APPENDIX 1 PEDON DESCRIPTIONS

PEDON No. 1 (CFP2) -- TABULAR DESCRIPTION

Taxonomic I.D.: sandy-skeletal, mixed (calcareous), thermic "Camborthidic" Torriorthent **Est. Min. Age:** 6645 +/- 245 YBP (uncorrected radiocarbon) 7,310 YBP (+10% correction). **Geomorphic Surface:** Little Cones. **Pedon I.D.:** 1-FFP-1-CFP2-1 to 4 **Date:** 8/17/87 **By:** F.F. Peterson **Location:** Amargosa Valley, Nevada; 1.35 mi. W of US Hwy 95 on road to Ashton (site). **Physiographic Position:** Broad, low, basin-floor-remnant summit; broad Holocene (?) remnant is widely-dissected by 1-4 ft. deep, very gently-sideslopes, on-flat fluves, is abruptly cut by modern Amargosa River's anastomosing distributary-floodplain. **Parent Material:** Eolian dust & mixed volcanic, limestone, metamorphic alluvium. **Native Vegetation:** Creosote bush (70-95%), white bursage (isolated patches). **Slope:** 1% **Aspect:** 180° **Elevation:** 2685 ft. 818 m **Latitude:** 36.727°N **Longitude:** 116.662°W **Microrelief Position:** Broad pavette, adjacent creosote-bush coppice dunes only 4-6" high. **Surficial Gravel:** 75 %-area **Surficial Cobbles:** 0 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 75 %-area **Other Surficial Features:** Pavement is fine gravel, only slightly varnished, has thin underlying Av horizon.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-8	10YR 6.5/2	10YR 4.5/2	GSL	25	0	0	64	28	8	none
2[abc]	Bwk	8-22	10YR 6.5/2	10YR 4.5/2	GSL	33	0	0	74	18	8	none
3	Bk	22-42	10YR 6.5/2	10YR 4/3	VGSL	50	0	0	78	12	10	none
4[d]	2CBqk	42-70	10YR 5-6/2	10YR 4/2	EGCOS	75	0	0	94	5	1	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2COPR	SH	VFR	SO/PS	vsl dilatent	EO&E	8.6	3MV	none	AW
2	1FPL	VSH-H	VFR	SO/PO	none	EO&E	8.6	n.d.	1F	CW
3	M	SH	VFR	VSS/PS-PO	none	EO&ES-D&SPB	9.0	n.d.	1F	CW
4	SG	LO	LO	SO/PO	none	EO&E	8.6	n.d.	none	N

COMMENTS: [a]Zone of dust infiltration is Av + Bwk, 0-22 cm. [b]Some parts of Bwk VSS/PS, but not enough clay to make Bt.; Bwk is 1COPR structure in adjacent, old pit. Bottom of Bwk horizon is 3 cm short of >25 cm rule for cambic horizon, so keys to Torriorthent, am using implied "Camborthidic" subgroup to indicate almost-cambic horizon. [c]The Bwk contains 2-4 cm thick, hard lenses of finely-tubular pored, grey, apparently dust-impregnated material that is similar to buried Av horizons. [d]With thin pebble-bottom coatings of opal and cabonate, cabonate even less than in overlying Bk

PEDON No. 2 (CFP26) -- TABULAR DESCRIPTION

Taxonomic I.D.: sandy-skeletal, mixed, thermic Typic Camborthid. **Est. Min. Age:** 10180 +/- 270 YBP (uncorrected radiocarbon) 11,200 YBP (+10% correction). **Geomorphic Surface:** Little Cones. **Pedon I.D.:** 1-FFP-1CFP26-1 to 6. **Date:** 6/08/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 0.2 mi. ENE of northernmost cone of Little Cones, 1.05 mi. E of N-S road to Diamond Queen Mine on trail. **Physiographic Position:** Summit of very broad basin-floor remnant that has a few, shallow, on-flat fluves. **Parent Material:** Eolian dust and mixed limestone and volcanic alluvium. **Native Vegetation:** Creosote bush, white bursage, shadscale, pale wolfberry (all in coppices off of pavette), spineflower (on pavette). **Slope:** 2% **Aspect:** 180° **Elevation:** 3000 ft. 914 m **Latitude:** 36.774°N **Longitude:** 116.599°W **Microrelief Position:** 9x6 m, BARREN PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 0 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 80 %-area **Other Surficial Features:** 1-3 cm pebbles form pavement; only lightly varnished; 2-3 mm of fine sand mulch between pebbles; one layer of 2-3 cm pebbles embedded in underlying Av horizon.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1	Av	0-5	10YR 7/3	10YR 4/3	GVFSL	20	0	0	58	35	7	none
2	Ak	5-19	10YR 7/3	10YR 5/3	GSL	30	0	0	68	25	7	none
3[a]	Bwk	19-29	10YR 7/3	10YR 5/3	GSL	30	0	0	74	20	6	none
4	Bk	29-54	10YR 7/3	10YR 5/3	VGSL	50	0	0	76	19	5	none
5[b]	2Bk1	54-78	10YR 7/3	10YR 5/3	EGSL	65	0	0	80	15	5	none
6	2Bk2	78-100	2.5Y 7/1	2.5Y 5/2	VGCOS	50	5	0	95	3	2	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2VCOPR	SH	VFR	SO/PS	none	ES	8.6	3VF-MV	none	AS
2	1FSBK	VSH	VFR	SO/PO	none	ES-C1SF&SPB	8.8	n.d.	v1VF	CS
3	M	SO	VFR	SO/PO	none	EV-C1SF&SPB	9.0	n.d.	1VF	GS
4	M	SO	VFR	SO/PO	none	EV-CSPB	9.0	n.d.	1VFv1F	CW
5	M	SO	VFR	SO/PO	none	EV-CSPB	8.4	n.d.	1VFv1F	CW
6	SG	LO	LO	SO/PO	none	ES-CSPB	8.2	n.d.	none	N

COMMENTS: [a]Technically, this Bwk is the cambic horizon, but both the Ak and Bwk horizons could be considered the cambic horizon with in-transit, pedogenic carbonates; carbonate in the Ak is considered a more recent accumulation than that in the Bk horizons, hence evidence of polygenesis in the Holocene. [b]Pebble bottoms with 0.5 mm, some 1-2 mm thick lime pendants; sand grains and very fine gravel in 2Bk2 barely carbonate-coated; since both 2Bk horizons have less than 5% (vol.) pedogenic carbonate, do not comprise a calcic horizon.

PEDON No. 3 (CFP26A) — TABULAR DESCRIPTION

Taxonomic I.D.: sandy-skeletal, mixed, thermic Typic Camborthid. **Est. Min. Age:** SAME AS ADJACENT PEDON 2: 10180 +/- 270 YBP (uncorrected radiocarbon) 11,200 YBP (+10% correction). **Geomorphic Surface:** Little Cones. **Pedon I.D.:** 1-FFP-1CFP26A-1 to 4. **Date:** 6/08/87 **By:** F.F. Peterson **Location:** ADJACENT TO PEDON 2, Crater Flat, Nevada, 0.2 mi. ENE of northernmost cone of Little Cones, 1.05 mi. E of N-S road to Diamond Queen Mine on trail. **Physiographic Position:** Summit of very broad basin-floor remnant that has a few, shallow, on-flat fluves. **Parent Material:** Eolian dust and mixed limestone and volcanic alluvium. **Native Vegetation:** Creosote bush, white bursage, shadscale, pale wolfberry (in coppices), spineflower (on pavette). **Slope:** 2% **Aspect:** 180° **Elevation:** 3000 ft. 914 m **Latitude:** 36.774°N **Longitude:** 116.599°W **Microrelief Position:** BIOCOPPICE-INTERSPACE **Surficial Gravel:** 50 %-area **Surficial Cobbles:** 0 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 50 %-area **Other Surficial Features:** This few-meter wide biocoppice is covered with several cm of eolian LFS with some intermixed gravel; pebbles on surface have been recently dug up by rodents, few have any varnish, many have thin, partial carbonate coatings showing they were dug from a Bk horizon.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	A1	0-9	10YR 6/2	10YR 5/2	LFS	5	0	0	90	8	2	none
2[b]	Avkb	9-20	10YR 7/2	10YR 4/3	GFSL	25	0	0	64	28	8	none
3	Bwk	20-60	10YR 6.5/2	10YR 5/3	VGSL	50	0	0	62	30	8	none
4	2Bk	60-65+	As in Pedon #2									

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	v1MPL-M	VSH	VFR	SO/PO	none	EO&E[a]	n.d.	1FT	v1VF	AS
2	1MSBK	SH	VFR	SO/PS	none	ES-C1SF	n.d	2VF-FT	1VF-M	AS
3	1MSBK	SH	VFR	SO/PS	none	EV-C1SFCSPB	n.d	1FT	1FT	CW
4	As in Pedon #2									N

COMMENTS: [a]The A1 horizon is bioturbated eolian fine sand and gravel dug from rodent burrows; it is the analogue of the 2-3 mm of sand mulch between pavement-pebbles on the pavette. [b]The Avkb horizon was traced laterally into the adjacent pavette, where it is the Av horizon; the Avbk horizon has the greyness and slight dilatentcy of the adjacent Av horizon, but has tubular macropores (root channels) rather than vesicular pores (due to capillary bubbles), presumably due to burial and lack of periodic saturation subsequently.

PEDON No. 4 (CFP27) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Calciorthid **Est. Min. Age:** SAME AS ADJACENT PEDON #5: 25,700 +/- 360 YBP (uncorrected radiocarbon) 28,300 YBP (+10% correction). **Geomorphic Surface:** Black Cone; here there are two parts, or remnant-levels comprising this Black Cone surface, that have similar degrees of Av horizon thickness and horizon differentiation; a second, younger surface (Little Cones?) is inset below the Black Cones surface. **Pedon I.D.:** 1-FFP-1-CFP27-1 to 4. **Date:** 6/09/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, in SE corner of Diamond Queen Mine & Solitario Canyon roads; ca 160 m ESE on, ca 25 m S from Solitario Canyon road; ADJACENT TO PEDON #5. **Physiographic Position:** Lower-fan-piedmont-remnant summit; remnant deeply dissected by axial-stream channel here. **Parent Material:** Eolian dust and mixed limestone-volcanic alluvium. **Native Vegetation:** Creosote bush, white bursage, range ratany, mormon tea, shadscale, pale wolfberry (all in biocoppices). **Slope:** 3 % **Aspect:** 180° **Elevation:** 3190 ft. 972 m **Latitude:** 36.810°N **Longitude:** 116.602°W **Microrelief Position:** in BIOCOPPICE. **Surficial Gravel:** 50 %-area **Surficial Cobbles:** 0 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 50 %-area **Other Surficial Features:** surficial pebbles mostly 1-2 cm dia., a few 3-5 cm, few with any varnish, some with cabonate pebble-bottom coatings indicating excavation from Bk horizon by rodents; surficial 1 cm of LFS A1 horizon only weakly-coherent crusted, no evidence of Av character as expected for modern eolian deposit.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	A1	0-9	10YR 6/3	10YR 4/3	LFS	10	0	0	87	10	3	none
2[b]	Avkb	9-32	10YR 7/3	10YR 4/3	L	12	0	0	47	35	18	none
3[c]	Bwk	32-54	10YR 6.5/3	10YR 4.5/3	VGSL	50	0	0	72	20	8	none
4[d]	2Bk	54-120	10YR 7/2 & 10YR 8/1	10YR 5/3 & 10YR 7/3	EGLS	70	15	0	87	10	3	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	1COPR&1MPL	VSH	VFR	SO/PO	none	E-D	8.6	I,P	v1VF-F	CS
2	1COPR&1FSBK	SH-H	FR	SS/P	none	ES-SPB&D	8.8	3VFT,I,P	1VF-F	CW
3	1F-MSBK	VSH	VFR	SO/PO	none	EV-SPB&D	8.8	I,P	1VF-F	GW
4	M	VSH-H	FR-FI	SO/PO	20% CW lenses	EV-SPB&D	8.2	I	1VF-F	N

COMMENTS: [a]The A1 horizon is bioturbated, eolian LFS collected in a biocoppice; material nondilatent. [b]The Avkb horizon is somewhat dilatent; its finer texture is attributed to its being a buried Av horizon, not to illuvial clay accumulation. [c]The Bwk is only slightly dilatent, presumably due to slight dust-infiltration; it shows less pedogenic carbonate than the subjacent 2Bk and is considered a cambic horizon with in-transit pedogenic carbonate; the Avkb can also be considered a part of the currently operative cambic horizon. [d]The 2Bk horizon is considered a calcic horizon: limestone pebbles and pedogenic carbonate estimated >15% wt.; some 20% vol. is weakly cemented lenses with K-fabric fine earth and 2-4 mm thick carbonate pendants on pebbles; estimate total pedogenic carbonate >5% vol.

PEDON No. 5 (CFP27A) — TABULAR DESCRIPTION

Taxonomic I.D.: sandy-skeletal, mixed, thermic Typic Calciorthid **Est. Min. Age:** 25,700 +/- 360 YBP (uncorrected radiocarbon) 28,300 YBP (+10% correction). **Geomorphic Surface:** Black Cone; two remnant-levels having similar Av thickness, horizon differentiation, comprise Black Cone surface here; a younger surface (Little Cones?) is inset below Black Cone surface. **Pedon I.D.:** 1-FFP-1-CFP27A-1 to 4. **Date:** 6/09/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, in SE corner of Diamond Queen Mine & Solitario Canyon roads; ca 160 m ESE on, ca 55 m SSE from Solitario Canyon road, ADJACENT TO PEDON #4. **Physiographic Position:** Lower-fan-piedmont-remnant summit; remnant deeply dissected by axial-stream channel here. **Parent Material:** Eolian dust and mixed limestone-volcanic alluvium. **Native Vegetation:** Creosote bush, white bursage, range ratany, mormon tea, shadscale, pale wolfberry (all in biocoppices). **Slope:** 3 % **Aspect:** 180° **Elevation:** 3190 ft. 972 m **Latitude:** 36.810°N **Longitude:** 116.602°W **Microrelief Position:** in 20 x 5 m PAVETTE. **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 1 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 81 %-area **Other Surficial Features:** Many pavement pebbles, stones in adjacent "bar" are moderately-darkly varnished; pavement limestone fragments are deeply etched; mostly 1-2 cm pebbles, some 4-8 cm; 1 mm FS mulch; surficial pebbles loose, over a 1-pebble thick (1-3 cm) layer embedded in Av; loose surficial pebbles without SPB-carbonate coating, a few of embedded pebbles with SPB-carbonate coating.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-10	10YR 7/2	10YR 4/3	GL	25	0	0	45	40	15	none
2[b]	Bwk1	10-20	10YR 6/3	10YR 4/3	GL	25	0	0	50	35	15	none
3	Bwk2	20-32	10YR 6/3	10YR 4/3	VGSL	38	0	0	67	25	8	none
4[c]	2Bk	32-65+	10YR 7/2	10YR 5/2	EGCOS	80	5	0	94	5	1	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2VCOPR&1MPL	H	FR	SS/PS	none	E-D	9.4	3F-MV	none	AS
2	1FSBK	SH	FR	SS/PS	none	EO&E-D,SPB	9.4	n.d.	1VF-F	CW
3	1FSBK	SO	VFR	SO/PO	none	E&ES-D,SPB	9.4	n.d.	2VF,1F	GW
4	M&SG	LO	LO	SO/PO	CW lenses	ES-D,SPB	9.4	n.d.	1VF	N

COMMENTS: [a]The lower Av horizon with 2-3, 0.2 mm thick, smooth-topped, pustulose-bottomed, hard-brittle $CaCO_3$-laminae that are between the platy peds; these thin, brittle carbonate laminae are characteristic of Av horizons in many, if not most Black Cone age and older soils; occasionaly see in Little Cones age Av horizons; soil is fully dilatent; do not have the Avkb horizon of adjacent biocoppice pedon #4, hence is 22 cm shallower to presumably continuous 2Bk horizon, and the family particle size class is only sandy-skeletal rather than loamy skeletal. [b]Soil material is only slightly dilatent, indicating little infiltrated eolian VFS & SI; non-effervescent parts infer that Bwk1 once fully leached, that carbonate in Av is later cycle. [c]The 2Bk horizon has the same clean tops and 2-5 mm carbonate-pendants on pebble bottoms as in adjacent pedon #4; only lenses are cemented; considered a calcic horizon.

PEDON No. 6 (CFP32) -- TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Haplic Durargid. **Est. Min. Age:** 30,320 +/- 420 YBP (uncorrected radiocarbon) 33,400 YBP (+10% correction). **Geomorphic Surface:** Black Cone. **Pedon I.D.:** 1-FFP-1-CFP32-1 to 5. **Date:** 6/11/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, between Black Cone and Red Cone, ca 2.25 mi. ESE from corner with Diamond Queen Mine road on, and ca 75 m N of Solitario Canyon road. **Physiographic Position:** Summit of a low-relief, moderately-broad, elongate, lower-fan-piedmont remnant; dissection by 2-3 ft. deep, on-fan fluves, shoulders rounded. **Parent Material:** Eolian dust and volcanic alluvium **Native Vegetation:** Pale wolfberry, shadscale, white bursage, range ratany, creosote bush (all in biocoppices). **Slope:** 4% **Aspect:** 225° **Elevation:** 3,165 ft. 965 m **Latitude:** 36.787°N **Longitude:** 116.566°W **Microrelief Position:** 100x3-40 m wide PAVETTE. **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 1 %-area **Surficial Stones:** nil %-area **Total Surficial Rock Fragments:** 81 %-area **Other Surficial Features:** Moderately dark varnish on many pavement pebbles; 1-3 cm pavement pebbles loose, no apparent embedded-pebble layer.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-6	10YR 7/2	10YR 4/3	L	13	0	0	48	40	12	none
2[b]	Ak	6-15	10YR 6.5/2	10YR 4.5/3	GSL	20	0	0	64	28	8	none
3[c]	Bt	15-33	10YR 6/3	8YR 4.5/3	VGSL	50	0	0	60	25	15	1NPBC & PO
4[d]	Btk	33-51	7.5YR 6/3	7.5YR 4/4	EGSL	68	0	0	70	20	10	1NPBCC
5[e]	Bqkm	51-71+	10YR 8/1 & 10YR 6/2	10YR 7/2 & 10YR 4/3	EGLS?	65?	0	0	n.d.	n.d.	n.d.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2VCOPR	SH	VFR	SS/PS	none	EO	8.6	3VF-FV,2MV	none	AS
2	1FPL & 1VFSBK	VSH-SO	VFR	SO/PO	none	ES&EV-D,SPB,SF	9.4	n.d.	1VF-F	CW-I
3	1VF-FSBK	SH	FR	VSS/VPS	none	EO&E	8.4	n.d.	1VF	CW
4	1VFSBK	VSH	VFR	VSS/PO	none	ES&EV&EO-D,SP	8.4	n.d.	none	AW-I
5	2VCOPL	EH	EFI	n.a.	CS (CW?)	EV-D,SP	n.d.	n.d.	none	N

COMMENTS: [a]Soil material is fully dilatent, leached of carbonates. [b]Soil material only slightly dilatent; some 1-2 mm thick, dark bands of alkali-solubilized organic matter reflecting Na-salt accumulation. [c]Somewhat redder chroma and a few clayskins confirm argillic horizon status, but is barely enough more clayey than A horizon. [d]No evidence of opalization in lower argillic horizon. [e]A single carbonate and/or opal laminae on top of pan; cementation appears strong in place, but fragments of pan appear only weakly cemented; am presuming there is enough opal cement to make this a duripan rather than a petrocalcic horizon.

PEDON No. 7 (CFP37) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Durargid. **Est. Min. Age:** 128,000 YBP (cation-ratio age) **Geomorphic Surface:** early Black Cone. **Pedon I.D.:** 1-FFP-1-CFP37-1 to 5 **Date:** 8/17/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, ca 2.1 mi. NNE of Diamond Queen Mine & Solitario Cny. roads corner on E side of dirt road to N & NE Crater Flat. **Physiographic Position:** Fan-piedmont-remnant summit; clearly inset below Yucca fan-piedmont remnants to NE. **Parent Material:** Volcanic alluvium with a bit of limestone. **Native Vegetation:** Creosote bush, white bursage, pale wolfberry, shadscale, Nevada mormon tea, needlegrass, Joshua-tree (very few). **Slope:** 3 % **Aspect:** 180° **Elevation:** 3,374 ft. 1,028 m **Latitude:** 36.836°N **Longitude:** 116.579°W **Microrelief Position:** small PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 2 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 82 %-area **Other Surficial Features:** Pavement pebbles commonly darkly varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1	Av	0-5	10YR 7/2	10YR 4/2	L	10	0	0	45	40	15	none
2[a]	AB	5-11	10YR 6/2	10YR 4.5/3	GCL	15	0	0	36	35	29	none
3[b]	Btk1	11-35	7.5YR 6/4	7.5YR 4/4	VGCL	50	0	0	37	25	38	2NCO
4[c]	Btk2	35-48	7.5YR 6/4	7.5YR 5/4	EGLCOS	65	2	0	80	15	5	none
5[d]	Bqkm	48-130	10YR 8/1	10YR 7/3	n.d.	70	5	0	n.d.	n.d.	n.d.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	SH	VFR	SS/PS	none	EO & EV	8.4	3FV	none	AS
2	3COPR & 1MPL	SH	VFR	S/P	none	EO & EV	8.4	1VFV	v1VF	AW
3	3VFABK	SH	FR	VS/P	none	EO & ES	8.6	n.d.	1VF,v1F	CW
4	1VFSBK	LO	VFR	SO/PO	none	EO & EV	8.8	n.d.	1VF	VAW
5	M	SH-VH	LO-VFI	n.a.	none-CS	EV	n.d.	n.d.	v1VF-M	N

COMMENTS: [a]AB designation because of finer texture than Av. [b]Btk1 with very thin, discontinuous SPB carbonate; EO parts and some places entirely EO indicate this Btk once leached, now accumulating carbonate; in half of pit is EGCL rather than VGCL. [c]Btk2 is continuous horizon; 1 mm thick SPB carbonate; some parts EGCOSL rather than EGLCOS; most of Bt-clay in Btk1. [d]Presume enough opal cement to call this pan a duripan; some 20-35% vol. of strongly cemented lenses with only slight pebble-separation, 15% vol. loose, remainder weakly-cemented pebble-bridges; only a single, discontinuous laminae at top of pan, but lenses imbricated so use Typic subgroup, though close to Haplic; roots enter deeply into pan.

PEDON No. 8 (CFP29) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Durargid **Est. Min. Age:** 137,000 YBP (cation-ratio age) **Geomorphic Surface:** early Black Cone **Pedon I.D.:** 1-FFP-1-CFP29-1 to 5 **Date:** 6/10/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, SE corner of Solitario Cny. & Trench CF2&3 roads. **Physiographic Position:** Mid-fan-piedmon-remnant summit **Parent Material:** Eolian dust & volcanic alluvium. **Native Vegetation:** Creosote bush, white bursage, pale wolfberry, Nevada mormon tea, range ratany, shadscale. **Slope:** 4% **Aspect:** 235° **Elevation:** 3,360 ft. 1,024 m **Latitude:** 36.802°N **Longitude:** 116.532°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 3 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 83 %-area **Other Surficial Features:** Many pebbles & cobbles dark varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-5	10YR 7/2	10YR 4.5/2	GL	20	0	0	48	40	12	none
2[b]	Ak	5-12	10YR 6.5/3	10YR 4.5/3	SL	10	0	0	74	18	8	none
3[c]	Btqy	12-24	7.5YR 6/3	7.5YR 4/4	GCL	20	2	0	27	35	38	2MKPF & PO
4[d]	Btq	24-47	7.5YR 6/3	7.5YR 4/4	"SL"	50	5	0	n.a.	n.a.	n.a.	1NPO & PBC
5[e]	Bqkm	47-55+	10YR 8/1 & 10YR 7/2	10YR 7/3 & 10YR 4.5/3	n.a.	60	10	0	n.a.	n.a.	n.a.	

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2COPR	SH	VFR	SS/SP	none	EO & E	8.8	3VF-MV	none	AS
2	1VFSBK	SO	VFR	SO/PO	none	ES	8.4	n.d.	1VF	AW
3	2VFGR->ABK	SO->SH	VFR	S/P	none	EO & ES	8.2	n.d.	none?	AS
4	1COPL & 3FABK	H-VH	VFI	SO/PO	CW	EO	8.2	n.d.	none	CW
5	M	VH-EH	V-EFI	brittle	CS	ES-D,SP,SF	8.2	n.d.	none	N

COMMENTS: [a]The Av is fully dilatant; has 5-8 mm (10YR 5/1D 3/1M) bands and small, pale brown, thin, brittle, pustulose carbonate laminae at bottom. [b]The Ak is not dilatant. [c]With 1-2 mm soft gypsum masses and salt-flocculated in upper part; with a few pebble-bottom opal coats. [d]The Btq is notably crunchy-opalized; coarse plates are weakly cemented. [e]Pan is 1-3 ft. thick where exposed in adjacent arroyo; thin lamina on top.

PEDON No. 9 (CFP30) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Haplic Durargid. **Est. Min. Age:** Same as Pedon 8's est. 137,000 YBP (cation-ratio age) because are on adjacent fan-piedmont remnants that appear to be same level and age. **Geomorphic Surface:** early Black Cone. **Pedon I.D.:** 1-FFP-1-CFP30-1 to 5 **Date:** 6/11/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 0.1 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads. **Physiographic Position:** Mid-fan-piedmont-remnant summit; apparently same as Pedon 9 surface. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** Creosote bush, shadscale, white bursage, pale wolfberry, Nevada mormon tea. **Slope:** 4 % **Aspect:** 235° **Elevation:** 3,370 ft. 1,027 m **Latitude:** 36.801°N **Longitude:** 116.530°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 2 %-area **Surficial Stones:** 0.5 %-area **Total Surficial Rock Fragments:** 83 %-area **Other Surficial Features:** Pavement pebbles 1-3 cm, many with dark varnish.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-7	10YR 7/2	10YR 4.5/3	GL	20	0	0	50	40	10	none
2[b]	Ak	7-21	10YR 7/3	10YR 4.5/3	GSL	25	0	0	65	25	10	none
3	Bt	21-37	7.5YR 6/3	7.5YR 4.5/4	GCL	25	0	0	35	35	30	none
4[c]	Btkq	37-49	10YR 6/4	7.5YR 4.5/4	VG"SL"	50	0	0	65	20	15	1NPBC & PF
5[d]	Bqkm	49-62+	10YR 7/2	10YR 5.5/4	n.a.	60	5	0	n.a.	n.a.	n.a.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2COPR	SH	FR	SS/PS	none	EO	8.6	3VF-MV	none	AS
2	1FPL & 1VFSBK	VSH	VFR	SO/PO	none	EV	9.0	n.d.	2VF	CW
3	1VFSBK	SH	FR	S/P	none	EO	8.8	n.d.	1VF	CW
4	1VFSBK	SH	FR	SO/PO	none	ES-SPB	8.6	n.d.	1F	AW
5	M	VH	EFI	brittle	CW-CS	EV	n.d.	n.d.	none	N

COMMENTS: [a]The Av is fully dilatent. [b]Lowest Av and upper half of Ak with several, thin, brittle, pustulose-bottomed carbonate laminae; Ak is only slightly dilatent. [c]The Btqk is opalized: thin opal coats on pebble bottoms, fine earth is "crunchy." [d]Pan has only a thin, discontinuous upper lamina; brittle but only very firm when moist; opal on pebble bottoms; cementation is weak enough, apparently lensy enough that will call this a HAPLIC Durargid.

PEDON No. 10 (CFP35) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Haplic Durargid. **Est. Min. Age:** 26,970 +/- 375 YPB (uncorrected radiocarbon) 29,700 YBP (+10% correction). **Geomorphic Surface:** late Black Cone. **Pedon I.D.:** 1-FFP-1-CFP35-1 to 5. **Date:** 6/12/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 0.55 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads; across wash to N and on next higher, older surface than Pedon 11. **Physiographic Position:** Fan-piedmont-remnant summit. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** Creosote bush, pale wolfberry, white bursage, shadscale, Nevada mormon tea, range ratany. **Slope:** 3% **Aspect:** 247° **Elevation:** 3,370 ft. 1,027 m **Latitude:** 36.796°N **Longitude:** 116.526°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 1 %-area **Surficial Stones:** nil %-area **Total Surficial Rock Fragments:** 81 %-area **Other Surficial Features:** Well sorted pavement of 0.5-2 cm pebbles, some dark-varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-7	10YR 7/2	10YR 4.5/2	GL	30	0	0	50	40	10	none
2	Ak	7-28	10YR 6.5/3	10YR 4.5/3	VGSL	40	0	0	65	25	10	none
3[b]	2Bt	28-43	10YR 6/3	10YR 4/3	VGL	50	0	0	59	25	16	?
4[c]	2Bqk	43-68	10YR 6/3	10YR 4/3	EGSL	60	0	0	72	20	8	none
5[d]	2Bqkm	68-73+	10YR 8/1 & 10YR 7/2	10YR 7/2 & 10YR 6/2	n.a.	80	0	0	n.a.	n.a.	n.a.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2COPR & 1MPL	SH	VFR	VSS/PS	none	EO	8.4	3F-MV	none	CS
2	1VFSBK-M	SO	VFR	SO/PO	none	ES-D&SPB	8.8	n.d.	1-2VF,F	CS
3	1VFSBK-M	SO	VFR	SS/PS	none	EO&E-SPB	8.4	n.d.	1VF	GS
4	SG	LO	VFR	SO/PO	none	EO&E-SPB	8.4	n.d.	?	AW
5	M	H	VFI	brittle	CW	ES	n.d.	n.d.	none	N

COMMENTS: [a]Top 2/3 of Av is EO, lower 1/3 is E with a couple thin, brittle, pustulose-bottomed carbonate laminae. [b]Argillic horizon assignment by relatively finer texture than A horizon; only carbonate is a few pebble-bottom coatings. [c]The loose, extremely gravelly 2Bqk is noncalcareous except some pebbles with opal and some carbonate on bottoms, tops clean. [d]Pan lacks an evident upper laminar cap, weakens notably when moistened, may be a single ca. 5-cm thick lens; opal-yellowing on pebble bottoms; at best a HAPLIC pan.

PEDON No. 11 (CFP33) -- TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Camborthid. **Est. Min. Age:** 17,280 +/- 370 YBP (uncorrected radiocarbon) 19,000 YBP (+10% correction). **Geomorphic Surface:** late Black Cone. **Pedon I.D.:** 1-FFP-1-CFP33-1 to 5 **Date:** 6/12/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 0.65 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads; across wash to S from Pedon 10. **Physiographic Position:** True inset-fan-remnant summit; next younger surface than that of Pedon 10. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** Shadscale, creosote bush, white bursage, pale wolfberry, Nevada mormon tea, range ratany. **Slope:** 3% **Aspect:** 247° **Elevation:** 3,360 ft. 1,024 m **Latitude:** 36.794°N **Longitude:** 116.526°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 85 %-area **Surficial Cobbles:** 2 %-area **Surficial Stones:** 0.3 %-area **Total Surficial Rock Fragments:** 87 %-area **Other Surficial Features:** Pavement of 0.5-2 cm, only thinly-varnished pebbles.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-5	10YR 7/2	10YR 4.5/3	GFSL	25	0	0	55	35	10	none
2[b]	Ak1	5-11	10YR 7/3	10YR 5/3.5	GL	25	0	0	42	40	18	none
3[c]	Ak2	11-27	10YR 7/3	10YR 4.5/3	GFSL	30	0	0	62	30	8	none
4[d]	Bwk	27-60	10YR 6/3	10YR 4/3	GSL	30	0	0	55	30	15	none
5[e]	2Bk	60-95	10Y4 7/2	10YR 4.5/3	EGSL	70	10	0	67	25	8	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	2COPR & 1F-MPL	VSH	VFR	VSS/VPS	none	EO	8.2	3F-MV	none	AS
2	2COPL	SH	VFR	SS/PS	none	ES-D,SPB	8.4	n.d.	v1VF	AS
3	1FSBK	SO	VFR	SO/PO	none	EV-SPB,D	9.0	n.d.	2VF	CW
4	1FSBK-M	SO	VFR	VSS/VPS	none	EV-SPB,D	8.8	n.d.	1VF	CW
5	M-SG	LO	VFR	SO/PO	none	EV-SP,SPB	9.0	n.d.	?	N

COMMENTS: [a]Only slightly dilatent Av; evidence of limited dust accumulation [b]A few, faint, slightly darker lamellae may reflect some clay accumulation or alkali-organic matter; only very slightly dilatent. [c]The Ak2 is slightly dilatent; evidence of some dust infiltration? [d]Note pick-up of clay in Bwk, but no suggestion of argillans (clayskins) and color not reddened, so keep as a cambic horizon with in-transit carbonates rather than an argillic horizon; in adjacent old SCS pit is slightly redder and clayeyer, might call it a Bt horizon. [e]Described in adjacent old SCS pit.

PEDON No. 12 (CFP34) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Haplic Durargid. **Est. Min. Age:** On similar surfaces, hence similar to Pedon 10: 26,970 YPB (uncorrected radiocarbon) 29,700 YBP (+10% correction). **Geomorphic Surface:** late Black Cone; adjacent to and a slightly higher, older surface than that of Pedon 11. **Pedon I.D.:** 1-FFP-1-CFP34-1 to 7. **Date:** 8/20/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 0.75 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads. **Physiographic Position:** Fan-piedmont-remnant summit. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** White bursage, creosote bush, pale wolfberry, shadscale, Nevada mormon tea, range ratany. **Slope:** 4% **Aspect:** 230° **Elevation:** 3,370 ft. 1,027 m **Latitude:** 36.793°N **Longitude:** 116.524°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 0.5 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 80 %-area **Other Surficial Features:** Many of fine pebbles in pavement are darkly varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-5	10YR 7/3	10YR 5/3	VGFSL	30	0	0	57	35	8	none
2[b]	Ak1	5-13	10YR 7/3	10YR 5/3	VGL	40	0	0	47	40	13	none
3[c]	Ak2	13-21	10YR 7/3	10YR 5/3	VGFSL	30	0	0	67	25	8	none
4	Btk	21-30	10YR 6/4	9YR 4/4	GL	30	0	0	50	33	17	none
5	Bt	30-46	7.5YR 5.5/4	7.5YR 4.5/4	VGFSL	55	0	0	70	15	15	v1NBR & PO
6	BC	46-64	10YR 6/4	10YR 4/3	VGS	50	5	0	93	5	2	none
7[d]	Bqkm	64-75+	10YR 8/1	2.5YR 7/2	n.a.	80	15	0	n.a.	n.a.	n.a.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	SH	VFR	SO/PS	none	E & EO	8.4	3F-MV	none	AS
2	1MPL & 1FSBK	SH-H	FR	SS/PS	none	ES	8.6	n.d.	v1VF	AW
3	1MPL & 1FSBK	VSH	VFR	VSS/PO	none	EV-SPB	9.0	n.d.	1VF	CW
4	1FSBK	SH	VFR	SS/P	none	E	8.6	n.d.	1VF-F	CW
5	1MSBK	SH-H	FR	SS/PS	none	EO	8.6	n.d.	1VF-F	CW
6	SG	LO	LO	SO/PO	none	EO	8.6	n.d.	2VF	vAI-B
7	M	EH	EFI	brittle	CS lenses	EV	n.d.	n.d.	none	N

COMMENTS: [a]The Av is somewhat dilatent. [b]The Ak1 is dilatent. [c]Soluble salts efflorvescing on the pit wall from the Ak2 a few weeks after thunderstorm. [d]Pan consists of 5-7 cm thick lenses that are fretworks of pebbles with many interstices open; a thin laminar cap only on top of lenses; interpret as a HAPLIC pan; presume enough opal cement to call it a duripan.

PEDON No. 13 (CFP41)— TABULAR DESCRIPTION

Taxonomic I.D.: sandy-skeletal, mixed, thermic Typic Torriorthent. **Est. Min. Age:** Modern, <1000 years? **Geomorphic Surface:** very-late Crater Flat. **Pedon I.D.:** 1-FFP-1-CFP41-1 to 2. **Date:** 8/20/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 1.2 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads. **Physiographic Position:** Raw inset fan with prominent bar & swale microtopography. **Parent Material:** Volcanic alluvium. **Native Vegetation:** White bursage, creosote bush, range ratany, Nevada mormon tea, pale wolfberry, shadscale. **Slope:** 3 % **Aspect:** 225° **Elevation:** 3,290 ft. 1,003 m **Latitude:** 36.788°N **Longitude:** 116.519°W **Microrelief Position:** Proto-pavette between stone bars. **Surficial Gravel:** 65 %-area **Surficial Cobbles:** 3 %-area **Surficial Stones:** 1 %-area **Total Surficial Rock Fragments:** 69 %-area **Other Surficial Features:** Surfical pebbles, cobbles, stones clean of rock varnish; no evidence of dust infiltration in top of AC horizon.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1	AC	0-19	10YR 6/2	10YR 4/2	EGS	65	0	0	95	3	2	none
2[a]	Ck	19-100	10YR 6/2	10YR 4/2	EGS	65	3	0	95	3	2	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	SG	LO	LO	SO/PO	none	EO & E	8.6	no V's	1VF	GW
2	SG	LO	LO	SO/PO	none	E	8.6	n.d.	1VF-F, v1M	N

COMMENTS: [a]Very thin, powdery, discontinuous pebble-bottom carbonate coatings in the Ck horizon suggest minimal pedogenesis; roots follow crude 5-8 cm thick stratifications.

PEDON No. 14 (CFP31) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Haplargid. **Est. Min. Age:** Because on inset-fan remnant similar to Pedon 11's, hence age: 17,280 +/- 370 (uncorrected radiocarbon) 19,000 YBP (+10% correction). **Geomorphic Surface:** late Black Cone **Pedon I.D.:** 1-FFP-1-CFP31-1 to 5. **Date:** 8/21/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 1.27 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads, just S and next older surface from Pedon 13.. **Physiographic Position:** True inset-fan-remnant summit. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** White bursage, Nevada mormon tea, creosote bush, pale wolfberry, range ratany. **Slope:** 4% **Aspect:** 235° **Elevation:** 3,300 ft. 1,006 m **Latitude:** 36.787°N **Longitude:** 116.519°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 1 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 81 %-area **Other Surficial Features:** Many pavement pebbles darkly varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-6	10YR 7/2	10Y 4/2	L	25	0	0	43	45	12	none
2	Ak	6-19	10YR 6.5/2	10YR 5/3	VGSL	40	0	0	65	25	10	none
3	Btk	19-33	10YR 6.5/3	10YR 4/3	L	25	0	0	45	35	20	1NPBC
4	2Bt	33-52	10YR 6/4	10YR 4/4	EGCL	65	0	0	40	30	30	none
5[b]	2Bk	52-99	10YR 6/3	10YR 5/3	EGFS	65	15	0	87	10	3	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	SH	VFR	SO/PS	none	EO & E	8.4	3F-MV	none	AS
2	1FPL & 1VFSBK	SH	FR	SO/PO	none	ES-SPB	8.8	n.d.	v1VF	AW
3	1VFSBK	SH	FR	SS/PS	none	E	8.8	n.d.	1VF-F	CW
4	2VFSBK	SH	FR	S/P	none	EO & E	8.2	n.d.	v1VF	CW
5	SG	LO	LO	SO/PO	none	EO & ES-SPB	8.4	n.d.	none	N

COMMENTS: [a]A few dark grey bands in Av horizon; some pebbles with pustulose bottom carbonate coatings. [b]The 2Bk horizon contains a few thin carbonate-cemented lenses.

PEDON No. 15 (CFP36) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Durargid. **Est. Min. Age:** 28,920 +/- 400 YBP (uncorrected radiocarbon) 31,800 YBP (+10% correction). **Geomorphic Surface:** late Black Cone. **Pedon I.D.:** 1-FFP-1-CFP36-1 to 6. **Date:** 8/21/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 1.85 mi. SE from intersection of Solitario Cny. and Trench CF2&3 roads and 0.15 mi. NE of CF2&3 road; 30 ft. NE of E end of Trench CF3, which is across the Windy Wash fault. **Physiographic Position:** Remnant surface of beheaded Black Cone ("Q2") inset fan. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** White bursage, creosote bush, shadscale, Nevada mormon tea, pale wolfberry, range ratany. **Slope:** 3% **Aspect:** 270° **Elevation:** 3,300 ft. 1,006 m **Latitude:** 36.782°N **Longitude:** 116.510°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 5 %-area **Surficial Stones:** 1 %-area **Total Surficial Rock Fragments:** 86 %-area **Other Surficial Features:** Many pavement pebbles, cobbles, stones darkly varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-7	10YR 7/2	10YR 4/3	GL	25	0	0	42	45	13	none
2[b]	A	7-15	10YR 7/2	10YR 4/3	L	10	0	0	40	40	20	none
3[c]	ABk	15-21	10YR 6/3	10YR 4/4	VGL	50	0	0	39	38	23	none
4	Bt	21-31	7.5YR 6/3	7.5YR 4/4	EGL	65	0	0	62	20	18	1NPBC
5[d]	Bk	31-40	7.5YR 6.5/4	7.5YR 5/4	EGSL	75	0	0	72	20	8	none
6[e]	Bqkm	40-82	10YR 7/1 & 10YR 7/2	10YR 6/3 & 10YR 5/3	n.a.	75	5	0	n.a.	n.a.	n.a.	none

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	SH	FR	SO/PS	none	E	8.6	3F-MV	none	AS
2	2COPR & 1MPL	SH	FR	SS/PS	none	E	8.6	n.d.	v1VF	AS
3	1FSBK	SH	FR	SS/PS	none	EV-SPB	8.8	n.d.	1VF	AW
4	1FSBK	SH	FR	SS/PS	none	EV	8.6	n.d.	2VF	CW
5	SG	SO	VFR	SO/PO	none	EV-SPB	8.2	n.d.	1VF	vAW
6	M	VH	VFI	brittle	CS	EV	n.d.	n.d.	none	N

COMMENTS: [a]The Av is dilatent, has pustulose pebble-bottom carbonate coatings. [b]The A horizon is dilatent. [c]The ABk horizon is dilatent. [d]The Bk horizon has prominent carbonate pebble-bottom coatings. [e]Pan comprised of 15-20 cm thick lenses with thin laminae on tops of lenses; similar to Pedon 7; this pan could include older cemented materials not removed during formation of the Black Cone inset fan at this site.

PEDON No. 16 (CFP38) — TABULAR DESCRIPTION

Taxonomic I.D.: "fine-loamy", mixed, thermic Typic Durargid. **Est. Min. Age:** 380,000 YPB (cation ratio). **Geomorphic Surface:** Yucca. **Pedon I.D.:** 1-FFP-1-CFP38-1 to 5. **Date:** 8/18/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, 4.2 mi. NNE of Black Cone. **Physiographic Position:** Upper-fan-piedmont-remnant summit; moderately-wide remnant with wide, low, solifuction steps. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** Spiny menodora, blackbrush, Nevada mormon tea, creosote bush, white bursage, pale wolfberry, Joshua-tree, Stipa spp. **Slope:** 5% **Aspect:** 210° **Elevation:** 3,885 ft. 1,184 m **Latitude:** 36.873°N **Longitude:** 116.542°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 3 %-area **Surficial Stones:** <1 %-area **Total Surficial Rock Fragments:** 83 %-area **Other Surficial Features:** Cobbles and some pebbles darkly-varnished, many pebbles not so; stones weathering-spalled where not darkly varnished; no more prominent rock varnish than on early Black Cone surface; black banding on photo is elongate pavettes above low, vegetated scarps of solifluction steps.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-7	10YR 6.5/1	10YR 4.5/2	GL	20	0	0	50	35	15	none
2[b]	Ak	7-17	10YR 6/2	10YR 4.5/2	GL	20	0	0	42	40	18	none
3[c]	Bt	17-28	7.5YR 6/4	7.5YR 4/6	FG"L"	20	0	0	n.a.	n.a.	n.a.	4KPF,BR,CO
4[d]	Btqkm	28-72	7.5YR 6/4	7.5YR 4/4	G"LS"	15	0	0	n.a.	n.a.	n.a.	3KPF
5[e]	Bqkm	72-77+	10YR 8/1 & 10YR 7/2	10YR 7/3 & 10YR 7/3	n.a.	30	0	0	n.a.	n.a.	n.a.	n.d.

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	H-SH	VFR	S/P	none	EO & E	8.6	3F-MV	v1VF	AW
2	1MPL & 2VFSBK	SH	VFR	SS/PS	none	ES-SPB	9.0	n.d.	1VF,v1M	AW
3	1MPL & 3VFABK	H	FI	SS/P	VCW peds	EO	8.4	n.d.	2VF,1M	VAW
4	3MPL	H	FI	SO/PO	CW	EO & EV	8.4	n.d.	none	VAW
5	M	VH	EFI	n.a.	CS	EV	n.d.	n.d.	none	N

COMMENTS: [a]The Av is very dilatent. [b]The Ak is dilatent and banded with (10YR 6/2D 4/2M) illuvial "humus" and browner (10YR 7/3D 4/4M) material, possibly illuvial clay. [c]The Bt is opalized and "crunchy" but hasn't macroscopic opal, so not designated Btq, i.e., individual peds very weakly cemented; actual texture if could be dispersed should be a CLAY. [d]The Btqkm is not part of the duripan proper, though it is as a mass (i.e., the platy peds) brittle, "crunchy", and weakly cemented; actual texture probably a CLAY; calcite accumulation is on the bottoms of platy peds only; contains some gypsum crystals. [e]Based on gully-wall exposures to the N, the duripan proper, i.e., the Bqkm horizon has an about 68 cm thickness (72-140 cm depths) of strongly-cemented material; it has opaline surficial laminae and is densely-impregnated with opal and some calcite cement.

PEDON No. 17 (CFP39) — TABULAR DESCRIPTION

Taxonomic I.D.: clayey-skeletal, montmorillonitic (?), thermic Typic Durargid. **Est. Min. Age:** 360,000 YBP (cation ratio) **Geomorphic Surface:** Yucca **Pedon I.D.:** 1-FFP-1-CFP39-1 to 5. **Date:** 8/19/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, about 0.7 mi. S of mouth of Solitario Cny. between road to GW10 & 11 and Solitario Wash. **Physiographic Position:** Moderately-wide, upper-fan-piedmont-remnant summit. **Parent Material:** Eolian dust and volcanic alluvium. **Native Vegetation:** White bursage, Nevada mormon tea, pale wolfberry, creosote bush, shadscale, range ratany, needlegrass. **Slope:** 5% **Aspect:** 180° **Elevation:** 3,675 ft. 1,120 m **Latitude:** 36.809°N **Longitude:** 116.492°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 80 %-area **Surficial Cobbles:** 3 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 83 %-area **Other Surficial Features:** Many pebbles and most cobbles darkly varnished.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-8	10YR 7/2	10YR 4/2	L	5	0	0	53	35	18	none
2	Ak	8-17	10YR 6.5/3	10YR 5/3	L	10	0	0	50	35	15	none
3[b]	Bt	17-38	7.5YR 5/4	7.5YR 4/6	VGC	30	10	0	28	30	42	4KPF
4[b]	Btk	38-57	10YR 6/6	10YR 4.5/6	VGC	45	2	0	22	38	40	4KPF&CO
5[c]	Bqkm	57-61+	10YR 8/1 & 10YR 7/4	10YR 7/4 & 9YR 5/4.5	n.a.	50[d]	n.d.	0	n.d	n.d	n.d	n.d.

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR & 1MPL	SH	VFR	SS/P	none	EO & E	8.8	3F-MV	none	AW
2	1MPL & 2VFSBK	SH	VFR	SS/PS	none	ES-SPB	9.0	n.d.	1VF-F	CW
3	3VF-FABK	SH	FR	VS/VP	none	E	8.8	n.d.	v1VF	CW
4	2FSBK	H	FI	VS/VP	none	EO & E-SPB	8.6	n.d.	none	VAW
5	M	EH	EFI	brittle	CS	ES	n.d.	n.d.	none	N

COMMENTS: [a]The Av with low-contrast, dark-grey, probable illuvial-humus banding. [b]The Bt and Btk horizons do not have the "crunchy", very weak opalization-cementation that Pedon 16 has. [c]Exposures of the Bqkm pan in adjacent gullies suggest a 2-3 ft. thickness of strongly cemented material; only a thin surficial-lamina is present on this pan. [d]Rock fragment content of pan estimated from adjacent gully exposures.

PEDON No. 18 (CFP40) — TABULAR DESCRIPTION

Taxonomic I.D.: loamy-skeletal, mixed, thermic Typic Durargid / Typic Durorthid (complex) **Est. Min. Age:** 660,000 YBP (cation ratio) **Geomorphic Surface:** Solitario. **Pedon I.D.:** 1-FFP-1-CFP40-1 to 4 **Date:** 8/19/87 **By:** F.F. Peterson **Location:** Crater Flat, Nevada, about 0.7 mi. S of mouth of Solitario Cny. on road to gw10 & 11, and on W side of Solitario Wash from Pedon 17. **Physiographic Position:** Broad crest of a ballena. **Parent Material:** Eolian dust, volcanic alluvium, and fractured duripan fragments. **Native Vegetation:** White bursage, Nevada mormon tea, shadscale, creosote bush, pale wolfberry, spiny menodora. **Slope:** 5% **Aspect:** 180° **Elevation:** 3680 ft. 1,122 m **Latitude:** 36.809°N **Longitude:** 116.495°W **Microrelief Position:** PAVETTE **Surficial Gravel:** 83 %-area **Surficial Cobbles:** 2 %-area **Surficial Stones:** 0 %-area **Total Surficial Rock Fragments:** 85 %-area **Other Surficial Features:** Many volcanic cobbles and pebbles are darkly varnished; some 10-65% of the pavement is pale brown, indurated, gravel-size chips of the duripan surficial laminae; variation in number of pan chips probably reflects previous rodent activity.

No.	Horizon	Depth cm	Color Dry	Color Moist	Texture	Estimated Gravel (% vol.)	Estimated Cobble (% vol.)	Estimated Stone (% vol.)	Estimated Sand (% wt.)	Estimated Silt (% wt.)	Estimated Clay (% wt.)	Argillans
1[a]	Av	0-5	10YR 7/2	10YR 4.5/3	VFSL	10	0	0	67	25	8	none
2[b]	Ak	5-9	10YR 7/3	10YR 5/3	L	8	0	0	42	35	23	none
3[c]	Btk	9-19	7.5YR 6.5/4	7.5YR 5/4	VGCL	50	0	0	30	35	35	?
4[d]	Bqkm	19-21+	10YR 8/2-3	10YR 7/3	n.a.	50[e]	0	0	n.a.	n.a.	n.a.	n.d.

No.	Structure	Consistence Dry	Consistence Moist	Consistence Wet	Cementation	$CaCO_3$ Effervescence & Morphology	pH	Pores	Roots	Lower Boundary
1	3COPR	SH	VFR	SO/PS	none	E & EO	8.8	3F-MV	none	AS
2	3COPR	SH	FR	S/P	none	EV	8.8	n.d.	none	AW-B
3	1VFSBK	SH	FR	S/P	none	EO & EV	8.8	n.d.	1VF-F	VAW
4	M	EH	EFI	brittle	CI	EV	n.d.	n.d.	3VF-F[f]	N

COMMENTS: [a]The Av is dilatent; surface littered with pan-laminae chips. [b]The Ak is dilatent and has a few thin, pustulose carbonate laminae, some hollow carbonate nodules and some carbonate pebble-bottom coatings. [c]The Btk is a DISCONTINUOUS, REMNANTAL HORIZON PRESENT ONLY IN DEPRESSIONS IN THE DURIPAN where it has not been stripped off; MOST OF SOIL LACKS THIS REMNANTAL ARGILLIC HORIZON; gravel in the Btk is about half pan-laminae-fragments and half carbonate-coated pebbles. [d]The duripan has an about 1 cm thick, continuous, indurated laminar cap that breaks off on top of 1-2 cm thick platy fragments. [e]Rock fragment content estimated. [f]Roots are matted between the upper plates of the duripan.

Appendix 2 of GSA Repository 9__-XXX. Cation-ratio dating material.

The purpose of this appendix is to provide more information on the cation-ratio dating conducted in this paper. The appendix is divided into three sections: chemical analyses; cause for rejection of samples; and controversies associated with cation-ratio dating.

Chemical analyses

The following 12 pages provide detailed chemical analyses of rock varnishes used for cation-ratio dating in the paper. Both PIXE and electron microprobe analyses are included.

Appendix 1: Chemical analyses of rock varnish used in the paper. Electron microprobe measurements made by JEOL superprobe with wavelength dispersive mode. Samples were prepared and analyzed according to Dorn et al. (1990).
PIXE measurements have also been made on the some of the same samples analyzed by the electron microprobe. The PIXE results have been normalized to 100%. Zero is listed where PIXE values were not reported for an element or it was below limit of detection.

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
Red Cone	2.62±0.12													
Red Cone_a	2.57	Used in Calibration	0.86	14.40	45.11	1.21	0.35	1.15	0.32	0.77	9.28	7.75	0.24	81.44
Red Cone_b	2.80	Used in Calibration	0.99	11.41	36.01	0.89	0.10	0.99	0.35	0.64	8.34	6.78	0.12	66.62
Red Cone_c	2.60	Used in Calibration	0.55	10.80	33.89	0.44	0.12	0.80	0.29	0.56	7.01	5.83	0.12	60.41
Red Cone_d	2.53	Used in Calibration	1.06	12.37	38.11	2.41	0.07	0.93	0.21	0.61	7.19	5.98	0.09	69.03
Little Cone	2.63±0.08													
Little_a	2.73	Used in Calibration	0.51	17.10	26.94	2.62	0.15	1.59	0.58	1.06	10.55	12.55	0.14	73.79
Little_b	2.55	Used in Calibration	0.35	13.45	22.19	3.60	0.24	1.00	0.40	0.73	6.85	8.00	0.26	57.07
Little_c	2.63	Used in Calibration	1.33	15.63	23.50	1.95	0.07	1.44	0.72	1.08	8.74	10.49	0.11	65.06
Little_d	2.67	Used in Calibration	0.50	13.66	23.15	3.62	0.05	1.41	0.63	1.01	8.80	10.09	0.07	62.99
Little_e	2.55	Used in Calibration	0.91	13.23	22.19	4.01	0.15	1.51	0.56	1.08	9.58	11.32	0.13	64.67
Black Cone	2.53±0.06													
Black_a	2.54	Used in Calibration	0.68	14.18	28.56	0.70	0.00	2.34	0.52	1.53	10.77	12.42	0.18	71.88
Black_b	2.60	Used in Calibration	0.43	19.10	37.17	0.25	0.02	2.69	0.54	1.69	12.48	13.12	0.13	87.62
Black_c	2.46	Used in Calibration	0.22	17.51	35.45	1.33	0.15	2.21	0.49	1.49	10.83	12.90	0.18	82.76
Black_d	2.51	Used in Calibration	0.33	17.11	32.44	1.05	0.05	2.13	0.41	1.38	8.92	9.76	0.07	73.65
CFP 2	6.47±0.13													
CFP_2_a	6.35	Used in Calibration	0.88	21.15	27.95	1.27	0.15	4.18	1.03	1.11	21.01	18.58	0.17	97.48
CFP_2_b	6.47	Used in Calibration	0.95	25.05	30.35	0.67	0.07	4.83	1.03	1.23	21.40	13.07	0.05	98.70
CFP_2_c	6.59	Used in Calibration	0.80	15.70	20.80	0.38	0.10	3.90	0.86	0.98	18.93	17.17	0.09	79.71
CFP_2_d	6.32	Used in Calibration	0.71	15.54	22.47	0.38	0.02	3.63	0.85	0.96	19.18	17.07	0.00	80.81
CFP_2_e	6.60	Used in Calibration	0.91	20.91	28.44	1.03	0.00	4.92	1.00	1.22	22.37	18.11	0.00	98.91

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
CFP 26	6.13±0.09													
CFP_26_a	6.06	Used in Calibration	1.27	19.62	28.33	2.05	0.00	3.77	0.72	1.01	8.33	13.11	0.05	78.26
CFP_26_b	6.25	Used in Calibration	1.99	18.03	27.47	1.55	0.00	3.84	0.69	0.99	8.52	12.30	0.06	75.44
CFP_26_c	6.07	Used in Calibration	1.90	16.55	47.84	1.08	0.15	4.16	0.84	1.12	5.29	7.79	0.18	86.90
CFP_26_d	6.14	Used in Calibration	1.01	14.23	42.03	2.45	0.17	3.76	0.75	1.00	4.81	6.94	0.21	77.36
CFP 33	5.75±0.06													
CFP_33_a	5.74	Used in Calibration	0.91	9.32	52.60	2.09	0.15	2.79	0.64	0.81	4.00	8.05	0.15	81.51
CFP_33_b	5.82	Used in Calibration	1.94	9.88	46.73	1.12	0.00	2.48	0.98	0.79	3.16	7.09	0.00	74.17
CFP_33_c	5.69	Used in Calibration	1.66	12.66	54.81	1.55	0.00	2.12	1.13	0.75	2.91	6.64	0.06	84.29
CFP_33_d	5.73	Used in Calibration	1.96	13.38	57.21	1.83	0.15	2.70	1.15	0.89	3.50	7.32	0.17	90.26
CFP 27	5.42±0.12													
CFP_27_a	5.38	Used in Calibration	1.79	20.12	40.61	1.08	0.17	3.40	1.00	1.10	10.04	10.17	0.22	89.70
CFP_27_b	5.24	Used in Calibration	1.46	12.48	29.40	3.12	0.55	2.72	0.83	0.91	8.69	9.30	0.61	70.07
CFP_27_c	5.46	Used in Calibration	1.36	15.92	31.77	2.38	0.07	2.79	1.11	0.95	8.00	8.75	0.07	73.17
CFP_27_d	5.45	Used in Calibration	1.88	13.07	31.89	1.70	0.00	3.07	1.33	1.07	8.35	9.19	0.00	71.55
CFP_27_e	5.56	Used in Calibration	2.04	12.12	29.04	1.99	0.00	1.06	0.40	0.35	7.71	8.37	0.05	63.13
CFP 35	5.34±0.15													
CFP_35_a	5.26	Used in Calibration	1.06	14.66	27.51	2.98	0.10	3.49	1.89	1.34	17.76	13.13	0.14	84.06
CFP_35_b	5.27	Used in Calibration	1.39	14.13	22.66	1.79	0.10	3.86	1.35	1.32	17.38	12.55	0.17	76.70
CFP_35_c	5.21	Used in Calibration	0.81	16.51	25.38	2.57	0.22	3.92	1.57	1.40	17.49	15.36	0.32	85.55
CFP_35_d	5.58	Used in Calibration	1.28	16.78	22.46	2.73	0.40	3.36	1.20	1.09	14.08	10.11	0.41	73.90
CFP_35_e	5.37	Used in Calibration	1.74	15.83	22.25	0.99	0.00	3.72	1.31	1.25	15.54	10.50	0.17	73.30
CFP 36	5.32±0.07													
CFP_36_a	5.23	Used in Calibration	2.89	21.56	31.92	0.66	0.00	3.97	1.99	1.50	18.07	15.06	0.03	97.65
CFP_36_b	5.26	Used in Calibration	2.45	10.68	27.79	0.80	0.00	1.40	1.00	0.59	11.01	12.94	0.10	68.76
CFP_36_c	5.39	Used in Calibration	1.29	8.85	24.67	0.41	0.17	1.30	0.67	0.48	10.79	13.49	0.17	62.29
CFP_36_d	5.32	Used in Calibration	2.11	16.88	25.04	0.37	0.00	2.99	1.31	1.07	15.46	14.05	0.02	79.30
CFP_36_e	5.39	Used in Calibration	0.88	16.23	23.46	0.78	0.25	2.17	1.11	0.80	10.46	13.08	0.29	69.51

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
CFP 32	5.14±0.07													
CFP_32_a	5.09	Used in Calibration	1.26	16.58	24.36	1.33	0.12	2.35	1.75	1.04	15.14	12.46	0.12	76.51
CFP_32_b	5.14	Used in Calibration	1.43	19.14	27.61	1.44	0.25	2.32	1.88	1.05	16.38	11.11	0.27	82.88
CFP_32_c	5.20	Used in Calibration	0.95	20.28	27.80	2.84	0.32	2.37	1.60	0.99	13.99	10.75	0.31	82.20
CFP_32_d	5.04	Used in Calibration	1.69	19.09	29.67	1.81	0.00	1.68	0.54	0.59	13.84	9.98	0.00	78.89
CFP_32_e	5.21	Used in Calibration	0.93	20.13	29.20	1.23	0.07	1.79	0.63	0.62	14.57	9.43	0.12	78.72
CFP 40	2.95±0.10	572,000 ± 66,000												
CFP_40_a	2.92	591,088	0.56	19.04	26.83	1.05	0.52	1.28	0.42	0.78	11.93	11.39	0.17	73.97
CFP_40_b	2.92	588,223	0.95	15.11	22.21	0.44	0.80	1.40	0.48	0.86	12.95	12.15	1.02	68.37
CFP_40_c	2.93	581,508	0.86	17.15	25.57	0.66	0.55	1.60	0.73	1.05	11.77	10.24	0.88	71.06
CFP_40_d	3.12	461,333	0.81	19.75	27.81	0.73	0.15	1.74	0.70	1.04	11.70	9.57	0.39	74.39
CFP_40_e	2.86	640,003	0.22	18.15	27.05	0.88	0.00	1.61	0.37	0.94	15.63	14.25	0.06	79.16
CFP 38	3.29±0.11	373,000 ± 50,000												
CFP_38_a	3.31	360,009	1.18	28.35	39.73	0.60	0.12	2.30	0.83	1.26	4.01	11.61	0.07	90.06
CFP_38_b	3.23	399,985	0.90	21.28	35.33	0.66	2.15	2.38	1.15	1.44	2.86	11.98	2.54	82.67
CFP_38_c	3.19	422,094	0.99	28.18	43.43	0.34	1.27	2.84	1.93	1.94	3.21	9.95	2.28	96.36
CFP_38_d	3.44	308,345	0.91	35.37	35.84	0.62	0.00	3.65	1.90	2.12	2.29	11.85	0.00	94.55
CFP 39	3.29±0.11	375,000 ± 53,000												
CFP_39_a	3.27	380,379	1.06	19.87	27.03	1.08	0.12	1.59	0.71	0.93	13.95	11.09	0.13	77.56
CFP_39_b	3.15	443,765	2.17	18.44	27.73	0.34	0.07	1.60	0.68	0.96	14.19	12.62	0.05	78.85
CFP_39_c	3.31	360,589	0.98	19.83	30.61	0.48	0.22	2.01	0.75	1.11	14.07	11.06	0.25	81.37
CFP_39_d	3.42	315,941	1.81	18.66	29.85	0.34	0.40	1.98	0.80	1.08	14.23	15.29	0.31	84.75
JWB 20	3.79±0.11	200,000 ± 29,000												
JWB_20_a	3.81	192,613	1.14	15.34	28.35	0.78	0.32	2.52	0.91	1.20	16.86	13.67	0.25	81.34
JWB_20_b	3.80	194,862	1.41	16.05	28.33	0.37	0.17	2.14	0.60	0.97	13.49	10.61	0.20	74.34
JWB_20_c	3.60	250,665	1.71	19.57	32.82	0.30	0.05	2.64	0.92	1.32	17.47	14.50	0.07	91.37
JWB_20_d	3.89	175,118	1.82	17.06	35.28	0.34	0.00	1.74	1.61	1.10	11.92	11.57	0.00	82.44
JWB_20_e	3.83	187,792	1.06	16.08	36.92	0.37	0.30	1.96	1.22	1.08	11.71	9.07	0.15	79.92

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
CFP 29	3.98±0.32	168,000 ± 75,000												
CFP_29_a	4.22	116,299	0.93	17.04	38.22	0.48	0.05	2.77	1.43	1.31	7.76	16.80	0.00	86.79
CFP_29_b	4.22	115,732	1.26	20.84	36.98	0.69	0.17	2.59	0.84	1.09	5.30	15.09	0.12	84.97
CFP_29_c	4.12	130,592	1.92	23.34	33.95	2.18	0.12	2.28	0.66	0.96	4.90	15.84	0.11	86.26
CFP_29_d	3.86	182,798	0.81	23.87	33.50	1.42	0.07	2.33	0.68	1.05	5.07	10.30	0.15	79.25
CFP_29_e	3.48	292,089	1.08	17.66	25.29	0.76	0.00	2.35	0.52	1.12	8.03	19.82	0.07	76.70
CFP 37	3.98±0.19	159,000 ± 38,000												
CFP_37_a	4.12	131,924	0.85	14.00	22.54	0.89	0.00	2.25	1.02	1.05	16.31	13.85	0.00	72.76
CFP_37_b	4.12	130,625	1.34	23.11	29.93	1.19	0.15	2.36	1.00	1.08	16.59	13.94	0.21	90.90
CFP_37_c	4.12	131,845	0.90	15.50	30.38	0.92	0.15	2.45	0.70	1.03	13.91	10.34	0.16	76.44
CFP_37_d	3.75	208,203	1.24	17.17	30.21	0.57	0.20	2.41	0.65	1.10	14.37	12.08	0.12	80.12
CFP_37_e	3.81	192,630	0.83	15.04	29.50	0.66	0.20	2.29	0.59	1.02	13.01	10.22	0.12	73.48
JWB_YM36-V2	7.94±0.17													
a C-14 Calibration	8.19	Used in Calibration	1.18	14.85	22.85	0.55	0.10	1.35	1.41	0.43	21.00	13.87	0.07	77.66
b Site	8.19	Used in Calibration	0.86	15.66	25.37	0.50	0.25	1.65	1.06	0.43	25.93	14.53	0.15	86.39
c	8.07	Used in Calibration	0.95	15.80	24.39	0.78	0.10	1.65	1.47	0.50	19.68	13.45	0.05	78.82
d	8.09	Used in Calibration	1.16	14.85	22.81	0.60	0.75	1.41	0.97	0.38	16.75	15.22	0.45	75.35
e	7.82	Used in Calibration	2.52	18.61	27.83	0.66	0.00	1.75	0.73	0.42	17.03	18.89	0.00	88.44
f	7.82	Used in Calibration	1.36	17.50	25.31	1.01	0.00	1.53	1.97	0.56	15.65	19.55	0.00	84.44
g	7.65	Used in Calibration	0.99	20.63	30.06	0.57	0.12	2.00	0.99	0.52	15.32	13.75	0.00	84.95
h	7.95	Used in Calibration	1.33	16.95	23.88	1.17	0.02	2.24	1.62	0.63	15.40	10.77	0.00	74.01
i	7.86	Used in Calibration	0.78	17.59	24.77	0.73	0.55	1.67	1.25	0.48	22.00	13.85	0.45	84.12
j	7.77	Used in Calibration	2.60	15.09	29.05	0.48	0.25	1.52	1.50	0.50	19.25	18.34	0.19	88.77
k	7.88	Used in Calibration	1.24	17.46	22.57	1.26	0.05	1.99	1.33	0.55	18.96	18.96	0.07	84.44
l	8.00	Used in Calibration	1.06	16.51	25.52	0.64	0.32	1.73	1.79	0.57	18.68	14.76	0.25	81.83

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
JWB_YM41	5.99±0.13													
a	5.83	Used in Calibration	0.91	17.29	27.17	0.53	0.22	1.61	1.22	0.63	20.69	13.25	0.26	83.78
b	5.92	Used in Calibration	1.86	17.61	22.44	1.26	0.00	1.83	1.02	0.63	18.96	12.17	0.00	77.78
c	6.10	Used in Calibration	1.06	16.02	34.70	2.18	0.11	1.74	1.34	0.65	13.87	11.19	0.14	83.00
d	6.02	Used in Calibration	1.08	15.61	21.24	1.28	0.00	1.70	1.71	0.72	22.13	13.60	0.00	79.07
e	5.90	Used in Calibration	2.59	19.39	27.64	0.76	0.00	1.88	0.69	0.58	16.08	13.94	0.11	83.66
f	5.75	Used in Calibration	1.09	15.78	24.90	0.78	0.00	1.87	1.23	0.70	20.00	13.19	0.00	79.[illegible]
g	6.11	Used in Calibration	2.42	19.12	26.76	0.87	0.10	1.67	0.73	0.52	17.38	13.72	0.13	83.42
h	6.20	Used in Calibration	0.63	17.19	23.70	1.01	0.27	1.20	0.97	0.45	21.10	15.28	0.47	82.27
i	6.01	Used in Calibration	1.23	18.21	29.29	0.57	0.07	1.65	1.13	0.60	17.76	14.46	0.05	85.02
j	6.06	Used in Calibration	1.04	13.26	16.02	1.67	0.25	0.98	1.72	0.55	19.51	12.20	0.22	67.42
k	5.98	Used in Calibration	0.85	13.83	33.78	0.94	0.92	1.47	1.06	0.55	17.39	12.67	0.97	84.43
l	5.94	Used in Calibration	1.09	14.98	26.64	1.83	0.10	0.95	1.18	0.45	20.93	12.48	0.11	80.74
JWB_YM38	6.37±0.13													
a	6.32	Used in Calibration	1.96	17.06	40.73	1.58	0.37	1.75	1.62	0.68	9.53	9.58	0.38	85.24
b	6.31	Used in Calibration	1.11	17.57	26.04	0.78	0.17	1.84	1.51	0.68	15.63	14.39	0.15	79.87
c	6.48	Used in Calibration	1.54	20.69	30.46	1.10	0.00	2.48	1.04	0.72	12.23	13.45	0.00	83.71
d	6.54	Used in Calibration	1.11	18.10	22.72	1.72	0.05	1.59	1.20	0.55	23.58	11.11	0.06	81.79
e	6.67	Used in Calibration	1.19	15.36	29.03	1.12	0.50	2.20	1.80	0.77	20.71	8.02	0.41	81.11
f	6.24	Used in Calibration	1.76	16.36	22.16	1.12	0.00	1.64	0.99	0.55	24.38	9.85	0.06	78.87
g	6.32	Used in Calibration	1.31	13.02	26.86	2.13	0.15	0.90	2.17	0.59	28.67	15.07	0.18	91.05
h	6.40	Used in Calibration	1.39	20.39	26.06	2.15	0.05	2.04	1.18	0.66	17.57	11.81	0.06	83.36
i	6.29	Used in Calibration	1.04	13.53	24.22	2.45	0.12	1.07	1.78	0.56	21.02	19.61	0.10	85.50
j	6.24	Used in Calibration	0.7	15.54	22.11	2.57	0.32	0.64	1.79	0.47	22.1	12.82	0.32	79.38
k	6.36	Used in Calibration	1.59	16.48	21.67	2.57	0.37	1.54	1.90	0.68	20.21	13.22	0.40	80.63
l	6.29	Used in Calibration	1.16	18.42	29.48	0.85	0.22	1.81	1.47	0.67	20.46	4.70	0.23	79.47

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
JWB_YM39	5.68±0.15													
a ADJACENT TO	5.82	Used in Calibration	1.58	15.55	19.94	1.33	0.00	1.47	1.25	0.60	27.88	9.74	0.09	79.43
b TRENCH CF 8	5.44	Used in Calibration	1.21	15.30	19.02	1.86	0.07	0.99	1.60	0.59	27.80	9.15	0.12	77.71
c	5.49	Used in Calibration	1.48	15.66	19.60	1.19	0.00	1.42	1.05	0.58	27.50	9.65	0.00	78.13
d	5.90	Used in Calibration	1.71	15.89	20.71	1.26	0.00	1.48	1.29	0.60	26.56	9.69	0.00	79.19
e	5.85	Used in Calibration	0.91	9.92	16.34	0.89	0.15	1.60	1.78	0.73	37.61	2.53	0.18	72.64
f	5.74	Used in Calibration	1.67	15.80	20.32	1.33	0.00	1.46	1.12	0.58	26.34	10.02	0.00	78.64
g	5.48	Used in Calibration	1.19	15.04	23.68	0.89	0.35	1.70	1.61	0.77	30.18	4.70	0.41	80.52
h	5.55	Used in Calibration	1.74	16.25	21.37	1.19	0.12	1.57	1.09	0.62	25.17	9.62	0.16	78.90
i	5.67	Used in Calibration	1.79	17.27	26.06	2.41	0.30	1.88	1.67	0.80	16.19	13.41	0.34	82.12
j	5.57	Used in Calibration	1.96	16.44	23.92	1.22	0.00	1.19	1.22	0.55	17.51	14.67	0.00	78.68
k	5.61	Used in Calibration	2.32	16.74	23.02	0.92	0.00	2.28	1.28	0.83	22.74	9.12	0.00	79.25
l	5.71	Used in Calibration	0.95	11.79	12.92	2.34	0.10	0.65	1.46	0.45	32.54	12.34	0.15	75.69
m	5.74	Used in Calibration	1.14	14.47	26.96	0.41	0.50	1.94	1.74	0.82	28.39	4.12	0.31	80.80
n	5.77	Used in Calibration	1.34	14.70	19.40	1.99	0.25	1.13	1.81	0.63	25.72	14.61	0.30	81.88
o	5.89	Used in Calibration	1.81	16.99	21.82	1.26	0.00	1.78	1.17	0.65	19.91	11.64	0.00	77.03
JWB_YM36-V1		1,100 ± 400												
a NOT THE	8.33	672	1.34	18.80	27.70	0.39	0.10	1.61	1.82	0.52	25.61	3.97	0.07	81.93
b CALIBRATION S	8.23	762	0.86	12.77	20.39	0.69	0.15	1.54	1.50	0.47	37.03	3.52	0.17	79.09
c SWALE LOCALE	8.31	689	1.11	10.62	23.39	1.24	0.46	1.18	0.88	0.32	23.35	6.78	0.38	69.71
d	8.02	991	1.04	16.36	26.49	0.64	0.20	1.63	1.16	0.45	29.96	3.27	0.14	81.34
e	7.80	1,306	0.93	14.89	25.07	0.89	0.22	1.73	1.50	0.53	30.20	3.89	0.23	80.08
f	7.87	1,196	0.98	12.19	18.53	0.78	0.25	1.77	1.62	0.55	38.48	2.97	0.25	78.37
g	7.64	1,596	1.13	16.85	19.70	1.51	0.12	1.58	1.61	0.53	26.88	9.25	0.15	79.31
	7.74	1,408	0.90	12.41	19.23	0.50	0.15	1.48	1.85	0.54	36.45	2.30	0.15	75.96
i	7.89	1,167	1.31	17.52	21.35	1.72	0.00	1.78	1.41	0.52	24.11	10.18	0.00	79.90
j	8.03	979	1.36	17.70	23.75	1.26	0.05	2.29	1.62	0.63	21.65	10.84	0.07	81.22
CFP-41-V1	9.17±0.25	300 ± 200												
a PETERSON	9.25	212	1.19	16.19	20.88	1.40	0.05	1.93	1.90	0.53	15.74	17.58	0.00	77.39
b PEDON 13	8.68	434	0.88	12.77	21.37	0.60	0.17	1.70	1.43	0.47	12.92	17.29	0.14	69.74
c	9.36	185	1.04	15.79	26.43	0.32	0.12	1.57	1.85	0.47	12.33	13.24	0.15	73.31
d	9.23	218	1.13	18.56	24.61	0.34	0.07	1.54	2.08	0.50	12.73	14.64	0.07	76.27
e	9.36	185	0.83	15.87	24.15	0.50	0.27	1.70	1.30	0.42	12.92	19.26	0.25	77.47
f	9.15	241	1.21	16.61	20.77	1.26	0.15	1.71	1.47	0.45	18.35	17.28	0.12	79.38

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
CFP-31-V1	5.67±0.15	19,000 ± 4,000												
a PETERSON	5.63	19,797	1.64	18.29	19.28	1.55	0.08	1.04	1.09	0.48	22.85	11.89	0.10	78.288
b PEDON 14	5.77	16,613	2.45	18.18	28.58	1.22	0	1.35	1.02	0.53	18.21	9.31	0.00	80.85
c	5.53	22,440	0.93	14.61	19.54	2.75	0.27	0.93	1.43	0.53	26.87	9.34	0.24	77.44
d	5.92	13,766	2.22	18.04	25.72	0.87	0.12	1.61	0.98	0.57	19.07	8.76	0.13	78.09
e	5.48	23,890	1.67	19.2	21.09	1.88	0.17	1.22	0.9	0.5	18.23	10.45	0.20	75.511
f	5.60	20,556	1.13	15.63	23.25	1.53	0.07	1.58	1.69	0.75	24.66	8.96	0.07	79.32
g	5.61	20,300	0.98	16.14	22.72	1.79	0.00	1.47	1.83	0.75	29.92	3.00	0.00	78.60
h	5.79	16,201	0.71	11.26	23.95	2.2	0.23	0.98	1.59	0.55	24.22	10.84	0.17	76.70
JWB_YM40	2.84±0.09	660,000 ± 71,000												
a ADJACENT TO	2.77	712,386	1.81	15.66	28.54	0.99	0.47	1.08	0.66	0.82	17.33	15.79	0.48	83.63
b TRENCH CF 1	2.87	628,501	2.22	19.05	34.27	0.34	0.25	0.73	0.69	0.63	15.07	13.05	0.22	86.52
c	2.95	568,563	0.85	15.81	25.03	1.31	0.05	0.74	1.01	0.74	19.80	14.06	0.09	79.49
d	2.75	730,461	1.09	11.47	22.04	0.94	0.07	0.82	0.41	0.59	24.86	13.63	0.13	76.05
e	2.77	712,386	0.27	12.64	24.37	1.05	0.36	0.88	0.55	0.67	18.99	14.56	0.29	74.63
f	2.93	582,989	1.01	19.18	29.81	1.28	0.00	0.83	0.73	0.68	15.32	9.81	0.00	78.65
g	2.72	758,438	1.43	18.46	25.12	0.99	0.00	0.75	0.46	0.58	23.07	12.14	0.04	83.04
h	2.92	590,339	0.61	16.67	24.73	1.56	0.12	0.84	0.58	0.63	23.83	12.66	0.15	82.38
i	2.84	652,573	1.96	17.86	29.61	0.44	0.05	1.02	0.67	0.77	17.59	17.12	0.07	87.16

Site & Subsamples	CR	CR Age ± 1 Sigma	MgO	Al2O3	SiO2	P2O5	SO3	K2O	CaO	TiO2	MnO	Fe2O3	BaO	Total
JWB_YM42	3.90±0.11	176,000 ± 25,000												
a EARLY BLACK	3.69	224,983	1.26	16.78	27.88	0.55	0.10	1.02	1.08	0.72	17.68	10.03	0.15	77.25
b CONE SURFACE	3.77	203,527	1.24	17.18	23.92	1.05	0.00	1.17	0.89	0.70	21.49	11.50	0.00	79.14
c NEAR	3.89	175,118	0.83	11.53	23.80	1.10	0.12	1.12	1.08	0.72	21.14	10.01	0.17	71.62
d	3.92	168,658	1.11	13.56	23.34	0.37	0.12	1.20	0.65	0.62	21.10	13.07	0.15	75.29
e	3.90	172,938	0.18	12.74	25.60	0.41	0.10	0.95	0.96	0.62	21.32	12.00	0.12	75.00
f	4.02	148,799	1.11	12.51	24.75	0.76	0.77	1.29	0.46	0.58	18.85	14.60	0.80	76.48
g	4.08	138,023	0.90	13.91	26.04	0.82	0.40	1.24	0.70	0.62	28.34	13.40	0.58	86.95
h	3.88	177,326	1.23	17.69	28.69	0.50	0.42	1.17	1.01	0.72	22.20	9.79	0.45	83.87
i	3.85	184,117	1.87	19.08	27.55	2.22	1.07	1.36	0.79	0.73	17.86	10.52	1.17	84.22
j	3.95	162,437	1.41	12.88	23.17	0.55	0.07	1.26	0.77	0.67	22.42	13.07	0.09	76.36
JWB_YM43	3.17±0.10	433,000 ± 54,000												
a	3.16	437,038	0.86	16.21	26.98	0.82	0.15	1.07	0.85	0.78	29.57	12.99	0.15	90.43
b	3.25	390,437	1.03	11.62	20.47	2.89	0.37	1.15	0.50	0.67	21.48	13.59	0.29	74.06
c	3.07	489,201	0.63	14.45	22.01	0.53	0.10	1.31	0.35	0.73	28.82	11.89	0.12	80.94
d	3.13	453,776	0.48	16.82	20.33	2.77	0.87	1.22	0.78	0.83	24.82	10.85	0.99	80.76
e	3.02	520,825	2.85	15.35	24.05	0.27	0.07	1.03	0.40	0.63	27.26	16.25	0.08	88.24
f	3.21	410,501	1.18	15.33	27.18	0.53	0.27	1.07	0.57	0.67	22.03	12.52	0.25	81.60
g	3.36	340,173	1.01	15.53	27.26	1.03	0.25	1.05	1.16	0.83	20.80	12.69	0.27	81.88
h	3.22	405,390	0.96	14.38	21.24	0.50	1.55	1.18	0.47	0.68	20.42	14.78	1.56	77.72
i	3.13	453,776	0.91	12.34	17.97	0.69	0.02	1.19	0.64	0.77	29.11	12.92	0.00	76.56

PIXE RESULTS

Sample	PIXE CR	Al	Si	Ca	K	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	Mg	Sr	Ba
Red Cone_a	2.61	12.89	50.48	1.95	0.90	1.09	0.25	17.40	14.13	0.10	0.00	0.11	0.69	0.00	0.00	0.00
Red Cone_b	2.68	12.21	47.81	1.84	1.16	1.12	0.27	18.84	15.80	0.06	0.07	0.12	0.69	0.00	0.00	0.00
Red Cone_c	2.48	13.06	50.43	1.65	0.98	1.06	0.24	17.17	14.37	0.05	0.00	0.11	0.88	0.00	0.00	0.00
Red Cone_d	2.54	13.82	51.63	1.92	0.77	1.06	0.19	16.20	13.62	0.10	0.04	0.09	0.56	0.00	0.00	0.00
Little_a	2.73	16.12	32.35	2.75	1.73	1.64	0.14	20.54	23.77	0.00	0.00	0.18	0.80	0.00	0.00	0.00
Little_b	2.55	16.40	33.45	2.30	1.53	1.50	0.15	18.15	21.11	0.18	0.00	0.15	0.75	4.32	0.00	0.00
Little_c	2.54	17.18	32.21	2.57	2.25	1.90	0.19	19.44	23.34	0.00	0.04	0.14	0.74	0.00	0.00	0.00
Little_d	2.66	14.29	30.25	2.68	2.05	1.78	0.16	20.04	23.78	0.04	0.06	0.26	0.84	3.77	0.00	0.00
Little_e	2.57	14.92	30.88	2.94	1.92	1.89	0.15	21.26	24.71	0.15	0.09	0.15	0.91	0.00	0.00	0.00
Black_a	2.56	13.53	33.48	4.13	1.62	2.25	0.18	20.75	22.87	0.19	0.04	0.22	0.73	0.00	0.00	0.00
Black_b	2.57	13.73	33.89	3.85	1.36	2.03	0.14	19.24	21.61	0.15	0.00	0.17	0.77	3.04	0.00	0.00
Black_c	2.49	14.70	36.27	3.48	1.37	1.95	0.11	18.04	20.06	0.04	0.05	0.14	0.00	3.77	0.00	0.00
Black_d	2.41	16.38	37.87	3.67	1.18	2.01	0.19	17.47	20.29	0.00	0.00	0.19	0.76	0.00	0.00	0.00
CFP_2_a	6.34	13.97	23.20	5.30	2.25	1.19	0.29	29.26	23.68	0.00	0.00	0.00	0.85	0.00	0.00	0.00
CFP_2_b	6.57	15.32	23.44	5.86	2.15	1.22	0.23	27.98	23.18	0.00	0.02	0.00	0.60	0.00	0.00	0.00
CFP_2_c	6.57	12.53	20.69	5.89	2.26	1.24	0.26	31.02	25.27	0.00	0.00	0.00	0.84	0.00	0.00	0.00
CFP_2_d	6.46	12.17	22.10	5.56	2.26	1.21	0.25	30.88	25.54	0.00	0.04	0.00	0.00	0.00	0.00	0.00
CFP_2_e	6.60	13.14	22.33	6.13	2.18	1.26	0.21	29.64	24.40	0.00	0.07	0.09	0.56	0.00	0.00	0.00

Sample	PIXE CR	Al	Si	Ca	K	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	Mg	Sr	Ba
CFP_26_a	6.02	16.84	30.26	6.25	2.06	1.38	0.17	14.96	24.35	0.00	0.00	0.00	0.64	3.10	0.00	0.00
CFP_26_b	6.24	15.53	29.53	6.37	1.99	1.34	0.11	15.21	23.34	0.00	0.04	0.00	0.71	5.84	0.00	0.00
CFP_26_c	6.08	13.57	48.23	6.55	2.32	1.46	0.00	8.83	18.29	0.00	0.00	0.12	0.63	0.00	0.00	0.00
CFP_26_d	6.12	13.02	47.47	6.66	2.27	1.46	0.09	9.02	19.32	0.00	0.00	0.00	0.68	0.00	0.00	0.00
CFP_33_a	5.79	8.47	59.38	4.86	1.92	1.17	0.07	7.51	16.08	0.00	0.00	0.11	0.43	0.00	0.00	0.00
CFP_33_b	5.82	10.03	58.23	4.53	3.04	1.30	0.10	6.69	15.45	0.00	0.00	0.10	0.54	0.00	0.00	0.00
CFP_33_c	5.65	11.46	62.81	3.26	2.95	1.10	0.00	5.47	12.90	0.00	0.00	0.06	0.00	0.00	0.00	0.00
CFP_33_d	5.67	11.31	60.17	3.89	3.03	1.22	0.08	6.04	13.85	0.00	0.00	0.08	0.33	0.00	0.00	0.00
CFP_27_a	5.40	15.25	38.76	4.78	2.51	1.35	0.17	15.72	16.15	0.00	0.06	0.15	0.68	4.42	0.00	0.00
CFP_27_b	5.20	12.66	36.41	4.96	2.69	1.47	0.16	18.20	18.27	0.00	0.00	0.10	0.00	5.09	0.00	0.00
CFP_27_c	5.46	15.27	38.05	4.64	3.27	1.45	0.13	15.90	16.32	0.00	0.05	0.12	0.00	4.81	0.00	0.00
CFP_27_d	5.33	13.53	40.21	5.24	3.82	1.70	0.00	17.25	17.59	0.00	0.00	0.17	0.49	0.00	0.00	0.00
CFP_27_e	5.51	13.39	39.86	5.22	3.27	1.54	0.00	17.48	18.52	0.00	0.00	0.22	0.49	0.00	0.00	0.00
CFP_35_a	5.28	11.63	27.80	4.72	4.15	1.68	0.00	29.43	19.56	0.00	0.04	0.19	0.80	0.00	0.00	0.00
CFP_35_b	5.28	11.80	22.96	5.33	3.43	1.66	0.32	29.08	22.35	0.00	0.06	0.15	0.00	2.86	0.00	0.00
CFP_35_c	5.19	12.77	24.00	5.16	3.56	1.68	0.35	27.41	21.65	0.00	0.02	0.15	0.00	3.25	0.00	0.00
CFP_35_d	5.42	15.41	25.81	5.55	3.40	1.65	0.30	26.96	20.74	0.00	0.06	0.13	0.00	0.00	0.00	0.00
CFP_35_e	5.35	13.77	24.16	5.85	3.52	1.75	0.29	28.23	22.24	0.00	0.03	0.16	0.00	0.00	0.00	0.00
CFP_36_a	5.27	14.17	26.54	4.49	3.78	1.57	0.22	24.84	19.99	0.00	0.00	0.15	0.50	3.75	0.00	0.00
CFP_36_b	5.27	10.34	33.81	2.03	2.71	0.90	0.17	22.22	27.08	0.00	0.00	0.11	0.64	0.00	0.00	0.00
CFP_36_c	5.17	9.56	32.53	2.13	1.90	0.78	0.16	23.33	29.51	0.00	0.00	0.10	0.00	0.00	0.00	0.00
CFP_36_d	5.22	14.58	26.54	4.36	3.26	1.46	0.32	27.28	21.98	0.00	0.08	0.15	0.00	0.00	0.00	0.00
CFP_36_e	5.39	15.19	27.28	3.39	3.02	1.19	0.27	20.32	25.77	0.00	0.02	0.13	0.00	3.41	0.00	0.00

Sample	PIXE CR	Al	Si	Ca	K	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	Mg	Sr	Ba
CFP_32_a	5.04	15.12	26.94	3.14	4.02	1.42	0.24	27.91	20.94	0.00	0.10	0.16	0.00	0.00	0.00	0.00
CFP_32_b	5.18	15.53	27.21	2.86	3.82	1.29	0.36	26.28	19.39	0.00	0.00	0.12	0.63	2.51	0.00	0.00
CFP_32_c	5.21	16.60	28.66	3.38	4.02	1.42	0.26	24.37	20.32	0.00	0.06	0.17	0.74	0.00	0.00	0.00
CFP_32_d	5.09	18.11	34.04	2.78	1.55	0.85	0.13	26.15	15.62	0.00	0.06	0.11	0.60	0.00	0.00	0.00
CFP_32_e	5.20	18.16	32.20	2.86	1.77	0.89	0.14	26.69	16.55	0.00	0.00	0.11	0.63	0.00	0.00	0.00
CFP_40_a	2.94	17.69	31.10	2.17	1.30	1.18	0.20	23.04	22.05	0.07	0.16	0.21	0.83	0.00	0.00	0.00
CFP_40_b	2.95	15.17	26.99	2.41	1.45	1.31	0.65	26.13	23.36	0.00	0.08	0.18	0.99	0.00	0.00	1.29
CFP_40_c	2.80	16.54	30.36	2.45	1.95	1.57	0.60	23.04	21.58	0.13	0.13	0.15	0.77	0.00	0.00	0.73
CFP_40_d	3.01	17.80	31.10	2.61	1.84	1.48	0.59	21.62	20.88	0.19	0.05	0.15	1.18	0.00	0.00	0.51
CFP_40_e	2.93	14.39	26.55	2.46	1.00	1.18	0.14	25.99	23.36	0.10	0.09	0.18	0.00	4.56	0.00	0.00
CFP_38_a	3.22	20.47	35.29	2.80	1.74	1.41	0.26	5.72	25.49	0.00	0.07	0.22	0.94	5.58	0.00	0.00
CFP_38_b	3.39	19.92	40.45	3.92	3.30	2.13	0.00	5.39	20.52	0.05	0.00	0.22	0.00	0.00	0.00	4.09
CFP_38_c	3.31	21.12	41.36	3.40	3.94	2.22	0.00	5.07	19.36	0.00	0.14	0.09	0.00	0.00	0.00	3.29
CFP_38_d	3.32	23.37	29.07	4.02	3.64	2.31	0.00	3.14	34.39	0.07	0.00	0.00	0.00	0.00	0.00	0.00
CFP_39_a	3.21	17.28	29.61	2.29	1.79	1.27	0.31	25.03	21.46	0.03	0.11	0.15	0.67	0.00	0.00	0.00
CFP_39_b	3.27	16.24	29.83	2.51	1.80	1.32	0.34	25.59	21.44	0.06	0.06	0.13	0.68	0.00	0.00	0.00
CFP_39_c	3.30	15.64	29.49	2.69	1.77	1.35	0.23	22.48	22.32	0.11	0.00	0.11	0.67	3.13	0.00	0.00
CFP_39_d	3.46	14.73	29.09	2.82	1.92	1.37	0.16	23.24	22.90	0.12	0.04	0.12	0.73	2.75	0.00	0.00
JWB_20_a	3.91	12.81	28.85	3.65	2.29	1.52	0.34	28.13	21.55	0.00	0.00	0.16	0.70	0.00	0.00	0.00
JWB_20_b	3.63	15.32	31.95	3.50	1.76	1.45	0.35	25.46	19.39	0.00	0.03	0.15	0.63	0.00	0.00	0.00
JWB_20_c	3.71	14.42	30.17	3.59	2.09	1.53	0.34	26.81	20.14	0.00	0.07	0.18	0.66	0.00	0.00	0.00
JWB_20_d	3.69	14.50	37.69	3.30	2.09	1.46	0.10	20.87	19.17	0.00	0.08	0.12	0.61	0.00	0.00	0.00
JWB_20_e	3.85	12.47	37.69	2.66	2.84	1.43	0.10	20.12	18.60	0.00	0.07	0.11	0.70	3.22	0.00	0.00

Sample	PIXE CR	Al	Si	Ca	K	Ti	V	Mn	Fe	Ni	Cu	Zn	Pb	Mg	Sr	Ba
CFP_29_a	4.09	14.09	39.48	3.74	3.34	1.73	0.00	13.23	23.55	0.05	0.00	0.13	0.66	0.00	0.00	0.00
CFP_29_b	4.03	15.41	32.81	3.15	1.77	1.22	0.00	7.80	29.29	0.00	0.00	0.15	0.00	8.40	0.00	0.00
CFP_29_c	3.95	20.24	34.86	3.29	1.65	1.25	0.00	8.28	29.71	0.03	0.00	0.16	0.52	0.00	0.00	0.00
CFP_29_d	3.82	20.59	34.36	3.18	1.60	1.25	0.00	8.25	30.58	0.00	0.06	0.13	0.00	0.00	0.00	0.00
CFP_29_e	3.80	16.72	29.82	4.58	1.76	1.67	0.27	15.87	29.01	0.00	0.09	0.19	0.00	0.00	0.00	0.00
CFP_37_a	4.10	12.15	23.44	3.17	2.45	1.37	0.27	28.00	24.75	0.00	0.00	0.19	0.97	3.24	0.00	0.00
CFP_37_b	4.02	16.82	28.00	2.95	2.16	1.27	0.33	25.52	22.06	0.00	0.00	0.12	0.77	0.00	0.00	0.00
CFP_37_c	3.99	14.07	33.97	3.96	1.94	1.48	0.17	25.08	18.55	0.00	0.00	0.15	0.63	0.00	0.00	0.00
CFP_37_d	3.90	14.75	32.00	3.81	1.73	1.42	0.16	25.70	19.72	0.00	0.00	0.11	0.61	0.00	0.00	0.00
CFP_37_e	3.92	13.97	33.58	3.95	1.77	1.46	0.18	24.59	18.44	0.00	0.00	0.09	0.64	1.33	0.00	0.00

Cause for Rejection of Samples

This section presents explicit reasons for why samples were rejected for cation-ratio and radiocarbon dating in this study. These are factors that have been published previously in more general papers on the subject of varnish dating (Dorn, 1989; Dorn et al. 1990; Krinsley et al., 1990), as explained in the text of the paper. This section is presented to highlight particular sampling and sample analysis issues that came up the Crater Flat research. In this way, the reader is also better able to compare the criteria for sample use and rejection utilized by the Los Alamos varnish researchers who employ rock varnish cation ratio dating (cf. Harrington and Whitney, 1987).

1. Not right type of rock varnish.

Rock varnish is a dark coating on rocks, typically <200 μm thick. It is composed of clay minerals cemented to the underlying rock by oxides of manganese and/or iron (Potter and Rossman 1977, 1979). It is an accretion with chemical and morphological characteristics distinct from the underlying substrate (Dorn and Oberlander 1982; Perry and Adams 1978; Potter and Rossman 1977).

Beyond these characteristics, rock varnishes differ greatly in structure and chemistry at all scales from kilometers to micrometers. Even at the scale of cubic millimeters, great differences exist between varnishes of different colors, between black varnishes found in subaerial environments and non-subaerial environments, and between varnishes found in different types of subaerial environments.

The only type of varnish that has been tested for cation-ratio dating is Mn-rich, black varnishes. Black varnishes are greatly enriched in manganese (which provides the dark coloration) in the upper few microns, typically >10% MnO (Dorn and Oberlander 1982). Orange varnishes (Munsell 10R4/8, 2.5YR4/6 to 5/6, 5YR7/6 to 7/8) generally have MnO concentrations of <0.2% throughout the entire varnish. Dusky-brown varnishes (Munsell 10R3/3 to 4/4) are those intermediate in surface chemistry; they have enough manganese to darken the color (in the range of ~0.5-5%), but not enough manganese to give the varnish a black appearance.

The most common type of Mn-rich black varnish found at Crater Flat is not appropriate for dating. It is varnish that started to form in a rock crevice, and was later exposed by rock spalling. The type of gravel shattering that makes planar surfaces is a common process in desert pavements (Amit et al., 1993).

Manganese-rich varnishes that do not form at the surface have different structures than varnishes that form at the air/rock interface (Dorn, 1986; Dorn and Oberlander 1982). Trace element chemistries also differ. For example, varnishes that originally developed in rock crevices, but have been exposed by rock spalling, have much higher levels of barium than varnishes formed exclusively in a subaerial environment (Dorn 1993).

Distinguishing different types of manganese-rich varnishes can be tricky. Experienced desert geomorphologists who have confused varnishes developed only in a subaerial position with varnishes originally developed in a subsurface position. It is an easy, but important error. Varnish on hillslopes and talus typically start out a in a crevice, but are later exposed by rock spalling along a joint plane. Similarly, ground-line band varnishes, which originally form at the soil-rock-atmosphere interface, are often found in exposed in desert pavements that have experienced soil erosion.

Many varnish researchers are drawn towards crack and ground-line varnish because of their darker and shinier appearance. Crack varnish and ground-line band varnish are almost always darker, smoother, and better looking than adjacent varnishes that have only experienced a subaerial environment. This is due to their development in protected environments that favor the concentration of manganese (cf. Dorn and Oberlander 1982).

The location of original varnish formation is of concern to varnish dating, because what is of interested is when varnish started to form over a surface that was abraded by a physical process (e.g., transport by floods). If a rock surface has spalled or been exposed by soil erosion, the newly exposed varnish would not date the event of interest. The temptation is strong to collect the best looking varnishes, but it is often the wrong type of varnish and will yield incorrect results. For example, a very well developed crack varnish collected from an *unexposed* fracture on Ayers Rock, Australia, yielded an AMS ^{14}C age of 27,100 ± 400 B.P. (Beta 19893; ETH 2809), indicating that *unexposed* varnishes can have considerable antiquity.

The sample collection philosophy followed is to avoid specific varnish characteristics and microenvironments that have produced results that are inconsistent with independent age controls. Also implicit in this approach is collecting and analyzing large volumes of sample: typically cubic millimeters to cubic centimeters. This is because the extreme microchemical variability that occurs at the scale of microns (e.g., Dorn 1989; Dorn and Oberlander 1982; Dragovich 1988; O'Hara et al. 1989, 1990; Raymond et al. 1991; Reneau and Raymond, 1991) is vastly reduced when greater volumes are analyzed.

A critical factor in sampling is the realization that any spot of varnish will not do. Varnish should be sampled from micropositions where varnish first starts to grow. Ongoing studies of historical rock engravings and stones faced during historical construction reveal that colonization occurs first in specific types of places on different lithologies. For example, varnish first colonizes vesicles in basalt, impurities in chert, fractures in quartz and silicified dolomite, and grain boundaries in granitic rocks and sandstones.

When a new method develops, different investigators often have their own approaches to sample collection. This is the case in rock varnish research. Unfortunately, not all varnish researchers specify the type(s) of varnish they have analyzed, so the author in unable to compile a chart comparing different sampling procedures. A few investigators have noted avoidance features like lichens or places where aeolian abrasion occurs (Glazovskiy 1985; Zhang et al. 1990). Others simply indicate: "the darkest varnish is sampled because, in comparing spots with similar settings, relative darkness may be the best field criiteria for relative age. The smoothest varnishes are sampled to minimize surface roughness effects in SEM analyses of natural surfaces" (Reneau et al. 1991: 54) or that varnish is collected from "outcrops possessing the darkest, most consistent varnish at each site" (Raymond et al. 1991: 38). Still others do not specify what type of varnishes are collected or analyzed (Harrington et al. 1991; Harry, Bierman et al. 1992).

The lack of quality control in sample collection has led to inaccurate comparisons in the published literature. Certainly, there is no evidence to indicate that any two varnish investigators have analyzed the same type(s) of varnishes. This is not to suggest that data from any particular investigator(s) is invalid or unrepresentative for the type(s) of varnish analyzed. On the contrary, when varnish type is factored in, results among different groups appear to be fairly consistent. Until investigators specify the different type(s) of varnish analyzed, readers interested in varnish studies need to be aware that 'apples and oranges' are being compared, often unknowingly.

2. Not Correct Surface Characteristics

What is of interest in the Crater Flat study is learning when the last flood event occurred that deposited the alluvial unit. It is, therefore, inappropriate to sample cobbles that do not have a 'rounded corraded' appearance. This is a qualitative judgement, but a critical one. Cobbles that are not rounded have a high likelihood of being from gravel shattering (cf. Amit et al., 1993), hence they were not sampled.

This point relates to the issue of the 'appearance of varnish'. Cobbles with rounded corraded surfaces often do not have the best 'looking' varnishes on smooth surfaces. Truly corraded surfaces have small indentations and pits reflecting fluvial or slurry-flow transport.

3. Lichens are to be avoided, because they lower cation ratio from acidification.

4. Microcolonial fungi, are to be avoided because they lower cation ratio when they actively erode into varnish. However, they do not appear to alter cation ratios when they are adventitious. Microcolonial fungi were particularly abundant on the ignimbrite samples.

5. Areas where water runoff occurs is to be avoided, because they lower cation ratio, unless source of water runoff is locale where alkaline dust collects

6. Basins of water collection are avoided because they lower cation ratio due to enhanced leaching effect of longer water contact.

7. When organic matter is in direct contact with varnish, cation ratios appear to be lower due to prolonged contact with organic acids.

8. Northeast facing aspects in North American Deserts tend to have slightly lower cation ratios than varnish on boulder tops or south-southwest aspects. This is probably due to the cumulative effect of more mesic conditions.

9. Filamentous fungi lower CRs when surface area greater than ~5%, due to secretion of organic acids, and hence should be avoided.

10. When varnishes have acidic pH values (<6), cation ratios tend to be lower than near neutral varnishes.

11.Ground-line band varnish must be avoided, although it can often produce a very dark and shiny varnish on a rounded cobble. Many of the Crater Flat sites are where dust collections in a depression have a cumulic aeolian (loess) soil. A ground-line band is created at the
soil-varnish-atmosphere, creating a different environment for cation leaching.

12. Titanium anomalyies occur in local environments can contain abundant titanium detritus, that once incorporated into varnish decreases the cation ratio.

13. Varnishes collected near a soil surface of cryptogamic algae, fungi, lichens and mosses have lower cation ratios.

14. Although quite rare in Crater Flat, when rock varnish interlayers with films of oxalate, cation ratios decrease.

15. Varnishes collected within a few centimeters of a soil surface have higher cation ratios, perhaps due to deposition of salts carried by capillary flow.

16. Local environments can contain abundant calcium carbonate detritus; once incorporated it increases the cation ratio.

17. Local environments can contain abundant potassium-rich detritus; once incorporated it increases the cation ratio.

18. Varnishes with uncommonly great abundance of botryoids have slightly lower cation ratios. due to greater leaching between stromatolitic-like structures.

19. The interdigitation of amorphous silica skins greatly with amorphous silica decreases the rate of leaching and increases the cation ratio.

20. If sampled from locations where varnish does not grow initially (see text for further discussion), CRs are higher for the varnish that spreads out from initial colonization point.

21. If varnishes did not form continuously, as evidenced by scanning electron microscope observations, there are particualr characteristics indicative of a sample that is bad for dating (Krinsley et al., 1990).

Controversies Associated with Cation-Ratio Dating

Table A1 presents a summary of issues under contention in the CR dating literature. Most of these differences have a root cause of different investigators analyzing different types of varnishes. The following discussion over the cause of CR change with time shows this well.

Since its discovery, the trend of decreasing CRs with age has been replicated by several researchers around the world (e.g., Bull 1991; Glazovskiy 1985; Harrington and Whitney 1987; Pineda et al. 1988; Pineda et al. 1990; Zhang et al. 1990). At issue is why the cation-ratio dating method works. One hypothesis is cation leaching (Dorn 1983; Dorn and Krinsley 1991, 1992), also supported by O'Hara et al. (1990) and Krinsley et al. (1990) who found ubiquitous textural and geochemical evidence of cation mobility. The alternative hypothesis is contamination from the underlying rock (Reneau and Raymond 1991). After collecting "darkest, best developed varnishes" Reneau and Raymond (1991:937) found a "lack of evidence for leaching."

These seemingly discordant interpretations can be explained by different researchers examining different types of varnishes. "Dark", "smooth varnishes", and "best developed" are *the* published sampling criteria of the Los Alamos varnish group (Raymond et al. 1991; Reneau et al. 1991; Reneau and Raymond 1991). Recently exposed crack varnishes are usually the 'darkest' due to high Mn concentrations in the outermost layers and the 'smoothest' due to formation on a planar fracture surface. Ground-line bands are typically the darkest, best developed, and smoothest varnishes because growth occurs in such a favorable microenvironment (e.g., Dorn and Oberlander 1982: 359-60). The texture and chemical profiles in Raymond et al. (1991) are remarkably similar to varnishes collected from former crevices.

While *subaerial* positions are exposed to alternating conditions of dust deposition, water flow, and acid-producing organisms, *crack varnishes* formed in rock crevices and exposed by later spalling provide an environment of wetting and drying buffered by long-term contact with collected alkaline dust. The crack varnish environment promotes superior varnish cementation all while avoiding exposure to the acidity of rainfall and rock-surface organisms in the subaerial environment. The tight layering found in crack varnish does not open itself to leaching the way subaerial varnishes do.

The 'barium' controversy may also be explained by comparing different varnishes. Some varnishes have high levels of barium, while others have virtually none. Crack varnishes contain a Ba-Mn oxide romanechite (Potter and Rossman 1979:1221). Varnishes that originally developed in rock crevices have relatively high barium levels, strong Mn-Ba correlations, and a surface layer enriched in Mn (see Harrington et al. 1991). In contrast, the manganese mineral found in subaerial varnishes is birnessite (Potter and Rossman 1979), which does not contain barium. This is consistent with observations of low barium concentrations in varnishes formed only at the air/rock interface (Dorn 1993).

In summary, apparently contradictory findings move towards convergence of views when the types of varnish analyzed are factored in. To avoid future confusion, varnish researchers should specify as explicitly as possible: (a) the type of environment where the sample was collected (e.g., Dorn 1989: 568-9; Dorn and Oberlander 1982: 359-60; Dragovich 1984, 1987, 1988; Jones 1991; Potter and Rossman 1979; Whalley et al. 1990; White 1990; Zhang et al. 1990); (b) cross-sectional textures and surface micromorphologies of varnishes selected for chemical analysis (e.g., Krinsley et al. 1990); and (c) the volume of material analyzed.

Table A1. Issues under contention in cation-ratio dating, discussed in greater detail in Dorn (1993).

Issues	Critiques	Discussion
Theory Behind Cation-Ratio Dating	Reneau and Raymond (1991) argue that the decline in cation ratio over time is from different amounts of contamination from the rock underlying the varnish, rather than from greater rates of leaching mobile (Ca, K) cations than immobile (Ti) cations. Reneau and Raymond (1991) argue that older varnishes are thicker and have less contamination from the underlying rock, and hence lower cation ratios. Harry, Bierman, and Fratt (1992) argue that there is no evidence of cation-ratio reduction over time in comparisons of artifacts and bedrock cortical surfaces. Watchman (1992a) questions whether cation leaching occurs. There is no other proposed alternative to explain the observed cation-ratio reduction over time other than differential chemical mobility and differential rock contamination.	1. Five of the six different groups that have found that cation ratios decline with time (Dorn 1983; Glazovskiy 1985; Harrington and Whitley 1987; Pineda et al. 1988,1990; Zhang et al. 1990; not Bull 1991) have used different rock types -- observations inconsistent with the rock contamination hypothesis. In contrast to their conclusion, Harry, Bierman and Fratt (1992, p. 101) also show that varnishes scraped from cultural surfaces have younger (higher) cation ratios than scraped varnish on cortical controls. 2. Zones of cation-leaching have been identified in rock varnish (Dorn and Krinsley 1991, 1992). 3. Laboratory experiments have verified that cation leaching occurs from rock varnish (Dorn and Krinsley 1991).
Sampling	Bierman and Gillespie (1991a) argue that forest fires erode varnishes, resetting the varnish clock. Harry, Bierman and Fratt (1992) argue that desert pavements are not stable enough for the investigator to know the modified surface of an artifact to been exposed continuously, based on qualitative observations at one site in the western Mojave Desert.	Petroglyphs occur on stable talus or bedrock; ones examined in this study are distant from forest fires. We agree that some pavements are not stable. Yet pavements sampled by Bamforth and Dorn (1988) are felt to be quite stable. Desert pavements in the Mojave Desert have remained in place for 10^4 to 10^5 years (McFadden et al. 1987; Wells et al. 1991).
Sample Examination	Watchman (1992b) argued that unlayered samples of varnish are inappropriate for dating, and that layered samples were not found at the South Australian petroglyph site examined.	Dorn and Nobbs (1992) and Nobbs and Dorn (1993) agree that unlayered samples are not appropriate for dating. Yet, the samples used for dating in South Australia and this study were found to be layered.
Accuracy of Measuring Cation Ratios	Bierman and Gillespie (1991b) submitted material to Crocker Nuclear Lab (CNL) at the University of California at Davis for analysis by proton induced x-ray excitation (PIXE). CNL is the same laboratory used by Dorn in earlier studies of cation-ratio dating. Bierman and Gillespie (1991b) reported that CNL did not adequately separate barium from titanium. Bierman and Gillespie (1991b) concluded that because the PIXE method combined barium and titanium, cation ratio [(K+Ca/Ti] measurements from PIXE are inaccurate.	Cahill (1992) explained that Bierman and Gillespie (1991b) misrepresented PIXE data given to them by CNL to derive invalid conclusions: "The data in Bierman and Gillespie (1991) Table 1, described as 'PIXE UCD' did not in fact come from us..." Importantly for this study, the wavelength dispersive electron microprobe technique we used (described in Dorn et al. 1990) to measure cation ratios does separate barium from titanium, as Bierman and Gillespie (1991b) agree.
Calculating Cation Ratio Ages	There is disagreement over the procedure used to assign cation ratio calibrated ages (e.g. Bierman et al. 1991; Lanteigne 1991). The alternative suggested to the method utilized here calculates the mean and variation of multiple cation-ratio measurements; this implies that the different samples that are being grouped together have the same exposure history. For example, if a petroglyph were to be dated with the approach suggested by Bierman et al. (1991), different collections of varnish from different parts of a petroglyph would be treated as a mean with a variation.	As elaborated in Dorn et al (1990), we treat each cation ratio as an independent indicator of age. Each cation ratio is assigned a separate age, based upon a least-squares multiple regression using only radiocarbon ages on petroglyphs as calibration points. These independent calibrated ages for a given surface are then averaged to assign a mean age for the surface, and the uncertainty is derived from the standard deviation of these ages. Strictly, the oldest (lowest) cation ratio should represent the closest minimum age for the petroglyph.

There is also uncertainty as to how to to assign CR ages (Dorn 1989; Dorn, Cahill et al. 1990). CRs are calibrated by K-Ar dates andradiocarbon, depending on the timescale. Each CR is treated an independent indicator of age. If the material being dated has definitely not experienced erosion, these separate CR ages for a given surface are averaged to assign a mean age for the surface; the uncertainty is derived from the standard deviation of these ages. If the substrate being dated may have experienced erosion, for example an alluvial-fan boulder, the oldest CR age is considered to be a minimum age for surface exposure.

An alternative approach to calculating CR ages, suggested by Bierman et al. (1991), uses the mean and variation of multiple CR measurements. This implies that the different samples that are being grouped together have the same exposure history. For example, if a petroglyph were to be dated with this approach, different collections of varnish from different parts of a petroglyph would be treated as a mean with a variation. However, varnish growth is time-transgressive, starting first in one place and growing vertically and horizontally. By treating each CR as a separate time indicator, inter-sample variability can be treated as indicating time-transgressive growth. Treating each CR as a separate time signal requires fewer assumptions: only that the calibration curve is the best estimate of CR age and that CR ages are normally distributed. In essence, this approach keeps the assignment of calibrated ages as close to the raw data as possible.

There is one controversy, however, that cannot be resolved easily. It regards the accuracy of CR measurements made by PIXE (proton-induced X-ray emission) by the Air Quality Group at Crocker Nuclear Lab (CNL) at the University of California at Davis. Bierman and Gillespie (1991a) claimed that PIXE analyses by this group were invalid. They sent 'artificial varnish' of known composition for PIXE analysis. Cahill (1992) informed Bierman and Gillespie in writing that the analyses would only be qualitative, because a dedicated run on geological material was not feasible for only a few samples. The samples were analyzed and qualitative data were sent. Bierman and Gillespie (1991a) then published these measurements as absolute values that were used to claim that PIXE data from the Air Quality Group were inaccurate. In response Cahill (1992: 469) wrote:

> 'The data in Bierman and Gillespie (1991a) Table 1, described as "PIXE UCD" did not in fact come from us. They appear to have been prepared by Bierman and Gillespie from "reduced" and "raw" X-ray spectra that was clearly labelled "The Raw Values In These Tables Are Incorrect" (written communication to Bierman, June 18, 1990). I deeply regret that they were used to generate Table 1, since we notified Bierman and Gillespie in the memo that "there is no way to obtain absolute or relative values" without particle size or proper standards, and "Ba is not in the tables we used for this run. These data were provided to Bierman and Gillespie for "evaluatory" purposes," with an explicit written prohibition against their publication...'

Bierman and Gillespie (1992) responded that oral permission was given to publish these data. One side is misrepresenting information. Cahill's case makes sense for two reasons. First, when I started submitting samples for analysis, I was also told the data would be qualitative, not publishable, and only useful to assess whether a dedicated run would be warranted. Second, I have seen the extensive written documentation available at the Air Quality Group, and it is quite clear that Bierman and Gillespie were told in great detail why the PIXE data were qualitative, just as Cahill (1992) indicates.

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Appendix 3 of GSA Repository 9__-XXX: Discussion on interpretation of rock-varnish radiocarbon ages.

The primary interpretation of rock varnish radiocarbon ages in the paper is that the ^{14}C measurement provides a reliable minimum-limiting age for the exposure of the varnished cobble to the atmosphere. A secondary interpretation is that the radiocarbon age is likely within 10% of the true age of cobble exposure. The purpose of this appendix is to present uncertainties associated with the accuracy and precision of varnish radiocarbon dating.

The primary interpretation of a minimum-limiting age is based on comparison of over 280 accelerator ^{14}C measurements with established site contexts. Out of over 280 measurements, the only problematic sample is a measurement on a petroglyph which yielded a petroleum hydrocarbon signal in analyses by Gas Chromotography/Mass Spectrometry, probably added by an archaeologist who was attempting to 'record' the petroglyph (Tretabas and Dorn, in preparation). Dorn et al. (1989), Reneau et al. (1989), and Nobbs and Dorn (1993) also suggest that it is theoretically possible that natural, older organic matter could be incorporated into a sample; e.g., older carbon from nearby soils or older carbon from a pre-existing weathering rind. Yet, in all other tests, including comparisons of varnish radiocarbon ages with control radiocarbon dates, the varnish radiocarbon age has been younger than the control (Dorn et al. 1989). Since we have not found evidence of a petroleum hydrocarbon signal in any of the samples from Crater Flat, there is no plausible reason to interpret our AMS ^{14}C ages as anything other than minimum ages for the exposure of the cobble surfaces by geomorphic processes.

A related issue is whether varnish radiocarbon ages post-date the exposure of cobble to the atmosphere. To this, we answer yes. The most likely source of any contamination is younger material that could get incorporated into a varnish coating after the varnish started to form. Watchman (1992b) exemplified this hazard by radiocarbon dating plant fragments collected from within varnish, rather than organic remains from underneath the varnish. As expected, this produced younger radiocarbon ages than subvarnish samples (Nobbs and Dorn 1993). In sample collection and processing, it is also easy to contaminate a sample with younger organics; but again, the result is younger rather than older age estimates. Examples include: sampling unlayered varnishes (Watchman 1992a, 1992b); improper chemical pretreatment (Dorn et al. 1989); the inclusion of textile filaments with a varnish sample sent to a dating laboratory (A.J.T. Jull, personal communication, 1991); and collecting organisms growing on the surface of the varnish (Nagy et al. 1991). However, in dozens of tests (Dorn et al., 1986, 1987, 1989, 1990, 1991, 1992a,b) varnish radiocarbon ages are often within 10% of the age of the control. Tests have been conducted on replication with multiple samples, different types of sampling sites, different types of chemical processing, and different ways of removing the carbon.

A third issue is the nature of the organic matter being dated. The organic material associated with rock varnish consists of remnants of what appear to be lichen, charcoal, fungal mats, cyanobacteria, algae, pollen, plant remains, as well as unidentified organic matter (Dorn and DeNiro 1985; Dorn et al. 1989; Nagy et al. 1991; Watchman 1992b; Nobbs and Dorn 1993). The samples dated in this study include endolithic algae, lichen remains, and unidentified organic matter that was removed from underneath varnish. Future tests are needed to resolve what type of subvarnish material yields the most reliable radiocarbon ages.

A fourth issue involves the replication of varnish radiocarbon dating. Watchman (1992b) obtained two measurements on organic matter extracted from within varnish that

did not overlap with two-sigma errors. Other replicate measurements that have been published do not overlap within two-sigma errors about half of the time. (Dorn et al. 1989, 1992; Nobbs and Dorn 1993). The lack of overlap is consistent with the interpretation that the dates provide reliable minimum ages for the specimens, because we are dating organics resting on worked surfaces that have been buried by the varnish at different times.

A fifth issue involves the continual refinement of sampling. Mechanical removal of varnish and associated organic matter is a tedious procedure (Dorn et al. 1992; Watchman 1992b), much like picking roots from a charcoal sample. Its accuracy has been questioned (Reneau et al., 1989). Yet, the sampling method has evolved greatly over the last several years (Dorn et al. 1986, 1989, 1992a,b). The next step is laser extraction of organic matter, if the problems associated with chemical preparation of cross sections can be overcome (cf. Nobbs and Dorn 1993).

In summary, there is no empirical reason to support the position that a varnish radiocarbon age provides anything other than a minimum age for the exposure of the underlying surface. Available empirical evidence indicates that varnish radiocarbon ages are usually within 10% of established age control for the underlying rock.

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