## U.S. DEPARTMENT OF THE INTERIOR U.S. GEOLOGICAL SURVEY



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Figure 1B. Map showing the Sangre de Cristo Range and San Luis Valley in south-central Colorado. White arrows show location of the Sangre de Cristo fault, which bounds the western side of the range. **PP**, Poncha Pass. Outline shows area of figure 1C. Image obtained from NASA Applied Sciences Directorate Earth Science Enterprise Scientific Data Purchase Program map server at https://zulu.ssc.nasa.gov/mrsid.



Figure 1C. Map showing the San Luis section of the Sangre de Cristo fault; dashed red line shows trace of the fault. Outline is location of the Rito Seco study area shown in figure 1D. Image obtained from NASA Applied Sciences Directorate Earth Science Enterprise Scientific Data Purchase Program map server at https://zulu.ssc.nasa.gov/mrsid.



Figure 1D. Aerial photograph of the Rito Seco study site. Solid red lines show generalized traces of the Sangre de Cristo fault; bar and ball on downthrown side. Dashed fine red line shows probable fault along eastern side of mesa. Outline shows approximate area of most of the geologic site map shown in figure 2A. The green triangle labeled WP indicates location of waypoint Ritoseco-Rd 19.5 in table 4.





Figure 1F. Oblique view to the east of the San Luis section of the Sangre de Cristo range showing the relatively subdued range-front morphology and distance to the range crest. Image available at http://earth.google.com (last accessed December 2006).





















Figure 5. Map of south wall of trench across Sangre de Cristo fault at the Rito Seco North (RSN) site. Full description of units is given in table 2. Data for luminescence and radiocarbon samples are given in table 5.

Horizon <sup>a</sup>	Unit number	Depth top (cm)	Depth base (cm)	Lower <sup>b</sup> boundary	Color <sup>c</sup> moist	Texture <sup>d</sup>	Gravel <sup>e</sup> (percent)	Structure <sup>f</sup>	Dry <sup>g</sup> consistence	Wet <sup>g</sup> consistence	Clay <sup>e</sup> (percent)	Comments
Profile RS Amalia so	N–Soil pit, oil series, U	hanging wall stic Calciargi	, 20 m east of a	fault								
A	NA	0	15	C, S	7.5 YR 8/2	L	10	1–2, f–m, gr	ND	ss, ps	14	Subrounded clasts, non-calcareous.
Bt	NA	15	38	C, W	7.5 YR 3/3	L, vgr	45	2. f-m. sbk	sh	ms, mp	26	Subrounded clasts, non-calcareous, thin clay films on ped faces.
3k <sub>1</sub>	NA	38	79	Ċ, W	7.5 YR 3/4	LS, xgr	75	sg	ND	ND	<5	Subrounded clasts, slightly calcareous, CaCO <sub>3</sub> disseminated in ma clasts.
Bk <sub>2</sub>	NA	79	165	C, W	7.5 YR 7/3	LCOS, xgr	75	sg	ND	ND	<5	Subrounded clasts, strongly calcareous, $CaCO_3$ disseminated in m clasts.
C	NA	165	NE	NE	7.5 YR 4/4	COS, xgr	70	sg	ND	ND	<5	Subrounded clasts, non-calcareous, few thin CaCO <sub>3</sub> coats under c
Profile RS Kibin soi	S–Trench fo l series, Pac	ootwall, south hic Arginstol	h side, near 5.5 l)	m								
A	6-1	0	23	C, S	10 YR 3/1	L	10	1. f. gr.	ND	ND	13	Non-calcareous.
Bkt	6-1	23	46	C, W	10 YR 3/3	L, gr	25	2. f–m. sbk	ND	ND	24	Few thin CaCO <sub>3</sub> coats on base of clasts.
2Bkt <sub>2</sub>	7	46	74	C, W	7.5 YR 5/4	L, gr	17	2, f-m, pr-sbk	ND	ND	26	Strongly calcareous, CaCO <sub>3</sub> coats on clasts and masses in matrix.
2Btk <sub>3</sub>	7	74	114	C, W	7.5 YR 4/4	L, gr	17	2, m, sbk	ND	ND	26	Strongly calcareous, few thin CaCO <sub>3</sub> coats under clasts.
$3C_1$	8	114	185	C, W	7.5 YR 7/6	COS, xgr	80	sg	ND	ND	<2	Few thin $CaCO_3$ coats under clasts.
4C,	9	185	NE	NE	7.5 YR 5/4	SL, vgr	45	ND	ND	ND	10	Santa Fe Group; seams and coats of $CaCO_3$ .

<sup>g</sup>Consistence: Dry: sh, slightly hard; Wet: ss, slightly sticky; ms, moderately sticky; ps, slightly plastic; mp, moderately plastic; ND, no data.

# DATA RELATED TO LATE QUATERNARY SURFACE FAULTING ON THE SANGRE DE CRISTO FAULT, RITO SECO SITE, COSTILLA COUNTY, COLORADO

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### **RITO SECO NORTH (RSN) TRENCH**



Unit numbe	Location <sup>a</sup> X/Y (m)	Matrix <sup>b</sup> texture	Gravel (percent)	Clast size (mm) (Max. avg.)	Sorting	Clast <sup>c</sup> shape	Dry color	Dry <sup>d</sup> consistence	Stratification <sup>e</sup>	Lower <sup>f</sup> boundary	CaCO <sub>3</sub> g content	Genesis	Comments
1	24.75/2.0	S	Var.	8 (2)	Well	ND	ND, lt. gray	LO	M–L	A, S	ND	Canal fill	Filled, man-made canal channels. Mainly pebbly, medium- to fine-grained sand.
2	20.5/2.45	L to SL	5–25	ND (0.5)	Modwell	SBA-SBR(?)	10YR 3/4	SO–SH	М	C, S	ND	Cumulic A horizon	Organic-rich slope deposit, large clasts most abundant in lower part. Contains abundant rootlets and charcoal fragments.
3	21.0/2.0	SL, pebbly	30–40	3-5 (0.5-1)	Poor	SBA-SBR(?)	7.5YR 5/3.5	SO–SH	М	C, S	ND	Slope colluvium	Abundant root tubes, krotovina (filled burrows), and charcoal fragments. Coarser-grained upslope (to east); contains 40–50 perce gravel at 16–17 m interval.
4-1	21.1/1.6	CL, sandy	<5	5-8 (0.5-1)	Modwell	ND	7.5YR 4/4	SH–H	М	A, S	ND	"Prismatic" B horizon	Distinct prismatic structure. Peds are 3–6 cm in diameter, 10 cm tall, and have weak clay films. Contains abundant charcoal fragments and significant amount of loess.
4-2	23.0/0.95	S	<5	1 (<1)	Modwell	SBA-SBR(?)	7.5YR 5/3.5	SO	M–W	C, W	ND	Channel fill, sandy facies	Locally contains ripple marks and laminated fine sand that is capped by organic-rich silt (mud that collected in bottom of paleochannel).
4-3	23.1/0.55	S, gravelly	>10(?)	10 (1-2)	Well	A–SBR	7.5YR 5/4	SH	М	NE	ND	Channel fill, basal facies	Scattered gravel clasts in sand matrix.
5-1	14.75/2.75	S, gravelly	>50(?)	20 (>2?)	Modwell(?)	RD	7.5YR 4/4.5	LO–SO	М	A, S	ND	Colluvium on footwall	Matrix-supported cobble gravel; clasts derived from unit 8. Unit has maximum thickness of 35 cm.
5-2	17.0/2.0	S, gravelly	>50(?)	15 (3–5)	Mod.(?)	SBA-SBR(?)	10YR 6/3.5, var.	SH–H	W	A, S	ND	Colluvium on hanging wall	Weakly cemented. Unit dips 15-30° to west. Contains 20-25 cm diameter blocks of Santa Fe Group. Maximum thickness of 70 c
7	17.0/1.4	S, silty, gravelly	25–40	10 (1–2)	Poor	SBR-RD	7.5YR 3/3.5	SO–SH	М	C, W	Stage I	Debris flow	Disseminated CaCO <sub>3</sub> gives unit whitish color. Predates faulting. Eroded by younger fluvial channel (unit 4).
8	18.5/0.7	S, gravelly	>50	35 (10–15)	Poor-mod.	RD	10YR 6/6 to 5YR 5/8	LO-SO	МО	NE	Non-calc.	Fluvial gravel	Heavily Fe stained, locally Mn stained. Clast imbrication indicates westward-flow direction. Predates faulting.
6-1	3.8/4.9	LS	5–20	3-5 (1)	Mod.	ND	7.5YR 4/4	SO	W	A, S	Non-calc.	A horizon on debris flow and colluvium	Weak, platy, moderate to massive soil structure; abundant root hairs and organic matter.
6-2	3.8/4.7	SL	5-20(?)	3–5 (1)	Poor	ND	7.5YR 5/4	SH	М	C, S	Stage I+ to II-	B horizon on debris flow	Weak B horizon. Medium, moderate, subangular-blocky soil structure; CaCO <sub>3</sub> veinlets in matrix and weak stage II on clasts; no of films on peds.
7	4.0/4.4	LS	20–40	10–15 (1)	Mod.	SBR-SBA	7.5YR 6/3.5	SO–SH	M–W	C, W	Stage I+ to II-	Debris flow	Ranges from granular, silty sand to cobbly silty sand; CaCO <sub>3</sub> in upper 40 cm. Abundant charcoal in krotovinas.
8	8.5/3.4	S	>50	30-35 (10-15)	Mod.(?)	SBR-RD(?)	5YR 5/8 to 7.5YR 6/6	LO	W-MO	A, S–W	ND	Fluvial gravel	Clast-supported gravel, heavily Fe stained, no Mn staining. Clasts are fresh, mainly Precambrian rocks. Imbrication shows westward-flow direction.
9-1	14.3/1.3	S, silty	0	NA	Well	ND	7.5YR 7/3.5	H–VH	M–W	A, S	ND	Santa Fe Gp., sandy facies	Highly fractured. Possibly eolian facies of formation. Locally Mn stained.
9-2	15.5/2.25	LS	2	1 (<1)	Well	NA	2.5YR 7/2	Н	ND	A, S	ND	Santa Fe Gp., lacustrine facies(?)	Locally Fe stained; burrowed.
9-3	15.5/1.5	S	Var.	10 (3–5)	Modwell	SBR-SBA(?)	7.5YR 7/3 to 7.5YR 6/8	Н	МО	NE	ND	Santa Fe Gp., gravel facies or bed	Metamorphic rock clasts are weathered; igneous clasts are intact. Colors vary. Subtle imbrication indicates westward-flow direction
9-4	East of 12 m	S(?)	>>50	35 (10)	Poor-mod.	SBR–SBA(?)	5YR 5/8 to 7.5YR 7/4	Н	M–W	NE	ND	Santa Fe Gp., conglomerate facies	Clasts are 5-10 percent volcanic rocks, 25-30 percent metamorphic rocks; volcanic and metamorphic rocks are generally grussifi

n	Unit Iumber	Location <sup>a</sup> X/Y (m)	Matrix <sup>b</sup> texture	Gravel (percent)	Clast size (mm) (Max. avg.)	Sorting	Clast <sup>c</sup> shape	Colors: dry (d), moist (m)	Dry <sup>d</sup> consistence	Stratification <sup>e</sup>	Lower <sup>f</sup> boundary	CaCO <sub>3</sub> g content	Genesis	Comments
	1	23.5/4.0	SL	Var.	ND	ND	ND	10YR 6/2 to 6/3 (d)	ND	W	A, W	ND	Canal fill	Filled, man-made canal channels. Mainly pebbly, medium- to fine-grained sand.
	2-2	23.5/3.6	S–SL	10–20	4 (0.5–1)	Mod.	SBR	7.5YR 5/3.5 (d)	SO	М	C, W	Non-calc.	Colluvium from PE1	Contains 40–60 percent clasts between 12 and 18 m (3–6 cm common diameter). Grades upslope to finer grained slope-wash facies.
	3-1	15.5/4.5	SL(?)	35-50	15 (3–5)	Mod.	SBA-SBR	ND	SH	W	A, S	Stage II	Proximal colluvium from PE2	Contains blocks of footwall units. Fining upward sequence, lower part is slightly redder than top. Contains estimated 3–5 percent CaCO <sub>3</sub> .
FOOR	3-2	23.4/3.3	LS	<5	0.6 (0.6)	Modwell	SBA	7.5YR 6.5/3 (d)	SH-H	M–W	A, W	Stage I+	Distal colluvium from PE2	Probably contains considerable eolian sand and silt reworked into the colluvium. Contains 5–10 burrows. Blocky soil structure.
	3-3	20.5/3.1	S	20–30	<1 (ND)	Well	ND	7.5YR 6.5/3.5 (d)	LO	М	A, W	Minor	Basal distal colluvium from PE2	Thins and is finer grained to west; slightly coarser to the east. Pinches out at 22.2 m.
	4-1	27.0/1.9	S	<<5	3 (0.5–1)	Well	ND	10YR 6/3.5 (d)	LO	W	A, S	Non-calc.	Channel fill, upper sand facies	Increasing amount of pebbles downward. Channel cut and filled after deposition of colluvium from PE3 and before deposition of colluvium from PE2.
	4-2	27.2/0.7	L–SL	<2	16 (0.5–1)	Well	SBA-SBR	7.5YR 6/4 (d)	LO	М	NE	Stage I	Channel fill, basal facies	Initial infill in paleochannel. Probably contains substantial eolian sand and silt.
	5-1	15.5/3.4	S	5–10	ND (<5)	Modwell	ND	7.5YR 6.5/3 (d)	LO	W	A, S	Minor	Proximal colluvium from PE3	Unit fines upward and westward; gravelly component ends near 16 m.
	5-2	19.3/2.75	S	15–25	10 (1–2)	Mod.	SBR-RD	7.5YR 6.5/3 (d)	SO	M–W	A, S	Stage I+ to II-	Upper distal colluvium from PE3	CaCO <sub>3</sub> variably distributed in unit and decreases with depth.
	5-3	19.0/2.45	SL	5–20	8 (1–5)	Mod.	SBA-SBR	7.5YR 6/4 (d)	SO	M–W	A, W	Stage I	Basal distal colluvium from PE3	Consists of coarse-to-fine-to-coarse sequence from bottom to top; middle fine interval has <5 percent clasts. Probably has significant amount of eolian sand and silt.
	6	21.65/2.3	LS-L	NA	NA	Modwell	NA	5YR 5/5 (d)	SH	М	A, W	Stage I+ to II	Colluvium from PE4(?), Bkt horizon	Buries minor relief on underlying unit 7. Has relatively strong color, structure, and carbonate content.
	7-1	22.0/1.0	S	50–90	30 (1-5)	Modwell	SBR-RD	Var.	SO	W-MO	NE	Non-calc.	Fluvial gravel	Clasts are fresh Precambrian rocks; clast imbrication indicates westward-flow direction. Clast-supported deposit.
	7-2	18.1/0.9	S	0	NA	Well	SBR	5YR 7/5 (d)	SO	МО	A, I	Non-calc.	Fluvial gravel, sandy facies	Deposit is mottled with 5YR 6/8 (d) orange color.
LE VE	7sz	13.5/3.0	S–LS	ca. 50	>10 (1-5)	Poor	SBA-SBR	5YR 5/7 (d)	LO	NA	NA	Non-calc.	Fluvial gravel, sheared	Matrix is highly oxidized and clay enriched; clasts have clay skins. Unit has strong fabric parallel to faults.
ZOZ	8sz	11.5/5.0	Var.	0->50	Var.	Var.	SBA-SBR	Var.	H–VH	NA	NA	ND	Santa Fe Gp., sheared	Highly oxidized pebble-cobble conglomerate, sand, and silt beds that are bounded by faults. Clasts are Precambrian rocks.
 ∡	2-1	3.0/9.1	SL	5–20	<10 (ND)	Mod.	SBA–SBR	7.5YR 3/4 (d) to 7.5YR 4/4 (m)	LO	М	A, S	ND	A horizon on slope colluvium	Grades downslope into unit 2-2.
BLUC	7-1	5.0/7.5	S	Var. 10–90	30 (Var.)	Modwell	SBA-SBR	Var. to 7.5YR 6/4 (d)	LO	M–MO	A, S	Var.	Fluvial gravel	Unit varies from cobble gravel to fine sand. CaCO <sub>3</sub> is probably deposited by ground water (nonpedogenic). Unit is present on bot sides of fault.
I WALL	8-1	9.1/5.4	S	<50	<5 (±1)	Modwell	SBA-SBR	7.5YR 6/3 (d)	H–VH	MO–S	NE	ND	Santa Fe Gp., bedded sandstone	Sandstone beds are 10-cm thick, strike N. 5° E., and dip 43° W.
L'UU	8-2	10.35/4.25	S	Var.	<5 (±1)	Mod.	SBR-SBA	Var.	H–VH	MO–S	NE	ND	Santa Fe Gp., interstratified	Less oxidized than other units in Santa Fe Group. Bedding is well defined.

<sup>b</sup>Texture classes (<2mm): L, loam; LS, loamy sand; SL, sandy loam; S, sand. <sup>c</sup>Clast shape: SBA, subangular; SBR, subrounded; RD, rounded. <sup>d</sup>Dry consistence: LO, loose; SO, soft; SH, slightly hard; H, hard and weakly cemented; VH, very hard and moderately cemented. <sup>e</sup>Stratification: M, massive and non-stratified; W, weak and discontinuous; MO, moderately distinct and mostly continuous; S, strongly stratified, continuous bedding. <sup>g</sup>Calcium carbonate: Nomenclature in stages I–II from Birkeland (1999), + and - indicate strong and weak development of carbonate stage, respectively; Non-calc., non-calcareous.

	Luminescence sample data							
(cal. yr)	Blue-light OSL age <sup>c</sup> (cal. yr)	Preferred age <sup>d</sup> (ka, kiloannum)						
5,456±314	5,312±429	5.5±0.4						
not analyzed	not analyzed	—						
not analyzed	13,521±903	13.5±0.9 <sup>h</sup>						
10,380±940	14,500±2,680	$12.4{\pm}1.8$						
not analyzed	5,130±247	5.1±0.2 <sup>h</sup>						
8,750±540	9,790±660	9.2±0.6						
$17,020\pm1,000$	20,030±1,270	$18.5 \pm 1.1$						
21,270±1,290	25,650±4,010	23.5±2.7						
25,780±1,650	28,880±770	27.3±1.2						
19,070±2,420(?) <sup>e</sup>	e 27,700±2,750	27.7±2.8 <sup>e</sup>						
$51,235\pm3,780^{f}$	42,230±4,830 <sup>g</sup>	51.2±3.8						
<sup>a</sup> Position on south wall of trench in horizontal (X) and vertical (Y) directions where described sample was collected.								
<sup>b</sup> Infrared-stimulated luminescense (IRSL) age determination; age given in calendar years (cal. yr) referenced to the present.								
<sup>c</sup> Blue-light optically stimulated luminescense (OSL); age given in calendar years (cal. yr) referenced to the present.								
<sup>d</sup> Preferred age is usually the average of the IRSL and OSL determinations rounded to the nearest 100 years. The plus-or-minus values are similar averages. The preferred age is shown on the trench maps (figs. 4 and 5).								
<sup>e</sup> The age is queried because the sample vielded erratic results during analysis. Preferred age for this sample is from the OSL measurement								
<sup>f</sup> This IRSL age is the average of two measurements: 55,530±5,250 and 46,940±2,310. <sup>g</sup> Luminescense analysis of this sample suggests that it could be approaching saturation and thus, this number could be a minimum estimate of its actual age. Preferred age for this sample is from the IRSL measurements.								
							sults from the blue-light O	t OSL analysis. IRSL ages for
11 0 10 e	alts during analysis. Prefe 0±5,250 and 46,940±2,3 Id be approaching satura easurements. esults from the blue-light	<ul> <li>alts during analysis. Preferred age for this sample is from 0±5,250 and 46,940±2,310.</li> <li>be approaching saturation and thus, this number concentration and thus, this number concentration and the saturation and thus, this number concentration and the saturation and</li></ul>						

<sup>f</sup>Lower boundary: Distinctness: A, abrupt (<1 cm); C, clear (1–5 cm); Shape: S, smooth; W, wavy (pockets wider than deep); NE, not exposed. <sup>g</sup>Calcium carbonate: Nomenclature in stages I–II from Birkeland (1999), + and - indicate strong and weak development of carbonate stage, respectively; Non-calc., non-calcareous.

Abbreviations: Var., variable; Mod., moderate; NA, not applicable; ND, not determined; (?), value uncertain; >, greater than; >>, much greater than; <, less than.

- <sup>f</sup>Lower boundary: Distinctness: A, abrupt (<1 cm); C, clear (1–5 cm); Shape: S, smooth; W, wavy (pockets wider than deep); I, irregular (pockets deeper than wide); NE, not exposed.
- Abbreviations: Var., variable; Mod., moderate; NA, not applicable; ND, not determined; (?), value uncertain; >, greater than; <, less than; <<, much less than; ±, plus or minus; ca., approximately.

Any use of trade names is for descriptive purposes only and does not imply endorsement by the U.S. Government This map was produced on request, directly from digital files, on an electronic plotter For sale by U.S. Geological Survey Information Services, Box 25286, Federal Center Denver, CO 80225; 1-888-ASK-USGS A PDF file is available online at: http://pubs.usgs.gov/sim/2006/2955 Crone, A.J., Machette, M.N., Bradley, L.-A., and Mahan, S.A., 2006, Data related to late Quaternary surface faulting on the Sangre de Cristo fault, Rito Seco site, Costilla County, Colorado: U.S. Geological Survey Scientific

Investigations Map 2955, 1 sheet.