the university of south dakota.

Radon and LBC at the Homestake Mine

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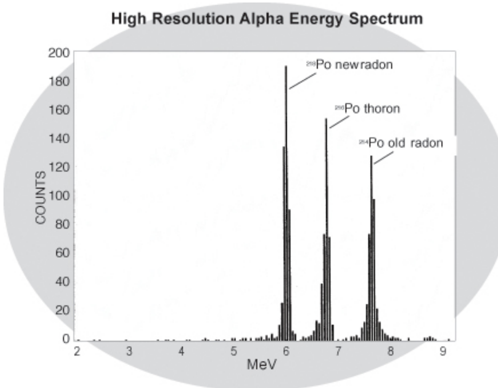
LRT2010

Instruments



- Started (in earnest) in May 09
- Instruments on loan from various institutions and labs.
  - 2-3 Rad7's (USD, Brown, BNL)
  - 3 Alphaguards (LBNL)
- Advantages/Disadvantages for each type of detector.
- Concerns/Limitations underground: humidity, power availability, access

Factors Affecting Radon

- Ventilation: surface air dilutes and exhausts radon laden air, this can reduce radon in some areas and increase in others.

- Local geology: grain size of rock, porosity, U/Th content and distribution, etc.

- Moisture: Water in pore spaces increases the effective radon emanation coefficient.

- Metal Oxides: weathering process on rock increases porosity of outer surfaces, sorbs Ra and other heavy metals to effectively enrich the oxide layer in Radon parents…

→Ventilation: present capacity reduced compared to past

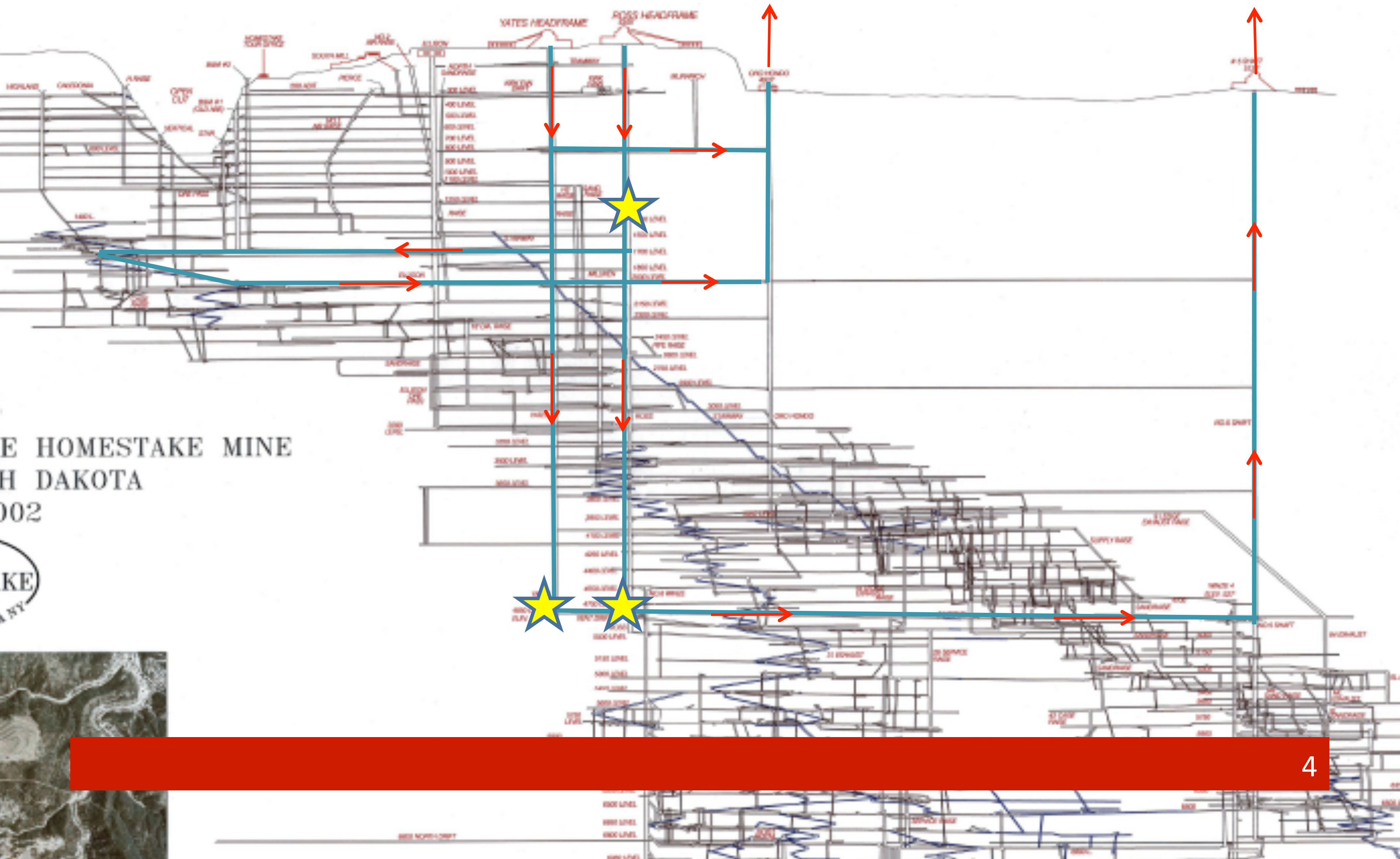
→Levels below 4550L:

-were/are underwater

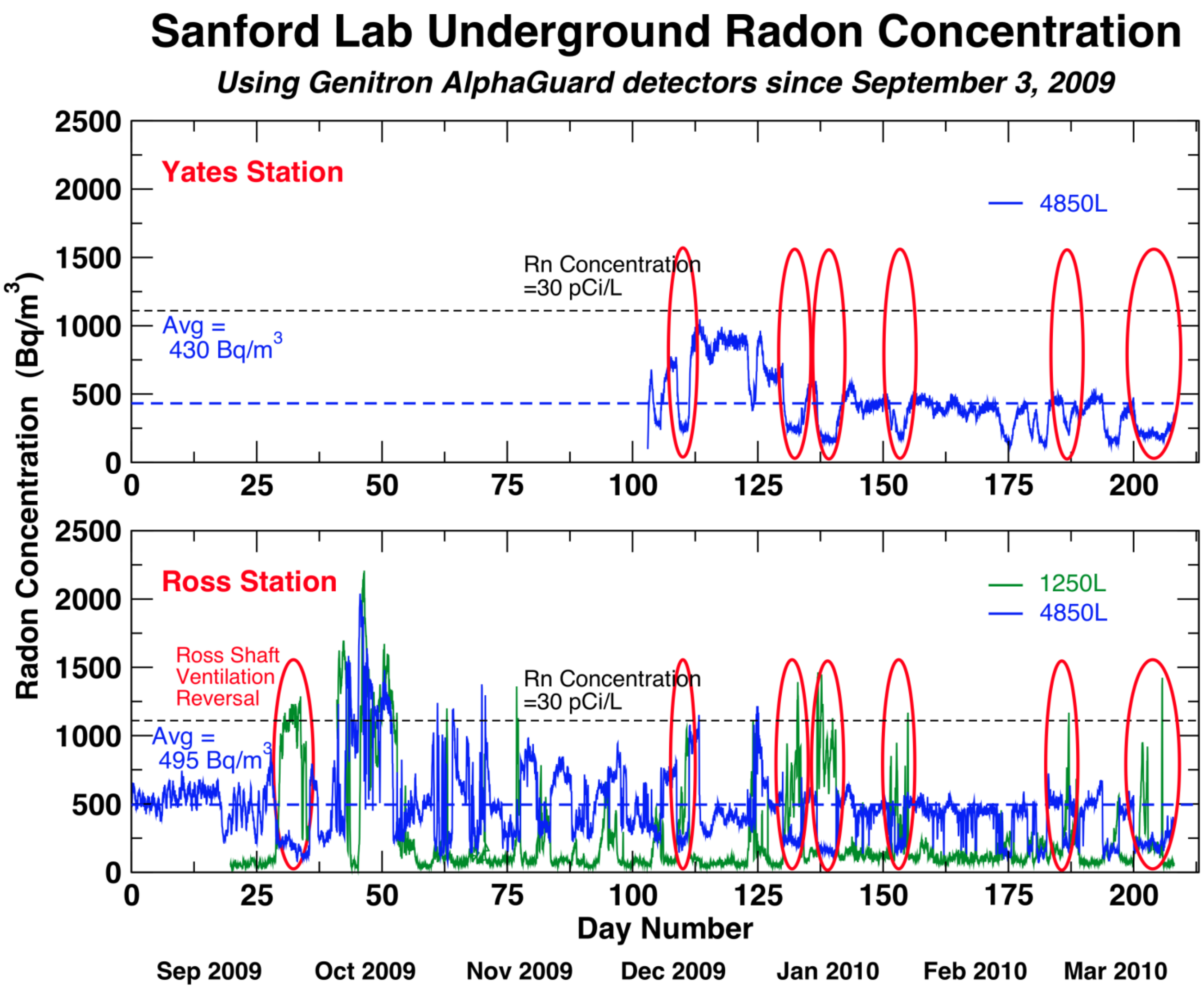
-covered by a layer of Iron Oxide sludge/dust

Mine Ventilation

<u>Only 30-50% of Historical Capacity. (and very dynamic)</u>

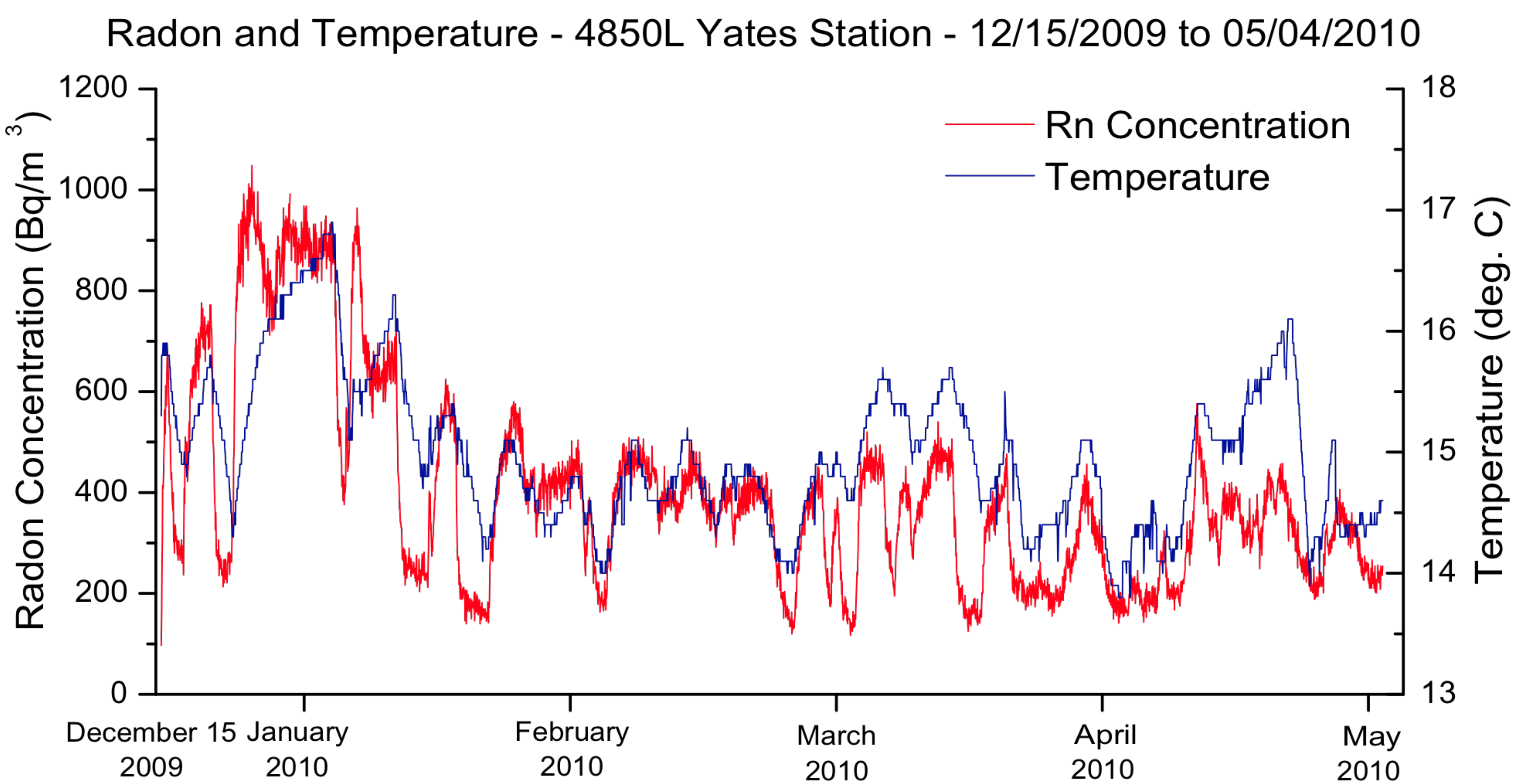


1250L vs 4850L



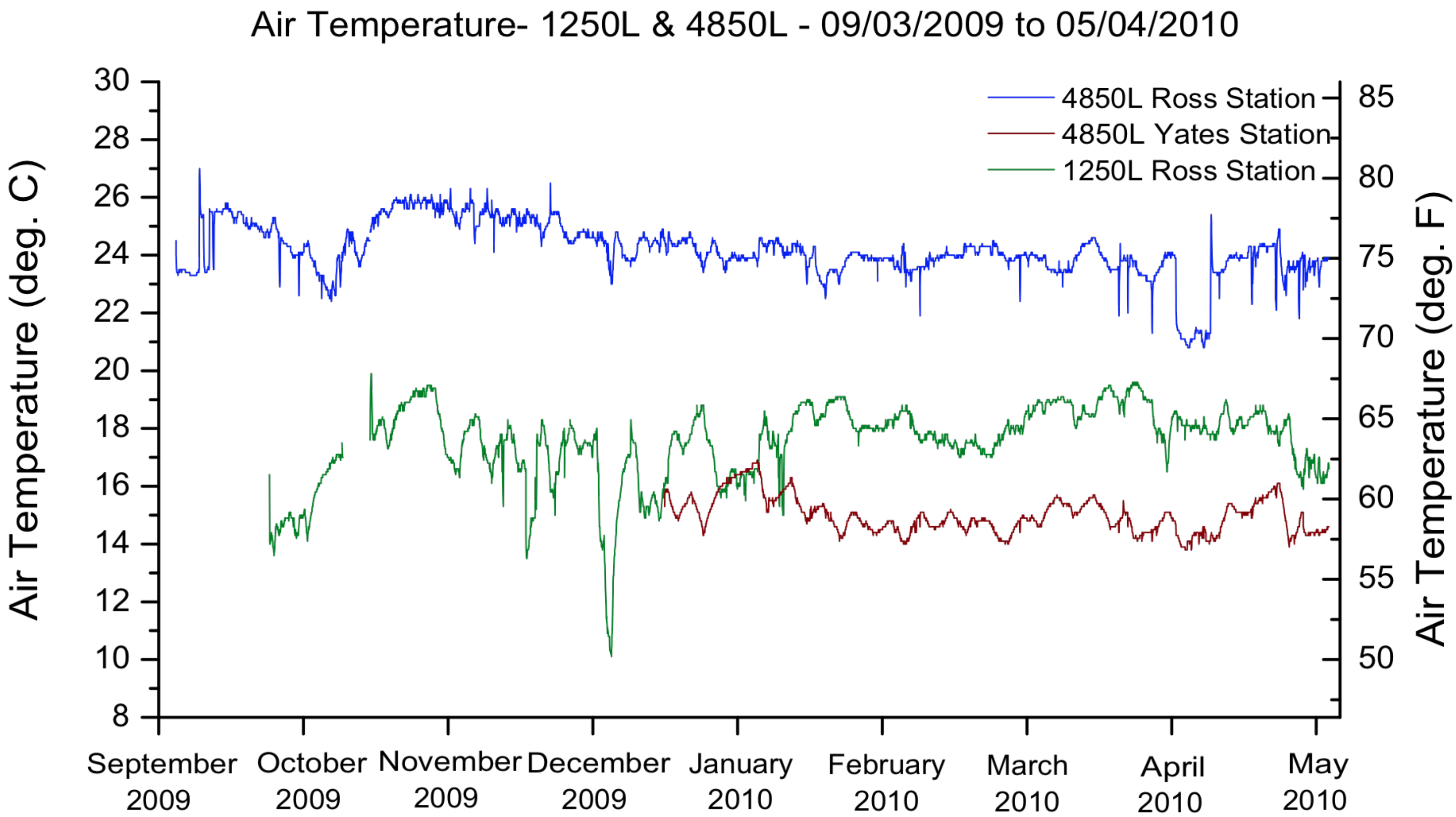
Comparisons of vertical locations on the Ross shaft reveal some ventilation events, such as air direction reversals. Some understood/accounted for, others not.

Yates Station Rn vs. Temp.

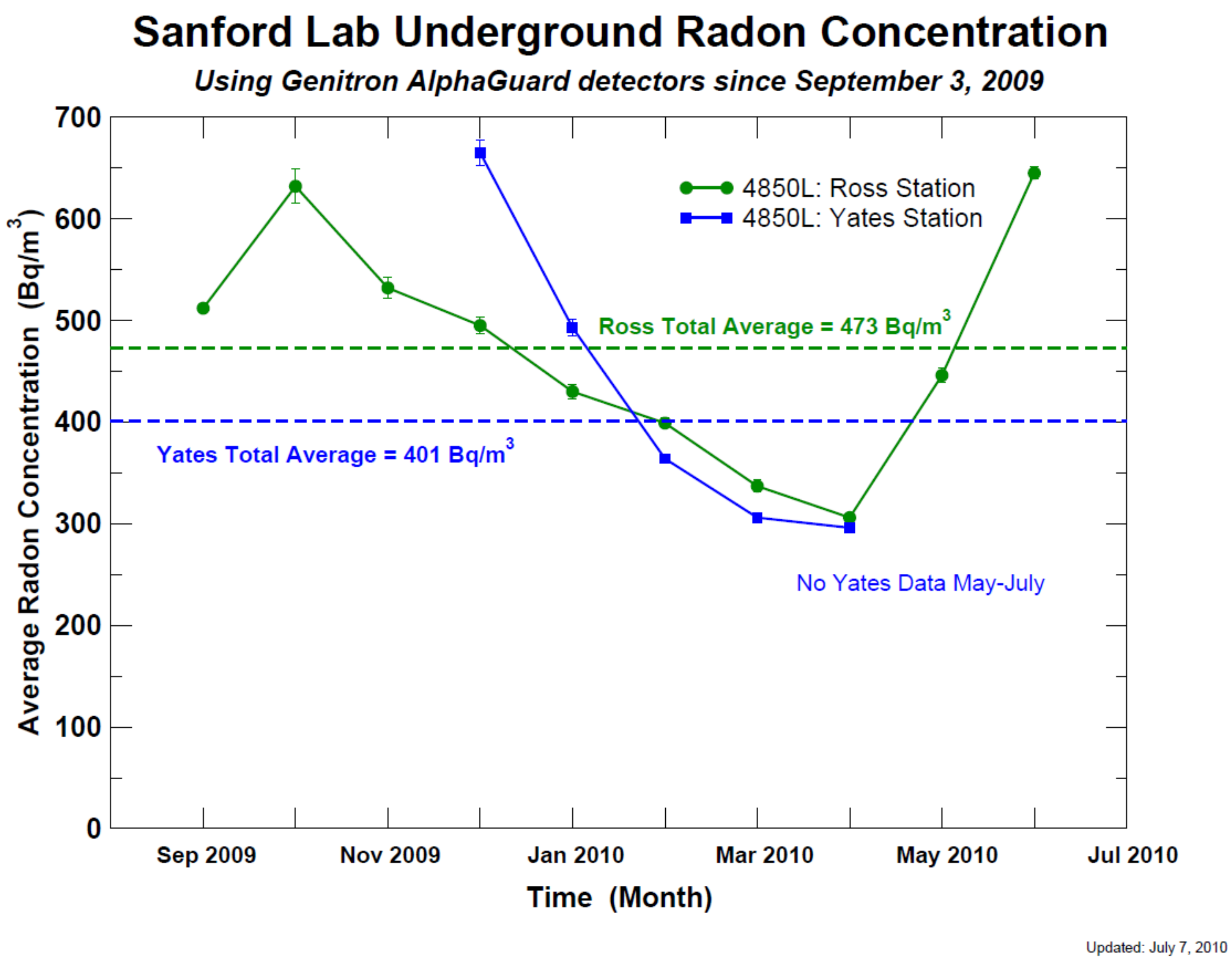


Temperature changes can imply changes in how ‘fresh’ the air is entering the location. The temperature relationship clearer at the 4850L Yates location is more evident, where the ventilation is presumably less chaotic.

Temperature



On the 4850L, the temperature is consistently much cooler, which would imply that the Yates shaft provides a better source of direct surface air to the 4850L.

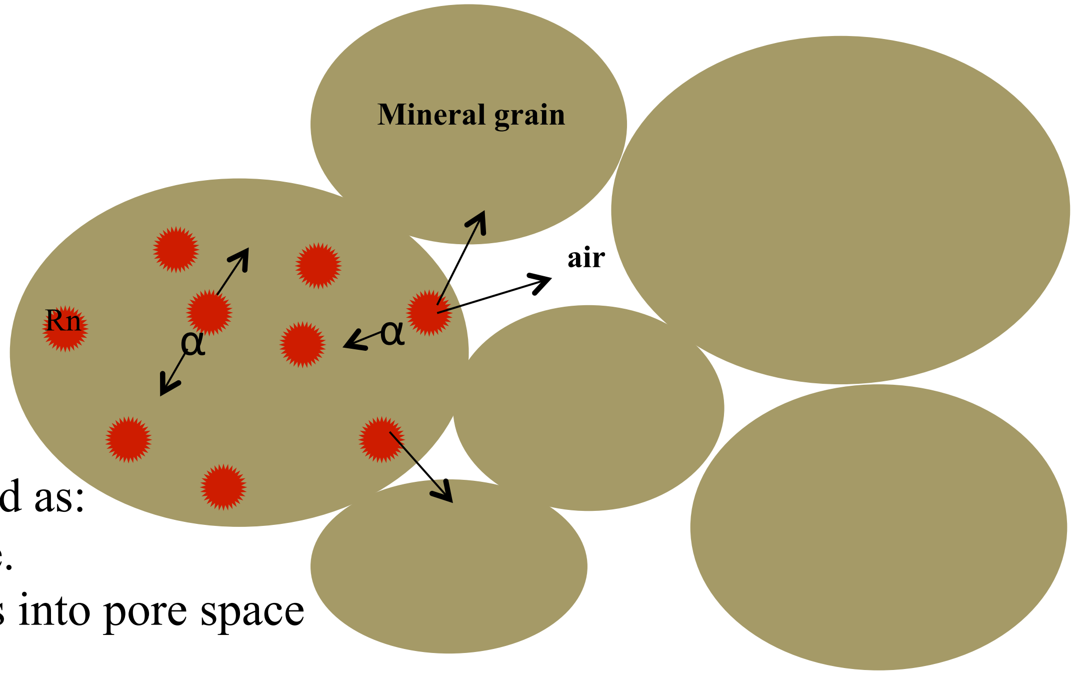


Summary plot of average radon levels– overall they are going down, likely due to ventilation improvements.

Radon Emanation Coefficient

Upon the alpha decay of radium, ^{222}Rn recoils a distance dependent upon the density of composition of surrounding material, which is around 0.02-0.07 µm in common minerals. In air, this recoil distance is 63 µm.

3 possibilities upon recoil:
1)Remains in grain
2)Exits grain, remains in pore
3)Exits grain, traverses pore, enters adjacent grain.



Radon emanation coefficient is defined as:
A (Bq/g) of total Rn born in substance.
B (Bq/g) Rn born in substance, recoils into pore space

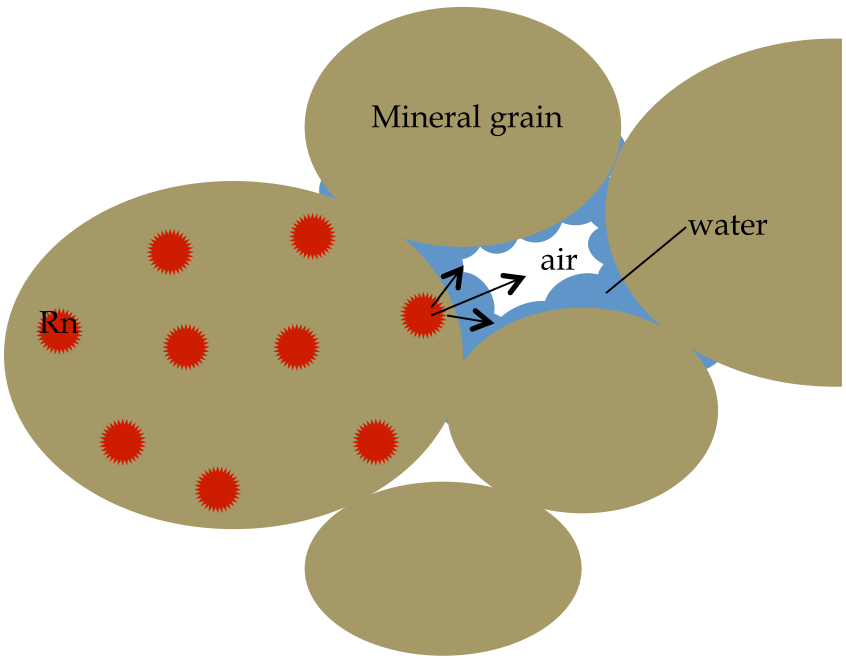
Rn emanation Coefficient= B/A (the fraction which remains in pores)
For rocks and soils, this ranges from 0.05-0.70

Therefore, with uniform radium distribution, emanation coefficients are inversely proportional to grain size since only atoms close to the grain boundary have the chance of escaping into pore spaces.

Schuman and Gundersen (USGS), Geologic and Climatic Controls on the Radon Emanation Coefficient, Environment International, Vol 22, Suppl. 1, S439-S446, 1996.

Rn Emanation and Moisture

When pores have moisture in them, there's a higher density of materials in the pore space, which alters the effective recoil distance of ^{222}Rn atoms. So More Rn atoms remain in the pore space, instead of becoming lodged on adjacent grains.



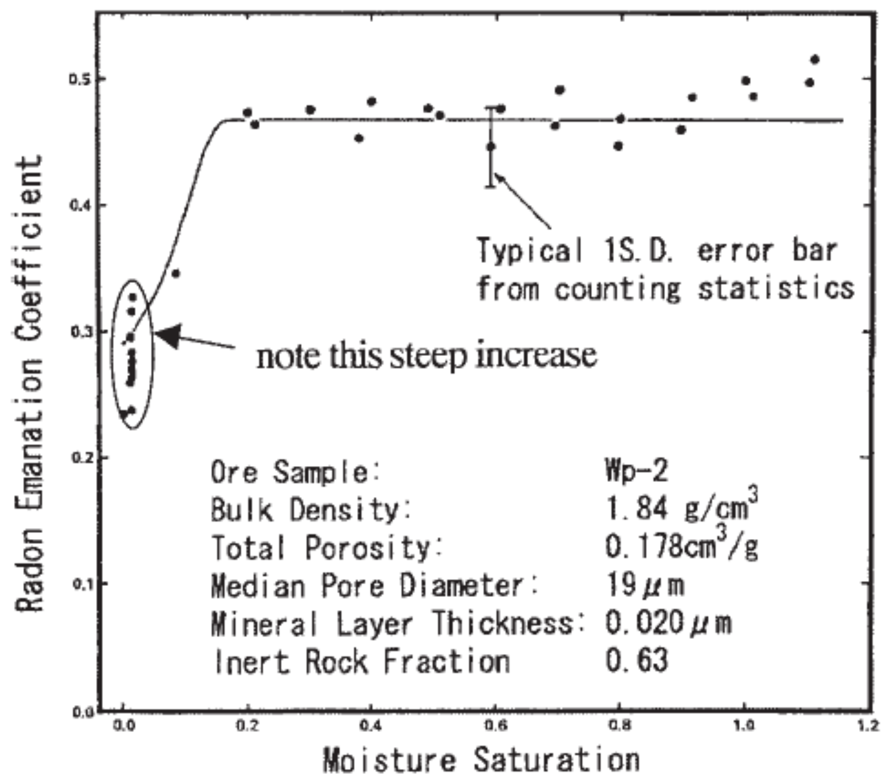
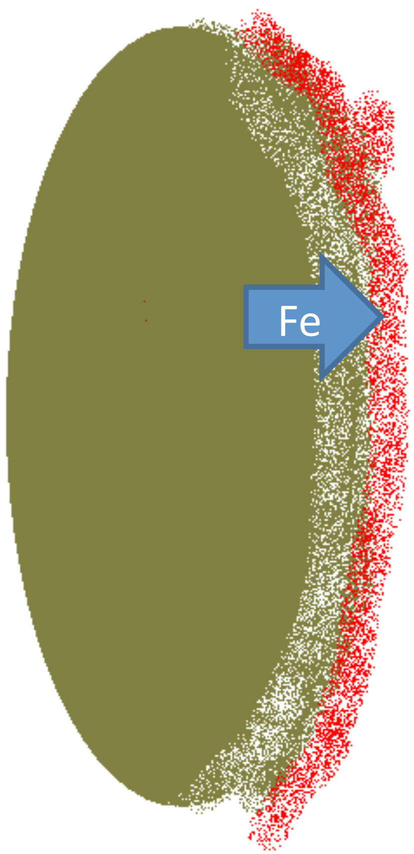


Fig. 1 Comparison of measured emanation coefficients with calculated emanation *vs.* moisture curve for ore sample WP-2 (Reproduced from Ref. 2))

Rn Emanation and Iron Oxide



Formation of metal oxides on minerals can enhance radon emanation.

1)As the iron leeches out of the mineral, it leaves behind nanoscale pits and pathways, thereby enhancing the pore structure. (weathering process)

2)Radium will often absorb in or co-precipitate with iron oxide….

Schuman and Gundersen (USGS), Geologic and Climatic Controls on the Radon Emanation Coefficient, Environment International, Vol 22, Suppl. 1, S439-S446, 1996.

Iron Oxide Sludge Sample

SDSTA Iron Oxide Sludge
3/11/10-2

^{234}Th	U(early)	1.3	ppm
$^{226}Ra\downarrow$	U(late)	14	ppm
$^{228}Ra/Ac$	Th(early)	44	ppm
$^{228}Th\downarrow$	Th(late)	11	ppm

- Preliminary results from sample taken from water filtration system on surface (3/11/10) and sent to Al Smith for counting at LBNL.

In comparison:

Homestake Country Rock

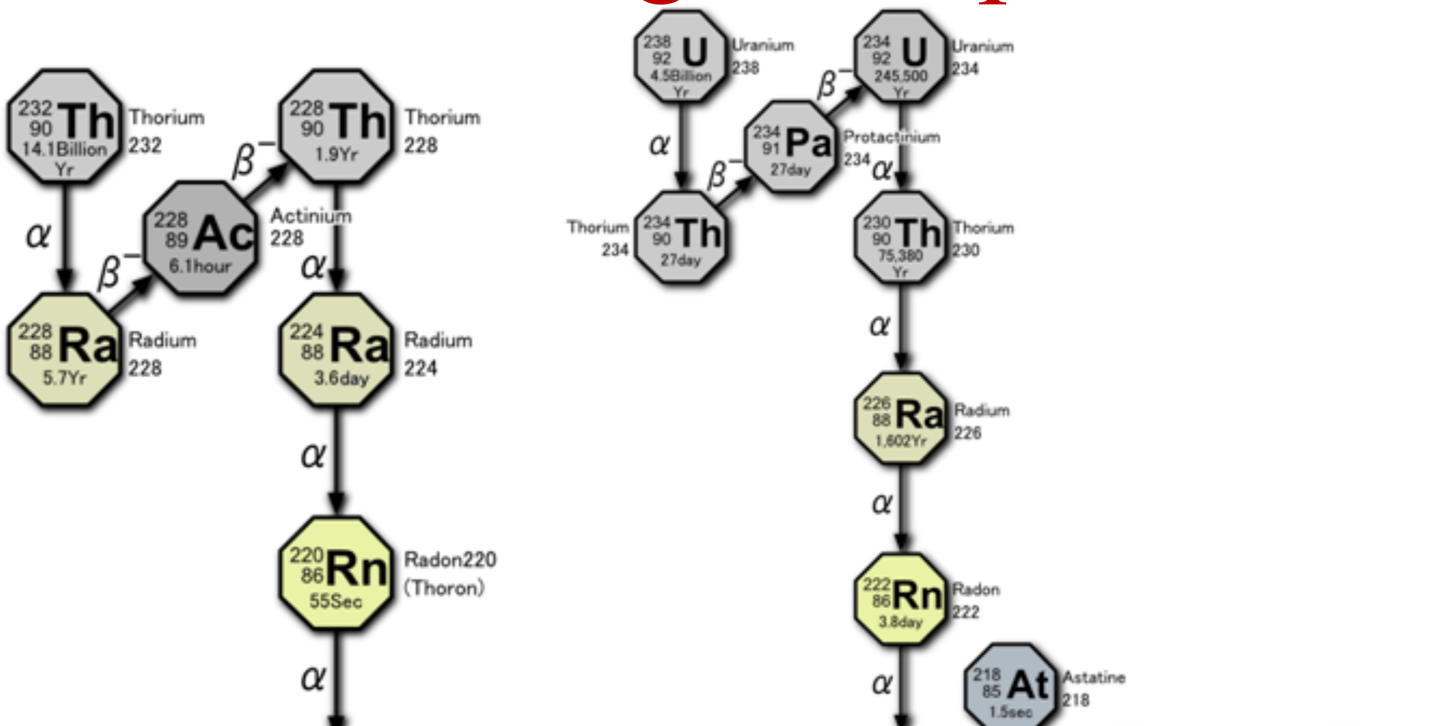
U	0.08-0.2	ppm
Th	0.2-0.3	ppm

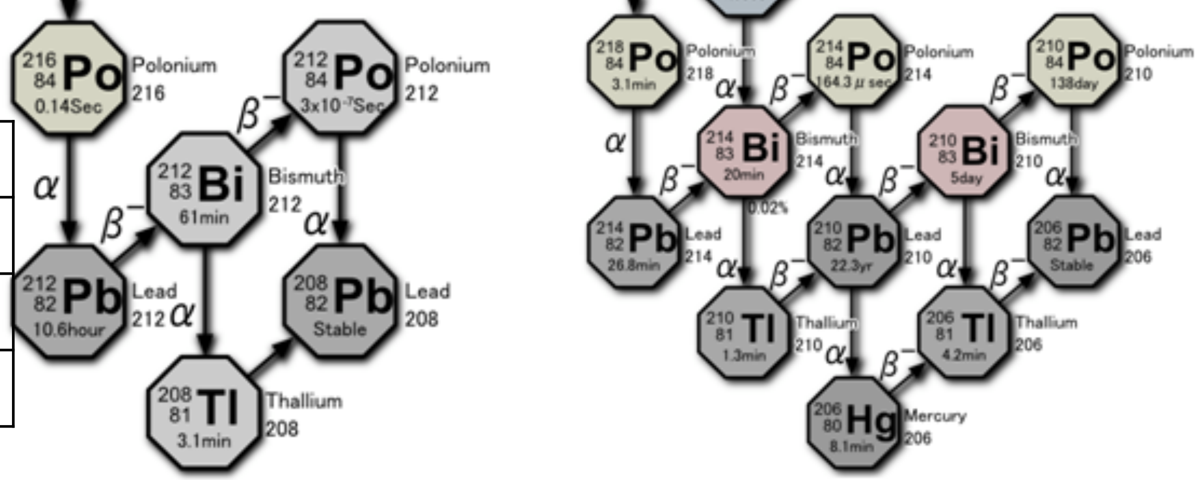
Homestake Rhyolite

U	8-10	ppm
Th	8-12	ppm

- Both U series, Th series *not in equilibrium*; in particular due to enrichment of Radium in the iron oxide (not because of Radon).
- Rn emanation: 8 pCi/g
- Fine iron oxide dust underground can pose source of contamination in clean room transitions, for example.

Iron Oxide Sludge Sample





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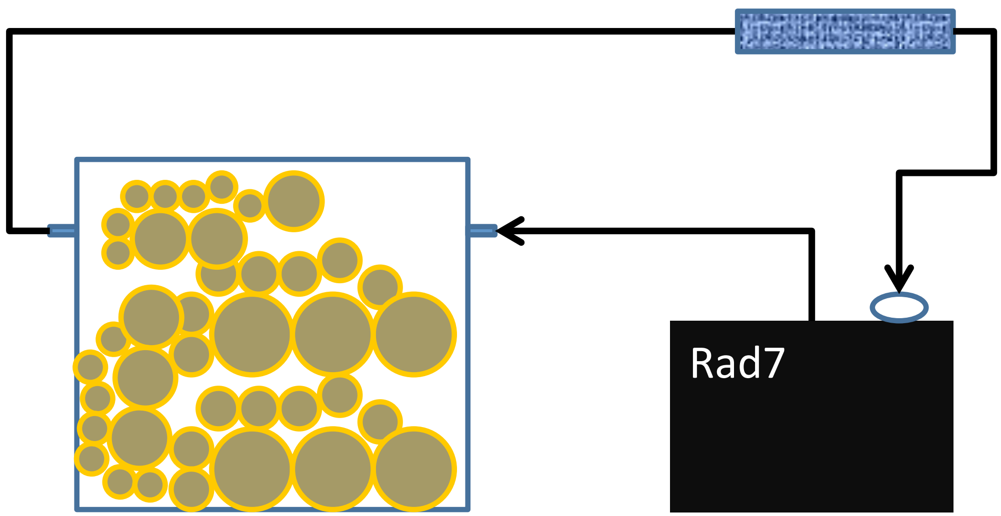
Further Rn Emanation Testing

Using Rn emanation chamber and more HPGe counting

- More iron oxide samples
- Rock samples (with and without iron oxide layers)
- Concrete and Shockcrete samples



Summary I

Relevant factors for Radon levels at Homestake:

Primary

Dominant factor for Radon levels underground.

Ventilation- Drastic changes in radon levels completely associated with the variations in the ventilation system. Ventilation is 30-50% of historical capacity, so improvements to the ventilation system (air doors, CFM increases, etc.) should yield changes in the radon levels.

Secondary

These may cause a higher baseline level than historical records.

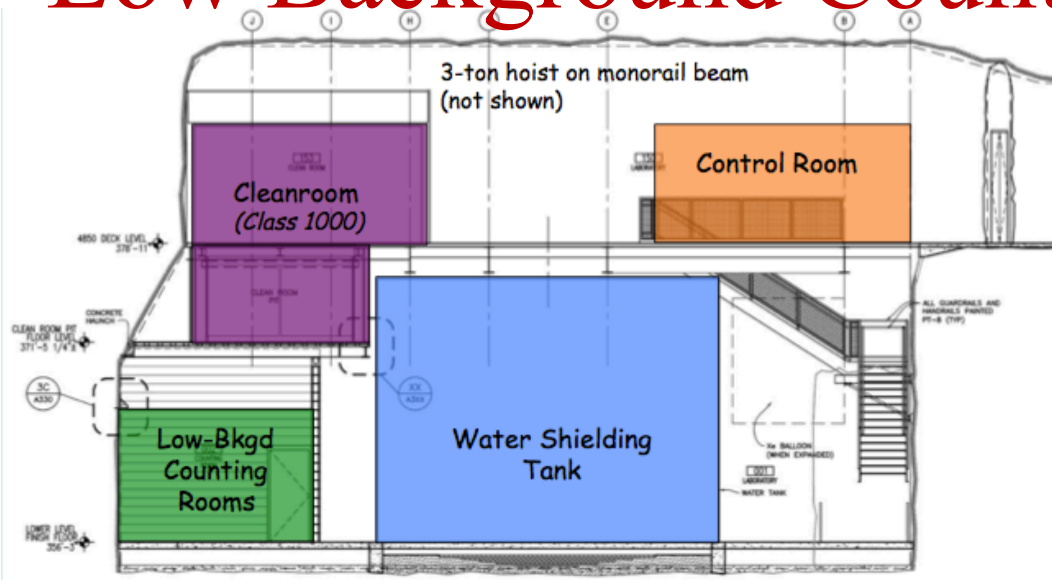
Iron Oxide- enriched Ra content, high Rn emanation.

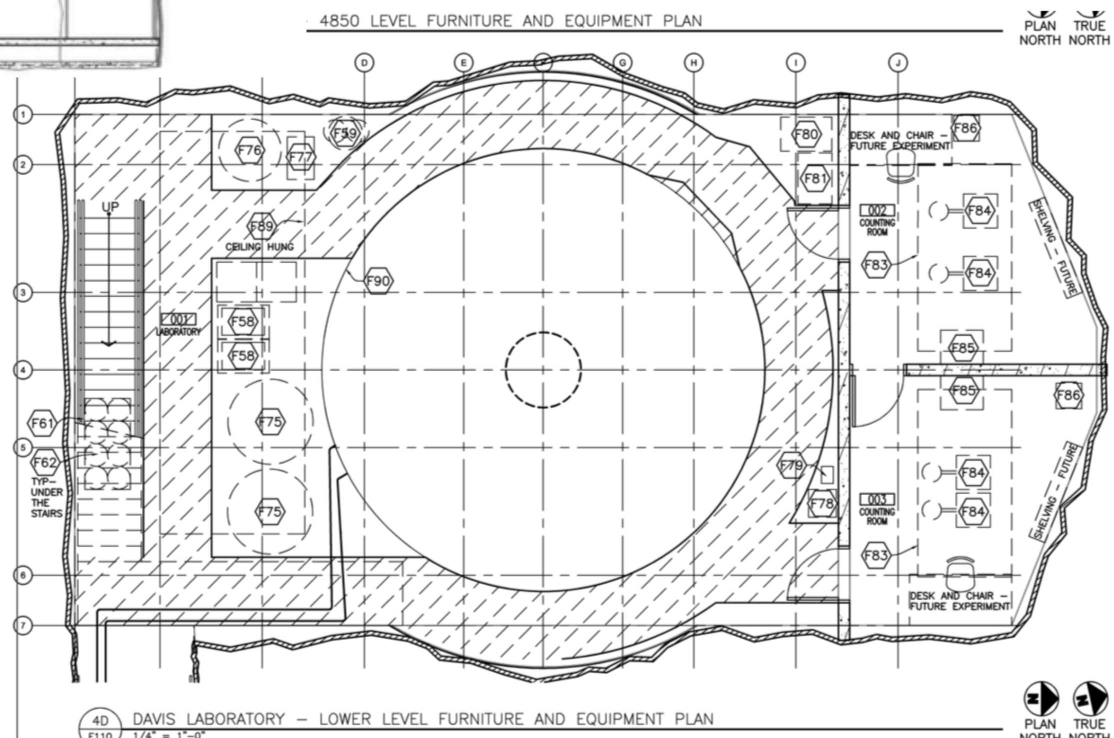
Moisture- enhanced emanation (from both rock and iron oxide)

Summary II

- Measurements underground reflect radon levels with little or no mitigation efforts in place: minimal/unstable ventilation *(30-50% of historical capacity),* no layers resistant to diffusion, no radon removal systems.
- Measurements reflect relationship of radon with exposure to path length through mine– i.e. (1250L 'exhaust' Rn levels)
- Moisture in the rock, presence of iron oxide may play a role in enhancing baseline radon levels on 4550L and below. Iron oxide appears as a fine dust underground, which may also be a concern for contamination.
- Improvements to the ventilation system (fans, air doors), receding water levels will change the ventilation conditions underground and therefore also the radon levels.
- Long term measurements will continue on the 1250L/4850L Ross Stations, 4850L Yates. Another detector will be deployed to monitor exhaust air soon too.

Low Background Counting at Sanford Lab





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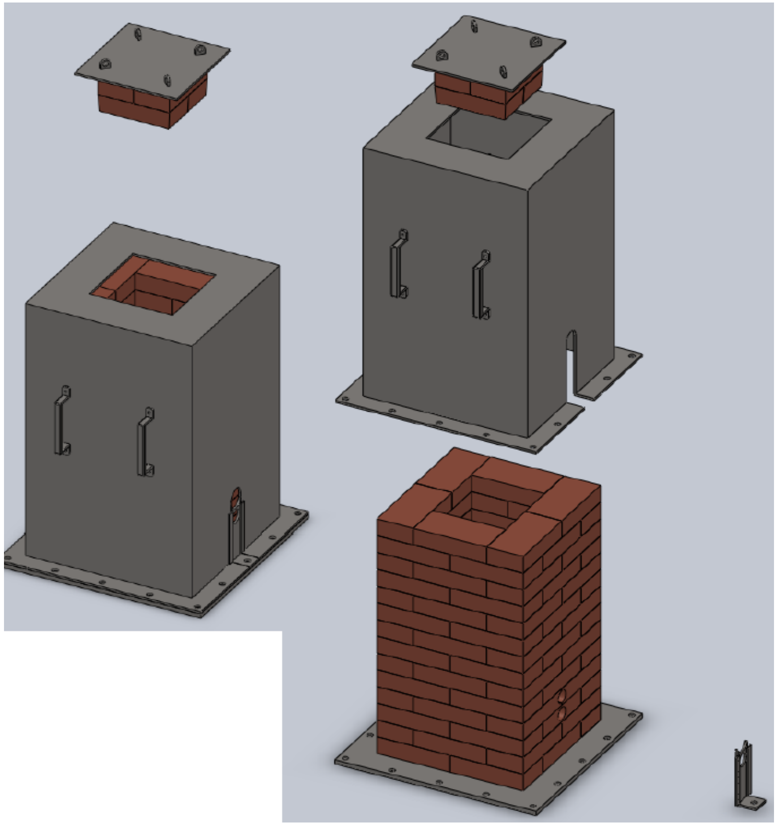
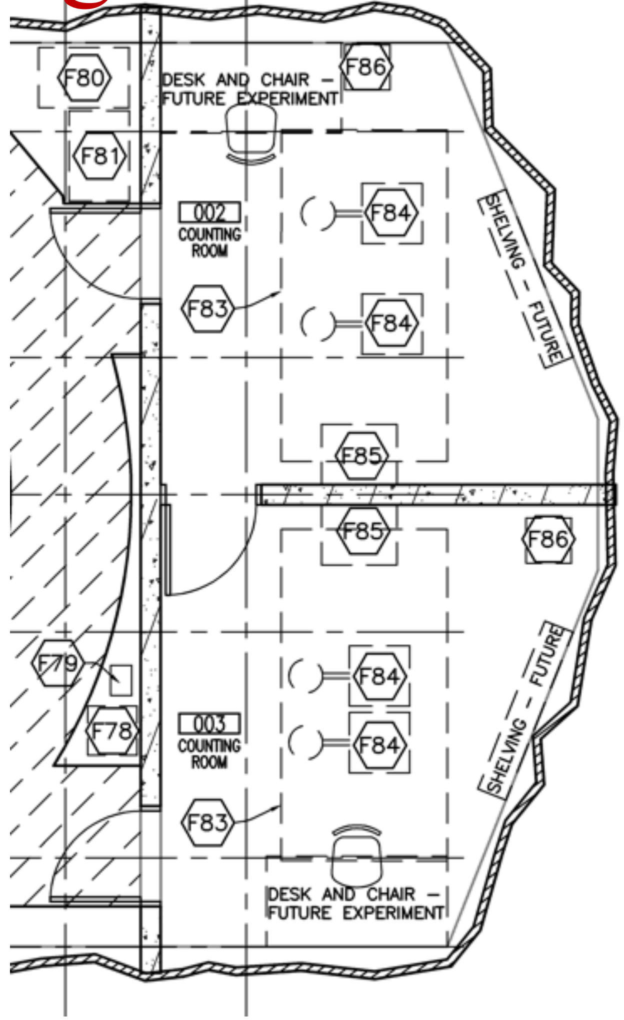


Prototype Rn-exclusion shield is currently under construction at USD for use with already purchased HPGE detector. Shield will incorporate an inner layer of OHFC copper, stainless steel radon-exclusion box, and outer layer of lead.



Space reserved for low-background counting with HPGE detectors in the LUX refurbishment of the Davis Cavern on the 4850L. The Davis Cavern is currently under construction.

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