UNDERSTANDING AND TRACKING RESPIRABLE DUST SOURCES IN UNDERGROUND COAL MINES

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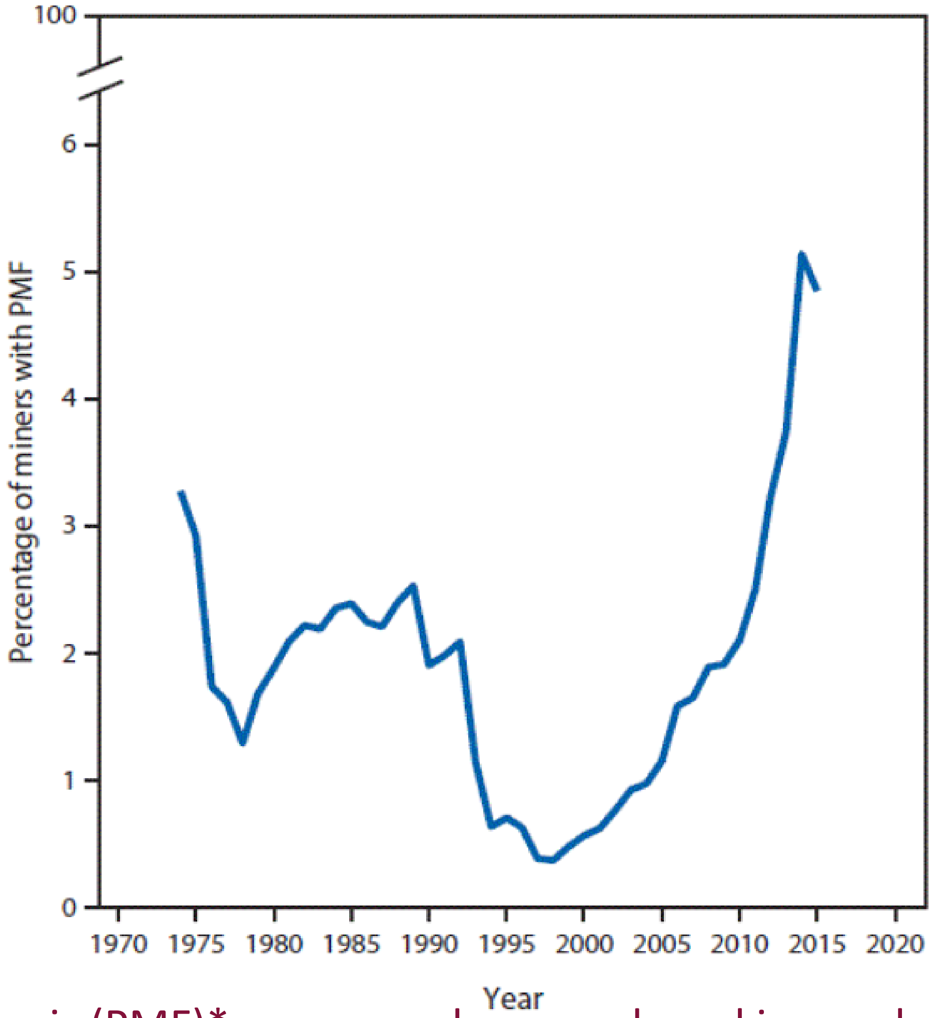
- Views expressed here are those of our research team, and do not necessarily represent the views of sponsors or our industry partners

Introduction

Respirable Coal Mine Dust (RCMD) is still a health hazard



Prevalence of progressive massive fibrosis (PMF)* among underground-working coal miners with = 25 years of underground mining tenure

Coal Workers' Health Surveillance Program, KY, VA, WV, 1974–2015 [1]

Analytical tools for dust characterization

Portable FTIR

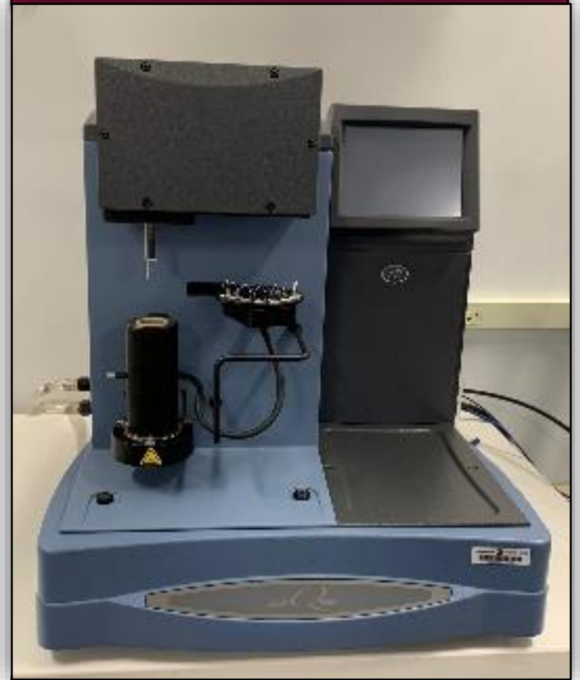
Bruker Optics ALPHA II FTIR Spectrometer

- quartz, kaolinite, and calcite fractions

% mass

TGA

TA Instruments TGA Q500



- coal, carbonates, non-carbonate minerals mass fractions

% mass

SEM-EDX

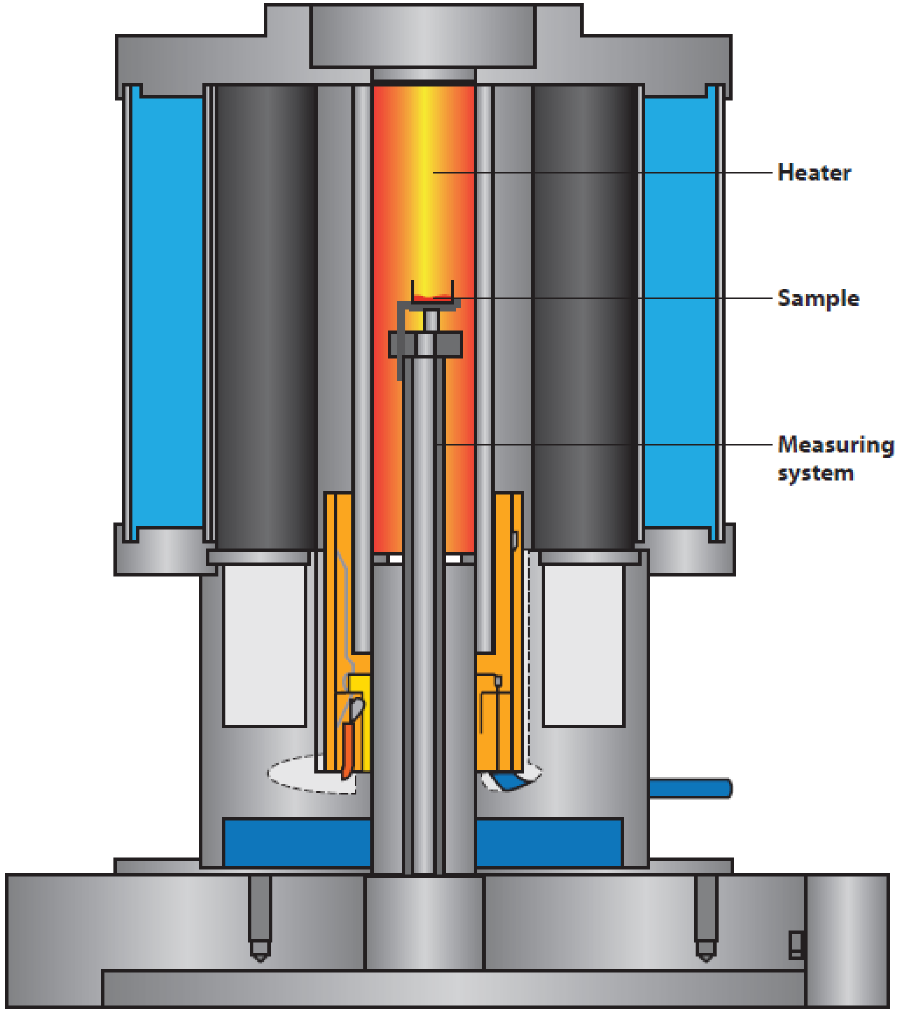
FEI Quanta 600 FEG environmental SEM

- size
- shape
- mineralogy class

0.1-10µm

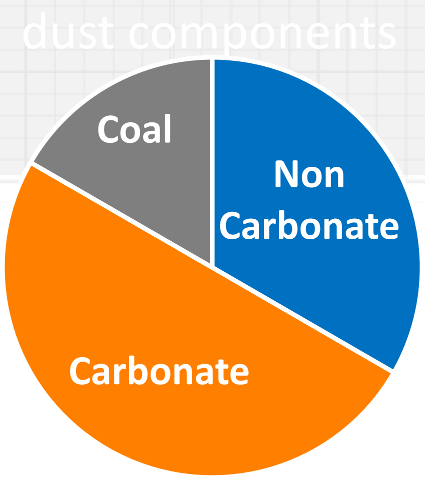
Thermogravimetric Analysis (TGA)

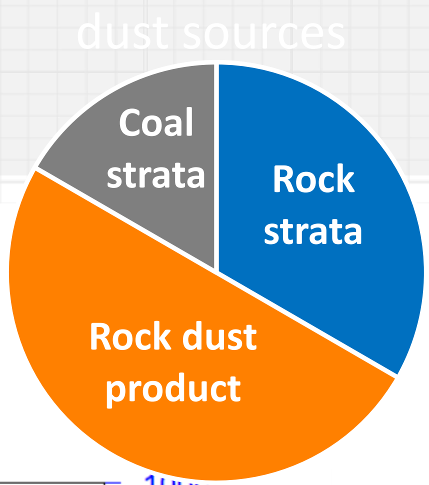
- Q500 Thermogravimetric Analyzer (TA Instruments, New Castle, DE)
- We previously developed a TGA application for respirable coal mine dust to split mass into 3 primary fractions
  - ✓ Coal
  - ✓ Carbonates
  - ✓ Non-carbonates

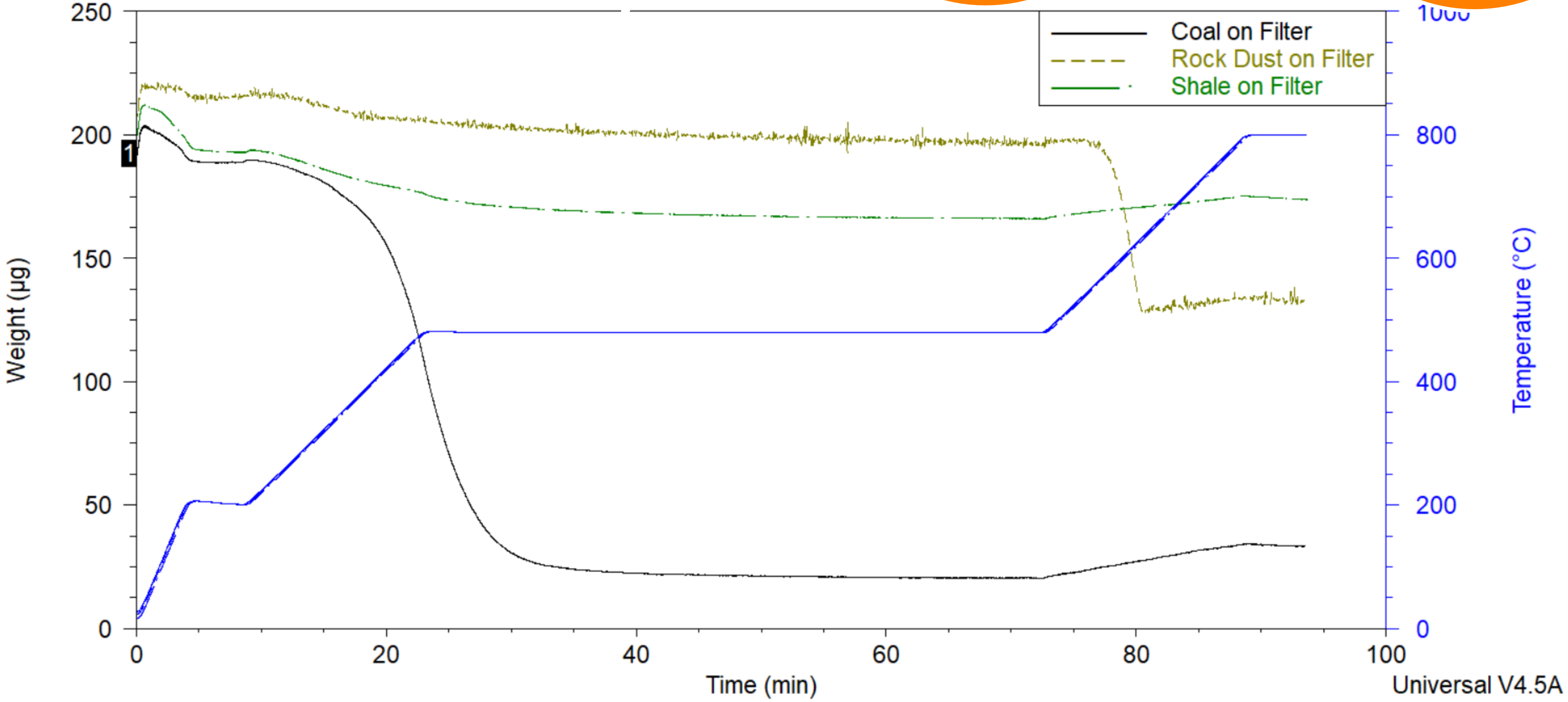


TGA concept

- Mass fraction estimation







Methodology

TGA Sample Preparation

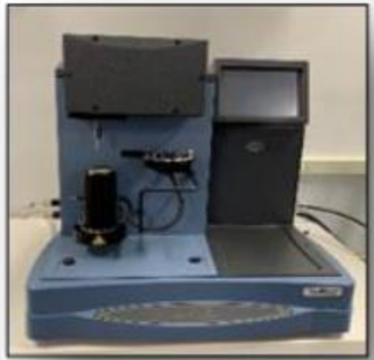
Filter with dust

Filter transferred to the tube with Isopropanol

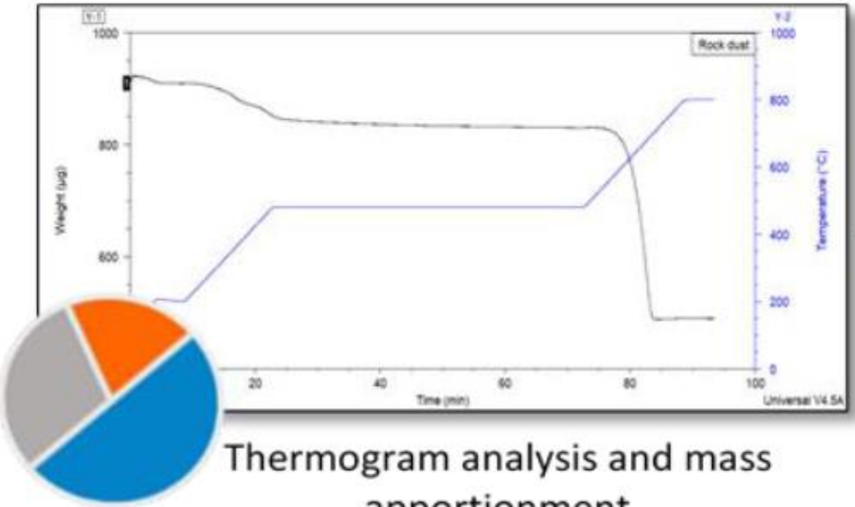
Tube placed in the ultrasonic bath

Filter removed and tube placed in the centrifuge

Dust pipetted from tube into a clean tared TGA pan

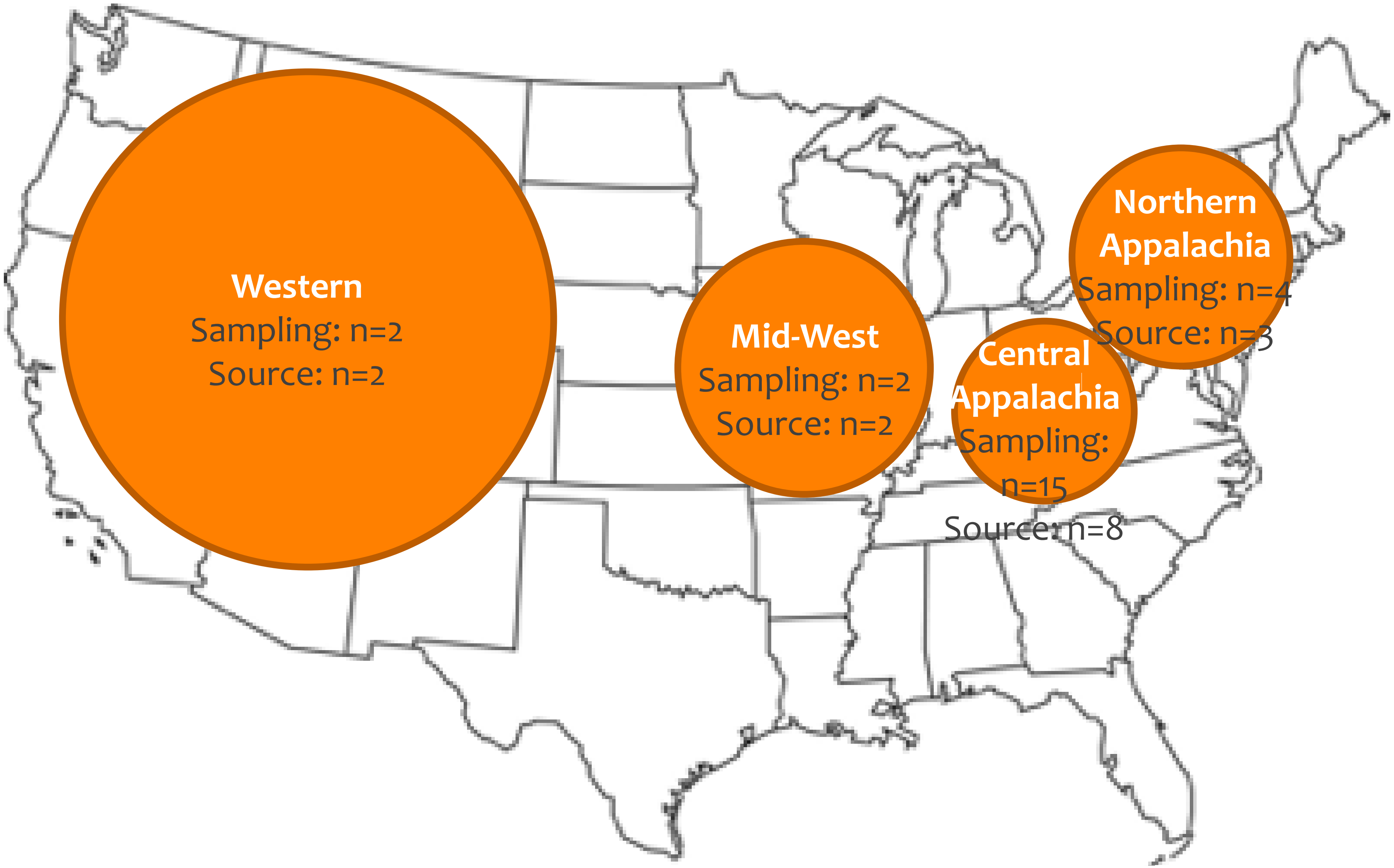


Pans are analyzed in the TGA



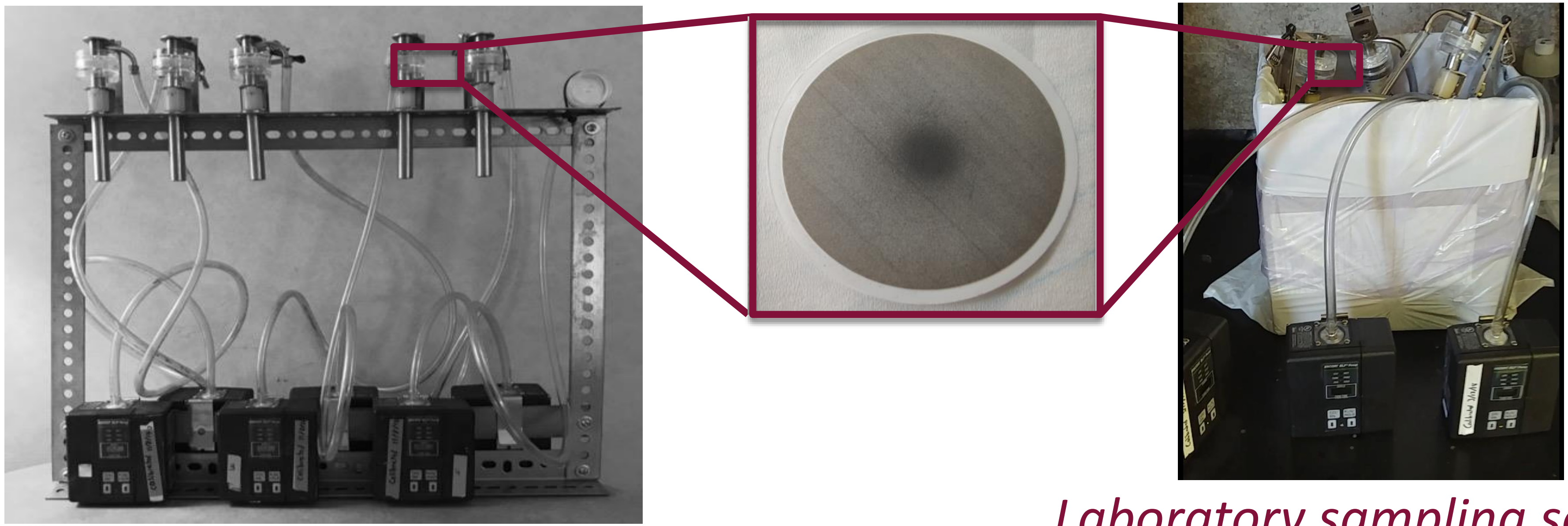
Thermogram analysis and mass apportionment

Mine locations for sampling



Sampling details

- 10-mm nylon Dorr-Oliver cyclones at 2.0 lpm flow rate
- Escort ELF air sampling pumps
- 37-mm two-piece styrene cassettes
- For FTIR: PVC filters (5.0 µm pore size)
- **For TGA & SEM-EDX: PC filters (0.4 µm pore size)**



Coal mine sampling setup (RCMD)

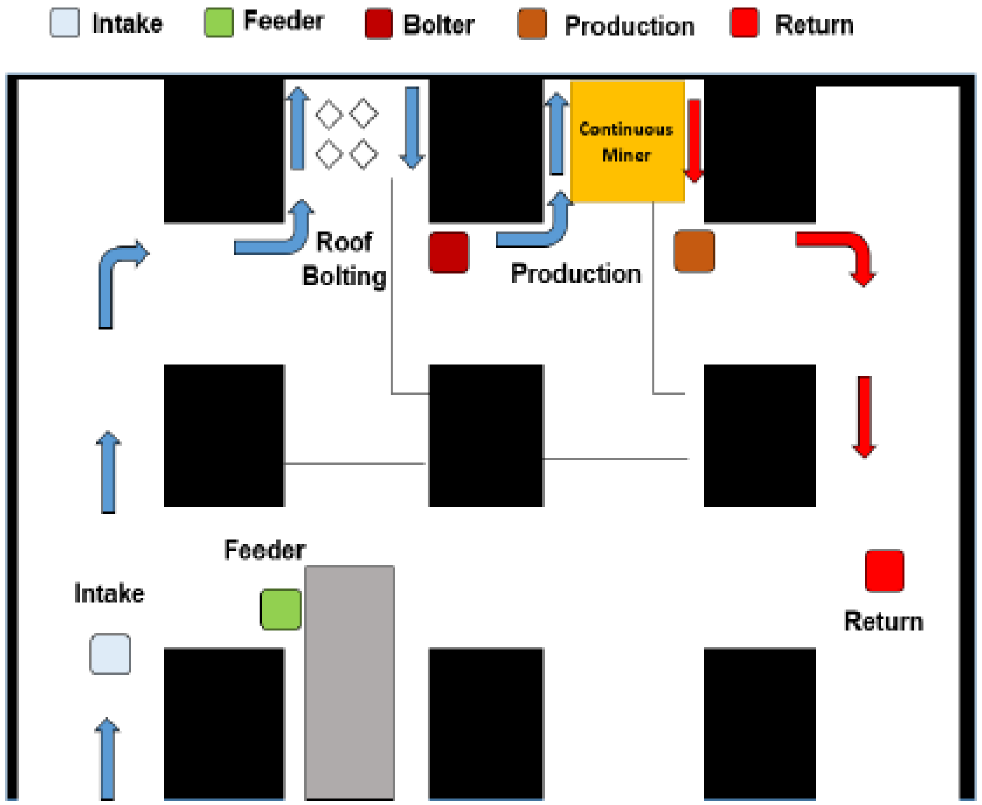
Laboratory sampling setup (respirable dust from source materials)

Primary source materials

- Primary dust source materials includes:
  - **ROM coal**: the coal seam being mined
  - **ROM rock**: the surrounding rock strata (i.e., typically dominated by non-carbonate minerals) being drilled or mined along with the coal
  - **rock dust products** (i.e., typically made from carbonate-rich limestone or dolostone) being applied in the mine to mitigate explosibility hazards

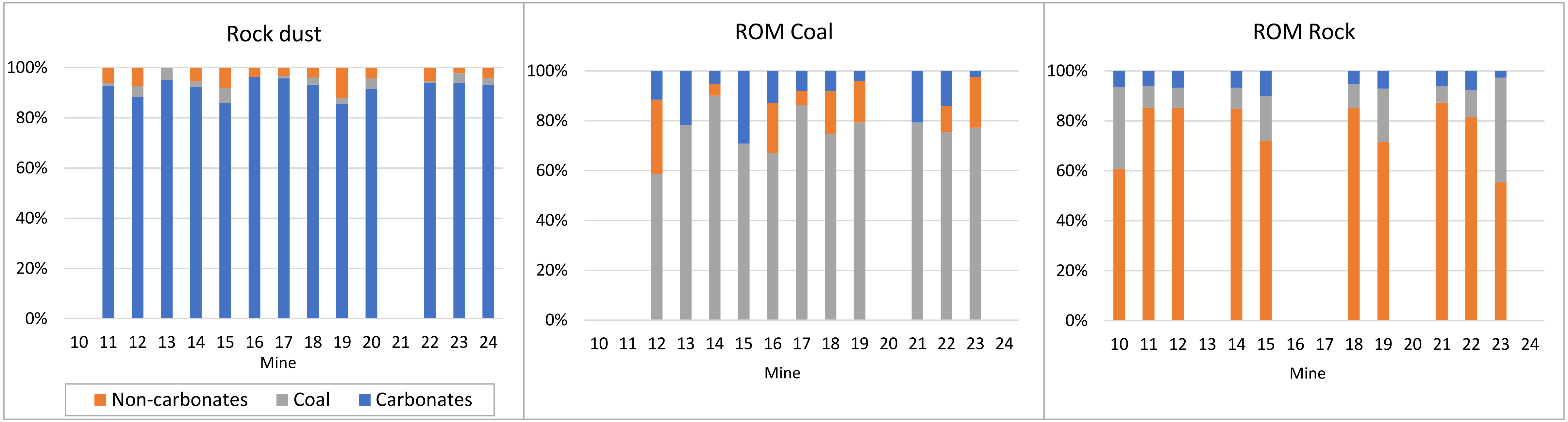
RCMD samples

Location	Description
Intake	In the fresh airways, upstream of any bolting or mining activities
Roof bolter	Just downwind of an active roof bolter
Feeder	Adjacent to the feeder breaker, or along the main conveyor belt or transfer points
Production	Just downwind of an active continuous miner, or on the longwall face
Return	In the exhaust airway, including downwind of ventilation tubing exhaust where present

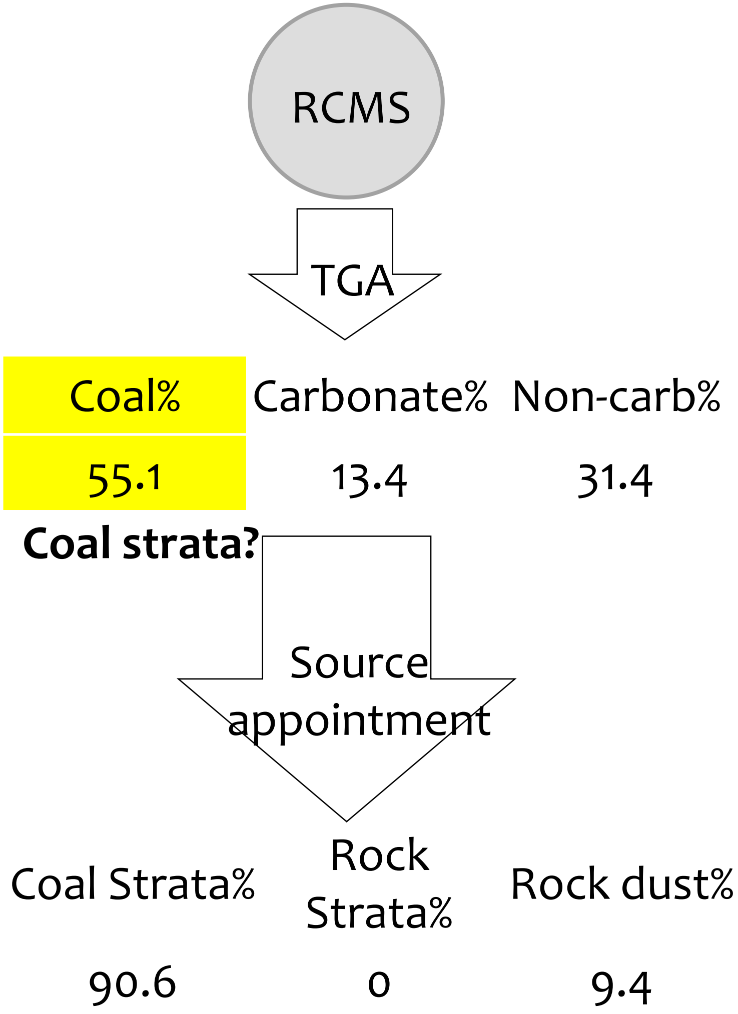


Data analysis and results

Dust Generated from Source Materials



Source Appointment Calculations for Model



$ROM\ Coal_{source(i)} = C_{coal(i)} + CB_{coal(i)} + NCB_{coal(i)} = 100\%$	*Eq 1*
$Rock\ Dust_{source(i)} = C_{RD(i)} + CB_{RD(i)} + NCB_{RD(i)} = 100\%$	*Eq 2*
$ROM\ Rock_{source(i)} = C_{rock(i)} + CB_{rock(i)} + NCB_{rock(i)} = 100\%$	*Eq 3*
$ROM\ Coal_{sample(i)} = \frac{C_{sample(i)} - \left(C_{rock(i)} \times ROM\ Rock_{sample(i)}\right) - (C_{RD(i)} \times Rock\ Dust_{sample(i)})}{C_{coal(i)}}$	*Eq 4*
$Rock\ Dust_{sample(i)} = \frac{CB_{sample(i)} - \left(\mathrm{CB}_{\mathrm{coal(i)}} \times ROM\ Coal_{sample(i)}\right) - (CB_{rock(i)} \times ROM\ Rock_{sample(i)})}{CB_{RD(i)}}$	*Eq 5*
$ROM\ Rock_{sample(i)} = \frac{NCB_{sample(i)} - \left(\mathrm{NCB}_{\mathrm{coal(i)}} \times ROM\ Coal_{sample(i)}\right) - (NCB_{RD(i)} \times Rock\ Dust_{sample(i)})}{NCB_{rock(i)}}$	*Eq 6*

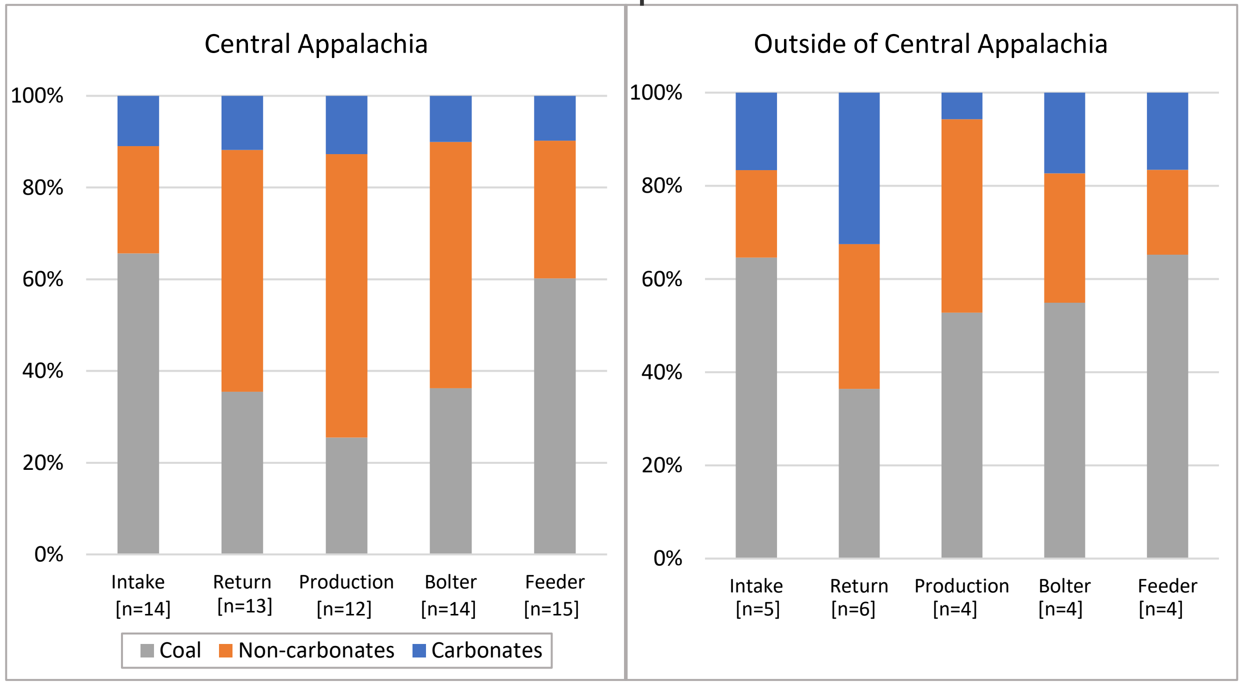
Notes:

Equations 1-3 set the coal (C), carbonates (CB), and non-carbonate minerals (NCB) fractions for the ROM Coal, Rock Dust, and ROM Rock source materials in the mine or mine region of interest (i) using the TGA data given in Table S1. If a source material was not available for the mine of interest, then the regional average for that source material was used instead. Table S6 shows the C, CB, and NCB fractions for each dust source used in the model for each mine.

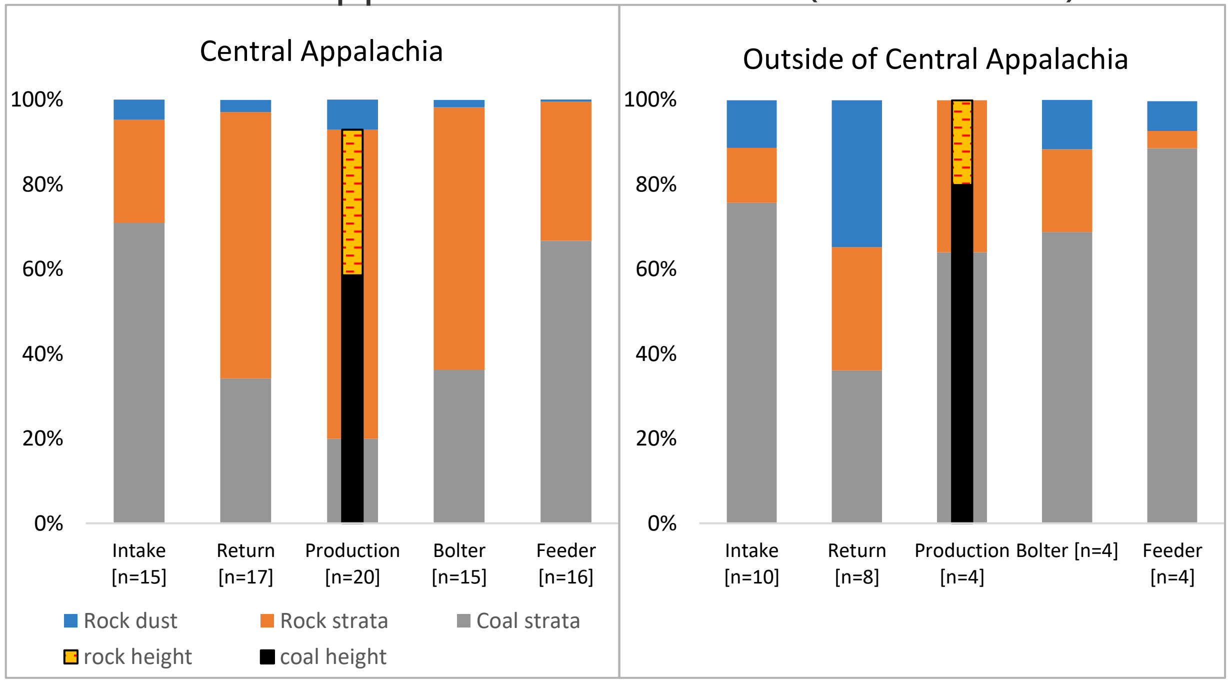
Equations 4-6 evaluate a given RCMD "sample", using its TGA-derived C, CB, and NCB fractions, in the mine or region of interest described by Equations 1-3. Equations 4-6 return the fraction of the sample apportioned to the ROM Coal, Rock Dust, and ROM Rock sources, respectively.

Mine dust and source appointments

Mine Dust Sample TGA Results



Source Apportionment Results (from model)



Conclusions

- Application of thermogravimetric analysis (TGA) to RCMD can enable simple dust source apportionment in many mines
- Some knowledge of the primary source materials is key for interpretation of the RCMD component fractions derived from TGA.
- Rock strata appears to contribute inordinately to the RCMD just downwind of the mine face. This emphasizes a need to improve the effectiveness of dust controls specifically for reducing rock strata-sourced dust during mining.

Other Source Apportionment Tools: Direct-on-filter FTIR

Portable FTIR

- **NIOSH's new direct-on-filter (DOF) FTIR method:**
  - DOF-FTIR analysis has been designed as an end-of-shift silica monitoring method, but it can also support research and engineering studies
  - Uses portable FTIR instrument and standard gravimetric sample filter
  - Miller et al. (2012) found strong linear correlation (ranging from 0.90 – 0.97) between DOF and the standard MSHA P7 method for *quartz*.
  - **Furthermore, the infrared spectra might enable mass estimates of additional minerals such as kaolinite and calcite—which could help in tracking dust sources**

Curious about the new "END OF SHIFT" method for silica monitoring?

In response to growing demand for rapid silica monitoring capabilities, NIOSH has been developing an "end of shift" method.

It uses a portable FTIR instrument and a simple software program to quickly measure silica on a traditional gravimetric filter sample—enabling results in just minutes.

To learn more, visit this site: https://tinyurl.com/3u7t8k6w You can watch a video that outlines the hardware requirements and demonstrates the FTIR analysis and software.

We'd also appreciate your anonymous feedback using the survey form!

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Questions?

Contact us at esarver@vt.edu

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THANK YOU! QUESTIONS?