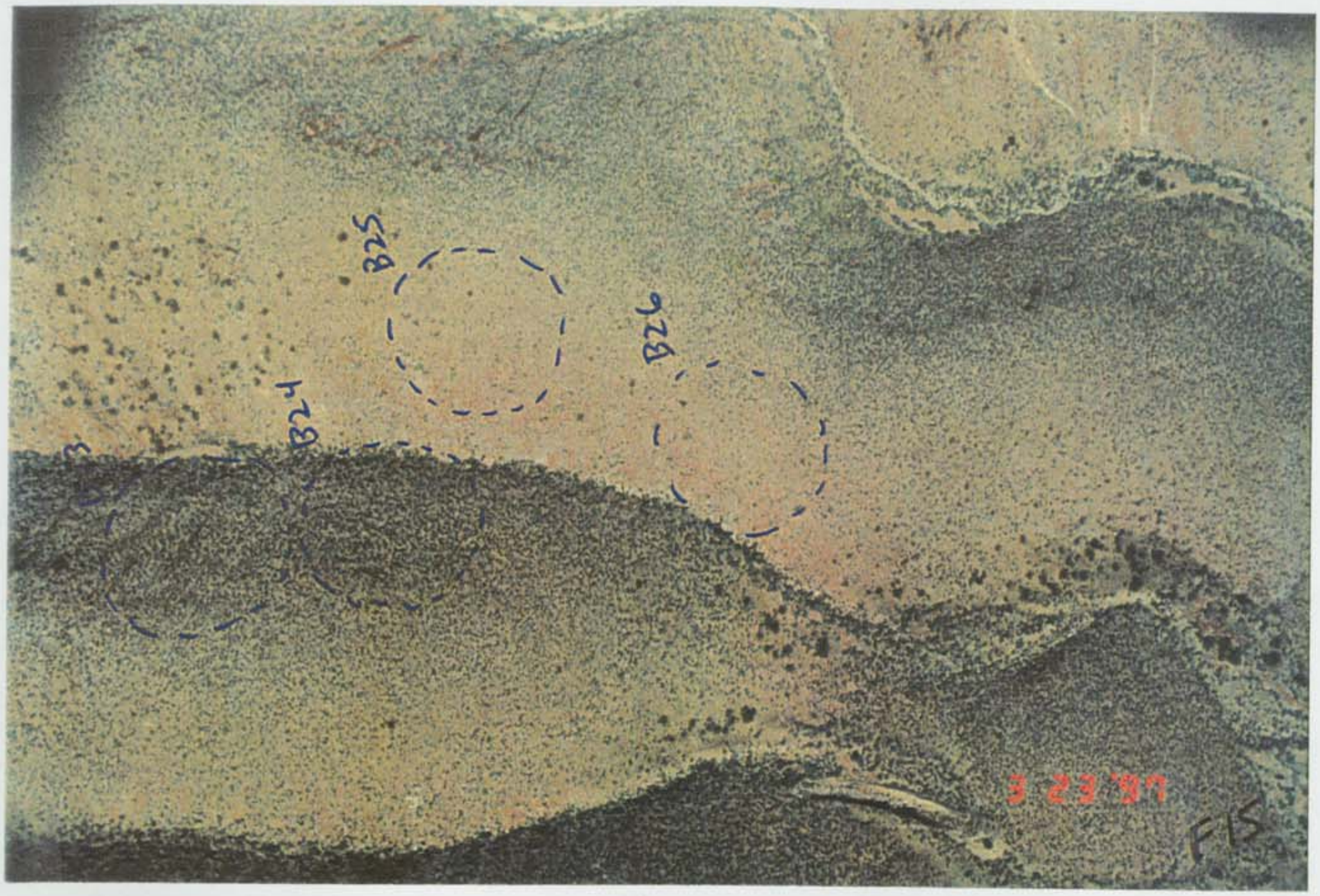

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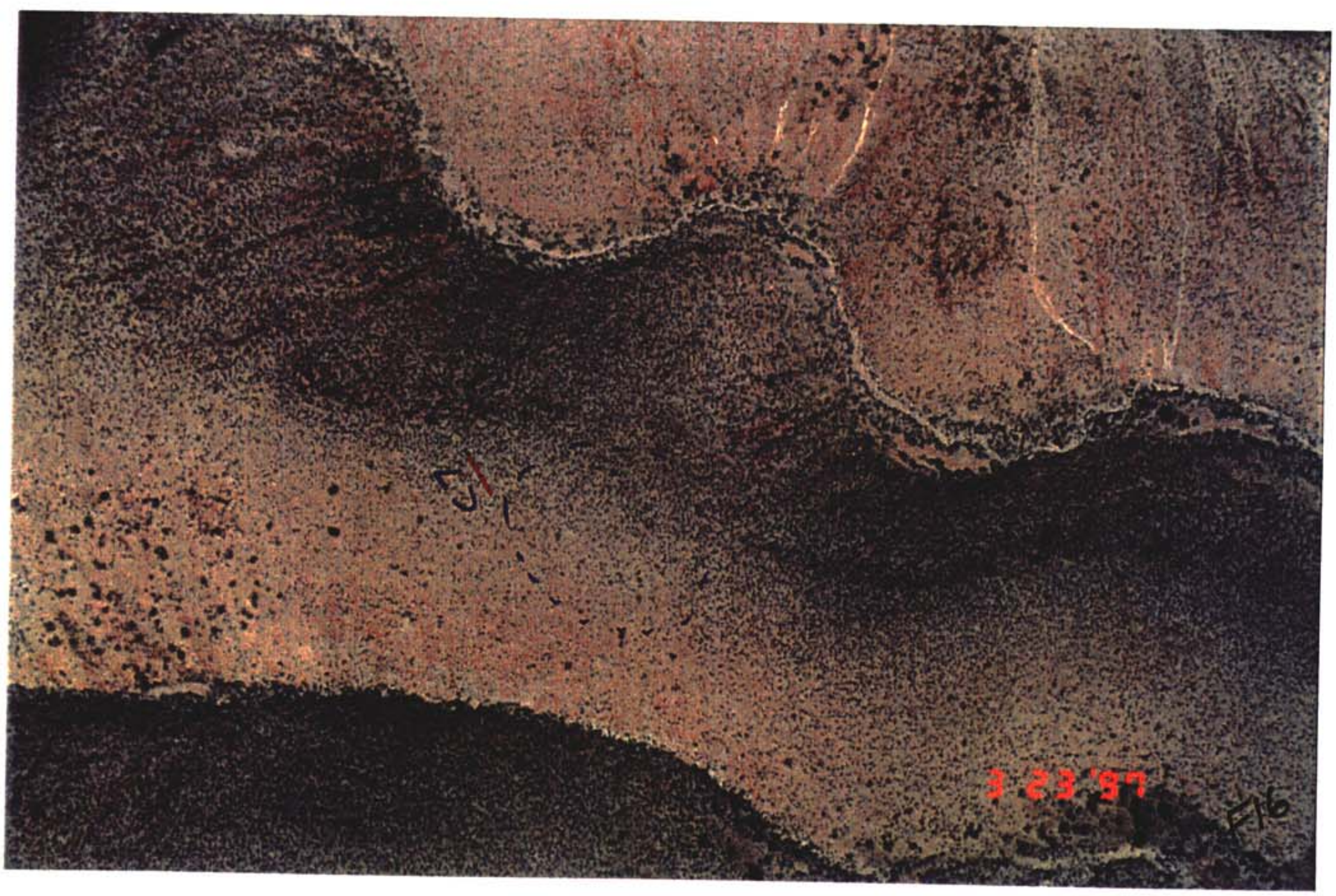

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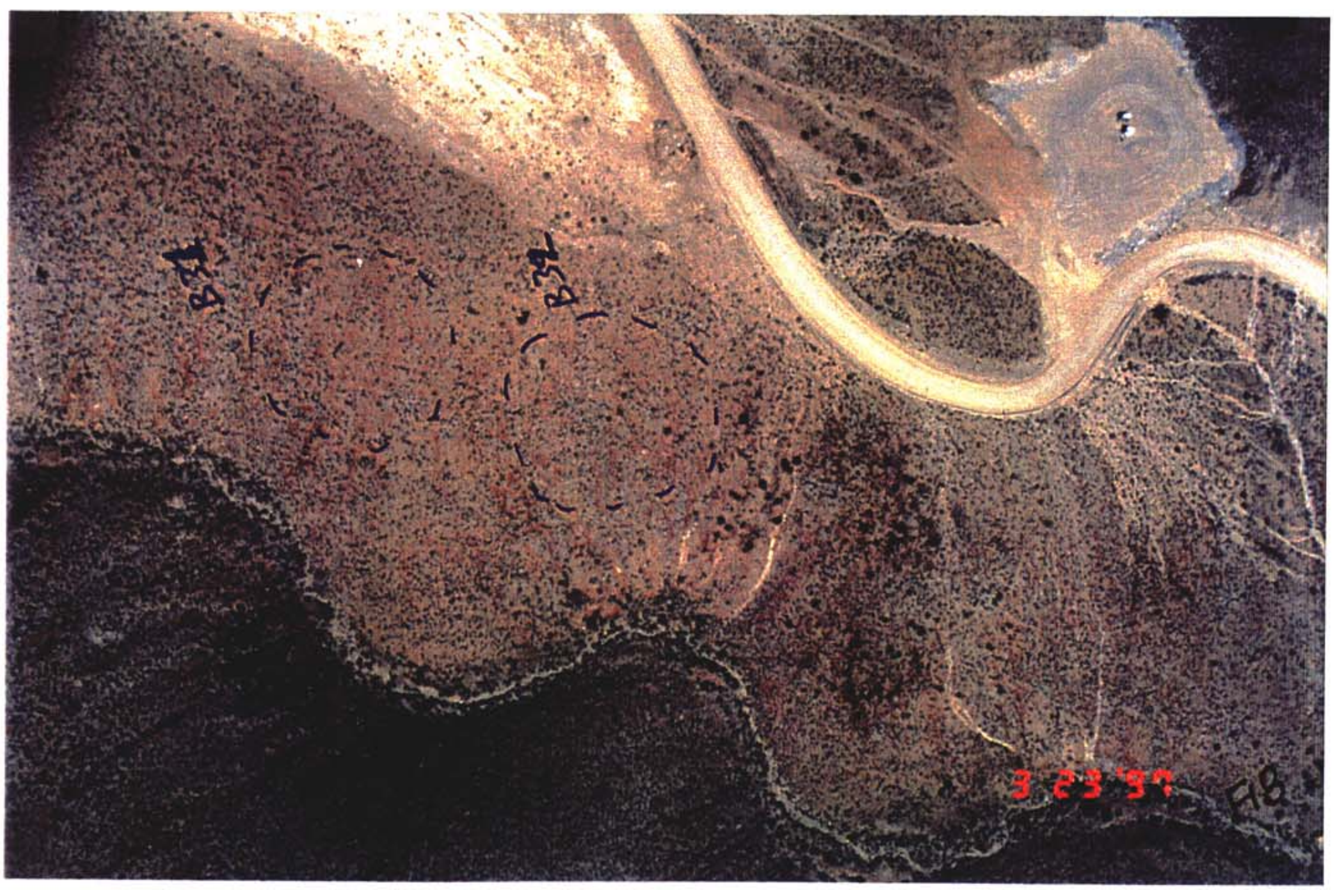

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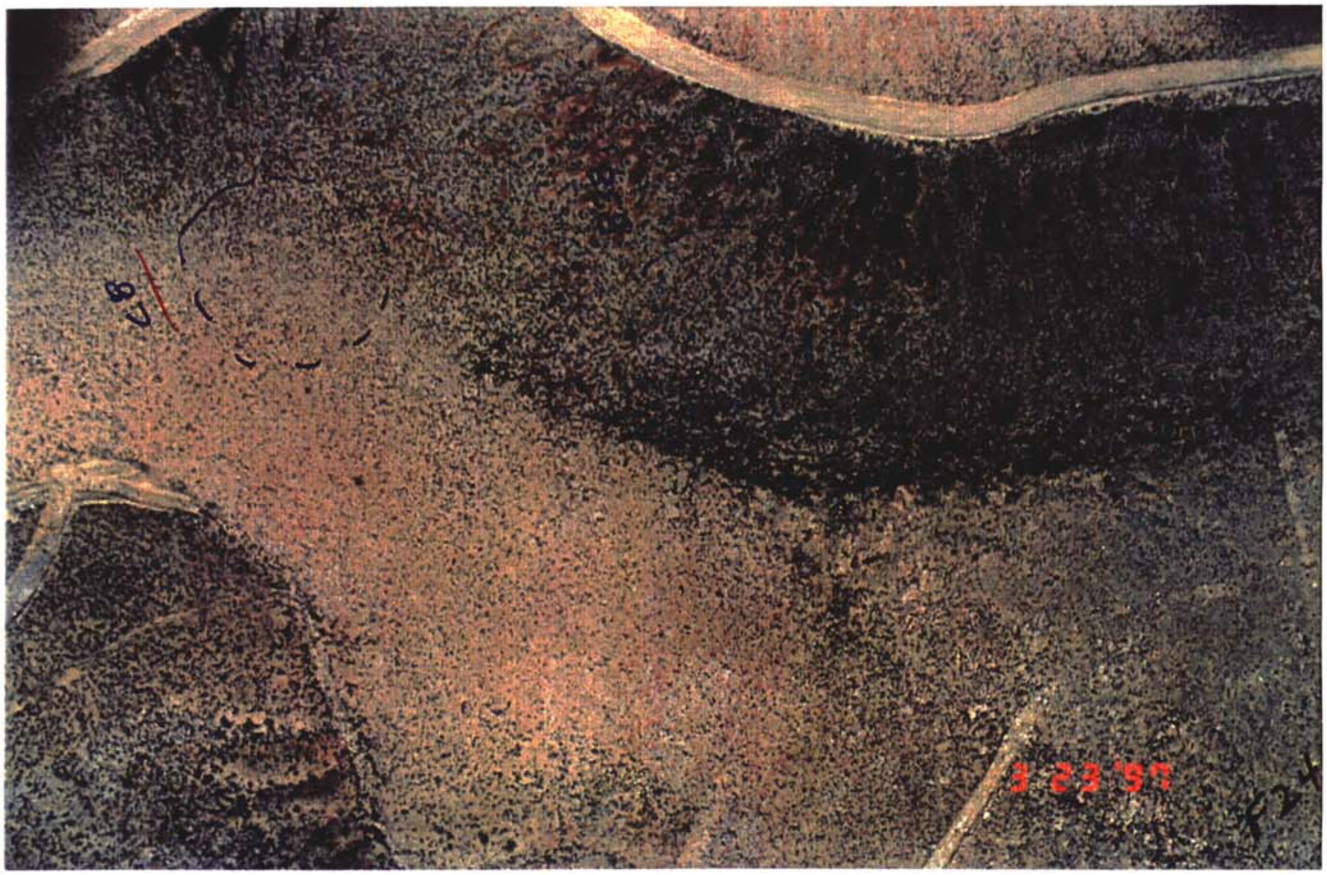

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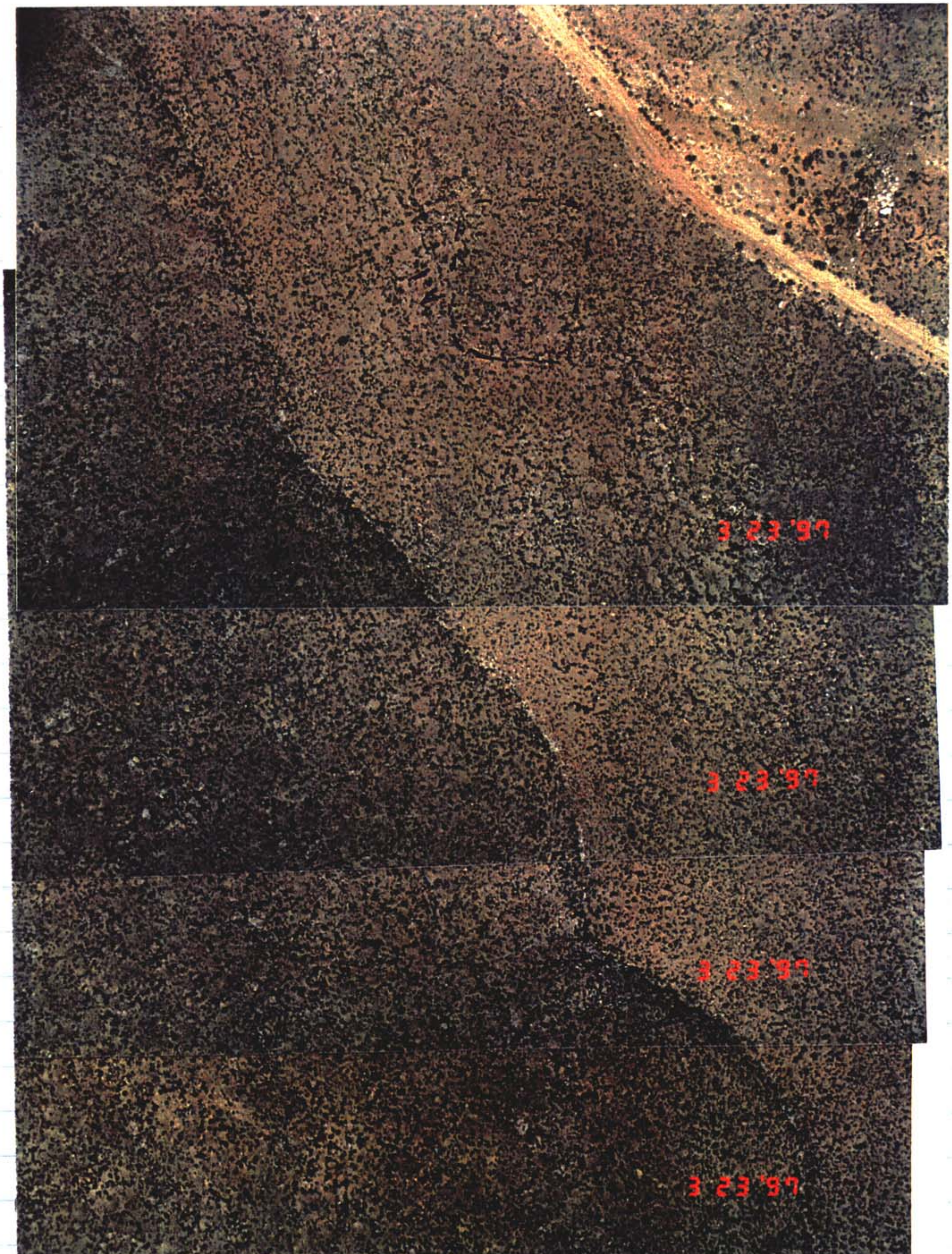

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"30", indicates pt. where fissure was excavated. Also, pt. RS 30 measured in fieldwork on 3-30-97.

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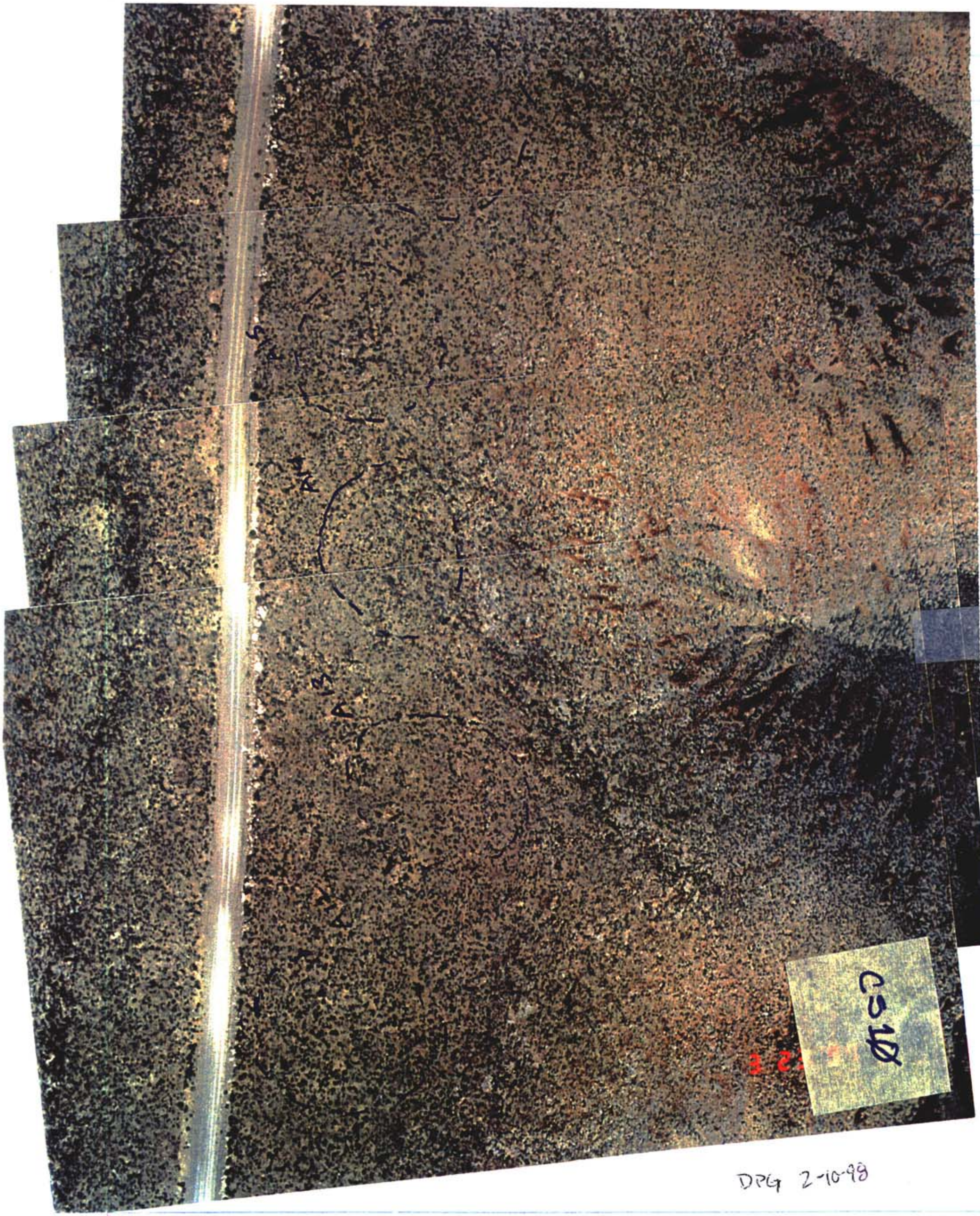

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Field Trip, June 5 through 9, 1997:
Scree as an infiltration hotspot, root growth, calcite in fissures and Yucca Mountain Prow and Shoshone Mountain as a climate-change analogs.

Field Notes:

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6-5 [Yucca Mtn: Scree site @ Abandoned Wash
– N 36°49.527'; W116°27.515'
– dissected scree pile, new fissures ... 16 ch ...
6-6 Dig & prep. plants in scree & slope over bedrock @ Abandoned Wash EPVI (note taking on this tomorrow)
– Roots to ≥ 7 m on small cyn S. of G.D. fault cyn, these definitely CHTE
– Pit in scree on 261° Aspect 57% larger scree ca 4x that @ Ab. Wash dig to 50 cm below soil surface wetter than −2 bar (could form ball)
– note that plants adj. to scree not benefitting from scree as at Ab. Wash or on scarp above Solitario Cyn. Why?
hypotheses: rain shadow of crest @ 5000' this site @ 4300'; also elevation in Streisfeld site for 60 yrs, dead shrubs – none were CHTE
→ Check in data base for recorded dead CHTE
greater heating? solar oven w/ less advective cooling and exposure to sky for radiation [16.0]

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Collect CHTE sample stem

notes on roots in dissected scree

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6-7 Field tour w/ Dave Woolhizer, Neil Coleman, D.O. & S.S. [11.0]

6-8 Tour of Yucca Mtn. Prow
N36°53' 975' ≈ 6000' need actual
W116° 28' 676' from map.

Juniperus osteosperma

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There coupled w/ cracks that, judging from cliff-face run several m. deep
joint pairs provide for overland flow in catchments measuring 10-30 m²
JUOS grows to only 5 m of cliff edge which may be catchment related. This is an island protected from fire, PTn below has evidence of spring flow

Notes on vegetation of Yucca Mt. Prow

- photo of CHTE, note cracks' roots, root of EPVI passing through, root proliferation in soil between rock faces, flattened roots to pass through cracks.
- EPVI - most roots upslope @ interface of scree and soil below. note adventitious roots (stem lifts) that give rise to new clones, fine roots in center of scree pile ca. 6 m from each edge; in one root that went downhill, then split & ca. 2/3 run uphill.

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- in dissected scree ≥ 10 m from edges top, bottom & side on W. Facing slope opposite Abandoned Wash, scree graded top coarse to bottom fine ca -2 bar potential @ 1 m total depth below scree

notes on exposed shrub roots @ Abandoned Wash

- On Yucca Prow - veg composition - JUOS(2), HALE(2), CORA(1), Yucca schid (very few), EPVI(3), ARTR(5) (in order of dominance)
JUOS may be 500-1000 yrs old [17.0]

Addnl. notes on Yucca Mt. Prow Veg.

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6-9 Shoshone Mtn., Alt. 7100'
N 36° 56.621'
W 116° 15.674'
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- majority of forest, uppermost, is PI
QUGA (Q. gambellii), EPVI, PUGL
ARTR, CHNA, Ind. ricegrass
SIHY, STSP, LYAN, UK shrub
Senecio sp., Spring flax sp., poa sp.
Lycium sp., Chrysothamnus greenii ?,
- wrap up [7.0]
- drive to BH [3.7]
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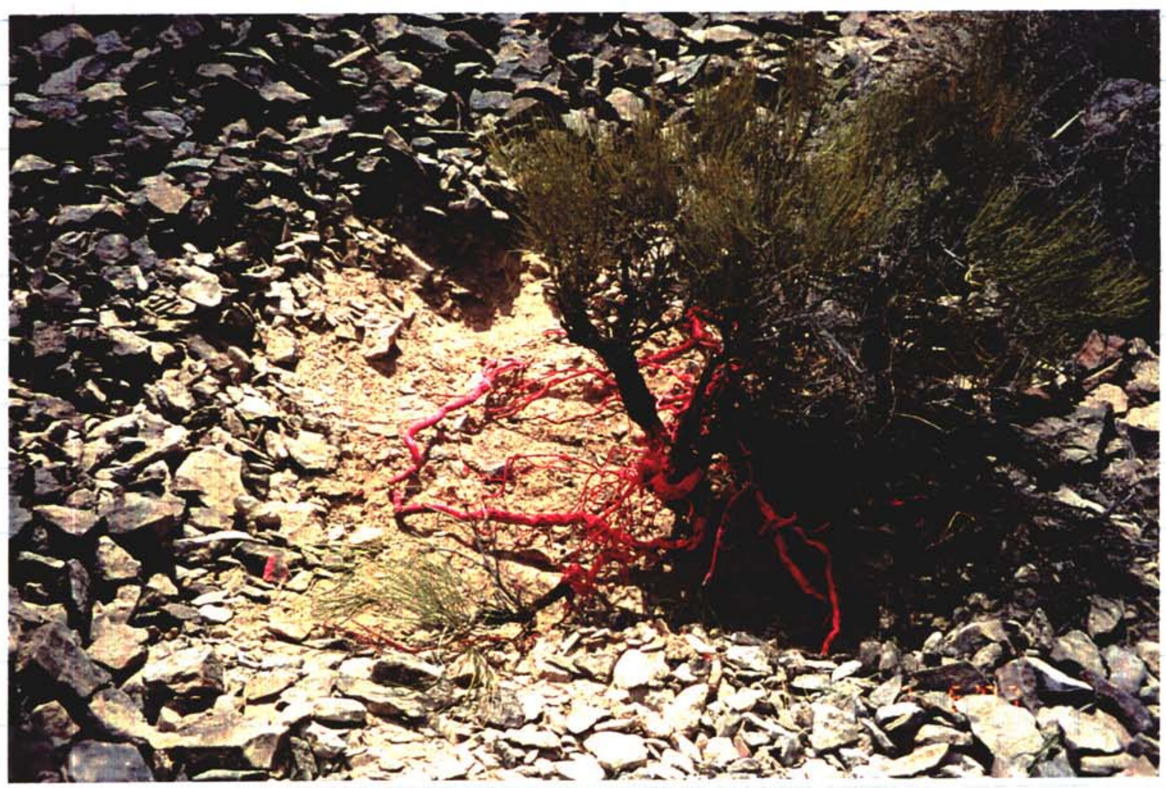
General species occupying Shoshone Mt. area.

Photos from Field that Illustrate Processes:

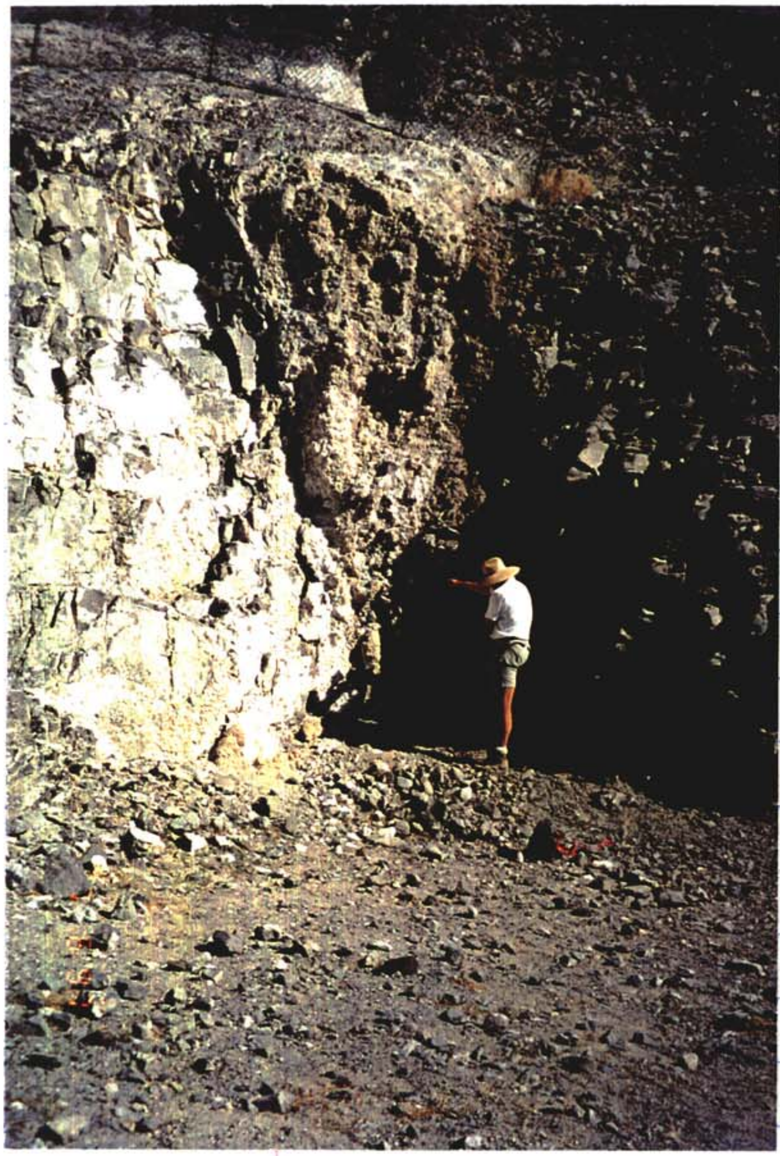
Scree pile in Abandoned Wash that dissected to expose roots and soil substrate

Scree has same aeolian SL soil found in all other locations of Yucca Mtn. and as was confirmed from samples taken in late March, 1997.



Ephedra viridis is associated with edges of scree patches.

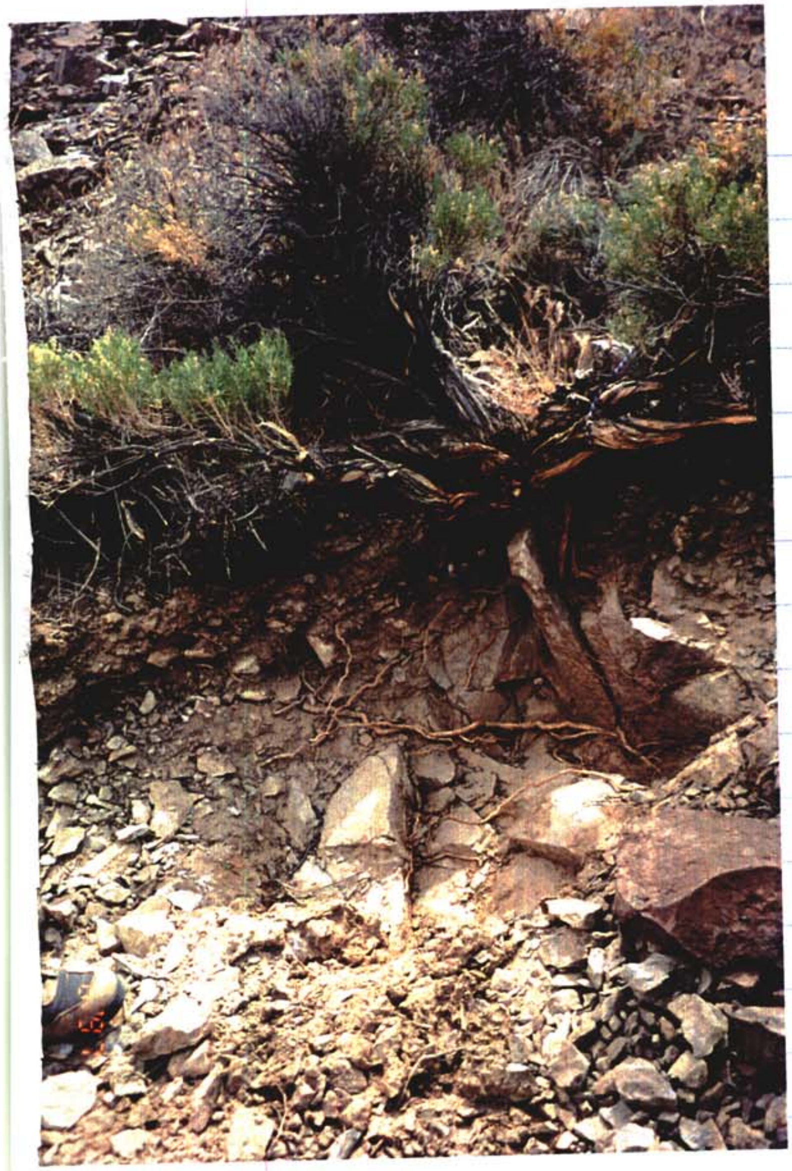
In Abandoned wash This Scree pile had roots in center, 6 m away



At this Ghost Dance Fault exposure roots of a shrub were found to have penetrated to 6 m. A severed root continued deeper from that point.

This is a close-up of the shrub root exposed penetrating the Ghost Dance fault.

2-10-98



This is a Chrysothamnus teretifolius located above the dissected scree pile in Abandoned Wash. A stem sample taken from this shrub has 97 annual growth layers

Roots of this shrub confirm that the roots observed penetrating the Ghost Dance Fault are from this species. A dark brown Ephedra viridis has penetrated beneath this shrub from about 4 m away (tip of finger in photo).

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S

Juniperus osteosperma exists on Yucca Mt. Prow because of the presence of crystal-rich caprock that provides catchments for precipitation. Note cover around tree constrained by buried rock.

The Shoshone Mt. site - a potential climate-change analog. This area has been repeatedly burned over last ~60 years. Note burn scars vs. unburned forest.

January 26 through 29, 1998:
Soil depths, calcite in fissures, growth rates of shrubs and trees on south- and north-facing slopes on Yucca and Shoshone Mountains.

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Trip Summary:

Yucca Mountain Study
Trip Report for Field Work, January 26-29
Prepared by David Groeneveld

DPG 2-10-98

Day 1, January 26

Dani Or, Randy Fedors and David Groeneveld began field work on Yucca Mountain in the unnamed canyon where the bedrock at Ghost Dance fault is exposed. This site lays on the south side of Antler Ridge where the canyon forks.

GPS cross-check

We began field work by obtaining data to cross check the accuracy of three GPS units. The data show relatively poor agreement, especially for latitude.

Dani's	36° 50' 36.70"	116° 27' 16.03"
Randy's:	36° 50 40"	116° 27 16.9"
David's:	36° 50 41.1"	116° 27 16.32

At Yucca Mountain, the approximate scale meters to seconds is,

Latitude: 30.9 m
Longitude: 24.9 m

Converted to distance, the range recorded was:

Latitude: 41.1-36.7seconds = 4.4 sec x 30.9 m = 136.0 m
Longitude: 0.9 - .03 seconds = 0.87 sec x 24.9 m = 21.7 m

Evidence of Root Dissolution of Calcite

Various tools (crowbar, wrecking bar, single-jack, cold chisel) were used to remove rocks to expose calcite fracture filling and in-situ roots. Samples were collected of root/calcite contacts. These were examined using a hand lens before and after wetting with water. The following was observed:

(1) needle-leaved rabbitbrush, ca. 3 years old, crown of 9 cm tall and 13 cm in diameter, taproot 11 cm long below the juncture with the crown, initially 8 mm wide then branching into several lateral roots that penetrated leaves of calcite filling the exposed fracture.

The roots penetrating the calcite were markedly flattened (as reported by other researchers). An upper weathering rind in the calcite (half circle with center at stem axis, radius ca. 15 cm) showed calcite that was very soft, moist, granular-to-friable and enriched with organic matter from roots. The overall appearance was that the roots had broken down the calcite in situ.

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Samples were obtained from deeper, ca 20-30 cm deep that clearly showed etching by a .8 mm diameter root across a flake of calcite. These were photographed.

Importantly, roots did not penetrate were the calcite fracture filling was solid. Instead, the roots appeared to penetrate only where the rock was already loose and where a space existed between the calcite filling and the tuff.. An hypothesis emerges that all calcite fillings on these side slopes is continuous and will prevent both infiltration and root penetration. As weathering occurs on these slopes, rock blocks become loosened, thereby permitting penetration by roots. Roots then create "tanks" within the fracture by dissolution and breakdown of the calcite and enrichment with root-derived organic matter. These tanks fill up following precipitation.

There is no doubt that the fractures are promotional to growth of the plants that penetrate them, however, the amount of promotion is limited. This can be seen by comparison of seedlings of needle-leaved rabbitbrush that have started on nearby drill pads and trench spoils. Here the seedlings, judged to be of about the same age (samples collected for verification), are far more robust probably due to the lack of inter-shrub competition, freedom for root expansion in all directions, and a medium that is open to infiltration in all locations.

(2) the root system of a buckwheat (*Encelia farinosa*, a sub-shrub with woody base and mostly herbaceous stems) was examined in the same manner as the root system of the needle-leaved rabbitbrush. Root etching of calcite was found beneath this buckwheat (roots of 0.5 to 1 mm)

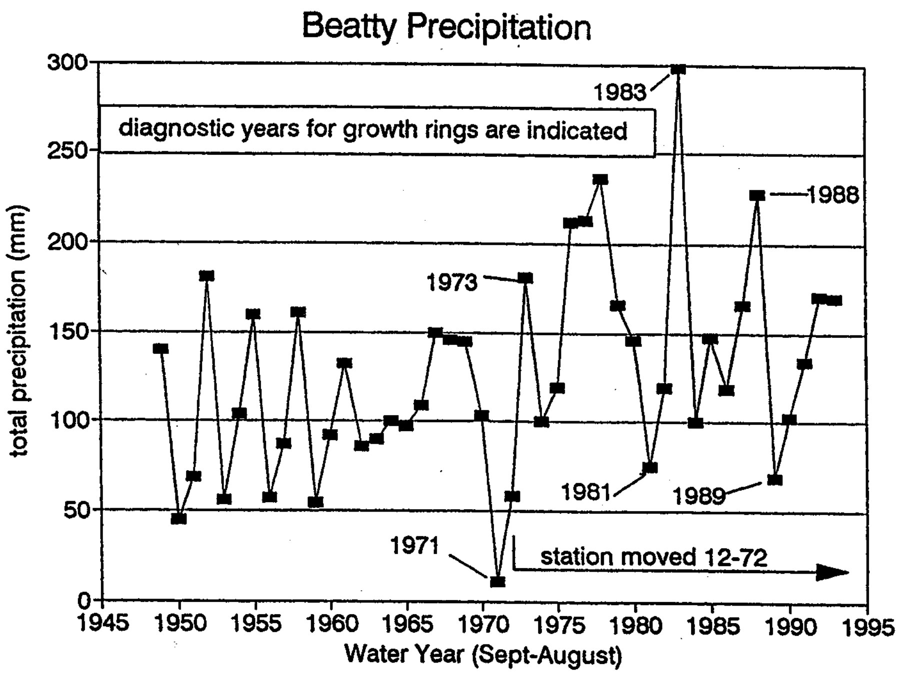
(3) the root system of a perennial herb *(Stephanomeria pauciflora)* was also examined in the same manner. Roots growing within an open crack were in contact with highly weathered (powdered) calcite. Most roots were very fine and the etching on the calcite was only observable under 10x magnification; these being less than 0.5 mm across.

Shrub Stem Samples

Dani and Randy dug a series of pits up the south-facing slope of Antler Ridge along the fall line and beginning at the east margin of the cleared zone. Needle-leaved rabbitbrush *(Chrysothamnus teretifolius)* grows on this slope and on various north-facing slopes. In other work in the Owens Valley, I have found that rubber rabbitbrush *(Chrysothamnus nauseosus)*, supported by shallow groundwater in the Owens Valley, California, grows annual layers in its stem. If the growth layers of needle-leaved rabbitbrush are also annual, this offers the opportunity to examine growth rates on north- vs. south-facing slopes to better understand the partitioning of precipitation water into evaporation or transpiration. This is of direct interest because plants that are coupled with fissures (in particular, needle-leaved rabbitbrush under the present climate) offer the only means for removal of infiltrated water once it has passed a depth of about 0.5 m.

Twelve shrub stem samples that were collected on S-facing Antler Ridge with position relative to the soil pits dug by Dani and Randy recorded. The distance between each of the pits on this slope were measured on 1-27 by Stu and myself

Shrub stem samples were obtained in anticipation that each growth ring represents one year. This will need to be confirmed in the laboratory by correlation of diagnostic wet and dry years with the patterns of thin and thick rings represented in the stem. Weather data from Beatty, Nevada obtained from Stu was sent to assist this analysis. These data are shown in the figure below.



Day 2, January 27

Exposure at UE25-NRG5

In the company of Stu, Dani and Randy I examined the cut into the S-facing slope above well NRG5. This cut intersects a series of debris fans? located at the break in slope between the hillside (45%) and the nearly level wash. The cut also intersected a fault running transverse to the wash. The tuff exposed is heavily cemented with calcite (samples collected). An apparent concentration of water occurs from runoff from the hillslope that infiltrates into the debris fans. This mechanism was apparent in the presence of wet calcite-cemented colluvium dissected by the western wall of the cut. The colluvial debris fans are an obvious site of water concentration and storage. Whether this is a site permitting infiltration into tuff fractures is up for question. The

appearance, though, is that this water is perched due to cementation by calcite. More discussion is due.

Exposure at UE25-NRG6

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This site had poor calcite formation in relatively open fractures. The soil development here appeared to be greater than on steeper hill slopes: the hillside above this location was relatively shallow (not measured, but probably less than 30%). As a possible confirmation of the lack of cracks/calcite filling, needle-leaved rabbitbrush were rare on the surrounding hillslope (only 2 present in 1 hectare compared to 30-100/h on nearby hillsides).

Location of soil pits

Working with Stu, we measured out and marked sampling locations for soil pits on the N-facing slope of Antler Ridge and on the S-facing slope of Split Wash.

Day 3, January 28

Stu, Dani, Randy and I visited Shoshone Mountain with the intent to (1) evaluate this site as an analog for climate change and (2) gather botanical additional data. Dani, Stu and Randy looked at scree and soil pits while I concentrated on gathering botanical data.

Tree ring data for N– vs. S-facing Slopes

To add to our understanding of partitioning of precipitation into evaporation vs. transpiration, cores were obtained from 7 pinyon pine *(Pinus edulis)* growing on S- and N-facing slopes at the Shoshone Mountain crest. The site is located at approximately 6,700 feet elevation with north and south slopes aligned perpendicular to about 350° and 170°, respectively. The parent material is identical for both slopes: poorly welded tuff. The slope of the S-facing slope was a relatively uniform 41% while the N-facing slope was more variable: 40%, but variable by 5%.

Fires, Fire Frequency and Forest Regeneration

Shoshone Mountain has been burned repeatedly in recent years owing to human activity. Tree samples were obtained in order to help assess the year that two different fires occurred. Regrowth of native vegetation on the most recent burn (ca 3-6 years) appears to be severely hampered by the presence of cheatgrass. This is definitely of issue since a cheatgrass-dominated site will have much higher infiltration than one dominated by deeper rooted shrubs and trees. The older burn (40-50 years?) has had minimal regrowth by conifers and appears to be vegetated mainly with species that have resprouted from root crowns: Mormon tea *(Ephedra viridis)*, Gambel oak *(Quercus gambellii)*, and bitterbrush *(Purshia tridentata)*.

Shoshone Mountain as a Climate Change Analog

Although this is an excellent site because of its proximity to Yucca Mountain, the much deeper soil afforded by (1) wet climate and (2) poorly welded parent material probably offer much better opportunity for growth than would Yucca Mountain under similar climate. Thus, although we are learning a lot from Shoshone Mountain, the extrapolation to Yucca Mountain may not be linear. Additional sites should be evaluated.

Cracks, Roots and Buildup of Root-derived Mulch

Dani and I excavated the roots of a rubber rabbitbrush growing within cracks in highly weathered/poorly welded tuff. We found that the cracks were the site of a large buildup of organic-rich (peat-like) material where roots had penetrated. This material resulted from many generations of roots living, dying and decaying inside the same crack. Their is a remaining question whether the fractures and cracks on Shoshone Mountain have calcite filling.

Day 4, January 29

Twelve stem samples were obtained from needle-leaved rabbitbrush growing on the N-facing slope of Antler Ridge to complete the samples necessary for ring-analysis. These samples were obtained with measured reference to the soil pits on this slope. Several samples of seedling needle leaved rabbitbrush were collected for comparison to the seedlings that can be found growing in the exposed cracks at the Ghost Dance fault exposure. One question to be answered is whether this species can resprout from a severed root (hypothesized earlier) or whether this species starts only from seed. The question is germane because of the apparent ease with which the needle leaved rabbitbrush were able to establish in the cracks with minimal soil. The samples collected can help answer this question.

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Field Notes:

1-26 [Yucca Mt: field
double check GPS units:
DO's 36° 50' 3970" N | 36° 50' 40"
116° 27' 1603" W | 116° 27' 16.9"
DG's 36° 50.685' N
116° 27.262' W

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Randy's

158

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- at ghost Dance Fault Exposure
CHTE 9 cm high, 13 wide w/ rootstock
rootstock 8mm in dia where joins
with swelling at base of crown
tap root is 11 cm long before major
branching.
root structures markedly flattened
and penetrating v. soft ? and
$CaCO_3$ in space between rocks
there form "tank" w/ fan of roots
note that rock material penetrated by
roots tend to be + loose

This canyon is the south of Split wash

ENFA (or Encelia sp. ?)
$CaCO_3$ is highly etched w/
channels; indications are that
roots in situ are those that
caused etching (0.5-1.0 m dia)
STPA - w/in open crack - many fine
roots but no indication of etching other
than highly weathered surface structure of
calcite; etching is microscopic ca < .5mm
as confirmed under 10 X

Observations that confirm root penetration and breakdown of $CaCO_3$ filling in fissures

started @ bottom working up

- Transect of CHTE samples S Facing Slope
SF1: 112 x 104 x 48; 5 m E of lowest pit near GD fault
SF2: 34 x 50 x 52; 4 m E of " " " "
SF3 78 x 67 x 42 ; 2 m S, 3 m E of 2nd pit
? ? ? (...)

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Pits dug by Randy & Dave for Soil Depth

SF4 ; 189 x 82 x 70 ; 1 M N & 2 m E of Pit 3
SF5 ; 107 x 102 x 56 ; 6 M S & 2 m W of Pit 4
SF6 ; 122 x 93 x 63 ; 6 M S & 6 m W of Pit 4
SF7 ; 127 x 123 x 58 ; 8 M N & 1 m W of Pit 4
SF8 ; 110 x 108 x 52 ; 4 M S & 2 m W of Pit 4
SF9 ; 95 x 74 x 54 ; 1 m S & 10 m W of AIS
SF10 ; 94 x 83 x 57 ; 15 m S & 3 m W of Pit 6
SF11 ; 112 x 110 x 56 ; even & 8 m W of Pit 6
SF12 ; 120 x 104 x 53 ; even & 8 M E of Pit 6
SF12 split into A, B & C representing 3 different stems 11.5

Chrysothamnus teretifolius shrubs sampled for stem sections on S-facing side of Antler Ridge

1-27 [Yucca Mt : visit to cut face @ UE25-NRG 5
- note calcite fillings - sample taken from NS fracture,
- note alluvial fan like feature ; possibly dissected alluvio-colluvial bajada
slope angle is 45% ; note drainage H_2O flows
UE25-NRG 6
poor calcite formation in open fractures
virtually no (2 in 100 x 100 m) CHIPS
liquid H_2O (sheen) on rock faces ; carbonate where rock is friable, such calcite (dry)
- found roots ca 40 cm deep w/in granular $CaCO_3$; granular $CaCO_3$ sampled 12.0]

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1-28 [Yucca Mt.: Shoshone Mt.
tree cores
new sprouted PIMO multiple trunk
8 cm dbh; ca 20-30 cm tree
(within annuli of 2 dead JUOC) → 1 PIMO 12898 in position (1) of wood box
→ 1 JUOC 12898 in pos (2)
ca 15 cm DBH killed in fire
- 2 PIMO 12898 dead; 22 cm dbh
fallen over (3)
- 3 PIMO 12898, split below dbh 20; 27 cm (4)
→ from location in wash leading to Shoshone Mt.

on ridge of Shoshone Mt. above
abrupt transition from Burn to Forest
(aging major burn) - 4 PIMO 12898, burned but died immediately
after (note bark beetle channels)
- 5 PIMO 12898, as above; note remainder
of trunk is partially buried in road cut

N vs. S-facing 355 and 175 (+-) 10° ← Aspect of sampled sites

PIMO SF-1; 3.2 m tall; 22 cm base		in Metal BOX	1
SF-2; 4.2; 26 cm (few borer holes in trunk)			2
41%	SF-3; 4.8; 29 cm		3
slope	SF-4; 4.4; 28 cm		4
uniform	SF-5; 3.6; 26 cm (main branch at base		5
	SF-6; 4.0; 24 cm		6

slope of S-facing site → (41% slope uniform)

} *Pinus monophylla* Sample trees for cores - S-facing slope of Shoshone Mt.

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SF-7 ; 3.6 ; 30 cm 7

PIMO NE-1 ; 4.6 ; 29 cm (main branch dead) Box 2 : 1
2 ; 4.8 ; 28 cm (trunk scarred) 2
3 ; 4.6 ; 33 cm (light mistletoe @ base) 3
40% (also borer activity in core and pith)
slope 4 ; 6 in (est) ; 33 cm (slight mistletoe) 4
variable ±5% 5 ; 4.8 ; 23 cm 5
6 ; 3.9 ; 26 cm 6
7 ; 4.2 ; 31 cm (mod. mistletoe) 7

6 POMO 12898 died from bark beetle following recent (ca. 4 yr. old ?) fire
died from bark beetle 12.0

Sample Core collected from *Pinus monophylla* on N-facing slope of Shoshone Mt.

1-29 [Yucca Mt. : sampling on North facing side of Split wash - CHTE, stems (work up from bottom)

NF-1 ; 104 x 108 x 43 ; 5 m N ; 5 m E of Pit 1
NF-2 ; 142 x 92 x 51 ; 6 m N ; 5 m E of Pit 2
NF-3 ; 124 x 125 x 70 ; 7 m S ; 2 m E of Pit 2
NF-4 ; 158 x 137 x 54 ; 6 m S ; 5 m W of Pit 2
NF-5 ; 180 x 148 x 50 ; 9 m S ; 5 m E of Pit 3
(photo) this shrub overmature ; center is gone
(photo) NF-6 ; 86 x 81 x 45 ; 10 m S ; 8 m E of Pit 3
NF-7 ; 142 x 119 x 48 ; 5 m N ; 10 m E of Pit 4
NF-8 ; 226 x 89 x 61 ; 5 m N ; 14 m E of Pit 4
this shrub overmature ; center is gone
NF-9 ; 201 x 117 x 92 ; 5 m S ; 11 m W of Pit 3
NF-10 ; 153 x 140 x 87 ; 4 m N ; 12 m E of Pit 5 (photo)
in soil strip, score both sides

Chrysothamnus teretifolius stem section from N-facing side of Antler Ridge

DPG 2-10-98

NF-11 ; 173 x 209 x 82 ; 0 m S/N ; 11 m E pit 6
NF-12 ; 125 x 107 x 80 ; 15 m S ; 19 m E pit 7
NF-12 is growing beneath copwith (photo)
- where CHTE @ Ghost Dance fault seedlings or root sprouts ; collect two seedlings from trench spoils in Split wash to compare to Ghost Dance fault pavement CHTE seedlings
- drive Mercury / YM to BIH 12.5

Photo Documentation :

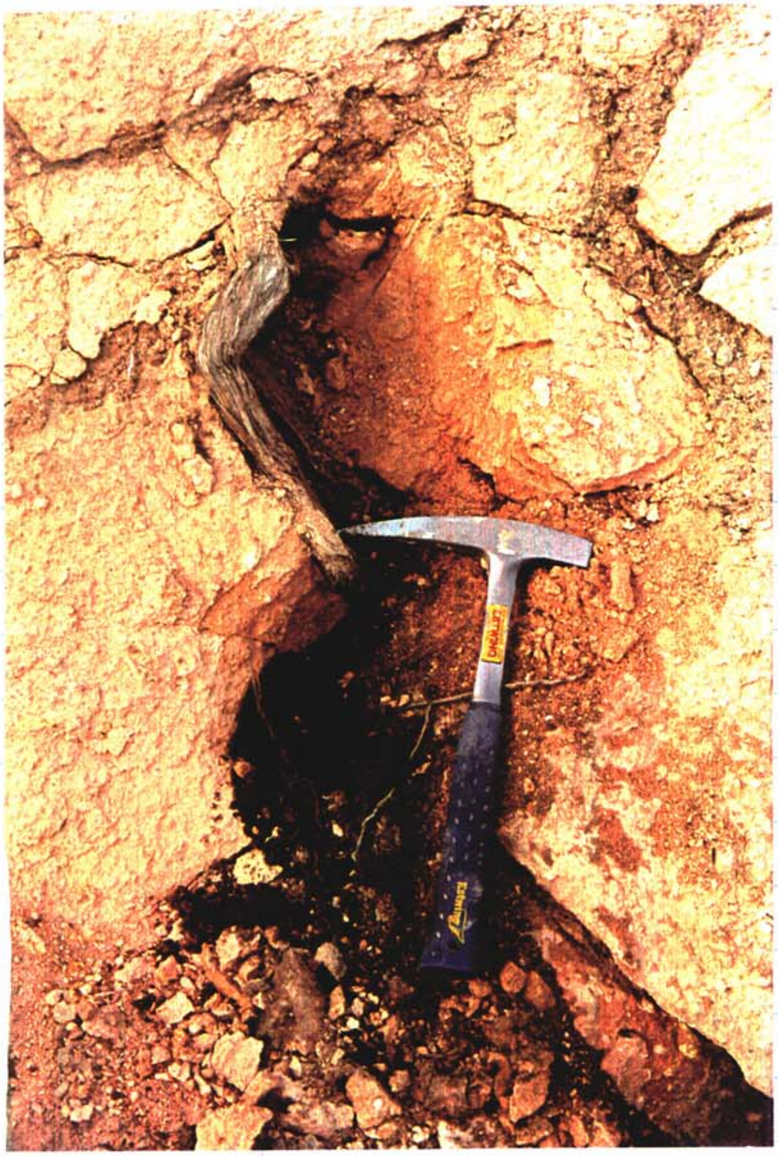
This calcite rind is weather by dissolution from this piece of scree - an indicator that calcite crack fillings may dissolve under conditions of climate change to cooler and wetter.

Chrysothamnus teretifolius seedling root system exposed @ Ghost Dance Fault exposure (canyon south of Split wash). Calcite in root matrix has broken down to friable conditions and is enriched with organic material sloughed from root system. This forms a "tank" to trap and hold infiltrating water.

This flake of calcite was located beneath the seedling shown above. A root passed through the center and etched this calcite. Thus positively confirming that roots of shrubs can easily penetrate and break down the calcite filling in fissures.

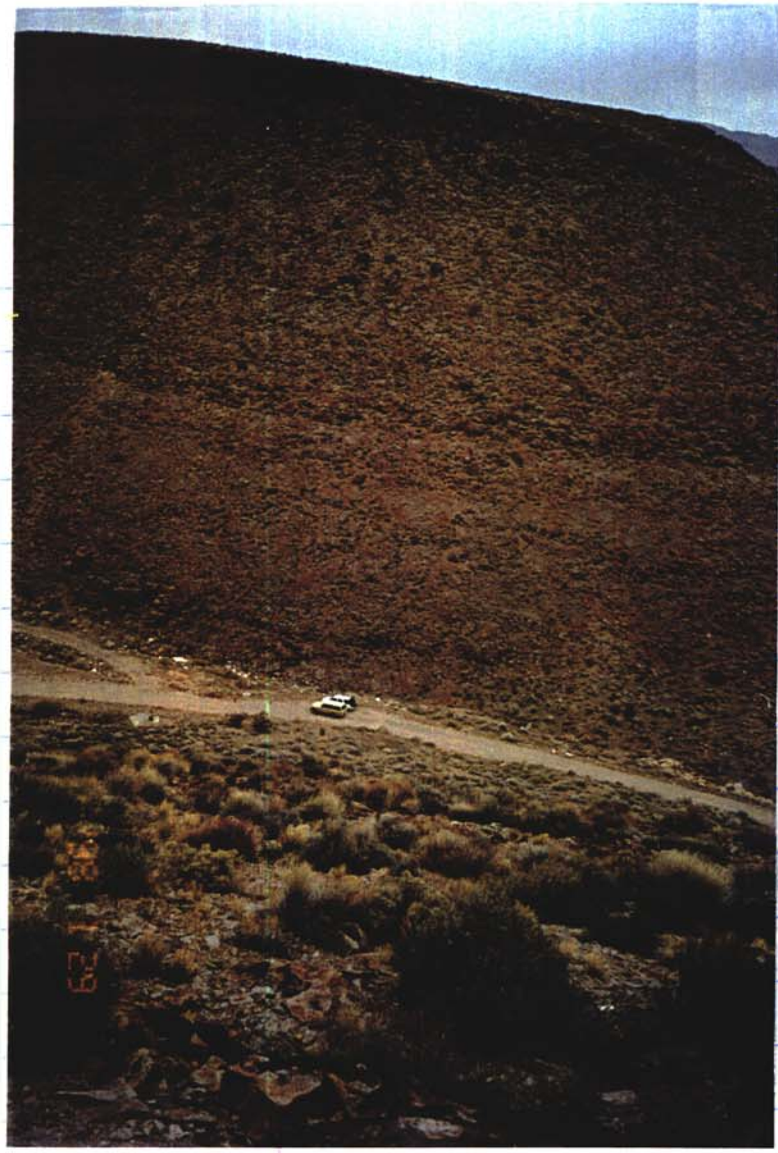
Roots of the subshrub (woody only @ root interface with stem) Encelia sp. (probably farinosa) penetrate and broke down calcite in the same manner as C. teretifolius

As shown here, roots from the perennial herb Stephanomeria pauciflora also broke down calcite fillings. Note the dark brown of the organic filling.



Tap root from a Chrysothamnus nauseosus on Shoshone Mt. Crest. Note the buildup of organic matter forming an enriched "tank" around the root. The rock matrix is non-welded to poorly welded tuff.

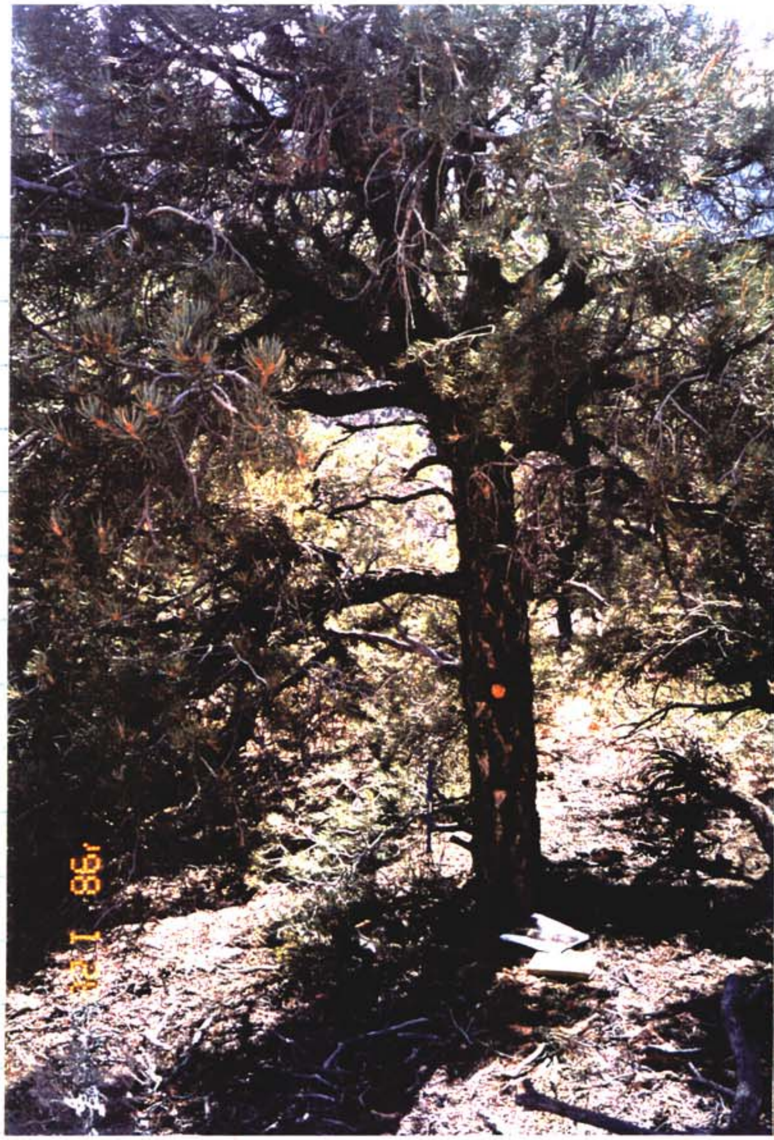
Dissected scree pile on Shoshone Mt. which shows enrichment with aeolian soil. Note root of Pinus monophylla. The closest trees were 6 to 12 m away.



Shrub stem specimens were collected on the N-facing slope of Antler Ridge in the foreground. The ~~ridge~~ south-facing slope in the background has the reduced cover typical of South-facing slopes on Yucca Mt. Here, more of the precipitation water is cycled into evaporation than through plants.

RF for DP 60 9/26/0

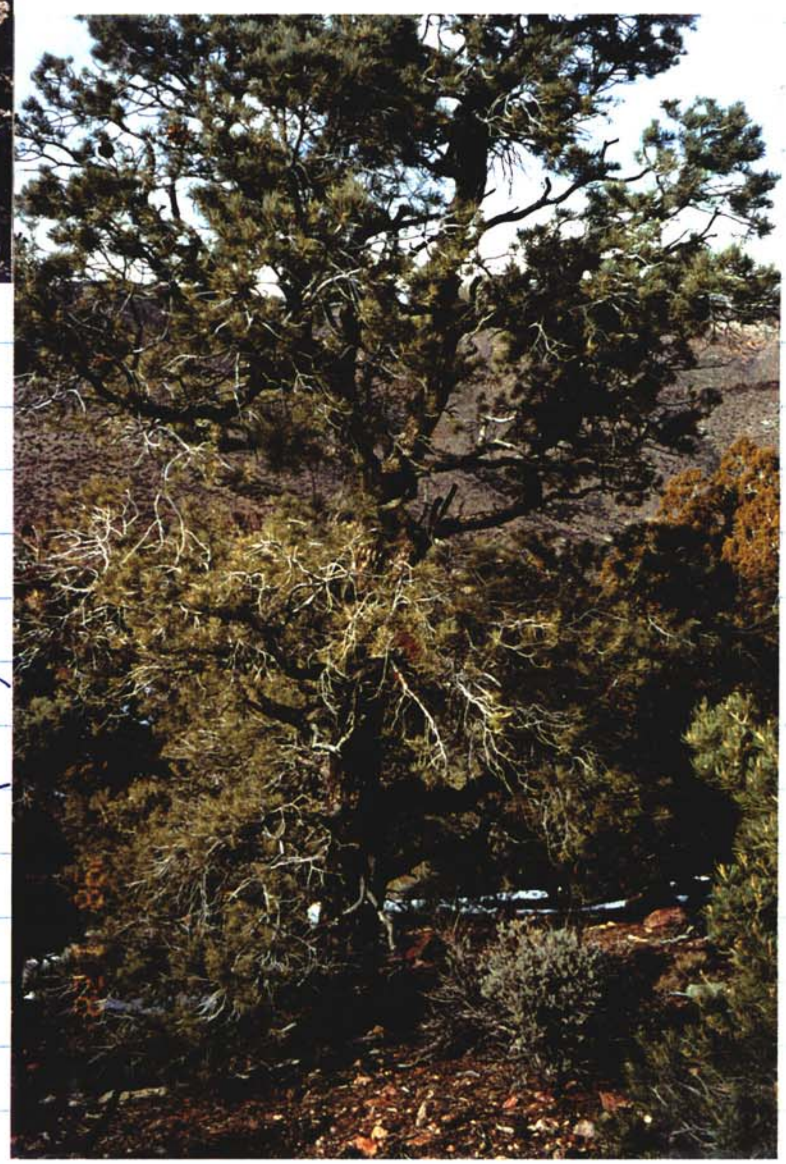
A Chrysothamnus teretifolius shrub collected for a stem section from the slope shown above.



Pinus monophylla

from Shoshone Mt.

South facing slope.
Note relatively open vegetation.



North-facing slope.
Note thicker vegetation cover.

P. m

Laboratory Analysis, February, 1998:

Growth rates of *Chrysothamnus teretifolius* from Yucca Mountain and *Pinus monophylla* from Shoshone Mountain.

Purpose:

For potential recharge, north- and south-facing slopes are very different environments due to the amount of insolation they receive. Work performed during Spring, 1997 showed that north facing slopes on Yucca Mountain have much greater cover south-facing. As analyzed on air photos this difference was 32.2% cover versus 14.2%. Since more of the water from precipitation is channeled through the plants on north facing slopes, this leads to testing the **hypothesis that plants of north-facing slopes should also show more rapid growth rates**.

Methods:

The genus *Chrysothamnus* has been shown to develop annual growth layers (communication with Rex Adams, Laboratory for Tree-Ring Research, Arizona, on file). Twelve stem sections each were collected of *C.teretifolius* on south- and north-facing slopes of Antler Ridge in locations that were well spaced but random. These were taken to the laboratory, re-sectioned to achieve a cut perpendicular to the direction of growth and polished with successively finer grades of sandpaper. Because of various environmental factors not always corresponding to regional precipitation, I decided to measure only the most recent 6 years of growth. This period was easily discernable as following a period of restricted growth due extremely low precipitation during water years 1989 and 1990 (as measured in nearby Beatty and Desert Rock, NV). Measurements were made using a calipers along the thickest radius in three positions (A, B, and C) for separate stems.

Cores from seven *Pinus monophylla* were obtained from opposing south- and north-facing slopes of Shoshone Mountain. All cores were obtained from the east side and at right-angles to the slope. Cores were dried, mounted and polished with a series of successively finer sandpaper. Rings were analyzed then counted and measured using a micrometer.

For both collection sites, Antler Ridge and Shoshone crest, slopes were with several percent between both sides (50% and 40%, respectively, for the two sites and the both slopes were comprised of the same parent material (densely welded and poorly welded tuff, respectively).

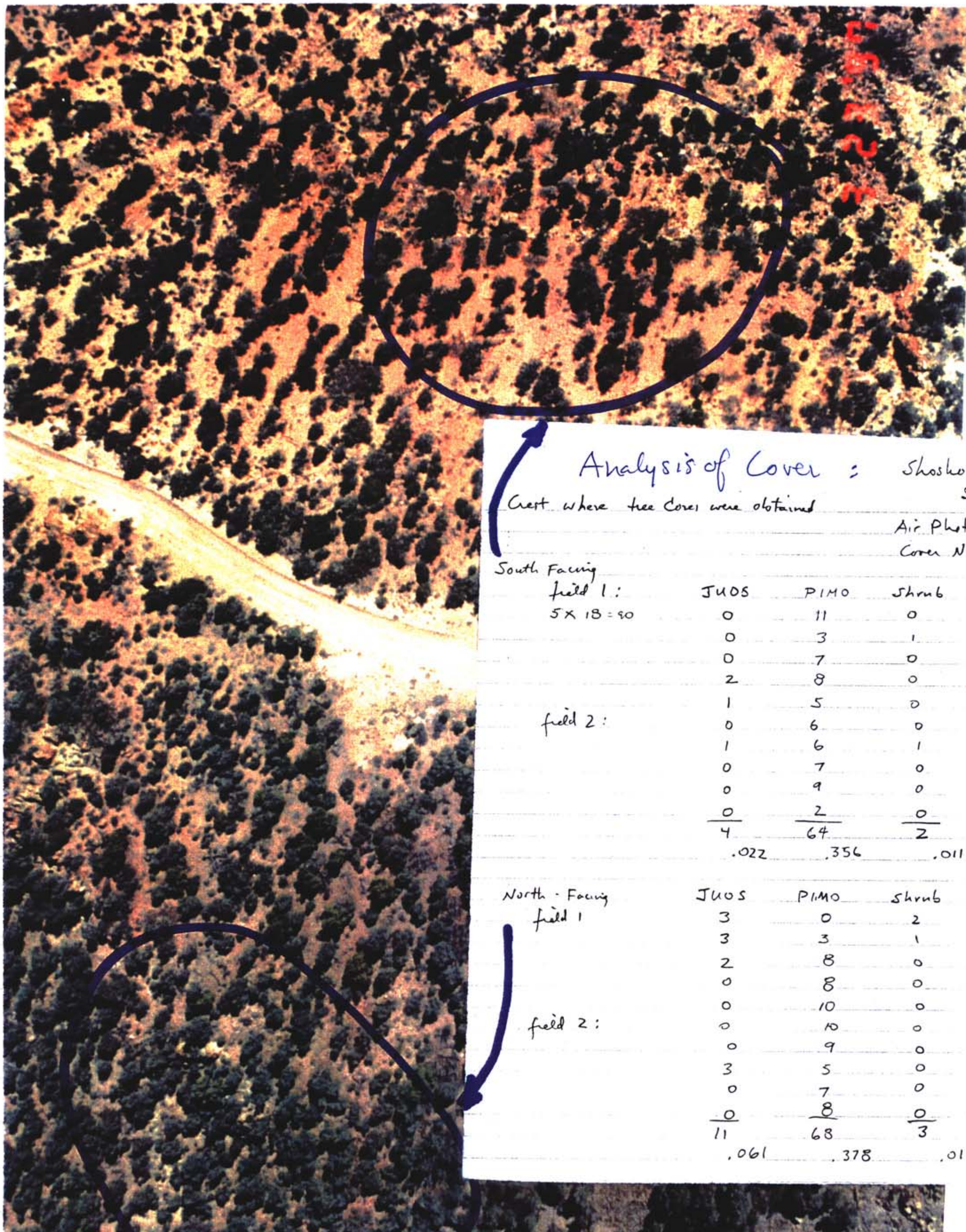
Crown cover of the north- and south-facing slopes of the Shoshone Mountain site were measured on a low-altitude high resolution photograph under 15 x magnification by counting the intersection of a grid of points with tree crowns. Cover was then determined as the ratio of the number of grid-point contacts by the total number of grid points.

Results:

The growth rates of both species were statistically the same which indicates both environments are intensively water limited and closed to establishment of new plants unless other plants die:

	South-facing mean (stdev.)	North-facing mean (stdev.)
P. monophylla	0.486 (0.085) mm/yr	0.424 (0.088) mm/yr
Cover:	0.389	0.456
C. teretifolius	0.861 (0.242) mm/yr	0.816 (0.176) mm/yr
Cover:	around 0.14**	around 0.32 **

**Measured during May, 1997 and an average of the regional north- and south-facing slopes.



Analysis of Cover : Shoshone Mt Analog Site.

Air Photo Interp. of Cover N- vs. S-facing

Crest where tree cores were obtained

South Facing

	JUOS	PIMO	Shrub	
field 1: 5 × 18 = 90	0	11	0	
	0	3	1	70/180 = .389
	0	7	0	
	2	8	0	
	1	5	0	
field 2:	0	6	0	
	1	6	1	
	0	7	0	
	0	9	0	
	0	2	0	
	4	64	2	
	.022	.356	.011	

North - Facing

	JUOS	PIMO	Shrub	
field 1	3	0	2	
	3	3	1	
	2	8	0	82/180 = .456
	0	8	0	
	0	10	0	
field 2:	0	10	0	
	0	9	0	
	3	5	0	
	0	7	0	
	0	8	0	
	11	68	3	
	.061	.378	.017	

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Growth Rate Analysis, N-facing Slope of Shoshone Mt.

Feb 12, 1998
Yucca Mt. Project
Shoshone Mt. Cores

Pinus monophylla

NF-1 220 yrs in 97.5 mm or 0.443 yr/mm
age is $230 + 5 + \left(\frac{6}{4.4} \times \frac{9.72}{13}\right) = 248$

yrs. ago	increment
0-50	25.7
50-100	15.0
100-150	17.5
150-200	24.8

(6 trace layers) 2.4%

NF-2 200 yrs. in 10.92 cm or 0.546 mm/yr.
age is > 210 yrs.

yrs. ago	increment
0-50	29.6
50-100	22.4
100-150	33.2
150-200	24.0

Cored through buried branch

(5 trace layers) 2.4%

NF-3 200 yrs in 88.2 mm or 0.441 mm/yr.
age is $230 + 9 + \left(\frac{4}{2.7} \times \frac{10.4}{15}\right) = 254$ yrs

yrs. ago	increment
0-50	29.9
50-100	16.0
100-150	21.8
150-200	20.5

(6 trace layers) 2.4%

NF-4 200 yrs in 95.1 mm or .476 mm/yr.
age is > 236 yrs.

yrs. ago	increment
0-50	35.5
50-100	28.9
100-150	30.7
150-200	32.0

(2 trace layers) .85%

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NF-5 Age is > 265 years (branch primordium intersected)
250 yrs. in 79.6 mm or .398 mm/yr.

yrs. ago	increment
0-50	18.5
50-100	13.7
100-150	14.0
150-200	11.6
200-250	21.8

(12 trace layers) 4.8%

NF-6 200 yrs. in 5.16 or .258 mm/yr.
age is $270 + 13 + \left(\frac{6}{3.3} * \frac{53}{10}\right) \doteq 293$

yrs. ago	increment
0-50	12.7
50-100	12.1
100-150	9.4
150-200	17.4
200-250	36.4 (branch in radius)

(15 trace layers) 5.6%

NF-7 200 yrs. in 81.0 mm or .405 mm/yr.
age > 219 yrs.

yrs. ago	increment
0-50	25.5
50-100	16.9
100-150	19.1
150-200	19.5

(4 trace layers) 1.8%

Summary

	Age (yr)	$\bar{X}$ increment (mm)
NF-1	~248	0.443
2	>210	0.546
3	~254	0.441
4	>236	0.476
5	>265	0.398
6	~293	0.258
7	>219	0.405

$\bar{X} = .424$
Sd = .088

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Growth Analysis, S-facing Slope of Shoshone Mt.

Pinus monophylla collected 1-28-98

Feb. 11, 1998
Yucca Mt Project
Shoshone Mt. Cores

SM-SF-1 60 years in 61.2 mm or 1.02 mm/yr.
off center; projected age: last rings 4.4 mm per in 4 years = 1.1 mm/yr
increment to projected center: 11.0 mm = 10 years
est. total age = 60 + 7 + 10 = 77 yrs.
(no trace inclusions)

SM-SF-2 220 yrs. in 121.8 mm or 0.554 mm/yr
age is > 220 years

years ago	increment
0-50 yrs	25.5 mm
50-100	39.3 mm
100-150	24.4 mm
200-150	25.8 mm

diagnostic triple ring series 1891, 92, 93 ?
(13 trace layers) 1.4%

SM-SF-3 200 yrs in 118.6 mm or 0.593 mm/yr.
age is ≥ 214 yrs. (note triple ring series & missing rings)

yrs. ago	increment
0-50 yrs	24.4 mm
50-100 yrs.	23.4 mm
100-150 yrs.	29.8 mm
150-200 yrs.	41.0 mm

diagnostic triple is @ 96', 97', 98'
(5 trace layers) 2.3%

SM-SF-4 220 yrs in 100.8 mm or 0.458 mm/yr.

yrs. ago	increment
0-50	20.4
50-100	20.4
100-150	21.0
150-200	28.3

diagnostic triple not visible ca 100 yrs.
(9 trace layers) 3.6%

age is 220 yrs + 11 + $\left(\frac{4 yrs}{2.4} \times 9.6\right)$ = 247 yrs

SM-SF-5 250 yrs. in 98.3 mm or 0.393

yrs. ago	increment
0-50	17.7
50-100	14.8
100-150	16.9
150-200	20.0
200-250	30.5

diagnostic triple not visible
(9 trace layers) 3.3%

age is 260 + 4 + $\left(\frac{4 yrs}{3.0} \times 5.0\right)$ = 271

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SM-SF-6 230 yrs. in 90.4 mm or 0.393 mm/yr.
age is 230 + 12 + $\left(\frac{4}{3.8} \times 76\right)$ = 250 yr.

yrs ago	increment
0-50	18.4 mm
50-100	21.2
100-150	20.0
150-200	19.1

(6 trace layers)

SM-SF-7 200 yrs in 105.1 mm or 0.526 mm/yr
age is 210 + 5 + $\left(\frac{3}{3.9} \times 16.2\right)$ = 227

yrs. ago	increment
0-50	16.5
50-100	23.2
100-150	22.9
150-200	42.5

(3 trace layers)

Summary

	Age	$\bar{X}$ layer (mm)
SF-1	~~60~~	~~1.02~~
2	>220	0.554
3	>214	0.593
4	~247	0.458
5	≈271	0.393
6	~250	0.393
7	~227	0.526

$\bar{X}$ = 0.486
Sd = 0.085

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Chrysothamnus teretifolius

North-facing Slope of Antler Ridge
measurements in inches of last 6 growth layers

	A	B	C
NF-1	.165	.158	.179
NF-2	.222	.152	.198
NF-3	.178	.210	.161
NF-4	.151	.164	—
NF-5	.171	.159	—
NF-6	.194	.194	.190
NF-7	.134	.148	.142
NF-8	.175	.179	.168
NF-9	.156	.311	.195
NF-10	.228	.245	—
NF-11	.256	.218	.212
NF-12	.231	.287	.228

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Yucca Mt. Shrub Samples

2-16-98 Analysis

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Chrysothamnus teretifolius

South Facing Slope
measurements in inches of last 6 growth layer

	A	B	C
SF-1	.118	.215	.211
SF-2	.381	.175	.212
SF-3	.215	.200	.218
SF-4	.298	.228	.314
SF-5	.257	.158	.148
SF-6	.266	.271	.181
SF-7	.196	.152	.244
SF-8	.154	.164	.119
SF-9	.211	.257	.240
SF-10	.172	.215	.130
SF-11	.160	.169	.184
SF-12	.187	.156	.146

Yucca Mt. Shrub Samples

2-15-98 analysis

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DPG 2-16-98

Yucca Mt.
6-year and mean annual increment thickness for *Chrysothamnus teretifolius*,

totals for 6 growth layers

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MTB > prin c1-c4
 ROW   SF-inT   SF-mm   NF-inT   NF-mm

   1   0.118    0.500   0.165    0.699
   2   0.215    0.910   0.158    0.669
   3   0.211    0.893   0.179    0.758
   4   0.381    1.613   0.222    0.940
   5   0.175    0.741   0.152    0.643
   6   0.212    0.897   0.198    0.838
   7   0.215    0.910   0.178    0.754
   8   0.200    0.847   0.210    0.889
   9   0.218    0.923   0.161    0.682
  10   0.298    1.262   0.151    0.639
  11   0.228    0.965   0.164    0.694
  12   0.314    1.329       *        *
  13   0.257    1.088   0.171    0.724
  14   0.158    0.669   0.159    0.673
  15   0.148    0.627       *        *
  16   0.266    1.126   0.194    0.821
  17   0.271    1.147   0.194    0.821
  18   0.181    0.766   0.190    0.804
  19   0.196    0.830   0.134    0.567
  20   0.152    0.643   0.148    0.627
  21   0.244    1.033   0.142    0.601
  22   0.154    0.652   0.175    0.741
  23   0.164    0.694   0.179    0.758
  24   0.119    0.504   0.168    0.711
  25   0.211    0.893   0.156    0.660
  26   0.257    1.088   0.311    1.317
  27   0.240    1.016   0.195    0.826
  28   0.172    0.728   0.228    0.965
  29   0.215    0.910   0.245    1.037
  30   0.130    0.550       *        *
  31   0.160    0.677   0.256    1.084
  32   0.169    0.715   0.218    0.923
  33   0.184    0.779   0.212    0.897
  34   0.187    0.792   0.231    0.978
  35   0.156    0.660   0.287    1.215
  36   0.146    0.618   0.228    0.965

MTB > mean c2
   MEAN      =       0.86097
MTB > stdev c2
   ST.DEV.  =        0.24218
MTB > mean c4
   MEAN      =       0.81576
MTB > stdev c4
   ST.DEV.  =        0.17632
MTB > nopaper
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Photo of sample x-section of C. teretifolius.
(South-facing slope, sample 9)

Photo of sample P. monophylla core.
(S-facing slope, tree 2)