

Detector and Conventional Facilities Materials Assay Results: Rock, Shotcrete & Concrete

Juergen Reichenbacher

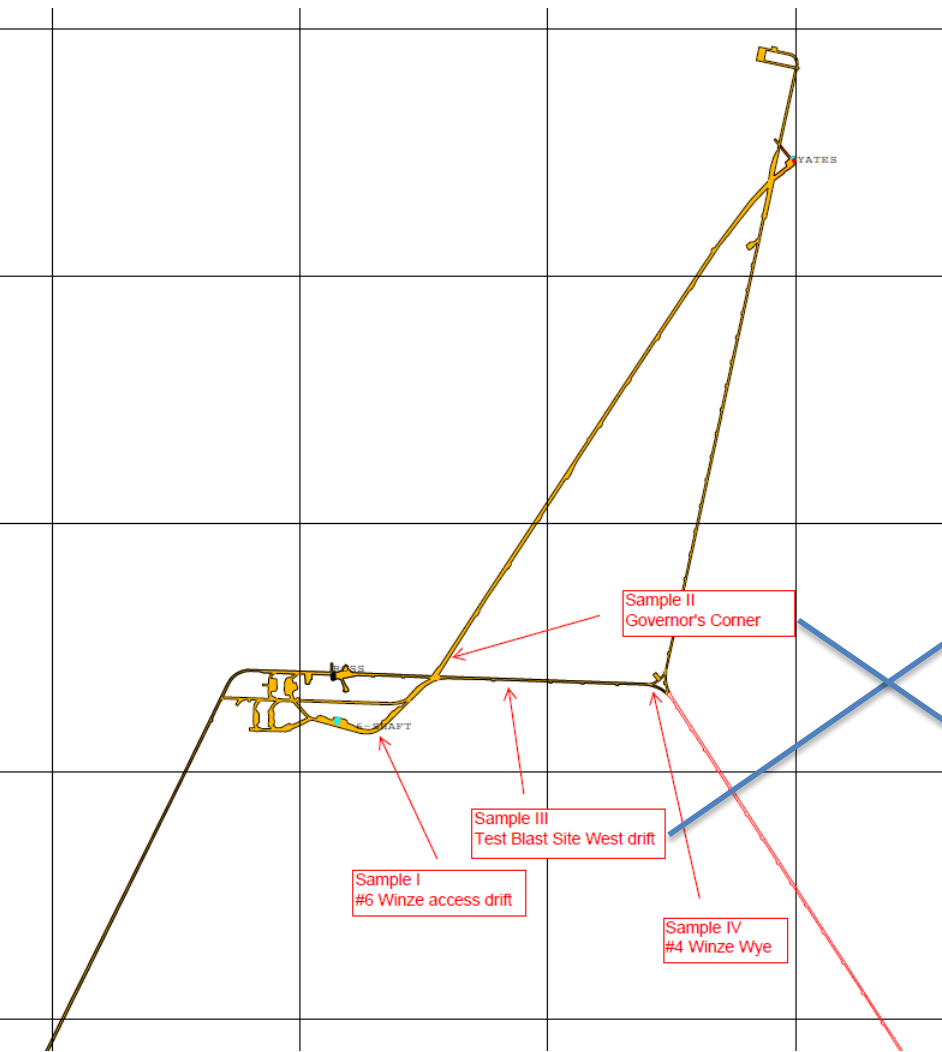
South Dakota School of Mines & Technology (SDSMT)



DUNE Backgrounds Mitigation Strategies Workshop

July 22, 2020

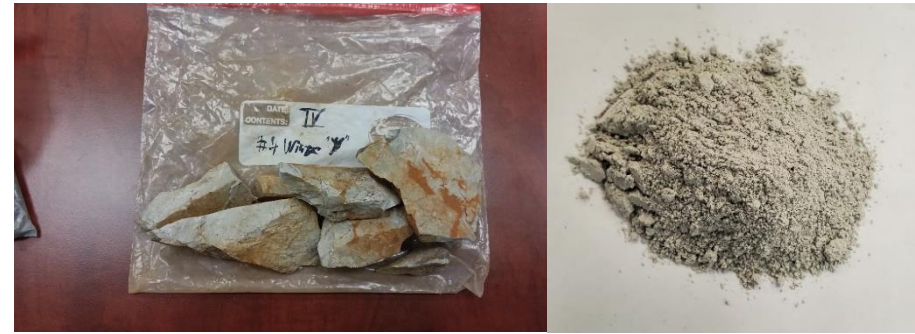
SDSMT @ SURF: Collected 4 Representative Rock Samples at Ross Campus Just Before Lockdown



4 Representative FD Rock Samples from Ross Campus



from #6 Winze before & after crushing



from #4 Winze before & after crushing



Governors' Corner before & after crushing



Test Blast Site before & after crushing

James Haiston

Manual Course Crushing Needed

James Haiston



Sample #2 from Governors Corner at SURF 4850 Level.



Bucket and mallet used to crush samples into small pieces.



Sample #2 during crushing operation.



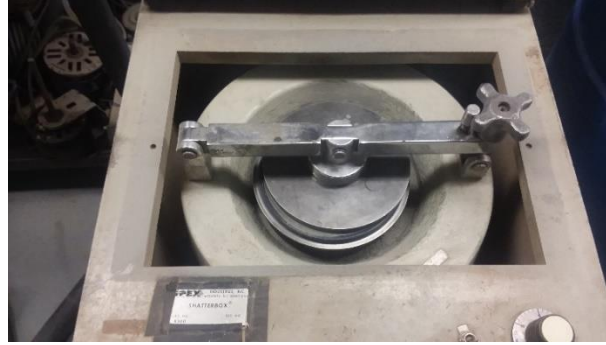
Sample #2 crushed to size for milling.

Rock Crusher Machine for Last Step

James Haiston



Milling machine external view.



Milling machine hood open.



Milling machine internals before fill.

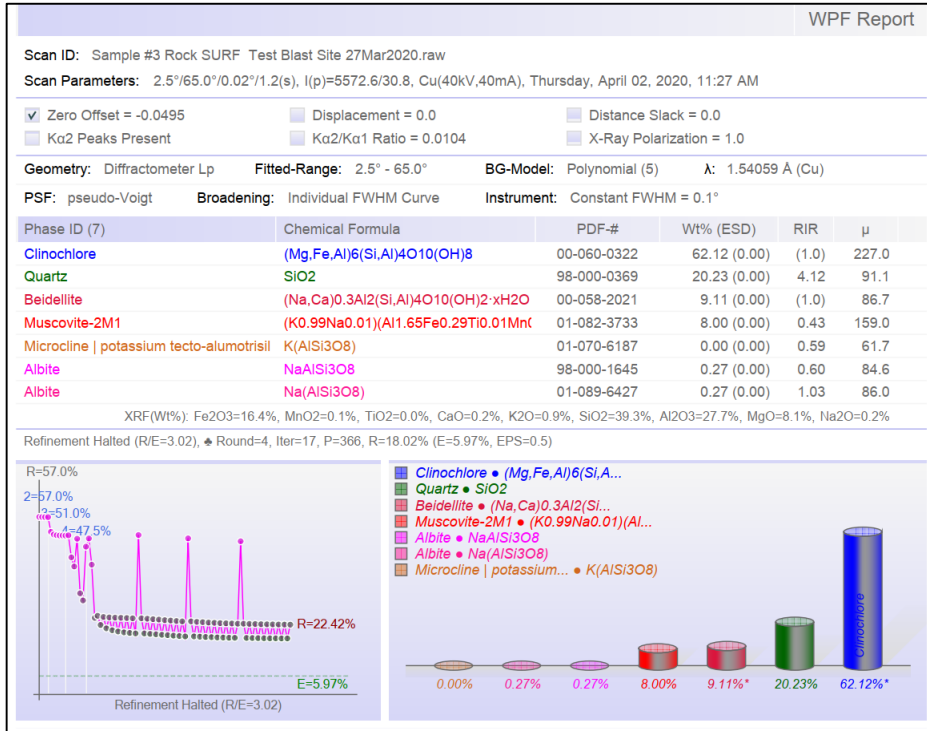


Milling machine with aggregate sample.



Milling machine with milled sample.

SDSMT: XRD Analysis of Chemical Composition



⇒ Chemical composition very different for each sample location!

⇒ Will have to collect many samples during/after excavation to accurately map rock induced backgrounds!

Previous assays activities

SDSMT assayed shotcrete & concrete materials from ALL potential bidders in Black Hills area for informed decision making of LBNF for Conventional Facilities at SURF:

<https://indico.fnal.gov/event/20144/session/19/contribution/262/material/slides/0.pdf>

- GCC Cement Plant (Rapid City): Portland cement with rock from local RC quarry, fly ash (coal firing plant in NB)
- Pete Lien (Rapid City): GCC cement, fly ash (coal firing plant in NB), gravel (RC quarry), sand (Oral/SD, near Uranium-Mine)
- TCC (Rapid City): GCC cement, fly ash (coal firing plant in NB), gravel (South America), sand (packaged)
- Croell (Spearfish): GCC cement, fly ash (coal firing plant in NB), gravel (Sundance/WY), sand (Nisland/SD)
- Industrial and sump water from SURF (Davis 4850 ft)
- ProtoDUNE Cu-getter & molecular sieve (zeolite) -> Stephen Pordes, David Montanari
- ProtoDUNE Steel (I-beams) and SS cryo-wall -> Filippo (Luxembourg corp.)



LAr filter material samples sent to Marseille



Rock Assay Results

Layne Tieszen,
Serenity Engel

(do not share outside DUNE)

sample	description	U-238 [Bq/kg]	error [Bq/kg]	ppm U	err. [ppm]	Ra-226 [Bq/kg]	error [Bq/kg]	Th-232 [Bq/kg]	error [Bq/kg]	ppm Th	err. [ppm]	K-40 [Bq/kg]	error [Bq/kg]	% K	err. [%]
#1	DUNE Ross - #6 Winze	35.6	5.0	2.88	0.40	66.0	0.8	48.9	0.4	12.03	0.09	435.3	1.7	1.406	0.005
#2	DUNE Ross - Governor's Corner	24.4	6.9	1.98	0.56	79.1	1.1	20.5	0.4	5.05	0.10	420.6	2.4	1.358	0.008
#3	DUNE Ross - Test Blast Site	63.0	7.8	5.11	0.63	146.0	1.5	19.6	0.4	4.83	0.11	376.3	2.3	1.216	0.007
#4	DUNE Ross - #4 Winze	107.0	9.5	8.66	0.77	172.5	1.3	38.1	0.5	9.38	0.13	1429.7	4.0	4.618	0.013
mean		57.5	3.7	4.66	0.30	115.9	0.6	31.8	0.2	7.82	0.05	665.5	1.4	2.149	0.004
stddev / sqrt(N)		18.4		1.5		25.8		7.1		1.8		255.0		0.8	
stddev		36.7		3.0		51.5		14.2		3.5		510.1		1.6	

The three main rock types and the contamination of ^{238}U , ^{232}Th and ^{40}K in the rocks [25] as measured from a number of samples.

Ross Campus
(DUNE FD)

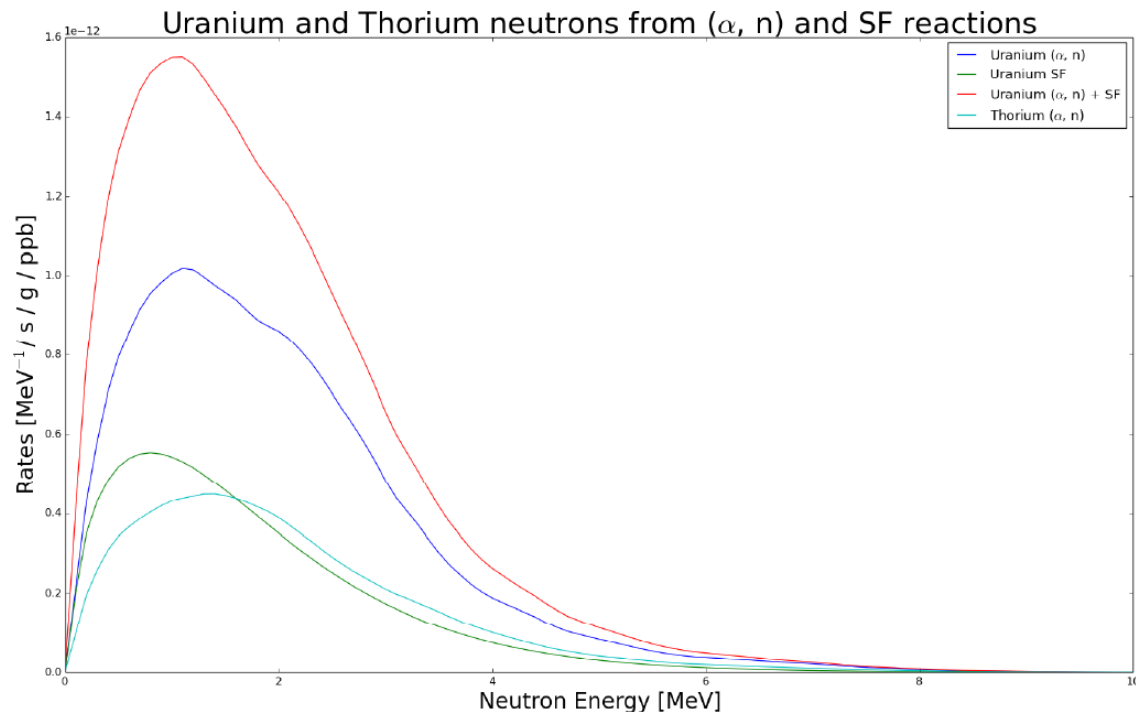
Davis Campus
(LUX, LZ,
MAJORANA)

		^{238}U	^{232}Th	nat-K
Poorman Formation	Average	3.43 ppm	7.11 ppm	2.66 %
	Standard Deviation	3.73 ppm	5.64 ppm	1.05 %
	Number of samples	7	7	141
	Maximum Value	11.7 ppm	18 ppm	4.98 %
	Minimum Value	0.1 ppm	0 ppm	0.04 %
Homestake Formation	Average	1.51 ppm	7.38 ppm	0.96 %
	Standard Deviation	0.94 ppm	4.04 ppm	0.91 %
	Number of samples	24	24	263
	Maximum Value	3.5 ppm	15 ppm	4.31 %
	Minimum Value	0.4 ppm	1.9 ppm	8.3e-3 %

[25] H. Rogers, Geology of Precambrian rocks in the Poorman anticlinorium and Homestake mine, Black Hills, South Dakota, in Metallogeny of gold in the Black Hills, South Dakota, eds. C. J. Paterson, and A. L. Lisenbee, Guidebook Prepared for Soc. Econ. Geol. Field Conf. 5-9 September, 1990.

Input for External Neutron Background Simulation

- **Neutron production spectra for rock, shotcrete and concrete neutrons**
 - Using rock, shotcrete & concrete composition in new geometry (**Aran, James, Eric, Juergen**)
 - **Vitaly** has run SOURCES4A to produce a neutron production spectrum and he can consider Uranium and Thorium chains' equilibrium being broken according to assay measurements
 - Simulation takes longer and produces very large files
 - Study required as to what rock thickness is required for accuracy



Identified 3 Potential Local Companies for Shotcrete & Concrete Work for DUNE FD and Tracked Down Their Supply Chain and Obtained Samples

- GCC Cement Plant (Rapid City): Portland cement with rock from local RC quarry, fly ash (coal firing plant in NE)
- 1.) Pete Lien (Rapid City): GCC cement, fly ash (coal firing plant in ND), gravel (RC quarry), sand (Oral/SD, near Uranium-Mine)
- 2.) TCC (Rapid City): GCC cement, fly ash (coal firing plant in NE), gravel (South America), sand (packaged)
- 3.) Croell (Spearfish): GCC cement, fly ash (coal firing plant in NE), gravel (Sundance/WY), sand (Nisland/SD)
- Industrial and sump water from SURF (Davis 4850 ft)

Identified 3 Different Potential Suppliers (Collected and Analyzed Detailed Ingredients at SDSMT)

(example
Pete Lien & Sons)

Cement:	Type I-II (LA), GCC Dacotah Cement, Rapid City, SD	
Fly Ash:	Class F Modified, Boral Resources, Coal Creek, ND	
Coarse Aggr.:	Crushed Limestone, Pete Lien & Sons, Inc., Rapid City, SD	
Fine Aggr.:	Natural Sand, Pete Lien & Sons, Inc., Oral, SD	
Fine Aggr.:	Fine Limestone, Pete Lien & Sons, Inc., Rapid City, SD	
Admixtures:	BASF Admixtures Co., Air Entraining Agent, MBVR Water Reducing Agent, Polyheed 997 & 322N	
Required Strength:	4000 PSI Comp. @ 28 Days	
Maximum Size Course Aggr.:	3/4 Inch ASTM C-33	
Slump:	4 ± 1 Inch	
Air Content:	4.5 – 7.5%	
Cement (Sp. Gr. 3.15):	452 Lbs.	2.30 CF
Fly Ash: (Sp.Gr. 2.59):	112 Lbs.	0.69 CF
Course Aggr. (Sp. Gr. 2.68):	1745 Lbs.	10.43 CF
Fine Aggr. Oral (Sp. Gr. 2.62):	394 Lbs.	2.41 CF
Fine Aggr. Rapid City (Sp. Gr. 2.66)	917 Lbs.	5.52 CF
Water (@ Maximum Slump):	30.5 Gals. (254 Lbs.)	4.07 CF
MBVR:	3 Ozs. (Approx.)	1.62 CF
997:	12.0 Ozs. (Approx.)	
322N:	12.0 Ozs. (Approx.)	
Theoretical Yield @ 6.0% Air		27.04 CF
Water/Cementitious Ratio:	.45	
Percent Fine Aggregate:	43%	
Cementitious Factor:	6.00 Sacks	

⇒ Goal not only to realistically simulate external neutron backgrounds
but also to identify best possible supplier regarding background mitigation!

Chemical Composition & Density of Rock and Shotcrete Materials Measured at SDSMT

sample	description	density [g/cm ³]	error	O [a%]	Fe [a%]	Mn [a%]	Ca [a%]	K [a%]	Si [a%]	Al [a%]	Mg [a%]	Na [a%]	N [a%]	C [a%]	H [a%]
#1	DUNE Ross - #6 Winze	2.67	0.05	55.3	2.8	0.0	0.0	0.3	13.9	6.0	6.8	0.2	0.0	0.0	14.8
#2	DUNE Ross - Governor's Corner	2.65	0.10	62.4	0.6	0.1	0.0	2.0	26.2	3.1	1.1	0.5	0.0	0.0	4.0
#3	DUNE Ross - Test Blast Site	2.68	0.10	54.8	2.5	0.0	0.1	0.4	13.3	6.6	6.1	0.1	0.0	0.0	16.0
#4	DUNE Ross - #4 Winze	2.60	0.09	62.8	0.0	0.0	0.4	3.7	26.8	3.9	0.0	2.0	0.0	0.0	0.5
mean	mean DUNE rock	2.65	0.04	58.742	1.501	0.030	0.112	1.554	19.854	4.940	3.580	0.692	0.000	0.000	8.996
mean	Serenity's x-check on DUNE rock			58.9	1.5	0.0	0.1	1.6	20.0	4.9	3.5	0.7	0.0	0.0	8.8
mean	Vitaly/Aran early numbers			59.0	2.3	0.0	0.1	1.4	18.3	7.6	2.2	0.6	0.0	0.0	8.5
shotcrete & concrete ingredients:			<XRF>	56.4	4.1	0.05	6.63	3.04	21.32	4.95	2.29				
Pete Lien	sand (Cheyenne River, Oral/SD)	2.56	0.09	64.3	0.0	0.0	0.0	2.7	26.3	2.4	0.0	1.2	0.0	3.1	0.0
TCC	sand (commercial bag)	2.66	0.10	64.6	0.0	0.0	0.0	2.4	28.3	2.2	0.0	1.1	0.0	1.4	0.0
Croell	sand (Fisher in Nisland/SD)														
Pete Lien	gravel (Rapid City limestone quarry)	2.57	0.09	58.4	0.0	0.0	24.7	0.0	0.5	0.0	0.0	0.0	0.0	16.4	0.0
TCC	gravel (bag from South America)	2.49	0.09	63.1	0.0	0.0	0.0	5.1	27.4	3.6	0.0	0.8	0.0	0.0	0.0
Croell	gravel (Rogers Pit, Sundance/WY)	2.9 cement?													
GCC	Portland cement (Rapid City)	1.34	0.14	54.1	0.2	0.0	29.9	0.0	6.5	0.1	2.3	0.0	0.6	3.4	3.0
Whelan Energy	fly ash (power plant, Hastings/NE)	2.90	0.04	44.1	3.8	0.0	21.1	0.2	14.3	8.8	4.1	0.0	0.0	0.0	0
SURF	water (4850 Davis industrial & sump)	1.00	0.01	33.3	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	66.7
mean	mean Pete Lien	2.332		56.538	0.132	0.001	21.061	0.283	4.173	0.514	0.382	0.120	0.067	12.005	4.724
mean	mean TCC	2.501		60.121	0.132	0.001	4.100	3.123	23.129	2.630	0.382	0.717	0.067	0.874	4.724
mean	mean Croell		<XRF>	53.787	2.737	0.055	28.798	0.550	7.033	1.291	0.359				4.724
mean	mean combined contractors	2.40	0.10	56.815	1.000	0.019	17.986	1.319	11.445	1.479	0.375	0.279	0.044	4.293	4.724

Radioactivity of Rock and Shotcrete Materials Measured at SDSMT

sample	description	U-238 [Bq/kg]	error [Bq/kg]	ppm U	err. [ppm]	Ra-226 [Bq/kg]	error [Bq/kg]	Th-232 [Bq/kg]	error [Bq/kg]	ppm Th	err. [ppm]	K-40 [Bq/kg]	error [Bq/kg]
#1	DUNE Ross - #6 Winze	35.6	5.0	2.88	0.40	66.0	0.8	48.9	0.4	12.03	0.09	435.3	1.7
#2	DUNE Ross - Governor's Corner	24.4	6.9	1.98	0.56	79.1	1.1	20.5	0.4	5.05	0.10	420.6	2.4
#3	DUNE Ross - Test Blast Site	63.0	7.8	5.11	0.63	146.0	1.5	19.6	0.4	4.83	0.11	376.3	2.3
#4	DUNE Ross - #4 Winze	107.0	9.5	8.66	0.77	172.5	1.3	38.1	0.5	9.38	0.13	1429.7	4.0
mean	mean DUNE rock	57.5	3.7	4.66	0.30	115.9	0.6	31.8	0.2	7.82	0.05	665.5	1.4
mean	Serenity's x-check on DUNE rock	18.4		1.5		25.8		7.1		1.8		255.0	
mean	Vitaly/Aran early numbers	36.7		3.0		51.5		14.2		3.5		510.1	
	shotcrete & concrete ingredients:												
		U-238 [Bq/kg]	error [Bq/kg]	ppm U	err. [ppm]	Ra-226 [Bq/kg]	error [Bq/kg]	Th-232 [Bq/kg]	error [Bq/kg]	ppm Th	err. [ppm]	K-40 [Bq/kg]	error [Bq/kg]
Pete Lien	sand (Cheyenne River, Oral/SD)	33.9	12.2	2.75	0.99	38.3	1.2	15.8	0.5	3.89	0.12	647.3	3.9
TCC	sand (commercial bag)	54.0	18.3	4.38	1.48	42.4	1.9	19.1	0.8	4.70	0.19	613.1	5.8
Croell	sand (Fisher in Nisland/SD)	75.4	24.5	6.11	1.98	119.3	3.1	40.3	1.2	9.91	0.30	442.8	6.0
Pete Lien	gravel (Rapid City limestone quarry)	28.1	6.5	2.28	0.53	38.2	0.9	0.8	0.3	0.20	0.06	28.1	6.5
TCC	gravel (bag from South America)	42.6	11.2	3.45	0.91	98.2	1.5	7.8	0.4	1.92	0.11	42.6	11.2
Croell	gravel (Rogers Pit, Sundance/WY)	15.1	7.6	1.22	0.61	27.1	1.0	1.0	0.3	0.25	0.07	15.1	7.6
GCC	Portland cement (Rapid City)	47.1	16.4	3.81	1.33	65.1	2.1	12.7	0.7	3.13	0.18	147.7	3.3
Whelan Energy	fly ash (power plant, Hastings/NE)	100.7	21.5	8.16	1.74	174.6	3.3	80.6	1.4	19.83	0.33	119.4	3.2
SURF	water (4850 Davis industrial & sump)	3.8	6.4	0.31	0.52	0.6	0.7	0.1	0.2	0.03	0.06	0.0	0.0
mean	mean Pete Lien	31.430		2.546		42.832		5.996		1.475		105.849	
mean	mean TCC	46.114		3.735		71.267		13.795		3.393		247.358	
mean	mean Croell	40.981		3.319		65.272		17.915		4.407		177.330	
mean	mean combined contractors	39.5		3.2		59.8		12.6		3.1		176.8	

- ⇒ Pete Lien is clear winner and has best defined supply chain!
- ⇒ Shotcrete would have less than half of activity levels of rock
- ⇒ Good news as Pete Lien & sons are already likely to get contract (LBNF test slab was successful)
- ⇒ Might not even need a passive shield for DUNE FD?