CHICOS
Portable Cosmic Ray Detector

Experiment 5: Geologic Attenuation of Cosmic Rays

A. Maximum to Minimum
B. Cosmic Ray Images
C. Entrance Cut Off

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A. Maximum to Minimum

The following data were taken to reveal the amount of attenuation of cosmic rays afforded by the geologic materials (rock and soil) above road tunnels, as well as the relationship between the thickness of the rock and soil and the amount of attenuation, which they provide. The count rate can drop to essentially zero once the measuring device has been taken deep enough into the tunnel and the thickness is great enough. If the overbearing structure is not thick enough, which was the case for the following experiments, the count rate reaches a very small minimum value, stays there a while and then, eventually increases again to the outside value.

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CHICOS
Portable Cosmic Ray Detector
Experiment 5A: Underground Detection
Data Table

Location (GPS)	
Length of Tunnel	
Initial Count Outside of Tunnel	
Elevation of Tunnel Entrance	
Type of Rock/Soil	

Location	Trial # (Counts/m)					Average Value	Error	Check
	1	2	3	4	5			
Entrance								
10 m								
20								
30								
40								
50								
60								
70								
80								
90								
100								

CHICOS
Portable Cosmic Ray Detector
Experiment 5A: Underground Detection
Data Table

Location (GPS)	Kanan Road Tunnel #1
Length of Tunnel	
Initial Count Outside of Tunnel	
Elevation of Tunnel Entrance	1680 ft
Type of Rock/Soil	Sandstone

Location	Trial 3 (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance	191	209	166	192	195	**191**	6.2	
10 m	64	61	70	73	62	**66**	3.6	
20	25	35	21	26	32	**28**	2.4	
30	18	19	18	19	23	**19**	2.0	
40	14	15	14	13	15	**14**	1.7	
50	10	11	11	11	7	**10**	1.4	
60	7	10	10	8	7	**8.4**	1.3	
70	2	7	4	8	2	**4.6**	1.0	*Half-way through tunnel*
5 m out	228	217	210	220	236	**222**	6.7	
10 m out	238	230	239	233	204	**229**	6.8	

This data shows a steady decrease in count rate, down to a near zero minimum, as the detector is taken deeper into the tunnel.

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Portable Cosmic Ray Detector
Experiment 5A: Underground Detection
Data Table

Location (GPS)	Kanan Road - tunnel #1
Length of Tunnel	About 100 m
Initial Count Outside of Tunnel	At 10 m out 229
Elevation of Tunnel Entrance	1680 ft
Type of Rock/Soil	Sedimentary (sandstone)

Location	Trial # (Counts/m)					Average Value	Err	Check
	1	2	3	4	5			
-10 m	238	230	239	233	204	**229**	6.8	
-5 m	228	217	210	228	236	**224**	6.7	
0.0	191	209	166	192	195	**191**	6.2	
5.0	121	136	100	129	125	**122**	4.9	
10	64	61	70	73	62	**66**	3.6	
20	25	35	21	26	32	**28**	2.4	
30	18	19	18	19	23	**19**	1.9	
40	14	15	14	13	15	**14**	1.7	
50	10	11	11	11	7	**10**	1.4	
60	7	10	10	8	7	**8**	1.3	
70	2	7	4	8	2	**5**	1.0	

This table shows a steady decrease in the count rate, as the detector is taken deeper into the tunnel. The count rate deep in the tunnel was only a percent or two of the un-attenuated value.

CHICOS
Portable Cosmic Ray Detector
Experiment 5A: Underground Detection
Data Table

Location (GPS)	Tunnel 2
Length of Tunnel	
Initial Count Outside of Tunnel	
Elevation of Tunnel Entrance	1920 ft
Type of Rock/Soil	Sand stone

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance	196	206	193	219	221	**207**	6.4	
10 m	71	65	62	61	71	**66**	3.6	
20	19	28	28	27	22	**25**	2.2	
30	13	9	20	13	13	**14**	1.7	
40	6	7	5	4	9	**6**	1.1	
50	x	x	x	x	x	**x**		
60	2	5	4	5	1	**3**	0.8	
70								
10 m out	229	219	215	231	233	**225**	6.7	

This data shows a steady decrease in count-rate as the detector is taken deeper into the tunnel. The final amount in the deepest part is only about one percent of the untenanted count rate.

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Portable Cosmic Ray Detector
Experiment 5: Underground Detection
Data Table

Location (GPS) 34 03.634N, 118 26.930W	UCLA Plasma Lab
Length of Tunnel	XXXXXXXX
Initial Count Outside of Tunnel	364
Elevation of Tunnel Entrance	370 ft
Type of Rock/Soil	Reinforced Cement (10 ft thick)

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Courtyard	372	307	379	368	393	**364**	8.5	100%
Plasma Lab A (Front)	167	164	153	146	176	**161**	5.7	Average 181cpm
Plasma Lab B (Middle)	170	196	202	180	217	**193**	6.2	50 %
Plasma Lab C (Rear)	194	172	200	187	193	**189**	6.1	Average 181cpm
Front Desk (Just Roof)	331	287	304	299	321	**308**	7.8	85 %
LAPTAG Lab	275	333	369	273	297	**309**	7.9	85%

This table shows single location count rates at a few locations at the LAPD plasma lab at UCLA. The first (364) is outside, in the courtyard. The next 3 are in three locations at the front, middle and back end of the lab itself, under the 10-foot thick, steel reinforced ceiling. The last is on the roof of the lab, which is the street level floor at the front desk. The only thing between the detector and the sky at the front desk was the metal roof of the building.

B. Cosmic Ray Images

The following data were taken to study the relationship between the thickness of the overbearing rock and soil and the count rate for the entire length of the tunnel. Once a value of zero is reached for the count rate, the device is continued to be moved, until non-zero values are found once again. In each of the following, zero was never reached, as the overbearing rock and soil never became thick enough.

There is an inverse relationship between thickness and count rate. Graphing the data, distance versus count rate, can provide profiles of the geology above the tunnels. Comparing the inverted graphs to photos of the geology or GPS elevation profiles reveals geological portraits. These data may be said to provide ‘strip images’ of the geology above the tunnels, a type of Cosmic Ray Image.

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CHICOS
Portable Cosmic Ray Detector
Experiment 5B: Strip Image
Data Table

Location (GPS)	
Length of Tunnel	
Initial Count Outside of Tunnel	
Elevation of Tunnel Entrance	
Type of Rock/Soil	

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance								
10 m								
20								
30								
40								
50								
60								
70								
80								
90								
100								

CHICOS
Portable Cosmic Ray Detector
Experiment 5B: Strip Image
Data Table

Location (GPS) 34 04.356N, 118 48.754W	
Length of Tunnel	149 m
Initial Count Outside of Tunnel	132
Elevation of Tunnel Entrance	1563 ft
Type of Rock/Soil sandstone	

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance	120	137	139			**132**	6.6	
10 m	31	35	39			**35**	3.4	
20	26	7	16			**16**	2.3	
30	11	10	10			**10**	1.8	
40	5	5	7			**5.7**	1.4	
50	5	4	5			**4.7**	1.2	
60	5	6	6			**5.7**	1.4	
70	6	4	4			**4.6**	1.2	
80	1	2	2			**1.7**	0.75	
90	3	6	11			**6.7**	1.5	
100	4	8	11			**6.7**	1.5	
110	9	8	14			**10.**	1.8	
120	14	13	16			**14**	2.2	
130	31	20	28			**26**	2.9	
140	85	80	66			**77**	5.1	
150	178	186	165			**176**	7.7	*End of tunnel*
160	183	196	248	206		**208**	8.3	*Out of tunnel*

This data is continuous, from one end of the tunnel to the other. This is a Cosmic Ray Image of the overbearing rock above the tunnel. Notice the values decrease as they approach the maximum thickness, reach a minimum value, and then go back up to the outside value at the altitude of the other end of the tunnel.

CHICOS
Portable Cosmic Ray Detector
Experiment 5B: Strip Image
Data Table

Location (GPS) 34 06.321N, 118 48.665 W	Tunnel 2
Length of Tunnel	305 m
Initial Count Outside of Tunnel	303
Elevation of Tunnel Entrance	1676 ft
Type of Rock/Soil	Sandstone

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance	272	312	324			**303**	10	
10 m	129	124	123	110		**121**	5.5	
20	71	74	76	61		**79**	4.4	
30	48	47	42	45		**45**	3.4	
40	23	42	36	33		**33**	2.9	
50	33	32	27	41		**33**	2.9	
60	40	26	22	24		**28**	2.6	
70	24	21	27	26		**26**	2.5	
80	35	21	33	28		**29**	2.7	
90	32	19	24	26		**25**	2.5	
100	19	20	13	15		**17**	2.1	
110	20	28	18	27		**23**	2.4	
120	18	28	21	26		**23**	2.4	
130	22	32	25	28		**27**	2.6	
140	13	19	16	16		**16**	2.0	
150	21	26	25	20		**23**	2.4	
160	15	26	26	25		**23**	2.4	
170	28	19	22	23		**23**	2.4	
180	22	21	24	31		**23**	2.4	
190	20	27	28	16		**23**	2.4	
200	19	30	35	34		**29**	2.7	
210	29	26	25	24		**26**	2.5	
220	30	35	24	33		**30**	2.7	

230	44	51	36	28		**40**	3.2	
240	47	40	41	33		**40**	3.2	
250	42	45	36	50		**43**	3.3	
260	53	41	58	53		**51**	3.6	
270	72	57	70	56		**64**	4.0	
280	87	90	69	82		**82**	4.5	
290	168	169	153	159		**162**	6.4	
300	278	257	294	330		**290**	8.5	*Exit*

This data show a continuous collection from one end of the tunnel to the other. This is a Cosmic Ray Image of the overbearing rock above the tunnel. There is a long roof of fairly even thickness above this tunnel. The thickness is not enough for 100% attenuation. The ends of the tunnel are nearly vertical faces, accounting for the very sudden decrease in attenuation within 10 or 20 m of the entrance and exit.

CHICOS
Portable Cosmic Ray Detector
Experiment 5B: Strip Image
Data Table (SL means shoe-length (1ft))

Location (GPS) 34 06.554N, 118 48.275W	Tunnel 3
Length of Tunnel	120 m
Initial Count Outside of Tunnel	323
Elevation of Tunnel Entrance	1440 ft
Type of Rock/Soil	Sandstone

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
Entrance	302	327	339			**323**	10	
35 SL	135	123	134			**131**	6.6	
70	75	85	77			**79**	5.1	
105	58	63	73			**65**	4.7	
140	65	61	52			**59**	4.4	
175	47	53	50			**50**	4.1	
210	45	38	46			**43**	3.8	
245	37	43	38			**39**	3.6	
280	44	40	42			**42**	3.0	
315	59	58	63			**60**	4.5	
350	75	77	73			**75**	5.0	
385	135	134	122			**130**	6.6	
405 *End of tunnel*	323	305	333			**320**	10	*South exit*

This data is a continuous collection, from one end of the tunnel to the other. This is a Cosmic Ray Image of the overbearing rock above the tunnel. This data set shows a gradual increase in thickness with no constant thickness section, followed by a gradual increase back to zero rock thickness (maximum count rate). In other words, there was a round hill through which the tunnel was dug.

C. Vertical Cut Offs

The following data were taken to study the area at or near each tunnel entrance. These data show that not all cosmic rays are vertical. Graphing the count rate v the distance from the vertical tunnel face does not show a sudden drop (say 95% in 5 m) in count rate, it shows a more gradual change over 20 m (82% from 6 m out to 14 m in). This clearly indicates the fact that cosmic rays are not all perfectly vertical, some have somewhat non-vertical paths.

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CHICOS **Portable Cosmic Ray Detector**
Experiment 5C: Vertical
Data Table

Location (GPS)	
Length of Tunnel	
Initial Count Outside of Tunnel	
Elevation of Tunnel Entrance	
Type of Rock/Soil	

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
10 m out								
8								
6								
4								
2								
0								
2 m in								
4								
6								
8								
10								
12								
14								

CHICOS Portable Cosmic Ray Detector

Experiment 5C: Vertical

Data Table

Location (GPS) 34 04.356N, 118 48.754W	Tunnel 1
Length of Tunnel	
Initial Count Outside of Tunnel	204
Elevation of Tunnel Entrance	1563 ft
Type of Rock/Soil sandstone	

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
10 m out	186	208	217			**204**	8.2	
8	215	205	217			**213**	8.4	
6	218	209	204			**210**	8.4	
4	186	174	171			**177**	7.7	
2	183	183	180			**182**	7.8	
0	120	137	139			**132**	6.6	*ENTRANCE*
2 m in	139	123	129			**130**	6.6	
4	100	114	96			**103**	5.9	
6	101	95	88			**95**	5.6	
8	83	86	61			**77**	5.0	
10	71	46	64			**60**	4.5	
12	61	54	48			**54**	4.2	
14	41	33	43			**39**	3.6	

This data show a relatively gradual cutoff at the entrance to this tunnel, down to about 20% of the outside count rate at 14 m into the tunnel. A photo will reveal the fact that the rock face into which the tunnel was cut, starts back about 10 m behind the beginning of the tunnel. The tunnel has a metal structure extending out of the rock face suggesting that the cut off is more abrupt than suggested by the data.

CHICOS **Portable Cosmic Ray Detector**
Experiment 5C: Vertical
Data Table

Location (GPS) 34 06.322N, 118 48.665 W	Tunnel 2
Length of Tunnel	305 m
Initial Count Outside of Tunnel	400
Elevation of Tunnel Entrance	1676 ft
Type of Rock/Soil sandstone	

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
10 m out	418	425	423			**422**	12	
5 m	385	399	396			**393**	11	
0 m	272	312	324			**303**	10	
5 m in	148	194	172			**171**	7.5	
10 m in	129	124	110			**121**	6.4	
Other end of tunnel	1562 ft elevation 34 6.352 N 118 48.483 W							
25 m in	72	57	70	56		**64**	4.0	
15 m in	87	90	69	82		**82**	4.5	
5 m in	168	169	153	159		**162**	6.4	
0 m	278	257	294			**276**	9.6	
5 m out	329	341	399			**356**	10.9	
10 m out	360	344	362			**355**	10.9	

This cut off data is for both ends of tunnel 2. The bottom set suggests a steady value outside of the tunnel and an attenuation of 82% at 25 m into the tunnel. The top set suggests an attenuation of 72% at 10 m into the tunnel.

CHICOS **Portable Cosmic Ray Detector**
Experiment 5C: Vertical
Data Table

Location (GPS) 34 06.479N 118 48 271 W	Tunnel 3 south end, south bound side
Length of Tunnel	400 ft
Initial Count Outside of Tunnel	330
Elevation of Tunnel Entrance	1400 ft
Type of Rock/Soil	Sandstone

Location	Trial # (Counts/min)					Average Value	Error	Check
	1	2	3	4	5			
20 m in	135	134	122			**130**	6.6	
10 m	154	174	155			**161**	7.3	
0 m	323	305	333			**320**	10.3	
10 m out	316	334	325			**325**	10.4	
20 m out	343	324	381			**349**	10.8	

This data set suggests an attenuation of 63% at 20 m into the tunnel. Variations in sharpness in drop off of count rate are due to the shape of the rock face into which the tunnels are cut.