STATEMENTS UNDER OATH

OF

WALTER ARABASZ, PH.D. AND JAMES PECHMANN, PH.D.

Taken pursuant to Notice by Richard J. Lipuma, a Court Reporter and Notary Public in and for the Commonwealth of Pennsylvania, at the Browning Building, University of Utah, 135 South, 1460 East, Salt Lake City, Utah, on Friday, November 30, 2007 beginning at 8:09 a.m.

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P R O C E E D I N G S

- -

MR. ZELANKO:

My name is Joe Zelanko. I'm an accident investigator with the Mine Safety & Health Administration (MSHA), an agency of the United States Department of Labor. With me today is Derek Baxter from the Solicitor's office, and Tom Morley, a mining engineer with Technical Support, MSHA Technical Support.

I, together with other government investigators and specialists, have been assigned to investigate the conditions, events, and circumstances surrounding the fatalities that occurred at the Crandall Canyon Mine in Utah in August, 2007. The investigation is being conducted by MSHA, under

Section 103(a) of the Federal Mine Safety & Health Act, and the Utah Commission of Labor. We appreciate your assistance in this investigation.

After the investigation is complete, MSHA will issue a public report detailing the nature and causes of the fatalities in the hope that greater awareness about the causes of accidents can reduce their occurrence in the future. Information obtained through witness interviews is frequently included in these reports. Your statement may also be used in other proceedings.

You may have a personal representative present during the taking of this statement and may consult with the representative at any time. Your statement is completely

voluntary. You may refuse to answer any question. And you may terminate your interview at any time or request a break at any time. Since this is not an adversarial proceeding, formal cross-examination will not be permitted; however, a personal representative may ask clarifying questions as appropriate.

A court reporter will record your interview. Please speak loudly and clearly. If you don't understand a question, please ask me to rephrase it. Please answer each question as fully as you can, including any information you may have learned from someone else.

I would like to thank you in advance for your appearance here. We appreciate your assistance in

this investigation. Your cooperation is critical in making the nation's mines safer.

After we have finished asking questions, you'll have an opportunity to make a statement and provide us with any other information that you believe to be important. If at any time after the interview you recall any additional information that you believe might be useful, please contact Richard Gates at the telephone number or e-mail address provided on the card.

Ms. Hansen, would you swear in Dr. Pechmann?

JAMES PECHMANN, PH.D., HAVING FIRST BEEN DULY SWORN, TESTIFIED AS FOLLOWS:

MR. ZELANKO:

Would you also swear in Dr. Arabasz, please?

WALTER ARABASZ, PH.D., HAVING FIRST BEEN DULY SWORN, TESTIFIED AS FOLLOWS:

MR. ZELANKO:

Ms. Hansen, are you empowered as a notary in the State of Utah?

MS. HANSEN:

I am.

MR. ZELANKO:

When does your commission expire?

MS. HANSEN:

February 17th, 2010.

MR. ZELANKO:

And have you sworn in Dr. Arabasz and Dr. Pechmann?

MS. HANSEN:

I have.

MR. ZELANKO:

Okay. Ordinarily, we've interviewed people individually. However, today, I think we're all in agreement that it would be beneficial to combine the interviews and have both of you appear at the same time. However, I would like to say that it's going to be a little bit more difficult on Rich. So I'll try to address each of the questions to you by name. And we'll just try to speak individually among us, one at a time, so that it's clear for Rich. But Tom will also be asking questions as well.

Do either of you have any questions about the interview process as I've described it?

DR. PECHMANN:

No.

DR. ARABASZ:

No.

WALTER ARABASZ, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. Okay. Dr. Arabasz, are you appearing here today voluntarily?

A. Yes, I am.

Q. Would you mind giving us a brief description of your educational background?

A. Yes. I have a Bachelor's Degree in Geology from Boston College in 1964, a Master's Degree in Geology from the California Institute of Technology, 1966, and a Ph.D. in Geology and Geophysics from the California Institute of Technology, 1971.

Q. Would you also please give me a brief overview of your employment history?

A. After completion of my Ph.D.

degree, I had a post-doctoral fellowship from the New Zealand Government for three years, 1970 to '73. There is a slight overlap with my --- the formal date of award of my Ph.D. in 1971, but I had finished all of my Ph.D. requirements before going to New Zealand. And in New Zealand I worked in observational seismology, micro-earthquake research for that entire time. Afterwards, I went to the Lamont-Dougherty Geological Observatory of Columbia University for about ten months. And moved here to Utah in 1974, where there was a position opening for a research seismologist at the University.

I have been here since 1974, involved in network seismology and observational seismology. I am a research professor of geology and geophysics. And I have been director of the University of Utah Seismograph Station since 1985.

MR. ZELANKO:

Thank you. Dr. Pechmann, I'll ask you the same questions.

JAMES PECHMANN, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. Would you mind describing your educational background?

A. I have a Bachelor's degree in Geology from Hamilton College in Clinton, New York, 1976. Subsequently I earned a Masters' degree in Geophysics at the California Institute of Technology in 1979, and then a Ph.D. in 1983.

Q. Okay.

A. Let's see, after graduating in 1983, I came to work here initially as a post-doctoral research fellow, and subsequently as a member of the research faculty. And I'm currently a research associate professor of

geology and geophysics.

Q. And your employment history is pretty much ---?

A. Since getting my Ph.D., this has been my only full-time job.

MR. ZELANKO:

Okay. Great.

WALTER ARABASZ, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. Dr. Arabasz, would you please describe the mission of the University of Utah Seismograph Stations?

A. We are a research, academic and public-service entity within the Department of Geology and Geophysics. Earthquake recording here on the University of Utah campus dates back a hundred years to 1907, since which time there has been continuous earthquake recording here on campus.

The entity, University of Utah Seismograph Stations dates from 1966. And modernly we are involved in earthquake monitoring and associated research with the benefit of an extensive telemetered regional seismic network, the telemetry basis beginning in 1974, whereby we have remote instrument packages which continuously transmit data by microwave radio, telephone line, here to a central recording laboratory on the University of Utah Campus.

Q. Some more practical questions. How many seismic events are detected in Utah each year?

A. On average, about a thousand. The number will always depend on the magnitude threshold that is specified, so that if there were a local data acquisition with more dense instrumentation, the numbers of events recorded might increase. But the average, about a thousand.

Q. And some of those events are

tectonic in origin and some of them are mining-induced. What is mining-induced seismicity and how is it different from other seismic events?

A. Mining-induced seismicity, spatially and temporally can be associated with mining activities. The energy release resulting from stress concentrations produced at mine openings or in the surrounding rock mass, the locations will be invariably shallow, and to the best of our understanding, occurring at or close to mine level, or perhaps in some cases, above mine level but not significantly beneath mine level. The published literature indicates focal depths perhaps kilometers below mine level in the vicinity of mines. In my judgment, these are probably the result of inadequate focal-depth resolution.

MR. MORLEY:

Do you want to --- could you define the term

mining-induced seismicity and earthquake and tectonic earthquake and what the difference is?

A. I'll give my interpretation. When seismic energy is released from a seismic source below ground surface, the energy radiates out in the form of seismic waves, produces vibrations that are recorded on seismographs, and perhaps perceptible at the surface. In publication, I commonly equate mining-induced seismicity, mine tremor, mine seismicity as basically equivalent. If the source of the energy release is at depths of typically kilometers, and produced by slip on a fault, and as a result of tectonic stresses, this type of event would be referred to as a naturally-occurring or tectonic earthquake.

There are circumstances in which human activities can induce seismic-energy release on a fault, a

release of accumulated tectonic strain energy. And typically this would be in the case of fluid injection at depth into the earth. It might result from reservoir impoundment to influence either pore pressure or stress changes at depth, in which case accumulated tectonic energy might be released.

BY MR. ZELANKO:

Q. Okay. Of the total events that are detected here, some thousand a year, roughly, what percentage would you estimate would be mining-induced seismic events?

A. I believe on average, the proportion might be somewhere as much as two-thirds of the total listing of events detected and located on average.

DR. PECHMANN:

Can I chime in? It varies. I mean, it can be 40 percent to two-thirds, depending on, you know, what

the time period is.

MR. MORLEY:

What time period are you talking about?

A. We'll define the Utah region basically being the rectangular region extending from 42 degrees and 30 minutes north, 37 degrees, three-quarters of a minute on the south. It basically surrounds the Utah region a quarter of a degree to the south, a quarter of a degree east and west, and then going up to 42-and-a-half degrees to the north.

I guess this variability depends on how one counts earthquakes. For example, if there is a main shock/aftershock sequence that might occur in a given year, then the balance there might shift to a large number of recorded tectonic earthquakes, or there might be a special study, as there was in the 2000/2001 time frame, where we added additional instrumentation in the

Trail Mountain area, and recorded thousands of mining-induced or mining-related events equivalently, and these were entered into the catalog.

MR. MORLEY:

What percentage would be mining-related events in the Wasatch plateau or Cliffs Mining Area?

A. In our publications, we define two polygons, one is effectively a U-shaped polygon. And then also we identify a separated box surrounding the SUFCO Mine. And in our compilations of seismicity, where we have plotted such events, the question naturally arises, are all of these mining related or might there be tectonic earthquakes in the mix. And in special studies, and I can think of three, where we've made systematic attempts to look at this problem of answering the question, are there tectonic earthquakes in the

mix which will require a judgment of focal-depth quality. And also information relating to source mechanism, the tectonic earthquakes will have reliably deep depths below --- a kilometer or two below the surface. And they will also have characteristics, notably a mixture of positive, or up and down P-wave first motions, as recorded on seismograms, typical of naturally-occurring earthquakes.

In those studies, candidate events number typically less than two to three percent of the total sample size, so that when we look at these plots, we make the statement that the predominance of these events are mining related. And again, recognizing that only a very minor percentage can be identified as tectonic earthquakes, again, nearly all of the events are mining related.

DR. PECHMANN:

Just one other comment,

the proportion of mining-related events to the total number of events processed depends a lot on the station coverage in the coal-mining area and how we have adjusted the triggering on the network in that area. There's just so many small seismic events in that area, that you can change the number very easily by adding a station or changing the threshold for triggering. And so there's some years where there's --- I think we've recorded and analyzed a couple thousand there, even not counting the Trail Mountain study.

DR. ARABASZ:

Correct. So that if we looked at a plot such as before me, which is an illustration from a PowerPoint presentation to the Utah Mine

Safety Commission on November 20th, and the title of the illustration is How Common is Mining-induced Seismicity in Utah, there is an indication that from 1978 to 2007, more than 19,000 events above magnitude one are included in this plot. This doesn't necessarily represent an equal weight year by year. It's an aggregate catalog where there has been improvement in the seismographic coverage, which leads to more events, and also the inclusion of data such as from the Trail Mountain special study, which increased the number.

MR. ZELANKO:

We can enter the document that Dr. Arabasz is referring to as Exhibit One.

(Arabasz-Pechmann Exhibit One marked for

identification.)

MR. MORLEY:

You mentioned small roof fall. What did you mean by that?

A. Repeat the question, please.

MR. MORLEY:

You mentioned small roof fall, an event from small roof fall. What did you say?

MR. GATES:

Is that what one of those thousands of events could --- at least such as ---?

MR. MORLEY:

Some of these events, would it be from a small roof fall, or could they be, depending on the sensitivity that you're measuring at?

A. I believe that a small roof fall, meaning just the gravitational fall of material from the roof, probably would not be energetic

enough to produce an event large enough to be recorded by our regional seismic network.

BY MR. ZELANKO:

Q. You mentioned Trail Mountain and your involvement there and some of the work that you've done in the Book Cliffs area and Wasatch Plateau in general. Having said all of that, is mining seismicity now, or has it ever been, a specific area of interest for the seismological stations?

A. I would answer this way, that our interests in the mining seismicity has evolved because of various factors. One, the numbers of events that are recorded by our regional seismic network, vis-à-vis our total earthquake catalogue. Coincidentally, after the mid-1990s, with the closure of the U.S. Bureau of Mines, there was no one actively recording mining-related seismicity to be of use to the

miners. And we also made a judgment that we were recording information that we thought might be useful to mining operators. And we have done our best progressively with resources available to augment instrumentation in the area and to, through various publications, summarize the information that we have recorded, which importantly represents a continuous temporal and spatial record of mining-related seismicity over decades.

Since 1978, we've judged that we've had quite reasonable seismographic control in that area, so that we've made attempts to spatially and temporally correlate what we've recorded with mining activities to the extent that that information is made available to us.

Q. Would you say that the University of Utah is recognized for its expertise in this area? You mentioned that you've tried to fill

the void left by the Bureau of Mines and facilitate --- provide that information to operators. Is the university recognized specifically for expertise in this area?

A. I think we will not make any claim to be experts in mining-induced seismicity. What we are expert in is observational seismology and interpreting, producing information recorded by our regional seismic networks, and with the benefit of special-purpose studies. And coincidentally, over the past few decades we have published information both in journal and report form, where we have summarized information available to us. And also with collaborative involvement of Professor Kim McCarter, Chair of the University of Utah's Department of Mining Engineering. We have had the benefit of learning about the mining engineering part of the story. And also, such as in the aftermath of

Crandall Canyon, with Dr. McCarter's collaborative involvement, had the benefit of information being provided from the mining side.

Q. Who else in the U.S. has similar expertise with mining-induced seismicity?

A. Sadly, it's a very --- to my awareness, a very small group of people interested and expert in mining-induced seismicity. Near the top of that list, I would certainly place Dr. Art McGarr of the USGS, who has mine experience dating back to his doctoral work in South African mines. There is residual expertise from the Bureau of Mines that was migrated to NIOSH. There are people at Virginia Tech, I believe, who have interest in mining seismicity. Perhaps one requirement for expertise in mining-induced seismicity is involvement in data acquisition, notably with in-mine micro-seismic arrays versus observations just with

surface sensors, as is chiefly the case with our observations.

DR. PECHMANN:

There's a group up with the University of Idaho that's worked on mining-induced seismicity in Idaho mines.

DR. ARABASZ:

And Walter Arabasz adding, yes, and one always needs to make a distinction between monitoring in hard rock metallic mines versus coal mines.

BY MR. ZELANKO:

Q. Yeah, I believe there's been some work done in Canada, a number of folks up there I'm familiar with. And the folks in Idaho, is that Wilson Blake? Does that come --- is that one of the people?

A. Let's see, Mr. Wilson Blake, a representative of the mining company, specifically Murray Energy, contacted us after the Crandall Canyon seismic

event, indicated that he was a geotechnical consultant to a lawyer for the mine company, and requesting information and data relating to the event.

DR. PECHMANN:

I was thinking about somebody who is on the faculty at the University of Idaho. Isn't it Sprenke? Is that his name?

DR. ARABASZ:

Ken Sprenke.

DR. PECHMANN:

Kenneth Sprenke.

MR. ZELANKO:

And hasn't NIOSH done some work in the quarter-lane still, too?

DR. PECHMANN:

Yes.

DR. ARABASZ:

Yes. Walter Arabasz, adding my characterization of the depth of expertise was

referring to the United States. Certainly, internationally, the picture is completely different.

BY MR. ZELANKO:

Q. Can you elaborate on that just a bit, and say where would most of the mining-induced seismicity expertise lie outside of the U.S.?

A. In the international literature, one would find that in South Africa, Eastern Europe, for example, Poland, Czechoslovakia, Australia, Canada, extensive involvement in studies of mining-induced seismicity.

BY MR. MORLEY:

Q. You described the University of Utah seismograph stations and network just in general. Explain roughly how many stations you have and how it works and when was it --- its history, a little bit.

A. There is representative information included in other

illustrations presented to the Utah Mine Safety Commission on November 20th. The University of Utah currently operates more than 160 seismic stations within the Utah region. And by the Utah region, again, I refer to this rectangular area, including and slightly overlapping the boundaries of the State of Utah. These stations include a subset of modern digital broadband stations, modern digital accelerographs, and legacy stations, single component short-period stations that are --- for which the data is transmitted in analog form.

The development of this regional telemetry network dates back to 1974. It has progressively evolved. In its current form, the greatest station density is in the Wasatch Front area, north central Utah, encompassing the Wasatch Front urban corridor, where the focus is on earthquake hazard and risk in the

densely populated, seismically hazardous Wasatch Front area. Examination of the seismographic coverage in east central Utah, in the area of the Wasatch Plateau and Book Cliffs area will show a lesser station density.

Q. This illustration of the regional seismographic coverage we'll call Exhibit Two. And the local coverage to the Book Cliffs area we'll call Exhibit Three.

(Arabasz-Pechmann Exhibits Two and Three marked for identification.)

A. Exhibit Three is an enlargement of the Wasatch Plateau/Book Cliffs area, that shows an outline of the polygonal areas encompassing the mining areas. And what is shown on Exhibit Three are white triangles marking the location of five single-component analog stations. A yellow star is shown for

the location of the 6th of August, 2007 Crandall Canyon mine collapse. And the nearest stations would be noted to be 18 kilometers away --- 18 kilometers or more distant from the mine collapse.

Also in this local area, there are two modern digital broadband stations, one about 18 to 19 kilometers south of Crandall Canyon, another to the southeast in the San Rafael Swell. And one will also note three blue triangles, modern digital seismographs, which coincidentally are located above three mines in the Book Cliffs area.

DR. PECHMANN:

These ones are modern digital accelerographs. And they also have a high-gain vertical component on them.

BY MR. MORLEY:

Q. Can you just describe what the difference is between those? Is there a difference in the quality of

the recorded data or the sensitivity?
A. Yes. The dynamic range of those instruments vary greatly. In other words, the ability to capture on scale signals over a wide range and amplitude. And also a distinction between the legacy stations, which transmit in analog form --- let's see, ask Dr. Pechmann to continue.

MR. MORLEY:

Jump in at any time.

DR. PECHMANN:

Sure. The digital stations have a much larger dynamic range than the analog-telemetry stations. The accelerographs are good at recording large ground motions or motions from very close earthquakes, even if they're small. They're not particularly good at picking up distant seismic events. So for example, in the Wasatch

Front region most of those stations are accelerographs, so they're primarily to record strong ground motions from large damaging earthquakes, although we do pick up some very small earthquakes on those instruments and on the instruments in the Book Cliffs area.

The broadband instruments are called broadband because they record over a broader range of frequencies than the short-period sensors.

DR. ARABASZ:

I'll add one point. One of the key pieces of information that legacy short-period stations still usefully provide are the first motion of the P-waves as they are recorded on the seismograms. The broadband stations are

important for looking at the full recorded wave form on scale, which become important in interpreting the source mechanism.

BY MR. MORLEY:

Q. Getting to that, could you briefly just describe the general process on how you determine the location of seismic activity from the seismographs, in layman's terms?

DR. PECHMANN:

The way that we locate seismic events is that we look at the arrival time of the first seismic waves that arrive at a number of different seismic stations. And if you know these arrival times, and you know the speed at which the seismic waves travel through the earth, then you can triangulate the location of the source of the seismic waves.

We rely primarily on the first arriving types of seismic waves, which are called P-waves. But we also, when possible, measure arrival times from S-waves, which actually S stands for secondary waves. To record or to recognize S-wave travel times, you really need horizontal component instruments because the seismic waves tend to travel near vertically near the surface of the earth. And the S-wave vibration is perpendicular to the ray path. And so those are recorded primarily on the horizontal components.

MR. MORLEY:

Go ahead.

A. There is another illustration in the PowerPoint from the Utah Mine Safety Commission which I think will

be illustrative to the layman. Do you have the complete set?

DR. PECHMANN:

One of the critical things in earthquake location is knowing the seismic velocity.

MR. MORLEY:

That was my next question.

DR. PECHMANN:

You at least need to know it as a function of depth within the earth. And ideally, you'd like to know it as a function of three-dimensional location within the earth.

MR. MORLEY:

How do you determine that or develop that model?

DR. PECHMANN:

There is a variety of different ways. The model that we use to locate seismic

events in the coal-mining region comes from first of all, sonic logs, from near the surface. So we have some information from sonic logs in the area that we use to put together the shallow velocity structure. It also comes from seismic-refraction studies, where explosives are set off to generate seismic waves. And then the waves are recorded over a range of distances and analyzed to determine velocity as a function of depth within the earth. Did anything else enter into the models that we were using other than sonic logs and refraction studies?

DR. ARABASZ:

I believe in the case of East Mountain, going back to the 1980s, there were some high-frequency reflection

data.

DR. PECHMANN:

Reflection data, yeah. Although we didn't use that in --- we did not use the reflection data derived velocities in the model that we're currently using.

MR. MORLEY:

Does topography affect that model?

DR. PECHMANN:

Well, it can. Our model doesn't really take into account near-surface topography, the way we calculate the travel times. But certainly that's an issue for this very shallow mining-related seismicity in an area of fairly large topographic relief.

(Arabasz-Pechmann Exhibit Four marked for identification.)

BY MR. MORLEY:

Q. Did you want to ---?

A. Yes. I'll comment briefly on what has been identified as Exhibit Four. It's an illustration, again from the PowerPoint presented to the Utah Mine Safety Commission on November 20th. It's titled Epicentral and Focal Depth Control (Plus Precision Versus Accuracy). The upper part of the illustration shows a sketch in map view of a distribution of seismic sensors making the point that to locate an epicenter it requires station coverage that's reasonably well distributed azimuthally surrounding the seismic event.

The illustration also shows a distinction between a computed epicenter with a dashed ellipse, intended to represent the confidence bounds on that location. And this is displaced from what is indicated as the true epicenter. And the point

here is that we show a computed epicenter, let's say perhaps with 95-percent confidence limits, which are separated from the true epicenter. And this circumstance might arise where one uses a velocity structure, typically horizontal layers with assumed homogeneity in all directions of the velocity structure.

If there is inhomogeneity in the velocity structure, even though one has good azimuthal coverage, all of the epicenters can be systematically shifted away from the true epicenter. And this becomes relevant in the case of our early location of the Crandall Canyon main event.

The bottom part of the illustration is a cross-section view, making the point that in order to resolve the focal depth, namely the distance below the surface where a seismic event originates, and its

hypocenter, or focus, the nearest sensor distance on the surface has to be of the order of or less than focal depth. Once the distance becomes very large, then at least with our regional network, we lose resolution of the focal depth. And hence an inability to precisely fix a location at mine level versus below mine level.

Q. So in the Crandall Canyon event, I think you said your closest seismograph was roughly 18 kilometers away?

A. Correct.

Q. And we're talking of an event in order of the depth of less than one kilometer?

A. Correct.

DR. PECHMANN:

Focal depth for the mining-related events are difficult to calculate accurately because they're so shallow. I mean they're

typically half a kilometer deep, which means that you would need a station within half a kilometer to accurately calculate the depth.

MR. ZELANKO:

Do you want to take a short break here? Do you need to take a break?

DR. ARABASZ:

I'll take a quick bathroom break.

MR. ZELANKO:

Let's go off the record for a minute.

SHORT BREAK TAKEN

MR. ZELANKO:

Back on the record then. I'll ask the question to each of you.

WALTER ARABASZ, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. When and how did you learn that there was a seismic event on August 6th, Dr. Arabasz?

A. I was awakened approximately five to six minutes after the origin time of the event, which was at 02 hours and 48 minutes, Mountain Daylight Time, on Monday morning of August 6th. So my first awareness was a pager alert. As a matter of habit, I wear my pager 24 hours a day, so that when I go to sleep, the pager is on my hip in vibrating mode. And that's how I learned of the event.

Q. And how did you respond? When you got the page, what did you do there?

A. The indicated magnitude was 4.0. And also the location was within the Utah region. Our protocol is that for a seismic event of magnitude three and a half or greater, we respond to the extent of

1 going to our network-operations
2 center, issuing a press release. I
3 got up out of bed, went to the
4 computer to look at our website where
5 an automated location and magnitude
6 would have been posted, observed its
7 location in central Utah, and then
8 got dressed and went to our seismic
9 lab.
10 I was aware that Dr. Pechmann
11 was the duty seismologist and that he
12 would be responding to the earthquake
13 interactively at home, to review the
14 event location and size. And our
15 working arrangement is that while Jim
16 is reviewing the event online at
17 home, I and, when available, Relu
18 Burlacu, our seismic network manager,
19 simply act collaboratively. And both
20 Relu Burlacu and I arrived at our
21 network-operation center with Dr.
22 Pechmann arriving soon thereafter.
23 Q. And at some point you made a
24 decision to alert authorities about
25 the event?

A. Correct. We have a prescribed telephone notification list. Notification to mine operators is not part of that prescription. Basically because of an attempt at due diligence and awareness that this was an event occurring within an area of active mining, and also because of a habit of mine, recognizing that in early morning or nighttime hours, a local sheriff's office typically --- if there is a seismic event that is felt, will typically receive many phone calls. And so I made a specific attempt that has been time stamped as 3:47 a.m., a call to the Emery County Sheriff's office. That was at 3:47 a.m. And I spoke with a person who identified himself as John. I made an immediate follow-up call to the Carbon County Sheriff's office in Price, and spoke with a person named Bucky.

Q. Have you alerted authorities on other occasions, either Carbon

County, Emery County or elsewhere?
A. When you say authorities, our primary contact with emergency managers is with the Utah Department of Public Safety, and specifically the division --- what is now termed Homeland Security, and let's see, I guess Emergency Services. So that we routinely notify that office as one of our first notifications with the understanding that they then communicate that information downward to the emergency management structure in the state.

Now, with respect to mine operators, my memory doesn't serve me well. I can't recall the circumstance of the Willow Creek seismic event in March 2000, the magnitude 4.2. But typically if we recognize something as a mining-related event, we will make a diligent attempt, either ourselves or in coordination with Kim McCarter, to try to alert mine operators.

I'll give you an example. The evening of November 21st, just before Thanksgiving a week ago, there was a magnitude 3.4 event in Southwestern Wyoming, in the vicinity of Trona Mines, where there had been the 1995 incident of the Solvay Mine collapse. And I took the initiative to call mine operators in that region, inform Dr. McCarter. And between us on that evening and the next day, an attempt to notify, inform mine operators of what possibly might have been a mining-related event in their vicinity.

MR. ZELANKO:

Okay. Dr. Pechmann, I'd like to ask you the same questions.

JAMES PECHMANN, PH.D., HAVING BEEN SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. When and how did you learn

that there was a seismic event on August the 6th?

A. I learned when my pager went off shortly after the event. And I looked at the pager and it tells me the estimated magnitude and location as determined by an automatic-processing system. It was over the threshold for which we have agreements to provide telephone notification to emergency responders and utility companies, so I got out of bed and went downstairs to look at the data and review it, working from my home computer.

As Walter mentioned, I was the primary earthquake responder on duty that day, so I was primarily responsible for doing that review. So I went down there, and I can access the data via a web interface from my home computer. And I reviewed it and posted a reviewed solution by about 20 minutes after I had gotten the notification. So

about --- let's see, we have the time on here. It was about 27 minutes after the origin time, about 3:15. After that, I got dressed and went up to the earthquake recording lab, where I found Walter and Relu, who had been there for a few minutes already.

Q. When the event is received, it's automatically processed, to some extent, the page is sent out to you. When you looked at the event, what are you trying to accomplish within that short time frame and put out on the web? What are you actually --- just verifying with the computer there wasn't a problem?

A. Well, first of all, I'm making sure that it's a real seismic event, that it's a real local earthquake. Our automatic-processing system is pretty good about locations and magnitudes for seismic events over magnitude two and a half or three. It doesn't usually miss them.

However, we do get occasional false alarms.

In fact, we just had one yesterday. There was an earthquake down in the Caribbean that our automatic-processing system recorded --- reported as an earthquake in Southwestern Wyoming with a coda magnitude of 4.7 and a local magnitude of 3.3. Was that it? The automatic-processing system in California reported it as a magnitude six up in the Bay area. So yeah, the very first thing is to make sure that it's real. You can often tell false alarms just from looking at the information that's transmitted on the pager, but not always. So you always want to look at the wave form data and see, yeah, is this real. And sometimes the magnitude can be way off, too, for a variety of reasons. Most typically, if there happens to be another seismic event at the same time, a smaller one that's far away,

the system will get confused about the source of the waves. So that's --- the first thing is to verify that it's real.

The second thing is to make sure that the location is reasonably good. I don't go through and repick all of the arrival times, but if there is any for which there's a large mismatch between the observed and the computed arrival times, I'll take a look at those. And if the azimuthal coverage it not very good, then I would try to add stations in the gaps in the azimuthal coverage. That wasn't an issue for the Crandall Canyon Mine event, but it is an issue sometimes. And if there isn't good azimuthal coverage, it can be off by tens of kilometers.

And then finally, I will look at the magnitude and the magnitude determinations from the individual stations. And if there's any big outliers, I'll go and take a look at

it, the data from those, and see if there's anything wrong with it. And if there is, then I'll just delete it. And then after doing this, I will hit a button that will post the reviewed location and magnitude to the website.

Q. And this activity is 24/7 by someone at the seismological stations?

A. Yes, there's always somebody who is responsible for responding to earthquakes of magnitude three and a half or larger. Our pager threshold is magnitude three for most areas in the Utah region, two and a half in the Wasatch Front urban corridor.

Q. And once you've gone through and verified that this is real and it's above a certain threshold, three and a half I think you mentioned, you're going to --- you make a decision about whether it's important to alert whether it's the DSP or the local sheriff or whatever; is that

correct?

A. Well, we ---.

Q. The utility company, I think you mentioned.

A. We have agreements --- well, we have agreements with a number of organizations who have asked to be notified about significant earthquakes and who we judge have, you know, an important reason to know. So we --- and the notification thresholds are different for different organizations. So we run a computer program that tells us who we need to call for --- and that looks at the magnitude and the location and will tell us who we need to call. We also have a table that we can look up the information on.

Just one detail about the 24-hour response. Currently, the person who is on duty needs to be in a position to start reviewing the data within a half an hour after getting the page. So that's --- the

1 person who's on duty is not
2 necessarily sitting around at home or
3 in the lab the entire time, so ---
4 but they're expected to be able to
5 respond within a half an hour.
6 DR. ARABASZ:
7 This is Walter Arabasz,
8 adding comment. Our
9 laboratory is not staffed on a
10 24/7 basis. We have a duty
11 seismologist response.
12 Also, we operate as
13 part of an advanced national
14 seismic system in tandem with
15 the U.S. geological survey,
16 particularly the National
17 Earthquake Information Center
18 in Golden, Colorado, which is
19 staffed on a 24/7 basis. So
20 that insofar as our regional
21 network is a subset of the
22 advanced national seismic
23 system, the duty staffer at
24 NIC, the National Earthquake
25 Information Center, in Golden,

Colorado, has a responsibility to intervene to correct information that might have been automatically posted on the web if the regional network does not respond in a timely way to correct information. So inherently we have a reliance for 24/7 backup with the National Earthquake Information Center.

And in terms of availability of information or notification, the protocols that we follow are basically somewhat archaic and inefficient in the sense that we have a telephone notification list, but in human terms there are problems when, in a stressful situation, we're simultaneously dealing with earthquake analysis and telephone notification. There

is a service provided as part of the Advanced National Seismic System called the Emergency Notification Service. This is publicly available to anyone. Any individual can go to the USGS website at earthquake.usgs.gov and subscribe to a notification service, specifying a geographic area or areas of interest and magnitude thresholds. So that assuming that an event is above a threshold where an automated location has been posted to the web, which goes simultaneously, in the case of Utah seismic events, to our website and to the USGS website, then that automated notification would then propagate through this earthquake notification service to a user.

MR. ZELANKO:

Well, in the case of Crandall Canyon, the event that occurred on August 6th, at some point you recognized that it was an event that would have effect in the Wasatch Plateau area, Huntington and Price area, and you made a decision to call the local authorities. To some extent you had determined that that was a mining-related event, is that true, and that's what prompted you to make the call to those folks?

DR. ARABASZ:

Not a determination that it was a mining-related event but that it might be. We had experience, for example, in a study that Doctor Pechmann and I made in 1999, I believe it was. It was a report to Lawrence

Livermore Lab of an evaluation of mining seismicity in Utah for purposes of a comprehensive test ban treaty.

This publication is referenced on our website. Excuse me, the date is March 1, 2001. It's a report entitled Seismic Characterization of Coal Mining Seismicity in Utah for CTBT Monitoring. And there is a link within one of the FAQs on our website pointing to this report. Coincidentally, there had been a magnitude three event, I believe it was, several kilometers south of the Skyline Mine in 1996, a naturally-occurring tectonic earthquake, normal faulting, focal mechanism.

We knew that there was a possibility that there could have been a tectonic

earthquake for reasons chiefly relating to the appearance of consistent downward first motions on the --- most of the stations in the network or those that Jim was able to examine during the early review process. This raised a red flag that it might be a mining-related event.

Those downward first motions are not proof positive, but it raised the possibility that this might be a mining-related event. Now, frankly, in my mind, Crandall Canyon wasn't on my mental radar screen as a mine where there was significant production under way or attention at least in terms of patterns of mining seismicity had shifted to the Book Cliffs area.

And just that, Crandall

Canyon, as an active operating mine, wasn't mentally on my radar screen, so that it wasn't until the next morning when I awoke that I learned that miners were trapped, that there was active mining going on at Crandall Canyon.

MR. GATES:

Would you have made that call if there had not been --- if you had not had the indications that it was mine induced? Did you make some notification regardless of the --- I guess once you confirmed that an event had took place, would you contact anybody?

DR. ARABASZ:

We have our prescribed notification list. But as I mentioned earlier, as a matter of habit, I would have called the sheriff's office to inform

them because typically they would be receiving telephone calls. This would be an attempt to inform the dispatcher or duty person that a seismic event had occurred and where they could get additional information on our website.

MR. GATES:

So that's effectively --- when you made the calls, that's effectively what you said to --- I think you said John and Betty.

DR. ARABASZ:

Becky, correct.

DR. PECHMANN:

Correct me if I'm wrong, the other reason for calling the sheriff's office is to get any information that they might have, okay? So that was, I think --- a good part of the motivation, too,

was, do you know anything about any problems that --- any collapses at any of the local mines or do you know about --- in the case of an earthquake, do you know of any damage reports?

Because we don't have any way of finding out about damage reports accept from civil authorities in the news media. So we will --- but people always ask us about it. And we like to know, so we will make phone calls sometimes for that purpose. And the sheriff's offices are not on our calling list because they will be notified through the Division of Homeland Security, through their communication system, for events that are large enough that they would --- that the state officials would

consider it, you know, important to notify them.

I guess the phone calls to the Division of Homeland Security have a higher threshold in the middle of the night than they do during the day. And this did not meet the threshold for calling them. I think it's magnitude five or something for the Homeland Security, for waking them up at home.

MR. GATES:

And I guess I was going to follow up with that, did you contact anybody other than the Carbon County and Emery County sheriffs that evening?

DR. ARABASZ:

Yes. There were parties on our routine notification list.

MR. GATES:

Do you recall who those

parties are or were?

DR. PECHMANN:

Do you have that list?

DR. ARABASZ:

Yes.

MR. ZELANKO:

So you have a well-established protocol for a certain magnitude that these people need to be notified?

DR. ARABASZ:

Yes. And we will call them. For some people the thresholds are different at 3:00 a.m. than at 3:00 p.m. While Doctor Pechmann is reviewing some notes, let me add to your line of questioning, because there is some relevant information here as it relates to our response. I have a memory of asking one of those sheriff's offices, do you have a telephone number for the Crandall Canyon Mine.

And the tape from the Emery County contact makes it evident that I didn't ask that question in that tape. My memory may fail me, but I just have this recollection. The sequence then was at 3:47, when calling the Emery County Sheriff's Office and immediate follow-up call to the Carbon County sheriff's office. In each case I explained that the character of events suggested that it might be mining-related.

I gave them information in the magnitude and location, pointed them to our website for more information, asked if they had any information, in which case they did not. They had not received any reports of a felt seismic event and had no information to return to me.

As best I can recover, at about four o'clock, Becky, from the Emery County Sheriff's Office, phoned back and I believe spoke with Relu Burlacu, reporting that she had talked with the Emery County Sheriff's Office and learned that there had been a mine collapse at Crandall Canyon.

With that information, I called back the Emery County Sheriff's Office shortly after 4:00 a.m. and spoke with a person who identified himself as Ray. And from the feedback judged --- I asked the question whether the mine had publicly confirmed the mine collapse. And the information I got back led me to judge that they hadn't. And why this was relevant was that we were in the process of

producing the press release, which was phoned to the Associated Press between 4:10 and 4:20 a.m.

And it's our policy not to be reporting information which some affected party appropriately should be reporting publicly. And so when we issued the press release, it was a straightforward reporting of factual information about the occurrence of a seismic event, its magnitude, location and time.

And also in this sequence of events, when information came back to me that the local authorities were aware of the mine collapse, had been in contact with the mining operator, and I judged that --- that this, in my mind, brought closure to

our need as a reporting unit to be providing relevant information to affected parties and to authorities.

DR. PECHMANN:

Okay. The people who we called that night were the Associated Press, U.S. Bureau of Reclamation, Salt Lake Regional Office, U.S. Army Corps of Engineers, Sacramento District Office, the Utah Division of Water Rights and Dam Safety, Questar Pipeline Company, Utah Power, Questar Regulated Services. And let's see, National Weather Service, so ---. And then there were other people who we contacted the next day. So these are mostly utility companies and emergency managers, people responsible for dam safety.

MR. GATES:

Is that kind of an

automated call or one that somebody from --- either you or somebody from your staff would make that call and share essentially the same information with each of those parties?

DR. PECHMANN:

Yes, we personally make the phone calls. And as Walter said, this system is archaic, and we really kind of need to replace it. Nowadays, there are more automated ways that we can do this.

MR. GATES:

I was going to say, I can see you being here for quite some time, unless you've got a pretty big staff here at 3:00 in the morning continuing to go through the --- go through the calls.

DR. PECHMANN:

Oh, yeah, well we

weren't actually --- we weren't actually that fast about it that night. The last calling here is, let's see, National Weather Service, 4:42 a.m., Questar 4:30. Division of Homeland Security gets an automated page or email. So even though we don't call them, they do have access to that.

I don't know if ---. Yeah, they do have access to that. But, yeah, these other people --- we need to replace the system. Although there always is the danger with an automated system, you don't really know if they got it exactly.

MR. GATES:

Would it be possible for us to get a copy of that calling list that you have there?

DR. ARABASZ:

Yeah.

DR. PECHMANN:

Yeah. Sure.

MR. GATES:

We can take care of that. We can do it later.

MR. ZELANKO:

There are several facets of the seismological stations information that appear to have been interpreted in a variety of different ways. And we'd like to try to clarify some of that if we could. And there are about four of them. So I'll address the question to Dr. Arabasz to begin with.

WALTER ARABASZ, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. Media reports soon after the accident reported that a 3.9 Richter-magnitude earthquake had occurred. And that earthquake seemed to be interpreted by some in the media as a tectonic or naturally-occurring earthquake. Do you know why that may have happened that way or is there anything that ---? First of all, do you concur with that interpretation that it was a naturally-occurring earthquake on August 6th?

A. The press release would have reported the occurrence of an earthquake. And one of the FAQS' that we describe on our website relates to this question, did we record a quote, earthquake and then change our minds.

In our practice we would not distinguish a mining-induced earthquake from a naturally-occurring earthquake. Again, both releases seismic energy underground so that in our parlance as seismologists, these

would equivalently be earthquakes.
Q. So the term earthquake encompasses both mining-induced activity and tectonic earthquakes?
A. Correct.
Q. Okay. In layman's terms would you describe how seismologists distinguish mining events from other sources?
A. There are different diagnostic tools available. The simplest tool is this recognition of a consistent pattern of downward first motions of recordings on vertical sensors. This however, is not proof positive because if this class of event, one which produces downward first motions, is to be distinguished from the naturally-tectonic earthquake, which has some mixture of upward and downward first motions ---. You have to have confidence that you haven't missed any of the upward motions.
And the other more diagnostic tool for interpreting the source

mechanism comes from the analysis of broad --- of high quality broadband waveforms where a broadband instrument has recorded with high fidelity on scale complete waveforms of a seismic recording. And there are techniques available for using that information to interpret the source mechanism. It turns out in practice that there are programs to do this that assume that the event is a naturally-occurring earthquake.

There is a subset of specialists in the United States who deal with unusual events. And those practitioners are affiliated with nuclear test band treating monitoring. And this subset of practitioners is more expert in dealing with events like explosions, discrimination of explosions from earthquakes, discrimination of collapses from earthquakes. And this leads to the involvement of the Berkeley seismic team. I'll pause

here and let Jim add to the general question.

DR. PECHMANN:

So as Walter said, the first motion information is not definitive in itself typically for many seismic events. But if all of the first motions were up, then it would be an explosion. If they're all down, then it would be an implosion or a collapse. And if it's a mixture of up and down first motion, then the source is probably slip on a fault, like this.

And then the --- well, this diagram here illustrates the first motions for the Crandall Canyon Mine main shock. These three right here are the Crandall Canyon Mine event. They're all down first motions. I don't know if

you've ever looked at these kind of plots before.

MR. MORLEY:

A little bit.

DR. ARABASZ:

Do you want to refer to them as an exhibit?

DR. PECHMANN:

Yeah. I even brought an extra copy.

MR. ZELANKO:

For the record, can you describe what the drawing is and we'll put a --- we'll label it Exhibit Five.

(Arabasz-Pechmann Exhibit Five marked for identification.)

DR. ARABASZ:

Yeah. Okay. This is a lower --- this is a plot of observed P-wave first motions on a lower hemisphere equal area stereo net projection. And A, B and C are for the

magnitude 3.9 Crandall Canyon Mine main shock. A represents our preferred interpretation, that of an implosion, so there's no nodal plains drawn on there.

B illustrates how a normal faulting earthquake type mechanism could be fit to this data, at least for the focal depth at which we've plotted these first motions; okay? Now if I change the focal depth, then the distribution of the first motion points on the stereographic projection would change. And it may or may not be able to fit a normal faulting mechanism to it. But these --- these curves right here represent projections of a dipping plain onto this two-dimensional diagram.

So without getting into

a lot of detail, one could fit this data with a normal faulting earthquake. But C here shows the best --- the nodal plains plotted on C show the best fitting earthquake type mechanism determined by the group Berkeley Group for waveform modeling.

And this is totally incompatible with the first motion information. Because one would expect to see these curves on the diagram separating up and down first motions. And this curve here runs right smack through the middle of a bunch of down first motions. So in --- especially in this case, the waveform modeling is a much more definitive technique.

The idea is that you calculate predicted waveforms at low frequencies for a

1 particular type of seismic
2 event and compare it to the
3 observations. And you try to
4 match the observations. And
5 what the Berkeley Group found
6 was that the observations were
7 much better fit by a collapse-
8 type model than by an
9 earthquake-type model.
10 MR. ZELANKO:
11 So given just the first
12 motion analysis, the ambiguity
13 is that you could fit a model
14 to that data, but once you
15 look at the Lawrence Livermore
16 analysis, it pretty much fits
17 the collapse source mechanism
18 rather than a naturally-
19 occurring earthquake.
20 DR. PECHMANN:
21 Right, now D here is
22 for the magnitude 1.6 seismic
23 event that occurred on August
24 17th, UTC, August 16th local
25 time. And because we had the

portable stations in place at the time, these first motions are distributed over a broader area of the diagram. And it's not possible to fit a normal-faulting earthquake to this data, at least if the source depth is fixed at .6 kilometers, as I have done so here. If we didn't know the depth of that, and I tried doing this at different depths, then I might be able to fit a normal --- fit an earthquake-type mechanism to it for another depth. So that's one of the ambiguities that enters into this type of analysis which isn't really illustrated here.

DR. ARABASZ:

Walter Arabasz, for clarification of Exhibit Five, what is plotted are open circles conventionally in

seismological practice for a dilation on downward first motions. And upward compression first motion would conventionally be plotted as a solid symbol and normal note, but there are no compressions or solid circles on these diagrams, only open circles dilatations.

DR. PECHMANN:

This will be in our publication about the seismic-event analysis.

MR. ZELANKO:

The Lawrence Livermore people, am I correct that they did look at different elevations of the source, deeper, shallower?

DR. ARABASZ:

Yes, what we've been referring to as the Berkeley Group is actually a collaborative effort between

Berkeley and Lawrence Livermore. And, yes, they did look at waveform fit as a function of focal depth. And found that focal --- I have that paper here. One kilometer or --- yeah, here we go.

Okay. It looks like the best fit to the data is at about one-kilometer depth with pretty comparable fits for a couple of depths that they've tried that are shallower than one kilometer. And then the fit deteriorates for depths of two kilometers and more.

From the travel time information alone, we can't constrain the depth of the Crandall Canyon Mine event very well. Okay. Yeah. Depths of 600, 800 --- 600 meters, 800 meters and one kilometer give similar levels

of fit. The slight increase in fit from two to three kilometers' depth is likely due to the presence of velocity discontinuity in the structure model. So their --- you know, their analysis indicates that it's a very shallow depth and, you know, something comparable to mine level.

MR. MORLEY:

For clarification, their method is building a model of the event and then generate --- generate the waveforms from the model and then compare them to the actual waveforms and see if they match or --- is that what they're doing?

DR. PECHMANN:

Yes, although the trial --- I described it as kind of a trial-and-error process.

It's really an inversion process. They have a computer program that will look at the observed waveforms and then try to find the source that best fits it. So it's semi-automated in that respect. And the type of source that they use to try to fit the data is a very general source that --- very general source model that can include volumetric changes, i.e. explosions or collapses as well as shear-slip motion on faults.

And they're one of the few groups that's actually set up to model these general types of sources because they've been using this technique to work on discrimination of explosions, collapses and earthquakes.

MR. ZELANKO:

Can we enter this from your presentation before the Mine Commission, a figure, it's titled Berkeley Report Key Evidence for Non-Tectonic Seismic Source and we'll call it Exhibit Six.

(Arabasz-Pechmann Exhibit Six marked for identification.)

MR. ZELANKO:

And on this diagram maybe you can explain it a littler further, but there's a star that represents the Crandall Canyon event.

And it's plotted very near a group of green events that are marked Crack. Can you interpret this a little bit for us? It appears that we have a great number of explosion events at the top of the figure indicated in red. And the bottom are implosion

events.

The direct couple of events in the middle appear to be naturally occurring tectonic events. Can you explain a little bit about the CLVD and why these cracks appear over here?

DR. PECHMANN:

I'm smiling because before Walter went to speak to the Mine Safety Commission he asked me this exact same question. And I had to go and drag out a textbook in order to really answer it, because it's not something that I'm used to thinking about. And the CLVD is not a very intuitive concept.

So yes, in the middle of this diagram --- okay, let's see, the axis --- the vertical axis is the isotropic perturbation from a double-

couple mechanism. Okay, what's double couple? A double couple is a shear-slip motion. So a double-couple mechanism is a typical earthquake-type mechanism.

An isotropic perturbation from the double couple would be indicative of some sort of volume change at the source. Okay. So they're talking about the isotropic component of the moment tensor. And the moment tensor is the sort of generalized source model.

The horizontal axis is the deviatoric perturbation from the double couple. So okay, double couple, it's very hard to explain this without getting technical. But, okay, a shear-slip source can be represented for computational purposes as equivalent to a

distribution of point forces near the source, okay? And the --- and it's just easier to calculate synthetic seismograms or calculated waveforms using this kind of representation.

And in an earthquake-type source, you have asymmetry to the double couples and asymmetry to the radiation pattern of the seismic waves. And so this represents a deviation from the symmetry and the double couple.

Okay. In a Compensated Linear Vector Dipole, which are the end members on the horizontal axis, you have a combination of implosion and explosion that cancels out. And I don't know of any actual physical source that can generate the Compensated

Linear Vector Dipole, but it's more like a mathematical construct that's useful.

I guess the important thing about this diagram is where you have explosions and where you have cracks. So here you've got --- okay, in this green area down in this corner, you've got a collapsing horizontal crack, so a crack that looks like this and it's collapsing.

So this crack up here would be an exploding crack, like you I suppose could get if you, you know, buried a distribution of explosives underground. And in this moment tensor parlance, the collapsing crack model turns out to equal the sum of an isotropic collapse, so like a spherical-type collapse and this Compensated Linear Vector

Dipole.

DR. PECHMANN:

Yeah, in order to do any better, I'd have to get far more technical than that.

MR. ZELANKO:

I think that's fine.

DR. PECHMANN:

Like drawing diagrams on the board.

MR. ZELANKO:

At the end of the day, the information we have suggests pretty strongly that this was a massive pillar collapse event that occurred on August 6th at Crandall Canyon, fair enough?

DR. PECHMANN:

Well, the seismology can tell us it was a collapse. It can't really tell us whether it was pillars or anything like that.

MR. ZELANKO:

It was a collapse. Is it possible that an earthquake, a naturally occurring tectonic-type earthquake could have preceded this larger event and actually provided some triggering mechanism for the bigger event? Is there any indication in the information that you have, the seismic information, that there was some naturally occurring perhaps smaller event that preceded this one?

DR. PECHMANN:

No, there is not. There were seismic events that preceded it. The last one that was big enough to trigger our network and be routinely located was, what, seven hours before?

DR. ARABASZ:

Approximately. That

information will be in a publication that we're preparing.

DR. PECHMANN:

Yeah, we did look at continuous seismic records from the closest station, specifically to look for any possible triggering event. And I'm digging for that information right now. There were, you know, quite a few events visible on that record within that several-hour period.

But this isn't unusual in the coalmining region. I mean if you put a seismometer out near a mine, you will typically see a seismic event every few minutes. A lot of these are very small and can't be located. And that was true for most of the events that we found on the records. There

were --- you know, there were a few that were able to be located after we went and pulled data from places.

And, you know, some of those were in the Crandall Canyon Mine area. The last event that we saw on the station that was 18 kilometers away was at 8:48:08, but it was unlocatable. So this was --- yeah, UTC, 08:48:08. So this was something like 30, 32 seconds before the Crandall Canyon Mine main shock. But we don't know where it is.

It is an extremely small event. And there were lots of other events going on, you know, in this several hour time period. So I wouldn't --- I wouldn't consider this to really be any sort of significant triggering event. Now, in terms of something

right before it, like that would be maybe part of the main shock waveforms, I think we can rule that out from the first motion information in combination with the waveform modeling.

One complication that I did not mention yet is that the Berkeley Lawrence Livermore analysis found that about 20 percent of the energy release in the Crandall Canyon Mine event was due to something other than a collapse mechanism and could be interpreted as a shear-slip source, okay?

And they talk about that in their report. But this could not have come first, because when they look at what that shear-slip source would look like, the mechanisms are similar to the

one that is plotted here. So if the seismic event started with that, then the first motion pattern would be a pattern of compressions and dilatations separated by the curves on this plot, and they're clearly not.

MR. ZELANKO:

This miner component of a shear-slip source in the Berkeley modeling --- and I'll direct my question to Jim --- is this not just an indication that the source was not a simple collapse, but somehow it was complicated and might have involved some kind of a horizontal dislocation?

DR. ARABASZ:

Yeah, let's see. Well, there's a variety of different ways that you could interpret it. Non-uniform collapse is one of them. Slip on

basically a crack in the roof could explain it, with the east side down. So if you had a new vertical crack in the roof, maybe sort of at the western edge of the collapse that occurred at the time of the collapse, then that could explain it.

It could also be explained by motion of the roof relative to the floor at the time of the collapse due to perhaps, you know, some sort of topographic effect.

MR. MORLEY:

You're aware of the barrier movement that was observed in the mine, where the barrier pillar was displaced. Would that be a potential source of that energy?

DR. PECHMANN:

We've thought about

that. I guess the short answer is, it's hard to explain it that way, because that motion was mostly --- well, let's see, it's hard to explain it that way.

DR. ARABASZ:

Let me just suggest that in complete interpretation this isn't an example of where the other pieces of relevant information from the mine setting, combined with the seismology, ultimately will yield a better interpretation, but this is the state in where we're at now with what we know seismologically.

MR. ZELANKO:

I want to go off the record a minute.

OFF RECORD DISCUSSION

DR. PECHMANN:

It's hard to explain it

that way. It might be possible. At least at the present time, given the information we have, you know, the breakthrough in the roof would seem to be one of the more logical explanations for it, ---

MR. ZELANKO:

Okay.

DR. PECHMANN:

--- but certainly not the only one.

MR. ZELANKO:

And do you have anything to add about --- Dr. Arabasz, about earthquake triggering a massive pillar collapse event at the mine? Our interpretation being a massive pillar collapse, asking you if it's possible that a natural earthquake can trigger such a collapse event?

DR. ARABASZ:

Two possible examples of a trigger would involve a nearby earthquake which produces a static-stress change influencing instability elsewhere or the dynamic passage of seismic waves that might destabilize a structure and produce a collapse. And I think on that count we can rule out both of those possibilities.

MR. ZELANKO:

In this instance.

DR. ARABASZ:

Correct. In terms of a deformational event, there always is a scaling of deformation, let's say in the --- I would imagine in a laboratory sample. For example, you could have microcracks preceding a larger failure where they're all part of the same deformation

environment and event. If hypothetically there had been some tiny precursor, would that have been --- let's say the precursor, a naturally-occurring earthquake, could that have triggered the collapse, I think we could confidently say no.

If there --- could there have been a tiny precursor that was part of the deformation preceding the collapse? I guess that's hypothetically possible, but the bottom line, is there any seismological evidence for a naturally-occurring earthquake in the immediate seconds or minutes preceding this energy release interpreted to be associated with the mine collapse? No evidence for that.

MR. ZELANKO:

Okay. To move on, another source of confusion appears to be the calculated depth of the event, since it was well below the mine level, as initially reported at least, some people interpreted that to mean it was not associated with the mine.

I think you explained earlier, referring to figure four, the difficulty with determining the depth given the array, the geophone array. Is there anything further that you'd like to add about that? Do you feel that the original --- was that the source, do you think, of the confusion?

DR. ARABASZ:

Yes, in the real world earthquake locations change with time. That's a fact. Constantly seismological determinations of an event

location and depth progressively we find with added information and with subsequent analysis.

To us as seismologists, frankly it was no big deal that our preliminary location was spatially separated from the inferred area of mine collapse. We expected that with refinement of our event location --- we expected conversions.

DR. PECHMANN:

I can't remember what focal depth I got when I did the reviewed solution. But the next day when the seismic analysts process the data and posted a third revision on the website, the depth they got was 1.6 kilometers. Most seismologists would look at that and say, well, all right it's somewhere right near the

surface.

A seismologist would not consider the difference between the .6 kilometer depth of the mine and the 1.6 kilometer depth of the source here to be significant. That said, this 1.6 kilometers was not very well constrained either. It could have been, you know, considerably deeper and fit the data also.

DR. ARABASZ:

And the assumption here, or the circumstance is that the observations are coming from a regional seismographic network. They're not coming from an above mine or in-mine array.

MR. ZELANKO:

Similar question for the aerial location. Initially the location was determined to lie southwest of

the mining section. And later the location was recalculated several times. And I think in reference earlier to Exhibit Four you also explained how that position changed as the data was interpreted finer and finer. Is that --- can you again say in layman's terms why the position changed several times?

DR. PECHMANN:

Sure. And let's dig for one of the other figures in here that shows the locations where --- no, it's actually not that one. There's another one that has the uncertainty limits for the main-shock locations, at least two of them. It's a color figure with ---. I know it's in here. Yeah, this one right here.

Okay. We have ---

there's two main shock locations plotted out on this figure, okay? The one that's labeled ML 3.9 standard location is the one that was posted the next day after the seismic analysts processed the data. And that has 95 percent confidence limits on it, which you will note, sort of barely intersect the western boundary of the mine.

There's ML 3.9 revised location on here, which is shown by another star with dash lines around it, indicating the confidence limits. And those confidence limits encompass most of the estimated collapse area that we obtained from your team. The confidence limits for these two solutions don't overlap very much, although they do overlap.

And part of the problem here is that those confidence limits only take into account sort of the random error in the solution. They don't take into account systematic error due to unmodeled lateral velocity variations. So again a seismologist would not consider this difference to be surprising.

Now to get this particular revised solution, what we did is we used the known location of the magnitude 1.6 on August 16th mountain time and used that to determine corrections to the travel times to the various stations in the area. And then we applied those corrections and used them to relocate the main shock and then other seismic events before and after. And those

are the epicenters that are shown on this plot. Subsequently we did another revision of the locations using these locations as starting locations. And that's shown in this next diagram.

MR. ZELANKO:

We'll mark it as Exhibit Eight.

(Arabasz-Pechmann Exhibit Eight marked for identification.)

DR. PECHMANN:

So this next technique that we used and Kris Pankow of our lab is the one who did most of this work. It's called the double-difference method. And the advantage of this method is that it looks at differences in travel times recorded at a single station for two different seismic

events, okay? And I'll do this for a bunch of different stations. And because it's just looking at travel time differences between two events, it can do a better job of calculating the relative locations.

The disadvantage of this method is that it can't relocate all of the events. So in this case I think there is something like 150 out of 189 events in the sample were successfully relocated using the double-difference method.

So what's shown on this plot are only the seismic events that were able to be located using the double-difference method. So they're over here and then the master event locations for that same reduced dataset are on the left. Now you'd have to look

hard to tell the difference, but except for the missing events, these epicenters are the same as these. Okay. The ones master event here are the same as on this one here.

MR. ZELANKO:

The events in ---?

DR. PECHMANN:

Exhibit Seven are the same as the ones on the left side of Exhibit Eight. The locations are the same, but not all of the events in Exhibit Seven are shown on Exhibit Eight. Okay. The reason that the double-difference method can't relocate all of the events is first of all it --- let's see, it needs I think eight, was it eight pairs or eight --- or four pairs?

Anyways, it has a certain minimum number of

travel --- of differences that you need to get at the same station for the two different events. And so there's some events right off the bat for which you just don't have that information. And then the other limitation of this method is that if the event at some point in the interative process pops above the surface, then it will simply discard it.

But actually it worked very well. And we consider those our best effort to date. And on this one the main-shock location is approximately --- is it 270 meters west of the western boundary of the collapse area, estimated by your team.

(Arabasz-Pechmann Exhibit Seven marked for identification.)

MR. ZELANKO:

Let's take a break.

SHORT BREAK TAKEN

MR. ZELANKO:

All right. To follow up on things that were maybe misrepresented in the media, it was reported that the signal trace of one of the seismic station's geophones indicated that the instrument responded to the August 16th event for more than four minutes.

And the interpretation in the media was, at least by some, that the event actually occurred over a period of four minutes.

JAMES PECHMANN, PH.D., HAVING BEEN PREVIOUSLY SWORN, TESTIFIED AS FOLLOWS:

BY MR. ZELANKO:

Q. Can you discuss geophone response relative to the duration of the event? And I'll address this to Dr. Pechmann.

A. To clarify the question, August 16 or August 6th?

Q. August 6th, I think that there was a four-minute duration reported and interpreted as the mine collapse occurred over that duration of time period.

A. Right. The duration of a seismic event recorded on a high-gain instrument is well known by seismologists to be orders of magnitude longer than the actual duration of the source. I should have looked it up before I came, but the --- we do have measurements of the duration of the event on high-gain instruments. And, yes, they're probably several minutes. This is one of the ways in which we calculate magnitudes, is from the duration of the event.

Now, the reason that the duration of the signal recorded on a high-gain instrument was much longer than the duration of the source is that what you're recording are seismic waves that have traveled many paths from the source to the receiver.

In particular you're recording seismic waves that are back scattered from velocity, heterogeneities in the crust and upper mantle. So if you've got let's say a source here and a receiver here, then a lot of these waves have been shown to be waves that maybe travel out here and then get scattered back to the receiver. So they've traveled very long travel paths. And so you can't really interpret the data that way.

Q. Can you estimate what the actual duration of the event that caused that geophone response, what it might have been? If you can't do it precisely, at least you said in an

order of magnitude different?

MR. MORLEY:

Put a boundary on it.

A. Yeah, we've tried to do this in a rigorous way and so far we have not succeeded in doing that. But I would guess that the duration of the source was only a second or two. This is based in part on source studies for earthquakes of similar magnitude and also the following consideration that ---. Well, certainly earthquake ruptures and likely pillar collapses will propagate at a speed that's a little bit less than the shear-wave velocity speed.

And the shear-wave velocity, in our velocity model at the mine level is, I believe a couple of kilometers a second. And the length of the collapse area that was supplied by your team is less than a kilometer. So, you know, that would give you a source duration of

something less than a second. And so I would guess it was only a --- I would guess it was only a second or two.

We haven't given up totally on this, although we're kind of stuck. There is a technique you can use to remove the propagation effects from a recorded seismogram for say a large earthquake using the record of a small earthquake, a much smaller earthquake. In this case the problem is that the smaller earthquakes are so small that they're not very suitable for this kind of exercise.

BY MR. ZELANKO:

Q. So it's fair to say that the interpretation that the collapse occurred over four minutes is an incorrect interpretation of those signals?

A. Right. I should have brought this with me. Well, as an example, that magnitude 1.6 event on August 16th, I think that had a duration on

high-gain instruments of a couple of minutes, okay? And I think --- well, this is one of the questions that we posed to you, how long did it actually last. There were people who were there at the time. And my guess it wasn't anywhere near two minutes, or they would have gotten out of the way. It was ---.

MR. ZELANKO:

Yeah, we can discuss that later off the record, but the interpretation generally was that it was a fairly instantaneous event as experienced by the people underground.

A. Right. And, yeah, I can look up what exact duration we measured for that event. But it --- you know, it was minutes, or, you know, at least over a minute anyways.

BY MR. ZELANKO:

Q. That leads pretty well into the next question. You mentioned

that perhaps there's a way for you to do more analysis on the event duration. Are there other analyses that also are ongoing of the Crandall Canyon, the 6th and the 16th events?

A. Let's see. I think we finished up most of what we are planning to do with the exception of that. Oh, one thing that --- yes, there is one other thing that I want to follow up on and that's comparison of the waveforms for the larger events and the smaller events. In that it looked like --- and this was actually first pointed out to us by Doug Dreger at Berkeley that the first part of the waveforms for the Crandall Canyon Mine main shock, the first swing or two, was comparable in amplitude to that of some of the very small aftershocks. So it looked like it started out as a small event and then got bigger.

DR. ARABASZ:

On a very short

timescale.

A. On a very short timescale. Yeah, we're talking like, you know, fractions of a second here. Fractions of a second. So, yeah, we're looking at that. And other people may be looking at other things. There's at least one other person who is --- was trying to get at the source duration using this empirical Green's function method. Relu happens to know and talked to in a meeting, but that ---.

MR. MORLEY:

That's not here at the university.

A. No, that's not here. And we don't even have those results. She's just working on it.

MR. GATES:

I guess I'd be interested if you could maybe explain, you said it started off small and got bigger? I think that's what you said.

And I know it was a very short time frame.

A. Yeah. I'm digging for a figure here that I made. Well, I'm going to have to give --- I want to copy it first. So --- because this is my only copy, I don't want to have to go regenerate them. And I actually haven't looked at these in a while.

MR. MORLEY:

Is this analysis complete?

A. No, not really.

DR. ARABASZ:

Would you like to explain to Richard off the record later or ---?

MR. MORLEY:

Maybe you could, rather than specific, just ---.

A. Right. Yeah. Let's just say this is an ongoing analysis. And I'd be happy to show this to you afterwards. I don't really want to

try to present this sort of half-baked stuff on the record, when I haven't looked at these plots in weeks either. So ---.

MR. MORLEY:

That's fine.

BY MR. ZELANKO:

Q. The reason we asked about ongoing analysis, it's our understanding that you and others --- you, Dr. Pechmann, and others are preparing a technical publication about the Crandall Canyon seismic event. And we're just curious, is it likely that any of these ongoing analyses altered the primary observations and conclusions that you're going to reach in the paper that you're working on? I mean I know it's hard to be a fortune teller, but there's nothing major that you're working on right now that's going to alter things, as far as you know?

MR. MORLEY:

Or is there?

A. No, both of these sort of ongoing investigations are related to sort of separate issues. More like the duration and then the details of, you know, the time history of the event as opposed to the location or the basic mechanism.

BY MR. ZELANKO:

Q. By the way, when does the paper --- when do you anticipate having it done?

A. I don't even want to answer that.

Q. When is it going to be presented?

A. Well, there will be a poster presented at the American Geophysical Union meeting a week from next Monday, okay? Many of the figures in that poster were in Walter's PowerPoint, not all of them. I just gave you one of the other ones, that focal-mechanism plot, which Walter chose not to try to explain to the

Mine Safety Commission. Actually, maybe I haven't even given it to you yet. So --- yeah, so, you know, there will be this poster presentation.

DR. ARABASZ:

The timing of the manuscript? I've already given several estimates that I've failed to meet, but that's --- I was actually hoping to distribute preprints at the meeting, but --- so that's my goal.

MR. MORLEY:

I guess our question is, do you expect any of your conclusions to substantially change between now and your ---?

A. No.

BY MR. ZELANKO:

Q. And can we get a copy of the preprint as well?

A. Yes. When it's done you will

certainly get a copy.
Q. Is it likely that any further analysis with all the observations and conclusions provided in what we're calling the University of California Berkeley paper written soon after the accident occurred, their waveforms analysis, is it likely that that's going to change? Is there any additional work being done there?
A. They did say that the interpretation of that 20 percent shear-slip component was something that could use some further work, okay? So their --- they may do some additional work on that shear-slip component. But the overall conclusion that the source mechanism was dominantly a collapse-type mechanism is very unlikely to change.
Q. And you concur with the conclusions in that paper in general?
A. Yes.
MR. ZELANKO:

Dr. Arabasz, you'd agree with that, too?

DR. ARABASZ:

To the best of my --- to the extent that I understand the technical details in the paper, yes. So what they presented in the paper, yeah, just to put a fine point on that, what they presented in the paper looks convincing to me. But I didn't do the --- you know, I didn't redo the analysis to check it myself, so I didn't --- you know, there's a certain element of trust there. It's not like we replicated it.

But they also are among the world's experts in this type of analysis. They've been doing it for earthquakes at least for many years. And they've branched out into

doing it for these other types of sources. And Bill Walter, the seismologist from Livermore, worked with us on an analysis of the 1995 Solvay Mine collapse. So I know him and I know that he and Doug Dreger are pretty careful.

MR. ZELANKO:

If I could revisit, earlier we asked about expertise and the expertise of this group. If I could just say, are you being a little modest saying that you don't consider your mining --- yourself mining induced seismicity experts, when in reality there aren't a lot of other people, I mean I think you mentioned Art McGarr, maybe Martin Chapman and a handful of others. It seems to me that you'd have a great deal of experience dealing

with ---.

BRIEF INTERRUPTION

MR. ZELANKO:

It seems to me like you're being modest. You indeed have a great deal of experience, in fact, relative to others that we can see. And I'd like to draw a little bit of a distinction. There are a number of people from the Bureau of Mines you've mentioned who have done work looking at mining seismicity on a smaller scale with micro-seismic systems. And they may indeed be better versed to talk about patterns of smaller events localized around slopes due to mining stresses and so forth.

Granted you may not have that level of mining induced microseismic experience. But to look at

these type of large events --- with using a regional network the way you are, is it true that there aren't a lot of people that are better versed at it than what you are?

DR. PECHMANN:

In terms of understanding information as recorded by our regional seismic network, clearly we have many decades of experience. In terms of the analysis and interpretation of moment tensors, using broadband waveforms for non-earthquake sources, that expertise resides elsewhere. And to expand on that, early in the --- as early as August 6th both the USGS and we began to solicit help from these other experts.

And on, let's see, on --- in those early stages and

on August 8th, there was a teleconference involving University of Utah seismologists, USGS seismologists and the Berkeley scientists, recognizing that the codes available, for example, to seismologists at the National Earthquake Information Center inherently assumed earthquake sources, tectonic-earthquake sources, so that using those models to model the event were biased and would produce inaccurate information.

And the specialists who investigate unusual sources have to be engaged to look at this problem. Now when you ask about the current level of confidence of what further might evolve, I think we should point out two things. Oh, we should point out that

the Berkeley team is also in the process of preparing a scientific manuscript elaborating on the report that they posted to the web on August 8.

And if you were seeking an interpretation about their level of confidence or what further analysis might yield any different interpretation, sensibly that question ought to be posed to the Berkeley team.

MR. MORLEY:

To who in particular?

DR. PECHMANN:

Doug Dreger of the UC Berkeley Seismological Laboratory, or William Walter of Lawrence Livermore National Laboratories, or Shawn Ford, who is a graduate student who is the first author on the paper.

Just to give my own answer to your question, I guess there are people like Pete Swanson who devote their careers to studying mining-related seismicity. And so we are not, you know, at the same level of expertise as them. There's something like four Ph.D.-level seismologists in the state.

MR. MORLEY:

Which state?

DR. PECHMANN:

Utah. There's very few anyways. And as operators of the Seismic Network, we get involved in a lot of different studies. We're not as specialized as many other seismologists are. So we do --- you know, we've done work on strong-ground motion, seismotectonics, earthquake hazards, remote triggering, a

wide variety of things, and in any one of these there are people who will specialize in this as their main research area. So ---.

DR. ARABASZ:

I would add this, that our observations are either made remotely from our central recording lab, or in the case of special studies typically at the surface. And this experience differs from let's say someone who might have formerly worked with the Bureau of Mines who is in the mine with recordings and, you know, is more engaged with the observations, underground accompanying the mining operations and able to put information together.

Whereas we rely from our either remote or surface observations and the

availability of information from the mine to try to interpret or correlate.

DR. PECHMANN:

We have had papers published in peer-review journals on mining-related seismicity. So that's one thing you can say.

MR. ZELANKO:

You mentioned earlier the Trona incident that ---.

DR. PECHMANN:

That's one and Walter has published at least a couple others. Well, there was paper on the Trail Mountain study published in the bulletin of the Seismological Society of America, what, a couple of years ago?

DR. ARABASZ:

Correct, 2005 or 2004.

DR. PECHMANN:

And I think Walter has published a couple of other papers in peer-review journals on mining-related seismicity. So we do have --- we do have that, but it's not our main career focus.

MR. ZELANKO:

Let me address some more specific questions. When it comes to looking at something like first motions on waveforms from signals generated within this network, is there anyone in a better position to make those determinations than this group?

DR. ARABASZ:

No.

DR. PECHMANN:

No.

MR. ZELANKO:

To digress a little bit, you mentioned the Trail

Mountain study, I believe in one of your articles on the website you mention ---.

DR. PECHMANN:

That's one of the strengths that we can bring to collaborative studies with other people, because we really understand the data very well, okay? And so for many people, even if they want to work with our data, it's hopeful for them to work with us, because we really know all the ins and outs of the data and the instrumentation and the data processing.

MR. ZELANKO:

And on your website you have an overview of mining-induced seismicity in Utah. And you mention two of the largest shocks --- I'll just read it. Two of the largest shocks were magnitude 3.8 in

February, 1998, and magnitude 4.2 in March, 2000. Both had shear slip focal mechanisms and occurred in a rock mass adjacent to workers in the Willow Creek Mine.

The remaining mine tremors were shown or inferred to be caused by sudden roof floor closure --- and you reference Fletcher and McGarr --- either associated with pillar runs and older room and pillar workings or with pillar failure in entryways adjacent to longwall workings. How did you reach the determination that they were pillar runs in older areas? Were you working with an operator that shared that information with you?

DR. ARABASZ:

There was a publication from I believe it's a 1988, maybe 1981 event in the Old

King Mine, the ground truth for this information is summarized in an appendix by Kim McCarter in the Lawrence Livermore report, 2001, that we referred to earlier. And there also was a published report by Steve Taylor in the bulletin of the Seismological Society of America on that event.

So at the time, we were not involved in investigating ground-truth information or correlating what had happened in the mine. And to the best of my recollection, it was determined that it was in an abandoned part of the Old King Mine.

MR. ZELANKO:

So there's some record of that in the Lawrence Livermore National Lab report?

DR. ARABASZ:

Correct, and there are other instances in that same appendix by Professor McCarter where they've attempted to recover what ground-truth information, what might be recoverable relating to some of these larger events in our earthquake catalogue.

MR. ZELANKO:

We'll switch gears a little bit. Go ahead.

DR. ARABASZ:

I had one point for emphasis. And this may be important to understand that not all seismic events are implosional. So that we can have different kinds of deformational events in the mining environment as described either at a mine opening or in the rock mass.

At a mine opening, at some scale we can have shear

failure attendant to the deformation of a pillar, depending on the scale at which one was recording seismologically and the frequency of the waveforms which see a block of crust at a certain scale, what we observed seismologically with our regional network is the net effect of this sudden flexing and roof floor closure, and hence this implosion event. Again on a micro-scale, or a smaller scale, you know that the failure in the pillar could be compression or shear failure.

And in the case of the Willow Creek events, the 3.8 and 4.2, those without question were shear-slip type events in the rock mass. So they're an example of a mining-related event that is

not simply an implosion.

DR. PECHMANN:

Yeah. So for --- we actually do have a pretty good focal mechanism for the Willow Creek 2000 event. It's reverse faulting, which is unusual in this part of the world. But some of the shallow mining-related events are reverse faulting. The only reason we could do a good focal mechanism from first motions from the Willow Creek event was that Pete Swanson was operating a seismic array in and above the mine at the time, which provided --- and he gave us his first motion data. And he also gave us the location, a good depth for this seismic event. Without that, we probably could not have done this.

With regards to that

sentence that you read from, that report, Walter and I discussed that sentence because we were having a version of that in our paper. And I think we can't rule out that some of the collapse-type events could be in areas where longwall mining is going on. And this is roof collapse behind the longwall, so they might not all be due to pillar failures or in room-and-pillar mining or in entryways to longwalls. If it's behind a longwall machine, you usually can't get in there to get any ground truth, so we just don't know. Okay. With that statement?

DR. ARABASZ:

We quibble.

MR. ZELANKO:

It's a definite maybe.

DR. ARABASZ:

You certainly see a lot of these. I mean, we saw a lot of seismic events with downward first motions, only downward first motions on the Trail Mountain study. But all we know is that they're in the vicinity of the longwall.

MR. ZELANKO:

That's fine. All right. If we could switch gears a little bit, some specifics again about the August 6th event. Were you contacted by the mine operator after the August 6th event?

DR. ARABASZ:

The first contact I had from any representative or even --- representative of the mine or with any affiliation with the mine was the contact from Wilson Blake. And this was on 13 August. Now, I have to indicate again that we work

collaboratively with Doctor McCarter, and I have no information about what contact he may have had from any of his associates in the mining engineering community who might have been affiliated with the mine.

MR. ZELANKO:

And did you ever try to make contact with the operator after August 6th?

DR. ARABASZ:

No.

MR. ZELANKO:

Additional geophones were installed near Crandall Canyon Mine soon after the operation --- rescue operations were initiated. Was that activity initiated independently by you or did someone request that you do that?

DR. ARABASZ:

When you say geophone, let's distinguish between a geophone and a portable or a temporary seismograph. Geophones, for example, in my understanding, were installed by MSHA above the mine, perhaps relating to an attempt to record sonic information from the subsurface. That was at our own initiative and also as a result of joint discussions with our U.S. Geological Survey counterparts. For example, from Golden, Colorado to --- digital portable seismographs were sent to us from Golden. We used those two instruments plus some of our own instrumentation. We make a judgment call when there's a need to deploy portable instruments, depending on whether we have sufficient

seismographic control from our fixed network. In this case we wanted to improve our ability to locate seismic events, and we also understood that with the collection of this data there would be the ability retroactively to refine the main-shock location, enduring locations.

MR. ZELANKO:

And that proved to be effective in those regards?

DR. ARABASZ:

Yes. And particularly as evidenced by the double-difference locations, which are the best locations that we have at the moment.

DR. PECHMANN:

With regards to the mine contacts, I did get a couple of e-mails from somebody at the mine asking for information about event

durations and I forget what the other one was about.

MR. ZELANKO:

When was that and who contacted you?

DR. PECHMANN:

Let's see. P.J. Jenson --- I have a printout of an e-mail here from August 19th. Okay. Unfortunately --- well, I think he sent it to me because Kim McCarter had responded --- well, he got my name I think via contacts with Kim McCarter and my e-mail address. Unfortunately, he sent this request directly to me. And I was out of town on vacation at the time, and I didn't get it until --- I didn't respond to him until August 24th. And I think he was trying to get this information for a meeting that had already taken place at

that point.

DR. ARABASZ:

Let me try to be helpful this way. We received a request for information from Investigative Counsel from the U.S. House of Representatives, Committee on Education & Labor. I'm searching for the specification of the nature of the request.

DR. PECHMANN:

Sunday, August ---.

DR. ARABASZ:

Let's see. Please send us copies of any e-mails or other written communications regarding the Crandall Canyon Mine incident that any of you sent to or received from the following, one, anyone at MSHA or the U.S. Department of Labor, and two, anyone representing or affiliated with Mine Energy Corporation,

so far as you know. And so that we provided a packet of information on September 17, 2007 and straightforward for us to copy and provide you this information, if you want it.

MR. ZELANKO:

Thank you. I'd like to just follow up with a couple questions. You took initiative on your own to go put in additional temporary seismograph stations and you worked with USGS to get some equipment to do that. To gain access to those properties, you put one right above the mine; correct?

DR. ARABASZ:

Yes.

MR. ZELANKO:

How did you gain access to get up there? Did you work through the operator to do

that?

DR. ARABASZ:

Intrepid field technicians. Honestly, I can't answer that question.

MR. ZELANKO:

Okay.

DR. PECHMANN:

Yeah. We --- they talked to us about where we'd like stations, and we told them, and they went out there and put them in. Is that land privately owned or is it Forest Service land?

MR. ZELANKO:

No. It was Forest Service land, but ---

DR. PECHMANN:

Okay.

MR. ZELANKO:

--- I thought to my knowledge they were limiting access down at the road. And I'm just curious as to if

whenever they did that someone at MSHA or the mining company would have known that that was being done. Because frankly, I was involved in the rescue underground and had made the suggestion early on that someone contact you for that express purpose and never heard anything more about it.

MR. MORLEY:

Was that the sheriff's department limiting access?

MR. ZELANKO:

No. It was --- to my knowledge, it was the Forest Service provided somebody down there.

DR. ARABASZ:

We can ask our field personnel about that. It's conceivable. I don't know if there would have been restrictions coming up from the Joe's Valley side.

MR. ZELANKO:

Yes.

DR. PECHMANN:

But they would have been in a University of Utah truck, ---

DR. ARABASZ:

A State vehicle.

DR. PECHMANN:

A State vehicle, okay, with University of Utah IDs and may --- I mean, I don't know what they did, but ---.

DR. ARABASZ:

That's a simple answer.

MR. GATES:

Don't ask questions.

MR. ZELANKO:

It wasn't an indictment at all.

DR. ARABASZ:

Are you asking us to presume an answer to that question?

MR. ZELANKO:

No. No. I'm just curious. Like I said, it was wonderful that you did it.

DR. PECHMANN:

You know, they often --- they have a lot of experience asking, you know, for access to property.

MR. ZELANKO:

The website, your website includes a map labeled seismic events between three kilometers of collapse in Crandall Canyon Mine. What's the significance of the three-kilometer radius?

MR. MORLEY:

That's shown on Exhibit Seven.

DR. ARABASZ:

He's got another one in here that has that ---.

MR. ZELANKO:

This shows Deer Creek.

(Arabasz-Pechmann

Exhibit Nine marked for identification.)

DR. ARABASZ:

This shows how he shows the three-kilometer radius. I wonder what's the significance of the three-kilometer radius? Yes. Why the three-kilometer radius ---?

I'll refer to another of the PowerPoint illustrations from the Utah Mine Safety Commission presentation, now labeled Exhibit Nine. And the text reads, why the three-kilometer radius area, question mark. And the answer, in parentheses, encompasses nearly all Crandall Canyon seismicity and excludes events from neighboring mines. A three-kilometer radius circle is superposed on a plot of seismic events, earthquakes in

our University of Utah earthquake catalog, dating from September 1, 2004 to September 5, 2007. Both as the aftershock activity was unfolding and in later summaries, we made this attempt to see where seismic locations were plotted, tried to find some sample area that excluded seismicity from neighboring mines and, indeed, was sufficiently capturing the seismic activity in the Crandall Canyon Mine area.

MR. ZELANKO:

In the color version of this, red dots refer to those prior to August the 6th, and yellow dots refer to those after the 6th --- no, I got that backwards. The yellow dots refer to the prior events.

DR. PECHMANN:

You're talking about the one on our website, the one that we updated on an event-by-event basis for this diagram?

DR. ARABASZ:

I think he's referring to the web display?

DR. PECHMANN:

Oh, this particular figure?

DR. ARABASZ:

Not to Exhibit Nine.

MR. ZELANKO:

Yes.

DR. PECHMANN:

Okay. The web display.

MR. ZELANKO:

I thought we had a copy of it here in color. The question is ---.

DR. ARABASZ:

This one right here.

MR. ZELANKO:

Yes. Is there a reason

why the yellow dots cluster to the southeast and the red dots cluster in the west-central part of the three-kilometer circle?

DR. ARABASZ:

The time span, as I recall, for the events on this red/yellow illustration on our website include data from January 1st, 2007.

DR. PECHMANN:

January 2nd, 2007 is the first event here. Well, the simple answer is that this is our observation. And typically, given an observation like this, we would not make an interpretation without having information about activity in the mine.

MR. ZELANKO:

So it's fair to say you need to look more at

production records and things to really interpret that. Is it also fair to say that that's not a function of something to do with your seismograph array?

DR. ARABASZ:

What we are seeing is a resolution of seismic events, as discussed --- or main event, which inherently have uncertainties in location and also the possibility of systematic errors due to that lateral velocity change. So this can be viewed as raw data.

DR. PECHMANN:

These were the routinely-processed locations that were obtained at the time, in early 2007. The events which are in yellow in this plot are the events that are shown by the green

diamonds on the relocated epicenter plot. They are much more tightly clustered near the center of the circle after the relocation.

MR. ZELANKO:

So we should probably discount some of the earlier stuff and go with the very latest data?

DR. ARABASZ:

Yes. I would look at Exhibit Eight specifically with an understanding that the double-difference locations in the right part of the illustration are the best available.

DR. PECHMANN:

There were a few events down in the southeastern part of that circle after the relocation, but most of them were over here, around the area of the mining in 2007.

Most of the relocated events in the southeastern corner of the circle ---. Yeah, Exhibit Eight. Okay. Exhibit Eight shows that most of the relocated events in the southeastern part of the circle occurred between July 2005 and December 2006. Most of the events in 2007 were in this area.

MR. ZELANKO:

All right. Not all the events presented on the website have Richter magnitudes, but they do have coda magnitudes. In layman's terms, can you describe the difference between coda and Richter? And also, can coda magnitudes be used as a relative measure of the size of events at Crandall Canyon?

DR. PECHMANN:

A coda magnitude is

calculated from measurements of the duration of the signal recorded on vertical component high-gain seismometers. And that's been shown to be a very good measurement of earthquake size. Local or Richter magnitudes are calculated from maximum amplitudes measured on a specific type of instrument called a Wood-Anderson seismograph or on a digital record that has been processed to make it look like it was recorded on a Wood-Anderson-type seismograph. In our lab we measure the maximum peak-to-peak amplitude anywhere in the record, and then we use that to calculate the magnitude of the event.

We can't calculate the Richter magnitude for many of the smaller events that we locate. We can calculate the

coda magnitude for the vast majority of them, although there's some --- a few events we can locate and can't determine any magnitude for.

The second part of your question, the coda magnitudes are a good measurement of the relative size of the seismic events. There does seem to be a systematic difference between the Richter magnitudes and the coda magnitudes for the Crandall Canyon Mine events. We don't see that difference for ordinary earthquakes. In fact, the coda magnitude scale was calibrated against measurements of Richter magnitude.

MR. MORLEY:

So they were intended to be the same?

DR. PECHMANN:

Yes. And on the average, they are for earthquakes, for ordinary earthquakes. They are not for --- the difference is one-half a magnitude unit or something?

DR. ARABASZ:

Yes. And I believe that the reason is that for mining-related events occurring shallow in crust where there are reverberations and hence a longer recorded duration on a seismograph, these near-surface resonances and surface waves extend the recorded record. So that if we had a magnitude of one mining event versus a magnitude of one natural-tectonic earthquake at depth, their recorded durations would be different, longer for the mining event. And so because it has a longer duration, its

duration coda magnitude systematically is greater.

And what you'll note in our presentations and in our publications is that we can determine a coda or duration magnitude for every event, not a Richter magnitude. So if we want a uniform sample to represent temporal or spatial distribution, we might systematically use the coda magnitude.

MR. ZELANKO:

At several times during the rescue effort a series of three blasts were initiated on the surface in attempts to signal the trapped miners. Were seismologic station personnel alerted that these blasts were scheduled to occur?

DR. ARABASZ:

Not ---.

DR. PECHMANN:

Not that I know of.

MR. ZELANKO:

Are you aware that the activities were undertaken?

DR. ARABASZ:

I recall from news reports, yes.

MR. ZELANKO:

Okay. But you don't have the dates and times and things that they were done?

DR. ARABASZ:

No.

MR. ZELANKO:

You were never provided it?

MR. GATES:

Would any of that have shown up on the data that you have?

DR. PECHMANN:

It depends how big the blasts were and whether or not the portable stations were in

place at the time.

MR. ZELANKO;

I believe they were in place at some time and they were almost on top one of your ---.

MR. MORLEY:

A few hundred yards away.

DR. PECHMANN:

In that case, probably.

MR. ZELANKO:

Would the information regarding those blasts, for example, the location, the depths and the charges, be useful in estimating the energy associated with the recorded seismic events? Would it be of use to you at all to have that information?

DR. ARABASZ:

Yes.

DR. PECHMANN:

For size estimates?

MR. ZELANKO:

Well, for any reason first. Would you like us to try to provide that to you?

DR. ARABASZ:

You're a scientist, say yes. Are you not interested in data?

DR. PECHMANN:

Yes, it would be useful, but not for the purpose that you --- in your original phrasing of the question ---.

MR. ZELANKO:

It doesn't help you to estimate the energy associated with any of the underground activity?

DR. PECHMANN:

No. No. The amount --- if you're setting off a blast at the surface, the amount of energy that goes into the ground depends

strongly on the exact location --- how that is buried, how well it's tamped into the ground and, you know, the specific type of material in which it's detonated. There's a lot of factors involved there.

DR. ARABASZ:

May we go off the record a moment?

OFF RECORD DISCUSSION

MR. ZELANKO:

Has anyone here at the seismological stations or anyone else, you know, provided an estimate of equivalent force of the event, tons of TNT or anything like that associated with either the August 6th or the 16th events? Is that something that's done or not?

DR. ARABASZ:

It can be done, to my

awareness. I don't recall providing any estimate like that.

DR. PECHMANN:

Yeah. I don't believe that anybody here has done that kind of an estimate. It can be done. There are empirical relations between energy and magnitude from the --- it might be possible to make energy estimates from the collapse model in terms of the energy, gravitational potential energy. In fact, it is possible. But nobody here has really done that, so I'm not sure what it would tell us that we don't already know.

MR. ZELANKO:

There is a trend in the data, the seismic activity, where there was a quiet period following August 6th and then it built up again in the days

just prior to the 16th, five point something day quiet period. Have you reached any conclusions about that observation?

DR. ARABASZ:

Not a final conclusion, but I think we should amplify on the observation.

DR. PECHMANN:

Do you want your figure?

MR. ZELANKO:

Can we effectively say that it wasn't the result of equipment failure or something, the system was up and running during the time period?

DR. ARABASZ:

Let me give you an illustration that we used in our publication in preparation. And you can enter that as Exhibit Ten.

(Arabasz-Pechmann Exhibit Ten marked for identification.)

OFF RECORD DISCUSSION

DR. ARABASZ:

On this illustration is shown a plot of magnitude, coda magnitude versus time from August 1 through August 31. And I emphasize coda magnitude, for example, the size of the main event on August 6th would be shown with its coda magnitude of 4.5. There are horizontal dashed lines which represent the magnitude level of complete recording. There is a dashed line for magnitude 1.6 or, in effect, a magnitude 1.55 that extends from August 1. And this, in fact, was our level of --- our detection level of complete recording going backwards in time for prior

years at Crandall Canyon. And then it took some time before we were able to integrate the portable seismographs that we installed in the August 7 to 9 time frame into our recording system to effect the magnitude level of complete recording during the aftershock period. And, in fact, after some fits and starts of implementing the reporting --- excuse me, the recording in our central recording lab and also fine-tuning the detection subnets in the software. But it isn't until approximately August 13 that we have an effective decrease in the detection level of complete recording.

So that during that gap period the level that you need to view the gap is above a magnitude of 1.6. And this is in a early part of the

adjustment or aftershock period in the rock mass, where they would be expecting, in terms of weights of events per hour or day, more events than later in this sequence. But yet this is right where the gap is after about 38 hours.

Late on August 10 local time, we began recording on an invisible recorder in our laboratory signals from one of the portable stations. I believe it was station number three. And it's evident, at least from late on August 10 through the 11th through the 12th, that there are something on the order of maybe 20 events per day of a smaller size, not sufficiently large to be located within that, but still obviously the mountain didn't go completely quiet, as suggested by the appearance of

this graph.

So we have level-of-detection issues here. But above that 1.6 level, there is still this observation of no events after about 38 hours up to August 13.

MR. ZELANKO:

There are some events shown there on the 6th that are below that threshold level of 1.55.

DR. ARABASZ:

Yes.

MR. ZELANKO:

What's this --- how does that occur?

DR. ARABASZ:

That's an astute observation. And the reason that those --- I believe that two smaller events were able to be located is that coincidentally they were in a time window that had been

opened up --- or they were in the tail of preceding larger events, so that --- do you want to explain that further how they ---?

DR. PECHMANN:

The triggering?

DR. ARABASZ:

The triggering and how they could be located in that period but not by themselves if they weren't in the open ---.

DR. PECHMANN:

Right. Okay. The way our system works is there's a computer program that's monitoring the signals. And if it thinks it sees a seismic event, it will turn on and record the data until it thinks the event is over. And then an analyst will go and look at that data later and try to locate the seismic

event or events that he or she finds within that time period. So if there is a locatable smaller event that maybe wouldn't have triggered the network by itself, it can get analyzed in that manner.

Well, the other thing to keep in mind is that the 1.6 is the uniform-detection threshold. And the catalog is considered to be complete above magnitude 1.6. It doesn't mean that there aren't smaller events that are detected and located in the usual way below that threshold, okay? The effectiveness of the triggering depends on, you know, things like the background seismic noise level and, in some cases, whether or not stations are up or down in that area. So if you look at

any part of the state and you look at what the uniform detection threshold is, as determined by the methods that Walter used, you will find smaller events in there.

DR. ARABASZ:

It will maybe help the information gathering by asking you this question, Jim, with our data in hand, do we have or will we have any ability to locate smaller events that are not on Exhibit Ten from data that we've captured?

DR. PECHMANN:

It is possible that there are smaller events that can be located during this time period by going back and looking at the continuous digital records from our network and also from stations of the U.S. array, which we

weren't recording at the time, that were --- oh, this is a moveable array of seismometers that's on a ten-year deployment plan across the United States that's being deployed mostly for purposes other than modeling local seismicity.

The coal-mining area is the one place in the state where we don't have the triggering thresholds adjusted to the maximum sensitivity. The reason is that there are, you know, thousands and thousands of seismic events down in that area, and it's a fairly large data-processing workload to process all of these events. And it's --- you know, at least from the point of view of an earthquake lab, it's not clear how much information you're going to

get out of recording and locating thousands of earthquakes from a particular mine.

DR. ARABASZ:

Let me add this. In this gap period that's shown, I think --- I believe we're confident that we haven't missed any events of magnitude 1.6 or greater, but that with special effort we might be able to go back and locate some of the smaller events that I've indicated are recorded, for example, on those visible recorders for which we began recording on August 10, going back and retrieving, with special effort, some of the data recorded on the reportable seismographs. The net effect is that we would somehow be adding information at the

small-magnitude level in that gap.

DR. PECHMANN:

Kim McCarter has a couple of undergraduates looking at continuous records for some time interval in here. I forget exactly when. Were they looking at that gap or another time ---? I probably got some notes on that here.

So yeah, it can be --- this can be done. We don't have any current plans to do that, to go back and try to locate smaller events. It's a fairly time-consuming process.

MR. ZELANKO:

I have two questions about that. One is, can you extend the line there at 1.6 all the way across? And is it legitimate to just say if you wanted to normalize the data

to some extent, to one threshold, can you do that and say that on these days we had so many events in excess of that, that's a legitimate thing to do?

DR. ARABASZ:

Certainly. If I wanted to analyze the aftershock data from August 1 to 31, then I'd have to take the least-common denominator. I would have to use the threshold of 1.6.

MR. ZELANKO:

Okay. And the second thing is, if you had --- you have digital data from the station that's nearest the mine. Do you have a record of it going all the way back to August the 1st?

DR. ARABASZ:

Based on what data?

DR. PECHMANN:

Yes, we do.

MR. ZELANKO:

Let me phrase the question a little differently. You know, one of the things --- we early on would have liked to had some better information right over the mine during the rescue to see if what we were doing underground was generating more seismic activity. In other words, if we were moving material, not that you could ever predict when some major event might occur, but we felt it would have been an indication that, yeah, what we're doing is having an impact on the strata, just a relative measure.

And in that regard, is there information available today that we can go back and, for example, just set a threshold and look at

threshold crossings and get a relative number. Because we could track through the logs that were kept underground what the advance rate was, not hour by hour but probably pretty closely.

DR. PECHMANN:

Actually, there's --- I found my notes about the mining engineering students. They are looking --- they're actually doing exactly that. They're looking at data from August 6th to the 16th. These notes are from September 20th. This is when Kris Pankow and I met with these students who were working for Kim McCarter. This was the plan project. I don't know --- it may have changed with time, but they were going to look at data from the portable stations, and I think five of the

closest permanent stations. And they were just going to look at the times and the maximum peak-to-peak amplitudes. They weren't actually going to try to do locations, but they were going to try to get a time history of seismic events in that area. So they were going to try to distinguish from these travel times. And from the S-minus-P time intervals they were going to try to distinguish events in the Crandall Canyon Mine area from elsewhere and then prepare a list of them without actually doing formal locations.

MR. ZELANKO:

Can we go off the record for just a minute?

OFF RECORD DISCUSSION

DR. PECHMANN:

Kris Pankow was helping

these students out, one of the seismologists in our group. And they were also getting, I think, some help from some of our seismic analysts. But Kris Pankow was probably more knowledgeable about, you know, the current status of their project. But, yes, they were trying to get an event listing as some measurement of relative size from the peak-to-peak amplitudes. They wouldn't be able to calculate a magnitude directly from the measurements they were making.

But, you know, this is an undergraduate student project by students who are mining engineers and not geophysicists, so ---. I mean, they're good --- since they're good students they should be doing a good job. But, you know, we haven't

checked everything they've done.

MR. ZELANKO:

So for mining engineers they're not bad.

DR. ARABASZ:

From late on August 10 we have these visible paper records. And the tricky thing there --- you can look at events per unit time, which you have to make sure that you're not looking at something coming from Deer Creek.

MR. ZELANKO:

I see.

DR. ARABASZ:

And that's where this --- looking at the digital recordings and looking at some indication of proximity becomes important.

DR. PECHMANN:

Even then, part of the

goal is to look at the pattern of relative arrival times, not just the S-minus-P times to see if they could, you know, distinguish the events from within the Crandall Canyon Mine area. And I have not seen what they came up with for that. Kris may have seen that. But that's fairly critical.

MR. ZELANKO:

All right. There appears to be a discrepancy of about 10 to 13 seconds in the detected time of occurrence as determined by seismograph and Conspec records that we obtained at the mine site. Have you reached any conclusion regarding the difference or can you suggest any potential causes?

DR. PECHMANN:

We were hoping you

could tell us.

DR. ARABASZ:

You can leave it there.

DR. PECHMANN:

Actually, I would --- if possible, I'd like to see the calibration of the clocks done again, because the 10 to 13 seconds --- that range depended on whether or not there was a correction for clock drift applied that was possible within the parameters of the tests you did before. Now it's been long enough that if you did it again it would be possible to rule that out. And also, if it's not a uniform drift, if --- you know, sometimes clocks --- I'm not an expert in clocks. But if it wasn't a uniform drift with time, then maybe a check of the time difference between the clock at the mine and the

UTC might --- at this point in time, might be helpful, so ---.

DR. ARABASZ:

Period.

DR. PECHMANN:

Period. Okay. Walter doesn't want me to say any more. It would be just speculation anyways.

MR. ZELANKO:

Okay. Has the seismological stations done any work for UtahAmerican Energy and their predecessor, Andalex or Genwal, prior to the Crandall Canyon accident? And what was the nature of the work?

DR. ARABASZ:

We have cooperative agreements at Aberdeen Mine and Dugout Canyon and in West Ridge, and I don't track the ownership superstructure.

These relate to the blue triangles, these modern digital accelerographs shown on Exhibit Three, where we undertook partnering activities at these mine sites, whereby we provided and installed a seismographic package, installed it above the mine to enable connectivity --- real-time connectivity with our data-processing center, the provision of records on the web that the mine operator could inspect, thereby getting a continuous visual record of local activity. And if there were to be any significant event, that the accelerographs would capture on scale the seismic recordings. And also the presence of these above-mine seismographs would help improve the location

resolution in the vicinity of those mines.

MR. ZELANKO:

Who was your contact person with the people at Tower or Aberdeen, West Ridge?

DR. ARABASZ:

These partnering arrangements were basically facilitated through Professor McCarter. I don't have that information in mind. But insofar as we have ongoing agreements with these mines, whereby they pay us $200 a month to help defray the installation, maintenance, data-processing costs and so on, we would have on record the contact.

MR. ZELANKO:

Do you know how the information generated as a result of this cooperative effort was used by the mining

companies?

DR. ARABASZ:

No. Doctor McCarter would be more conversant with how the information would be practically used.

MR. ZELANKO:

Are you aware of any instances where seismic information has been used to predict a mining-induced collapse event, predict in time?

DR. PECHMANN:

In advance or retrospectively?

MR. ZELANKO:

In advance.

DR. ARABASZ:

From my familiarity with the international literature, the approaches tend to be statistical and probabilistic rather than a deterministic prediction that

an event is impending.

MR. ZELANKO:

Okay. Can you comment on the feasibility of using seismic monitoring to predict when a bounce might occur or to predict when the big one might occur?

DR. ARABASZ:

We can't do it outside the mine environment, so I would say that the prospect of a simple predictive capability with seismic monitoring in a mine --- an iffy proposition. That's not to say that seismic monitoring doesn't provide useful information that can be integrated with other information available to the mining engineer or the mine operator.

MR. ZELANKO:

It's the temporal part that becomes the sticky point;

right? Aerially, you could see maybe what was going on with high-stress buildup or something in a mine, but the timing of an event is the real sticking point?

DR. ARABASZ:

Correct.

DR. PECHMANN:

Well, even what you said about, you know, high stress versus low stress, I don't --- I think you would need other sources of information, okay? There are lots and lots of mining-induced events, okay? So you know, the occurrence of them, in and of itself, I'm not sure what that would tell you. And the weight of activity depends on a lot of factors, like the depth of cover, the rate of extraction, and probably other things, right, the type of ---

you know, the rock strata above and, you know, a lot of different variables. And if you didn't know all that, you couldn't really interpret the weight of seismic activity in any useful way.

MR. ZELANKO:

Okay. Do you have anything that you'd like to add that could be relevant to either the 6th or the 16th event? Anything that we didn't cover that you think is particularly --- would be important for the accident investigation team to know?

DR. PECHMANN:

Just a couple --- since you asked a lot of questions about the emergency response for the main shock, just a little bit of history about the 1.6 and what happened with that. I got a phone call at

home from people at the National Earthquake Information Center who had been getting phone calls about whether --- wondering whether or not there had been any seismic event at the Crandall Canyon Mine after word of the accident had gotten out. I didn't get a page about that because it was well below the threshold for which we do the paging. And so --- and this is maybe one of the first times that I can recall getting a call at home from these guys who are there 24 hours a day.

So they didn't have an event posted from our network. They asked me to go and take a look at it. The automatic location was --- so the automatic system had detected this event and located it, but

the location was way off. I think it might have been 20 kilometers off, 10 or 20 kilometers off. It was way off, for reasons I haven't had time to go back and figure out.

So in this case, when I reviewed the data, the location changed by quite a bit. You know, it was not --- the location was far enough off that if you just simply looked at the automatic location, you would have said, no, this is not in the Crandall Canyon Mine, this is somewhere else.

OFF RECORD DISCUSSION

SHORT BREAK TAKEN

MR. ZELANKO:

We'll go back on the record. We had asked you were there any issues that you thought were relevant that we

hadn't covered.

DR. PECHMANN:

I was recounting the events on the night of August 16th. So I was pretty done with that. After reviewing that at home, posting the location to the web, I then went with --- up to the seismic station's lab with --- let's see. Anyways, I did go up to the lab and we did talk to the people from NEIC. We took a few phone calls, then we went home. We didn't put out a press release on it, did we? Not that night, I don't think.

DR. ARABASZ:

I was in Colorado at the time.

DR. PECHMANN:

Yeah, because it was well below our threshold.

OFF RECORD DISCUSSION

DR. PECHMANN:

So that's pretty much all I have to say about that, the 1.6. Pretty much all I had to say about the 1.6. Relu did come up here with me.

MR. ZELANKO:

Anything further?

DR. ARABASZ:

I'm assuming that your question is aimed at a retroactive understanding of what has happened as opposed to seismic --- the value of seismic monitoring or other aspects of looking at the problem. Badly worded.

For example, we've talked about potential value of seismic monitoring in the case of prediction. This overlaps with considerations, for example, by the Utah Mine Safety Commission, where we go in the future or how response

protocols might be improved to --- given the Crandall Canyon situation, those kind of considerations, I'm assuming are for future discussion rather than for the purposes of this interview right here.

MR. GATES:

Right. I think what Joe was asking, was there any information that either one of you may offer to us that would help in our endeavor of trying to determine the root cause of this event. And I guess, importantly, as I stated earlier, what could be done to prevent a future occurrence. But I guess as kind of a follow up to that, once we kind of get into the closing statement, if there is --- there will be an opportunity for you to make one if you would like to put something on

the record as to what you perceive the value of the monitoring as it relates to the mining industry, or if you'd care to do it now.

DR. PECHMANN:

We haven't really talked about this too much. I mean, they have a figure, but --- should we maybe talk about that a little more?

DR. ARABASZ:

Yes, we should. Let me just gather my thoughts for a moment. In response to what you just said, Richard, I would consider this an interative process. Today we're here to capture what we know our involvement in the process --- beyond this interview there will be a sharing of information, a joint look at different pieces of information, puzzling it

together, posing maybe new questions. And then eventually, at some later stage, a more reasoned view about where we go from here.

DR. PECHMANN:

Let's see. I don't think we've talked about this figure too much.

MR. ZELANKO:

Regarding Exhibit Eight, Doctor Pechmann has expressed the need to discuss a little bit more --- some of the information on Exhibit Eight.

DR. PECHMANN:

There's some important observations that show up on this figure, especially the figure showing the double difference locations. Actually, on both sets of figures the aftershocks seemed to cluster at the western and

eastern ends of the approximate collapse area, okay? And this makes some sense in that one might expect a zone of stress concentration around the edges of a collapse. What shows up on the double-difference locations that does not show up on the master event locations is that most of the prior events in 2007 are located between the ends of the collapse and north of it. And a lot of them cluster around the area where there was damage during a bump in March. So this box here that says March damage is based on information in an Agapito consulting report that we got off the MSHA website. So you know, that's a significant observation there.

The location of the

main shock to the west of the collapse area by 270 meters, we're really uncertain what the uncertainty limits are on the double difference locations. The formal uncertainty limits are really small, like tenths of meters, but they're known to be underestimates of the actual uncertainty limits. Still, this suggests that the collapse may have extended farther to the west than is indicated on this diagram. And in any case, it looks like it likely started near the western end of the collapse rather than near the eastern end.

Another bit of information which is not in the conclusions in Walter's PowerPoint but only because we sort of forgot to put it in,

is that if we take the seismic moment from the Berkeley Lawrence Livermore Group and use it to calculate the area of the collapse, we come up with an area that's more than twice as big as this minimum collapse area here. Now, that's a bit of a basic calculation. But the --- for the moment, what I'm talking about here is the moment of the collapse part of the source, the 80 percent of it. So --- and that moment is proportional to the area times the vertical closure. All right?

MR. MORLEY:

How did you get the vertical closure?

DR. PECHMANN:

That's the dicey part of it. The dicey part of it is that --- well, okay. Let

me say that it would be really nice to have subsidence information from over the mine so that we didn't have to guess at it, basically. The way that we did it was that actually Kim McCarter and I looked at what the extraction ratio was in the area of the collapse. We then assumed 40 to 50-percent swell. And Kim came up with those numbers, although the --- you know, they're a bit soft as well. The numbers in the literature range from 35 percent to 55 percent. And so that's the amount of volume change when you take in situ coal and fragment it.

So if you take the extraction ratio and the swell and you assume that the pillars totally collapse, then you can calculate how much

roof floor closure you would get based on volume considerations. So I think the --- we did several different versions of this. And with some of the versions that we did, we would basically get no closure or negative closure numbers. So, you know, depending on what you assumed for these different numbers --- for example, you know, your original estimate of the collapse area, I think the east to west ends are --- you know, you were pretty clear about --- I think originally you said maybe it extended over the whole original range of the south barrier pillar. So if you put a box like this around there and assume a 40-percent swell and calculate the extraction ratio, you get

a potential closure of negative .4 feet. So that doesn't work. If you assume this kind of a box, okay ---.

DR. ARABASZ:

He's speaking to a recorder, so you have to explain it somehow.

DR. PECHMANN:

Okay. These are basically mine maps on which we drew various boxes with estimates in the collapse area. So then we decided, well, we'd try to do this for kind of a minimum-collapse area that was consistent with the information that you provided. So then we did the calculation with a box that looks like this, that basically went around this area that had been carved up into rooms and pillars.

MR. ZELANKO:

It encompasses just the entries of the --- the four entries of the south barrier pillar section?

DR. PECHMANN:

Right.

DR. ARABASZ:

May I suggest this? Let's go off the record.

MR. ZELANKO:

Go off the record for a minute.

OFF RECORD DISCUSSION

DR. PECHMANN:

So if we use this box, which is the same box that's shown on the other figures, okay, and its dimensions are described in some of the figures that are on the records, if we use that box, then the extraction ratio is 42 percent. If we assume a swell of 40 to 50 percent, we get a potential closure of one

to one-and-a-half feet, okay? And if you use those numbers and then you calculate --- in the moment and you calculate the area, you come up with something that's more than twice as big as this box.

So it --- unless we're missing something here, it looks like the collapsed area was likely bigger than this. We think it may have extended farther to the west because of the location of the epicenter, but that still doesn't give you enough area. You have to move it --- you have to extend it farther, probably to the north.

DR. ARABASZ:

I'll make one observation, and this potentially may become a lesson learned from this incident. The clustering of

aftershocks at the two ends of the collapse raises this issue, rescue safety and how one proceeds into the mine. If seismic activity is being monitored, the natural question arises, what relevance does that have to rescuers' safety. In this instance, if there were a collapse --- it might be expectable, at least from this case study, that there would be stress concentrations at the edges of the collapse. So perhaps unwittingly the rescue effort was heading westward, right into a stress-concentration area on the eastern side of the collapsed area.

Now, this is just kind of a speculative evaluation, but we'll see how this ---. This is one of the first

cases, I think, where we have a collapse and sufficient seismic monitoring to be identifying where the aftershock activity is occurring. But that thought does occur to me. So that in some future collapse, if there is some indication of ongoing seismic activity, perhaps caution in terms of entering through, you know, an anticipated area of stress concentration, which might be at the margin of the collapsed area.

DR. PECHMANN:

I would have to add, though, that unless there was a dense-seismic array in place at the time, we could never have gotten this information that quickly, okay? The only reason that we were able to come up with these precise

locations --- well, there's several reasons. One, I think the portable stations helped a lot. Two, knowing the location of one of these events was very important. Third, there was a lot of data processing that went into this, you know, that would be a lot easier maybe the second time around, because we had never really done this for this type of data set. But even with that type --- all of these relocation techniques mostly we find relative locations, not the absolute locations. To get the absolute locations you either need to know the location of event or you need some very close seismic stations that are close enough that you can locate them, the absolute locations, very well.

DR. ARABASZ:

My point being that even in the absence of precise locations, if there were an awareness that seismic activity in general were continuing, then you could at least anticipate that there might be a stress-concentration area at the margin of the collapse.

MR. GATES:

It may not be quite the predictive thing you talked about, but at least something to send up a signal ---

DR. ARABASZ:

Yes.

MR. GATES:

--- to be aware of?

MR. ZELANKO:

There were some other questions. I had one. You provided materials to UtahAmerican Energy,

Incorporated through a consultant, Wilson Blake. Can you say for the record what those materials were and could we also get a copy of them?

DR. ARABASZ:

I can check with our network manager, Relu Burlacu, but basically the request related to how seismic --- continuous seismic waveform data might be accessed by the consultant. He was particularly interested in examining for himself these observed downward first motions on these seismic recordings. And so we compiled a number of images depicting the beginning of the seismic recordings, and we will either reproduce or provide you with those same images.

MR. ZELANKO:

Thank you.

DR. PECHMANN:

The data, by the way --- the continuous recordings are available to anyone via a National Data Center, operated by the Incorporated Research Institutions in Seismology. And, in fact, that's where we get the continuous records when we want them, is we request them from that data center. And --- well, actually, we originally tried to send them there, but he not being a seismologist, it was not very easy for him to access and view that data. But it is available. It is available to anybody.

MR. ZELANKO:

Thank you. Richard, I think you had some questions.

MR. GATES:

Yeah. Maybe I'll just

kind of take you back upon what Joe had just asked about. I think also you mentioned sometime during the interview about unusual practitioners or people who look at --- I think that was the term you used.

DR. ARABASZ:

Unusual seismic events.

MR. GATES:

Right. And I think that's how I interpreted, yeah, there are people who look at these unusual events, and you mentioned the Berkeley and the Livermore. I guess I was going to ask, are there any others out there? And if so, do you know if any of those people have looked at the Crandall Canyon event and made any --- come to any kind of conclusions or is there anything else out there from those --- any of those ---?

DR. ARABASZ:

We need to go off the record, please.

OFF RECORD DISCUSSION

DR. PECHMANN:

There was a seismologist at --- was it Los Alamos, okay, who did look at the data at our request, and he did a very quick and dirty job of it, as he said himself. And although he sent these results to us, he said that we couldn't make them public unless he, you know, went up through the chain of command and got permission and all of that. And we never pursued that because the Berkeley results were publicly available and they had done a more thorough job of that. So yeah, there is one other person. I don't know of anybody else who's looked at

it as far as other groups that look at these types of events and try to distinguish explosions from earthquakes anyways, and they look at collapses as well.

There's a group called the International Monitoring Center in Vienna that's operated by the United Nations that monitors the world for nuclear explosions. Actually, what they do is they collect data and they process data. And they don't --- and then they provide information to countries who can then use this data to make their own determinations.

And then there's a group of seismologists that works for the Air Force, the Air Force Technical Application Center in Florida, and they monitor the world for

nuclear explosions. They don't monitor our country, but they monitor other countries. And those would be other experts. But almost all of their work would be classified. And there's also people in private industry who work on these kinds of things, and a lot of that work is classified as well.

MR. GATES:

And I guess as far as you know then, none of those entities are looking at the Crandall Canyon event to any extent or to any degree?

DR. ARABASZ:

To our --- well, let's see. I would suggest this, that an event like this would have great interest to that community. It would not surprise me if they were pursuing investigations. And

part of the reason being an attempt to understand events such as this in this context where a rogue state might attempt to hide a nuclear test in a mine environment, where there is abundant mining seismicity.

MR. GATES:

I guess you had mentioned --- I'll just follow up on that a little bit, the Solvay event in the past. Was there any study or any conclusions that any of these groups come to as a result of that or that were made public?

DR. PECHMANN:

We published a paper on it. I can get you copies.

MR. GATES:

Okay. But I mean any of these other entities that we just talked about, from the other groups that I'm talking

of ---. I guess I'm talking of these other ---.

DR. PECHMANN:

Not that I am aware of. But besides people from here, I think the second author on that study was Bill Walter from Lawrence Livermore National Lab.

MR. MORLEY:

How pre-eminent is the Berkeley group, if you can say, in that field?

DR. PECHMANN:

Nuclear test ---. I don't know. I don't really work in that field.

MR. GATES:

I mean, I didn't mean to get us off on a tangent there. I guess I was just curious if somewhere down the road that we might expect to read somewhere that this group or that group has analyzed the

Crandall Canyon incident and come to this or that conclusion.

DR. ARABASZ:

I would think, as suggested earlier, that the contact with Bill Walter, at Lawrence Livermore National Lab, or Doug Dreger, at the Berkeley Lab, would give you some idea of what tangential activity might be going on.

MR. GATES:

Another term that's been used several times during the interviews today has been collapse or pillar collapse or a massive collapse. And I guess I'd just be curious to what ---. When we use the term collapse, although it sounds probably fairly simple, for my simple mind, I guess I'd just like for you to explain or define what you

mean when you use that term collapse.

DR. PECHMANN:

Do you want me to answer that or do you want to answer that?

DR. ARABASZ:

We can both answer it.

DR. PECHMANN:

You go first.

DR. ARABASZ:

I think we're just following the terminology used in public discourse in the media. A quote mine collapse, we understand physically that it isn't necessarily a falling of a roof over a large area. Seismologically what we recognize, as I described, is somehow a sudden roof floor closure, which mimics physically an implosional type of mechanism, and that the roof floor closure can be

partial, total, resulting from loss of roof support.

DR. PECHMANN:

So the source model they're using is basically that of a closing horizontal crack, okay? So it's like this. This type of a mechanism is how they're modeling it. And, you know, so what happens in between the faces of the crack is not really something you can see seismologically. They're modeling the long period of waveforms, you know, ten seconds or something. I think, you know, that's in their report. I think, you know, they're looking at tens of seconds, period. So it's not that sensitive to the details of the source mechanism, but what you're seeing is this roof/floor

closure, as Walter said. And, you know, when you do the calculations, even if you assume complete pillar failure, it doesn't give you that much roof/floor closure. You're talking about, you know, maybe a foot, a foot and a half, or maybe none, depending on what you assume.

MR. GATES:

And I know you mentioned a lot about the --- I guess the first downward motion, I think, in --- that that was one of the criteria that you used in making some judgments. And I guess we found that sometimes if the floor is the weaker of the members, that sometimes that convergence actually takes place with the floor possibly --- instead of the roof coming

to the floor, the floor coming to the roof. And would that ---. I guess when I just heard the first downward motion --- again, I know probably I'm just talking in simple terms because that's a --- I'm a simple guy, but if the floor comes up, would that register as an upward motion or am I just way out of --- way off target there?

DR. PECHMANN:

That's a good question, actually, because I remember pondering that when we were working on the Solvay.

OFF RECORD DISCUSSION

(Arabasz-Pechmann Exhibit 11 marked for identification.)

DR. PECHMANN:

All right. Since you asked about it, maybe I should be showing this to you. This

figure is a cartoon that's comparing first motions from a collapse-type mechanism on the left from an earthquake-type mechanism on the right. So these big fat arrows --- okay. Let's see. You got this box here, and these little arrows inside of it, these little gray arrows are showing a collapse-type mechanism. These big fat arrows surrounding it are showing what the initial motion would be in the rock at that point. Okay.

So all the rock is going to be moving towards this collapse as the initial motion, but then the waves are traveling in the opposite direction. So the first motion is always going to be in the opposite direction of the travel of the ray. So

when you --- okay. So if it's going up here to the surface, okay, you're going to see downward first motion is everywhere. So these are the ray paths.

MR. MORLEY:

For the record, you're describing the mine collapse or implosion diagram?

DR. PECHMANN:

Right. I'm describing the mine collapse or implosion diagram. So even if --- so these rays that are going up, they're going to have a clearly downward first motion. The rays that are coming out the bottom likely travel downward and then back up. So it's always going to be a down first motion. In contrast, this diagram at the right shows what happens in an earthquake where you get this

mixture of upward and downward first motions.

MR. BAXTER:

By earthquake you mean a tectonic earthquake?

DR. PECHMANN:

A tectonic earthquake, yes. A slip on a fault.

MR. GATES:

I guess my next question, I was going to ask about the three mines that you put the sensors over, but I believe you've already addressed which mines --- particular mines those were. One comment that you had made earlier was that when you first heard of the event at Crandall Canyon Mine, I think you said that it surprised you a bit because the Crandall Canyon Mine was not on your radar screen. And I guess I was just curious or just

wanted to follow up on that if there were or if there are any mines on your radar screen and if they are because of the three sensors that you got put in place or if you've got some profiles that you've kept of other mines in Utah or maybe if you could expand on that.

DR. ARABASZ:

Yes. First I'll try to clarify my statement in terms of my level of mental alertness, as to a present danger, namely that there might have been active mining and hence people underground at risk because of this event. That's what I meant by saying Crandall Canyon wasn't on my radar screen. It wasn't prompting me to be saying mentally, oh, my gosh, there are people underground. An event has occurred in the

neighborhood. I've got to make sure that this information gets directly to that mine. And what this speaks to is, as we record this mining seismicity remotely, our level of attention is infrequent. It typically will come when we look at --- or when I look at the quarterly summaries of seismicity and see where there's clustered seismicity. I understand from experience that the clustering will change with time, depending on levels of extraction where active mines are operating. And somehow my attention had been more shifted to the Book Cliffs' area as a way of continuing ongoing activity, let's say, at Deer Creek. But more often than not, looking at the quarterly reports, my

attention was more drawn to the activity in the Book Cliffs' area.

And finally, I would add, that if we are generating information that may be informative, this seems to call for some mechanism of greater near realtime attention. And this doesn't necessarily have to be in our seismological lab, it should be either with the individual mine operators or someone who has a closer interest in mining activities throughout the region.

DR. PECHMANN:

Yeah. Just to follow up on what Walter said, --- well, how about would you like to comment on your awareness of which mines are operating and not operating and what type of mining they're doing?

You don't really follow that; right?

DR. ARABASZ:

No. We typically collect this information sometime later, when we might be observing an aggregate seismicity pattern and try to understand it, whether it's a magnitude versus time plot or an epicentral plot for the region. Simply put, we're not engaged on a day-to-day, week-to-week basis with correlating the seismicity with mining activity.

DR. PECHMANN:

I mean, that would be a full-time job.

MR. GATES:

I understand that. But I guess, just a comment, I just wanted to follow up just to let you clarify ---.

DR. PECHMANN:

We're an earthquake lab. We're not, you know, responsible for mine safety. We're not looking at this and trying to make any judgments at all about it, about, you know, what --- you know, what people are doing down in the mines. There are people who look at our information, we do know that, and maybe try to make those kinds of judgments, but we don't ---.

MR. GATES:

Right. I understand that. I just wanted to get that clarified.

DR. PECHMANN:

What was the first part of your question?

MR. GATES:

I think that was the first part. But I think you've answered it as well. I mean, when I mentioned the

three mines that you had put the devices over and were you, in fact, keeping --- was there some type of profile or something that you were developing as a result of those instruments being placed there or ---?

DR. ARABASZ:

No. It was just coincidental that, again, with the facilitation of Professor McCarter, that these three mines were instrumented. At Aberdeen the issue was mining under deep cover. At the easternmost --- at West Ridge Mine it was an approach to an earth-embankment dam and BLM being concerned about seismic hazard and urging the mine operator to undertake seismic monitoring at that mine. I guess it might relate to endangering the earth-

embankment dam.

DR. PECHMANN:

I guess the other thing I wanted to add is, we don't really know what's going on in all these different mines.

MR. GATES:

Exactly.

DR. PECHMANN:

You know, we might be able to find out if we ask. They may or may not tell us. Some if it's probably available, but we don't really make any effort to do that, ---

MR. GATES:

Right.

DR. PECHMANN:

--- except once in a while for a special study. Like in this Lawrence Livermore report there's some figures in here about amount of coal extraction, right, and

you know, we're trying to correlate that with rates of seismic activity. So once in a while we'll go back and do that kind of thing. But on a day-to-day or even year-to-year basis ---

MR. GATES:

No.

DR. PECHMANN:

--- we don't really track what's happening.

DR. GATES:

And I guess I'll ask this question anyway, but I think you've probably answered it, but it may be something that would fall over with Doctor McCarter. I was going to ask, have you ever put any of your monitoring equipment in a mine?

DR. ARABASZ:

Yes. In Skyline Mine and also in the Trail Mountain

Mine as part of the Trail Mountain experiment.

I'm going to go back one step and put a fine point on our correlation of observed seismic activity with mining activity. We're describing present circumstances. Where we go from here is a separate issue as to how our seismic monitoring might be more effectively utilized for mine safety. These are future discussions and this is part of the purview of the Utah Mine Safety Commission.

MR. GATES:

Thank you.

MR. BAXTER:

Just a question. Doctor Arabasz, you stated that the early data you reviewed sent you a red flag that the event on the 6th might have been a mine-induced

event. And you've stated also now that nothing in the data indicates that it was a naturally-occurring earthquake. And I'm just curious when you were able to reach that latter conclusion with the appropriate level of confidence that you need for it?

DR. ARABASZ:

In the early stages we surmised that it was a mining-related event. But as scientists, appropriately we had to suspend judgment, particularly because we were aware from other experience that naturally-occurring tectonic earthquakes have been observed in this area. Speaking for me, I was also mindful that the observation of downward dilatation first motions wasn't proof positive,

also mindful of the circumstances at Crandall Canyon --- excuse me, at the Solvay Mine in 1995, where the issue of mine collapse versus the possibility of triggering by a natural earthquake are --- is a major consideration, that you don't leap to a conclusion unless you really have well-founded information.

For me personally it wasn't until the Berkeley report was released that I developed this fuller confidence that the source was the mine collapse. We had narrowed the observations of the downward first motions, the confirming information from the broadband waveform modeling from an expert group. And beyond that, scientists always have to be careful. You just have to keep an open

mind for some tiny probability of some other explanation.

For example, looking hard at the --- those recordings of the event --- and this is something that Jim Pechmann did rather than I directly, to rule out that in the seismic recording there was no way that a tectonic earthquake was somehow hidden and not being recognized by us. And I think at this point all of the evidence just overwhelmingly points to the mine collapse as the source of that magnitude 3.9 event.

DR. PECHMANN:

I just want to clarify something here that I think may be evident from all of this talk in general, but even if it had compressional first motions, okay, we would probably still have thought

this was likely a mining-related event, okay? What Walter was talking about is whether or not it was --- you know, the mine collapse was the seismic event, okay. But even if I had seen some compressional --- I mean, there is those Willow Creek examples, for example. You know, those are reverse faulting. There was one in 2000 that we know was reverse faulting. There's one in 1998 that had compressional first motions as well, with the same mechanisms. So we would probably have still said, yeah, it's probably mining-related, as long as it was located near a mine and at relatively shallow depth.

MR. ZELANKO:

For some people, I think the fact that the Joe's

Valley Fault is right adjacent to the mine probably draws them to suggest that, gee, there's a fault right there. Wouldn't it be likely that movement would occur along that fault? Is there any historical evidence that suggests that that is the source of a lot of seismic activity, that --- Joe's Valley Fault and the sympathetic faults adjacent to it?

DR. ARABASZ:

In the early 1980s, together with the Bureau of Reclamation, we operated a microearthquake field experiment with a --- a dispersed array of portable seismographs, monitoring over East Mountain and extending to the west, into Joe's Valley. And we --- I frankly, was

surprised by the lack of natural-tectonic seismicity from our experiment. There was the paleoseismological information that shows prehistoric surface faulting on strands of the Joe's Valley Fault. But from our Trail Mountain experiment also, which overlapped the Joe's Valley Fault, no indication of background seismicity seeming to be associated with the Joe's Valley Fault.

DR. PECHMANN:

In general, it's very --- you generally can't map out locations of faults from microseismicity. The Wasatch Fault in Utah is noted for its lack of microseismicity over most of its length. In Southern California there's really not a very good correlation between small

earthquake epicenters and locations of major active faults. Northern California is one of the few places where you can actually map out fault traces from a seismicity map. So I guess what I'm saying is what --- the observation that Walter was pointing out about the Joe's Valley Fault isn't that unusual.

The other thing I wanted to point out is that, you know, the relocated epicenter is on the wrong side of the Joe's Valley Fault. It dips off to the west, okay? So if this is to the east, it's impossible for it to be on the Joe's Valley Fault because the subsurface trace of the fault would be west of this surface trace, not east of it. And even if it was a little bit east of it ---

excuse me, a little bit west of it, then it would be pretty unusual to have an earthquake that shallow on a tectonic fault. Usually when you have good focal-depth control, you know, as with studies of aftershocks, you don't usually see them in the uppermost one or two kilometers. They're usually deeper than that.

MR. BAXTER:

Let me just ask you a question as to that. The answer is obvious to all us here in the room, but I'll just ask it for the record. You've been here with this interview obviously voluntarily. And I just wanted to state that MSHA hasn't compensated you or retained you for this research. You've been very generously sharing the results

of your own independent research on this.

DR. ARABASZ:

That's correct. Do you want to speak for yourself?

DR. PECHMANN:

No, we have not received any funding from MSHA. The funding would come from the State of Utah and the U.S. Geological Survey, especially in this case, the State of Utah; right?

DR. ARABASZ:

Yes. And I will also add for the record that I was contacted on August 23rd by Colin King, of Dewsnup, King & Olsen, asking whether I would be interested in providing expert consulting. I know that my colleague, Doctor Kris Pankow, was also contacted by King & Olsen. And I and also Kris Pankow respectfully

declined. And basically I, as director of the seismograph stations, discussed this matter with Jim Pechmann, Relu Burlacu and others and indicated that, in the best interest of all parties, including those of the miners, that --- the interest of all parties, including those of the miners' families, would be best served if I and others in the seismograph stations provided information to all parties to the best of our ability on an independent and nonexclusive basis. And we are not receiving remuneration from any party relating to our investigation of Crandall Canyon.

DR. PECHMANN:

I agree with Walter. But I was never asked to be an expert for them.

MR. GATES:

I've got just a general question on your implosion model and the mechanism there. Could it be a dynamic mechanism also where you have the implosion and then it would rebound back to --- to some degree, back to where it may have been in the past?

DR. PECHMANN:

The model that's used has, you know, sort of a permanent one-way displacement. And you're looking at long-period waveforms on the order of tens of seconds. The exact frequency band is in the Berkeley report. Whether or not it could move down and then bounce back and that model would still fit, I can't say for sure. But I know that's not what the model is.

The model is this type of motion. And I guess I'd be surprised if you could have this almost instantaneous rebound and still fit the model. But I have never really looked at that myself. By instantaneous I'm assuming you mean like, you know, a second or, you know, something later.

MR. GATES:

Dynamic flexion.

DR. PECHMANN:

Seconds later.

MR. GATES:

Dynamic flexion.

DR. PECHMANN:

Dynamic flexion. The collapsing crack model, it's --- the model is a permanent displacement.

DR. ARABASZ:

Perhaps I misunderstood the question. Were you, in

effect, describing an analogy of an opening crack?

MR. GAUNA:

Well, typically when we go into bump-prone ground, you see very --- miners in particular, they see that the roof horizon doesn't appear to move. I'm just wondering, could some of that be because there might have been some rebound back?

DR. PECHMANN:

Well, it can rebound back some, but if ---. I think that if there was no net --- sort of a permanent closure, I'm not sure if you could fit it with a model at periods of tenths of seconds that, in fact, has a permanent displacement.

MR. GAUNA:

Permanent displacement.

DR. PECHMANN:

Yeah, at least permanent in the timescale of the waves that you're analyzing. But I haven't --- as a scientist, I have to tell you that I've never done that sensitivity analysis. This is just my best guess.

MR. ZELANKO:

On behalf of MSHA, I want to thank you for appearing and answering questions today. Your cooperation is very important to the investigation as we work to determine the cause of the accident.

After questioning other witnesses, we may call you if we have any follow-up questions that we feel we need to ask you. If at any time you have additional information regarding the accident you'd like to provide

to us, please contact us at the contact information provided on the card.

If you wish, you can now go back over any answer you've given during the interview and you may also make any statement that you'd like to make at this time. And if you're okay with that, I just want to thank you again for your cooperation and your hospitality.

* * * * * * * *

STATEMENT CONCLUDED

AT 12:59 P.M.

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