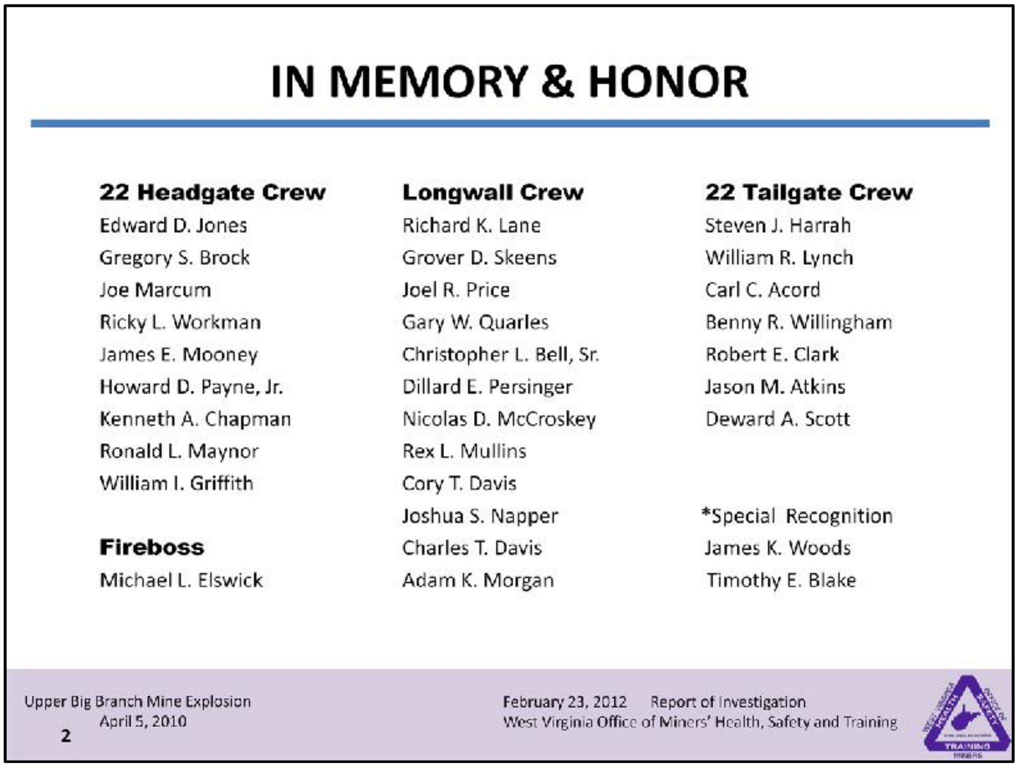
Slide 1 (Introduction). Begin 1st presenter: Barry Fletcher; Roof Control Specialist; Investigator



Slide 2 We would like to begin the presentation with an overview of our investigation. This overview will be followed by a detailed account of our findings concerning the explosion which occurred on April 5, 2010 by Mr. Monte Hieb our Chief Engineer. We want to again thank you for your patience as we finalized our investigation and report.

MINE RESCUE TEAMS

Alpha Natural Resources
Brooks Run – North
Brooks Run – South
Rock Spring – Gold
Rock Spring – Blue
Kingston – White
Kingston – Red
Cobra

Patriot
Federal #2
Southern Appalachia
Magnum

Black Mountain Resources
Kentucky – Blue
Kentucky – White

ICG
Wolf Run – Blue
Wolf Run – White
Hazard – Flint Ridge Blue
Knott County – White
Beckley – Black
Beckley – Gold

Mountaineer Mine Rescue Assoc.
Mountaineer 1
Mountaineer 2

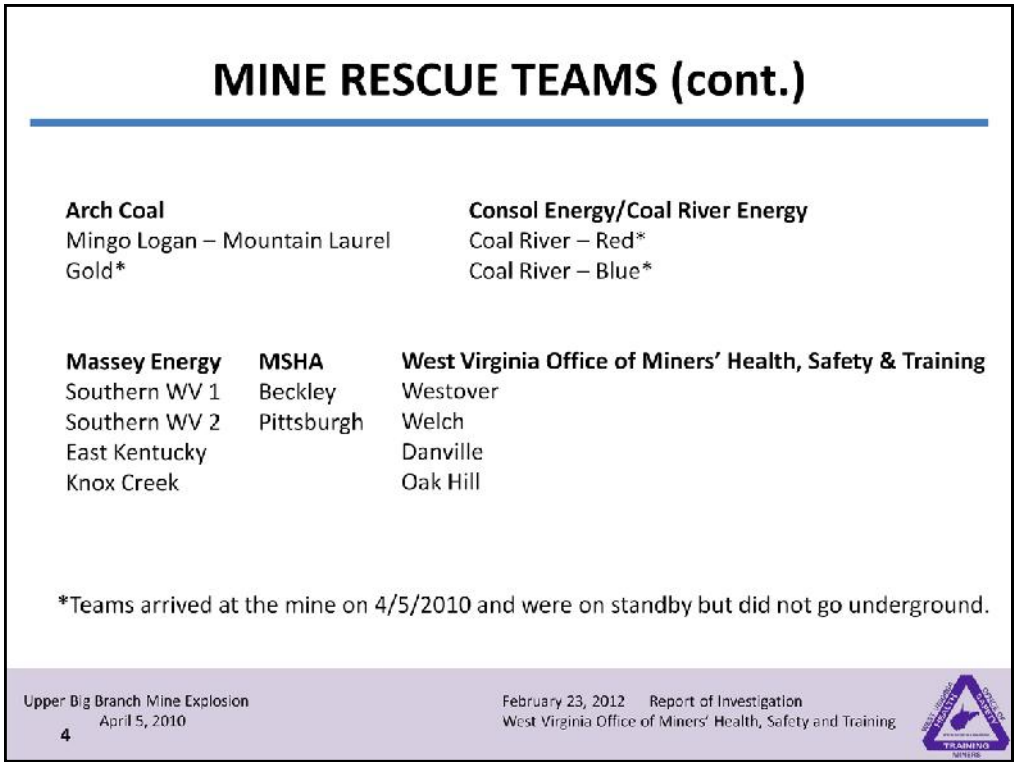
Cumberland Resources
Virginia – Maroon
Virginia – Black

Southern Pocahontas
Apache
Cherokee

Upper Big Branch Mine Explosion
April 5, 2010
3

February 23, 2012 Report of Investigation
West Virginia Office of Miners' Health, Safety and Training

<u>Slide 3</u> We want to personally communicate that the following Mine Rescue Teams, and others, were fully committed to do everything humanly possible during the initial rescue and recovery to bring your loved ones out of the mine. It was with heavy hearts that more could not have been done to change the eventual outcome.



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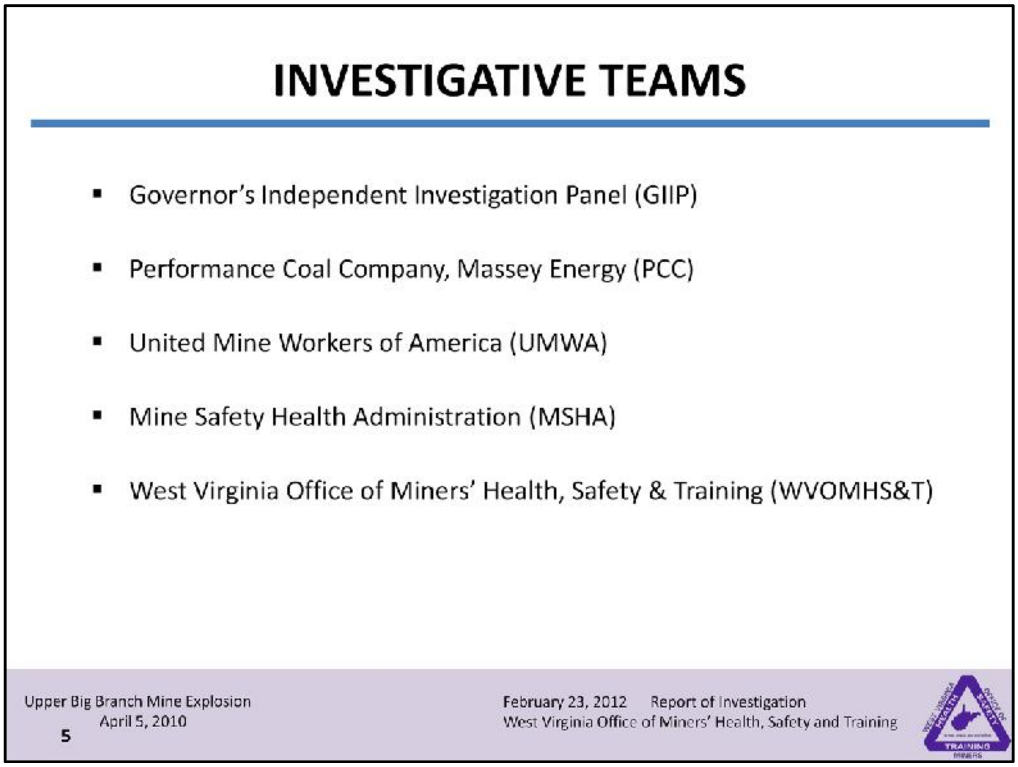


<u>Slide 5</u> INVESTIGATIVE TEAMS –There were 5 different entities involved in the investigation.

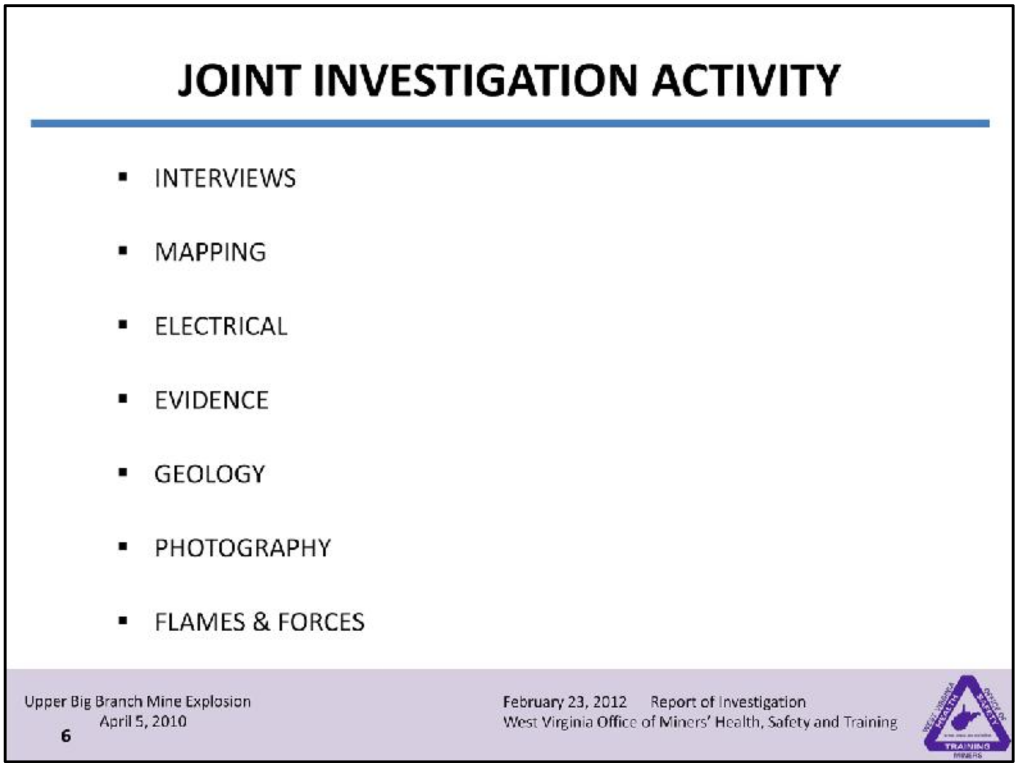
GIIP- Governors Independent Investigation Panel On April 13 2010 former Governor Manchin requested an independent investigative panel be organized. J. Davitt McAteer, along with seven associates, conducted their investigation in conjunction with the other teams, but with their independent findings. Their report was the first released in May of 2011.

PCC - Massey Energy, Massey Energy released their preliminary and only report to date in June 2011.

UMWA- The mine workers report was released in October of 2011.

MSHA- MSHA report was released in December 2011.

WVOMHS&T- All other reports had been released while the WVOMHS&T was still gathering information and awaiting testing results to complete our report.



<u>Slide 6</u> JOINT INVESTIGATION ACTIVITY included the following;

INTERVIEWS- There were 309 interviews conducted from May 2010 –October 2011. A total of 269 people were interviewed.

MAPPING- The first big undertaking of the investigation was the **mapping** of the entire explosion area. This was conducted from June 29-Sept 9th 2010 with additional work done on occasion as needed thru November, 2010. (double check this date)

ELECTRICAL- **Electrical Inspections** began outside in May of 2010 and UG on June 29th of 2010. There were multiple teams checking items on the surface and underground in the outby areas of the mine but the main focus was in the widespread regions of the explosion.

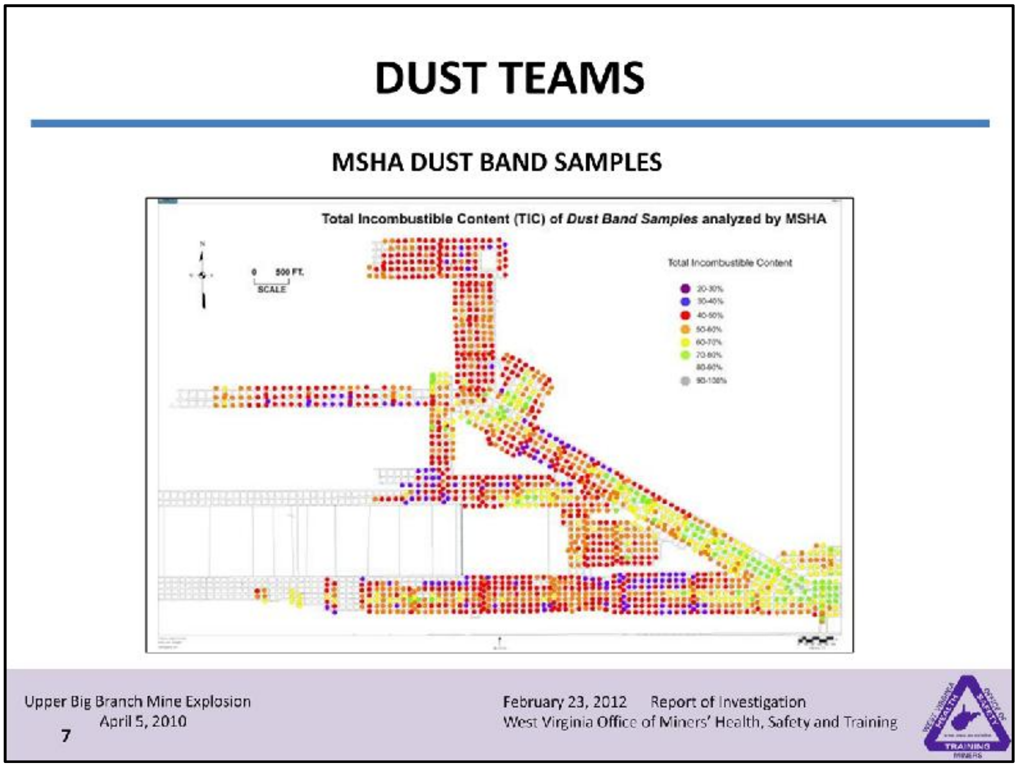
EVIDENCE- Hundreds of pieces of **evidence** was collected, and many of the collected items were tested and examined to assure they were working properly at the time of the explosion & these items helped us understand the many dynamics of the event.

GEOLOGY- Effort was put into understanding how the **geological** structure of UBB, the multiple mines above UBB, and the strata below UBB's Eagle Seam may have contributed to the conditions underground on the day of the explosion.

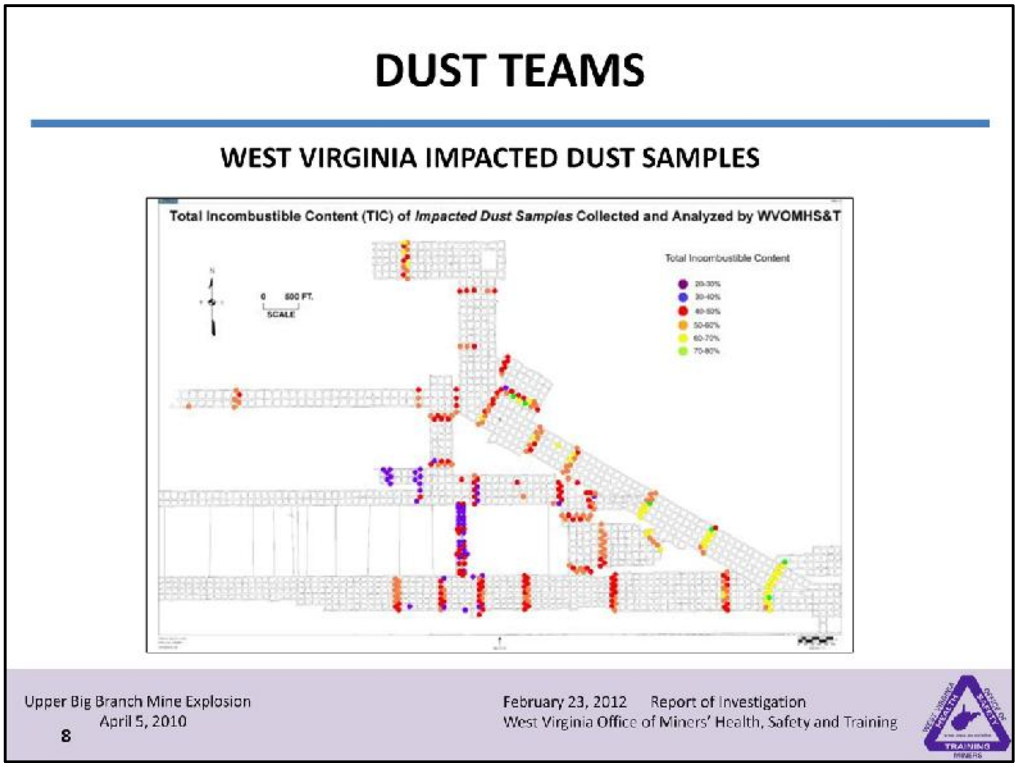
PHOTOGRAPHY- Thousands of **photos** and numerous **videos** were used to document the conditions in the mine during the course of our investigation. They were later used for reference and documentation during the investigation to help us understand and clarify many of our findings.

The FLAMES & FORCES group was assigned the responsibility of establishing the origin of the explosion, the ignition source, sources or types of fuel which existed in the mine on April 5th and determine the propagation sequences of the explosion**.**

The joint flames and forces work was completed on September 12, 2010. Supplemental mapping by the WVOMHS&T FLAMES & FORCES GROUP was conducted between September 13, 2010 and September 27, 2011, in order to further document damage and evidence in the explosion regions of the mine that was felt to be critical to our investigation.

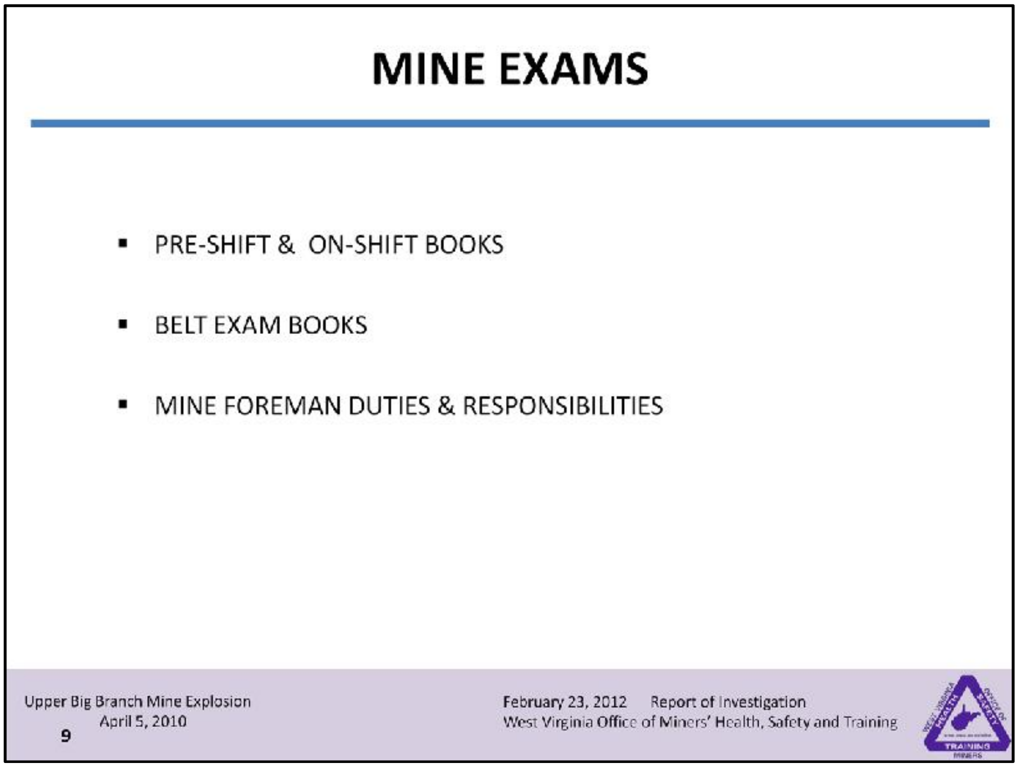


<u>Slide 7</u> MSHA DUST BAND SAMPLES—OR MINE DUST SURVEY A mine dust survey was conducted as part of the joint investigation process after the explosion. The purpose was to determine coking and incombustible content of the post explosion dusts to assist in the determination of the extent of flame, fuel sources, possible ignition sources and origin of the explosion.



Slide 8 WEST VIRGINIA IMPACTED DUST SAMPLES—We began a supplemental mapping and sampling initiative to document impacted dust deposits that may represent a more accurate picture of airborne dust involved in the explosion. Documentation of these dust deposits aided determination of explosion force direction, the sequence of multiple forces, the fuel involved in the explosion, and quantities of incombustible contents of the explosion dusts.

***The state, independently, used high definition digital scanning (3D imaging) in specific areas of the mine to help document details at locations and specific items during the course of our investigation.

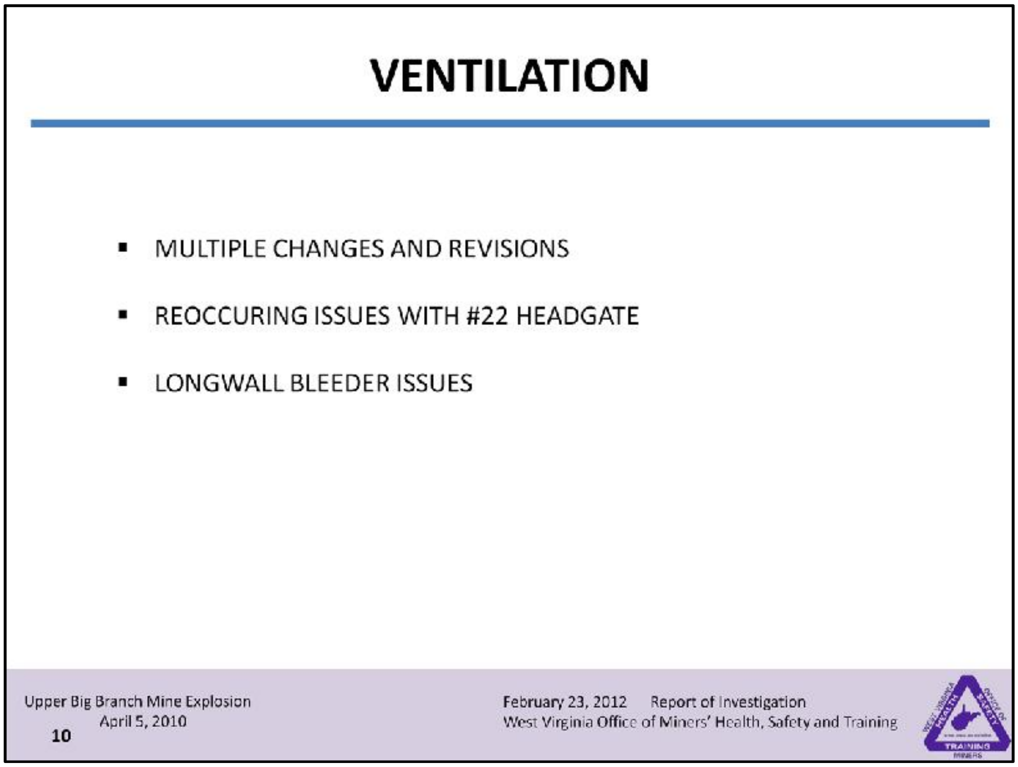


Slide 9 MINE EXAMS were an area of much deliberation during our investigation.

Preshift & Onshift Books During the course of our investigation record books revealed that there were some work procedures and practices conducted and not recorded properly or the documentation of work performed was less than complete. Some of the noted areas of concern are part of our recommendations to overhaul the examiners reporting and correction of hazards in the documentation procedures.

Belt Exam Books The issue of the belt books has been discussed at length in the previous reports. We have come to similar conclusions that the ongoing conditions noted in the daily examination books showing the need for additional rock dust along the active conveyor belts was a problem that was not addressed in a timely or efficient manner in the days leading up to the explosion.

Mine Foreman-Duties and Responsibilities WV law states that the "Mine Foremen" is to daily review and countersign the exam books at the mine to assure the hazardous conditions noted in the exam books are addressed promptly. The ongoing notations of the need for additional rock dust, listed in the mine belts examination book was an example of a constant and reoccurring condition at UBB that was not dealt with in a timely manner. We, WVOMHS&T, believe that the **ultimate responsibility** for safety issues at the mine should rest with those individuals involved in the day to day decision making process at the mine and "THOSE INDIVIDUALS" must be held accountable regardless of their title. We have recommended that the law be changed to hold higher executives and officials accountable for conditions at the mine.



<u>Slide 10</u> VENTILATION

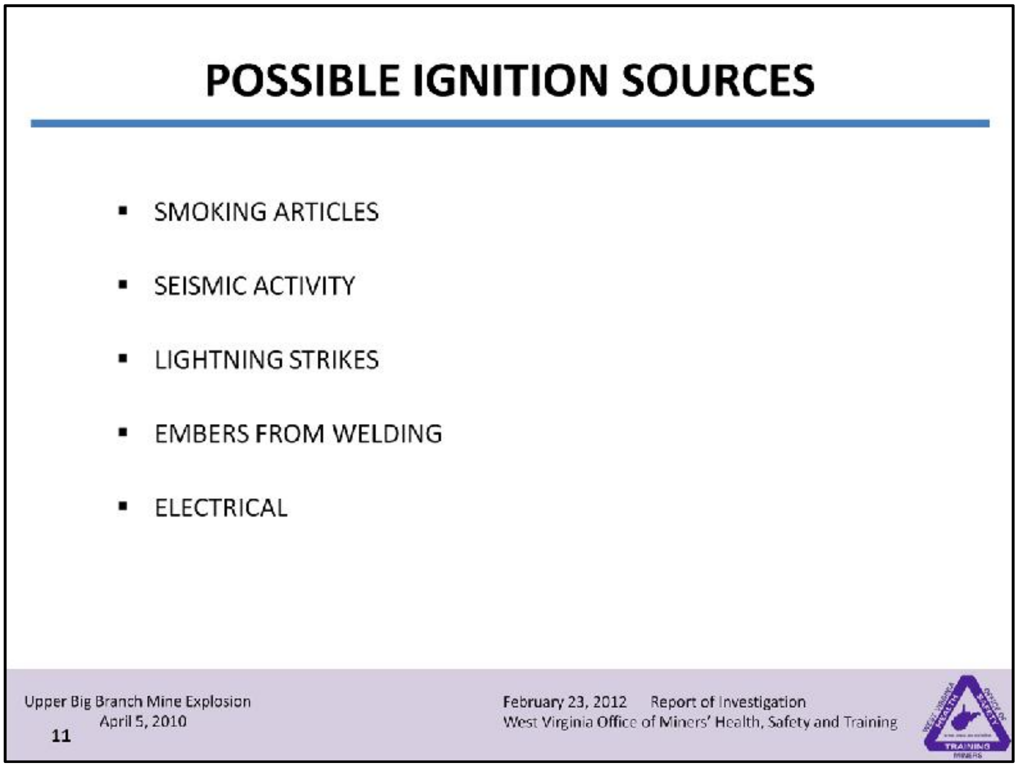
Numerous conditions Complicated Ventilation at UBB.
Multiple Changes and Revisions implemented in a short time period proved problematic.

Reoccurring Ventilation Difficulties on #22 Headgate Section confirmed some of the problems with ventilation. There were difficulties in maintaining consistent, adequate air on the section the few months it was in production.

Longwall Bleeder Issues

a. Roof failure on #21 Headgate which resulted in the unplanned startup of the #22 Tailgate section for the future longwall tailgate entries.
b. Floor heaving conditions.
c. Ongoing water problems behind the #21 Longwall

Our report addresses these ongoing issues and the problems associated with some of the ventilation difficulties present, due to these numerous revisions to the ventilation plans.



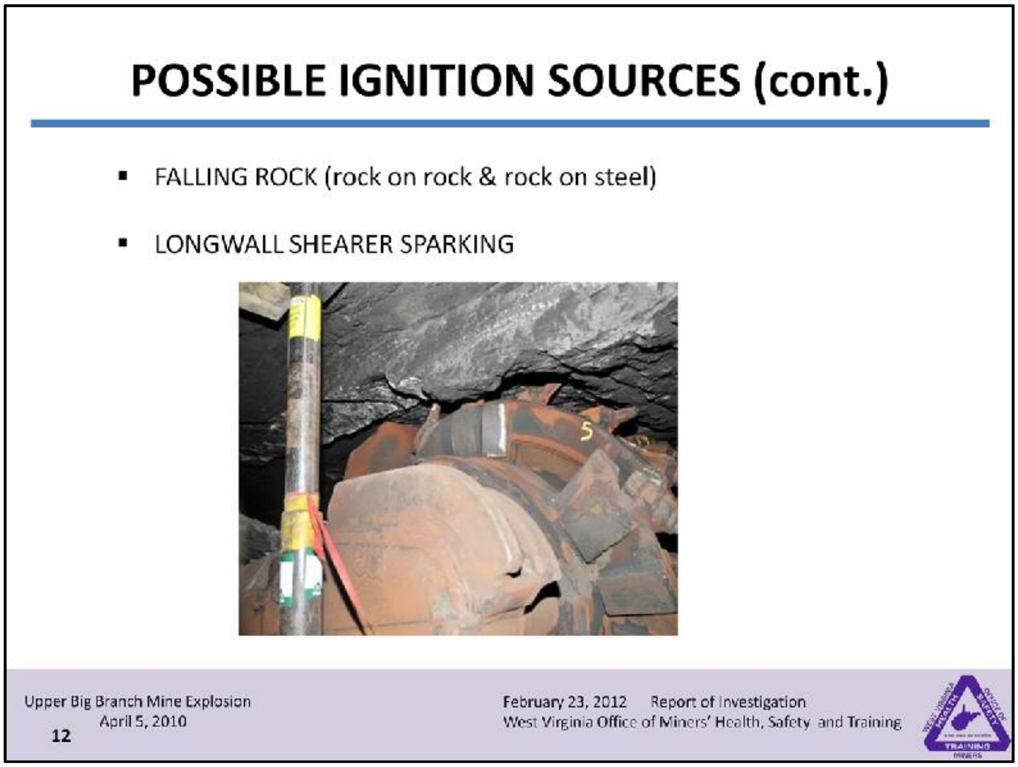
<u>**Slide 11**</u> The next 2 slides cover "POSSIBLE IGNITION SOURCES"

Smoking Articles were not a factor in the explosion.
Seismic Activity. Appendix 2.2-1 of our report addresses these events at UBB prior to and after the explosion but there was no indication that seismic activity was a factor on April 5.

Lightning Strikes were also ruled out as a possible ignition source.
Embers from cutting & welding were an early focus, because welding and cutting was conducted on the longwall face on the midnight shift of April 5th to replace flights on the steel longwall face conveyor chain and to repair the headgate side cowl of the shearer. There were also repairs made to the Shearer on the tailgate-side ranging arm b-lock on the dayshift but it is not certain if they had been cutting or welding during these repairs. We did not find evidence that welding or cutting provided an ignition source for the explosion.

Electrical. A systematic and through electrical inspection was conducted on the surface and underground during our investigation. Approximately 120 pieces of equipment were examined in the explosion region of the mine (areas located inby 78 break), including all the face equipment. Additionally the longwall was a huge area, with hundreds of electrical items which were checked, examined and tested.

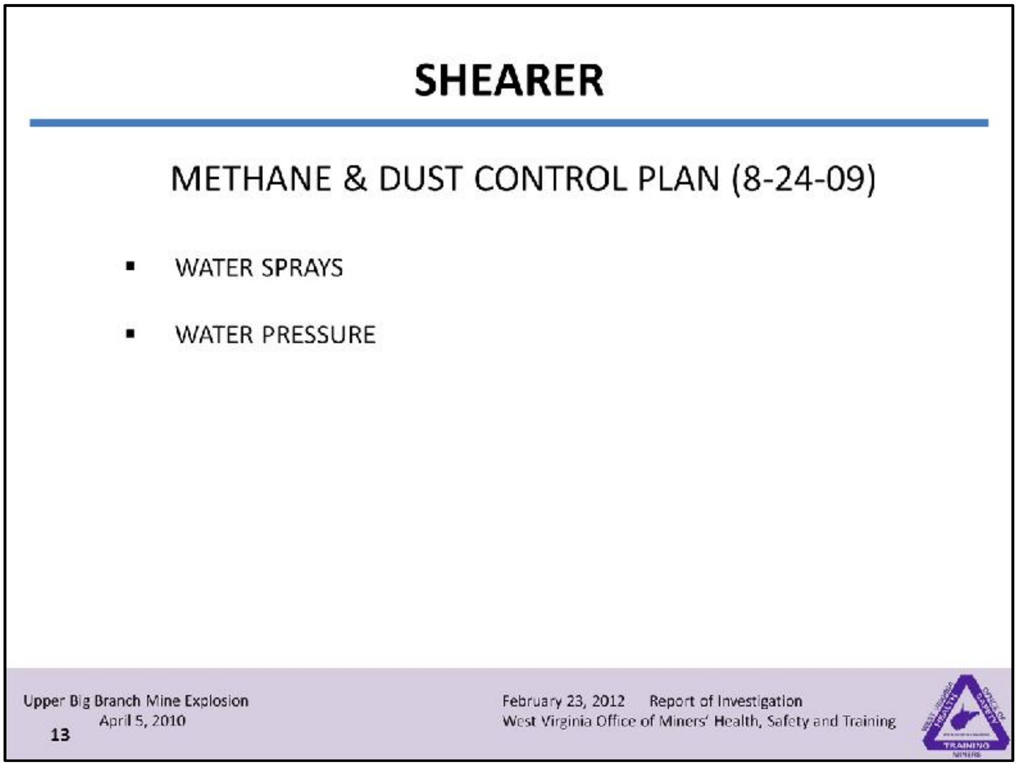
There was no indication that electrical equipment failure or malfunction contributed or caused the explosion on April 5, 2010.



<u>**Slide 12**</u> The final 2 of the POSSIBLE IGNITION SOURCES were examined most thoroughly.

Falling rock (rock-on-rock, rock-on-steel). It has been demonstrated that sandstone rocks colliding and rubbing together while falling, **or** falling sandstone rocks striking the steel of the shields, can create sparks hot enough to ignite methane. Not all sparks created between falling rocks or rocks striking steel are incendiary, **but** it is possible to ignite an explosive mixture this way. Explosions from this mechanism have happened, even at this mine where an ignition in the gob behind the shields at the tailgate occurred January 4, 1997, **that ignition was attributed to falling rock**, the details of the 1997 ignition is attached in the report appendices 3.2-1.

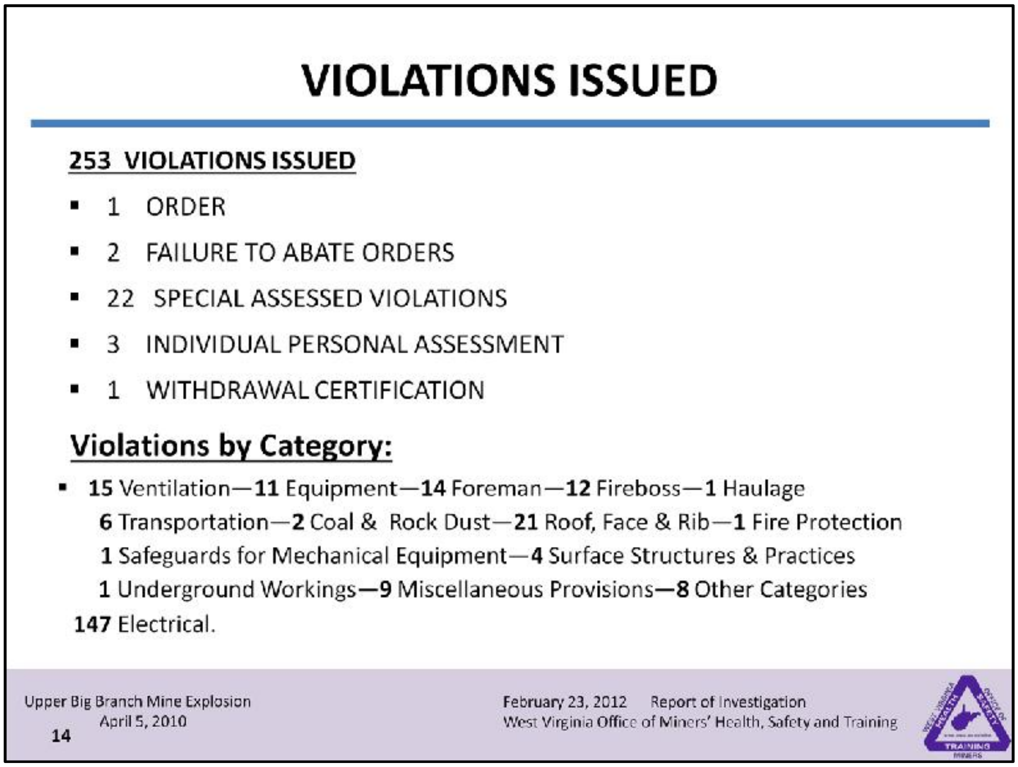
Longwall shearer sparking The cutting bits used on the shearer had tungsten carbide tips, inserted in steel. The tip is very hard and abrasion-resistant, much more so than steel. If the tip becomes worn (as a couple on the TG drum were) then softer steel of the bit can rub against the coal, or sandstone in this case, and rubbing of steel against sandstone can leave a hot streak behind the bit. For a very short time, about 20 milliseconds, this streak of hot material behind the bit, referred to as a smear, can ignite methane. This streak is hot enough to ignite methane for about 5 cm in length behind the bit; after that distance, it cools below the ignition temperature. This hot streak can be obtained with almost any bit material **but** is much more likely to occur with steel rather than tungsten carbide. This scenario is discussed in our report.



Slide 13 CONDITION OF THE SHEARER

The **Methane and Dust Control Plan** for the #21 Longwall Section was not being complied with on April 5th. Multiple sprays were missing from the Tail Drum when it was examined on December 20, 2010. This condition would have drastically reduced the required water pressure specified in the approved plan. When the water system was checked on December 20, 2010 the machine could not deliver the required pressure at the sprays on the tail side of the shearer due to the missing sprays.

The last slide in this portion of the presentation is a list of violations and enforcement actions taken as a result of our investigation.



Slide 14 VIOLATIONS

WE ISSUED 253 VIOLATIONS DURING OUR INVESTIGATION
WHICH INCLUDE:

1 ORDER
2 FAILURE TO ABATE ORDERS
22 SPECIAL ASSESSED violations

We have broken these SA violations down by category.

15 Special Assessed Violations were issued pertaining to ventilation
13 V's on plan submittals, or lack of ventilation submittals.
1 V for not complying with phase 2 of the Ellis Const. plan &
1 V for not having enough air on the Longwall, to render harmless and carry away flammable or dangerous gases on the day of the explosion.

4 Special Assessed Violations were issued under Misc. safety provisions, which includes

1 Violation for running the Longwall shearer with sprays removed on March 1 2010, on the B Crew

1 Violation for operating April 5th with sprays missing from the tail drum (12-20-10 TESTS)

<u>1 Violation for operating April 5th without the required water pressure at the tail drum spray on April 5. (12-20-10 Tests)</u>

1 Violation for not reporting the April 5th accident within 15 minutes. (12-20-10 Tests)

2 SPECIAL ASSESSED VIOLATIONS on rock dusting, non- sufficient rock dust being applied & maintained UG at UBB.

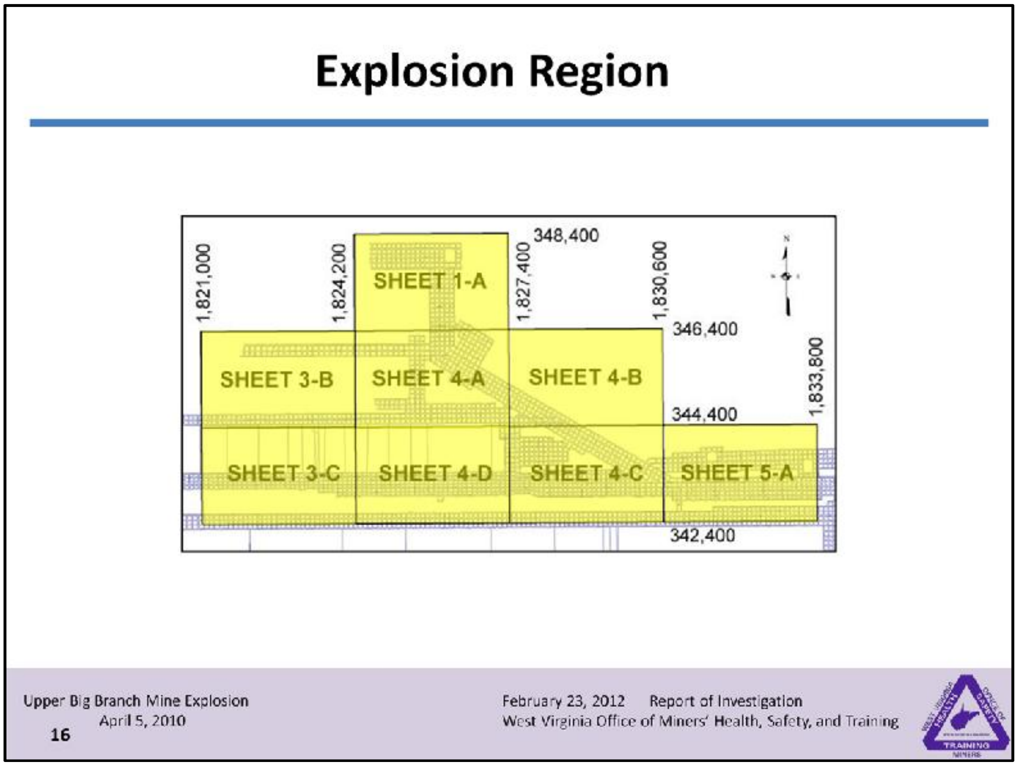
1 SPECIAL ASSESSED VIOLATION under fire protection where a water line at LBB, or Ellis Construction Site, was disconnected which made the firefighting line unusable from there to the Ellis portal.

3 IPA'S
1 WC

YOU CAN SEE THE VIOLATIONS BROKEN DOWN BY CATAGERY ON THIS SLIDE

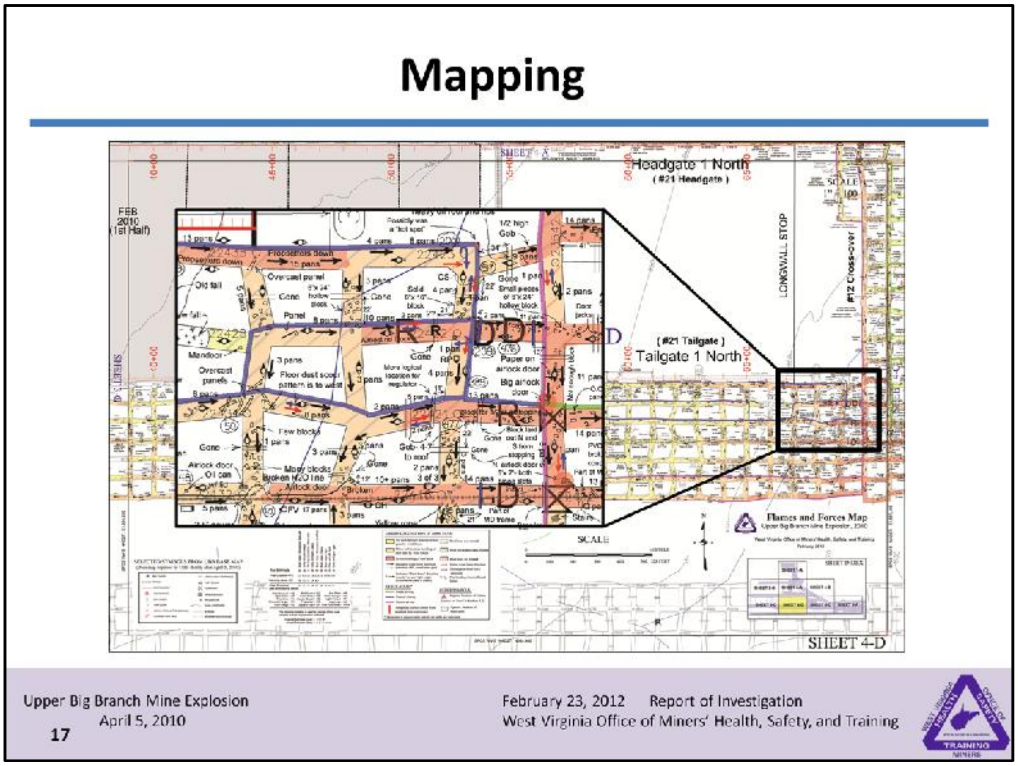
This concludes my portion, and at this time, I would like to turn the rest of the presentation over to our Chief Engineer, Monte Hieb.

Slide 15 (Blank slide) Begin 2nd presenter: Monte Hieb, Chief Engineer, Investigator.



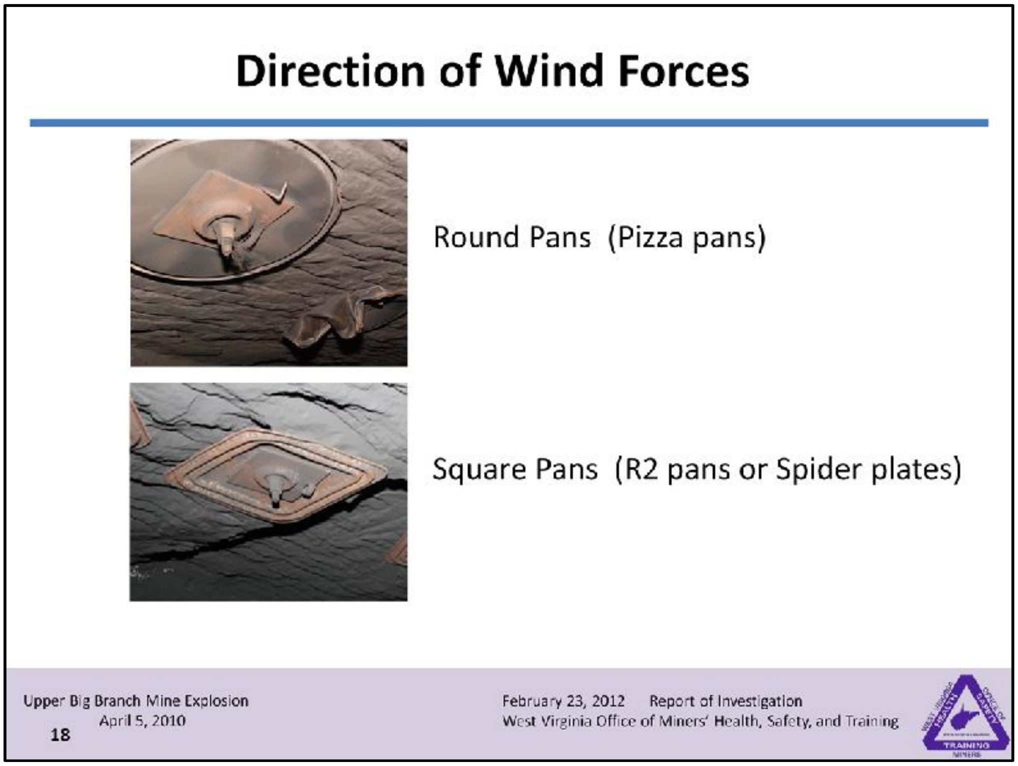
<u>Slide 16</u> The origin, direction, magnitude, and fuel of the explosion was determined in the part of our investigation referred to as "Fames and Forces." A summary of the of the documentary and investigative details from this effort can be found in our *West Virginia Flames and Forces Map* summarized in **eight (8)** separate sheets.

(click) These maps served as a working blueprint during our investigation, and are located in **Appendix 9** of our report.

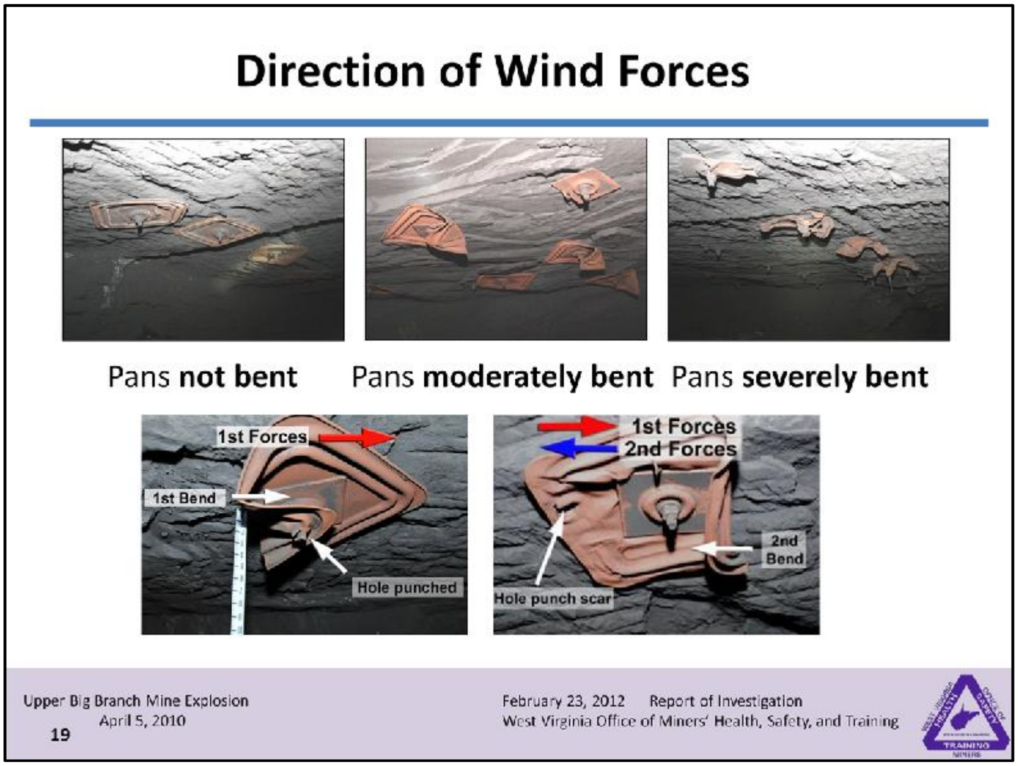


<u>**Slide 17**</u> An example of one of the maps is shown here.

(click) They document structural damage resulting from the explosion, deposits of explosion dusts, macro-coking deposits, and other details. This information was gathered and preserved to assist us in our investigation, and as a resource to determine appropriate measures to improve mine safety <u>and</u> for future research related to that objective.



Slide 18 One aspect of this effort focused on comprehensive documentation of the direction and sequence of wind forces through systematic description of damage to roof pans. Both round and square roof pans were typically installed under roof bolts at UBB as a supplemental roof control protection measure during mining. Explosion forces bent these and damaged their finish in ways that were useful for determining the direction the magnitude and the direction of propagation of explosion forces.



Slide 19 Our maps classify pan bending into 3 categories:

Pans that are "not bent" means that their angles of bending from explosion wind forces was < 90 degrees.

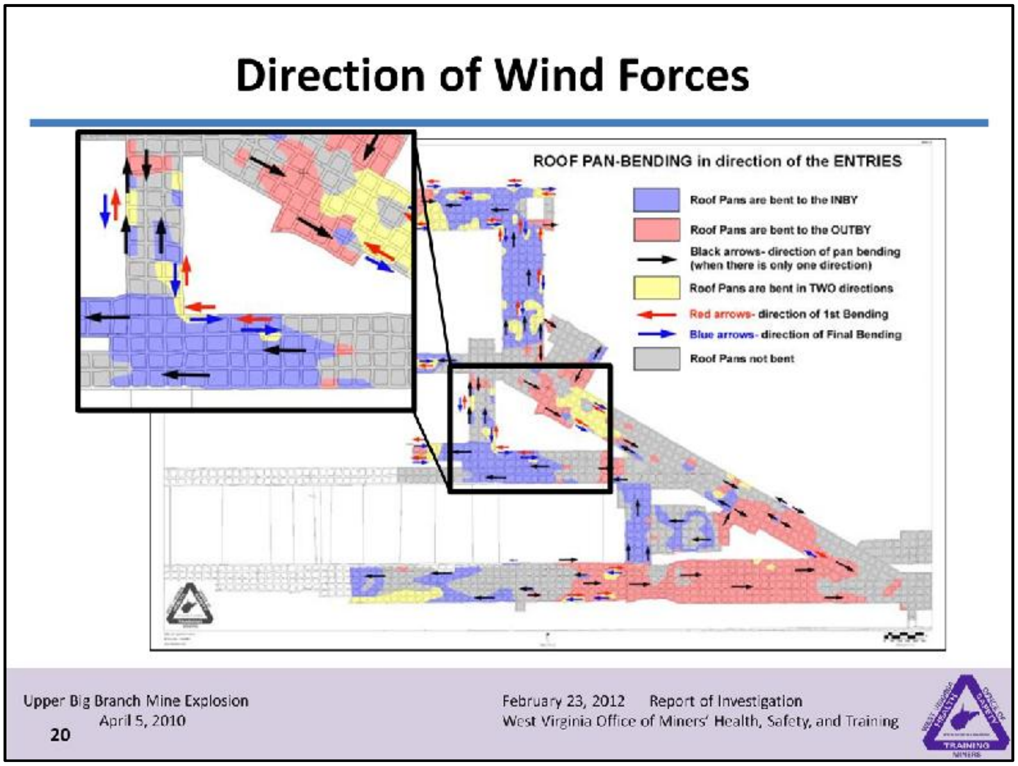
Pans that are "moderately bent" means that their angles of bending were > 90 degrees. Roof pans falling into this category were counted in the crosscuts and entries between intersections, and their numbers and directions of bending were recorded.

Pans that are "severely bent" means most or all pans are bent at angle(s) greater than 90 degrees, which was often accompanied by their tearing and twisting.

(click) Sometimes the pans were bent first one way, and then another. The order of such bending was a useful indicator of the sequence of wind forces.
In this example, the bottom left photo shows a roof pan whose corner was bent over the roof bolt by the initial wind forces, and a hole was punched into this corner by the protruding roof bolt.

The pan in the right photo was bent and punched the same way, as evidenced by the hole punch scar, but subsequent wind forces traveling right-to-left straightened it back against the mine roof, and also folded the opposite pan edge in the same direction.

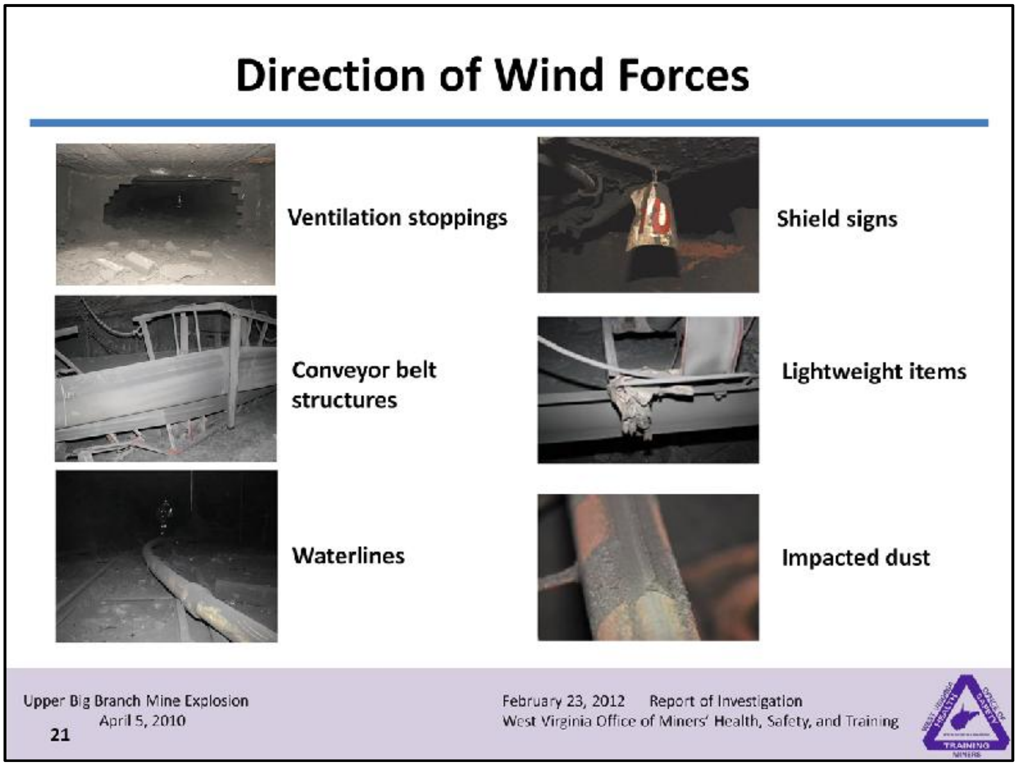
This is one example, of the indicators used to help determined the relative sequence of wind forces from the explosion.



<u>Slide 20</u> Individually, pan damage did not readily lend itself to interpretation, however as the pertinent details were carefully recorded and systematically mapped the pattern of explosion forces gradually emerged. West Virginia investigators classified and mapped these pans across as much of the explosion region as could be safely accessed. Smaller summary maps like this one distill the information by subject so that they could be more readily compared analyzed.

This *particular* map summarizes the bending patterns of the roof pans in the direction of the ***mine entries***.

(click) The <u>gray</u> regions are <u>*quiet*</u> areas where there is virtually <u>no</u> pan-bending from explosion forces. The regions shaded in <u>blue</u> are where pans are bent > 90 degrees to the <u>inby</u> and the regions shaded in <u>red</u> are where pans are bent > 90 degrees to the <u>outby</u>. The <u>yellow</u> regions indicate where pans are bent both ways. Red arrows indicate the direction of first bending, and blue arrows the direction of subsequent bending. When the bending sequence of individual pans could be determined, the 1st and Final bending directions are shown with red and blue arrows, respectively.

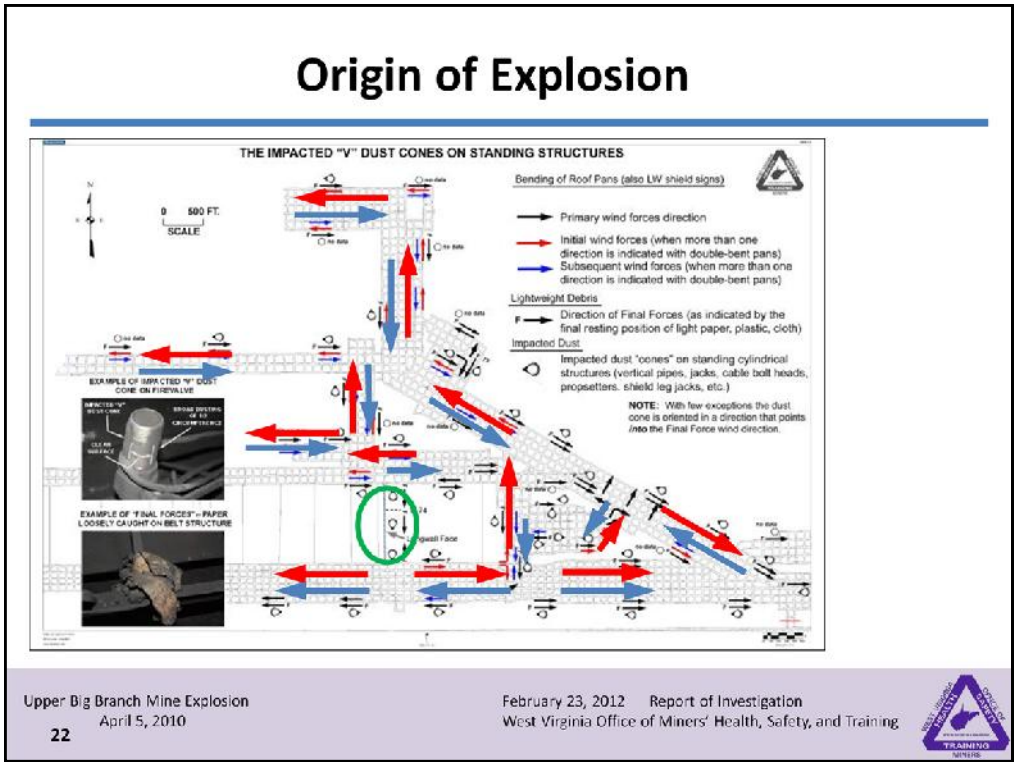


Slide 21 Other types of structural damage were similarly classified and recorded, including:

1. the directions in which ventilation stoppings were breached by explosion forces,
2. the directions that conveyor belt structures were deflected,
3. and the direction waterlines were deflected.

4. Along the longwall face, where there were no roof pans, we found that the modes of damage to hanging sign tags that numbered the shields were useful indicators of the direction of initial explosion forces there.

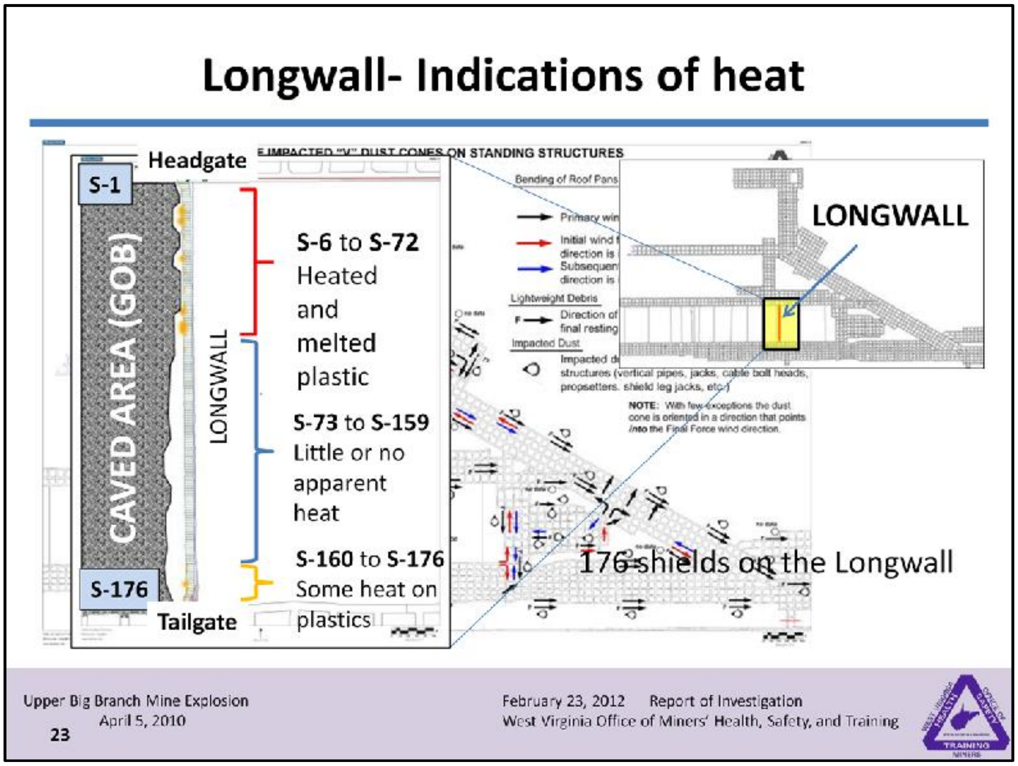
5 & 6. We similarly developed a system of the documenting Final Wind Forces which passed through each area. Evidence used included lightweight items like paper, plastic, and cloth that were loosely caught in a way that identified the direction of final wind forces, and also included impacted dust deposits on stationary cylindrical structures. These last two indicators, when combined with the roof pan data, and other information helped us determine the sequence of the explosion through the mine.



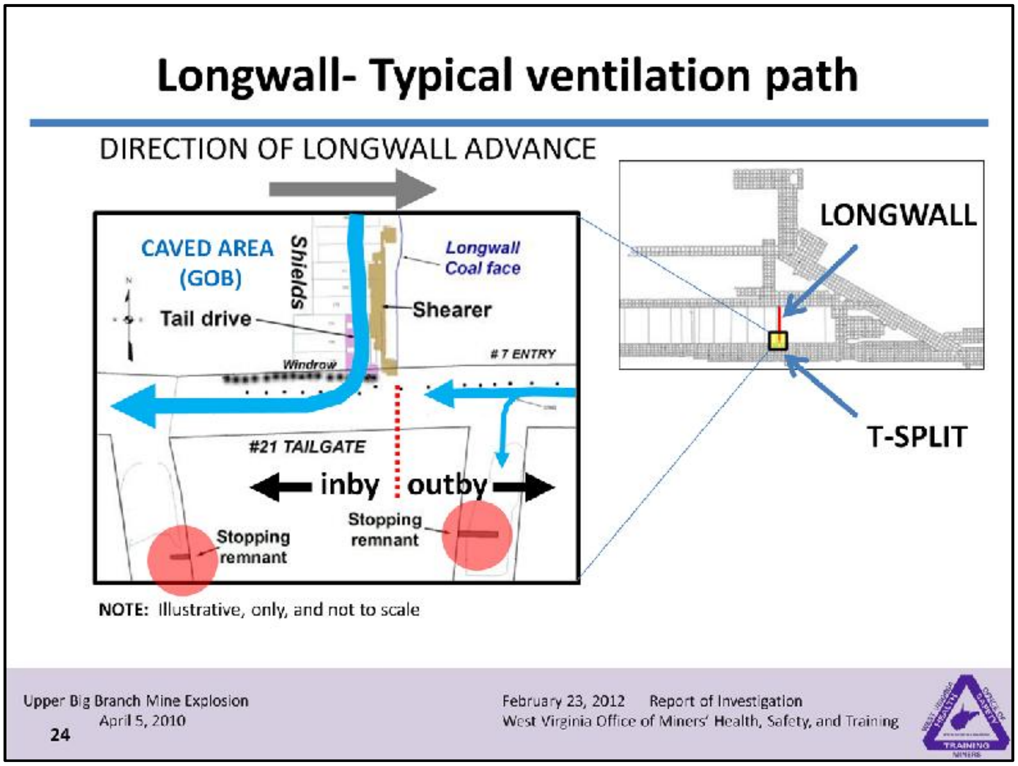
<u>Slide 22</u> By comparing roof pans and Final Force indicators we were able to determine the origin of the explosion using a *process of elimination*.

(click) Beginning at the *dead end* headings, we used this and other information to determine the direction of the ***first wind forces*** and the ***final wind forces*** of each area. For instance, dead ends where explosion forces *<u>first</u>* entered, *<u>then</u>* exited, could be discounted as the explosion origin.

(click) By doing each area this way, the candidate locations were reduced to just a few possibilities. It was there determined that the longwall region, specifically the region near the tailgate between Shield 117 and Shield 173, was where the explosion originated.

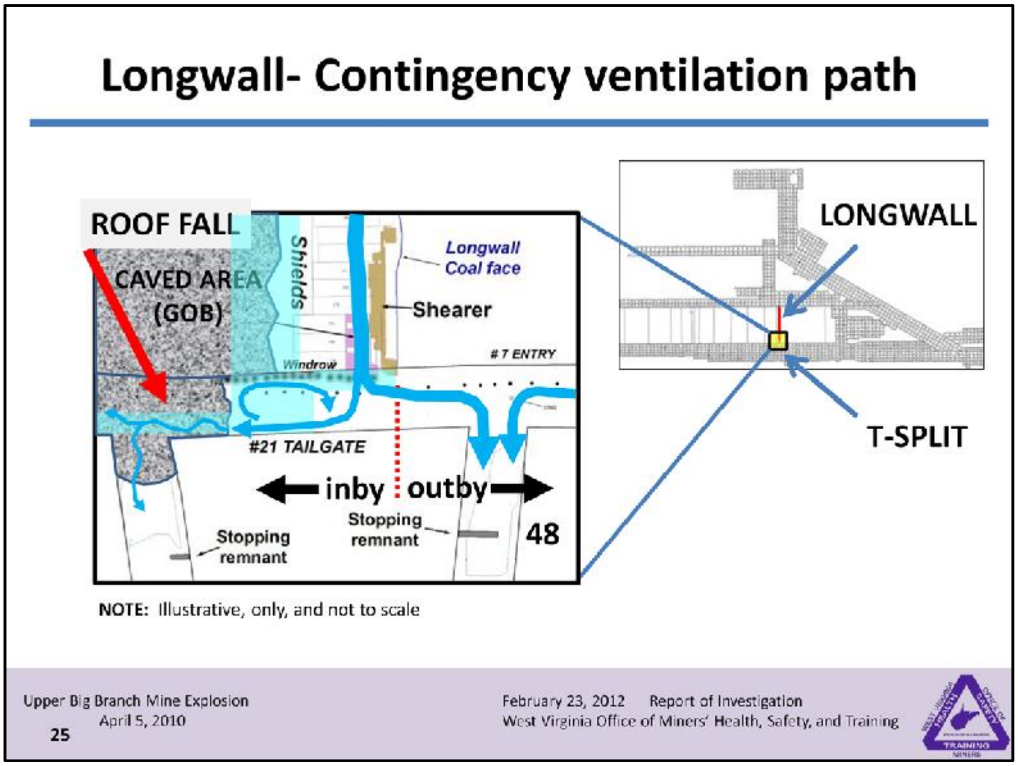


Slide 23 Indicators of heat, pressure, and wind forces on the longwall were mapped and analyzed. The most extensive heating and melting of plastic shield components on the longwall was found between Shields 6 and 72. There was a region of heating also at the tailgate, between Shields 160 and 176. There was little evidence of heat in the middle part of the longwall.



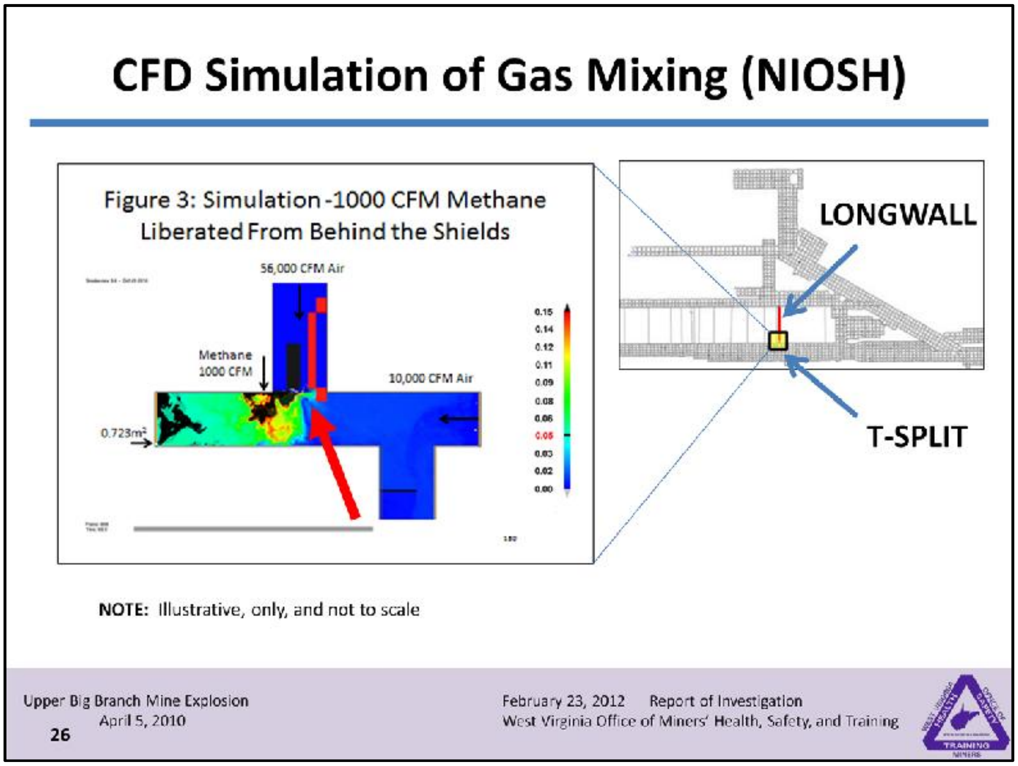
Slide 24 In the tailgate region of the longwall the ventilating air currents exiting the longwall merged and flowed west with the airflows in the #7 entry to the exhaust fan at Bandytown.

(click) Operationally, ventilation stoppings between the #7 and the #6 entries to the south were typically breached in succession as the longwall approached them in order to provide a contingency path for the return air from the longwall to go, in the event the #7 entry became blocked inby.



<u>Slide 25</u> Roof falls associated with the caving gob sometimes block the inby ventilation path, so any air volumes which cannot pass that way must exit through the next crosscut outby. This can result in eddy currents and inefficient air mixing until the longwall reaches the next outby crosscut, which here is #48.

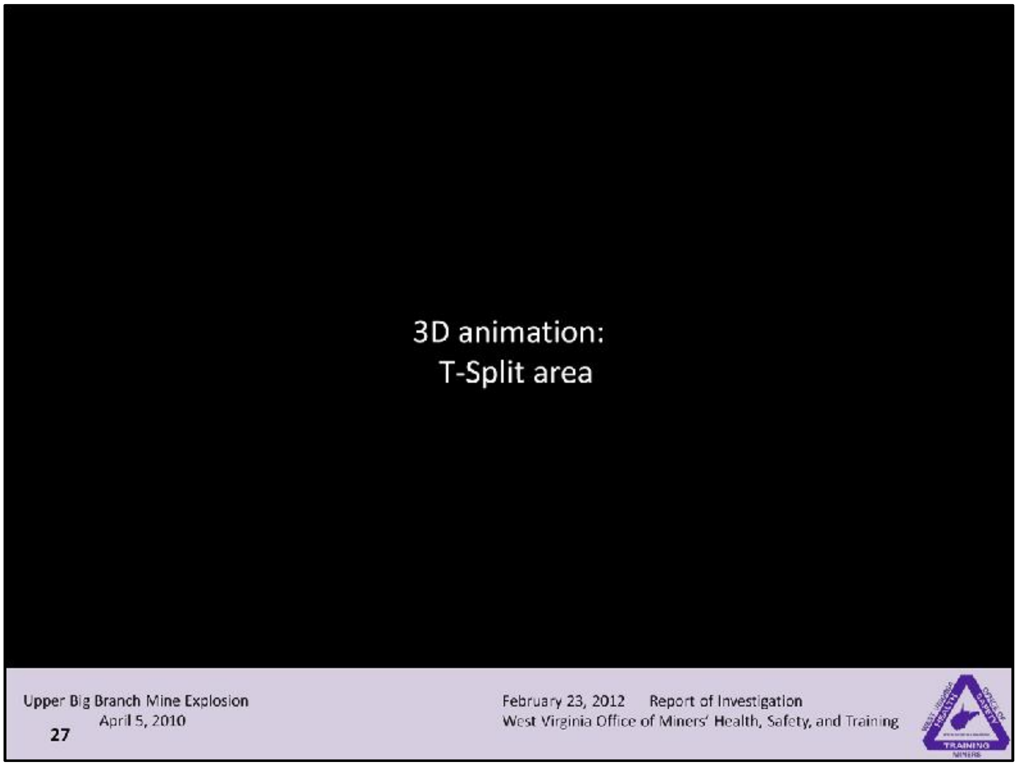
(click) This can also allow methane that is liberated from <u>behind</u> the shields to accumulate between the shearer and the roof fall. There are methane monitors on the shearer and on the Tail Drive that are designed to detect methane accumulations, but depending upon the location of methane liberations and the path of ventilation air it is <u>possible</u> that <u>some</u> gas accumulations might not be immediately detected. In such cases, additional monitors may be necessary.



<u>**Slide 26**</u> Computer simulations of the longwall “T-split” area, using the approximate geometries and airflows of the UBB longwall at the time of the explosion, show that gases liberated from the gob behind the shields <u>might</u> have been pulled near the shearer and exposed to sparking from the shear bits cutting sandstone roof.

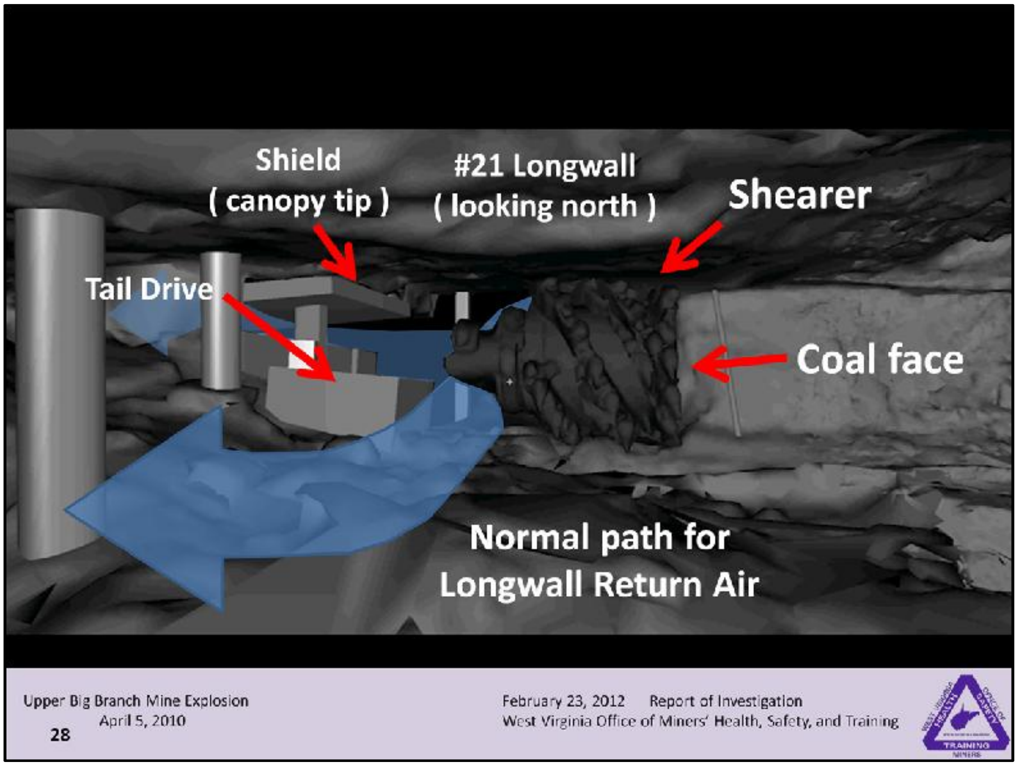
Available information suggests the flow of air through the longwall on April 5th was approximately 56,000 cubic feet per minute, and along the #7 entry neutral air split it was approximately 10,000 cubic feet per minute. This computer scenario assumes that 1000 cfm of methane was being liberated from behind the shields at the time, although the actual quantity is unknown.

The model is a simplified approach that does not duplicate all the geometries and events of April 5th, but it is a useful tool to demonstrate how subtleties like *eddy currents* and *wind shadows* can affect methane accumulations when the T-split becomes constricted.



<u>Slide 27</u> (blank slide) A special 3-D scanner was utilized at UBB to record the actual configuration of the mine in this part of the #21 Tailgate. A rendering of this data was prepared to display this area in a 3-D animation.

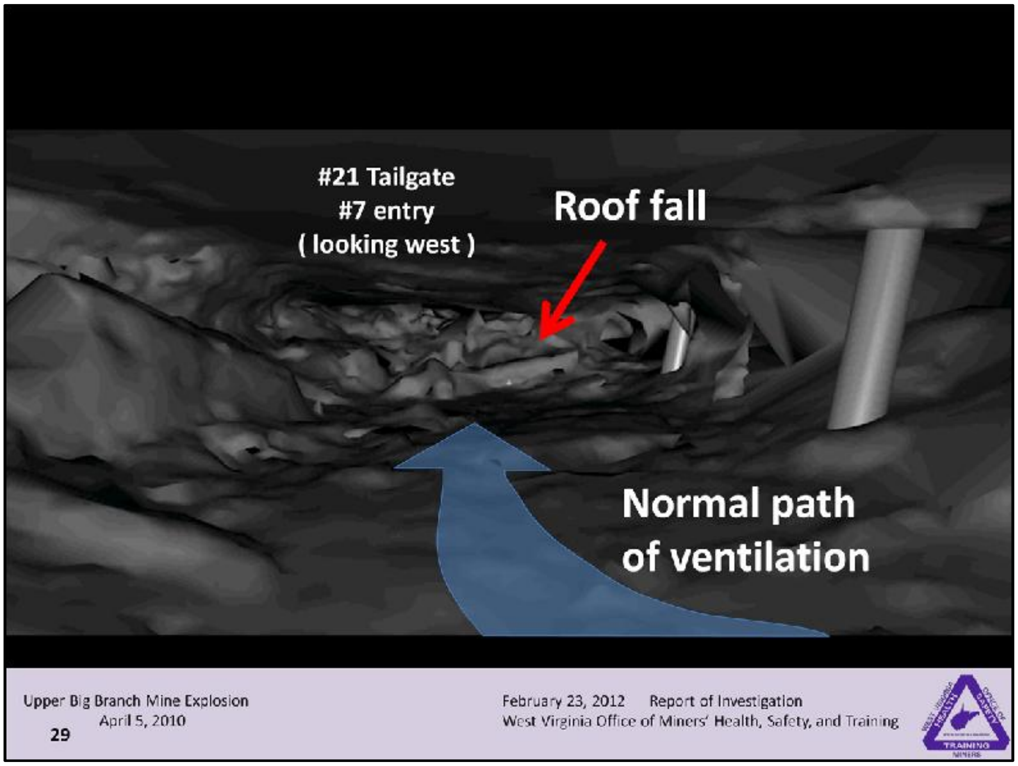
(NOTE: Powerpoint 10 or later is recommended to view the following animations. There may be a delay in video startup on some computers, depending how video and security are configured and the amount of random access memory or *RAM* available. The computer used for the presentation was an HP Elitebook 8760w, running Windows 7 with 16 GB RAM.)



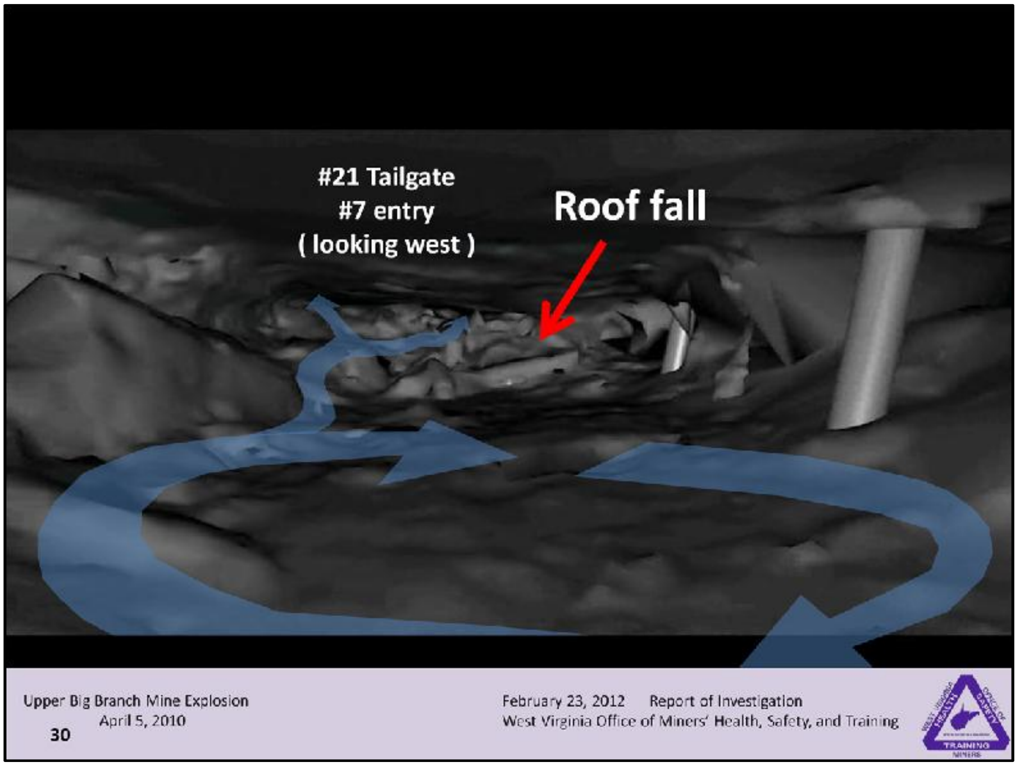
<u>**Slide 28**</u> In this view we are moving from the roof fall in the #7 entry toward the mouth of the Longwall, where the shearer cut out into the #7 entry. We are looking at the Tailgate Drum of the Longwall Shearer, which had just punched through, almost completing its 3rd pass of the shift on April 5th. We are looking north, parallel to the longwall in this view. The Longwall Shearer travels north-to-south as it's two (2) rotating drums cut coal from the solid longwall face. The longwall face is 1000 feet long.

(**click**) Heavy hydraulic shields support the mine roof as the longwall advances. There are 176 shields on the longwall, and we are looking at shield 176. The Tail Drive is the box between the shields and the shearer which helps drive the chain conveyor.

(**click**) Approximately 56,000 cubic feet per minute of air ventilate north to south through the longwall. The <u>preferred path</u> after it exits the longwall is to travel with the #7 entry return to the exhaust fan at Bandytown, as shown here.

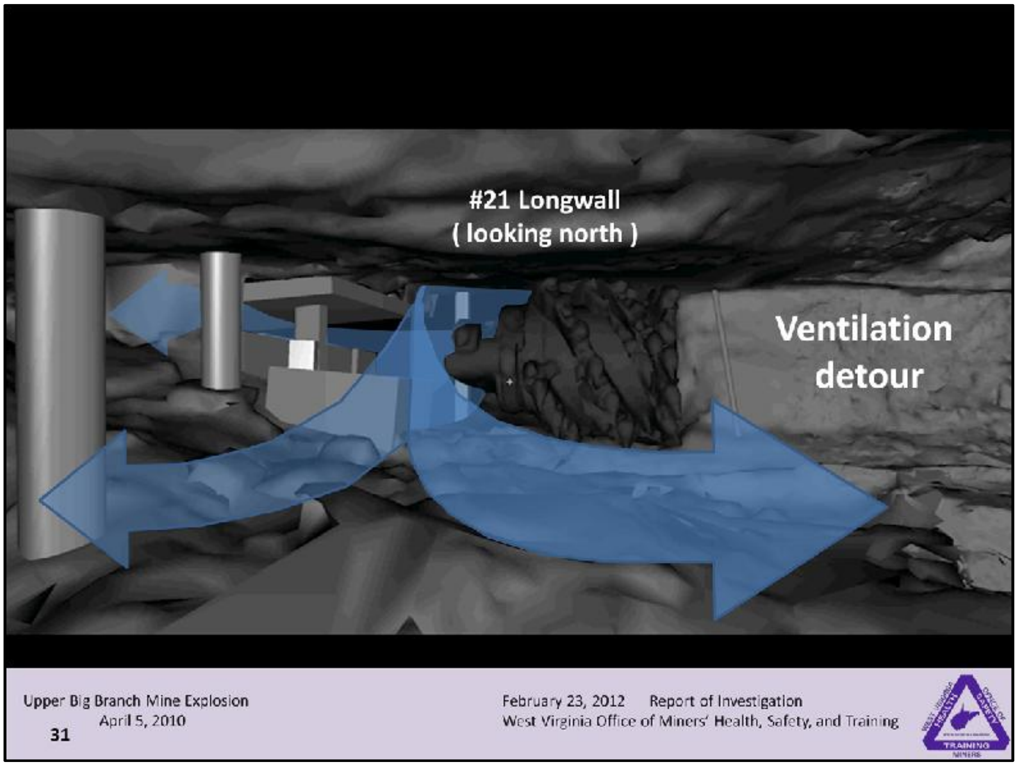


<u>Slide 29</u> Timbers are used to help support the roof in this entry until the longwall advances to the next open cross-cut. However, a roof fall had occurred approximately 45 feet west of the longwall which <u>would</u> have a least partially blocked the air currents from traveling this way.

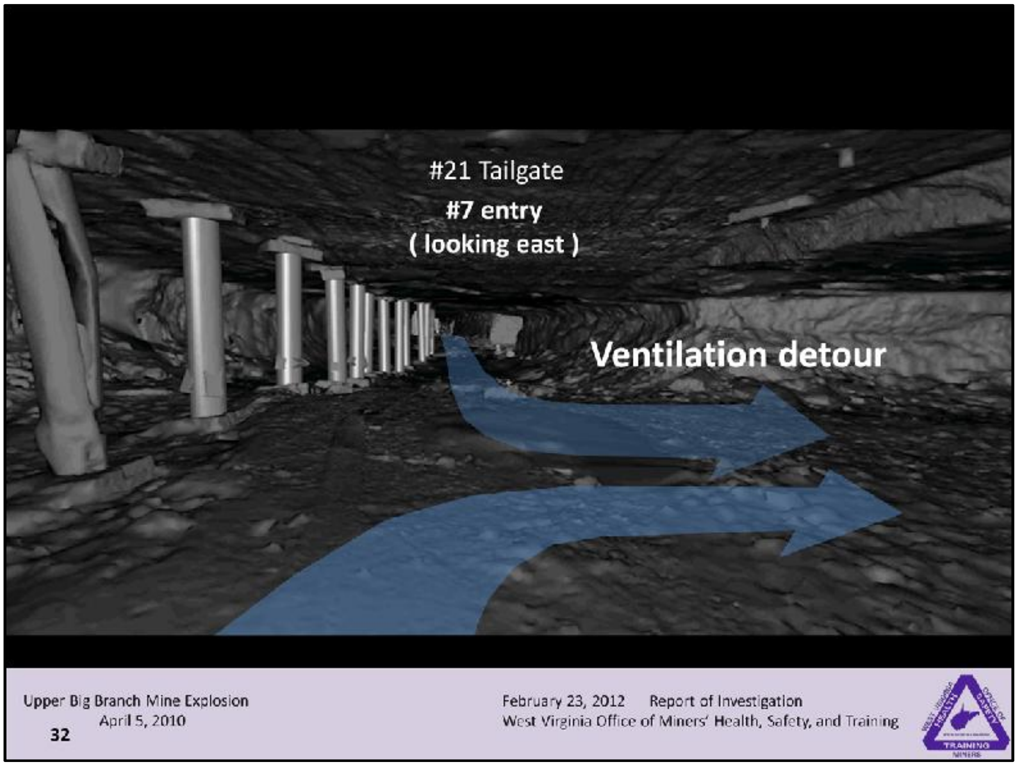


Slide 30 It is recognized that caving roof behind the longwall will fall across the tailgate entry and close it off, but best practices would require sufficient supports in the tailgate entry so as to delay the closing immediately behind the longwall face. This is a sensitive area in the longwall ventilation, as a blockage here can produce eddy currents in the "T-split" that result in incomplete air mixing and gas accumulations.

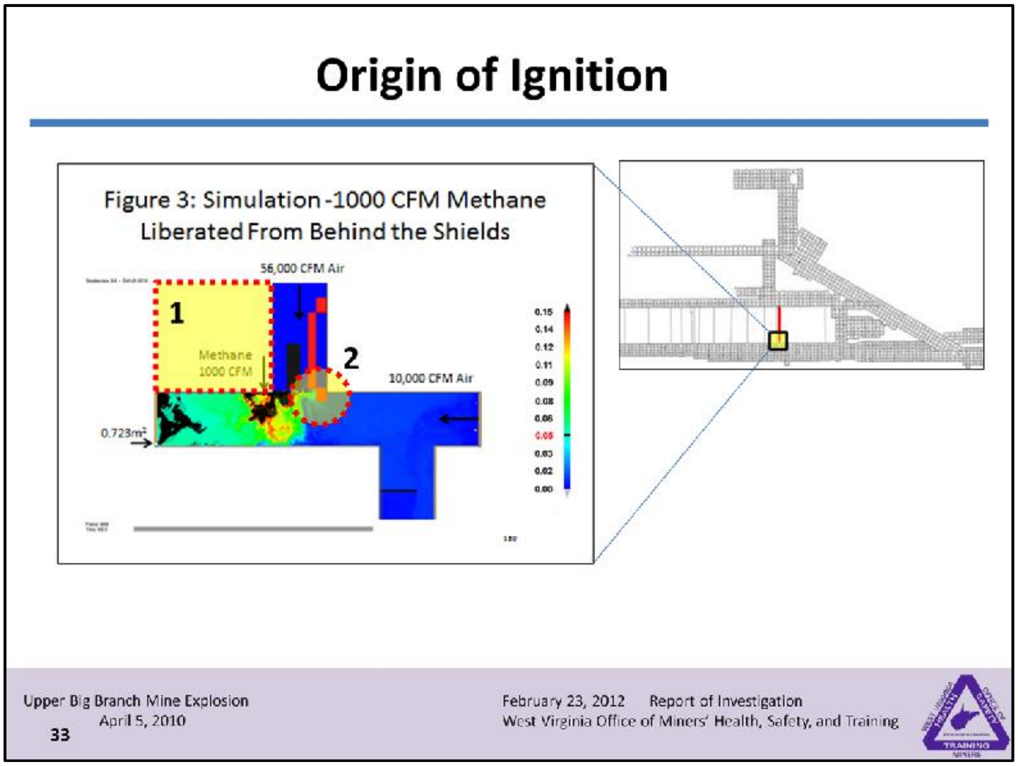
(**click**) The windrow of coal and the steel wall we see on the right can allow methane buildups near eddy currents to move toward the shearer, as suggested by the NIOSH models.



<u>Slide 31</u> When the #7 entry becomes blocked the affected air must take a <u>detour</u> to the <u>first</u> open cross-cut east of the longwall. To the extent that the roof fall is just partially blocked, some air also may flow inby (west).



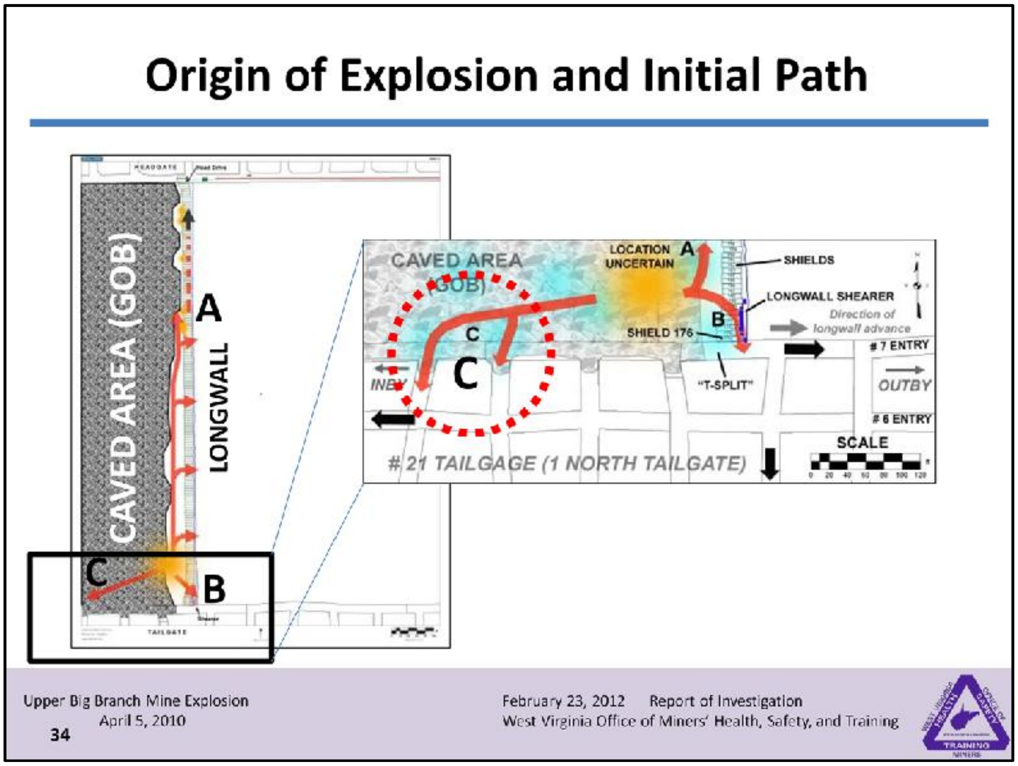
<u>Slide 32</u> The detoured air currents must travel outby about 30 feet to the open cross-cut at Break 48, where they meet approximately 10,000 cubic feet per minute of neutral air in the #7 entry. These two airflows mix and turn south and continue on to the Bandytown exhaust fan.



<u>**Slide 33**</u> Various origins for the ignition have been considered, of which two remain possibilities. Both involve methane as the fuel that was ignited.

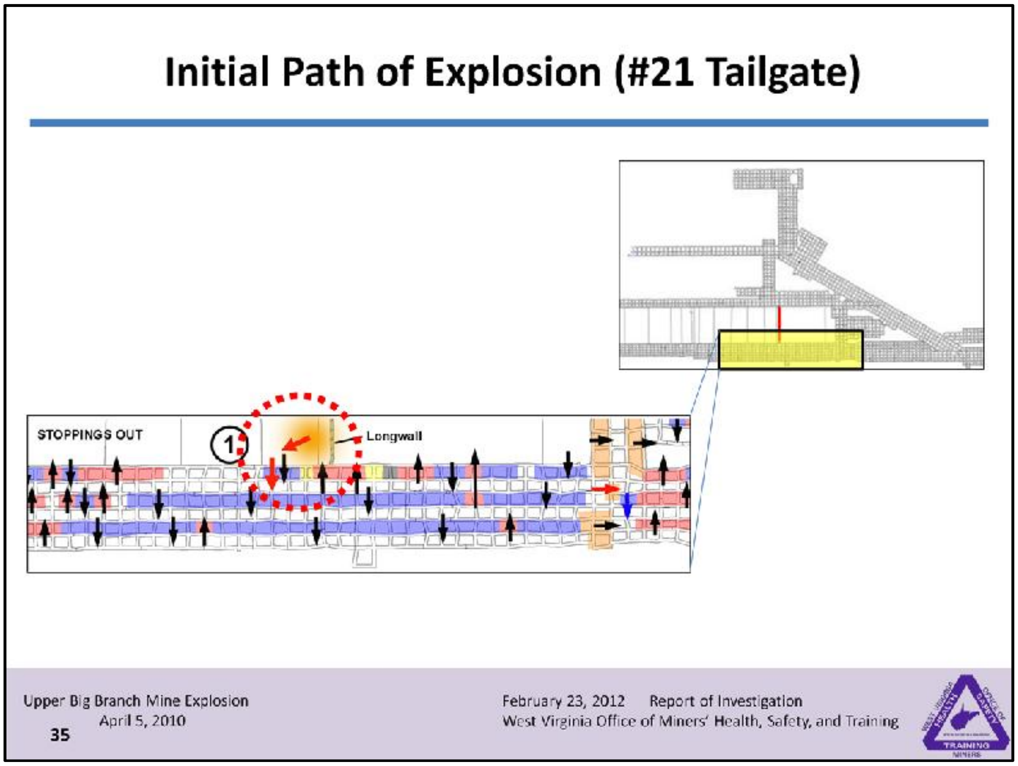
(click) The first possibility is that methane was ignited in the gob by frictional impact of sandstone rock colliding with steel supports or other rock while caving behind the longwall shields.

(click) The second possibility, and the ***most likely one***, is that the methane was ignited by frictional impact from the longwall shearer as it was cutting sandstone roof.
Once ignited, methane flame can travel some distance along a thin, flammable boundary between methane and air until the flame contacts a body of gas mixed with sufficient air to explode.



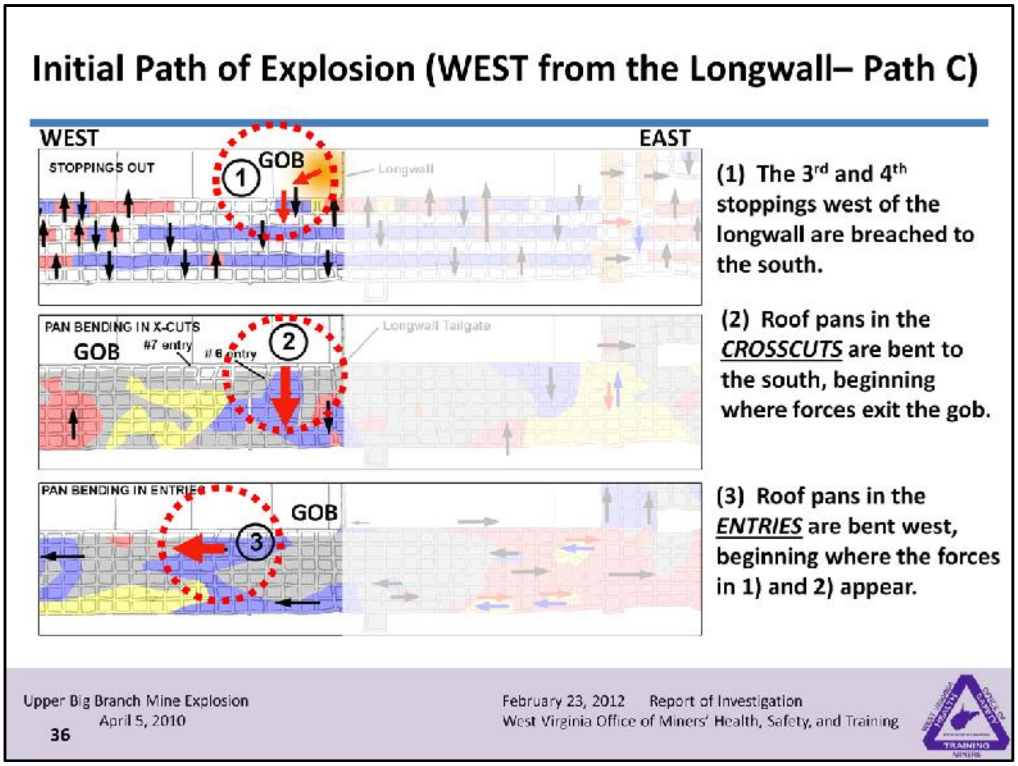
Slide 34 After a period of methane burning, a methane explosion occurred behind the longwall shields in the gob, somewhere between shield 173 and 117. From there, it appears to have propagated behind the shields to the north, along *Path A*, south, across the shearer along *Path B*…

(click) … and W-SW approximately 300-400 along *Path C*, where forces exited the gob and entered the #6 entry.



Slide 35 The part of #21 Tailgate indicated in yellow is where the explosion forces began their propagations both west and east. Parts of three (3) summary maps will be used to illustrate the direction of stopping breach and roof-pan bending, which are one of the indicators of the path(s) of the explosion.

(click) The first example will examine Path C, where explosion forces exited the gob behind the shields, approximately 300-400 feet west of the longwall.



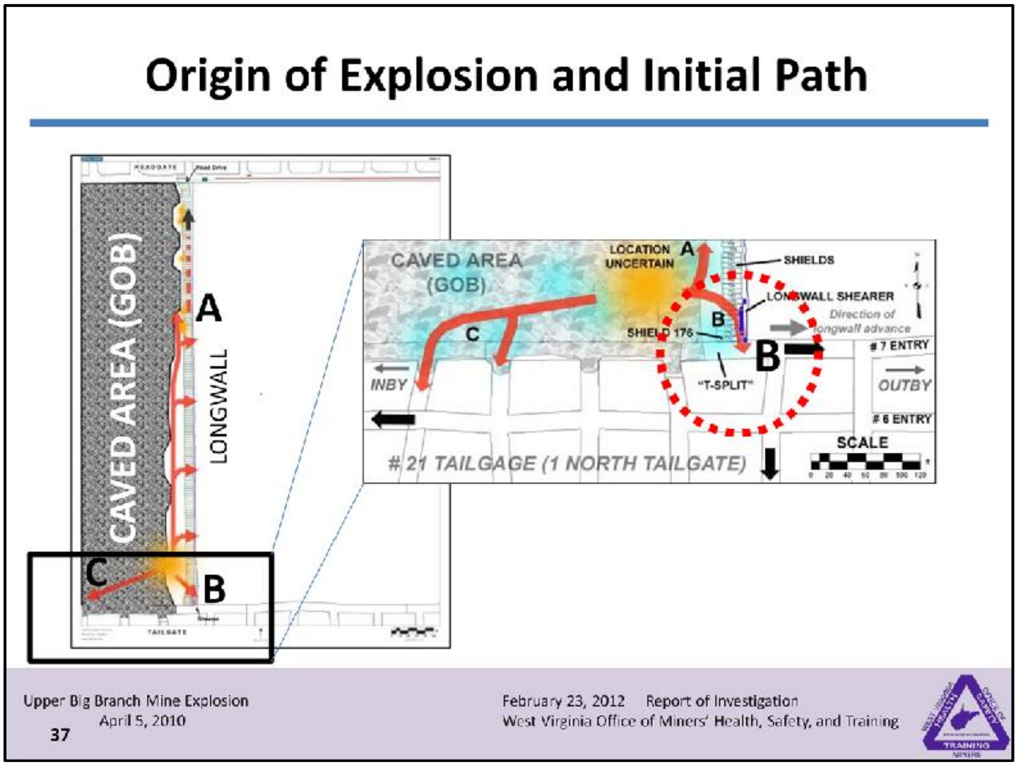
Slide 36 These three panels illustrate damage in the same region of #21 Tailgate. *Red arrows* indicate *Path C* of the explosion.

The 1st panel (top panel) illustrates the breach direction of ventilation stoppings from explosion forces. The regions shaded RED indicate where stoppings were blown north-- BLUE indicates where they were blown south.

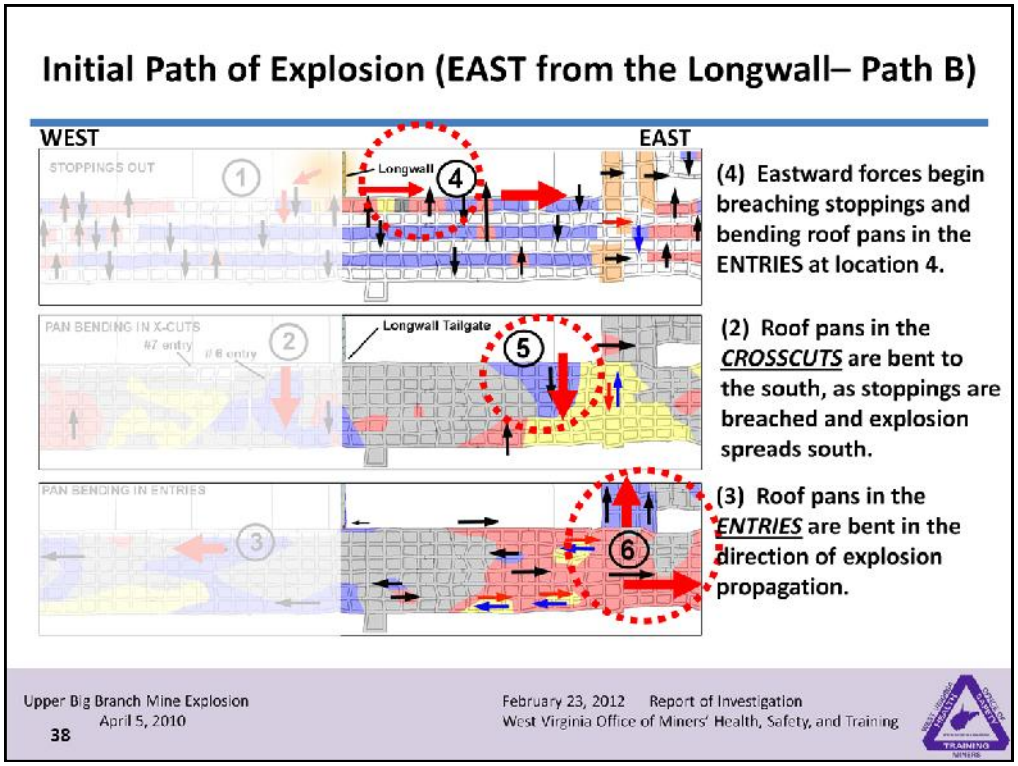
(click) The 3rd and 4th stoppings west of the longwall between the #7 and #6 entries were blown to the south, and these forces came from the direction of the gob.

(click) The 2nd panel illustrates the directions in which roof pans in the X-CUTS are bent. It shows that the forces exiting the gob bent the roof pans southward.

(click) The 3rd panel represents roof pan bending in the ENTRIES. It shows that at the location where forces appeared from the gob and traveled south, forces also traveled west with sufficient strength to bend roof pans in that direction.



<u>Slide 37</u> The part of the explosion that propagated east from the longwall in the #21 Tailgate is designated *<u>Path B</u>*. It began initially with forces from the gob entering the southern region of the longwall, then exiting the longwall, across the shearer.



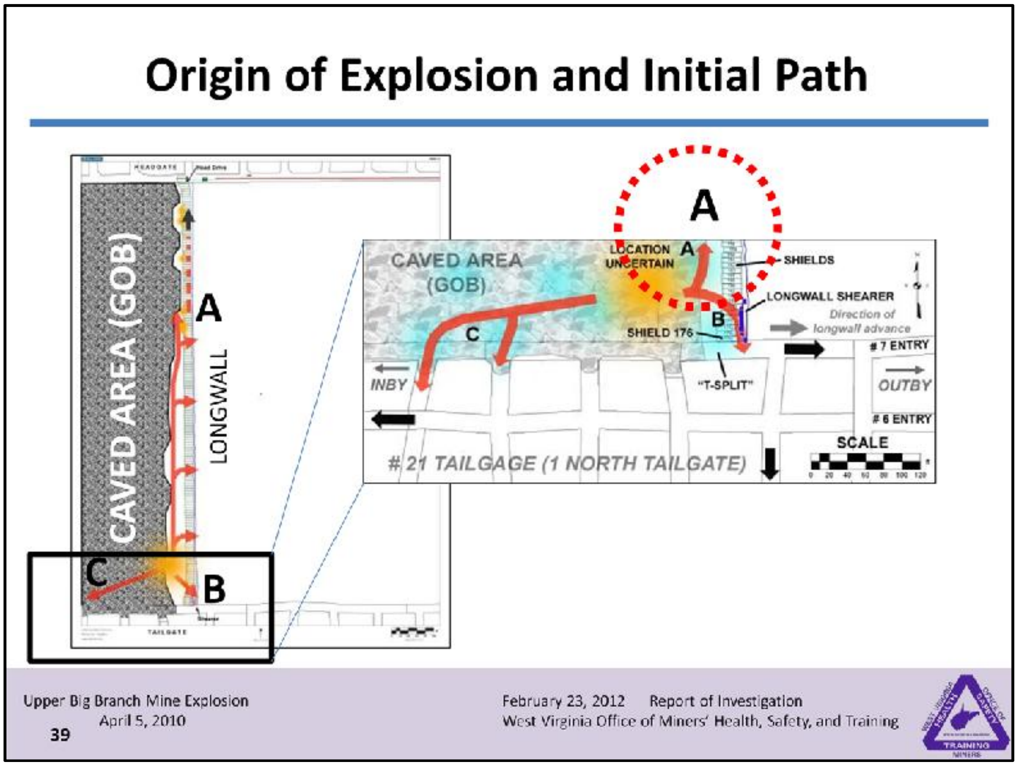
<u>Slide 38</u> From there the leading edge continued propagating eastward down the #7 entry, as forces also traveled south through the cross-cuts and eastward in the other entries. Initially, explosion forces here were not sufficient to bend roof pans nor topple stoppings. The 3rd stopping appears to have been recently repaired and was partially breached to the south.

By the time **location 4** was reached however, pressures were sufficient to breach *<u>some</u>* stoppings to the south and begin bending pans in the #7 entry to the east.

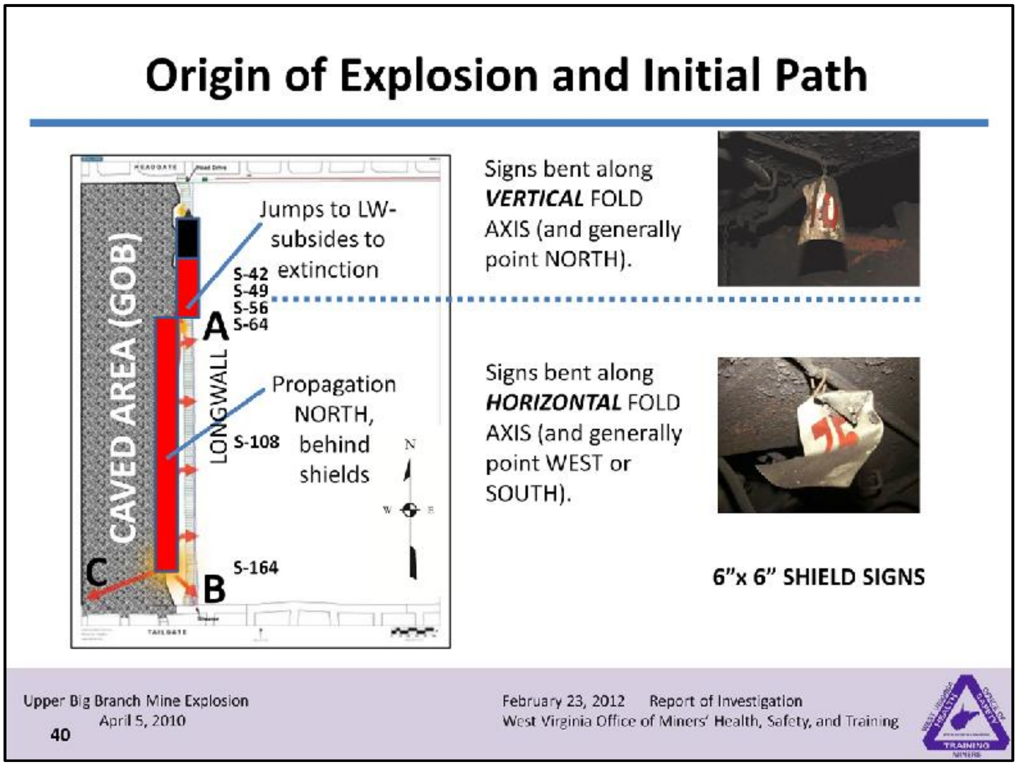
(click) When **location 5** was reached, wind pressures were sufficient to breach <u>all</u> stoppings southward, and bend roof pans in the cross-cuts to the south.

(click) At **location 6** explosion forces branched north into the #21 Cross-over while continuing east in #21 Tailgate. In the south, flame speed and pressures had increased sufficiently to produce severe roof pan bending.

The forces in #21 Tailgate propagated approximately 3000 feet more, then subsided to extinction, while the forces continuing north through the #21 Cross-over fueled the explosion to the rest of the affected region of UBB.



Slide 39 A third branch of the methane explosion in the gob (designated as *Path A*) appears to have traveled north of the explosion origin, behind the shields and along the edge of the gob.



<u>**Slide 40**</u> These forces propagated north along the gob fringe behind the shields, creating wind pressures through the shields and against the face of the longwall as they went-- until reaching shields 64 to 56, where forces became funneled into the longwall and where next they then subsided to extinction.

(click) Small aluminum signs hung from under the shield canopies developed two bending styles. These were studied to help determine the explosion path.

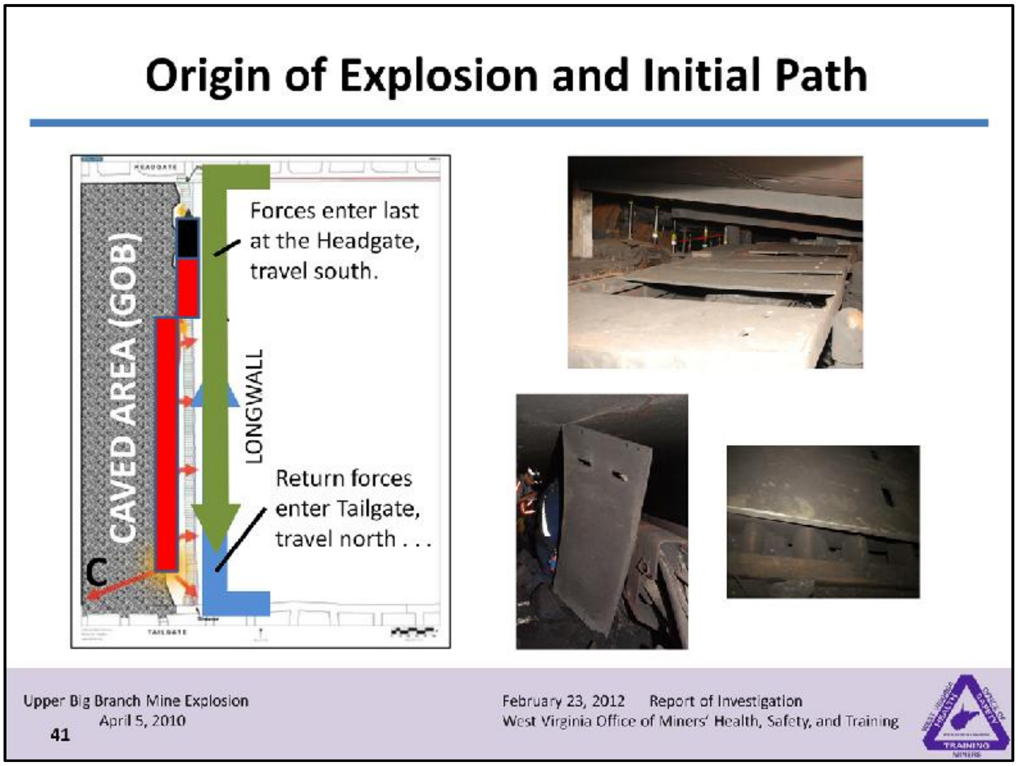
Signs hanging north of shield 49 were bent along a vertical fold axis and pointed generally to the north, toward the Headgate.

Signs hanging south of shield 56 were bent along a horizontal fold axis, and pointed generally to the south or west, toward the gob.

A study of the styles of bending of the shield signs was performed using special computer models, utilizing computational fluid dynamics. The analysis concludes that the characteristic horizontally-bent signs were not the result of wind forces traveling through the longwall, but were more likely the result of wind forces coming <u>from</u> the gob. The bent signs between shield 56 and shield 108 exhibited this mode of bending.

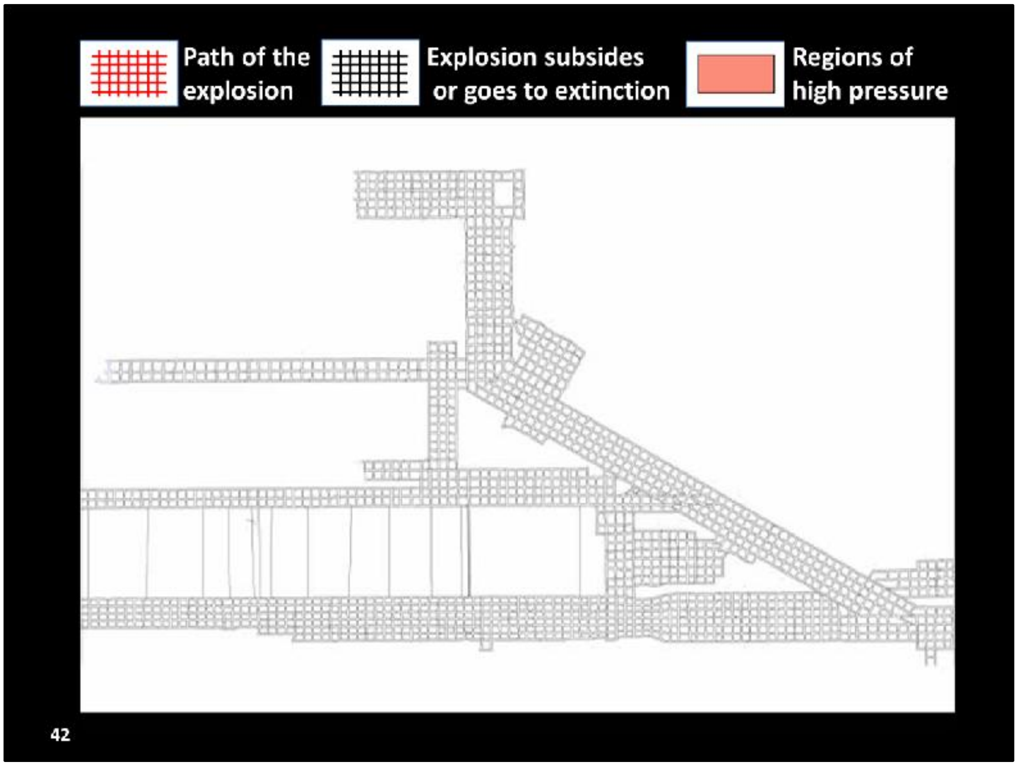
Between shields 64 and 56 there is a transition to the vertical-axis mode of bending. The surviving signs north of shield 42 were bent this way. The computer analysis demonstrates that signs folded along their vertical axes are from wind forces traveling in the direction of the longwall, not from the gob.

The highest apparent heating of plastic components on the shields occurred at shields 62 and 64. It is believed that the change in bending styles in this region is related to an obstruction in the gob that terminated propagation behind the shields and directed the forces into the longwall, where they did not find additional fuel, and where they subsided to extinction.



Slide 41 After the initial explosion, stronger wind forces returned to the Tailgate from the south. Two large aluminum covers were stripped off the top of the tail drive and transported 100 feet and 256 feet respectively northward.

(click) This was followed by wave of explosion forces from the Headgate, which carried a lid from the head drive, comtrol boxes, and other debris southward through the longwall. The final forces through the longwall traveled north-to-south, from the Headgate.

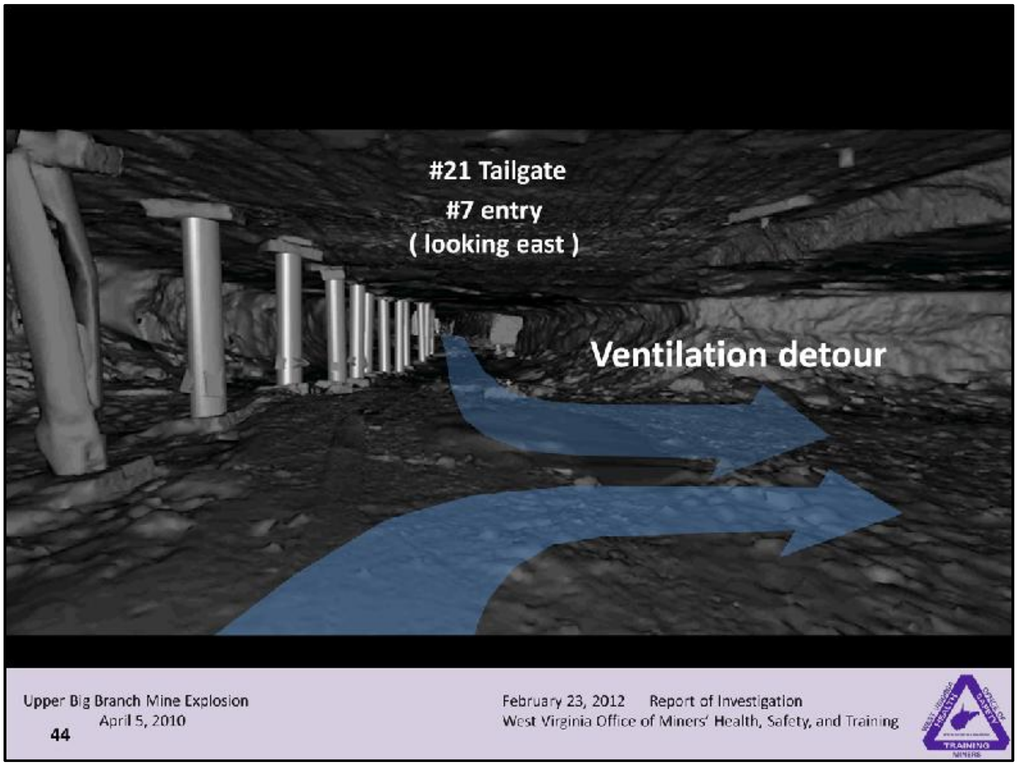


<u>Slide 42</u> An animation was created to illustrate how the explosion is believed to have spread through UBB mine from the #21 tailgate.

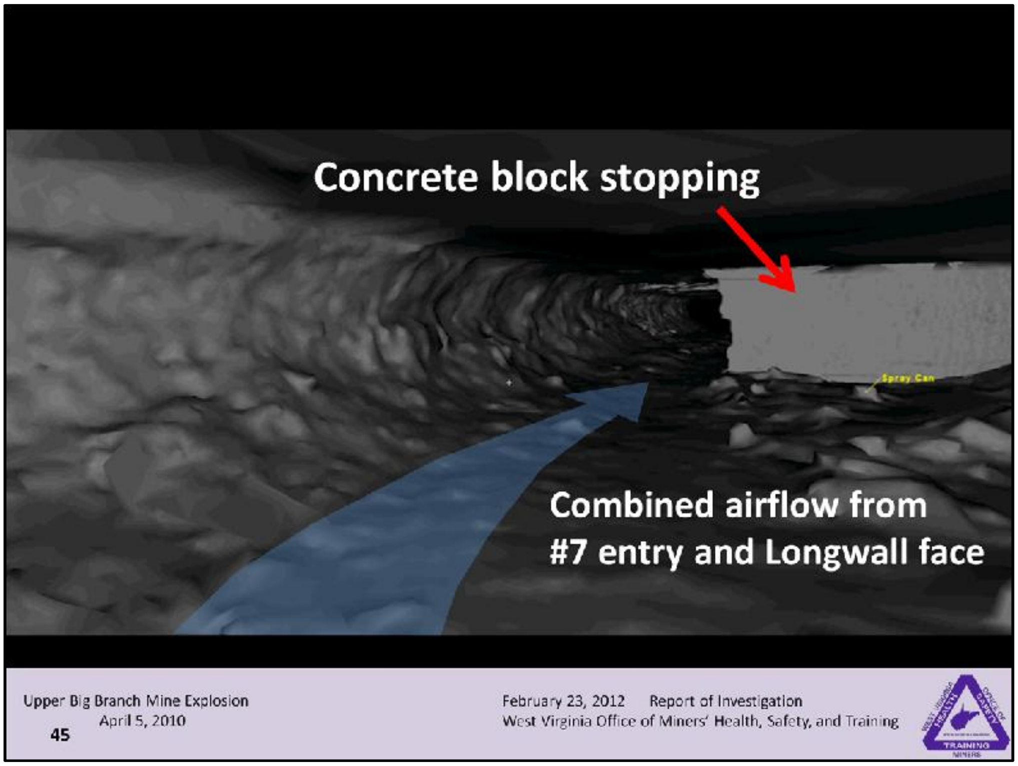
The initial wave of the explosion as it propagated through entries and crosscuts is shown in red. The solid pink regions are areas of high reflected pressure that are indicated from severe bending of roof pans. (High pressure regions developed where headings intersected and forces split, and in dead-ends of headings).

Regions where the explosion subsides or goes to extinction are indicated in black, which are areas where the explosion was unable to find combustible fuel.

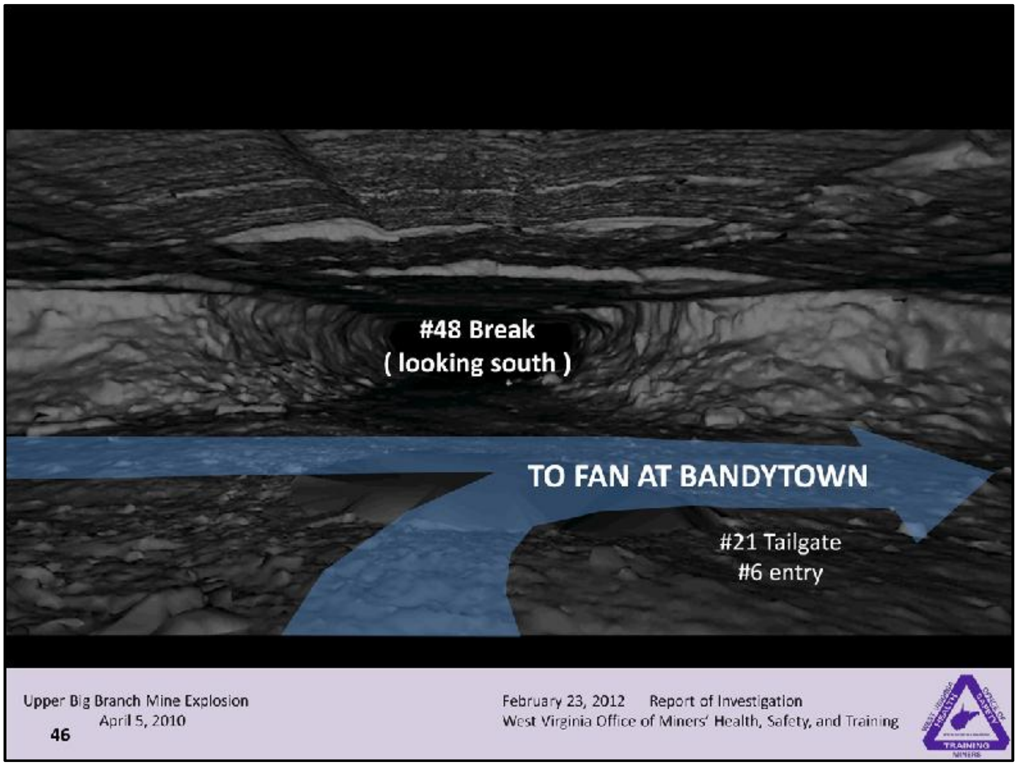
<u>Slide 43</u> Blank slide. Next we return to the shearer and the #21 Tailgate to continue a 3D tour using animation of our rendered 3D scanning of this region.



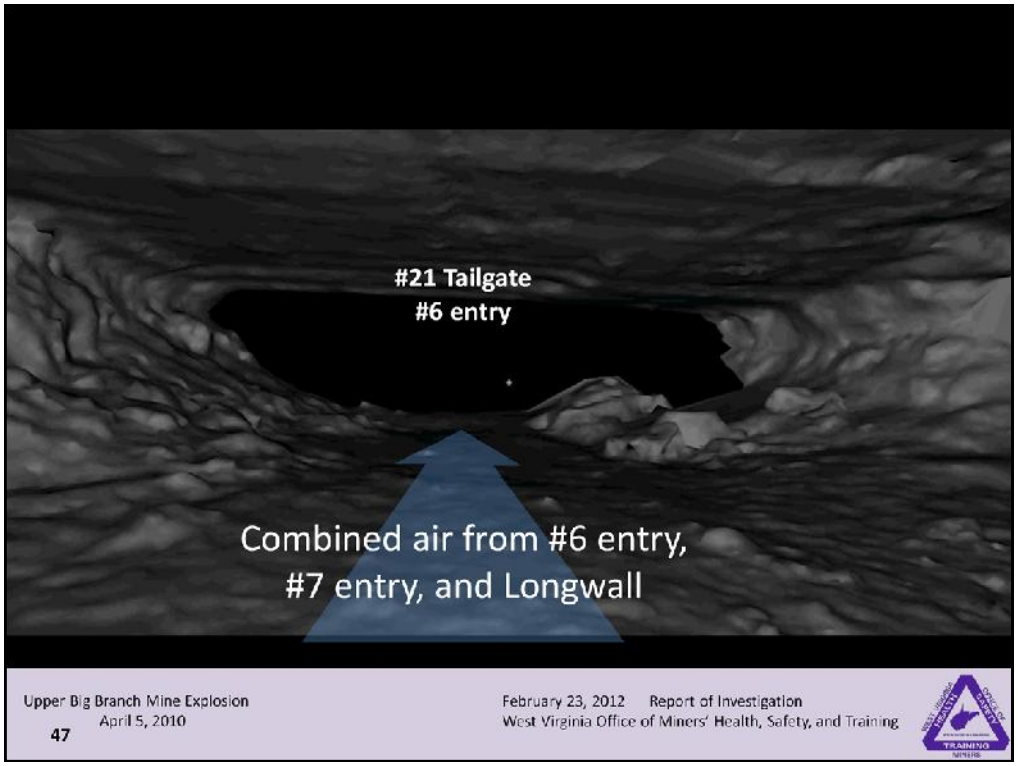
Slide 44 Starting at the shearer we travel east into the first outby intersection at Break 48 in the #7 entry. Due to the roof fall obstruction, most of the air currents in the #7 entry meet the detoured Longwall return air at Break 48, where they combine and exit south toward the #6 entry.



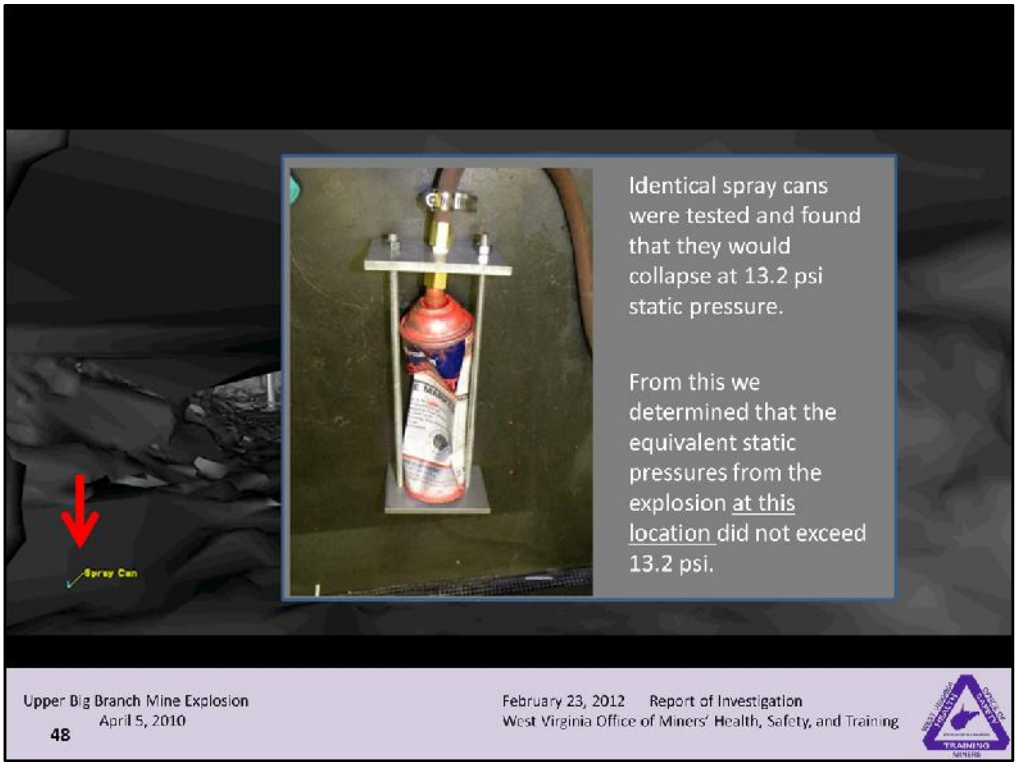
Slide 45 As this air travels south it passes through an opening that had been knocked out in the concrete block ventilation stopping. This is the alternate route for air to travel, should the #7 entry become blocked. These stoppings are typically constructed of solid 6" concrete block.



Slide 46 Passing through this opening and continuing south this air current merges with air traveling west in the #6 entry of #21 Tailgate.



Slide 47 From here, the combined air from the #7 entry, the Longwall face, and the #6 entry travel to the exhaust fan at Bandytown. Approximately 300 to 400 feet west of here is where explosion forces of *Path C* exited the gob behind the 3rd and 4th stoppings west of the longwall, then propagated west and south.

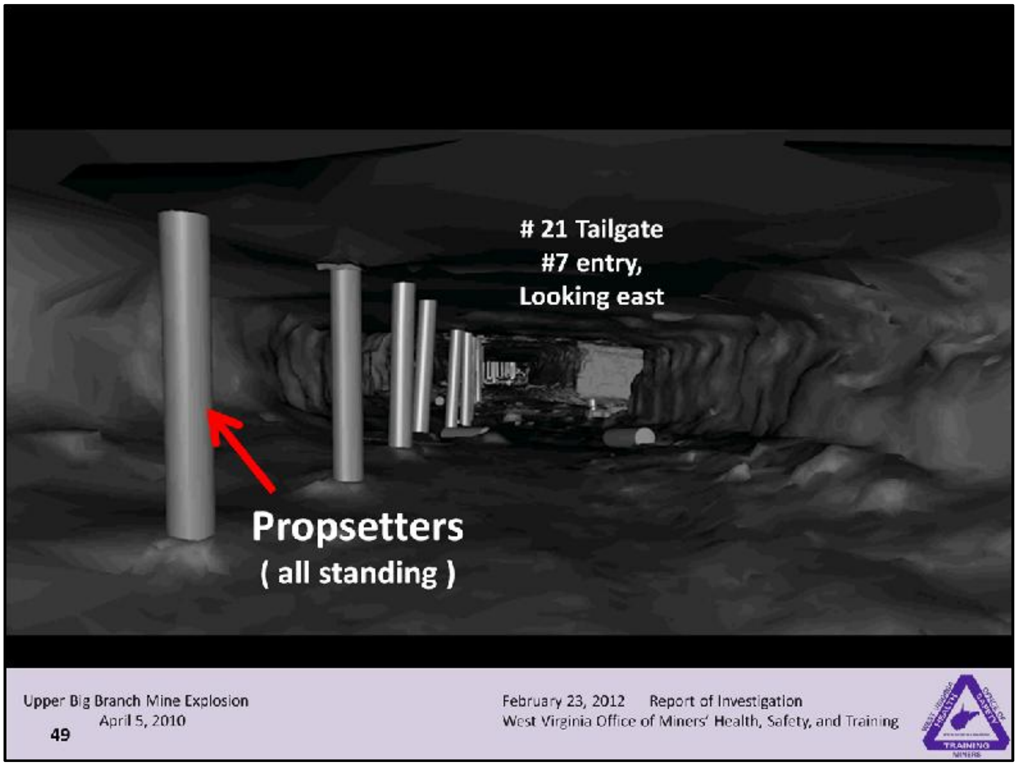


<u>Slide 48</u> Returning north through the same stopping, and just on the other side, is an example of how certain mine debris items were used to determine details about the explosion.

(click) An empty spray can found here provides clues about the maximum pressure of the explosion at this location. The top of this spray can as found had a melted plastic cap and with the exposed part of the paper label burned away.

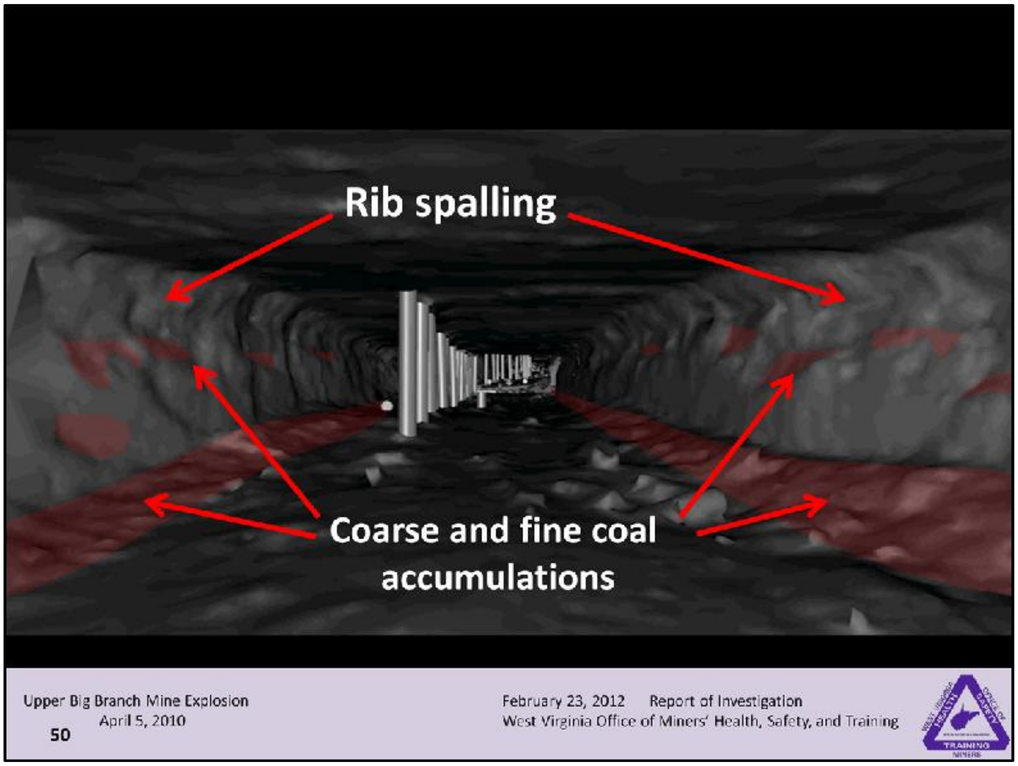
(click) But the bottom was basically intact, and was not burned or melted, which indicates that it probably was not transported during the explosion. This makes it a useful pressure indicator for this location. The can showed no sign of collapse.

(click) Identical spray cans were emptied and tested and it was determined they collapse at about 13.2 psi static pressure. From this we determined that the equivalent static pressure from the explosion <u>at this location</u> did not exceed 13.2 psi.



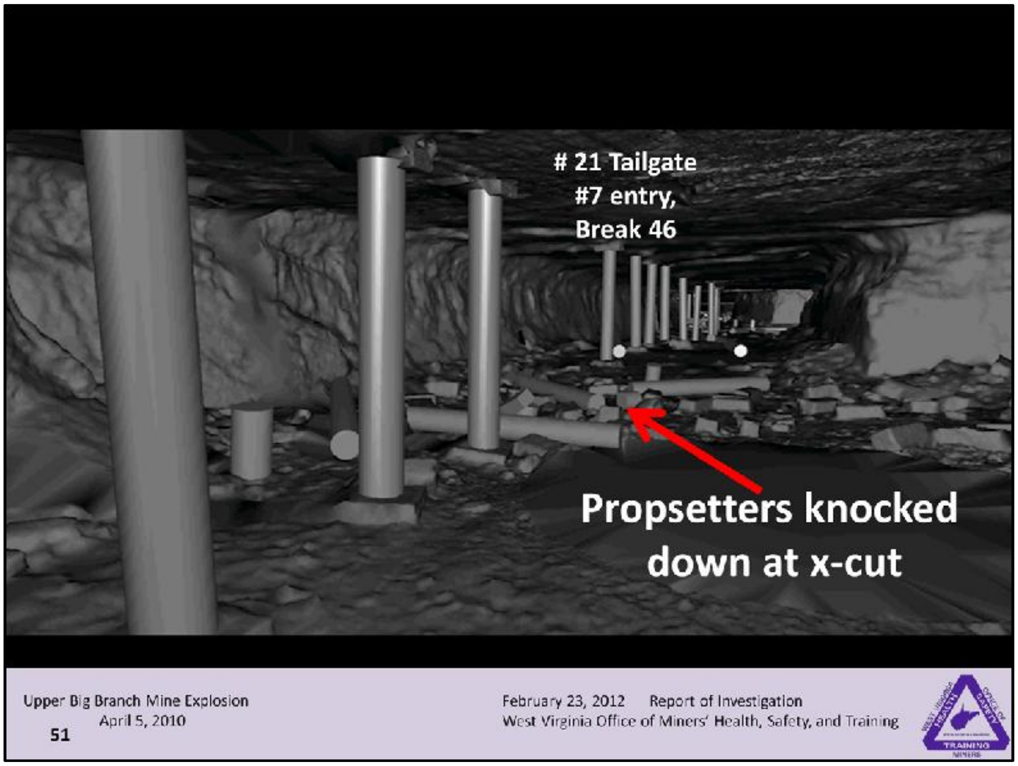
Slide 49 Continuing north we return to the #7 entry. Here at crosscut #48 all the timbers that were set in preparation for longwall mining remain standing. These timbers are machined round and are commonly referred to as *propsetters*. At this location, the explosion forces were not strong enough to knock down any of these timbers.

As we continue east along the #7 entry we will be tracing part of explosion *Path B*.

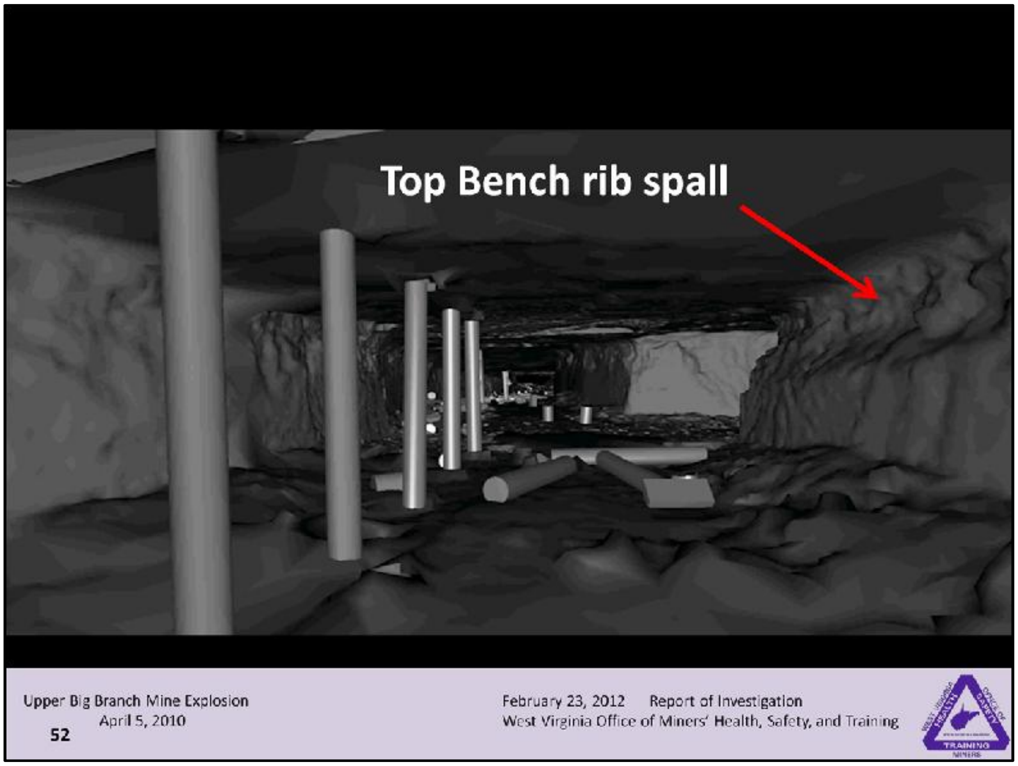


Slide 50 There were several items from the tailgate region of the longwall that were found at this location, including parts of the Comtrol phone system and circuit boards. Here we see scattered concrete block and a standing remnant of a ventilation stopping that was breached to the north. This stopping survived the initial explosion, but was knocked down by return forces from the south. The top of the Eagle coal seam is soft and friable, and exhibits significant rib spalling.

(**click**) The spalled material ended up on elevated ledges and as a talus windrow along the base of the coal rib. These accumulations contain both fine and coarse coal.

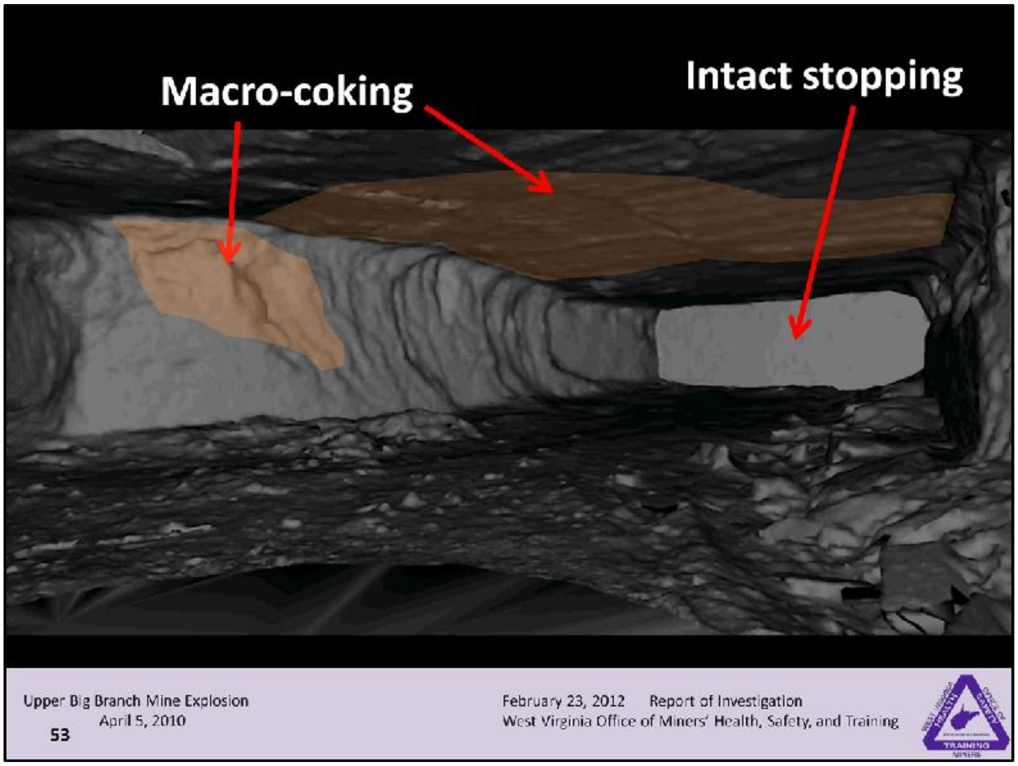


Slide 51 As we continue east we see the propsetters are standing until we get to cross-cut #46. Here we find the propsetters have been knocked down by explosion forces and block debris traveling north through the crosscut.



Slide 52 This next stopping is believed to have been partially breached to serve as a regulator, then repaired back just prior to April 5th. It survived the early explosion forces in #7 entry, but not the later forces from the south.

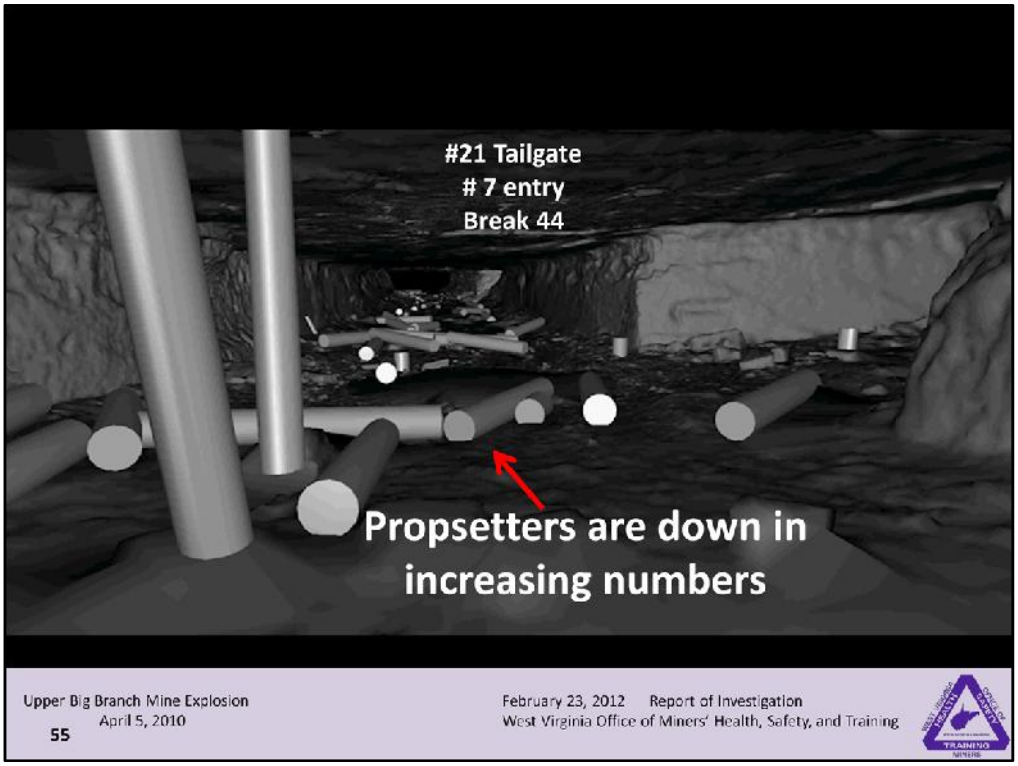
Here between Break 46 and Break 45 is another example of how the Top Coal bench spalls out onto the floor at the base of the coal rib, and also results in elevated ledges that can collect additional dust. This occurs because the mine roof, Bottom Coal bench, and mine floor are hard, compared to the Top Coal bench.



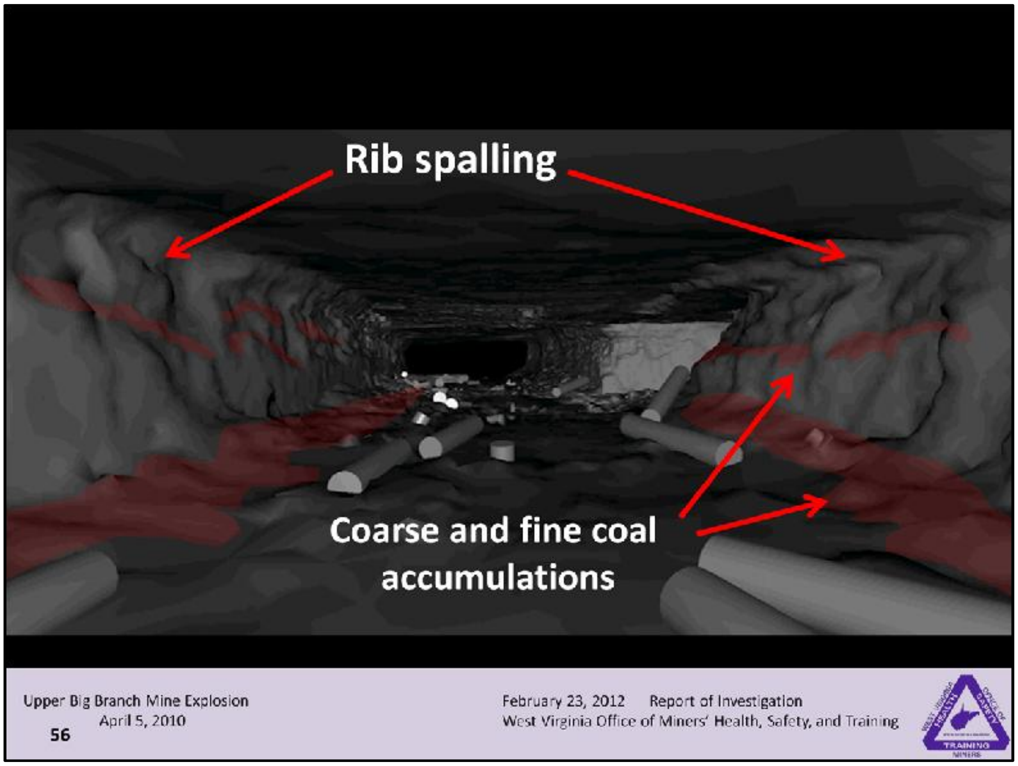
<u>Slide 53</u> The next cross-cut is Break 45. Here, the stopping in this cross-cut managed to survive the explosion. This location is marked as a regulator on the mine map, but it is fully intact-- although the previous stopping likely served that purpose before it was built back.

(click) The roof and east coal ribs at this location contain considerable *macro-coking*. This is coke that has <u>not</u> been transported by the explosion but is produced from coal dust on ribs and thin coal streaks of plant fossils in the mine roof.

Slide 54 These coked deposits are blisters and globules of coke that are easily discernable with the naked eye. They are evidence of flame of extended duration.

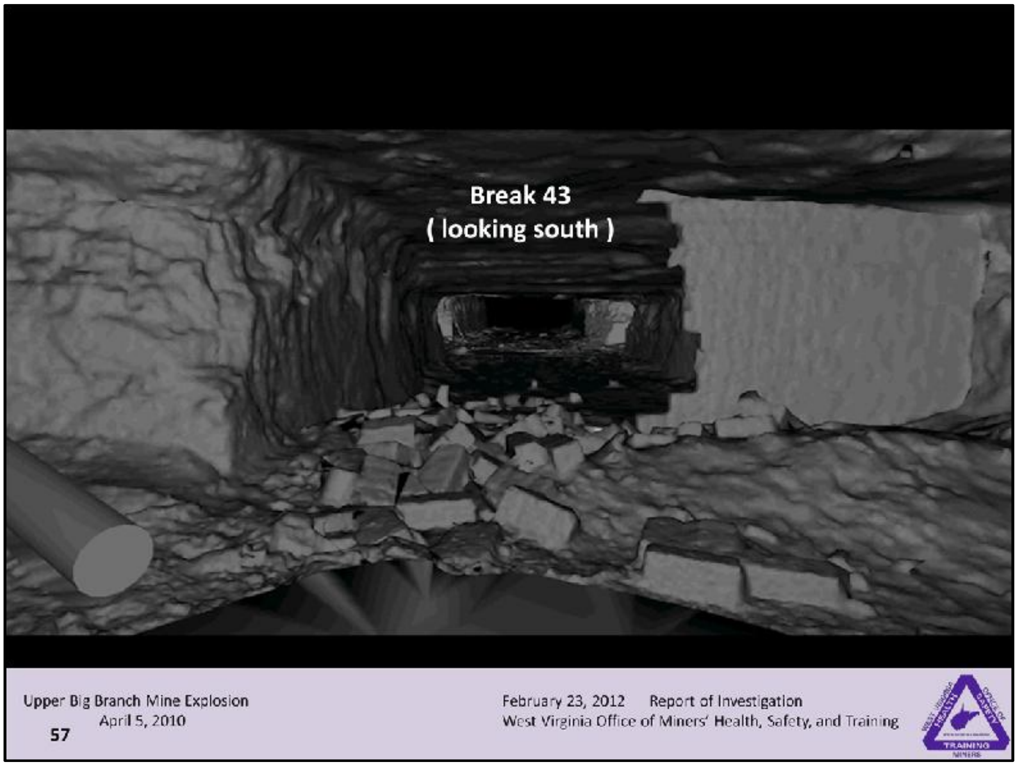


Slide 55 From here to the next cross-cut represents a transition where some propsetters are knocked down and some remain standing. Starting at Break 44 and continuing eastward, increasing numbers of propsetters are knocked down.

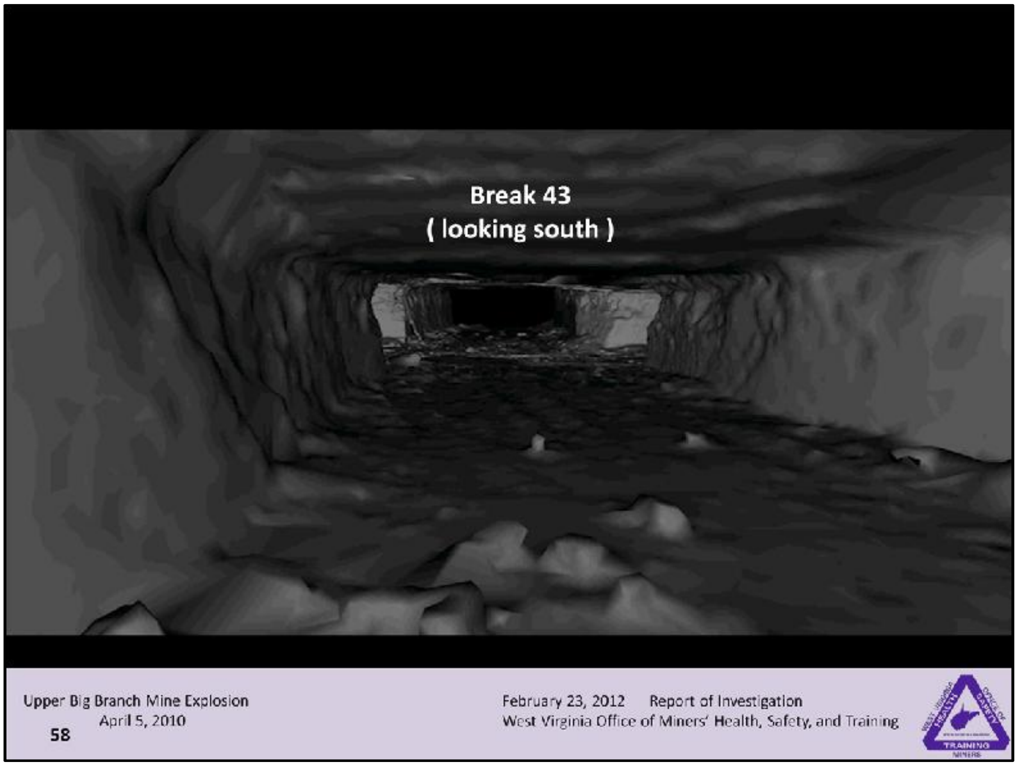


<u>Slide 56</u> The stopping in the crosscut of Break 44 appears also to have survived the initial forces through #7 entry. From Break 48 to this location we observed no pan bending resulting from the initial explosion forces, but from here forward the explosion speed and forces began to increase.

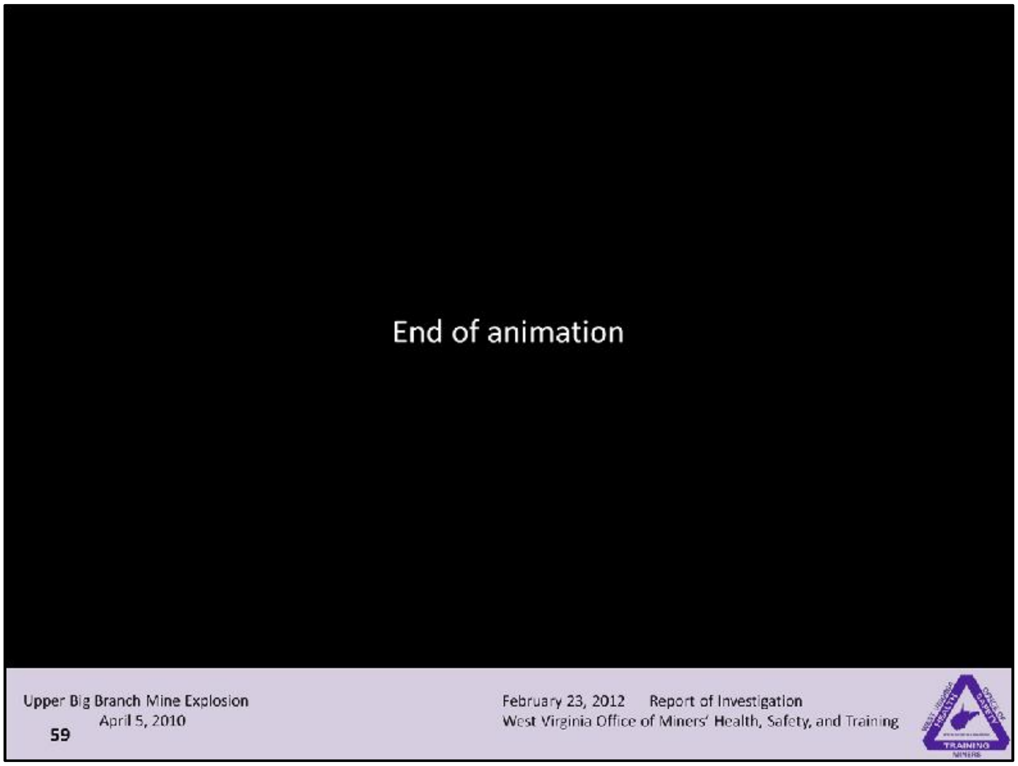
(click) Rib spalling of the Top Coal bench continues to be apparent from the hour-glass profile. Although the amounts of spalled material do not *<u>appear</u>* excessive the concentrations necessary to sustain an explosion can be surprisingly small. Accumulations of coarse and fine coal particles are perched on ledges and on the talus slopes along the toe of the rib, where the fine dusts dislodged by a propagating explosion front can become suspended and burned explosively.



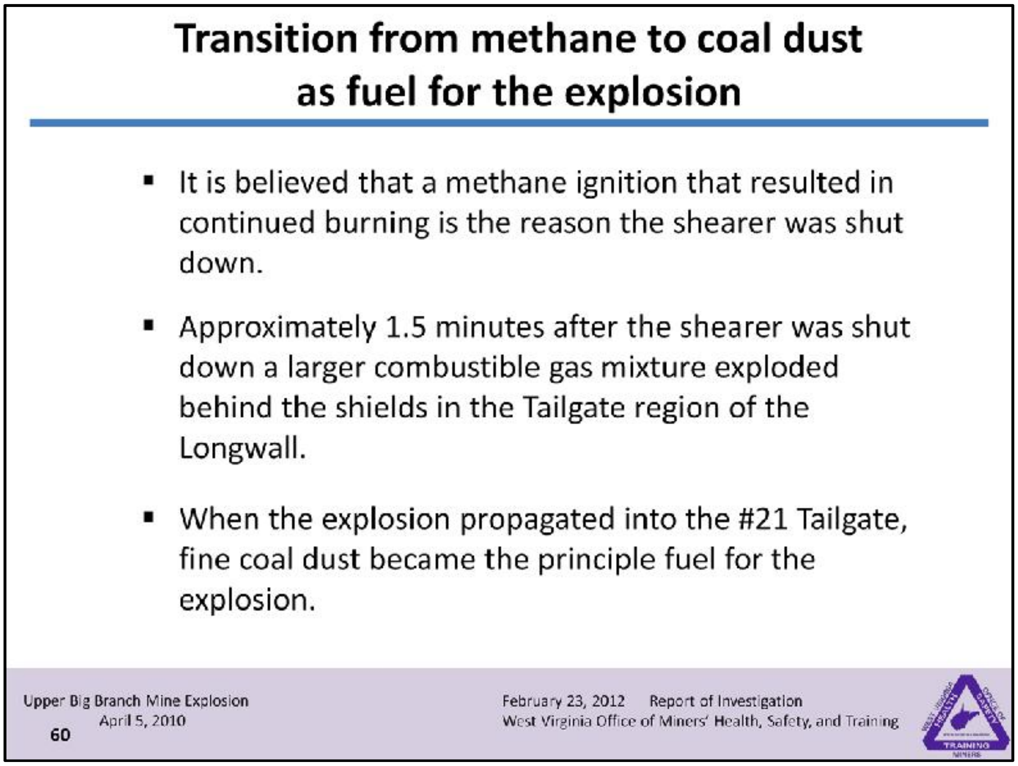
Slide 57 Approaching Break 43 we find the stopping was knocked down by forces from the south. However, were we to travel one more break east down this entry we would find that the explosion forces in #7 entry reached a threshold that began blowing out stoppings south and bending pans to the east.



Slide 58 This, however, concludes our trip eastward down #7 entry.



<u>Slide 59</u> **(**Black screen). The explosion path we just traveled is where the methane explosion transitioned to a dust explosion.



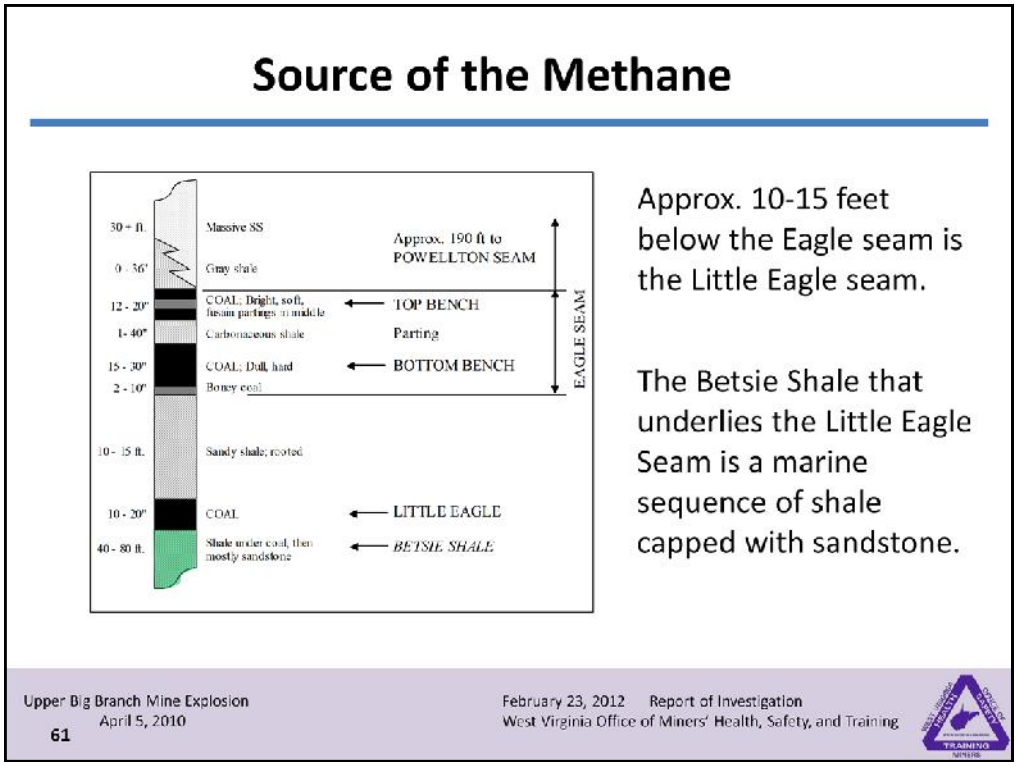
<u>Slide 60</u> In the events leading up to the explosion, methane was the primary fuel involved.

Initially, methane was ignited in the Tailgate area of the longwall and continued burning, resulting in the shearer being shut down.

(click) Approximately 1.5 minutes after the shearer was shut down a larger combustible gas mixture exploded behind the shields in the Tailgate region of the Longwall.

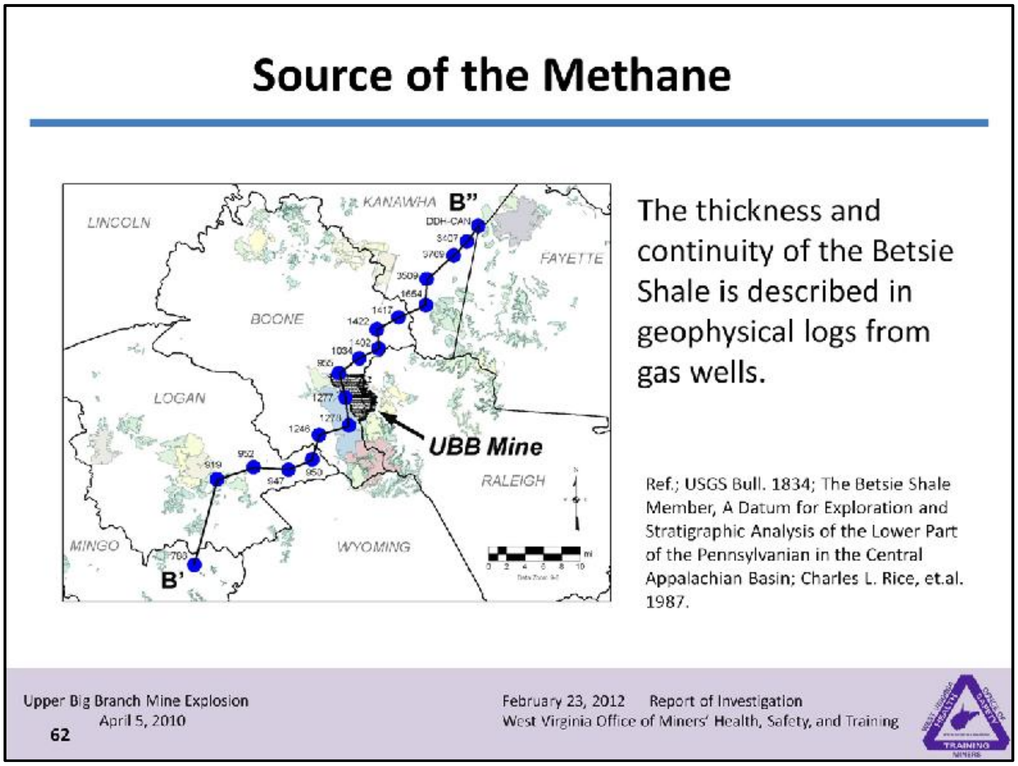
(click) When the explosion propagated into the #21 Tailgate, fine coal dust became the fuel for the explosion. Rock dust is effective in stopping a dust explosion, but not a methane explosion. We find the explosion forces of the initial propagation are increasing in speed and intensity slowly which indicates the fuel for propagation was coal dust.

Rock dust was retarding the explosion, but was insufficient to stop it. Nonetheless, we are interested in the source of the methane too, because that is what started the explosion.



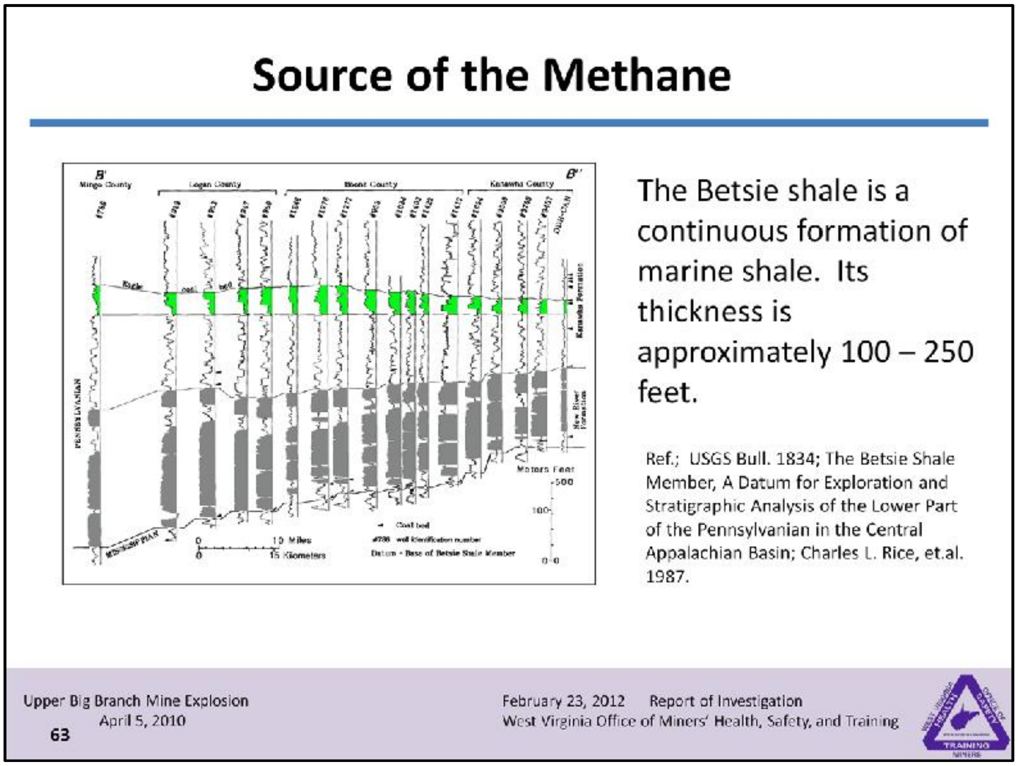
Slide 61 The Eagle seam is not a gassy seam, but it has a history of gas emanating from cracks in the mine floor. Gas from coal is derived almost entirely from plant remains, resulting in light hydrocarbon gases of almost pure methane-- or coalbed gas-- but containing trace amounts of the heavier hydrocarbons such as ethane and propane. These heavier gases are derived in greater amounts-- along with methane-- from source rocks rich in organics from microscopic animal remains, such as are contained in marine sediments. The gas that investigators noted coming from the mine floor contained more heavy hydrocarbons than would be expected from coalbed gas, alone.

Beneath the Eagle seam is a small but persistent leader seam called the Little Eagle, and beneath that is a marine shale that geologists refer to as the Betsie Shale. The Betsie Shale is capped with sandstone in the vicinity of UBB mine.

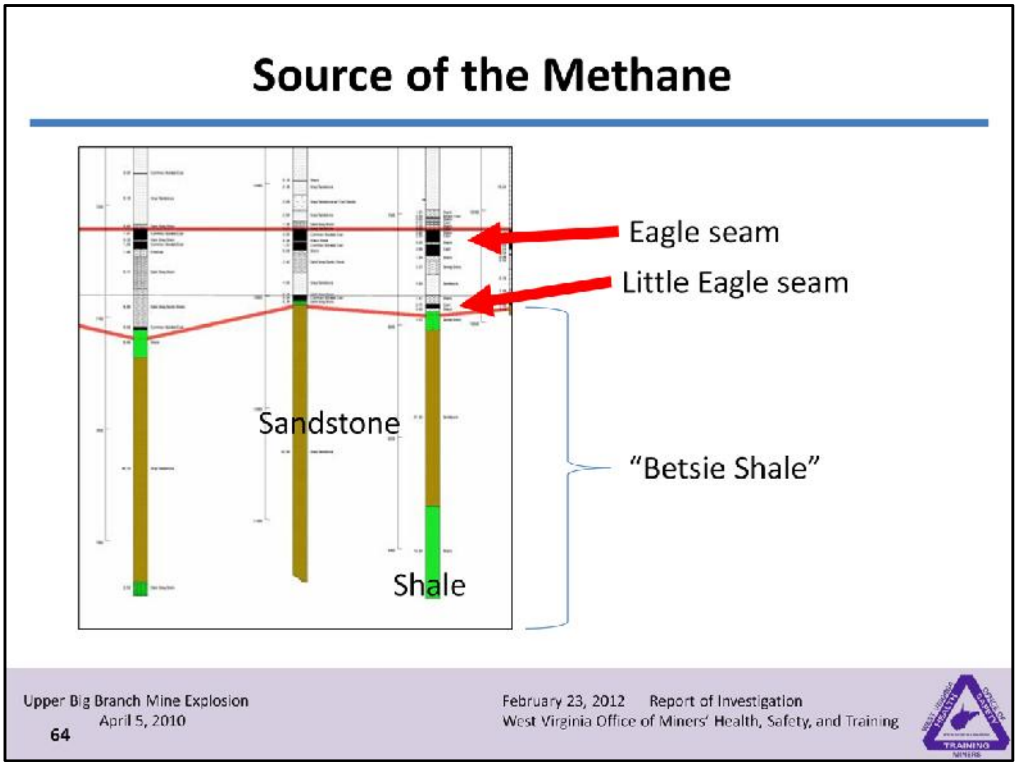


<u>Slide 62</u> Marine rocks can be source beds for natural gas. Although the marine rocks in West Virginia that produce commercial quantities of natural gas are considerably deeper, the Betsie Shale <u>could</u> be a source bed for limited quantities of natural gas.

A 1987 report by the USGS examines the Betsie Shale in southern West Virginia using geophysical logs from gas wells. One line profiling 18 gas wells through the Betsie Shale trends through the region of UBB.



<u>Slide 63</u> These data show that the marine Betsie shale formation ranges in thickness between 100 to 250 feet across the profile, averaging about 200 feet in the region around UBB. The Betsie horizon is indicated here in green.

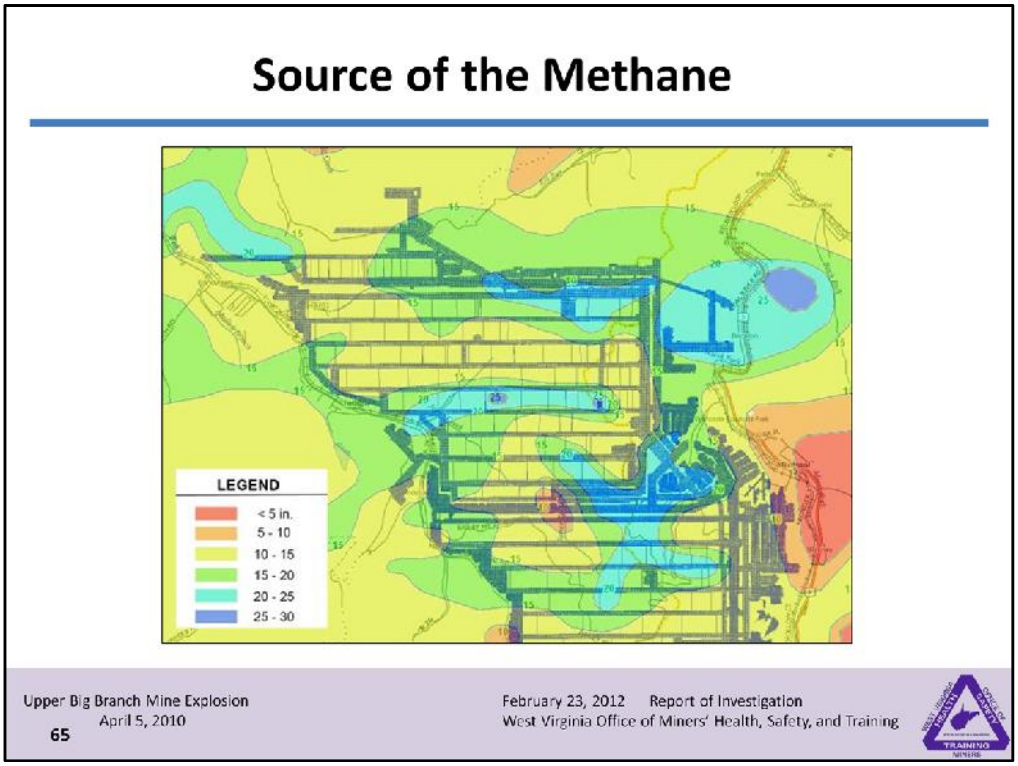


<u>Slide 64</u> Nearby core logs obtained from Performance Coal were plotted out in a graphic format. Although these logs do not penetrate very far below the Little Eagle seam, a few go as far as 50 feet and they show that the top 40 feet or so of the Betsie shale is actually comprised mostly of sandstone.

Sandstones make good reservoirs for hydrocarbons if they are porous and permeable and if they have an impermeable cap. Sandstone with sufficient porosity can collect hydrocarbons from neighboring shales.

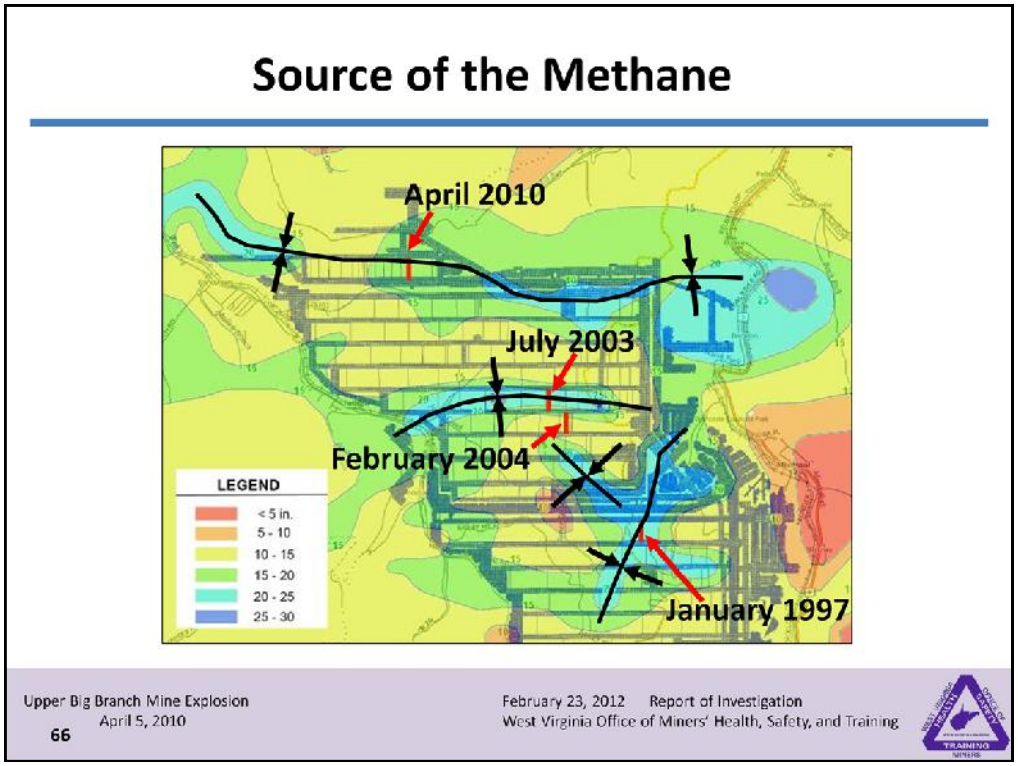
Any marine shale below the sandstone, including the Betsie Shale itself or the deeper Devonian shales, could be a source for gas. Deep shales such as the Marcellus are rich in natural gas, but are unable to release it freely because the shales lack permeability. Creating fracture conduits by hydrofracking provides permeability in tight shales by interconnecting their existing pores and fractures.

There is not enough known about the Betsie Shale to draw firm conclusions. However, it is possible that it is both source rock <u>and</u> reservoir for accumulated small pockets of gas, which are inadvertently tapped during longwall mining.

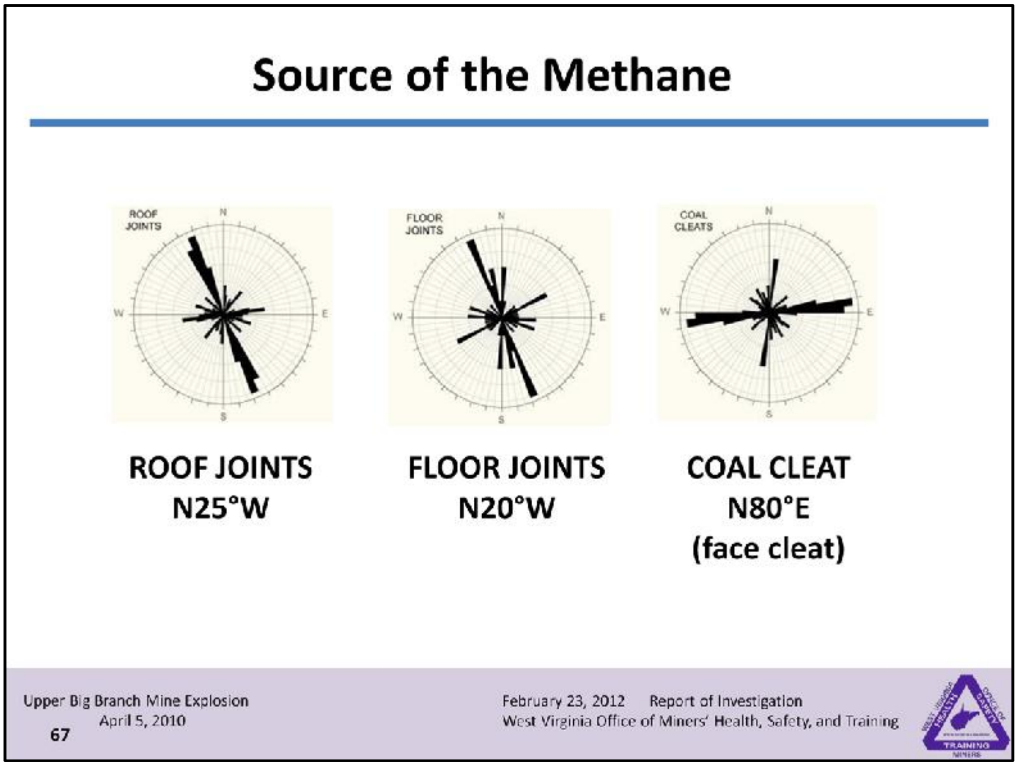


Slide 65 The cap for such a reservoir would be the rock interburden between the Little Eagle and Eagle seams. This thickness is approximately 10-15 feet.

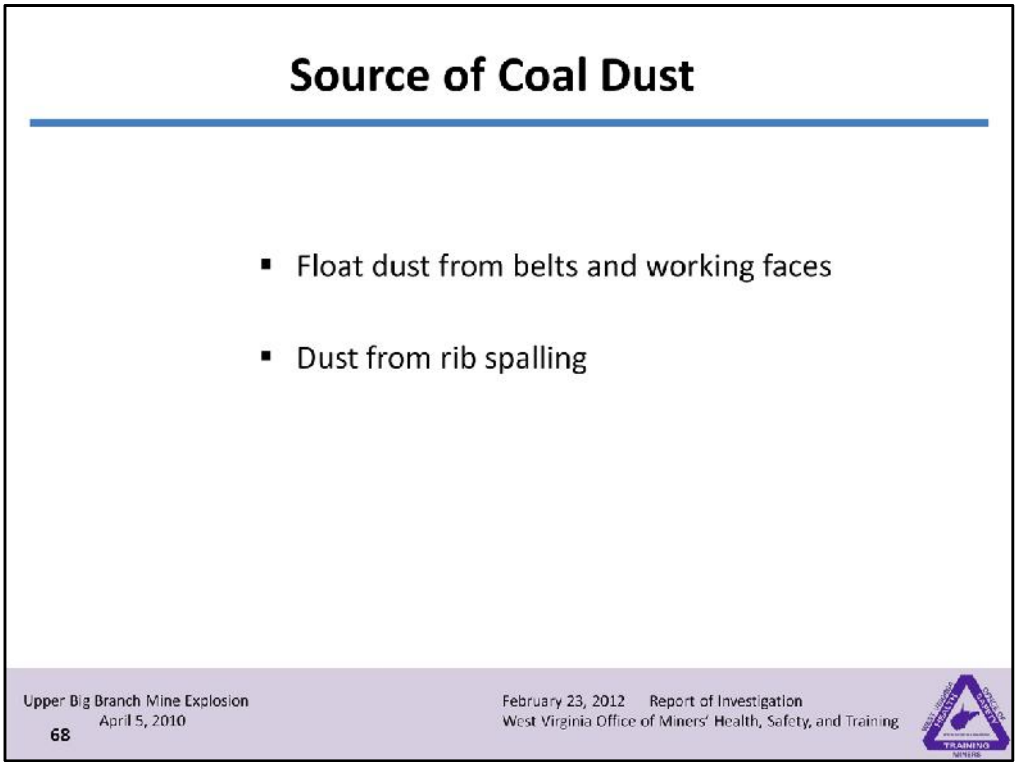
The thickness of the Little Eagle seam itself is known from coreholes. As illustrated in this map the coal thickness varies between 10 and 25 inches in the area of UBB mine. The blue and light blue regions show localized channels where the seam is thickest.



Slide 66 This isopach map suggests an association between depositional troughs and the occurrence of known UBB gas events. The margins of such local subsidence troughs are frequently associated with slips and fractures, along which relatively weak and porous zones can occur, which facilitates gas accumulations. Weak mine floor would be more sensitive to abutment stresses under cover depths exceeding 800 feet.

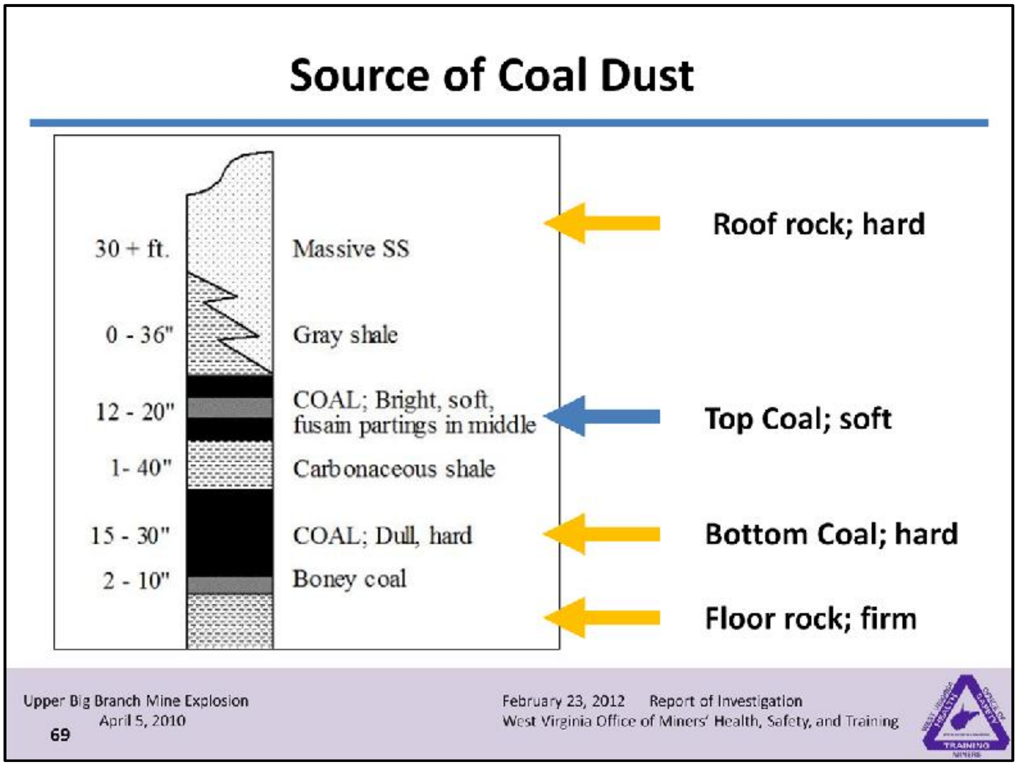


Slide 67 Because the dominant fractures in the sandstone roof above the Eagle seam are of similar orientation to the mine floor fractures, pre-existing conduits for gas migration might exist which are inadvertently intercepted during mining. These conduits might be pre-established pathways for upward-migrating gas that ceased when gas pressures and resisting stresses of confinement reached equilibrium. The Eagle/Little Eagle interburden may act as a cap or seal for this confinement, and when ruptured by abutment stresses under areas of deep cover can release pockets of residual gas where the floor is locally weakened and fractured.

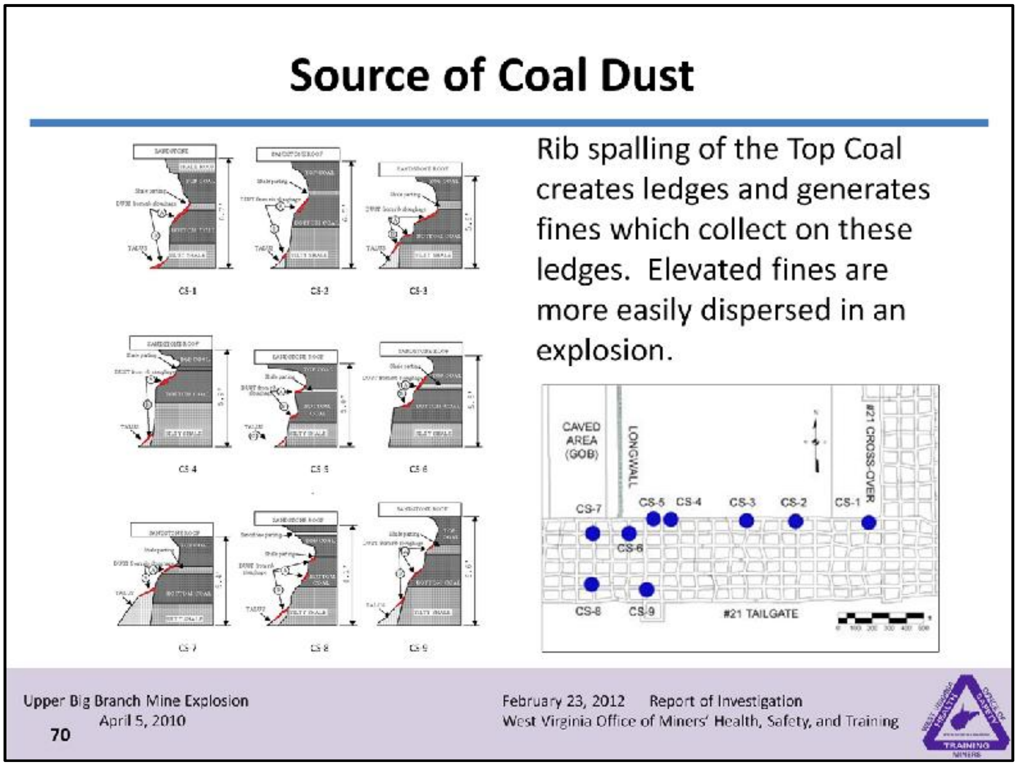


<u>Slide 68</u> Although methane is how the explosion started, our report discusses several factors which support the conclusion that the fuel for the continued propagating explosion was principally fine coal dust.

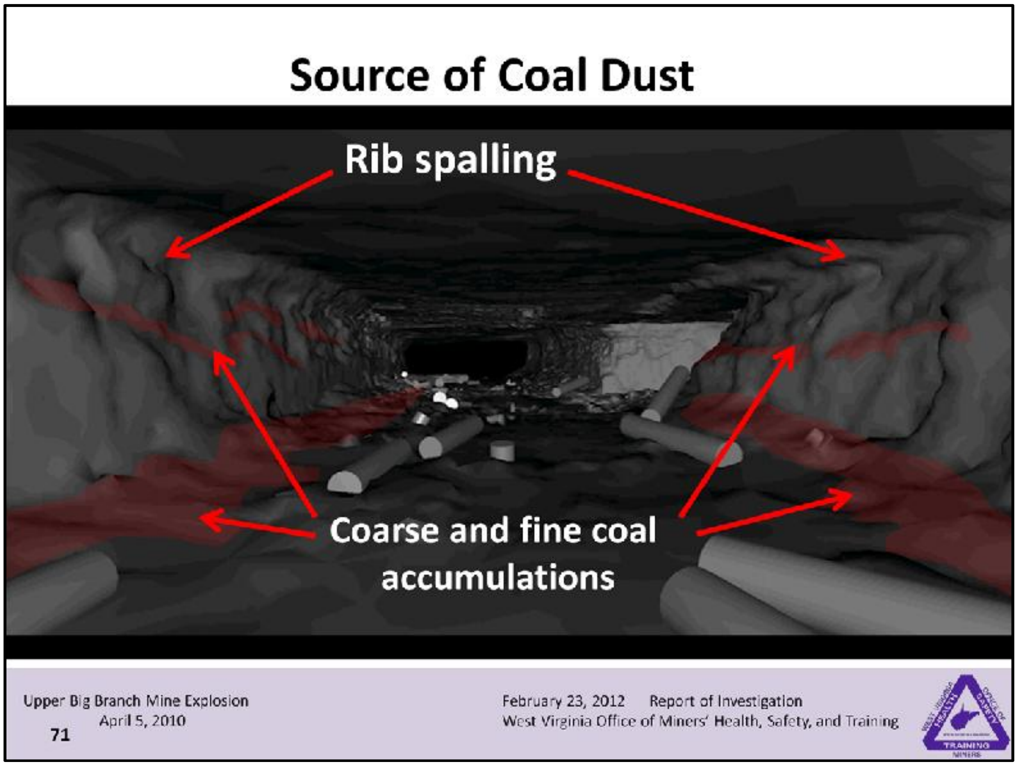
The potential sources for this dust include face equipment, conveyor belts, and rib spalling. The Top Coal of the Eagle seam may pose a fine coal hazard that has been previously overlooked and deserves additional attention.



Slide 69 The middle of the Top Coal bench of the Eagle seam is typically the softest geological strata exposed in the mine. When the mine ribs take weight under conditions of high depths of cover, this coal bench is prone to fracturing and spalling. It is composed chiefly of vitrinite (brittle, shiny coal), with discreet fusain partings (soft, sooty coal) that easily crumbles to a fine powder, making it a comparatively greater hazard.



Slide 70 Nine locations in the #21 Tailgate were sampled for coal and dust. Their general profiles are indicated in these seam sections. Dust and coarse particles were observed to collect on ledges created by the Top Coal spalling, and also at the floor along the ribs. Very fine coal particles that collect on elevated ledges are more easily dispersed in an explosion than dusts on the mine floor.



Slide 71 In the #21 Tailgate entry the cavities in the Top Coal represent spalling that occurred since the area was first mined and rock dusted. It is believed that this area was never re-rock dusted, and accumulating fine dust would not have had incombustible material mixed with it to arrest an explosion.

Source of Coal Dust

Rib spalling from the Top Coal bench.

Coarse coal does not pose an explosion hazard, but fine coal does.

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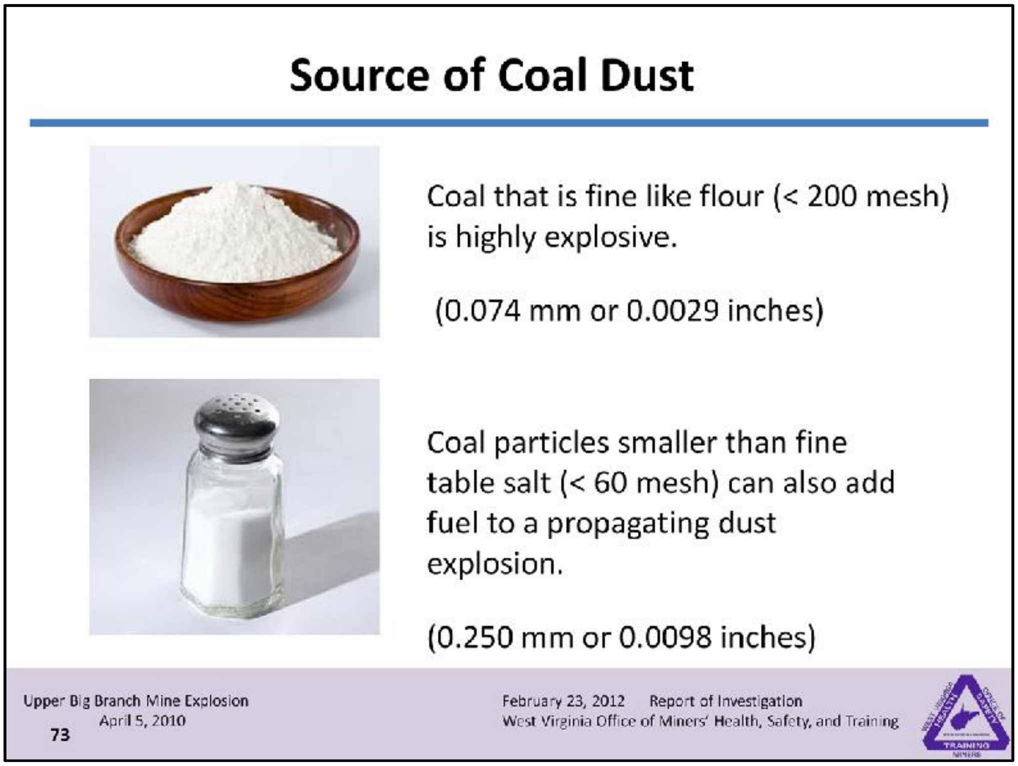
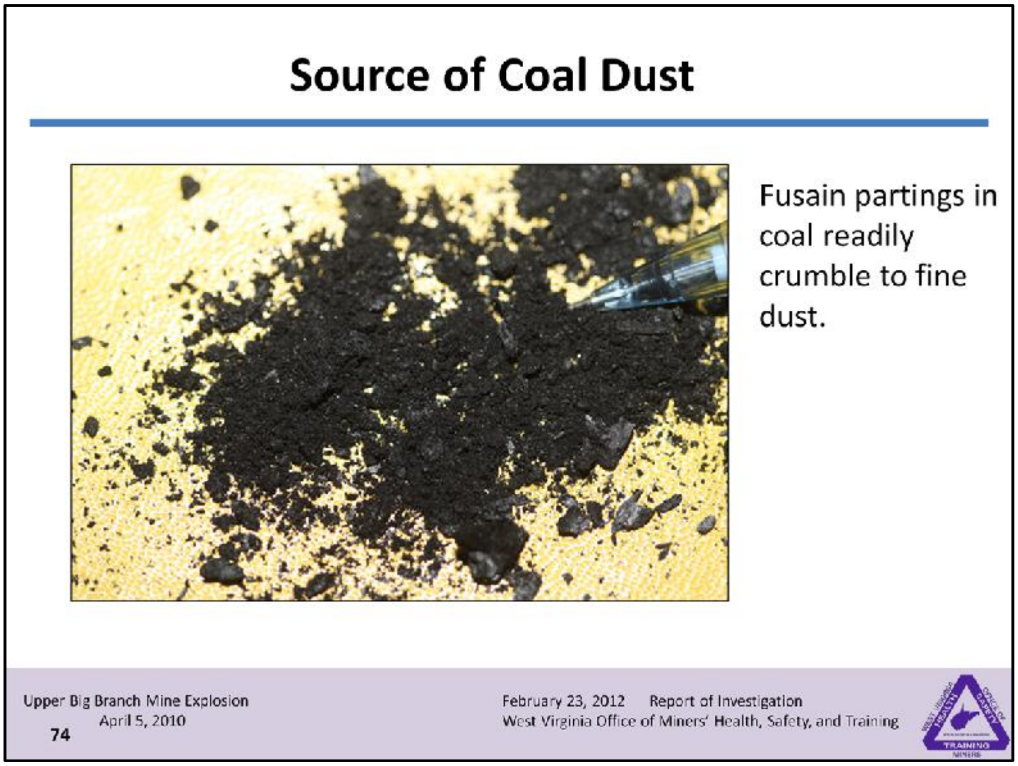
<u>Slide 72</u> These areas may not look that bad, but it is virtually impossible to determine the amount of fine dust and explosibility without close inspection, sampling and testing.

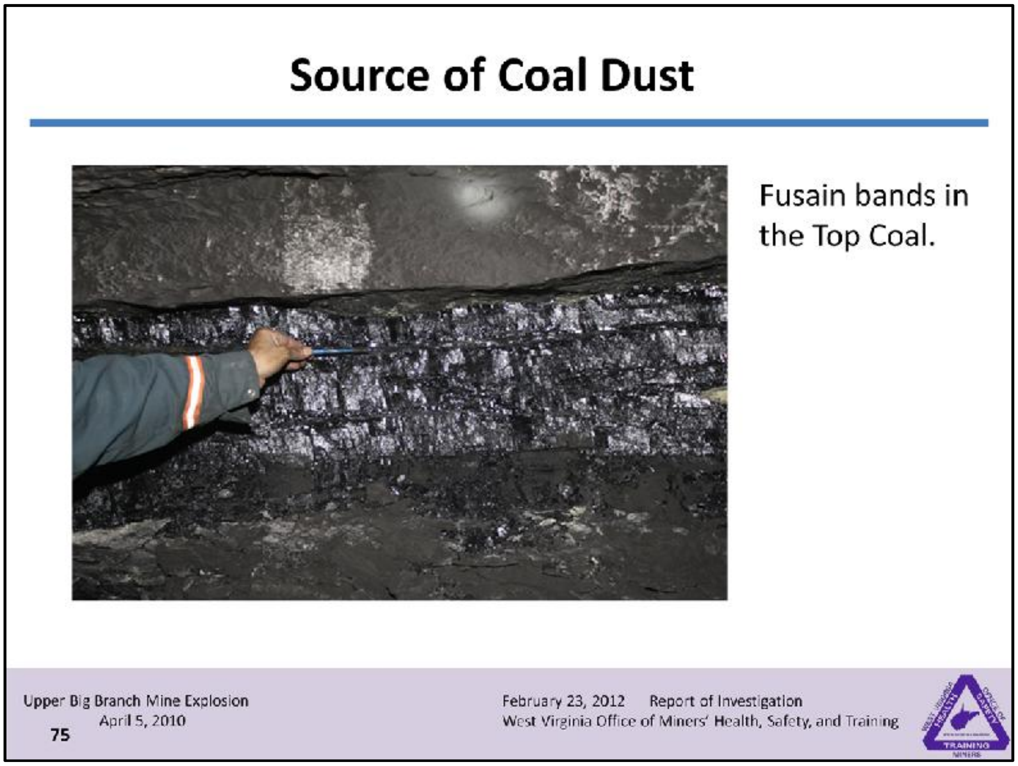


Slide 73 The most explosive coal dust is < 200 mesh in size, which is fine like flour. Dust of this particle size more easily gets ignited in the transition to and development of a self-sustained dust explosion. Rock dust must contain at least 70% less than 200 mesh to effectively neutralize the explosion.

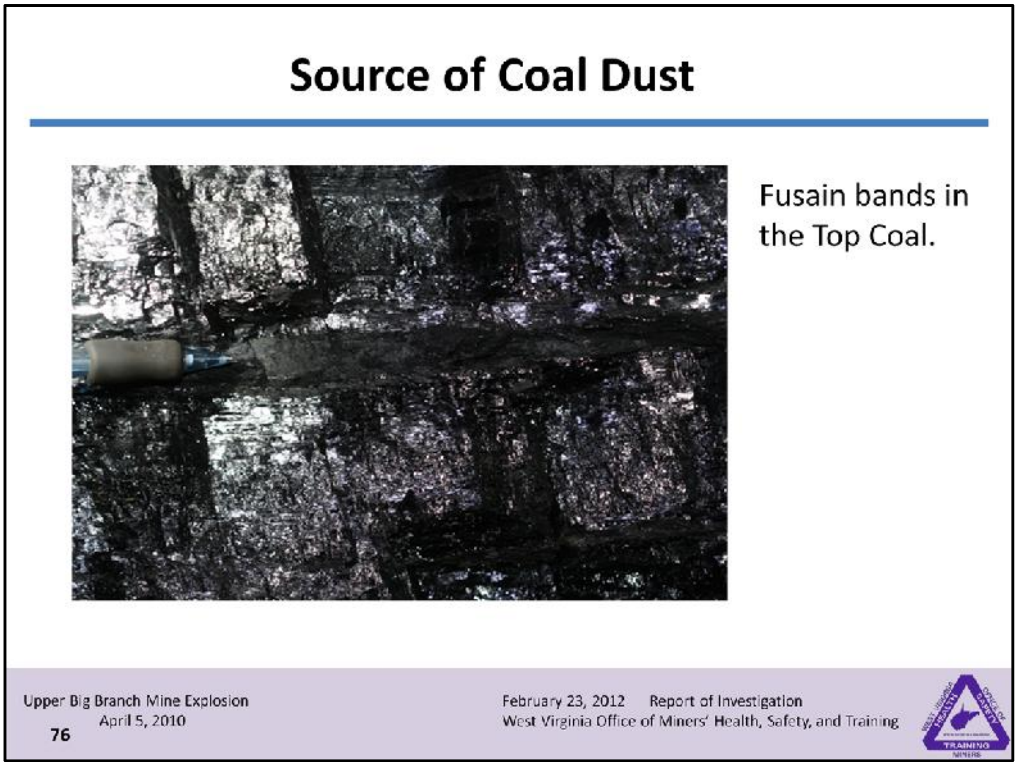
Once an explosion gets started, particles up to the size of fine table salt (60 mesh in size) can also participate in an explosion. Coal particles that are more coarse than 60 mesh do not seem to be a factor, but coarse coal accumulations along ribs receive more attention for rock dusting because they are more apparent.



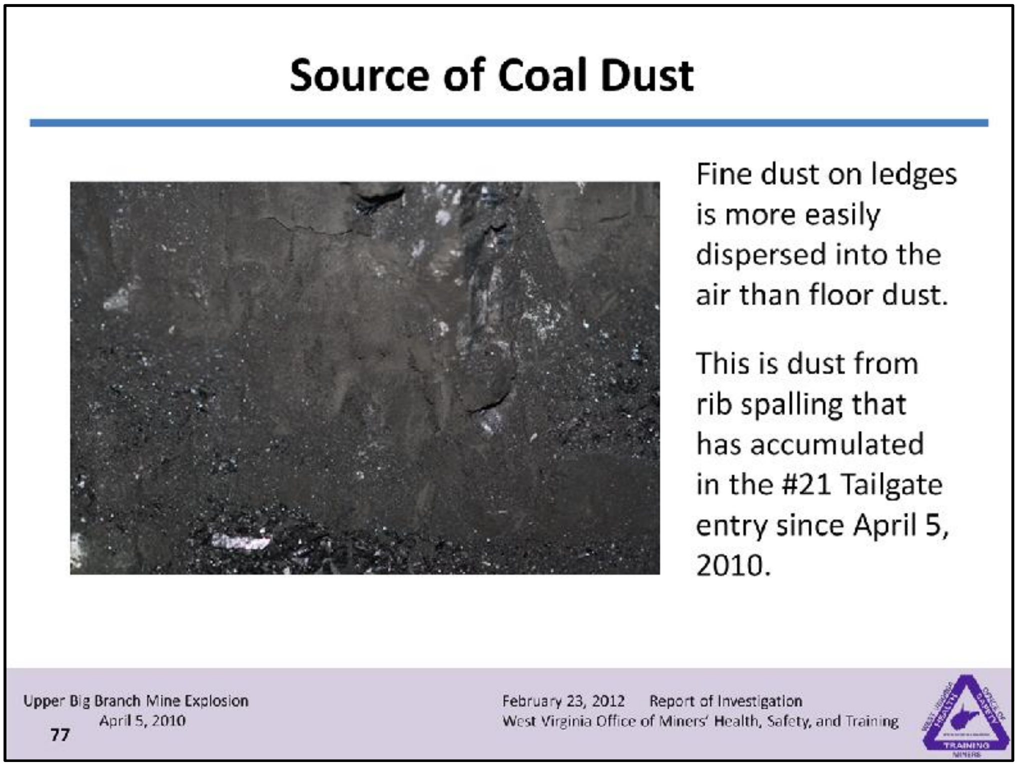
Slide 74 Fusain in coal is very common, but discrete partings of fusain are less common. The origin of fusain partings is thought to be from swamp fires which reduced the vegetation to a layer of charcoal. Because the volatile matter was largely driven off in the process, it was in effect already transformed into coal before it became buried. This may be why it is sometimes referred to as "mother coal."



<u>Slide 75</u> At UBB these bands are highly variable in thickness, and are visible only in the Top Coal bench. They are interbedded with fine, granular bands of pyrite and marcasite lenses, which are both iron sulfides. The aggregate thickness of these partings in the Top Coal appears to average only about 1.5 inches.

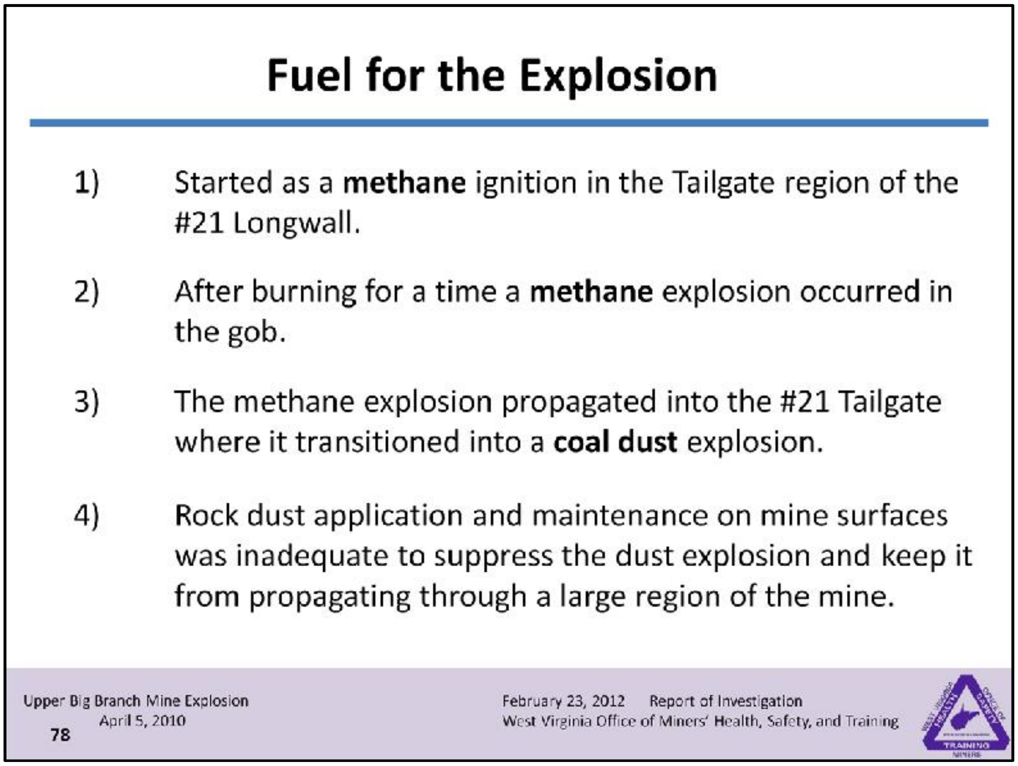


Slide 76 Typically, the visible partings are less than ¼". On appearance in the coal seam, they do not appear to be a threat.

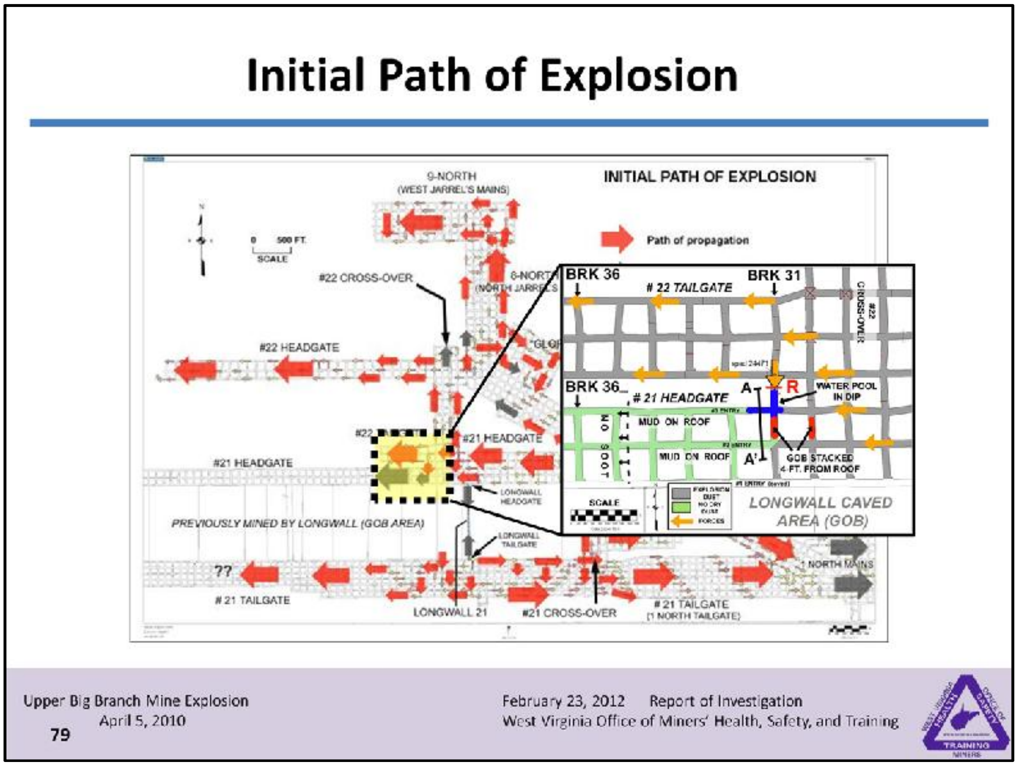


<u>Slide 77</u> However upon weathering they produce a surprising amount of fines. In fact they produce more fines than is reasonable to expect by their appearance in the coal seam. This condition may not be unique, but neither is it considered typical. Coals that have high vitrinite contents, such as the Top Coal at UBB, are <u>typically</u> softer--fusain partings or not.

Because the spalled fines appear to have played a role in the availability of explosive dusts that fueled the UBB explosion, it is prudent to do additional research to better understand them.



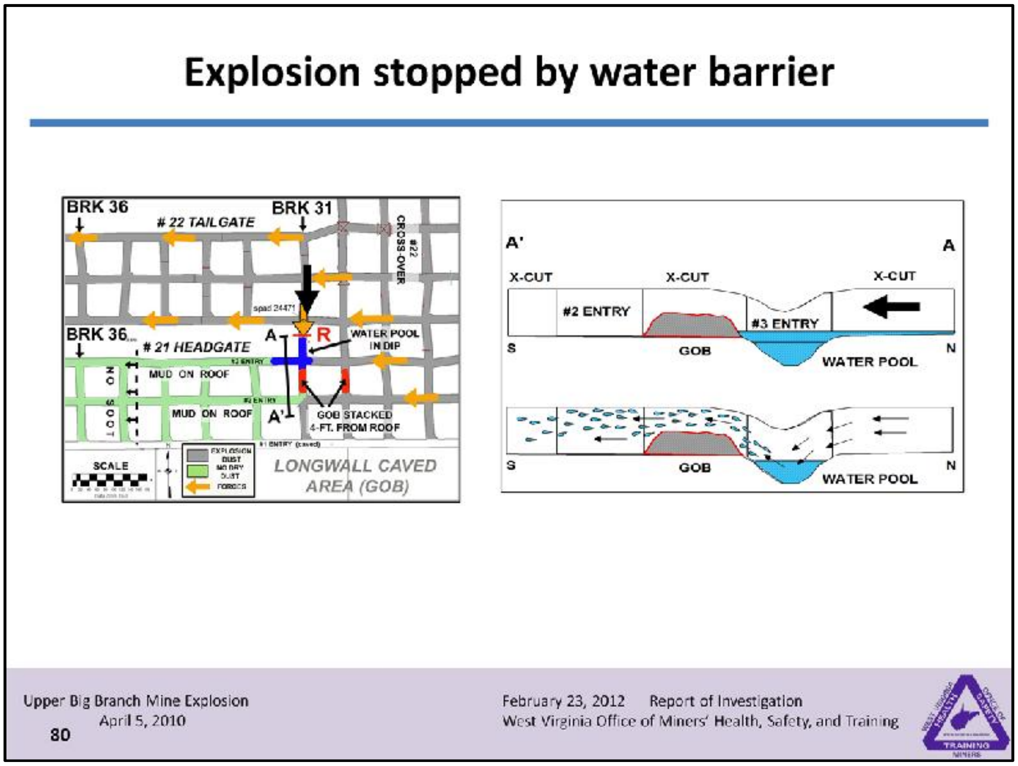
<u>Slide 78</u> It is our belief that a methane ignition occurred, then became a methane explosion in the gob which propagated into the #21 Tailgate entries. This methane explosion transitioned into a coal dust explosion that then propagated throughout a large portion of the mine, due to inadequate application and maintenance of rock dust on surfaces of the mine entries and crosscuts.



<u>Slide 79</u> During our detailed mapping we found at least one example where a water barrier stopped the explosion as it propagated through the mine.

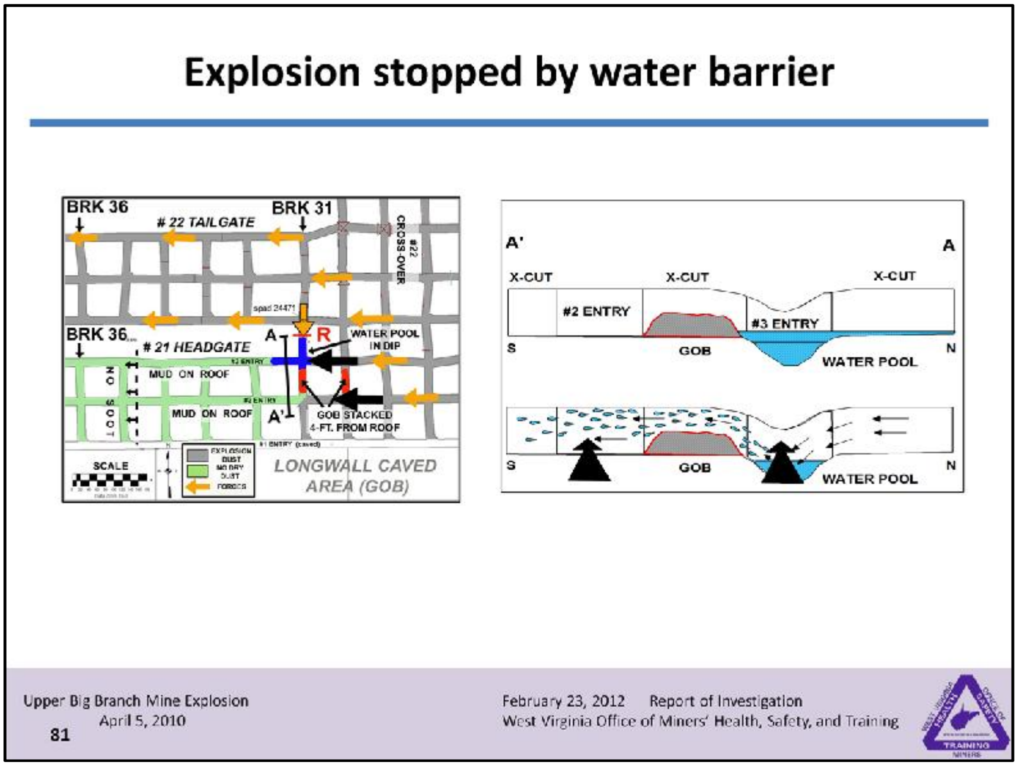
(click) This area was in the #21 Headgate entries west of the #22 Cross-over.

(click) Study of this area shows that flame was extinguished and the explosion forces subsided to extinction shortly after crossing a water-filled depression and a gob pile south of the regulator between #22 Tailgate and #21 Headgate.

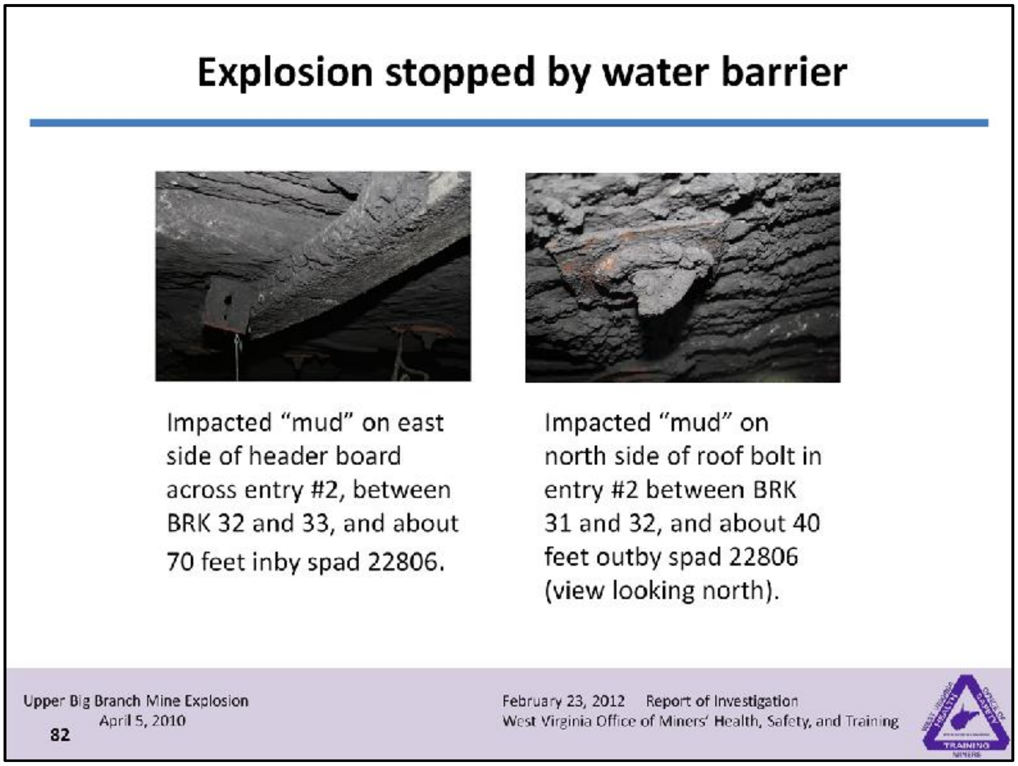


<u>Slide 80</u> Because the leading edge of the explosion was against the north side of #22 Tailgate, the first forces entering this part of #21 Headgate entered first through the cross-cut indicated with the black arrow. The intersection in #3 entry was a natural swag or depression which had filled with water.

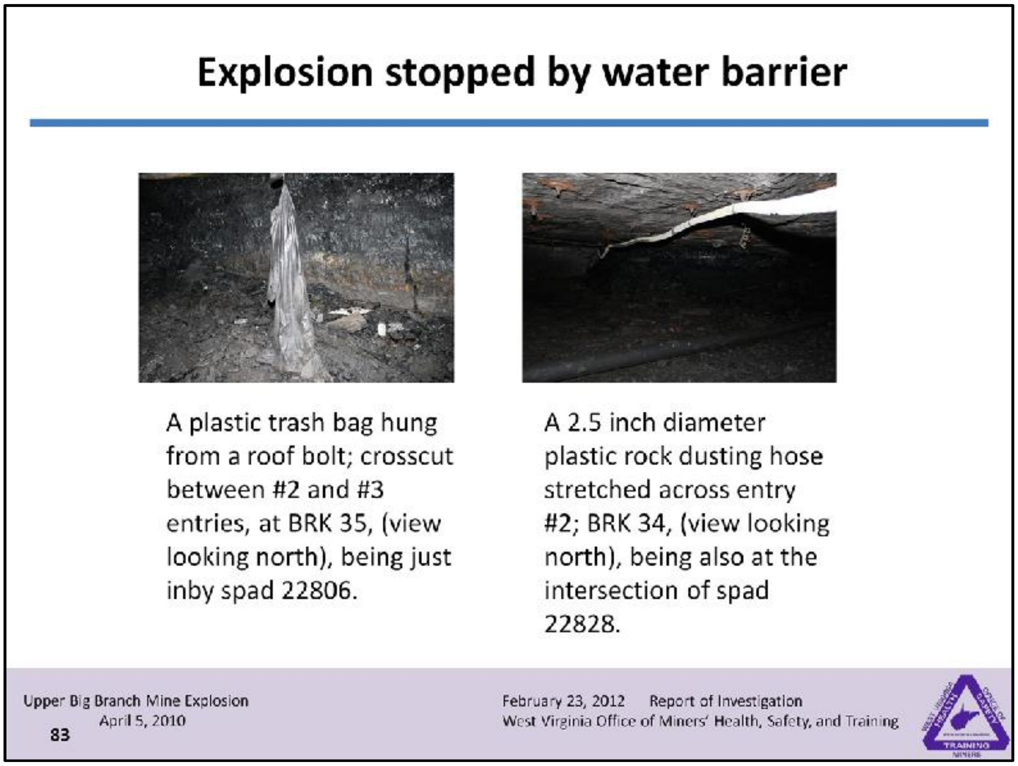
(click) When explosion forces entered this intersection they were directed downward, into the water pool, and continuing south passing though a constriction created by a gob pile between the #3 and #2 entries.



<u>Slide 81</u> An instant later, explosion forces from the east entered this same water hole through the #3 entry and also entered the unobstructed #2 entry. These forces dispersed water through the crosscut and then down the entries.

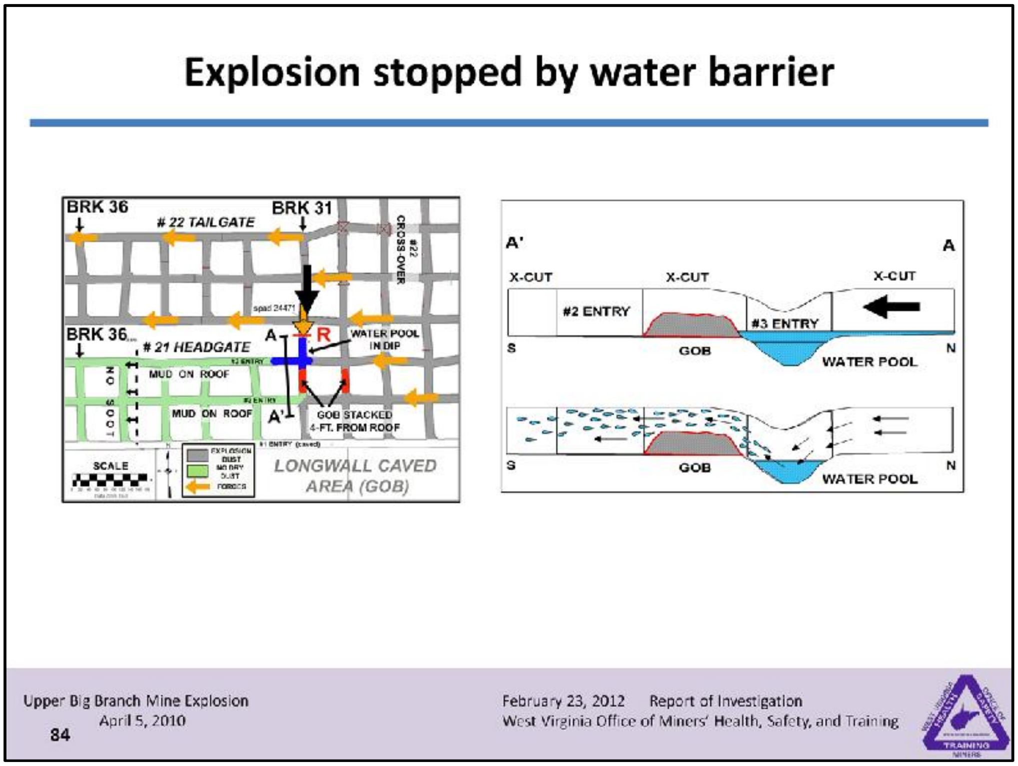


Slide 82 The heads of roof bolts show mud deposits on their windward side, rather than dust. These deposits point in the direction of the source of water. Mud coated the mine roof for approximately 400 feet of the entries lying to the west, but not their crosscuts.



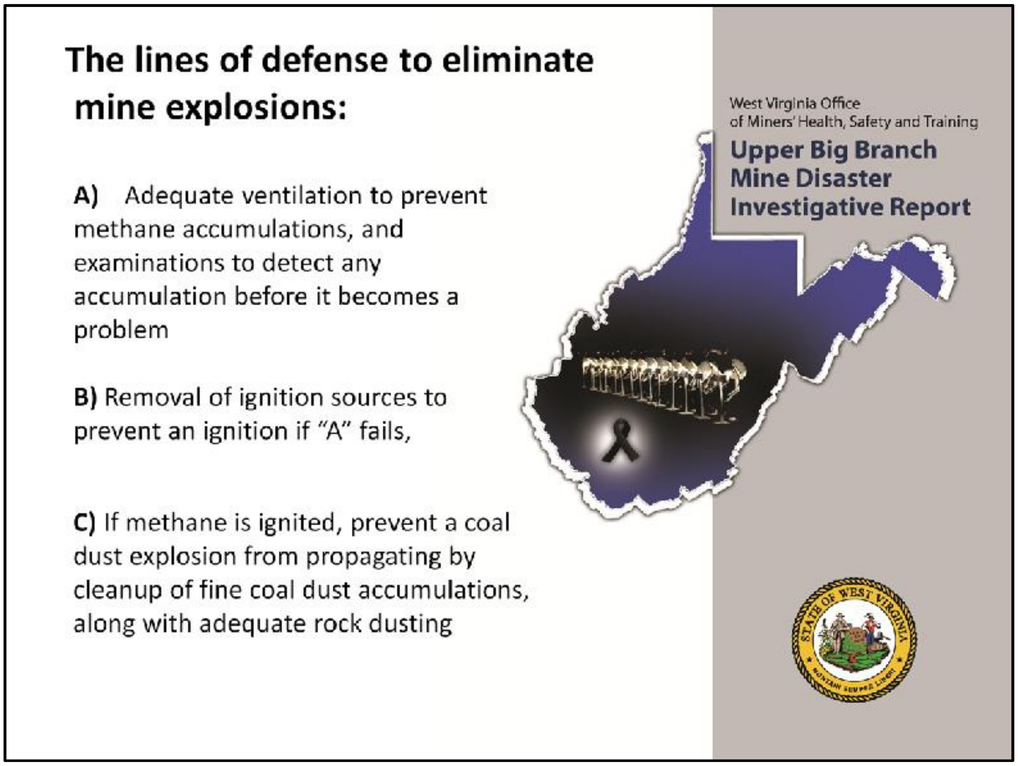
Slide 83 By the time explosion forces reached BRK 36 the overpressures were insufficient to breach stoppings and heat was insufficient to melt plastic garbage bags hanging from the mine roof. Vulnerable structures such as a 2 ½" diameter plastic dust hose that was hanging transverse to the #2 entry with nylon rope ties were unaffected by heat.

From this and other evidence it was determined that explosion forces subsided to extinction between BRK 31 and BRK 35.



<u>Slide 84</u> Prior research has shown that water barriers where the water can be dispersed by forces can quench propagating dust explosions. Observations and mapping during the investigation showed that the gob pile and downward contours created sufficient force and turbulence to direct air and disperse water into the #2 entry from the north crosscut. This appears to have increased effective wind velocity and enhanced turbulence through reduction in cross-sectional area and slope of the mine roof.

This example seems to validate the idea that water dispersion into explosion flame is effective in arresting the propagation of a coal mine dust explosion.



Slide 85 In closing: the lines of defense to eliminate mine explosions are:

(click) (A) Adequate ventilation to prevent methane accumulations, and examinations to detect any accumulation before it becomes a problem,

(click) (B) Removal of ignition sources to prevent an ignition if "A" fails,

(click) (C) and, if methane is ignited - prevent a coal dust explosion from propagating by cleanup of fine coal dust accumulations, along with adequate rock dusting.

All these defense mechanisms failed at UBB.

This explosive hazard of fine coal dust was not properly recognized and was allowed to accumulate without adequate rock dust. This includes fine dust accumulations from natural spalling as well as man-made sources. Training, sampling, and proactive rock dusting are necessary to prevent another UBB from happening.

Additional defenses are needed to prevent propagation of a methane explosion into a coal dust explosion. Explosion barriers have been studied for years and have been found to be effective in stopping an explosion.

Research is needed to demonstrate the practical application of water barriers, rock rubble barriers and other explosion mitigation strategies as supplemental protection.