STATE OF MICHIGAN

STATE OFFICE OF ADMINISTRATIVE HEARINGS AND RULES

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| In the matter of:<br><br>The Petitions of the Keweenaw Bay Indian Community, Huron Mountain Club, National Wildlife Federation, and Yellow Dog Watershed Environmental Preserve, Inc., on permits issued to Kennecott Eagle Minerals Company.<br>______________________________/ | File Nos.: GW1810162 and MP 01 2007<br><br>Part: 31, Groundwater Discharge<br>632, Nonferrous Metallic Mineral Mining<br><br>Agency: Department of Environmental Quality<br><br>Case Type: Water Bureau and Office of Geological Survey |

D R A F T  T R A N S C R I P T

HEARING - VOLUME NO. XVII

BEFORE RICHARD A. PATTERSON, ADMINISTRATIVE LAW JUDGE

Constitution Hall, 525 West Allegan, Lansing, Michigan

Tuesday, May 20, 2008, 8:30 a.m.

APPEARANCES:

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EXHIBIT INDEX



NOTE: Page numbers may change on final transcript. Full exhibit list for today will be included in the final transcript.

Lansing, Michigan

Tuesday, May 20, 2008 - 8:31 a.m.

MR. LEWIS: Intervenor Kennecott Eagle Minerals Company calls Trevor Carter.

REPORTER: Do you solemnly swear or affirm the testimony you're about to give will be the whole truth?

DR. CARTER: I do.

TREVOR G. CARTER, PH.D.

having been called by the Intervenor and sworn:

DIRECT EXAMINATION

BY MR. LEWIS:

Q Dr. Carter, would you state your full name and spell it for the record, please?

A Trevor Carter, C-a-r-t-e-r.

MR. HAYNES: Your Honor, before Dr. Carter starts, Petitioners object to his testimony today on the same ground that we objected to others in the past. The expected testimony as revealed in the Kennecott witness list is very short. It says for Dr. Carter, "Review of mine permit" --

"Expected testimony: Review of mine permit application materials and reports concerning mine stability and rock hydrology, analysis of stress-induced permeability changes, rebuttal as appropriate to Petitioners' expert opinions as to mine stability and stress-induced permeability changes.

Reports: None."

We have no report from Dr. Carter. We don't have any indication that he authored any of the materials that were part of the application. And so we are once again left not quite knowing what Dr. Carter is going to testify to except general subject matters. And for that reason, as with Dr. Stone last week, Petitioners object to Dr. Carter testifying today. We don't know the -- other than the subject matters that he is expected to testify to, which are very, very broad as I just read, we don't have any conclusions as to what he's going to testify to. We don't have the bases for his opinions. We don't have the facts that he's going to testify to. And when we get into it, I will also lodge an objection to the 95-page document that I was handed this morning before the hearing that apparently Dr. Carter is going to testify from. Because if this is his report, we weren't handed it today -- until just today. So again for the reasons that we stated last week for Dr. Stone, I object to Dr. Carter testifying today.

MR. EGGAN: I join in that objection, your Honor.

MR. WALLACE: Huron Mountain Club joins in the objection. I might just say, your Honor, that I think the partial effect of this is going to be to put greater emphasis on our rebuttal case. Because we received the 95-page document this morning. We have no opportunity to discuss it with out experts. It maybe mercifully right now curtails our ability to cross-examine. But down the road, we're going to have to handle this case in a different way with rebuttal testimony, which we were hoping, you know, not to so emphasize. But I think we're going to have to.

MR. LEWIS: Number one, Dr. Carter has authored a report that was submitted to the Petitioners with our exhibits according to the time lines in this court's order. It's Petitioner's Exhibits 592, so they've had that for some time now. At the time we submitted this witness list, that report had not yet been filed. But it was submitted again in keeping with the court's scheduling order. So there is a very detailed report by Dr. Carter. It's been made available to the Petitioners some time ago. It just sets forth in detail his opinions and conclusions as to the subject of the hydrogeology in the bedrock, which goes to what we heard Dr. Prucha testify about earlier as to how much water might come into the mine during mining. So that part is well covered. There's no basis for the Petitioners to claim that they do not have notice of that. And, in fact, they had full and fair notice and a full description of his analysis.

The slides today are not a report. They are just a summary outline for Dr. Carter to go through his opinions as we've been doing, as Petitioners did with a number of their witnesses. It will not be offered as substantive evidence. At most, it may be offered to assist the court as demonstrative alone.

As to the other basis of the objection, as to other issues that Dr. Carter might speak to, specifically that's going to be the mine subsidence issue. And, in particular, he's going to cover some of the claims and testimony made by the Petitioners' three experts on that subject at this hearing, much of which we didn't know they were going to say until they said it. And again I think, as Ms. Lindsey pointed out, our witness lists and so forth were due at the same time. We were not given subsequent time after we got the Petitioners' witness lists and descriptions to, in effect, be more broad in our responses. We had to guess to some extent. And I think we have to be given an opportunity to do fair rebuttal to the evidence that the Petitioners have put in here. As to the subject matter, as to the issues, it can be no surprise. This was all the subject of prior reporting by Golder and by the Petitioners and in their testimony. So Dr. Carter intends to rebut some specific points made by the Petitioners as to the subsidence issue and also to explain the report we already produced some time ago as an exhibit for these proceedings.

MR. HAYNES: Your Honor, as to the exhibit, this is proposed Kennecott Exhibit 592, which is -- this document which is, oh, maybe 150 pages long. That was produced to us by letter from counsel for Kennecott on April 17, two weeks after the deadline that this court set for exchange of exhibits.

MR. LEWIS: I'm sorry. I stand corrected on that. We did get it to them in timely manner before the hearing. But I will -- I assume Mr. Haynes is right about the date, your Honor.

MR. HAYNES: Well, I can show counsel the letter. It's on his letterhead.

MR. LEWIS: No. I take your word for it.

MR. HAYNES: So the exhibit was sent two weeks after the deadline for exhibits. It's a very -- with all respect to Dr. Carter, a very complex document. And so it was not produced timely. And when we get to that point, we'll object to it on that basis. But I wanted to make sure that the record is clear as to when we got it. We did not get it when the exhibits were supposed to be produced.

MR. WALLACE: And further to clarify the record, this report only addresses hydraulic conductivity, a single out of what looks to be a dozen subjects that Dr. Carter is going to testify on. And our witness testimony narrative produced to them made it very clear we were going to have several witnesses. And we've talked extensively about subsidence and crown pillar failure issues and we described what their testimony would be in pages of testimonial description which we thought what the court's direction.

JUDGE PATTERSON: Mr. Reichel, do you have anything to add?

MR. REICHEL: No. I think that -- no, nothing specifically.

JUDGE PATTERSON: Okay. I'm going to allow Dr. Carter to testify. I think there's been at least an effort. And his report has been furnished approximately a month ago.

THE WITNESS: Your Honor, if I'm allowed to say something?

JUDGE PATTERSON: Sure.

THE WITNESS: I also co-authored what is called Attachment 7, which is the July 7th memos which were produced as part of the application. And there are two of those, which I co-authored. And those are all in the record.

JUDGE PATTERSON: Okay.

MR. HAYNES: Of course, your Honor, despite Dr. Carter's suggestion that he helped author a couple of the reports, they weren't listed on the witness list as a report that he authored. So we have no expectation that he would be testifying based on those because counsel for Kennecott didn't list him as an author of any reports.

MR. LEWIS: Listed as Kevin Beauchamp's Golder reports. Petitioners know that Dr. Carter is with Golder Associates, your Honor.

JUDGE PATTERSON: That what I thought. So I will allow him to testify.

Q Dr. Carter, you are a principal at Golder Associates?

A Yes.

Q You're a registered professional engineer?

A Yes.

Q What does it mean to be a principal at Golder Associates?

A It means that you have reached a level of peer recognition by your colleagues that essentially confirms your level of capability in the industry. We are very hard on our individuals within the company that we appoint as associates and principals because we need to keep the reputation of Golder Associates at the highest level.

Q Is Mr. Beauchamp a principal as well?

A He is. And we recently made him a principal. At the start of these hearings, he was an associate.

MR. LEWIS: We've marked for the record, your Honor, as Intervenor 89 Dr. Carter's CV. By stipulation, I believe that's been admitted.

MR. HAYNES: That's correct, your Honor.

Q Could you review your educational background, please, Dr. Carter?

A I did my undergraduate in Swansea in Wales in geology. I then moved into civil engineering. And I did a master's in civil engineering at MIT in Boston. I then started working. And during the course of my early work experience, I was working on some challenging projects which were suggested that I write up as a Ph.D. And my Ph.D. is in geological engineering.

JUDGE PATTERSON: Where did you get your Ph.D.?

THE WITNESS: In the University of Surrey in England.

Q And could you take us through your work experience briefly, Dr. Carter?

A For the initial five years after I graduated with my master's, I worked for a firm called Binnie's. And Binnie's has built some of the largest dams in the world. And I was involved on several of those. And in my -- about my fourth year of working with Binnie's, I was involved with the Dinorwig power station in North Wales, which is one of the largest underground power stations. And that started me into more rock mechanics than some of the dam engineering that I had been doing, although I had done rock mechanics as an undergraduate and a graduate in MIT.

Then I joined Golder's, and I was sent to South Africa to work on the Drakensberg scheme. And I'll show you, I think, an image of Drakensberg in a minute, which was also a large underground power station. And in -- after five years -- four years in South Africa, I was transferred to Canada where I looked after a lot of mining work and increasingly got involved in underground and surface mining eventually all over the world. I've also been involved in quite a lot of tunneling and mostly in difficult terrain; the Himalayas and the Andes, which are high mountain ranges which give very poor conditions in tunneling even in good rock because the stresses are so high.

Q When did you begin at Golder? What year?

A 1976. So I've had over 30 years with Golder's.

Q When did you become a principal at Golder's?

A 1989.

Q Now, I don't want to go through all of your CV. But I'd like you just have you offer a little explanation as to the information contained in here. I believe on the second page of your CV, you have a title -- a heading which said "experience in crown pillar and mine closure rock mechanics."

A Yes, I do.

Q And then there are, I believe, three pages with several projects listed there representing that type of experience?

A That's correct.

Q And those are representative cases that you have worked on?

A I have done a lot of work in crown pillars ever since about 1989.

Q And did you -- maybe one project to highlight there -- and I know you're talking about some others when we get into your slides. But perhaps one to highlight is -- you have listed between 1989 and 1991 remediation of crown collapse in Glen Falls, New York. And what was that about?

A This was a room and pillar mine and turn of the century underneath a paper mill which the car park and part of the paper mill collapsed into the mine very suddenly and without any of the expected warnings that the mine, if it had been operating, would have expected. The paper mill had been built over the top of the mine workings without adequate investigation of what was underneath it. We were involved with remediating the paper mill and backfilling the workings and stabilizing the whole issue. But it had been operated as an original underground quarrying operation. And the paperwork for the old mine was not lodged in the system. So it's classic of legacy mines that very often the legacy mines are poorly documented and badly designed. So a lot of these issues are legacy problems. And this was a classic case.

Q You have a section -- in your CV after the representative listing of your experience in crown pillar and mine closure rock mechanics, you have a listing of technical papers, Dr. Carter?

A Yes.

Q And can you tell me roughly how many are there?
A This is a pertinent list of papers related to crown pillars and mining rock mechanics. I published over 50 papers. And these -- I don't know -- 18 or 20 are related to this issue.
Q Are they peer reviewed journal articles?
A Almost everything in this list is peer reviewed.
Q You also have a section your CV titled "experience with rock mass characterization for underground caverns and mine openings." And what does that section describe?
A This is essentially the focus of my career, trying to look at rock and put numbers around it so that one can design. So the critical issue for most geologists is that they can describe things but they cannot quantify them. Most engineers cannot identify from rocks what their engineering properties might be and characteristics. So this has been essentially what I've been doing for my entire career.
Q Bring those two areas together?
A Bring those two together.
Q And the next section of your CV is titled "experience with inflow prediction grouting and groundwater control." And again you have several items listed there. Are those selected items to represent your experience in this area?
A Yes.
Q And in general, can you give us a description of what that experience is?

A It ranges from grouting for dam curtains where you're trying to stop the water from the reservoir escaping underneath the dam into the surrounding environment to stemming underground water inflows in permeable mines. So I've been involved in detailed grouting design for a variety of different types of rock in various countries. The most, I would say, difficult mine grouting experience that I had was in a mine where they mined into a small fault, and the water inflow from the small fault was -- this was -- when a say a "small fault," it was about 5 meters wide. And this was seeping initially about 30 gallons a minute. And within 24 hours, it had gone up to 1,000 gallons a minute, which was more than the mine's pumping capacity. So we mobilized a complete crew to seal that, put bulkheads in place and stop the inflow. Again this was in a mine which had been essentially a non-designed mine. So it's another area which is legacy mining.
Q And the next section in your CV is titled "Experience in conventional and TBM tunneling." And can you give us a brief overview of the kind of experience you've had in that area?
A The transition in civil engineering for a long tunnels has developed over the last 20 years more or less that people are moving from drill and blast excavations for all of the major tunnels underneath the Alps and other places for the new high-speed rail links to use of tunnel boring machines.

And in that process, the need for more geotechnical understanding of the rock mass ahead of the tunneling has become a focus. And my experience has grown in the TMV data analysis and information gathering to provide guidance for design of the machines and also guidance for optimization of routes. And I'll explain. In the difficult mountain areas, this is a major challenge, because you can't drill a borehole 5,000, 6,000 feet down from the top of a mountain chain down to the tunnel level. So one has to do a lot of geological interpretation to cover the range that the machine might have to encounter along its alignment route. So this is one of the things that I'm working with mines in South American, El Teniente and Andina in particular. And I'll mention those because I'm going to talk about the block cave type of mining that they do there. Because they're thinking of doing TBM drives through the mountains for quite long distances, 30 or 40 miles. And these tunnels will be typically 8 to 10 meters in diameter and about the same sort of size as some of the slope sizes we've been talking about in terms of span.

Q Have you also authored a number of publications related to this tunneling subject?

A Yes.

Q What role did you have in the prior Golder reporting and analysis that I believe you mentioned earlier that you were

one of the -- you had some role in the July technical memo that we talked with Mr. Beauchamp about yesterday. Did you otherwise have a role in the reporting and analysis that Golder did as it related to the Eagle project?
A Not directly in the reporting. I didn't write up the reports. And that was Mr. Beauchamp and his team. And my role in the early stages was to provide advice and guidance on forward for the evaluation.
Q And were you consulted on that basis?
A There was a fair amount of dialogue with Mr. Beauchamp on those issues.
Q And prior to today, have you reviewed those various Golder reports again?
A I have.
Q And have you reviewed the various reports and some of the testimony of the Petitioners' witnesses?
A I have.
Q I'd like to turn next, if we could, Dr. Carter -- I think you have a few slides just illustrating some of your experience in heavy civil engineering as it is relevant to this project. Could you explain that, please?
A I've put up just a few slides to give some idea of the scale of the excavations that I've been involved with, which are generally larger than anything that's been planned for the Eagle project. This is the range of my experience from 1976

to 1980, building this underground power station. The machine cavern here is 50 meters high, 16 meters wide and 500 meters long. And this is in rock which is weaker than Eagle. And we have designed this underground power station with generators and all of the rest of the mechanical and electrical equipment for a 90-year life.

This is in India. And these are caverns designed to take the silt out of the river water which is so dirty that the silt just goes into the turbines for the power station and chews it up. So you can through a 2-inch piece of steel on the runner blades for the turbines in about two years if you don't take the silt out of the water. So the issue here is basically these caverns, you have -- the water comes in at the top. The silt basically falls out of the water. And there's a fresh water tunnel that leaves from the other end of these caverns, which is clean water. And all of the silt has gone to the bottom. And then there are under drawer points which you can open some gates and remove the silt. These caverns are also about the same size as the maximum stoping. These are about 20 meters in diameter across the width and about 40 meters high. And they are 500 meters long. And there are four of them alongside each other. And the crown cover for these caverns goes from about 50 meters, which is about one-to-one on the one end as it's a mountain range like this (indicating) and the caverns sit like this, the crown cover at this end is much lower than it is at this end. So we actually reach a crown cover of nearly 500 meters by the time we've gone -- because the slope is at about 45 degrees, which means that, at one end of the cavern, we have potential for low-stress conditions near surface near the river. At the far end of the caverns, we have quite high stresses because of the mountains arising right up to 12,000 feet immediately adjacent to this. So you go for -- in the same cavern you go from a complete stress range from low K-not essentially to high stress. So you cover the range. So we can design for all of that.

And the next picture shows what the inside of the caverns -- and if you just click once more. And if you look there, you'll see that's about the size of a man, the little red square.

Q That's the upper right-hand picture?

A In the upper right-hand picture.

Q I think you should have a pointer up there if you need to use it.

A Oh, right. Just press the little -- okay. This little square here, that's the size of a man just to give you some scale. And these caverns, they're -- this gives you a better cross-section of the entire cavern. This is -- this trench down the middle is where the silt flows in. And this is one of the -- what they call the silt flushing tunnels, so quite complex engineering structures.

Q This is another underground project you wanted to highlight, Dr. Carter?

A This is probably the highest profile, highest risk crown pillar job that I've ever been involved in. Two operations were done here. One was to drive a tunnel right underneath the House of Commons, which is the equivalent of your Lower House. And the other one was to undermine the library and put in a new whole basement in rock underneath the library to provide new heating, ventilation and air conditioning for the building.

Q This is Canada, I take it?

A This is the House of Commons in Canada. And this is the most prestigious building in the Canadian heritage. And if we go to the next slide, this gives a quick detail of what we were doing for the library. And this is the library building, which was built in the 1850's. And this is the shape of the excavation that was underpinned right under the building. We were to sink in shafts and development right underneath through and into the building. It shows up in this little isometric down here (indicating). A tunnel right underneath. And then we excavated this whole drum-shaped area underneath about -- a little bigger than the diameter of this room and about twice that height right underneath the building itself leaving a small rock crown pillar and stabilizing the zone to continue to support the building.

And the next slide shows what the building looks like. And it's a magnificent structure. And you can see on the right-hand side -- in the top right-hand side some pictures of use of the mining raise bore machine which was drilling drifts out from the side of the excavation for the ventilation ducts. Here we're putting some excavation controls into the side to do the underpinning zone. And this is finalization of the structure and concreting the final walls. And the building now looks like this with square walls and rooms in which they've got all the equipment.

This is just an article that was published in one of the construction journals about the awards that we won for this. But they were the highest engineering awards in Canada.

Q Now, Dr. Carter, I'd like to turn to a discussion about some representative experience you've had in the underground mining area.

A First I'd like to just give a brief summary of what I've been doing in hard rock mining and in soft rock mining and start to draw some comparisons between these and how we treat these mines differently, which I don't think has come through in the testimony that's been given so far to date.

There is a huge difference between these types of mines.

The hard rock mines, we use a whole variety of different mining methods because the rock basically can stand it and it's competent.  So shrinkage long hole stoping, the primary, secondary, open hole stoping that we've been talking around, those are typical hard rock mining.  Now, the end I've set through to block cave.  In the 1930's they couldn't take that transition.  And we'll come back to that presently.

In the soft rock, we're talking about gypsum, coal.  And these are the typical room and pillar mines and the long wall coal mines which have basically a lot of destruction to the surface.  And that's where some of the strain criteria that we've heard in the testimony come from, from the soft rock mines.  And the differences between these two mines are quite important.

Right now I'm working with Mr. Beauchamp on an advisory panel to Garson Mine, which is a deep mine in the Sudbury basin where high stresses are a major issue.  And they have rock base in the mine which are difficult to control and they need to design -- support an arrangement so that you can safely mine at those depths.

And I want to now talk a little bit about the Codelco work that I'm doing.  I mentioned my main focus in the tunnels -- new tunnels.  But this mine because I'm involved in the tunneling, I need to understand how the mining works. This is a picture of their block cave operation, which is state of the art. And it shows very briefly the -- what would call development -- these little tunnels coming in at the bottom and it's cut away. You can see the tunnels here (indicating). And above that you have these what we'll call drawbells which, once you get enough undercut area, you can actually get the rock to break out above. And I'll show some slides just to illustrate. And this is a mining method which is similar to the mining methods used at Athens and the other iron mine range mines. And we're going to go that route to look at the differences between long hole stoping and the iron range mines in this testimony.

Q And Athens and the so-called iron range mines are the mines I believe Dr. Vitton or perhaps Mr. Parker talked about earlier?

A Absolutely. So this is the sort of condition that develops from mining like is shown in this diagram where basically you break the ground right through to the surface and develop the surface settlement in a major subsidence trough. This graph, which is in the papers that have been referenced by the Petitioners, it's the Laubscher chart for the mining rock mechanics mining RMR, which has RMR essentially on the vertical scale and undercut geometry on the horizontal scale. And Mr. Beauchamp yesterday talked about the hydraulic radius, which is a measure of the shape of the underground mines. How much undercut we have here and how good the rock mass is controls whether we can cave it or not for these sort of mines. And we have three ranges on here; open stoping, increasing dilution and caving. And you can also think of this as -- in this area, the stopes and the ground around them is stable. This area it is totally unstable. And the green area is where we can put support in. We can economically support that type of ground. So if I plot the Athens mine information, I look at the span and the strike length of the failure and I work out the hydraulic radius, I get a number in the 30's. If I plot that here and a typical rock mass quality for the Athens Mine at the upper end of the quality, I can come back to that -- I get this sort of location for Athens Mine. This is where Eagle Mine is plotting. The hydraulic radiuses are all less than 10. And the rock qualities, whatever we want to argue about it, may be -- even if we want to go to Dr. Vitton's 30 or 85, it's still in that sort of area for our stoping. So it differentiates these two mining quite distinctly. The rock mass quality between the two is chalk and cheese. So these are very different types of rock. And if we look at the El Teniente ones that I'm going to show some pictures about, they're plotting way up here now. When they started at the turn of the century and even before, they were plotting the same as the Athens Mine. They've been pushing the envelope by making bigger and bigger undercuts, very complicated arrangements here, to try and cave even this sort of ground, which is very good rock on the caving scale. But you have to have an enormous underground excavation to be able to drop it.

So let's go through a few slides to show the development of how this starts. Here's your initial cave drift, which is one of these fellows. And we develop along this drift and blast out the top of the dumbbells like this. So basically we're breaking the rock. We want to cave this. The design for Eagle is the opposite. We don't want to cave it. So the whole focus of the rock mechanics for Eagle has been towards stability. The whole focus here and in the iron mines was to instability. So then we blast the top here. And you can see we're beginning to develop a cave zone. And what you'll notice is that it hasn't progressed very far. We've got cracking here. But what's not happening is that you aren't getting the full breakthrough. So they have to blast all of these right the way across until you get sufficient undercut zone created, very large hydraulic radiuses before you can break this through to surface and start these rock cave operations running. So this gives you some idea of the complexity of the workings underneath the blasting operation. And we're trying to build an undercut zone here. You can see the lower undercut, the upper undercut. And we have to keep these extraction levels stable. So this is what it looks like when we've got this thing built. These are all the draw points. And we're looking here at about 250 to 300 meters by about 200 meters, a big, big undercut. The dimensions we're looking at for the maximum of the Eagle crown pillar would fit in a little corner like that. So in order to get good rock to collapse, you have to have an enormous opening. So all of this outside infrastructure has to remain in operation, because you spend a lot of money creating this undercut for a new mine and for a production mine. If these things get over stressed and damaged and you can't operate it, then you've lost all your revenue from putting it into the first operation.

So this is the sort of support that has to be put in around the draw points to make sure that they do not fail. As you can see, we've got heavy steel sets and we've got a lot of Shock-Crete and what Kevin has been calling a screen. That's Mr. Beauchamp. And this is strapped around each of these intersections. Because this is where the rock will come down in the draw points. So the stresses on these became very high.

Q Again, that's in the so-called caving mine?

A This is in a caving mine. And the stresses here are many, many times higher than Mr. Parker was talking about at the White Pine Mine. And we can design for these. And that should be -- the stress at White Pine, I think, was what we would call induced stress -- mining induced stress, not the in situ stress. The in situ stress sits in the rock mass as a result of geological conditions. In most of this area around Canada, the stress state that exists in the rock mass is due to ancient geological processes plus the ice. And the rock has a memory. So when the ice melted, the vertical stress, which was pushing down on the rock, was forgotten. But the horizontal stress was still clamped in, which is why in many areas of Canada and northern U.S. we have high horizontal stress ratios. Much of that horizontal stress is related to the original cover thickness of ice before it melted. So we can use the same chart that Mr. Beauchamp used to do the design for these very heavy civil engineering excavation areas in a mine. So this is where we're mixing civil engineering and mining engineering. Because this is the sort of level of support that we have to also have for the long tunnels that go under the Alps, very heavy support often in very bad ground. So if I plot an RMR of 30, which I believe was the sort of number that we were looking at with Dr. Vitton and I use the appropriate span for these excavations, I'm still within the gray area of this chart, which is the zone where I can support. The band across here (indicating) is the band that Mr. Beauchamp talked about. this is entirely over here in the white area of self-supporting. This area over here it costs too much to support. And this is really the caving area. Extremely poor ground; extremely good ground. So this is the sort of rock mass that we're tending to -- I've got that wrong. This is the -- this is extremely poor area. This is the sort of ground we're looking at for Athens and the mines in the iron range. And this is the sort of ground we're looking at for Eagle.

Q I think we want to turn next, Dr. Carter, to a bit more discussion of the crown pillars here.

A This picture is from Sedona in Arizona. And I'm standing on a fairly thin crown pillar. There are lots around of natural crown pillars which have good rock and poor rock in an environment which shows that you can have quite thin crown pillars and still remain stable. The arching that develops in a natural environment, even though the rock mass here is quite poor quality, is controlling the pillar stability here. And that's what the view looks from underneath. So you can see that natural crown pillars give us an analogue of what we will be looking at for a real design. And on the scaled span chart, we have up in the right-hand corner some natural crowns from caves, big limestone caves like Mammoth Cave in Kentucky and other natural caves. And this sort of crown pillar here isn't dimensioned in the database but it could easily be done so. Because on can characterize the rock mass here, give it an RMR or Q rating. We can measure the geometry and we can put this as a stable crown pillar.

So in our tunneling environment, we can consider a crown pillar over the top of the tunnel. We just call that crown cover in that rather than a crown pillar. And the typical mining operation which we've haven't talking around where you might have a backfilled stope and a thinner crown over the top because we can backfill this to provide positive support.

Q And would you continue with the discussion of your crown pillar experience, please, Dr. Carter?

A My initial crown pillar experience comes through working with a junior mining company that were trying to reopen an old mine that had been mined in the 1930's through to the 1950's. And they can then into the latter part of that with gold prices having gone down had been allowed to flood. In the area there had been a history of problems with overburden and water running into these mines because they had various mining problems coming too close to surface. So this junior company wished to become major and they didn't want to tarnish their record by having problems with the start of the excavation for this mine. So we did a lot of analysis work and basically helped them dewater the old mine underneath the lake and get back in and start production with new crown pillars into these old areas that could have been problematic. And so that took a couple of years to -- of involvement.

In 1987, I got involved in a collapse at the highway over a legacy mine. This mine was a silver mine in a town called Cobalt. This was mined in about 1911. And a lady was driving along the main highway through there and she ran over what she thought was a lump in the road. And when she looked out from her car, she saw a small hole in the road about a yard in diameter with smoke coming out of it. And the -- she wisely didn't go back and look at the hole. She drove into the town a little bit further and went to the police station, and they got the fire brigade out and they went back and had a look at this hole in the road, which how was about half the size of this room. That lady was very lucky because, if she had arrived maybe even ten minutes later, she and her car and everything would have gone down the hole. This is the hole. That's the main road up there. And this was a crown pillar that had basically collapsed through to surface because it had been mined within about 3 or 4 feet of the ground surface. So they had only left about this much rock.

So this got started into remediation of a lot of the legacy mines. And as is typical with legacy mines and government, many of the areas where there were mines, the ground -- the land on surface was quite cheap, and they had been built on with old people's homes, schools and other infrastructure. So we did backfilling work underneath a school and underneath an old people's home and stabilized those crown pillars. And that really started the initiative into what do you need to design a crown pillar, why had so much gone wrong in the past?

And CANMET, which is the Canada Center for Mineral and Energy Technology, thought that this was a worthwhile cause to fund ourselves and some other university people to really start to study this problem, because it was seen as a multi-million dollar legacy problem for a lot of the old mining towns and right the way across Canada and probably across the world.

So in that first conference, Professor Hoek published the very first version of CPillar, which we've heard about in this -- these hearings, which is basically a plug design program to look at the shear on four sides of a crown block that might collapse. And we started work -- Mark Betournay from CANMET and myself looking and gathering data from old mines and from collapses. And our focus was on collapses. We knew from the mining industry that there were hundreds of stable crown pillars.  What we were really after was the legacy history of the collapses such as the one that Mr. Beauchamp talked about yesterday, Worthington, is in the case record.  This is right adjacent to the Totten Mine.  And so the database -- I believe it as Mr. Wallace was asking how many were in the database.  But there are more failures than there are -- as a percentage of the stable cases.  Because in the earliest versions of the crown, we were trying to define where the line was between failed cases and stable conditions.  In the more recent work, we've been adding a more representative split so that we could do may probable-istic analysis so we have a better balance.  And interestingly enough, the early data is still checking the old.  There was about 13 percent failures in the initial database, 30 failures of 230 crowns.  And in the latest work we have, we have 14 percent, which is interesting, because it hasn't changed that much.

So the other thing that is important about this database is the longevity of it.  Many of the failures that we're talking about occurred in the 1930's.  They occurred when mining was in a very uncontrolled state.  People were in depression mentality.  A lot of the mining was what I would call cavalier.  They were mining extremely close to the surface.  And they pushed beyond the envelope.  So the collapses occurred because of lack of control, lack of design very often because they didn't know where the overburden. And suddenly when they put a drill steel through -- when they were drilling the next blast, they hit the surface and very soon after it collapsed. And I can tell you all sorts of horror stories. But a lot of it comes down to poor design.

So in 1990 we prepared the landmark report with CANMET on the first database and produced the first graph of the scaled span, which I'll show later. In 1992 the first publicly available publication. And the 1990 report is available. And the database itself is also available and has been used by many universities. And there are probably at least a dozen Ph.D.'s that have been done subsequently using the database, which is freely available. And we in the process of updating it as more information comes in. And it's on a web page so that any student who wishes to use it can download it.

In 1995, because of all the work we were doing to try and identify a priority for -- particularly for the Ontario government as to which stopes and crowns needed fixing rather than others, we developed a risk assessment approach to be able to rank them. Because they only had so many million dollars to spend, and they wanted to prioritize which were the worst ones that they needed to go for first. So the risk assessment paper was produced at that stage.

In the interim, there was a major problem at a mine called Casa Beradi in the -- in about this period. And that's in Quebec -- where there was some failure due to in-rush of mud into the mine. And again we're dealing with a legacy issue here. And these crowns that had broken through to surface became an issue that people thought, well, maybe there is some concern for degradation and whether some of these crowns wear out with time. So that was when the time dependency paper was produced and why it was produced. 2000, just a basic ten-year update of where we were with the database. And the latest paper is to be presented in San Francisco this summer. And now we have 500 crown pillars in the database with 70 failures.

In about 2005, 2006, I started getting involved in the Eagle work providing advice and guidance to Mr. Beauchamp and his team. So if we go to the next slide, this is the original scaled span graph as published in the first report. And this has the original 30 failures on it, which I've marked in black on this side. And the first attempt to put the scaled span line on was just drawn simply on all these ones over here were stable, all these ones over here were unstable. The agreement that was reached with the various mining companies and governments that provided the information right across Canada was, although all the details of the mine crowns are in the report, the mines would remain nameless because there had been some lawsuits and there had been some legal proceedings related to some of those collapses.  So that rather than airing the dirty washing, the agreement was that every mine would remain in the database as just a number.  I have a master list, and Mark Betournay from CANMET has a master list.  That's the only lists of all the mines.  The rest of them to the general public are just numbered.

And this is Figure 28 from Exhibit Number 2, Appendix C-2, which is the scale span original line.  And I would say this is probably got maybe 50 failures in it now, because this is a much later version.  And the actual dots on here are the same dots as were on the previous chart. And if we look at the right-hand side here.  First, I want to put on "rock mass quality" across the top on the Q scale. On the original chart it was just numbered, but I've put the descriptions here from extremely good to extremely poor. And that's the Norwegian classification.  On the bottom scale here we have the RMR classification from very good to very poor.  And so in this (indicating) direction across the graph we have rock mass quality.

Now, I'm going to come back to this later.  Others have mentioned it in testimony.  We have the RMR 76.  The chart was produced using that data with the correlation between Q and RMR based on the 1976 data.  We have deliberately stayed in the 1976 data because there are flaws that the industry has noted in the 1989 RMR classification and it remains a subject of debate.  The GSI, which is the Geological Strength Index, has been published by Professor Hoek and Professor Marinos as an improvement to RMR to get away from all of the problems that people have been discussing and debating in these hearings for the last couple of weeks.  What is the exact number?  And the GSI starts to put things back into these sort of terminology and block size and descriptive terms to try and get you more back to their geology to define what quality in the rock.

The crown pillar geometry is on this axis and basically at the top we have big, at the bottom we have small scale spans.  "Small" can mean a very wide excavation with a very thick crown.  It can also mean that we're dealing -- if we're at the top here we can be dealing with a very thin crown.  So this scaling includes the thickness as well as the span in this (indicating) direction.  So what we do -- if you had -- and it's based on one to one.  If you had the crown pillar thickness exactly the same as the span this would be actual dimensions in meters, so -- and it's based on a Q of one.  So if come across the graph with a ten-meter span to this point here, on a Q of one, which is an RMR of 44, 45, it plots in the unstable zone.  If I have a span of one and I come across here with the same RMR, I get into the stable zone.

So the graph was based around the work that had been done and published by Dr. Barton on the original Q system, and by Dr. Bieniawski on the original RMR system so that all of this -- all of the charts would tie together. So that's the unstable side and the stable side. And this is the range for Eagle from Dr. Beauchamp's report, and so that's the general range for the Eagle Mine.

Q This is what geometry, Dr. Carter?

A This geometry in here was looking at the -- I think this is the C-2 report, so this geometry was looking at the 57-and-a-half meter crown and this would be from the first report.

Q And the dimension?

A That's the full span, I believe, so that these -- this covers from -- we can check here. Some of the numbers at the bottom may be -- yeah, this is four spans, so it's the 68-by-50 meter.

Q Assumes the open void, in other words?

A Yes. Oh, that's the basis to the entire crown pillar database; everything's open. And this is essentially where the iron range mines will plot and I'll show some actual data into that. But they're all in this zone on this (indicating) side of the chart. Very poor rock quality; in the Barton scale extremely poor. And typical, we're getting up to quite high scale span numbers.

Q I think we want to turn next, Dr. Carter, to addressing some of Dr. Vitton's testimony. And to bring us to review briefly, Dr. Vitton during his testimony on the first day he presented based on his recalculated RMR's with lower numbers he then presented what he purported to be the corresponding factor of safety numbers by going back to Golder's earlier reports and I had pointed out to him that he had failed to account for the actual mine dimensions; that being the 87.5-meter crown pillar and the fact that we were going to do one stope at a time rather than have a completely open void, which were the assumptions for the C pillar analysis used by Golder its initial reports.

And then he came in the next day and represented that he had corrected those incorrect assumptions and that's what we see here on your slide as Exhibit 139; those were Dr. Vitton's restated factor of safety. And just for the court's reference he -- Dr. Vitton had two cases there, the so-called case one, which he represented as assuming a 15-meter stope width and a length of 50 meters; and then a so-called case two, which based on his view that the backfill could not eliminate a void that we should in fact treat this as a wide open voide under the crown pillar; and therefore, he's got in his case two the fully open span of 68 meters by 50 meters. Those were his so-called case one and case two.

Now, Dr. Carter, I wanted to ask you first of all,

have you examined Dr. Vitton's purported recalculations of factor of safety?
A Yes, I have.
Q And have you prepared a response to his conclusions?
A Yes. And I think in this slide we can go through these conclusions. But just to clarify first a few definitions, because I think it's important that we understand what we're dealing with. The crown geometry: we define the span, which is always in the direction of the dip of the excavation. The stripe length, which is along the axis of the stope in the axis of the orebody, and the dip of the controlling geology, which is the dip of the structure, the hind wall and front wall. We can also look at the crown thickness, which is between the bottom of the overburden and the top of the highest stope.
Q And again, use the pointer to -- it may help us understand.
A I think it's quite easy, because we have these identified here; we have little circles around them. And now if we go to look at stabilized, the stop height, which is the area where we're going to backfill the stopes here (indicating) and in the crown pillar database this is basically assumed as open. And if we go to stabilization control measures -- and Mr. Beauchamp talked about that yesterday and it's mount on the top of the flip charts here, the sort of development for the top cross drift and the type of support: cable

bolting and rock bolts and screen that can be used for that top zone.

But this is where that support would be installed. And the backfill also provides support within here not just for the crown, but to the side walls. And this is critical because many of the failures that have occurred in the historical record have occurred because some of the side walls have sloughed, especially on ones that dip, so that the problems developed from the side walls rahter than the crown. So the backfill does two jobs here. It stabilizes the side walls as well as the crown conditions.

Q Before we continue just one more clarification, Dr. Carter. Again, referring to Dr. Vitton's Exhibit 139 chart, he represented there, as we see in the left-hand column, three different RMR scenarios, the first one being the one that Golder assumed in its calculations, but the other one, 5145, were, as I believe you heard, his recalculated RMR's, which both he and Dr. Bjornerud had done. And just briefly I -- we heard -- and I believe you have heard or seen the testimony of both Andrew Ware as to their opinion about the validity of Dr. Vitton's recalculated RMR's and also Mr. Beauchamp yesterday. And do you agree with what Mr. Ware and Mr. Beauchamp had to say about Dr. Vitton and Dr. Bjornerud's recalculated RMR's?

A I have faith in the RMR classification as done by Mr.

Beauchamp and Mr. Ware, because I think they basically used the correct data and got the answers which match the core and with the rock quality that they were able to describe from the real McCoy pieces of core. I have had problems with other cases where people have used photographs to try and estimate RMR. It's always fraught with problems. So the essence of these numbers; I think I believe and support Mr. Beauchamp and Mr. Ware in their assessment of the general rock quality.

Q Nevertheless, I've asked you then for purpose of your discussion here as to Dr. Vitton's recalculated factor of safety to assume the numbers that Dr. Vitton used.

A I mean, frankly, it's possible that in localized zones you will get zones in areas of low quality. We see that from the RQD data within the database and from some of the holes -- example 62 -- which are poor ground. But you will have locally poor ground zones. Which we will deal with on a normal basis. So from the purpose of the overall crown I don't think it's an issue; from the purpose of designing support it is an issue. And that's exactly where Mr. Beauchamp has gone in his reports, to address these poorer quality rock masses from a excavation support viewpoint.

So what I've put up now is a table of RMR's on the left-hand side and factors of safety on the right-hand side for the two cases of the 57.5 on the left, and -- 57.5 on the left up here (indicating), and 87.5 on the right over there, which are the two crowns. This was the early crown analysis, and this was the later crown analysis. And I'll now discuss these cases. Dr. Vitton has three RMR's, as Mr. Lewis just mentioned. Those are in this table here but it's been extended for the 85 RMR and the 75 RMR, which Mr. Beauchamp assumed. And also it's been extended downwards to the 30 RMR, which Dr. Vitton also had mentioned in -- and used on some of his earlier slides. So it encompasses the complete range.

So when I look at case one, which is the 15-meter span, a stripe length of 50 meters and an 87-meter -- 87.05-meter crown pillar thickness, this is what Mr. Vitton -- Dr. Vitton had reported: 3.79 for 70, and this calculation suggests it's about 4.9. For this (indicating) one, 1.96 versus 1.49. And not 1.58; 1.47. When we look at the case two, which is 68 meters by 50 meters, I get 1 -- Dr. Vitton had these numbers: 1.12, 0.44 and 0.17. And for this case we get 1.48, 0.58 and 0.44. So I find it rather difficult to compare these. So this actually looks somewhat closer to the numbers for the 57-and-a-half meter crown: 1.2, 1.1; .44, .47; 0.17, 0.35. The 0.17 actually is exactly the number for an RMR of 30. So I suspect Dr. Vitton has remained with the 57.5 and the slight difference is that we may here may relate to a slightly different dip that he used

in the calculations or to a slightly different density.
Q Does it appear then that he did in fact adjust his factors of safety talked about the first day, adjust them on the second day to account for the thicker 87.5-meter crown pillar?
A I don't think so, but perhaps we can go through a couple of slides where we've hand-calculated these to double check it. I'm looking at Table 6 from the Appendix C-3 on page 13, which is for a 68-meter span, stripe length of 50. And this was the numbers that Mr. Beauchamp presented yesterday: 70 in upper bounds, 60 at lower boundary, an average of 66.4. And these were the computed factors of safety.
Q And again, this was for a 57-and-a-half meter crown pillar?
A This is for a 57-and-a-half meter crown pillar.
Q And a completely open span?
A Yes. So what I did was I hand-checked the first line of that table. And if we look here these are the data: span, stripe length, fitness, density, and dip, which all fit into this equation giving you an answer of 9.77. If you look at the second equation, which is this (indicating) one, first I convert RMR to Q, which gives me a Q of 17.97 using that formula which we've seen throughout the report, which gives me the critical span as 11.75. Now, the critical span is the span at which for that rock quality things would start to fall down. The scale span is the span for that rock

quality that this actual excavation shape scales to. So if that number is bigger than that number, then we have -- it's on the safe side. If that number is bigger than this number, it's on the failure side.

So we have the quotient between these two giving us 1.2. And if we go to the next slide we'll see we have here an RMR of 70, factor of safety of 1.2. So this check -- this top line of the table I've hand-checked to see that it was correct and then developed this spreadsheet here, which checks all of the other numbers using exactly the same arrangement. And if you look from the spreadsheet for the same RMR range I get 9.77 for the scale span, because the geometry of the excavation does not change between these. All I'm changing is the rock mass rating and I get 1.2, 0.73 for that case, and 1 in this case. And if you look at the way that we've got the geometry laid out here, I've actually flipped these. I put 76 to 66.4. This is 70, 66.460, so the one applies to there, the .73 applies to there. So the calculations by hand and by the spreadsheet double check the table. And this was the calculation for the 9.77.

Okay. Now, on this table here I've listed Dr. Vitton's case one and two and I've added a third case which is the stable case for the permit, which was a ten-meter span still with the same stripe length, 50-meter stripe length. Case one is an 87.5 span -- I mean, an 87.5 thickness with a 15-meter span and a stripe length of 50. Case two is a 68-meter span, stripe length of 50. Which is exactly the two cases in Dr. Vitton's tabulation. And these are the same factors of safety as in the little summary table. If you remember, we had the RMR and the -- and those are from the spreadsheet to check those numbers there. In fact, this is just linked within the spreadsheet, so those are reported to here. So these numbers we've checked and I know that Mr. Beauchamp has also checked the Table 6, so we're fairly confident these are the right numbers.

Q As opposed to Dr. Vitton's numbers?

A Yes. So if I now look at case three, which is the permitted case, the scale span is 1.63, which is lower than any of these numbers. And the factors of safety, as you can see, are extremely high. Even for the RMR of 30, which is the worst case considered by Dr. Vitton, we get a factor of safety that's greater than one.

Q And again, that's the permitted current mining plan, which is an 87-and-a-half meter crown pillar and a ten-meter wide stope?

A That's correct.

Q And could you read the resulting factors of safety from that line, please? On the right.

A For an RMR of 70 we have 7.19; for an RMR of 51, 2.83; RMR of 45, 2.12; RMR of 30, 1.03. Now, if we look at the next slide here, this presents the graph from Dr. Vitton's report and I believe from his testimony where he plotted the RMR of 45, 30, 51, and Golder's 75 and 85 numbers as a comparison. And if we look first at the chart again we have rock mass quality still along the bottom, and crown pillar geometry up the scale here. The bigger the scale span is the further into the unstable zone you go. The smaller the scale span, the more stable you are becoming in terms of geometry. The further you go to the left the poorer the rock mass; the further you go to the right the better the rock mass. So this sort of rock down here (indicating) has small pieces; it's broken, it's like gravel or even finer to soils. This end up here, block size is the size of houses. And the stability is controlled by block size.

So rock masses at this end and rock masses at this end are chalk and cheese; totally different and their behavior is different. So if we take the 57.5-meter crown thickness and we draw the 9.77 line across, which is what I hand calculated, which is the first line of that table from the Appendix C-2, for Dr. Vitton's calculation this is where we plot, so well into the unstable zone. And all of those cases are in the unstable situation. The two Golder situations over here (indicating) with an RMR of 75 and 85, both plots in the stable case.

If we now go to looking at Dr. Vitton's case two and you can check back to the numbers, the scale span was about 8 rather than about 10.  We're looking at that geometry:  68 meters by 50 meters.  And as you can see for these RMR's Dr. Vitton's RMR's of 30, 45, and 51 we still plot in the unstable zone; these for 75 and 85 RMR is still stable.  And this is for the 87.5-meter crown thickness.  So if I know look at case one, which was for a single stope, and the -- Dr. Vitton's table, 15 meters by 50 meters, and I extend the lines down from Dr. Vitton's RMR 30 point, RMR 45 point and RMR 50 point and I plot here, these circles show the value of the calculation for those points.  And as you can see now, by the time we come down to a single stope of this size we have now dealt with an RMR of 45 and an RMR of 51, so the crown for those stopes would now be stable.  So we can make that opening that size and that shape and still control those rock masses.

Now, as Mr. Beauchamp mentioned, we would actually put support in out to this (indicating) line just to protect people from small and falling rocks and things like that which are an operational hazard.  But in terms of overall stability, we're now in an okay situation.  If we now plot the permitted case, which is a ten-meter span, 50 meters stripe length, you can see, as I mentioned earlier, the scale span is now down to 1.63 and if we plot the three points again the -- even the RMR of 30 is now just on the stable side of the line.

So as I was mentioning earlier, as you go down this scale you reduce the undercut geometry. When we plot El Teniente and the cave mines they plot up here, because in order to get the mines to cave in these better and better rock masses we have to make the undercut geometry bigger and bigger. So the issue is to -- for stability is to drive this geometry down and for caving to drive it up. So even for the 30 RMR we're now just in the range of being stable for the excavation. Which is why these recommendations were confirmed by Dr. Sainsbury and Dr. Blake as a sensible path forward. And as I mentioned, we look at the graph which Mr. Beauchamp plotted, which is Figure 19 from Appendix C-2 and we see here -- again, I'm going to put the RMR scale at the top so you can understand the relationship between the Q scale and the RMR scale.

This is the band that Mr. Beauchamp talked about and this is for the top cut drift span, which is these developments here (indicating) that Mr. Beauchamp drew on this flip chart showing the top drift across the top of the open stope. We actually will drive two drifts before we mine this: one here and one here. So both would be supported to match the quality of the rock mass that they go through, because people have to work in these during the development.

So again, we have caving in this area, supportable within the gray zone, and in this area over here no support needed. But as MR. Beauchamp mentioned yesterday, it's industry standard practice to support into this range also because it's general mine regulations and standard healht and safety regulations to do so. But this basically here (indicating), this straight line is the factor of safety of one line on this chart, so you can think of this in the same way as the scale span chart, that anything on this side is a factor of safety greater than one; anything on that side is a factor of safety of less than one. So for conservatism we do put support in here; although, we technically don't need it. And then here these lines which go across this chart on Figure 19 give increasing thicknesses of Shock-Crete and as you go up the scale here increasing density of bolting. So we can design the requirements for a different type of excavation.

And we're going to look now quickly at a -- the RMR 30 situation and we have in this scale, which is -- again, we're scaling the span by a factor of safety. This is how we use this graph. The civil engineering excavations, power station caverns, railway tunnels, things where the general public would go we use a factor of safety of one. So the actual numbers on this (indicating) side are real spans. So a ten-meter span with an RMR of 30 we would have to put in this sort of support to stabilize it. For a temporary mining excavation we typically use 1.6, which is what Mr. Beauchamp used. And in this case it's not actually the factor of safety; it's a divider on this span. So that drops it from the real spans here into this zone for support. And Mr. Beauchamp had three classes of support, so anything for a Q less than one, which is here, would be supported with pattern support bolting, metal screen, and four to ten centimeters of plane Shock-Crete. Which is what this chart predicts. This is the same chart that we used for that very heavy support design for those block caving mines in Chili and we're way over here (indicating). We have real problem support; it costs a fortune to do the support for those drives. But it's worth the money.

So the other way of looking at this chart is that if we sat at this point here in reality and we actually put in the support that's designed, we move the rock quality across to a point where it's now stable. So by putting in those bolts and the screen we essentially improve the rock. So this same excavation could be considered as an RMR of 58 just stable. So that's another way of using these charts. So we can say that when we put that drift right the way through even if we assume Dr. Vitton's 30 RMR, by the time the drift goes through we've made the RMR 58 just by putting

in our support.
Q Now, would you also talk about the stope design a bit, Dr. Carter?
A Mr. Beauchamp has used an industry standard method, the Mathews method, but first we'll just look briefly at the Laubscher method which was mentioned earlier in the testimony. As I plotted earlier, we have rock mass rating RMR in this (indicating) direction, an undercut geometry in this direction with the Eagle Mine plotting up here and the Athens Mine plotting down in this area here. If we look at the Mathews graph it's basically plotted in the same way as this graph, but instead of using RMR it uses a modified Q. So the stability number N is tied to Q, the Norwegian classification, rather than RMR, which is the South African classification. So that's the basic difference between these two charts. And again, we have a stable zone up here (indicating), a cave-in zone on this side, and between these lines here a transition.
Now, if I look at this chart in a little more detail -- and I've colored it now to match the other one on the next page just to make it easier to see what the chart shows. We have across the bottom hydraulic radius, which is stope geometry, and we have in the vertical access rock quality where N is basically the first two terms of Dr. Nick Barton's Q classification, and the Golder values for the

stopes plotting in the upper left here into the stable zone and just into the zone where we can support it. So the middle zone on this is supportable. The stable zone we really don't need any support. And the cave-in zone is where we'll real problems.

So this (indicating) is where Dr. Vitton's data would plot if we pushed the rock quality down until we're into the RMR 30 range, we plot at the bottom of this supportable zone. And if we just look at some of the worst case geometry, which is full span, we can just be heading just into the cave-in zone. Factor of safety very close to one. The iron range mines all plot way over here. If you remember, I calculated a hydraulic radius for Athens in the 30 area. So the iron range mines are off in this cave-in zone.

Now, what is very important for the open stope design is that everything has a hydraulic radius of less than ten for the permitted stope arrangements; which means that you're never getting into this range of hydraulic radius; you're always to the left of this (indicating) line. Which means that we can support it or it's already stable. And that's the basis of the stope design. So if I put the same color of lines onto the scale span chart just so that we -- everybody understands how it all fits together, the green line, the green band on here is the supportable zone as compared with all those other charts that we were looking at.

Q The red line is the number one line?

A The red line down the middle there is the factor of safety of one, probability of failure of 50 percent. That's the failure line. Unstable to the top left; stable to the bottom right. And this is typically the range where it's economic to put support in. There's no point in trying to support out here (indicating), because the ground wants to cave. Over this side if you get really out past this factor of safety of two line, which is approximately there, it really is unnecessary to support the rock. The mine regulations for small shoals and bad blasting and things like that have decreed that most mines will always use a support pattern even if you're out into these zones. And I just left on here the RMR 70, 51, and 45 numbers from Dr. Vitton's calculations for the 15-meter span stope, and as you can see they're all on the stable side.

Q And would you briefly discuss also the comparative probabilistic assessment that was reflected in the July Golder report?

A Mr. Beauchamp went through this yesterday, so all I will do I think today is give a little bit more background as to how the graph was prepared. If I just slide this aside we can see the background chart which provides the data that went

into these plots.
Q And these plots -- again, this is a figure in the Golder reports?
A This is a figure in the July 7th memo which I co-authored. And the graph on the right is the actual data and the analysis result that was used to plot these points. And if we look at each of the parameters -- maybe I'll just go back one for a second. Across here (indicating) we have a range for each of the parameters for rock mass rating, RMR, and for Q in -- by the divisions within the classifications. And then underneath there is a percentage of how much of the rock mass based on the database falls into those zones. So in order to do this the database was evaluated and a distribution of how many rock qualities in the zero range from RQD and in the hundred range from RQD, plus the 30 and 40 and 50 range. That gives this distribution here.
So you see there's some percentage of rock quality in the poor end, and there's some percentage of rock quality rock for the good end. So that encompasses the entire database for each parameter. So you have A-2, which is what we've been talking about a lot for RQD. We have the J end which is a parameter that comes out of the Q system.
MR. HAYNES: Excuse me, Dr. Carter. I hate to interrupt your monologue, but on the 95-page document we were handed this morning if we're looking at the chart that

you're now testifying about that chart seems to be cut off and I don't know the source of it. Perhaps for the -- if we could identify that for the record, please.

THE WITNESS: Okay.

MR. HAYNES: What report is it found in?

THE WITNESS: It isn't found in a report. This is background information to prepare this chart.

MR. HAYNES: I understand that, but I'm looking at the bottom of this table and it seems to be dated 2006 and there seems to be a Golder number on it.

THE WITNESS: It is in our files as the backup for the calculations which are on this document.

MR. HAYNES: So this backup table has never been reported in any of the Golder reports for this project, has it?

THE WITNESS: The backup has not been, but the results have been.

MR. HAYNES: Again, I don't have a -- I don't have a whole copy of that.

JUDGE PATTERSON: I don't either.

MR. HAYNES: So at some point we'll need to have that produced so that we can effectively cross-examine the witness on this. What I'm looking at, Dr. Carter, is this (indicating) page.

THE WITNESS: Yes, I understand.

MR. HAYNES: Which has a couple of bar graphs but nothing else.

THE WITNESS: Okay. Well, all I was doing here was illustrating the distributions and --

MR. HAYNES: I understand. My question is not to you; my question is to counsel, so we'll have to have that produced at some point.

THE WITNESS: Okay.

A So if we go on and I understand why it's partly obscured, because I put this over the top of it. Each one of these represents the sub-parameters. So we have the A-2, which is the RQD. We have the joint spacing in here. We have the number of joint sets, which is a parameter that goes into Q. We have an RMR parameter, the conditional joints. The joint roughness, which is a Q parameter. The joint alteration. And the strength of the rock mass. And the database was quizzed to produce that data, to produce these histograms. And then this model was run as a Monte Carlo type of simulation.

We've heard about the Latin Hypercube. We used the Latin Hypercube Method to do these calculations because it converges more quickly as a computational method than Monte Carlo. It's the same information. Basically what we're doing is we're throwing a dice 500 times, so I can do the RMR calculation -- and if I may go to the flip chart here -- what we're doing for RMR is we have a distribution of individual data that may look like this. Let's just say this is RQD and this was a hundred and that's zero. And in the RMR classification we have A-1 plus A-2 plus A-3 plus A-4 plus A5 minus B-1. And in Q we have RQD over JN times JR over JA times JW over SR.

So in this arrangement we're picking randomly a number off this distribution and substituting in RQD's case the direct number into here and in this case the direct number into the correlation value that's appropriate for that number in the RMR scale. So we do this 500 times, which means that we have 500 estimates of what the rock mass quality will be, which then gives us another distribution of what the quality is, which we then compare to the geometry in the scale span to see whether it falls on the stable or unstable side of the probability line. And that data then gives you the number which is included directly into here (indicating). So this was the probability number; the factor of safety number's in there also which gave us that point and that point.

And this information comes from the full database of borehole information, so this I believe is the 26 holes in the crown and it's just the data for the crown pillar area. All the RQD's included so every zero and every hundred, everything is included. And it's classified with Q and R- -- independently so that the values at the bottom of this calculation double checked the RMR's with the ones produced from the Q classification.  And then there's 500 iterations that are done for the calculations.

Now, if we look at hole 62, which we've talked about a lot, that comes -- it's basically the green holes down here.  We have 76 over there.  These are actually outside the ore zone and the crown pillar section is here. So if I give now just the eight holes that we've been talking about and you've been seeing core photographs for they basically fan the outside of the ore zone.  And this is hole 62, which goes basically down the contact margin.  Now, these eight holes were deliberately picked from the database for further evaluation as targets for further drilling by Mr. Ware and others for -- one of the reasons that a competent geologist looks at things is always to try and understand what's going on.  So many of the models that have been put up of wear faults and structures were became geological targets for the Kennecott folk to investigate and evaluate.

And one of the purposes that -- Mr. Beauchamp raised this and we actually discussed it -- of that early stage is to identify target points that need further investigation.  So part of the reason for these eight holes and the major structures was to put on the table these needed investigating. So if we look at the mining sequence very quickly here and just where the crown pillar is, that's the crown pillar zone so everything above there is your 87-and-a-half meter crown and if we look at -- as we mine up we go through this -- and this modeling sequence that's on here is what I shall go through very briefly with respect to the stress dependent and -- one is the natural rock mass before mining and we take out the lower part of the excavation of the stoping then move up. And there is our permitted crown level.

So all of this will be stoped and backfilled as part of the excavation, leaving us the permitted crown above that level. So this was elevation 327.5, which is the upper level drift arrangement from the mine plan. None of the elevations that we've been using for the 57-and-a-half meter crown pillar offer any of the other scenarios looked at in the earlier reports, as Mr. Beauchamp said yesterday, are actually design ones from a rock mechanics point of view. The numbers all came from the mine sequencing and from the mine plan arrangement. So these are where the excavation levels come in with the tunnels to do all this stoping.

So if we look now at the only significant hole within the eight holes where we have structure within the ore zone area itself and it's this hole which is number 45, I believe -- 55. And this is the core from 55, which I believe that Dr. Bjornerud put on the -- in her evidence. And I'd like to look at this just for a moment to give a representation of what we think is the general type of rock mass within the crown pillar. You can say it's a pretty good looking piece of core here. There are some -- there are some cracks in it and there are all sorts of chalk marks in -- on the actual core. And as we talked about yesterday, you can't see the other side of the core. So in order to log and define all of those fractures one would have to pick up the core and look at it.

Anyway, if we use this as an example and we look at what Dr. Bjornerud said for this entire hole her average value she came up with an RMR of 75, which is very close to the sort of numbers that Mr. Beauchamp has from his database evaluation of the entire crown. The Golder number for this particular hole was reported as 67 based on her calculations. So actually Dr. Bjornerud is getting us a confirmation that this rock is pretty good. In fact, her numbers are actually better than the Golder numbers. And this is the overall view of this hole and the reason this hole was picked is because of this poor zone here (indicating), which is obviously a target that needs further drilling by Mr. Ware as part of his exploration work for further definition. And we in later stages identified that this was best done from underground, which is part of the path forward to do detailed investigation for the crown pillar. But essentially the zone here is the reason that hole was picked.

Q I think Dr. Bjornerud also said something about the appearance of the rock surface at the outcrops and relied on that to some extent. Was her reliance on those the appearance of the outcrop applicable to this issue, Dr. Carter?

A My feeling is that the outcrop is a little bit misleading as all surface outcrops are for characterizing rock depth. And perhaps if we look here you can see the difference. And this is from hole 62. If I take core from the top of the hole and core from the bottom of the hole I see just a change which is due in large essence to the influence of weathering and ice action and all of those things in the near surface, and a much more solid condition at depth just because the rock is not damaged by surface effects. And you can see here the weathering that's taking place around the jointing so you're getting etching of the joints. When you drill these sort of joints at depth they will be typed and you will not see that structure as open and looking so horrible as this is.

The rationale for moving -- and this was said earlier as part of my career -- is when you look at that you need to interpret this (indicating) rather than looking at that and interpreting this, because this is the understanding of how rock improves with depth and what it means, and looking at core gives you that understanding once you drill enough holes. So Dr. Bjornerud had given a summary of the areas where basically there was zero or very low RQD's. And when I looked through that data a lot of it's in the near surface zone, so I suspect that again it's an issue representativeness of the actual crown pillar zone and I suspect that we're looking at core conditions in the near surface zone as being part of that issue.

MR. LEWIS: I think that completes this section of the presentation, your Honor. We're going to move next to Dr. Carter's report on hydraulic conductivity in the bedrock. If you'd like to break at this point.

JUDGE PATTERSON: I think we should.

(Off the record)

MR. HAYNES: Your Honor, for the record, during the break, Mr. Lewis handed me the backup page of figures that I questioned the witness about a few minutes ago. And I put it in this 95-pager as page 27a, just for my own purposes.

JUDGE PATTERSON: Okay.

Q Yes. Dr. Carter, again, I'd like to move into talking about the report you prepared which has been marked as Intervenor Exhibit 592 titled Evaluation of Possible Hydraulic

Conductivity Changes Due to Mining-Induced Stress Effects Eagle Deposit Crown Pillar dated --

MR. HAYNES:  Your Honor, before we get into that exhibit, you ruled on my objection to Dr. Carter's testimony, but I don't recall your ruling on my objection to the admission -- or the use of this exhibit, since it was provided after the cutoff date for exhibits.

MR. EGGAN:  I would add to that objection, Your Honor.

MR. LEWIS:  Number one, I haven't offered it yet. I do intend to offer it.  But number two, again, you heard about the timing of getting the exhibit to the Petitioners. And again, we had no obligation to prepare a report.  So I think given the timing they've had sufficient notice.  And if that's the objection, lateness, I believe they had sufficient notice and received this exhibit some month or so before the hearing, whatever it was.

MR. HAYNES:  Well, this tribunal's order said that exhibits that were not provided by April 1st could not be used without good cause.  And I don't see and I haven't heard any suggestion that there's been good cause for the late production of this report.

MR. EGGAN:  I would also add, Your Honor, as we went through the issues pertaining to discovery -- and I'm not trying to revisit that -- but we underscored an issue over and over and over again, and that is trial by ambush, trial by surprise. And we have a witness here who gave us just the absolute barest of description of what he might be testifying to, who has now come in today with a 98-page additional exhibit that we're expected to review and digest. He's now going into a report that was sent to us on April 17th after the time period. If your -- from our perspective, this really is trial by ambush. But if your pre-hearing order has any meaning at all with respect to exhibits, this exhibit should not be admitted. The exhibit he is going to talk about now, this latest Golder report, should not be admitted. And I haven't heard anything in terms of good cause as to why this should not have been produced to us earlier.

JUDGE PATTERSON: Can you address that?

MR. LEWIS: Yes. For one thing, Your Honor, keep in mind also as with the witness list the deadline that was established for sharing exhibits again was the same deadline; in other words, was not the typical course, let's say, in some courts where the plaintiff in effect, the person bringing the case, would produce exhibits first and then the did and in effect the person in Kennecott's position would have some period of time in order to review those, understand what issues they presented and put on the table and then present its own exhibits in response. So due to that circumstance, we were somewhat strapped in knowing what exactly the Petitioners might intend to do in this case. And in fact, the decision to have Dr. Carter do this work and prepare this report was based on what the Petitioners were -- what we saw in their exhibits, for one this, this Dr. Prucha. And now, for instance, if we look at the Petitioner's disclosure as to Dr. Prucha who's talking about the amount of water which may flow into the mine, you will see that he did not author a report. We were not given any report by Dr. Prucha. He was not a witness who had been involved with this public comment process and for which we had seen any prior reporting or information whatsoever until we got the Petitioner's exhibit list. And I think that that's the background for this. And I think again that Petitioners when we're confronted with new information first in their witness list with a rather cryptic list of what Dr. Prucha would testify about, not any report by any means, and then in their exhibits where there's some further illumination as to what Dr. Prucha might testify about, that we have to be entitled to fairly present some rebuttal to those points when we once become aware of them. And I think given that sequence and those circumstances, that we did I think a, you know -- we really made an effort to get this information done and to the Petitioners as soon as possible prior to this contested case hearing well in advance of the contested case hearing, I think there's been a fair disclosure. And the report to the extent that otherwise the foundation required in this forum is provided that the report ought to be received.

MR. HAYNES: Your Honor, I hate to draw this out further, but when Counsel suggested there was a fairly cryptic description of Dr. Prucha's testimony, Dr. Prucha's testimony is in the recitation of his testimony and the witness list filed on March 7 is a full page single spaced. It is not three lines like we have for Dr. Carter. It is a full page single spaced with his conclusions, the basis for his conclusions. And so for Mr. Lewis to suggest that this is cryptic really is not objectively correct.

MR. EGGAN: Let me add one thing too to the record, Your Honor. Every time we attempt to object to the lack of information that is presented or that we have available to us, what is thrown back at us is, "Oh, there's been several years of study of this project, and everybody should know and there shouldn't be anything more." Now we get to this proceeding and Counsel is suggesting, you know, he just didn't know what was going to be said. And so I guess from my perspective it either has to be one way or another. And again, I think this is an ambush situation. We're being surprised by -- we're being surprised by what a witness has to say and by new exhibits and by 98 pages, which I believe he intends to offer as an exhibit. I just think it's unfair. I would also add as just a minor point we don't have three copies of the document that he submitted. Mr. Haynes has a copy. Mr. Wallace has a copy. I don't have a copy. A copy was not given to me this morning. So there are only two copies for the three -- four lawyers that are here this morning. So again, Judge, we're just asking for there to be some consistency in how this is all being handled and to avoid this constant surprise.

MR. LEWIS: The copy thing, let's be clear. I think Mr. Eggan's confusing that issue. As to the exhibit, the report, Exhibit 592, which is my understanding of what we were talking about at this point, that's been provided to all the Petitioners. They've had that since April whenever it was.

MR. EGGAN: April 17th. That's right. I agree.

MR. LEWIS: I think Mr. Eggan is referring to PowerPoint slides that we're looking at. And I've handed Counsel two copies. It would be perfectly fine during the next break to get Mr. Eggan another copy. I hope that that's not viewed as some major issue here that bears much more discussion. But again, I've outlined the timing, the background, the fact that Dr. Prucha was new to this case; that we first knew about him with the witness disclosure. We got some information then, we got later information through the exhibits and response. We diligent -- we asked Dr. Carter to look at these issues. We diligently made an effort to produce a report and to get it in the hands of Petitioners as soon as we could to in fact give them as much fair notice as we could. And I think we've complied with our obligations here, Your Honor.

JUDGE PATTERSON: Did you intend to offer the exhibit at this point or not?

MR. LEWIS: No. After I talk with him about it. I'm not offering it at this point.

JUDGE PATTERSON: All right. All right. I'll defer a ruling, then, until that occurs.

Q Okay. Dr. Carter, identify what the exhibit is and the dat and the title. What was the purpose of your preparing that exhibit?

A This exhibit was prepared in direct response to the Petitioner's concerns about the fact that mining would change conditions in the crown pillar and thereby allow more water to come through into the mine from the overburden and from the surface water system.

Q And in that analysis as reflected in your report, did you rely entirely on data that was already included and summarized in the prior Golder Reports?

A Yes.

Q And also did you rely on the data that was referenced and

included as Kennecott's exhibits and admitted through Mr. Ware I believe last Friday?
A Correct.
Q Now, turning to next, if we could, Dr. Carter, to the analysis that you did for this study, what did you need information about in order to do this additional analysis?
A Basically I needed data on three things; the mining zone geometry, which we've talked a lot about, crown pillar thickness, and the extent of the workings. I needed data on the excavation sequence so that we could see what the influents of the mining was on the surface. And I needed data on the rock mass characteristics, the RMR and not being the entire picture for when we look at fractures.
Q And turning next, then, to the mining zone geometry, could you briefly review what you looked at there in terms of its relevance to this analysis?
A This the geometry of the mine workings are somewhat different in the east-west direction and in the north-south direction. And because of the Petitioner's concerns about the lack of stress orientation information and stress magnitude data, I needed to understand the geometry of the mine workings in both those key directions.
Q And are the various figures that we're looking at on these slides included in the report you've prepared, Intervenor Exhibit 592?

A Yes. This figure is Figure 1 from that report and shows the ore zone dipping north in the upper diagram and east-west in the lower diagram.

Q And then turning to the excavation, the second thing you said you needed to look at for this analysis being the excavation sequence, again, can you give us a brief summary of what you looked at and what is important for that part of the investigation?

A In order to see what happens within the crown pillar, we needed to replicate the sequence that's planned by mining. So the first stage is that there's no mining. And then we move up to what is labeled two on these drawings, which takes the first two levels at the bottom of the mine by stoping up to elevation 207.5. Stage three takes you up to elevation 267.5 and includes the large slice of the orebody that extends east-west. If you notice the illustration on the right-hand side of the slide and the Map3D model at the bottom of the slide. This is Figure 12 from the report and has the north-south section and the east-west section, so you can see the geometry of the orebody as it moves up. then we move to state four, which takes you up to the permitted elevation of the crown pillar. That's elevation 327.5. At the completeness and for a really worst case situation, stage five was modeled to a crown pillar of 30 meters, which takes you to elevation 387.5. And that was done to extend the range on the modeling to look at the worst case condition once we start to really affect the crown pillar.

Q Could you review, then, next what you looked at in terms of the rock mass characteristics for this analysis?

A The most important aspect to the rock mass is the fracturing from a hydraulic conductivity point of view. And so again, we quizzed the database to look at the key holes through the rock mass which had detailed fracture information relevant to this issue. And the Figure 3 from the report looks at holes 47, 54, 73, 77 and 83, which I believe were introduced by Mr. Ware. And the fracture data there is presented to give a distribution or a variability of the fracture spacing, which boils down to approximately two fractures per meter, which is an equivalent mean spacing of half a meter. And the range of fractures are typically between .3 of a meter to three meter spacing. So this chart here gives information about fracture spacing.

Q And then you looked at fracture roughness as well, Dr. Carter?

A On Figure 4 of the report, which is reproduced on the right-hand side of this slide, it is presented the fracture data for individual rock types. And at the top is a histogram, a chart, of the variation in fracture characteristics for all rock types. Here we're plotting the

descriptive code out of the Q classification system called the joint roughness coefficient. And in the left-hand side at the top of the chart, taken directly from Table 1 of the 2005 report which is I believe Appendix C-2, are the rock codes used in the database and the ISRM standard codes there match, which give the equivalent joint roughness numbers. And this is published information. And on the basis of the different rock types and the data here, an average -- an overall value of the roughness number, JRC, was determined. So this table is the backup for that number JRC equals seven.
Q And did you also look at fracture orientations?
A Again, I used the information in Mr. Beauchamp's reports. Figure 6 from this report has on the left-hand side two stereonets which come from the 2005 report, which is the -- all of the boreholes that went through the crown pillar. And the four stereonets on the right-hand side come from the -- sorry. All of the ones on the left-hand side are from all boreholes, and the ones on the right are from the 2006 report C-3, which is just the crown pillar.
And just to help everybody, because people will have seen these shown on the screen before, but it's these stereonet diagrams are quite difficult for people to understand. There's three-dimensional features. So I'll just very, very briefly show you what they are. I don't

know if these were explained any time in the testimony earlier. But basically you can think of them as a map of the globe looking from the top. And this would be the projection you would see looking down onto this like a goldfish bowl. And if I had a fracture in this situation dipping that direction as an imaginary plane, I could put a knitting needle through the goldfish bowl, for example, and poke a hole out through the other side and I will get a single point representing that fracture. If I plot that single point, it plots as a dot on these. We then counter the dots, and that gives a representation of all the fractures that have been measured. So the core data, we talked a lot about the oriented core yesterday and Mr. Beauchamp described the Craelius type core orientor, and so did Mr. Ware that collects this data. When you put the data into the stereonets, this basically shows a concentration here of joints that are flat, because all the poles plot in the middle. And if I look at something that's near the edge, say, down here (indicating), that reflects joints which are nearly vertical, because the knitting needle would come out of the side of the net horizontally. So this data is key to trying to establish which directions the fractures go within the rock mass, which is critical to looking at the potential passage of water and the potential influence with clamping or stretching when we analyze the crown pillar. So

that's the orientation information.
Q Is this more of that analysis here, Dr. Carter?
A This is taking the major structures, which we talked about with Mr. Ware, and putting them onto the same stereonets with the minor structures picked up from the core to make sure that there's not a major difference between the major structure characteristic and the minor structure characteristics.
Q And I think the next -- continuing on the rock mass characteristics part of your analysis, did you also look at site specific rock mass data as to the fractures and the stress states?
A This table briefly summarizes all the fracture data for Table 12, which is in the report. It just gives a summary of what we've already just talked about. I guess that didn't print either. That seems to be a blue blob instead of a table. I apologize for that on behalf of the technical printing. In Appendix C of the report, there's a map which has been drawn from the publicly available World Stress Map. This has been compiled in Europe from data provided by universities, mining companies, civil engineering organizations, thousands and thousands of stress measurements.
MR. HAYNES: Excuse me, Dr. Carter. Excuse me, Counsel. I'm looking at my copy of the proposed Intervenor

592, which is this multi-hundred page document. Dr. Carter just testified that there is a -- that these maps are in Appendix C?

THE WITNESS: Yes.

MR. HAYNES: My Appendix C is blank. So up until now I haven't seen this map. It wasn't provided on April 17 when this report was -- when this exhibit was filed late. It's not in the report. So the first time I'm seeing it now to try to figure out what this means is right now this morning. So I object to the witness' testifying about this map that we haven't seen until this morning.

MR. LEWIS: Well, I might say, Your Honor, there's been -- as you might imagine, there's been a lot of exhibits. Both parties have handled exhibits electronically and so forth. And for both parties there have been a number of cases where we found missing things and had to deal with various issues as to these exhibits. You probably recall earlier on for some time in the hearing we had various discussions about, for instance, Petitioner's Exhibit 3 in the Part 632 where we had a great deal of difficulty finding things and we had to verify on the record what was in and what was not in and so forth. And certainly this looks like an instance to me if Mr. Haynes or any of the other Petitioner's attorneys, if in fact when they receive these documents had made us aware of that, then we could have taken care of this problem. And certainly I would hope they could have taken care of it prior to today, you know. We have hard copies. I'd be happy to provide them, you know, immediately. But I think again that we could have -- if we had some notice that they did not perhaps receive everything we intended to be in this exhibit, that it would have been more appropriate to deal with it at that time, Your Honor.

MR. HAYNES: That's all well and good, Your Honor, except that it's not my exhibit. And if there are blanks, I don't know what the purpose of the blanks are. I really think that that is the burden of the proponent of the exhibit to take care of.

MR. LEWIS: Let me ask, if I may, Dr. Carter a couple questions.

JUDGE PATTERSON: Okay.

Q Appendix C, is that what you're referring to here, Dr. Carter?

A I am.

Q And Appendix C as to this map, can you tell me, are you referring to a particular paper there?

A Appendix C is a summary of available stress information pertinent to the Eagle Mine area. It includes -- and I have a copy of the -- a hard copy here of the report. It includes the Figure C-1, which summarizes the World Stress Map data, it includes a paper by Haimson on Crystal Stress in the Michigan Basin, which I believe is also a paper that the Petitioner's have put into their list. And there is a -- and we have certainly in the Kennecott list. And then there's a State of Stress paper by Zoback. And all of those are in the appendix as the main basis for stress measurement information within the Michigan area. And in situ stress measurements have not been taken at this mine site at this stage.

Q And the figure, then, that we're looking at on the slide and that you prepared, did you prepare that from the information contained in those published reference sources?

A I compiled this figure from information within two pages --

(Off the record interruption)

A This is contained -- the information on this figure is contained from the two references within the appendix, plus information from the World Stress Map, which is available online from Karlsruhe in Germany.

Q And does this figure fairly and accurately represent the information in those publicly available sources and articles you just referred to?

A Yes; yes, it does.

MR. HAYNES: Your Honor, before the witness testifies about these figures, I want to again place my objection on the record based upon the exhibit that we received. First -- and actually a couple other reasons.

One, the Haimson report -- the Haimson report is not in our exhibits, I don't think anyway. And secondly, the copy that I got from the Respondents -- excuse me -- from Kennecott has blanks in it. And I'm looking at page 5859 of the Haimson report. For the Zoback and Zoback report, which is found also in Appendix C to this proposed Exhibit 592, there are also several blanks. I don't understand why the blanks are there, Your Honor. I didn't copy the report. But this is KEMC Bates 252424. We have more blanks. On KEMC 252439 more blanks, and also on the next page. So the figures apparently from the Zoback report were just somehow not copied correctly. Again, I'm dealing with an exhibit here that was filed late. By April 17 you're hard-pressed to get ready for this hearing, so I wasn't really I think obligated to truth check the copying process from the Respondents. So to the extent that the figures about World Stress that Dr. Carter wants to testify about, I haven't seen before today. So I object to the witness testifying about these matters based upon these reports where we don't have the figures that apparently he's basing his testimony on.

MR. LEWIS: I think, Your Honor, we've laid a foundation that the figure is in fact based on publicly available published literature about this very issue and this very information. And I believe that's probably sufficient foundation in and of itself. Having said that, we're certainly -- I would get to Mr. Haynes directly the various articles that we attached. But again, we've heard a lot of testimony in this case I think already from the Petitioner's experts, for example, about information based on publicly available reference, articles such as these. And I think, again, that Dr. Carter has laid sufficient foundation for the -- that this figure accurately depicts that information and there's sufficient foundation at this time.

JUDGE PATTERSON: I think as far as foundation we're okay. The problem is if you can make sure everybody has a full copy of it so they can appropriately address that.

MR. LEWIS: Okay. Absolutely; absolutely.

Q Dr. Carter, can you show us what is reflected in this summary figure about the stress data?

A On the maps -- and there are two maps on this figure -- one is a complete map of North America and the other one is just a Great Lakes region. And on here I've marked the Eagle site with respect to the nearest available information. And you can see that's all somewhat south of the Eagle site. And there's a fair amount of information in New York and Canada also, all of which tends to show a northeast-southwest preferred orientation for the stresses. The data that comes from Zoback 1980, the paper of which is in the appendix, and from Haimson, also confirms a compressional northeast-southwest trend for the major principle stress. And I've diagrammatically illustrated what this means in the lower right-hand corner of this slide. The largest stress, the biggest pressure, is what's called sigma H1, which is northeast-southwest and the lowest horizontal stress is northwest-southeast, approximately the same magnitude as the vertical stress. So which is sigma V. So based on the literature, the best guess, because it is only a guess because there is no actual physical data on site yet, is that the horizontal to vertical stress ratio is 1.5 and the minor horizontal stress to the vertical stress is about equal, which is very similar to the numbers that Mr. Beauchamp presented yesterday and is essentially the background of the data that has been used for most of the modeling.

Q Okay.

A So given that, the major stresses are parallel with the orebody and perpendicular to the orebody, which means that in order to look at worst case conditions, the most conservative conditions, we went for a bracketed range outside of those estimated real stress data. And in order to get the deepest zone of possible tension, which means you're pulling apart the rock mass, we would need -- in the crown pillar we would need a low stress ratio, which would

tend to open the fractures and allow water through. And in the sidewalls, if we wanted to see the same sort of issue, that's the biggest possible tension, and for the fractures in the sidewalls to allow water through and to open up, we would be looking at a high stress ratio where the crown would be more clamped but the sidewalls would be put into more stretching. So we modeled a complete range of from 0.5, which would be a low stress -- and these are talking about in situ stress, which is the stress left after the Ice Age and geological stress, not mining-induced stress, which is another issue. We looked at both directions. So we said, all right, the major principle stress from the literature suggests northeast-southwest, but let's assume it's wrong. Let's say that it flips and the northwest-southeast is the major direction, which would give the worst case for a long strike versus a cross strike.
Q And did you model this information as to the various mining sequences that you discussed earlier?
A Yeah. We -- on the next slide, which is Figure 2 from the report, we have the stage sequence of mining starting off with no mining. And the bottom of the orebody is modeled at elevation 143, and the top of the mined excavation here for a very thin crown pillar is 387.5. So we're going to sequence right through 244 meters, which is an 800-foot vertical extent. So stage one's no mining. Stage two,

extraction of the lower sections, that's level six and seven. Stage three takes us up to elevation 267. Stage four to 327, the permitted level. And then to the thin 30 meter crown pillar at the bottom. And I've illustrated in the bottom part of the diagram the two cases, which we're going to look at in more detail, the permitted case on the left and the extreme case on the right.

Q And what were the results of this part of the analysis, Dr. Carter?

A In order to summarize the results, we quizzed these points within the top of the model. And on the left-hand side you have the plot for the north-south section. On the right-hand side you have the plot for the east-west section. In the top figure, the little red and yellow circles, which come from Figure 14 in the report and represent the points at which we interrogated the model to determine stresses. In the bottom of the model we have lines on which we determine strains. So the difference between these two is in the top ones we're looking at pressure and in the bottom one we're looking at as though we pull it apart. So these are the stress results for the low stress state. And the scale we're looking here at is the sigma 3, which is the least principle stress. There are two principle stresses; the major stress and the minor stress. The minor stress is the one we're interested in, because this is the one which will show tensile opening. And on these diagrams the more blue it is, and particularly if it's negative, minus one on this scale, the more we're going into a tensile range, which means that fractures in those zones would be pulled apart by the stress, which means that you would open up and increase the permeability. As we go more to the red end of the scale, the fractures are being squashed because the stress is increasing. So if we look at the diagrams here, the bottom left diagram from Figure 15 shows the permitted crown case stage four. And the next diagram on the right shows stage five, which is for the 30 meter crown. Now, I'm going to show you here -- well, first, all the little circles on that diagram -- and I'll show you some later on a little more easy to see that detail. But this comes from the plastic modeling. So this model here is run through the elastic range into the plastic range. And perhaps I should just quickly look at that, because that was an issue that was mentioned as a criticism by Dr. --

(Off the record interruption)

A When we test rock --

Q Dr. Carter, you say that was a criticism mentioned by somebody?

A Dr. Sainsbury; that we haven't used plastic analysis. And there's a rationale for why we didn't do that in the early analysis that Mr. Beauchamp presented yesterday. Typically, when you look at a rock mass and you test it, just like concrete, it has an elastic response. As we put more and more strain on it and stress, the curve goes up elastically. And that's the elastic range. When it reaches failure, it may go plastic. It may drop back and we get a peak before it goes plastic. This post-peak behavior is what we model in detail with some of the numeric codes when we get into really detailed modeling. When we are just looking at the preliminary level, within the elastic range, as long as we are actually seeing failure in the elastic range, all very, very high stresses that go beyond the rock mass capability, they show up even in the elastic models.

So at the preliminary stage we do not bother to take the extra computational time to do this part of the analysis. So in looking at an early phase of a job and a project, it is industry standard to do elastic modeling and not to really push the envelope to look at the plastic analysis.

Anyway, in order to do this and to make some comparisons for this case where we're looking in detail now at maybe the damage that's created by stress damage, we ran the worst case, which is the K0 of point 5 plastically to look at what might happen right in the crown pillar for the very thinnest case -- not the permitted case but the thinnest case. And if I look at the right-hand side here, the zone that's blue in that diagram is the zone that basically goes tensile in the upper part, which is where the fractures could be pulled apart.  So that's the zone of influence of the excavation due to high stress.

If we go to the next slide -- and again we look at the permitted crown, and we're seeing here everything in greens and yellows in both situations.  So what this shows is no tension.  It shows compression, so the crown is actually getting tighter.  The fractures are being closed. And it's still in the elastic range, which means those fractures aren't failing even when we mine to the worst-case situation.  So we are getting squashing reduction of permeability.

So if we go to the next slide, that's just a brief summary of the east/west section and essentially shows the same thing, but it shows more damage, if you like, into this area above.  If you remember, the excavation shape is rather odd in the east/west section, so you're getting more damage into this zone here, which is not an issue, because that's within the basic block of the mining area, and it doesn't extend up into the crown.  This is the permitted case.

So if we look now as a comparison -- and this now is the strain results, which are actually more useful to really define whether we've got a problem.  And if -- again, the same color scheme.  If we look at the left-hand side, that's the permitted case, and it's all in the yellows and greens. If you look at this side here, we've got a blue zone in the very thin crown pillar, and some of that zone right close to the excavation is damaged, which is what all these little circles show up as. And this shows the east/west section for the same conditions, which essentially is Figure 22 and 18 within the report, all of which show that, when you have a high K0; in other words, 3, 2 and 3 values; the crown pillar is fine. It actually is getting squashed.

When you have a low K0 for the 87-1/2- or 90-meter crown pillar, it's still getting squashed, but for a 30-meter pillar, it's not. It's starting to be opened. So this gives us some scale of when you start to then enter problems with the crown pillar being affected by the mining-induced stress effects. One immediate output of this model is that we can also look at the strains and directly along the crown pillar alignment. And I guess it's again printed with just the top slide, and you might want to give this out too.

What you have here is a plot running from 600 meters outside the crown. This is the center of the orebody on the north/south section, and this is the east/west section, and we're going from 600 meters outside on either side. And that's the strain behavior as you cross the crown pillar in both directions. If we go to the next -- and if we compare that to the SME strain criteria, which was mentioned yesterday, which is this sort of strain level, these values are way, way, way under what you would get.

And the reason that they're so low compared with the criteria which is set as an industry standard is the industry standard strain criteria is based on coal mining. It's based on removing the hole of the coal zone here and inducing ground settlement over the top so that the hole at the surface warps like this. And we're looking at a strain criteria on the edge of these but which damage starts to be developed for buildings. So that's where this criteria comes from. And in a hard rock mine, as Mr. Beauchamp was explaining yesterday, you hardly ever see any strain at all until it either fails or doesn't so --

Q What did you look at next in the analysis, Dr. Carter?

A Well, we come to the -- oh, I'll just summarize quickly. This little fellow here, this is a sort of plot that you see with a dipping orebody of the strain, and this would be the strain profile. If we put the strain criteria on these two diagrams, that's where the criteria line would be, and you can see it's way less than any of the numbers. And we're looking at negative strain, which is pulling apart, because that's the one that will increase the cracking to allow water to go through. So these are okay from the strain criteria.

Q And the next part of the analysis, Dr. Carter, is what?

A Looks at the water flow, so we're going to quickly go through. And we looked at two approaches analytically -- and I'm going to summarize this fairly quickly -- to show a stress-based approach, which looks at a change in hydraulic conductivity due to stress, and the change in hydraulic conductivity is directly proportional to the change in stress, according to equations developed in 1968 and through 1981.

The second approach is a strain-based approach, which was based on work that was done in 1994 and includes some of the background from Barton & Bandis, which is about the fracture characteristics. And that -- the actual change in this analysis is based on changing fracture aperture -- not permeability but fracture aperture as a result of changing strain, which is of course tied to stress, which means that the change in hydraulic conductivity is proportional to the change in strain to the Q power, because it's a parallel plate cubic lower, which is -- we will just quickly go through in the next slide.

If we imagine a fracture like this, work that was done in the 1960's developed a very well-known equation, which says the hydraulic conductivity is related to the viscosity of the fluid passing through it and the opening of the fracture, all to the power 3.  This is the famous cubic law, and this is the parallel plate cubic law and is now taken as an industry standard in analysis of fracture flow. And this little diagram on the left here, which is Figure 25 from the report, is a nice, easy, little diagram for us to plot that equation and see exactly what is happening.

So if I take the data which I showed earlier, everything in yellow is input data, so this is the hydraulic conductivity range, according to what is published in the Golder reports on hydraulic conductivity information -- I don't know exactly which exhibits those are -- and which gives this range from 10 to the minus 4 to 10 to the minus 6 centimeters per second, and I think in those reports they're quoted in meters per second.  On this side here is the data that I showed earlier with a mine fracture spacing of about half a meter and a range from about 30 centimeters to 3 meters.

So if I go up this chart this way on the fracture spacing and I come across the chart this way, I get that green dot.  And if I go from the green dot -- or I go -- I use the range that the fractures are here, that gives me that line and that line across the chart, and I tie with those two going up the chart.  I can define this ellipse of probable intersections, which defines, if I go this way up the chart, the typical fracture aperture.

Q And what's that number?
A That's the width of the fracture. And that is directly proportional in the stress-based approach to hydraulic conductivity and in the strain-based approach to the cube of the hydraulic conductivity. So if I use these fractures and I take those into my model, results from the stress determination, I can get a measure of whether the hydraulic conductivity is changing and whether we're going to get more water. So that's what we've done in the next couple of slides.

So if you remember, this is the 90-meter crown pillar with basically no adverse conditions in the crown but fairly adverse conditions in the sidewalls, as I mentioned earlier. So this is for a high-stress state, this particular plot, and this is for a K0 of 3. And this, if you remember, was the worst case for the crown pillar with a low stress. All right? And this was our permitted case, and this is the 30-meter crown. Now, if I look now at this zone in here, I'm going tensile and, if I look in that zone there, I'm going tensile. So again, I'm trying to pull a rock apart, which means that the fracture's increasing permeability.

So if we go to the next plot, this plots those little points within the crown pillar. And I've blown up -- and there's the points on the right-hand side, which we've monitored. And if we blow up the right-hand side top graph -- I'm monitoring point 3 in some detail on here so you can see what's going on. This is stage 1 when we've got no excavation. And this is the state of the hydraulic conductivity and the equivalent -- sorry. This is the stress, which is right on this side, and the hydraulic conductivity.

So this is the base case so -- the results are summarized all on this one little graph. So what it does here is it says hydraulic conductivity decreases in the crown pillar as you move from stage 1 to stage 2 as the stress increases, so it's getting squashed. As we move to stage 3, we're still squashing, but the stress that's imposed on the crown pillar is slightly less. All right? And we've mined up to this point here. If we go to the next, which is stage 4, we've now mined to the permitted crown, and you can see the permeability is starting to increase as the stress is starting to decrease.

Now, if we go to stage 5, which is the 30-meter crown pillar, the permeability is starting to rise, and the stress is starting to drop. And if we continued even more, we would get into these legacy mines, where the stresses would start to drop significantly. The permeability would be increasing dramatically, so you start to get a lot of water coming through, and the crown starts to fail and cave, which is what we have for the iron range mines, because the strength of the rock -- so this happens a lot earlier for those sort of mines.

So the issue we have summarized very neatly in this graph is that, as you mine through, you change the stress state, which is this black curve, and the permeability also changes. To start with it gets tighter. The permeability drops, and then it starts to increase.

Q What did you look at next, Dr. Carter?

A The next couple of slides just show exactly the same thing for the east/west section. And if we go one more slide -- okay. Now what I'm going to look at is point 13, which is at the top of the permitted crown, where you have the influence here on the east side due to the fact that you have this large excavation shape below. And if you remember, I pointed out this starts to go blue on those earlier graphs, showing it's going tensile. And if you look at the shape of the curve now as you go from -- through to stage 4, you start off with the stress increasing as previously, but then the stress starts to decrease much quicker, and the hydraulic conductivity comes back almost to where it started.

So by stage 4 it's still okay, but stage 5, if we were to mine stage 5 here, this is going to go out of sight. So basically you're starting to get an increase in

permeability of the crown pillar for a stage 5, the 30-meter crown, because of this problem. So summarizing --
Q Yeah. What does it all mean for our crown pillar we have here, this 87-1/2; whereas, you've been referring it -- to it for the modeling, the 90-meter crown pillar?
A Okay. Well, just -- we have four points here which summarize everything. The crown in the main becomes more planked, which reduces the hydraulic conductivity. And the low-stress state, a 5- to 10-meter-deep zone above the openings for the worst-case condition, might become more permeable. And the high-stress conditions, the crown is perfectly okay, but the sides out to maybe 20 or 30 meters deep become more permeable. So what came out of all this modeling is the recommendation for the future updated hydrogeological modeling then both of these worst-case assumptions be assumed. So that's 10 meters up into the crown and 20 to 30 meters out into the sidewalls be added into the worst-case scenarios for the hydrogeological modeling.
Q And is that for work that John Wozniewicz at Golder has followed up on?
A Yes, that is the work that they're doing.
Q Is there any additional conservatism that you've included in this analysis, Dr. Carter?
A Yes, there is. We've also not assumed any clamping, no

improvement in the models so --
Q Even though the models suggest that?
A Yes. Perhaps if we just run these bullet points here -- the models suggest that for most cases the mining actually improves the hydraulic conductivity of the crown pillar.
Q You mean it decreases it?
A It decreases the conductivity, reducing the amount of water that comes through. The benefit of that has not been incorporated into the new models, is my understanding. So we're assuming the highest conceivable worst-case hydraulic conductivity. And we're using the strain-based equations because it multiplies everything up by the cubic, so it makes the hydraulic conductivities even higher. It's somewhere in that range. This is all modeling based on not having measured the in situ stresses and not having all the data that one would like to have to do this modeling, which is why this is not normally done until you're way into a mining operation. This is extremely unusual to do this at this stage.
Q Dr. Carter, do you have the -- a copy of your report with you there?
A I do.
Q Could you refer to page 10 of that report, please, the bottom paragraph labeled "2.2 inferred stress state"?
A Let me find page 10 here.

MR. HAYNES: Your Honor, is this the report that has not been offered into evidence yet that the witness has been reading from? Because if it is, I object.

MR. LEWIS: It's a foundation question, your Honor.

A Yes, Section 2.2, I have it -- page 10.

Q And do you in fact reference there the various articles -- publicly available articles that we talked about earlier that you had also included as copied attachments to your report, the Haimson 1978 and Zoback & Zoback 1980 and further in that paragraph data from the World Stress Map and from Zoback & Zoback 1980?

A That's correct.

Q And would you assume that the other people with some familiarity to this industry like perhaps Dr. Vitton or Mr. Parker would have been able to find those references based on that -- the fact that you've given the citations in your report?

MR. HAYNES: Objection; calls for speculation.

MR. LEWIS: Based on his experience, I think it's a fair question, your Honor.

MR. HAYNES: Lack of foundation based on speculation as to whether or not anybody else could -- would find these reports, of where they are in the published -- and --

JUDGE PATTERSON: Yeah. I'll sustain the objection.

Q At any rate, you did include the references in the text of the report; is that right, Dr. Carter?

A The references were included in the text of the report. They're fully referenced also in the three pages of bibliography at the back of the report and again reproduced in Appendix C.

MR. LEWIS: Your Honor, we'll provide to Mr. Haynes as a courtesy copies of the various articles. But I believe the report itself -- as to the complaint that the articles were not in fact attached, the report itself with the very references and the bibliography provides sufficient foundation on that particular point. And then, with that said, I would offer Intervenor Exhibit 592 at this time.

MR. HAYNES: Let me restate my objections. First, the report is incomplete. Second, it was provided too late, and there's been no showing of good cause under this tribunal's order for production of exhibits, so for those reasons we object to the admission of the report.

MR. EGGAN: Same objection, your Honor.

JUDGE PATTERSON: Okay.

MR. WALLACE: I'm going to object as well, your Honor, and I'm going to add to my objection. You know, something's going on here that is turning this whole process upside down. We've -- we submitted reports in the public comment period years ago that have not been admitted into evidence. And now, you know, highly complicated, complex documents with explanation we received today have been long after the permit was filed, offered into the evidence as part of this record. And we've got all the wrong things forming this record now, not what was available to everybody years ago for analysis by experts but what's been created in the past few days and weeks and, according to Dr. Carter, is still being created, and he's testifying about it as part of the regulatory process.

The regulatory process for this mine application has been turned upside down. I looked at the exhibits -- which are, you know, frankly, with all due immodesty, pretty incomprehensible -- that were created in March of '08 this witness has testified to, and I picture your Honor in a room by himself some day looking at these documents and -- I mean, I feel as though I'm, you know, listening to somebody speaking a foreign language for half an hour and then saying, "And in conclusion, this proves that the Petitioner's experts are wrong" and then switching back to the foreign language.

How are we supposed to try this? And shouldn't all of this been made available to the DEQ with its experts and its ability to hire outside experts in connection with the application rather than two months ago? DEQ hasn't had a chance to vet this, and that's what's supposed to happen. So I object on all those bases.

MR. LEWIS: I believe, your Honor, that motion has already been heard and ruled on, that argument being that we ought to be restricted to the permitting record. And the other --

JUDGE PATTERSON: Yeah. This is de novo review. It's not --

MR. LEWIS: Right. And the other objection has already been ruled on, that being the timeliness of the presentation of the exhibit based on the earlier objection.

MR. WALLACE: Well, not in the context of an exhibit like this and testimony like we've had this morning. I mean, this just poignantly underscores the problem with this process at this point.

MR. EGGAN: Yes. And while the review is de novo, it is supposed to be de novo review based on the record. And so from our perspective, you know, that's another whole issue.

MR. REICHEL: Well, Judge -- and this issue has been briefed before, but I just have to note for the record that, again, the very purpose or function of this proceeding is to go beyond and start beyond what the -- was submitted to the DEQ prior to December 2007 decisions. The nature of this proceeding is to create a new record with evidence that's available and probative of the issues presented so that you ultimately can prepare a proposal for a decision, and ultimately the director of the DEQ can make a final decision based upon this newly created record. So to suggest that simply because this document was not submitted to the DEQ prior to December of 2007, it's inadmissible, is simply incorrect.

JUDGE PATTERSON: I think -- based on the fact that Dr. Carter's testimony and this exhibit was generated in response to a witness disclosed in Petitioner's exhibit list and the report was promptly generated and disseminated apparently with some deficiencies and which I think would be easily rectified over the lunch hour, I think the Intervenor is showing good cause for not literally complying with the deadline in addition. Because the report was furnished approximately a month ago and, therefore, available to the Petitioners, I don't see any prejudice. But I do share Mr. Wallace's concern with, frankly, a lot of what Dr. Carter said I frankly don't understand. And if there's some way that we can dumb it down, so to speak --

MR. LEWIS: I'll try harder, your Honor.

JUDGE PATTERSON: Obviously, as the trier of fact, I want to make sure I've got the facts in order.

MR. LEWIS: Right.

JUDGE PATTERSON: But I will admit the exhibit, but I think we need some more basic background of his opinion, because, frankly, at this point I think I know where he's going, but I'm not absolutely sure of it. So if we can maybe get a little more basic lesson --

MR. LEWIS: On this particular subject?

JUDGE PATTERSON: Yeah; yeah, the conductivity and the hydraulic.

MR. LEWIS: Okay. All right.

JUDGE PATTERSON: I understand what Petitioner's witnesses were saying, particularly Dr. -- the name escapes me.

MR. HAYNES: Dr. Vitton? Dr. Prucha?

JUDGE PATTERSON: Prucha.

MR. HAYNES: Prucha.

JUDGE PATTERSON: And obviously this is designed to counter that, and I want to make sure I understand the precise basis.

MR. LEWIS: Yes. We have a problem with translation from engineering to our form of English here.

JUDGE PATTERSON: This is true. Okay. With that, let's break. It's noon, so let's break for lunch.

(Intervenor's Exhibit 592 received)

(Off the record)

JUDGE PATTERSON: Whenever you're ready.

MR. LEWIS: Thank you, your Honor.

Q Dr. Carter, let me ask you a couple questions and see if we can perhaps put this more in laymen's terms, what we're talking about here. And I believe -- if we assume that this is the opening which would be created under the mine, Dr. Carter, and that the crown pillar would lie up here above it -- right? -- and you have rock out here on both sides and underneath. Is the issue here that you were looking at that was part of this analysis or the basis for this analysis then the potential for the so-called stress effect at the edges of these openings and above that opening in the rock? Is that what we're concerned with?

A We're concerned with that due to mining.

Q And is the idea, then, that, as a result of the mining and blasting, that there may be some effect on the rock around the edges of these openings that might cause whatever cracks and fissures there are in that rock to, in effect, dilate or open up?

A That's correct.

Q And thereby potentially increasing the ability of water to flow through those dilations or openings into the mine cavity?

A That's correct.

Q Okay. And -- now, Golder earlier -- as part of the mine permit application process, I believe some of your

associates at Golder had looked at this various issue and done some modeling to predict the amount of water which might flow into the mine. And you're aware of that work, are you not?
A Yes, I am.
Q And I believe that was by Mr. Wozniewicz and some other people at Golder?
A Correct.
Q And was the purpose of that work again which was submitted with the mine permit application to, in effect, calculate, predict and account for the amount of water which might flow into the mine during mining?
A Yes.
Q And was that, in part, to be able to have an understanding as to the operational controls that would be required during mining, the pumping out of the water?
A Absolutely.
Q And was another purpose of that analysis to look at how much water might flow into the mine from the aquifer above the mine?
MR. WALLACE: Your Honor, I realize one approach to it may be as simple as to have Mr. Lewis testify. But -- and I'm sympathetic to that. But he really should make the witness testify with non-leading questions.
MR. LEWIS: I'll try to do so, your Honor.

JUDGE PATTERSON: Okay.

Q Do you recall the predictions from the calculations in the Wozniewicz, et al, reports that they set forth for the base case predictions for mine water inflow?

A Not off the top of my head, but I am aware of them.

Q And then after that report had been sent in with the mine permit application, I think, as you indicated earlier, at some point did Dr. Sainsbury raise an issue as to whether Golder had done enough analysis of the potential for water inflow as a result of the mining itself that we looked at on this figure I drew?

A Yes. He basically criticized the Golder work for having not done a coupled model between the stress-related effects which govern the crown pillar stability and the groundwater inflow effects which controls the water into the mine and also the impact on the environment.

Q And Wozniewicz, et al, nevertheless made some assumptions as to the potential increased permeability and zone of potential increased permeability around the mine openings in their original reporting?

A They had made some assumptions. And based on a halo around the excavations that would be influenced by blast damage and fracture change due to the sort of things that we're looking at, stress-induced effects.

Q And was the purpose of your additional analysis that you talked about earlier to respond to the issue raised by Dr. Sainsbury and do some further and more rigorous analysis of that issue?

A It was to do that rigorous analysis to the level of detail we could at this stage and to confirm the information and the assumptions made in the modeling and to address the Petitioners' concern about increased groundwater flow.

Q And did you by your additional analysis, in fact, confirm the assumptions made by John Wozniewicz, et al, in the original reporting?

A For the permitted crown level, we confirmed those assumptions completely.

Q Now -- and once again, in general, what two types of data did you use in your analysis, Dr. Carter?

A We used the available published literature to establish the stress field, and we used site-specific data from Mr. Ware and Mr. Beauchamp's reports and from the modeling reports to provide the input.

Q And without at all going into how that modeling is done and so forth again, did you, as a result of your analysis, reach a conclusion both as to how far that zone of influence might extend on the sides and the top of the openings? Did you reach a conclusion as to that effect?

A We did. And the modeling for the worst-case situations shows 10 meters up into the crown and 20 meters out into the

side walls would be affected for the worst-case situations.
Q And by "affected," do you mean that the permeability might be increased within that zone as a result of the mining?
A Correct. However, it's -- for the permitted case, there is no influence in -- as deep as that in the crown.
Q So the dimensions you just gave for the zone of influence are not for the permitted conditions?
A They're the worst-case analysis.
Q Okay. And then did you also, through your analysis, then -- were you able to show what the overall effect would be as to this issue of stress-induced permeability around the openings of the mine and particularly did you -- were you able to reach a conclusion as to whether the permeability would, in fact, increase or would, in fact, decrease?
A Let me just talk about the permitted case. For the permitted case, all of the calculations and analytical assessment points to the crown becoming more clumped, the distress actually locking together the joints within the crown reducing the permeability.
Q And would that have the effect of further reducing the potential for water to flow into the mine?
A That's correct.
Q And would that further show that the assumptions made by Wozniewicz, et al, were conservative?
A I would say so, yes.

Q Now, we looked several days ago now. And I want to try to explain a little more these stresses we've been talking about. But I think what you talked about earlier, in general, the two stresses that we're concerned about here and as various witnesses have talked about are what are called lateral stresses, --
A Correct.
Q -- pushing against a rock, and then the so-called vertical stress, which is the effect of gravity trying to bring things down. And were you looking, in effect, through this analysis at the -- at the -- you know, what level of clamping there would be in this rock as a result of the mining operations?
A That's exactly what I was looking at.
REPORTER: Can we take a break for just a second?
(Off the record)
Q So your analysis was looking at the potential for this clamping effect. And again what did your results show in terms of whether the clamping would increase or decrease?
A The clamping will increase for the permitted case.
Q And what effect will that have on the permeability of the in situ rock? In other words, if you look at the rock now and we do the mining that's under the permitted conditions -- okay -- will the clamping increase or decrease relative to what it is now existing in the ground?

A For the permitted case, the clamping in the crown pillar will increase tending to lock the fractures together tighter.
Q Now, so that's this lateral stress effect you've been talking about, is it not?
A Correct.
Q And many days ago Dr. Bjornerud was here, and she presented a model up here on the front of the table. And the model, as I recall, had some sticks going through it and it had a bottom piece of plywood. And what she did with her model was in reference to these lateral stress fields was that, as she began taking rubber bands off, she was able to cause sticks to fall out the bottom of the model after she pulled the floor out. But, in effect, the work you've done and the analysis as reflected in your report and the testimony today, what effect would that have on her model, Dr. Carter?
A The exact opposite. It would be adding rubber bands, so it will be getting tighter. That would have a benefit for the stability, and it will also have a benefit for the water inflow.
Q Now, I want to turn next, Dr. Carter, to a little more discussion as to reliance by some of the Petitioners' witnesses on other mines, their position being that they're relevant to what might happen at this mine. And have you also prepared some slides to address what the Petitioners

had to say about the Athens Mine and some other mines in the so-called iron mining district?
A I have.
Q And could you explain with reference to your slides your opinion as to the relevance of those other mines the Petitioners' witnesses were talking about?
A Certainly. And this is a much less complex subject than the one we've just had to go through.
Q We're all relieved. Thank you.
A This is going to be a kaleidoscope of pictures rather than equations. The first picture here is the typical surface cave condition for one of the iron ore mines. This lake sits in the cave area from the subsidence crater. This compares with these sort of pictures for the Athens Mine which were put up by Jack Parker from using Googler. And if we go to the next picture, that's the actual surface condition of that mine as one would see it if you go on the ground. So these are significant collapse features. And these mines are totally different from the Eagle situation.
Q And can you explain that in terms of the different geometry in the Athens Mine and some of these other iron mines as opposed to the geometry of the Eagle Mine?
A Certainly. Let me briefly go through the sequence of excavation here.
Q This is the Athens Mine now?

A This is the Athens Mine. And the various testimony which was put forward by the Petitioners draws on some very important references in the mining literature which have been referenced into a number of textbooks. Essentially the mining took place of block two in this area (indicating), the second part of their development, which lead to raveling. And I'm going to put all of these into context in the next few minutes. They're mining method was caving.
Q What does that mean, "the mining method was caving"?
A It means that you dig out as big a hole as possible underground so that the roof will fall on top of your head.
Q Intentionally.
A Intentionally. And it's a very dangerous mining method. And I'll show you about it. So you intentionally develop that cave. And at a certain point when the size of that underground excavation got so big, the surface would collapse into it and you developed a chimney. And then the chimneying funneled right the way through to surface to give you your plug failure. In a nutshell, it's increased by the mining and the size of the mine.
Q Next would you discuss the various modes that are discussed in the literature of crown pillar failure, Dr. Carter?
A Well, first all of the modes of failure we just looked at on the previous drawing are covered in the case records. So if we go through this, we have plug failure cases, we have

chimney failure cases, we have cases where we have caving, we have cases where they're just raveling and delamination. And there's a little stretch here to show what all those different types look like and how we define them. So you got a little definition sketch.

Now, all of those occur by accident when you don't design properly. They also -- we can make them occur if we want to mine in that method. So we actually do design to cave for these large operations like I showed at the beginning of the day. So these big block cave operations are designed to make the ground cave. And so were the 1930's mines.

Q Are these various modes of failure represented in the -- I think it was the spanned filler database that you talked about earlier, Dr. Carter?

A Correct. Of the 70 failures, there are examples of each of these.

Q There are from how many case records?

A 500 now. And I should just give a little big of background. The iron mines are not in there. This database is essentially Canadian. It has some cases from Australia, some U.S. and some European. And now having analyzed these in some detail, I allowed them into the case record.

So perhaps we should look at the actual situation. This is a map which is out of the DEQ's web page and a report by Robert Reed from 1957 on the Michigan iron mines. It shows the location of all of the mines. And the Athens Mine is there. The picture that Mr. Parker put up covers that area of Negaunee. And the actual caves that we see, in fact, encompasses more than just the Athens Mine. It encompasses the Tracey Mine and the Bunker Hill Mine, which are alongside it.

If we go to the next map, which also comes from off the DEQ and we look at the two mines that were mentioned earlier, the Ropes Mine is a gold mine and the cave mechanism there is totally different. So I'm going to concentrate on the iron ore mines. And we have two types of mines geologically. All the ones that are mapped in yellow here I'm going to show some pictures of. The Athens Mine you've heard about already. Mather Mines is a fairly major complex. Cambria-Jackson -- all of these are very big mines and operated for many years from turn of the century until the 1940's. The next mine which is shown in green also operated over the same time period and is in the iron range but totally different. Again to use my analogy earlier, the difference between these yellow ones, which are in the soft haematite ore which I had read has been described as something close to coffee grounds when you actually met it underground. And it -- when it got wet, it turned into something that looked like tomato paste. That difference to

hard rock, which is what we have at Eagle, and the hard rock which we have at the Cliffs Shaft Mine. We are dealing with a totally different rock mass. These two are chalk and cheese. There is no comparison between the types of ore.
Q For point of reference, Dr. Carter, where is -- what city is the Cliffs Shaft Mine near?
A The Cliffs Shaft Mine incidently is directly underneath the City of Ishpeming. It completely undermines the city. So if we move on now, I'll try and explain as briefly as I can what the fellows were doing in the 1930's when they were mining these mines.
Q These iron mines?
A There are iron mines. Because only by understanding the method of mining can you understand the huge differences between what we want to do at Eagle and what is being raised by the Petitioners as a possible relevant case.
So here we have the top slicing method, which essentially drives a drift horizontally near the top of the orebody. So in this, which is a vertical section, we have the top of the rock mass here. Up above here way up into the ceiling is the rest of the rock all the way to surface. So this part here is the ore. This is the only bit they're interested in. They don't care what happens to the surface. So you develop this tunnel along here. And if you think about it, you're developing this tunnel in coffee grounds.

So in order to do that, you have to put a really heavy amount of timber in there. And this is the amount of timbering you would have to put in to excavate that drift along here. When you get right to the end, even there the ground is falling into the tunnel because it's so weak. And you put what you call a scraper or a slusher here and you pull it back to the shaft access that you have over here. So that's basically what you do. And you go underneath this and you keep going in lower and lower and lower. So having created this and put all that timber in, they then blast all the timber so that the whole roof collapses. And the whole ground from above it right to the surface eventually collapses into the mine. And the zone here now is ore, and the zone above is caved ground. And this was the level they were working on. And this was the previous level when they were working earlier. And they'll soon start working down here. So what they do is they drive a tunnel here called the haulage level. They then raise the shaft very heavily timbered so it's safe for the men to go in. Then they tunnel out using this arrangement horizontally to here, build this whole arrangement and then collapse it. So in plan -- this is a map. They came in here. And this is the shape of the orebody. And this is country rock. You've heard all about country rock on the sides. And they'll come in here and they'll go as far to the end so they're always what we call retreating into safer areas. And then they went out here in a rodeo pattern. They went here in square slices. And these are all different methods that they have named in the literature. And this information comes from a book which we in the mining industry consider the bible to all of this early mining technology. It was written by a chap called Peele. And he had 17, 20 ore fields, produced a mammoth tale, fantastic book.

Anyway so this is what they call top slicing. So this is method one of what they do.

Q And do you have a photograph of that type of mining?

A Yes. This is the end of a top slide drift. And you can see the timber in here. And this is what a scraper looks like. And this is what they were pulling the coffee grounds out with. And these photographs were in Exhibit 603 and they came from the Colorado School of Mines on their public website.

Now, if we look at Negaunee and we looked at the actual mine, that is his picture of the layout of the mine. And this shows just a very nice isometric of all this timber, the different levels. You can see the cave ground here, and there are little drifts into the cave ground and the caving up here and the caving up here. So that edge there is caving right through to the ground surface.

Now, on this map, they put a little scale. That's about 150 feet, which is about 50 meters. So if I lay on top of that the actual crown pillar for the Eagle Mine, it would look like that. And I've actually put the stopes in. So these are 10 by 50 meter stopes. So you can get some idea of the scale of these mines. This mine at Negaunee is not the biggest by any means. And the whole mining area is mining by these sort of methods, so significant mining compared with today. In fact, today I don't think there's a single operating underground mine in Michigan.

So this shows some of the work that the chaps would have to do to put the mines -- timber in. And you can see the scale of timber that they are using. And this is called forepoling, which is driving these pieces of wood out into the -- into this really weak soil-like rock. And they hammered them in. And that forms the next roof so they can advance the next stage.

And this is what happens when they start to get too much pressure coming from the overburden, which is now collapsing right through to surface to produce those little lakes and things. All the timber from all the stuff that they blasted before is starting to squash down. Because as they keep on going and blasting out the timber and the top drops and drops and drops, the pressure builds significantly.

This is another example where you can see that the whole rock mass on the side and they're now into country rock. This is the good rock on the edge, and that's being significantly damaged. So the damage is going out from the mine workings sideways as well as up.

Now, the Athens method was developed to try to be an improvement for the top slicing method. And what they did now was they bottom sliced. Okay. So instead of undercutting the capping, which is the good rock at the top starting at the top of the orebody, they started at the bottom of the coffee grounds-type material. They thought that this would have two advantages. Okay. This is the sequence. I'll come back to the advantages in a minute. They hoped it would slow the progressive cave to surface, and they hoped it would provide a better cushion to the surface which would reduce water inflow. Because it was easier to mine this soil when you were in basically a dry state than when it turned to tomato paste in the wet state. So the mining sequence here would -- each of these are working simultaneously. So at this point here, you're developing this way, you're developing that way, you're developing this way. So you're advancing on a front. This area here is unmined. This area over here is caved. So you're always working away from the caving bed because it's too dangerous to work in the caving bed. So what they're doing here is they mine this little drift then, and then all of this above it collapses, which has actually brought you to this point. Because you're actually mining below yourself each stage. So that's the Athens method.

I think having read all the papers, that they actually created the environment for the plug failure by just doing this rather than the top slicing. Because I think what happened was that they created a larger effective opening as far as the rock above it saw it, and then it suddenly let go, rather than a situation where it could be more progressive on the other ones. Because they had much more problems with heavy stress. And so they had to build these what we call cribs, criss-cross timber along the main access ways to hold the roof up while they were doing the initial development, which is a problem. It means it's costing them a lot more to do the excavation.

Q I think the next method you were going to discuss is- sub-level caving; is that right?

A Because of all the injuries and accidents and the dangerousness of these earlier methods, people moved more towards trying to be remote from the cave development. So they started a process called sub-level caving. And if we go to the next -- most of the iron mines used this in the later years. The little diagram on the left here which again -- this one comes from the Mining -- SME Mining Engineering Handbook -- shows you develop a drift along here and you then drill upwards on a pattern like this -- this is looking into the face -- to cave the zone above you. So you do this one first and then that and then this, and you work yourself down. And the accident rate dropped significantly in the years that this was developed. So this was a better method of cave mining than some of the earlier timbered method. But what we've now done is we've changed -- the rock bolts have been invented. Some of the support measures that we now use have come in. Diamond core drilling was coming in. Much more understanding of the process was coming in. This shows the process. This is a layered cake of sand different colors. And when you pull the bottom out here, this is how it affects the sand. So this is what happens in a cave when you start to extract the rock from the body. And eventually it just goes straight through to surface. And that's simply cave mining in a nutshell.

Q And could you contrast that now with what we've been talking, the long hole open stoping method of mining with backfill?

A Okay. This is what is proposed for Eagle. And basically we would have a 50-meter span in this direction and a 10-meter span in that direction, which gives you the scale of what we're talking about. You saw where that was on that earlier model. This is the geometry of what we would have. We have -- green is the rock areas. This is the production level, which would be this drift at the bottom. And this one at the top is the drill level. And you can see the drill in here. And it will drill these holes downwards like this. And then the blasted ore is trammed into these drawbells or these cones and then is mapped from the bottom in these haulage drifts. And then as soon as this entire little stope is removed, which would be -- for example, this would be a stope under production. That would be another stope under production. This stope here has been backfilled. So you end up with removing the primaries, removing the secondaries with primaries on the side as Dr. Stone explained and for the backfill technology. So this is a primary with rock on both sides. This is a secondary with primaries on both sides. But basically there's no open space. This is not the same by any means as the cave mining, which all you were trying to do is get the ceiling to fall on your head.

So you can contrast this, which is what the soft haematite with a caving crown is doing under pressure, to the geometry which we will look at at Eagle. It's totally different. So just to put these numbers on the graphs -- and I showed you earlier where these mines plotted on the scaled span chart. I did some calculations. And I won't go through them all. But here's a the hydraulic radius up in the 30's, a crown scaled span number. If we just flip to

the next one -- the Cambria-Jackson Mine, again this is in Petitioner's Exhibit 38. I've just taken the data from that. I also get very, very high scaled span number. These are all plotting way up on the chart, way to the left in this caving zone. Next. Here -- and if we just flip through this quickly, these fellows have plotted with time, so this is years along the bottom. And this is amount of tons mined or the area -- the size of the bottom of the excavation in square feet. And this line here is the line of the cave geometry. And it follows that of the undercut. What that means is that everything on surface is falling as the cave fell. So you mine a stope, the surface drops. If you mine a stope, the surface drops. And this is for top size mining. And based on the data when it started and when the cave broke surface, I can about calculate to put data into the crown pillar data. So if we just move on. This was three years, that was ten years. That's the sort of area that they had at the first break. So when they reached the span of 160 meters by 160 meters of undercut, it broke right through to surface. So that gives you a measure immediately of the surface stability.
Q We're still talking about these iron district mines?
A This is all the iron district mines. So again I've done some calculations. Again I've done some calculations here to get some numbers to plot the points on the graph.

And now let's look at the other mine, which is the hard magnetite mine. And if we go back to a scale and go to Parker's testimony where we talked about hitting a piece of rock and it would go "ding" versus "thud" -- all right -- this is ding stuff. We're into the high strength, high quality rock mass similar to Eagle. And you can see from the scale of the -- the mine is standing here. You have very large pillars, very large open spaces. And this is all under the city of Ishpeming. These are still open today mined in 1910.

Q They're not backfilled?

A They're not backfilled at all. Here's another picture of the same thing. They are working now on bursting out this next zone here. And you can see an arch there of a very large opening underneath them. They're had to come up about four levels on this ladder, which we wouldn't allow today. This is much too dangerous of a practice. This is about 1920. That ladder is nearly 50 feet high. Today we would have to put a bratticed arrangement with a spiral of different ladder ways to get to that level. But they did it open.

And this is the mine map for the Cliff Shaft Mine underlaid in the city of Ishpeming. I just Googled the surface road/streets and put it on the top. The head frames are still in place. And this is the various roads through the area. And I just picked up the locations of all the churches. So obviously the people who live in this town aren't particularly worried about the fact that they're undermined completely.

MR. HAYNES: Objection. Calls for speculation. How can the witness testify about how these people are worried or not? There's no foundation.

JUDGE PATTERSON: If they go into churches, they might really be worried.

MR. LEWIS: They all go to church.

Q All right. Dr. Carter, you've talked about the comparison that Mr. Parker and perhaps Dr. Vitton made between these so-called iron mining district mines and the Eagle deposit. And you pointed out that, if one wants to find a relevant example in the iron mining district, the Cliff Mine is the one to look at?

A I would say in the iron mining district, the Cliff's Mine is a good example of a similar rock quality.

Q Could you now give us a little more context as to how the Eagle Mine -- the rock in the Eagle Mine and mine geometry compares with other hard rock mines you've had experience with?

A I will suggest that it's probably a good analogy to take one of the Sudbury mines and just show you what that looks like. This is the Eagle orebody. And if we go to the next slide, this is the geometry of the McCreedy Mine, which is on the northwest rim of the Sudbury basin. And all of these little drifts and excavations are the sort of development on a large mine of the style that would be for the Eagle. And this is -- these sort of drawings are freely available and on the web pages. Because the mining companies are quite interested in making people aware, because there's a shortage of people entering the mining industry. And the -- one of the issues that people have always worried is that mining isn't a safe industry to go into. But today it is. So these drifts on here shown in blue and purple are the access ways. And the new mining area they're working on is shown in red. And the older mining area, which has all been mined out with basically the same type of backfill -- cemented backfill as is being used and proposed for this Eagle Mine permit is being used on the left. And if you contrast that with the next page which shows on the right the heavy timbering for a soft weak haematite mine versus the very big open stopes for the hard magnetite mines, that's the sort of difference in rock quality. So if I look at plotting this on a chart which Dr. Parker and Dr. Blake would be both very aware of, which is basically the oldest measure of designing crown pillars, which was thickness to span, and this comes from the very earliest risk paper, which is Petitioner's Exhibit 632-38. If I plot the Athens

Mine and the Negaunee Mine and the Maas Mine, they plot in that sort of area and Cliff Shaft on that side. And if I plot Eagle with the Golder RMR numbers, it plots about there. And if we came over on -- even to Dr. Vitton's 30 RMR, it would still be just about on the line between the two. But it's way different from these.

There has been a lot of discussion of the fact that there are two areas of potential collapse for mines. And this chart comes out of the time dependency paper that's been referenced several times in these proceedings. And I've put up a colored version so you can see this in quite significant detail.

Q Is that your paper, Dr. Carter?

A This is my paper published in 1996 and heavily referenced in a lot of the testimony in this proceeding. And essentially what we're looking at are two different types of rock. From the case records, all the old ones that are 70 and 80 years out for their failures are bad quality rock failing in long-term time. Now, why does it take a long time for it to fail? The crown pillar is very thick. So it's falling at the bottom, very slowly works its way all the way and eventually breaks surface. So some of these have very thick crown pillars that that process has taken awhile to work through. At the other end of the scale where you have good quality rock, the only cases that occur in this first ten years are all from bad design. Basically they mine too close to surface or they made their openings too wide for the rock quality. So that is the Cliff's Mine. If they had done too big an opening, then it would collapse the surface. So this is how you explain this graph here. And another graph that's in the same paper is this one, which again is a little difficult to immediately understand. This plots time in years on this side. So we have a hundred years, one year. And across the bottom here it plots rock quality. Now, there's no number in here as to span. This is just the propensity of the rock material to fall to pieces. So it depends on block size. So the data that's plotted here in little blue dots are the tunnel and roof falls. And that comes from a database published by Dr. Biniofski. And some of the data in there is also published Dr. Nick Barton, the originator of the Q system. Some of the data in there, the triangles are mining roof falls that have also been published by Dr. Biniofski. So this line here and earlier work is approximately the line which something will immediately fall. So if I was sitting one of the old iron mines, if I didn't put the timbering in it, the roof would start falling on me in less than an hour; half an hour to maybe an hour. The stuff starts to fall in because it's so weak. If I go to the Eagle situation, the stuff, if I put no support in it, would take a year to ten years or more before anything would fall out assuming we did good blasting, all those other things.

So if we look at the iron mines, they typically had three to ten years to first cave. And the crown pillars were about 300 meters thick. All of these points up here are the crown pillar case records. And the distance between these is just a time for how quickly it failed through to surface. So if we plot the Athens Mine and the iron ore mines, they sort of plot in this range. And if we plot Cliff's Mine, which certainly has a hundred year life, we're plotting in this sort of range, which is consistent with the data. And I shall add this into the crown pillar data.

So this is what we look at with Eagle somewhere in here (indicating). We had a lot of stability time to get out rock bolts in, put the support in for those top drifts. The single stope collapse is not an issue. It's not like the iron ore mines, which we're trying deliberately to collapse things. So this is what I expect Eagle Mine to look more like, although it'll be much neater than this without all these old wooden ladders and folk that aren't quite as protection conscious as we are today. And if I plot the Cliff's Mine data onto this graph and do exactly the same things that we've been doing before, I can calculate the approximate range certainly of what the scaled span would be. And if I go across through the scaled span -- I do not know these. So if I go from here to the failure line for both and just back-calculate what they are, I get an RMR of this (indicating). So it has to be more. So this blue circle represents where I would think the Cliff's Mine is in terms of rock quality. And the Athens Mine is obviously way off the other end of the scale.

So summarizing everything pulling everything onto one diagram, this is where the cave mines occur. This is where the Cliff's Mine occurs and also where the Golder data would be for Eagle. This was the range from Table 6. This is Dr. Vitton's RMR 45, 51 and 70 for the permitted single stope. And all of this is on the stable side of the line suggesting very strongly that the Athens Mine situation is not comparative to Eagle. And this is testimony from Dr. Wilson Blake's report, and I agree. His last sentence of the first part which is section 2.3, "While there may be some similarities between Eagle Mine and Athens Mine, there are also substantial differences." And the substantial differences are explained in the second paragraph. "The soft iron ore body is the key issue." And the last sentence of this second paragraph is absolutely correct. "The cave did not occur soon after mining but took from 14 years to reach surface. It was intentionally caved using top sliced caving. The proposed sub-level long hole mining at Eagle at not a caving method." The mining methods are totally different. So the controlling mining conditions are totally different. The ore geometry and structure and competence particularly. The mining method itself is totally different, open stope very cave mining. The mined rock geology is totally different. We have soft haematite versus competent peridotite hard rocks. And so conclusion is that making direct comparisons is grossly misleading.

Q You also prepared a summary slide of your various conclusions on the various issues you discussed today?

A And that -- yes, it's on one page which I can recall if you like.

Q No. I think that's fine.

MR. LEWIS: I think we'll offer these slides again as a demonstrative for the court's use if it would help. We've marked it as Intervenor 624, your Honor.

MR. HAYNES: And I have the same objection that we noted before to the lateness of the hour in producing this -- these materials could have been produced earlier and not produced earlier, so we're prejudiced in that regard.

JUDGE PATTERSON: Well, for the same reasons that I admitted the report -- and frankly I don't remember what the number of that was -- I will admit these demonstrative exhibits, which follow the report, I assume, since I haven't read the report yet.

(Intervenor's Exhibit 624 received)

MR. LEWIS: That concludes my direct, your Honor.

JUDGE PATTERSON: Okay.

MR. HAYNES: I'm waiting for me Reichel's reservation.

MR. REICHEL: Maybe I should surprise you, Jeff. I have no questions at this time but I reserve the right to ask Dr. Carter some questions based upon the cross-examination.

JUDGE PATTERSON: Okay.

MR. RICHEY: Your Honor, could we take a short break to consult my notes?

JUDGE PATTERSON: Sure; yeah. I was going to ask you if you wanted one.

(Off the record)

MR. HAYNES: We're ready, your Honor. Dr. Carter, good afternoon. My name is Jeff Haynes; I represent the National Wildlife Federation and the Yellow Dog Watershed Preserve.

CROSS-EXAMINATION

BY MR. HAYNES:

Q Dr. Carter, in going through your résumé it appears -- and correct me if I'm wrong -- it appears that you've not studied any mines in the Upper Peninsula of Michigan; is that right?

A That's correct.

Q Have you been to the proposed Eagle site?
A Yes.
Q How many times?
A Only once.
Q When?
A Within the time since they started the proceedings for this.
Q Within in the last month?
A Yes.
Q And who took you there?
A Mr. Ware.
Q Mr. Ware? And what did you see when you were there?
A I went to the site and I looked around the area of the Eagle outcrop and I walked up and down the area where the Salmon Trout River is and I went and visited the drill site locations for the majority of the crown pillar holes.
Q When you say "the majority of the crown pillar holes," how many holes approximately did you visit?
A Well, the road access for the main set of holes has now been rehabilitated and so it's back to a marsh and so it's not possible to walk around that road, so one can't access it today to look at the actual color locations.
Q I'm sorry. I'm having trouble hearing you, Dr. Carter. You'll have to speak up just a bit.
A Okay. Parts of the access drill roads that were used for the previous drilling have been rehabilitated and turned

back to natural vegetation, and so some of those areas are not accessible anymore.
Q So approximately how many drill holes did you visit, give or take?
A The sites of the main drilling areas.
Q When you were in Marquette County did you visit the coreshed in Negaunee?
A I did.
Q And what did you observe there?
A I asked to see and was shown examples in all of the various rock type units. I went through and verified some of the core that had been particularly picked out as examples for fractured zones from a variety of holes and I went right through the entire core of 62 top to bottom and I looked at some other representation cores that were picked out for me by Mr. Ware and his staff as representative.
Q I see. And for the hole 62 the slide show that you put together for your testimony today as I recall contained some photos of core 62, did it not?
A Yes. They were just obliques.
Q And those are photos that --
A From the -- from that visit.
Q From that visit within the past month?
A Yes.
Q You understand, Dr. Carter, that neither Mr. Parker, Dr.

Vitton, or Dr. Bjornerud have had a chance to go visit the coreshed?
A I understand.
Q And you understand therefore that their analysis under the circumstances of this proceeding has been limited much more so than your ability to analyze the rock mass; correct?
A Yes.
Q So your testimony is really -- strike that. Dr. Carter, you haven't been underground in any mines in Michigan, have you?
A As far as I'm aware there are no underground mines in Michigan.
Q I see. So your answer is no, you haven't been?
A I don't think anybody has except if you were around in the 1950's and '60's.
Q Okay. I just want a simple answer to a very simple question. You haven't been in any underground mines in Michigan?
A No, because there aren't any.
Q I'm sorry?
A No, I have not.
Q Thank you. Now, if we could turn to Kennecott Exhibit 624, which is your slide show, I'd like to go first to page 22. Good. And, Dr. Carter, you'll have to bear with me. We're using two different projectors so at some point we're going to have to switch and do that technological stuff, so just

bear with us on that.
A No problem.
Q I appreciate that. Page 22, Dr. Carter, is your -- you've plotted the various case histories that Dr. Vitton spoke of -- correct? -- on this slide?
A Correct.
Q And if we can look at -- I just want to make sure that I understand this for the record. By the way, what's on the screen doesn't match my --
A It's done in sequence so they'll pop up if --
Q Could we pop all of those up on the -- on this PowerPoint testimony that we have here?
A I think there should be one more there. That's it.
Q All right. Looking at this page 22 of Exhibit 624, Dr. Carter, we have the RMR line of 30; it's a vertical green line. Do you see that?
A Correct.
Q And that's from Dr. Vitton; correct?
A No, the triangles are Vitton's plot; I've just extended the line down the page.
Q Ah, right. Okay. And then the red horizontal lines on this chart represent -- the top red line represents the fully unsupported crown pillar; is that right? Or is that the second red line?
A Well, the two cases there, the one which is marked with a

scale span of 9.77 in yellow is the crown pillar for the 57.5-meter thickness, and the one marked with 7.92, case two, on the left-hand side is for the same condition for an 87.5-meter.
Q All right. So on this chart the top red line is the 57.5-meter crown pillar; correct?
A Correct; yup.
Q And the next red line down is the 87.5-meter crown pillar?
A Correct.
Q All right. And then the third red line from the top, second from the bottom is the 15-by-15 meter stope; is that correct?
A Correct.
Q And the fourth red line; that is, the bottom red line is the 10-by-50 meter stope?
A Yes; the permitted one.
Q All right. So when you say the "permitted one," that is -- it's a single stope, not the entire crown pillar?
A It's a single stope as per the permit.
Q But not the entire crown pillar?
A Not the entire crown pillar. The entire crown pillar are the top two lines as you point out.
Q Right. So it appears -- and correct me if I'm wrong -- that for the single stope, 10 meter by 50 meter, with an RMR of 30 that's barely on the stable line; correct? It barely

intersects the stable line; pretty exact?
A Correct. I think it was a factor of safety of 1.30-something.
Q Yeah, 1.0. So generally, Dr. Carter, from this chart the lower the RMR generally the less stable the crown pillar -- the crown pillar would be. Is that a fair statement?
A That is a fair assessment, yes.
Q Okay. Let's go to page 28. It's not marked as page 28, but it's I think the 28th slide.
A Yeah, I've got it.
Q The next one. There we go. Dr. Carter, I'm looking at the mine -- at the orebody figure here, which has the west semi-massive sulfide unit. Do you see that?
A Yes.
Q That's in the purple; correct?
A Uh-huh (affirmative).
Q "Yes" or "no."
A Yes.
Q And the massive sulfide is in red?
A Yes.
Q And then the brown on the top is the -- is that the sedimentary rock?
A No, the brown on the top I believe is the crown pillar and overlaid just a shade in terms of color. I think there's a segment that was shaded in this model just to illustrate

that.

Q Okay. So the crown pillar includes not only the semi-massive sulfide and a little bit of massive sulfide, but also the bedrock over the ore; correct?

A Yes; yes.

Q All right. And then there's a figure here called the east semi-massive sulfide unit. Do you see that?

A Correct.

Q That figure -- let me back up. As I understand Mr. Ware's testimony the geometry of the orebody is -- has been determined by the various boreholes that have been drilled; correct?

A Yes.

Q 109 at least through 2006; correct?

A As I understand it, yes.

Q Correct. I mean, that's -- in attachment 7 to the responses, the Golder report of July 7, 2006, that report dealt with 109 boreholes; correct? "Yes"?

A Yes. And that's --

Q And there have been some drilled since then; correct? But let's put those --

A Yes, which are not in this.

Q -- to the side. I'm sorry?

A Which are not in the stuff that I've reviewed subsequent.

Q Right. Okay. And so the -- this figure called the "East

Semi-Massive Sulfide Unit" -- right here?
A Yes.
Q That geometry would have been figured from those 109 boreholes; correct?
A As far as I'm aware. Perhaps I can refer you to slide 35.
Q Okay. Let's go to slide 35. Actually, I was going to get to that in the report, but -- in your April 2008 report, but let's go there now.
A The image at the bottom comes directly out of the C-2 report.
Q The image that's the graphic image?
A The graphic image.
Q Or the three-D --
A No, the graphic image comes directly from that report.
Q I'm sorry. I'm getting confused now. The graphic image; is this on the right-hand side of the slide or in the middle?
A Let me point it out. This graphic image here is the Map3D, three-dimensional representation of the orebody outline that was considered in Mr. Beauchamp's original report. And that little bit sticking out there (indicating) on the east side --
Q You mean part 3?
A Yes, the segment 3 corresponds to the segment sticking out here in the east-west section also in segment 3, which corresponds to that zone and as defined in the earlier work.

Q I see. So in a very rough way, if we describe the orebody as a boot, the toe out here, which is the east semi-massive sulfide unit you're saying is the section 3 on the graphic image?
A Correct.
Q The dimensions don't seem to add up, Dr. Carter.
A As far as I am aware, when you lay these things together and you look -- this is an oblique section. It's an isometric. But when you look at it in this shape and compare, this is the absolute east-west section, which is on the stripe and you compare to the absolute east-west section on the stripe it matches very closely. This is the mining block; this is actually the geological model, so things will differ slightly. But that (indicating) matches that, and this matches this. And so the outlines are basically the same as in the C-2 report, which takes us back to 2005.
(Pause in dialogue)
Q Okay. Dr. Carter, I'm sorry. We're going to have to leave this and come back to it. I want to -- I can do this with one of the other exhibits, so let me just leave this line of questioning and we'll come back to it. All right?
A Okay.
Q Because I want to stay on the -- on your PowerPoint slide show that we heard earlier. Could we on the Kennecott Exhibit 624 please go to page 61? Dr. Carter, on page 61 we

have the photos that Jack Parker testified about -- and you did as well -- concerning the Athens Mine, the lake over the Athens Mine structures; correct?
A Yes.
Q And then we have on the next slide, page 62 -- did you take this picture?
A I did.
Q And when did you take this?
A Last week.
Q Last week? And you said that this body of water that's represented in this picture is the portion of the Athens Mine that we --
A If you go back to the previous slide --
Q Right.
A -- I was standing on this little access road that runs down from here looking down into that.
Q I see. So go back to 62. Can you describe the width of that surface body?
A You can't see it all, because there's a fence and I'm standing behind the fence with the camera as high as possible. It actually comes in a fair bit underneath you. So it's not clear exactly the total geometry from that. It's easier if you want to get the total geometry to use the vertical Google images, Google Earth images.
Q On the previous slide?

A Yes.
Q Okay. And you said that you were on the access road that appears to be on the south side of the lake?
A Yes.
Q And then in this picture, Dr. Carter -- if you could look at the picture that's up there now where the corner is; what's that behind there? Is that a road or some other feature?
A I think that's an -- the road near the sign, which is a lower elevation.
Q I see. All right.
A I visited a group of the mines. I went to the head frames and whatever existed of all of the ones that we marked.
(Pause in dialogue)
Q Dr. Carter, you'll have to bear with us. We all have different numbering systems here. It's been a hazard throughout this entire proceeding.
(Pause in dialogue)
Q Dr. Carter, do you have with you Appendix C-2?
A Yes, I do.
Q All right. I'd like you to turn to Figure 30.
A Yup.
Q Figure 30's on the screen, is it not?
A Uh-huh (affirmative).
Q "Yes"?
A Yes.

Q Now, on Figure 30 -- this is the proposed mining sequence; correct? It shows the stopes and the tunnels that are going to be used for the stope mining; correct?
A Correct. And that is a parallel to the one that we were just looking at, which is Figure 31.
Q Right. And I'm going to get to that in a minute. If we -- on Figure 30 this is, by the way, looking south, so east is to the left; correct?
A Yes; that would be right. Yes, I think so.
Q All right. And on this we have -- on the left-hand side of the figure do you see the portion that says "massive sulfide"?
A Uh-huh (affirmative).
Q "Yes"?
A Yes.
Q Dr. Carter, I keep correcting you because for the court reporter's benefit and for us reading the transcript later you have to say "yes" or "no" rather than "uh-huh" or "unh-unh."
A Okay.
Q So we have our own little language in the courtroom. All right?
A Yes.
Q Thank you. And then below the massive sulfide on the top of the east bearing unit we have another portion of the massive

sulfide that seems to strike east as well; is that correct?
A It would appear so, yes.
Q All right. And so it appears on Figure 30 anyway that the furthest east that the mining will go is to the tip of that lower protrusion or intrusion of massive sulfide. Would you agree with me? Within one stope or so.
A That would apparently be the case, yes, according to this diagram.
Q All right. Let's go to Figure 31, the next page. Dr. Carter, Figure 31, as you said just now, is the graphic -- the 3-D representation of the area to be mined; correct?
A Correct.
Q And I think you said that Figure 31 is the 3-D representation of what appears in Figure 30; correct?
A I believe so.
Q All right. And this figure is looking -- what? -- about southeast -- correct? -- northwest to southeast?
A It looks like that. There's a north arrow marked on it. This is exactly the same geometry as we were looking at in two slides earlier
Q Fine. And so on the east strike of the orebody -- which is to the left of this figure; correct?
A Yes.
Q -- that would represent the area on Figure 30 where the massive sulfide -- that massive sulfide intrusion stops

going eastward; correct?
A Apparently so, yes.
Q Okay.
(Pause in dialogue)
Q Now, Dr. Carter, I've put up Figure 1 from your April 2008 report in Kennecott Exhibit 592; correct?
A (No verbal response)
Q And this is the same figure that we -- that you had in your PowerPoint slide; correct?
A Correct.
Q And correct me if I'm wrong, Dr. Carter, but remember the massive sulfide intrusions that I pointed out in the C-2 append -- C-2 figures? Those appear to be these red portions, don't they?
A Yes, they appear to be.
Q All right. And so if this figure is looking -- it seems to be looking north or northerly; correct?
A These two figures are normal and parallel with the strike direction of the ore zone.
Q All right. And the "strike direction" meaning the lengthwise portion of the ore; correct?
A Yes; yes.
Q So if the figure we're looking at now, which is on Figure 1 of Exhibit 592, shows the semi-massive sulfide going a good bit east from where -- the mine plan shows the end of the

mining, doesn't it?
A It does.
Q And that geometry of this -- of the toe of this boot, for lack of a better description -- that mining geometry was described in the 109 boreholes. That's what you testified, didn't you?
A No, I said that the geometry that I used for the modeling is the same as the geometry that was used for the Map3D modeling in terms of the geometry. I don't think that's been defined as part of -- in the permit application at this stage.
Q I didn't ask that question. The question is, how do -- how did you determine where this toe sits in space?
A As I said, we took the Map3D model and sliced the Map3D model to produce those sections.
Q All right. And then what data did you use to obtain the Map3D model?
A The data that was used by Mr. Beauchamp. This is all up to the date of the permit application.
Q I see. And the data that Mr. Beauchamp used was the 109 boreholes; correct?
A Correct.
Q So the 109 -- somewhere in those 109 boreholes is data that defines this toe of the boot of the semi-massive sulfide unit sticking out past the massive sulfide unit; correct?

A No, the geometry of the shape -- if we can pull back Figure 31 for a second.  The geometry of the shape that was modeled came from McIntosh Engineering and it's the geometry of the orebody excavation.  And for the analysis it really doesn't matter whether it's mineralized or not; it's the shape of the excavation that's the critical issue.

Q I understand all that, Dr. Carter.  My question is -- for the figure one in Exhibit 592 the question is, where did the toe come from?  And I think you testified it came from the 109 boreholes.

A No, I didn't.  I am stating that the geometry of the mine excavation that we modeled came from the arrangement of information provided within these three-dimensional models. The information for the geotechnical side came from the borehole data.  So the fracture information, the data on the spacing, that came from the 109 boreholes, but the geometry came from the Map3D model.

Q All right.   And you're saying the geometry in Figure 1 came from the Map3D model?

A No, no.  The geometry in Figure 1 is illustrative of just the ore zone extent and it just shows that what was modeled in the original isometric view from 2005 was appropriate.

Q Okay.  Perhaps I'm confused; that's a possibility here.  All I'm trying to figure out, Dr. Carter, is what information was used to develop Figure 1 in showing the toe on the boot.

Where did that -- where did that figure come from? Take us back from this figure to however you got to it.
A That figure was provided to me by Mr. Ware.
Q By Mr. Ware?
A Correct. As an illustration of the geometry of the intrusive rock package around the ore zone extent.
Q I see. So Mr. Ware developed this model?
A Correct.
Q And -- okay. He didn't -- you don't think he just made it up, do you? He had to derive that model from something.
A I cannot testify as to how exactly it was put together. It was provided to me as an illustration of the geometry of the ore zone in two directions to compare with the Map3D model to use to slice the east-west to north-south sections so that we could look at the stress dependent permeability issue.
Q Dr. Carter, I've gone back to Figure 31 of Appendix C-2. Do you see that?
A Yes.
Q The crown pillar analysis that you performed concerns the portion of rock over which stopes? Can you point that out on Figure 31?
A The crown pillar analysis for the discussions which have been continuing regarding the scale span assessments which are in the previous reports are looking at the crown above

here (indicating). This is the permitted 87-meter thick crown.

Q And when you say "here," just for the record on Figure 30 you're looking at from the right-hand side the three blue stopes and three red stopes; correct?

A That is correct.

Q Well, going eastward from there we have what appear to be four or four and a half more stopes; correct?

A Correct.

Q So those are going to be mined out; correct?

A Yes.

Q Just like the rest of the stopes?

A Yes.

Q So that there would be under those stopes -- excuse me -- over those stopes that are mined out there will be a rock mass; correct?

A That is correct.

Q And for the rock mass over the stopes to the east of the first six stopes; that is, these last four and a half that I'm point out here?

A Yes.

Q There will be in essence a crown over those; correct?

A This is true.

Q You didn't model any -- you didn't do a C-pillar or a scale span model for those -- for that area, did you?

A The zone of influence of this area here was explicitly not looked at in C-pillar or in the scale span in Mr. Beauchamp's testimony and it wasn't looked at by me specifically. I was reviewing what we had gone through previously. The whole zone was modeled in Map3D and the inference of this deep section here (indicating) has an effect, as we talked about, on the permeability within this zone here, but it doesn't extend up into the top here. And I if you slice this off and look at the Map3D model from that perspective it shows that once you get to a significant depth beyond about a hundred meters this is not having any affect on this surface. That's what the Map3D model -- early Map3D modeling by Mr. Beauchamp shows.
Q You're saying that the mining of the stopes to the east has no effect on the surface?
A There is always some effect on the surface, but the effect is of major concern when the crown pillar is thinnest and the stoping is closest to surface, which is what was discussed.
Q So you're not saying that -- you're not saying to us today even for the crown over the eastward stopes that there is -- that you're a hundred percent sure there's no effect on the surface from that mine? You're not saying that, are you?
A There will always be an effect, but it is inconsequential.
Q For what length of time?

A The length of time is an impossible number to actually define precisely.
Q Well, can you give us an estimate in decades or centuries?
A Not easily. The rock mass quality in these zones is sufficiently high that you're looking at a blocky rock mass. A blocky rock mass does not fail within hours.
Q Assuming that the RMR is high enough; correct?
A Yes.
Q And if the RMR's, however, drop then you could have failure within hours?
A Yes, provided you have a void space for it to fall into.
Q Right. But that's the worse-case scenario that you modeled, isn't it, a void space?
A Yes, no void space. I mean, a complete void space.
Q Right; yes. Right. Worst case is no void -- is a complete void space; correct? Best case is no void space?
A Yes.
Q And in conservative modeling you want to you use a worst-case scenario; correct?
A Yes.
Q So the modeling that you did, Dr. Carter, depends wholly on the values of the RMR's that were computed for the rock mass; correct?
A Which model?
Q Any of the models you've used.

A No. The modeling for the fracture data comes directly from the fracture information.
Q Ah, from the five holes; correct?
A From the crown pillar zone, yes.
Q But for the C-pillar and the scale span model those models depend on the quality of the RMR data; correct?
A That's correct.
(Pause in dialogue)
Q Dr. Carter, I'm back to your April report, Exhibit 592 and I'd like to explore a few things with you in that report if I may. We're looking at page three of that report, section -- do you have the report, Dr. Carter?
A Yeah, just give me a moment.
Q Sure.
MR. LEWIS: Page what, Mr. Haynes?
MR. HAYNES: Three.
Q Are you there, Dr. Carter?
A Yes.
Q In section 2.1.1 the first paragraph talks about the fracture frequency data for boreholes 47, 54, 73, 77 and 83. Do you see that?
A Correct.
Q So for this model you used the -- you used only five boreholes; correct?
A Those five boreholes were particularly picked because

they're the ones with hydraulic conductivity data, so we need the match.
Q I see. So none of the other boreholes that you know of have hydraulic conductivity data?
A This was my information from Kennecott and from Golder.
Q And who in Golder?
A John Wozniewicz.
Q Okay. So you did your modeling based upon the data that they gave you for the five boreholes; correct?
A Correct. There is fracture frequency data for all of the holes; I should just add.
Q I'm sorry. I didn't hear you.
A I said there is fracture frequency data.
Q But not hydraulic conductivity data?
A So that was the reason. There was packer testing and fluid logging within those holes.
Q And as far as you know there was no packer testing or fluid logging within any of the other holes -- 109 boreholes?
A I think you should ask that question to Mr. Wozniewicz, because it's not my understanding of all the details of the testing.
Q That's fine. We'll take that up with him.
(Pause in dialogue)
Q Dr. Carter, in your April 2008 report on page ten in section 2.2 you talk about the inferred stress site; correct?

A Correct.
Q And you refer to the reports by Hamson -- or Haimson in 1978 and Zoback and Zoback in 1980; correct?
A Correct.
Q The Haimson report which you attached to your report describes hydrofraccing in a deep borehole, does it not?
A It does.
Q And do you recall which county that -- which county in Michigan that occurred in?
A No, I don't recall.
Q You don't. If we turn to --
(Pause in dialogue)
Q Sorry, Dr. Carter. We're just -- we're trying to cycle through this. Do you have that report?
A I do.
Q All right. Let's look at the first page of the Haimson report.
MR. HAYNES: Just for the record this is KEMC 252416. It's page 5857 of the Journal of Geophysical Research, first page of the Haimson report.
Q In the abstract the first paragraph on the left, the asterisk says, "We conducted four successful hydrofracturing tests in a 53 -- 5,325-meter deep well in Gratiot County near the center of the Michigan basin." Do you see that?
A Yes.

Q Do you know where Gratiot County is?
A Not precisely, but the -- on Figure 5 all of the tests are plotted, so you can perhaps point out exactly where that is.
Q The trouble is, Dr. Carter, I don't have a Figure 5 in my version right now.
A Ah.
Q That's one of the things I complained about earlier if you remember.
A Yes, I do. Well, as far as I can see it's up towards the range where we are.
Q Gratiot County?
A Uh-huh (affirmative).
Q It's in the Lower Peninsula, isn't it?
A I don't know which one it is. Six -- yeah, maybe it's -- yes, it is. Okay. Lower Peninsula.
Q It's about in the center of the Lower Peninsula, isn't it?
A Yes, it looks like it.
Q All right. Not in the Upper Peninsula of Michigan?
A Correct.
Q All right. Dr. Carter, on page 19 of your report looking at section 5.2, that Fracture Aperture Hydraulic Conductivity Relationships?
A Yes.
Q Do you see that?
A Yes.

Q Now, when we're talking about hydraulic conductivity, Dr. Carter, usually the hydraulic conductivity is expressed in units of ten to the minus X meters per second or centimeters per second. Is that a fair generalization?
A That's correct.
Q All right. And if we have a hydraulic conductivity of ten to the minus four meters per second, what kind of soil or substrate would that be in, if you know?
A Ten to the minus four meters a second?
Q Yes. Let's just start there.
A Well, there's no data of that within this page.
Q Well, I understand that. I'm just trying to get a general understanding of the -- of how we deal with these vary small numbers and what kind strata they're going through.
A Okay. Ten to the minus four I think in centimeters a second, because that's what grouters use.
Q Let's use your method; that's fine with me.
A So ten to the minus four meters per second.
Q Well, centimeters. Let's start -- let's just start with centimeters.
A Okay. Well, ten --
Q Are you comfortable with that?
A Yes. It's easier for me.
Q That's fine.
A Ten to the minus four centimeters per second would be a fine

sand or a fairly fractured rock mass.
Q Fractured rock. And what would ten to the minus five centimeters per second be in?
A That would be a tighter rock mass and that's about the limit of cement grout.
Q Okay. What about ten to the minus six centimeters per second?
A That would be tighter rock mass than we can normally grout in a -- and we wouldn't even bother to grout in most civil engineering operations, because the water inflows are so low usually from the ten to the minus six.
Q All right. And ten to the minus seven centimeters per -- wait. Let me top there. Is ten to the minus six centimeters per second equivalent to ten to the minus eight meters per second?
A It is.
Q Looking at page 19 of your report in section 5.2, first bullet you estimate -- well, you give a figure for hydraulic conductivity of two times ten to the minus six centimeters per second; correct?
A That's correct. And that number I was given by Mr. Wozniewicz as their characterization number.
Q Okay. In your report, the April report that we're dealing with here, Dr. Carter, was the rock mass data that you used for this report the same as the rock mass data used in

Appendices C-2 and C-3; i.e., the 109 boreholes?

A I have not used specifically the rock mass data in this report. I've made assumptions of fracture intensity based on fracture data.

Q From the five boreholes; correct?

A Correct.

Q And you didn't use the fracture data from any of the boreholes; correct?

A I was -- I had discussions with my colleagues, Mr. Wozniewicz, and this was the data that was most representative of the information where there was pattern testing. So in order to address the question of fracture dependent permeability, this was the most appropriate place to start from.

Q Dr. Carter, in the RMR system, the A-3 parameter deals with fracture spacing, doesn't it?

A Correct.

Q And how, to your knowledge, was that parameter determined for the Eagle Mine core information?

A That was logged, as I understand it, by Mr. Ware. And I believe that Mr. Beauchamp and Mr. Ware testified as to the information that was derived. As I understand it from speaking with Mr. Ware, the core logging folk that were working on the core measured that parameter under his direction.

Q Okay. And for the A-4 parameter, your report I believe says that the A-4 parameter was calculated based upon joint filling, joint alteration and joint roughness. Do you recall that?
A And the key factor for this report is the joint roughness.
Q I see.
A And that again I think is something that can only really be done from core so you can determine the actual aperture and shape.
Q So for the A-4 parameter of the RMR, you really have to look at the cores to have the best information to determine --
A That's correct.
Q -- the A-4 parameter; correct?
A Yes.
Q Something that our experts have not been able to do, as you understand; correct?
A That is correct. And as I pointed out, I --
Q Wait; wait; wait.
A Sorry.
Q Wait for a question. Thank you. Dr. Carter, you spoke in your testimony earlier about the two methods that you used for the effective stress changes on hydraulic conductivity method one and method two. Do you remember that?
A Correct.
Q For method two, you used a model from Bai & Elsworth 1994;

is that right?
A That is correct.
Q Are you aware that that model is based on underground longwall mining operations?
A No. The model is not based entirely on that. It's based on an evaluation of the geometry of fractures and the strain that might develop on them. That's the hydraulic conductivity model. They did actually test it by using analysis and looking at various other environments.
Q In longwall mining operations?
A Yes, but it doesn't matter. The equations are ubiquitous.
Q All right. Do you understand that in that model that the rock stiffness values had to be lower in order for the model to match the field data?
A I believe that this is one of the issues. And it says in the report there are issues with the uncertainty of parameters accepted. And it's well recognized in this area.
Q Dr. Carter, I want to go back for just a moment to the stress question where you deal with a Haimson report and the data from the World Stress map. You're aware, aren't you, that -- well, you know who Jack Parker is, don't you?
A Yes.
Q Have you met him?
A No, but I've reviewed his reports at various stages.
Q All right. So you're aware of his report on measurement of

stress fields in the White Pine Mine?
A Yes.
Q And you're aware that those stress -- the White Pine Mine is about 100 miles west of the proposed Eagle Mine?
A Yes.
Q And so those stress measurements that were taken there would be somewhat closer than the hydrofraccing stress measurements done in Gratiot County in the Lower Peninsula?
A There's a lot of debate about the stress measurements that were done at the White Pine Mine; that they were too close to the excavations and, therefore, their mining-induced stress effects have changed the stress orientations. So that's why --
Q But you're aware --
A -- they haven't used those data in the --
Q You're aware that the White Pine Mine is both spatially and geologically a lot closer than anything in Gratiot County?
A I understood.
Q "Yes"?
A Yes.
Q Okay. Dr. Carter, your first real involvement in preparing a report for this proposal was the July 7th, 2006, memorandum, wasn't it?
A In terms of actually writing anything that was then forwarded to Kennecott, yes.

Q Right. I mean, you testified that you consulted with the other Golder folks on the earlier Appendices C-2 and C-3, but you didn't really have a hand in writing those; correct?
A Correct.
Q Dr. Carter, do you have that in front of you?
A The July 7th?
Q Yes.
A Yes.
Q If you could turn to page four, please?
A This is the one entitled Clarification Discussion? Because there are two on the same date.
Q Oh, no; no; no. I'm sorry. This is the geotechnical memorandum dated July 7th.
A Yes. There are two of them. One's called Clarification Discussion.
Q Yes, that's it.
A All right.
Q Page four.
A Yes.
Q In the section called Crown Pillar Characterization, first paragraph second sentence says,

"Based on this model, Kennecott determined that the crown pillar consists mainly of peridotite in the upper portions and a combination of PER for peridotite and massive sulfide and semi massive sulfide at lower

elevations."
Do you see that?
A Yes, I do.
Q The crown pillar is also made up of sedimentary rock, is it not?
A Let us check the figures for the lithology plans. I don't have an overlay. Perhaps you have one.
Q Oh, well, I'm just asking from your knowledge of the lithology of the area, the crown pillar includes sedimentary rock, doesn't it?
A Only at the contact margins.
Q Well, that is from the top of the bedrock to the surface of the rock; correct?
A Figures A-1 and A-2 in the April 2000 report apparently is where we should --
Q I'm sorry. Dr. Carter, I didn't hear you.
A I said it refers to Figures A-1 and A-2 of the 2000 report for the geometry, which I'm looking for.
Q Okay.
A And perhaps we can bring that up on the screen.
Q You're looking at what we've been referring to as Appendix C-2; is that right?
A Yes. It's Appendix C-2.
Q The geotechnical study?
A This is the geotechnical study.

Q And you're looking at Figure A-1?
A A-2 is a plan. And my understanding is that the orebody sits right over -- I mean, the crown pillar sits within that orebody block.
Q Right.
A That is my understanding from Mr. Ware.
Q I see. So would you disagree with a statement that the crown pillar includes the sedimentary rock over the orebody?
A As far as I am aware, I don't know. Because that information of the exact geometry is provided by Mr. Ware. And I am not exactly certain of his extent of the mining block with respect to the orebody outline.
Q All right. So would it be accurate to say that you're analysis in the July 7, 2006, memorandum does not take into account sediments that sit as part of the crown pillar?
A The analysis that was done in the July 7th memo takes into account everything that was in the crown pillar zone as defined by Mr. Beauchamp yesterday, which would include sedimentary rock, because it included a 30 meter zone around the crown pillar. But I can't on a piece of paper define the crown pillar geometry, because that's not shown on this. But it certainly would have included sedimentary rock.
Q All right. Dr. Carter, on page five of this report in the section called Potential Geologic Structure in the Crown Pillar, do you see that? I'm sorry. I'm going back to the

July 7, 2006, report.
A No. Right. Okay. And I'm just trying to find it again. As I saw you flipping through there, I think the table above lists all the rock types which are in the crown pillar; feldspathic peridotite, peridotite, semi massive sulfides, siltstone and sandstone and hornfels.
Q And this table, by the way, deals with discontinuity sets; correct?
A Well, I was actually quoting from the table that's on page five, and it does major and minor discontinuity sets. But it does encompass that complete range of sedimentary and intrusives.
Q Right. All right. On page five in the section called Potential Geologic Structure in the Crown Pillar, did your modeling include the major structures that were identified in the Kennecott boreholes?
A Yes, they -- it did, but not explicitly. The arrangement of this analysis was to look at the influence of stress change on permeability of fractures.
Q In the July 7 report?
A Oh, no. The July 7th report looks at what was in Mr. Beauchamp's. I thought you were referring to the --
Q No; no. I'm sticking with the July 7 report now.
A Okay.
Q So the modeling that you performed for the July 7 report,

did it or did it not include the major structures identified in the Golder database?
A The probabilistic assessment --
Q Yes.
A -- included everything.
Q Dr. Carter, turning to page six in this report, in the second paragraph right above the heading called Kennecott Mine Structure, in the middle of the paragraph there's a sentence that reads,

"As described in phase two study, discrete geologic structure may be present in the crown pillar which could have an affect on the behavior of the crown. Enough information exists to target the potential areas where these features may occur."

Do you see that?
A Yes.
Q What geologic structure are you talking about there?
A From the core holes certain areas, as I showed this morning, for example, on hole 55 were identified with structures in them. These were flagged because of zones of low RQD and other features. This then becomes a target for future investigation and for evaluation.
Q And future investigation when? After mining begins?
A This would be investigation, as Mr. Beauchamp explained yesterday, then starting even from the development drifts as

part of the phase three assessment.
Q All right. But that investigation, to your understanding, Dr. Carter, could occur now, could it not, for purposes of determining the kinds of structures that appear in hole 55?
A Detailed investigation of those zones is easier done from underground, because you have better access.
Q All right. But it's not impossible to do, is it?
A It wouldn't normally be done at any state of an early permitting process, because this is data that is flagged for further investigation.
Q That wasn't my question, Dr. Carter. My question was, it wouldn't be impossible to gather that data now, would it be?
A It would not be impossible.
Q It just happens not to be the practice, as you understand it; correct?
A I would say it's not standard practice to go that far.
Q Not industry practice?
A Correct.
Q Dr. Carter, I'm showing you what has been identified earlier in this proceeding as Petitioner's Exhibit 50, which is a paper that you co-wrote, I assume, with Miller, --
A Correct.
Q -- entitled Crown Pillar Risk Assessment Planning Aid for Cost-Effective Mine Closure Remediation?
A Correct.

Q You probably recall this paper, but let me pull up a specific page for you. If we can go to the third page, please? I'm on the third page of the report, Dr. Carter, left-hand column in the discussion called Crown Pillar Characterization. Are you there?
A Yes.
Q In the second paragraph about in the middle of the paragraph there's a sentence that starts, "There is seldom if ever."
A Yes.
Q Let me read that into the record, and I want to ask you a couple questions about it. The sentence says,

> "There is seldom if ever sufficient relevant information to define completely the spatial variation of rock quality across a given crown in a fully quantitative manner."

"Quantitative manner," do you see that?
A Yes.
Q Have I read it correctly?
A Yes.
Q

> "Furthermore, most crown pillars are characterized by different zones of competent rock usually in margins to the ore and weak faulted ground often the ore zone" -- "often the ore zone. In recognition of this, the approach that is developed in the present contribution is based on treating the quality of the

weakest zone of rock in a particular crown pillar as a random variable in evaluating the likelihood probability that this zone of the crown is sufficiently poor or extensive to result in a collapse."

Did I read that correctly?

A Yes.

Q Given your advice in this paper, Dr. Carter, was this type of analysis performed in your Eagle crown pillar stability analysis?

A In essence, the probabilistic runs, which are presented in this July memo, do that.

Q They use the weakest zone?

A They use a complete range.

Q Complete range?

A From the absolute data.

Q I'm sorry. From the --

A The real data that was available in the database. In fact, if you look at figure seven of this paper, which is on a few pages further on -- okay -- that's reminiscent of the plots that I put up this morning.

Q Right. I see that, Dr. Carter. And what was the weakest zone of block that you considered in your analysis for the Eagle crown pillar?

A Well, typically things like some of the zones in core 62. So those are included. So in the histograms, for example,

on the one you have, you have some zones of zero to 10 percent RQD.
Q And those are modeled in your modeling?
A They're modeled in the probabilistic model.
Q Okay. Using the database that we haven't had access to; correct?
A Uh-huh (affirmative).
Q "Yes"?
A Yes.
Q Dr. Carter, you testified earlier in direct examination that in hard rock mining one doesn't normally see subsidence until the crown pillar collapses. Do you recall that testimony?
A It goes back to my analogy between the graph that I showed of longevity. If you remember, there's a histogram graph. And let me just point it out in the slide show just so that we're talking about the same thing. This is the graph on page 88 of the slide show.
Q And that is that for crown pillar collapses in hard rock mines you don't see subsidence; you just have a collapse; correct?
A Yes. But I'm going to come to this to show you that basically the good quality rock bad design encompasses that issue.
Q Right. And so if one were to try to monitor any subsidence

in a hard rock mine from the surface, that monitoring would really be superfluous, wouldn't it, because it's not going to measure anything until there's a collapse; right?
A No. The strains are very low compared with coal mine conditions. So if one wished to monitor, one could put extensometers in. There are measures that can be taken to measure very small movements. And that's the sort of monitoring which one would do if you were looking at trying to pick up any differential movements.
Q Now, Dr. Carter, I may have covered this before, but let me just circle back. Your modeling doesn't show, does it, that crown pillar will be 100 percent sure not to collapse?
A 100 percent surety is never used by anybody in rock mechanics because there is always the 1 percent, as there always is in weather forecasting.
Q So to answer my question, the answer to my question is, no, you're not 100 percent sure that there will be no crown pillar failure?
A I cannot state 100 percent certain but I can state that I'm 99.5 percent certain.
Q Dr. Carter, you testified about various criticisms by Dr. Sainsbury of the rock mechanics work in this project; correct? You read Dr. Sainsbury's report, didn't you?
A I did.
Q And you're aware, aren't you, that as late as November 2006

Dr. Sainsbury still maintained that the rock mechanics work for this project were indefensible? You're aware of that, aren't you?
A Yes. And --
Q That's fine. I just wanted to find out and make sure you were aware of that. Now, you testified on direct examination that in your view mining is safe today?
A Mining today is a lot safer than it was in the 1930's.
Q Oh, I see.
A And as an industry, the safety record of mining is far above most industrial safety records.
Q So when you said mining is safe, that's a relative term, not an absolute term?
A As is everything. When you cross the road, your chances are much more likely of --
Q Oh, perhaps I misunderstood you. When you said mining is safe, I thought you meant there have never been any fatalities in the recent history of mining.
A No. It's like any other industry. Accidents do happen.

MR. HAYNES: Thank you, Dr. Carter. I have no further questions at this time.

MR. WALLACE: I have a few questions, Dr. Carter. My name is Bruce Wallace. I represent Huron Mountain Club.

CROSS-EXAMINATION

BY MR. WALLACE:

Q You mentioned this morning I think you described them as tunnel boring machines; is that correct?
A Yes.
Q And you said they're sort of the newest thing in the mining industry, words to that effect?
A Yes.  Let me explain a little bit.  The tunnel boring machines are designed for long linear production operations; for example, the Channel tunnel, tunnels that go underneath the Alps, something that's going 20 or 30 kilometers from A to B.  So in the mining industry, in normal production operations, one doesn't use a tunnel boring machine.  The -- my role for the Cadelco operations is looking at very long tunnels to transfer material from the mine to the mill.  So the tunnel boring machines becomes a viable approach to use for those situations.
Q Are mining machines increasingly used in the industry?
A Yes.
Q And are you familiar with what I think are called continuous miners?  Is that a --
A Yes.  The continuous miners are focused on soft ground.  So your potash and your coals and that sort of operation where you are basically sharing the soft ground to allow a longwall development.  And it's totally different again from hard rock mining of this type that we're talking about.
Q Are you telling us that hard rock mining can't be done by

machine?
A No; no. Some machinery that's been developed in the platinum reefs in South Africa and in a variety of other locations I'm quite familiar with those.
Q Okay. And mining by machine allows you to eliminate drill and shoot operations; right?
A Yes, but it's a problem of flexibility for the mining opening geometry.
Q Okay. You know, I'm really just trying to east the answer to a few very specific questions.
A Yeah; yeah.
Q And to be clear about that, if you mine by machine, you don't have to use explosives; correct?
A Well, yes, if you can develop a machine that will work for that type of rock, which you can't in some cases.
Q Okay. Another question I have is you've testified about bolting, cables, screening and so forth as support mechanisms subsurface; is that right?
A Yes.
Q Do you know if any of those are prescribed or set forth in the mining application in this case?
A Not in detail I don't, but they are implicit in the recommendations for geotechnical development for every drift.
Q Well, are they explicit anywhere in the application that's

been filed here, if you know? If you don't know, that's fine.
A I don't know.
Q Okay. And are you familiar with --
A I don't remember seeing it in the conditions.
Q Excuse me?
A I didn't see it in conditions that I remember.
Q That was my next question. In the permit condition, you've reviewed the permit conditions?
A I have.
Q So any of these devices that may increase stability that you've testified about here, bolting, cables, cable bolting and so forth, as far as you know, they are not required for this mining operation; correct?
A They would be required, two criteria; one is normal operational development of those drifts and for the safety and security of the men working in them. The second would be that if it's in very good rock, the labor unions usually have through negotiations with over the years come to a standard patent which then gets put in. So many mines have agreed to standard patent which they put in uniformly. And that is unnecessary often in rock types that are very good, but it's put in anyway. It's an industry standard.
Q You know, this would be shorter if you just answered my question. I'm trying to make them specific.

A Okay.
Q I know there's some things you want to say. Your counsel can ask you if you have more to say.
A Oh, I was trying to explain why it's --
Q I didn't ask the why question. In any event, I asked this of Mr. Beauchamp yesterday. You too as many other witnesses have said that there are advantages to picking up the cores and studying them and so forth, and these were advantages that were not --
A Correct.
Q -- afforded to Drs. Bjornerud and Vitton. I will ask you this. Are you aware of any RMR calculations by Dr. Bjornerud or Vitton that they used that you take issue with, any specific calculations at all?
A I take issue with the A-4 parameter.
Q Are there any RMR numbers that they generated that you believe are wrong? And let me just put this in context. The only one I've heard specifically referred to at all about anyone was by you this morning in which case you said Dr. Bjornerud came out with a higher RMR number than you did; isn't that true?
A The issue I was trying to portray this morning is that the rock quality of the central zone of the crown pillar was not represented within the eight holes that were looked at. And the only one that went through the center of the crown

pillar was the 55.
Q That's a different issue. You have taken issue with generally the procedure used by Drs. Bjornerud and Vitton, and Mr. Beauchamp who works for you did the same thing. Your pointing to any numbers that they calculated wrong and that you've recalculated some other way?
A I would say the A-4 parameter is wrong. Therefore, the RMR is wrong.
Q Okay. Which ones and by how much?
A Every one of them.
Q And by how much?
A I couldn't say. Because if, for example, on the surface of a joint there was a clay infilling, the A-4 parameter would change dramatically. And you can't see that from a photograph.
Q Well, the only one we've talked about is where Dr. Bjornerud came out with a 75 and you had a 68. Now, are you saying that that was wrong? Hers was too high, too low?
A It doesn't matter, because the basis of logging from core photographs is not founded well.
Q And if we wanted to see your recalculations of their work, where would we look for those?
A I can't recalculate their work because I can't log from a photograph.
Q You can't and you haven't recalculated their work at all,

have you, sir?
A I have not.
Q Now, I thought I read in the original application or the appendices that Golder considered a factor of safety below two as unstable. Did I read that correctly, sir? Do you recall that?
A I would imagine so, yes.
Q Okay. And that remains the case?
A Yes.
Q Golder considers a factor of safety below two unstable?
A That is the zone in which we would put support in for sure.
Q And if Dr. Vitton's calculations, which you had up here this morning and could look at again, but his calculations came up with factors of safety below two for several different sets of assumptions, that would indicate instability in this proposed mine, would it not, sir?
A Provided you had a void space into which that instability could propagate.
Q Using his numbers, which nobody's recalculated that you know of --
A I did this morning.
Q Well, you didn't recalculate his RMR's. Using his RMR's, he came out with factors of safety below two for several different assumptions, did he not?
A He did. And as I pointed out this morning, several of those

were erroneous.
Q You know, maybe this has been gone over, but I thought you had an exhibit this morning in which you were looking at RMR numbers on collapsed mines; is that correct?
A Yes.
Q Okay. And my question is, were not those mines mines that collapsed before the RMR system was even developed?
A That is correct.
Q Okay. Then how did you get these RMR values on these mines?
A Okay. I did explain very briefly this morning that Professor Hoek and Professor Marinos have come up with a system called GSI which is qualitative and descriptive and allows you to essentially get the final RMR by observation and assessment.
Q By picking up cores and holding them and looking at them with a magnifying glass?
A Yes.
Q And this was not your work, but you believe somebody's done this work?
A I did some of that work.
Q Went into collapsed mines and took core samples?
A Absolutely.
Q And where could we read about that?
A Some of it's referenced in my papers. Some of it is confidential that was used in the investigation and the

legal proceedings around some of these collapses. So I have actually seen a lot of information on mine collapse features.
Q Did you actually tell us this morning, sir, that you and one other person had data on collapsed mines that nobody else in the world had? Was I understanding correctly?
A No. The only thing that we've retained is one piece of information. That one piece of information is the name and location of the mine.
Q Name and location of collapsed mines?
A All mines. Every single record in the crown pillar database, all of the data is there except the name and location. And that's replaced by a number.
Q And that crown pillar database includes mines that haven't collapsed but are on the upside failure side of your graph line; right?
A That's correct.
Q Okay. So these are mines that are predicted to fail but have not yet?
A That is also correct.
Q And you and whoever else who has this data are keeping the names and identifications of the mines that haven't collapsed yet but are in a failure mode and may collapse secret? Is that what we understand?
A It's not secret. They're available to high levels of

government. That was the original agreement.
Q Are they available to the public that live near these mines?
A They have been made available. And the public are aware of these mines, because we live in a mining community area.
Q Well, I thought you said just the contrary this morning, sir, they kept the names of these mines that were in a collapse or failure mode secret.
A No; no. The ones that have been kept completely off the record are the ones which have had legal proceedings and the ones which have collapsed previously.
Q So you don't keep the names and identifications of the mines and the failure modes secret? I thought you just said you did?
A Let me clarify. The name is replaced by a number. That -- if you as an individual who were concerned about that number and that mine and that location wished to know about that, you're free to ask. The information has been deliberately kept in a confidential numerical order to allow that data to be published. Because we could not get the data from all sorts of sources unless that was the agreement on which it was given.
Q Well, did you not say this morning, sir, that these identifications were being kept secret rather than air the dirty laundry of these mines?
A Correct.

Q Your basic theory of hydraulic conductivity in your article or report, as I understand, is that a higher horizontal to vertical stress ratio will compress crown pillar rock and make it less conductive? Do I get the gist of this?
A That's correct; yes; yes.
Q And you used assumptions from k ratios of .5 up to 3.0?
A Correct.
Q Okay. And the higher the ratio the less the conductivity; correct?
A That's correct. The more the clamping, yes.
Q The more the clamping. Did you in that article or have you elsewhere translated this concept into, you know, gallons per minute inflow predictions about crown pillars in mines?
A No. My task here was to advance the understanding of the change as far as the hydraulic conductivity change and to pass that information to Mr. Wozniewicz and his team to continue the evaluation. So you should ask them.
Q Yeah. I guess what I'm trying to find out is, how do we understand -- maybe we have to ask a different witness -- if this report is significant in any particular way for this mine and the conductivity of this mine in terms of gallons per minute inflow?
A You should ask Mr. Wozniewicz. And as far as the outcome, what it's basically saying is for the 90 meter crown pillar, 87 ½, this report suggests that the rock is actually

tighter, so the permeability goes down.
Q I got that it was tighter. I'm just trying to figure out if it's tighter in any -- this is rock; right? It's not a sponge that you're squeezing tight. I'm just wondering if it's significant in any way to the conductivity of this mine that it be mined out to a certain level.
A The change in hydraulic conductivity is in those slides and in the report. And it moves them by half an order of magnitude at least.
Q Okay. And the trend of this concept, if it moves, is that the higher the k ratio the better; correct?
A Yes.
Q Is there a limit to that? I mean, do you reach a point where the horizontal stress begins to affect you negatively?
A Absolutely.
Q Okay. And can you put a number on that? You took it up to three. Is there a number higher than that that the process begins to reverse itself?
A We looked -- the top of that range is based on the credible range in the in situ stress database of Zoback and Haimson's report. The comment I made earlier about the White Pine report of mining-induced stresses, that's when you start to get higher stresses.
Q And if those higher stresses are accurate, then the theory falls apart -- right? -- because --

A No. It depends -- and the stresses will be focused in certain areas. So if you're mining to a very shallow location, at that stage your stresses start to increase, at which point you could get shear within fractures, which could lead to dilation, which could lead to an increase --
Q Extreme conductivity, can we say?
A Right. But you're not into that range, as I --
Q Well, you're not -- excuse me. But you didn't get into that range, because you stopped at three. But I'm asking you, is there a number that gets us in that range?
A Well, if you had very high stresses that you could logistically say were real, it is possible. But this is not this case.
Q Well, tell us the number. When do we start getting dangerous?
A I have no idea. You're still well in the elastic range on this modeling within the crown pillar.
Q But this modeling was based on assumptions; right?
A And the assumptions are within a credible range. Moving outside that wouldn't be credible.
Q Well, Sainsbury pointed out regional horizontal stresses of ten, did he not?
A No. I think he's really talking about mining-induced changes again.
Q Well, that's what you're talking about in your report, are

you not?
A Well, that's exactly what we feel. And this is where dialogue perhaps of Mr. Sainsbury at an earlier stage might have saved a lot of confusion.
Q Did you ever think of calling him up on the phone and asking him why he used ten as the number in his report?
A We responded to those.
Q Huh?
A We responded to those issues when that came to the --
Q Okay. And not only did he use ten in his report, he also pointed out that Jack Parker, although not giving a specific number, was several times the 2.0 number that you originally used in the Golder Report; right?
A And again, we maintain and, if we did a model similar to the ones that have been done here of the White Pine Mine for that area where they did the stress measurement, we think those are mining-induced stresses.
Q Okay. But just for the sake of completeness, did you try running Sainsbury's number ten or try running Jack Parker's levels several times two, whatever that might be, six, eight?
A No, on the same basis that we didn't consider Athens Mine, because it wasn't relevant. And those sort of decisions were made at an early stage when Mr. Beauchamp was developing his reports.

Q Well, how do you say mining-induced stress levels are not relevant when that's the whole subject of your report?
A But that was modeled. The mining-induced stresses are modeled in the model. The in --
Q Excuse me. But the ten and the several times two were not modeled, they were determined, they were measured?
A Exactly. But they were determined in mines which had already done mining which induces a stress change.
Q Which is the subject of your report.
A And it's also the basis of Mr. Parker's paper, which is an excellent paper giving information about what we think of mining-induced stresses.
Q Okay. Mr. Parker, whom Mr. Blake testified remains an icon in your industry; right?
A As does Peele, who was on the bottom of --
Q And Mr. Parker, who's report is still the report on horizontal stresses not only in the Upper Peninsula but, according to Dr. Blake, every place; correct?
A I wouldn't say that. I think that the work that's being done by Haimson, Zoback and others has superceded that. A lot of the Parker work is quite old. The technology and the information base has gone a long way further since. So maybe at that time that terminology is correct.
Q Did you call up Dr. Blake and tell him you disagreed with him, too?

A I don't disagree with Dr. Blake.

MR. WALLACE: I have no further questions. Thank you.

MR. EGGAN: I have a question or two, if I may.

CROSS-EXAMINATION

BY MR. EGGAN:

Q Mining-induced stresses, the term that you've been using, what exactly are mining-induced stresses? Do they include blasting?

A No. If I go back to the model from Dr. Bjornerud when she produced a little arrangement of pencils with rubber bands around it, that stress that holds those pencils together is the in situ stress. When she removed the space underneath -- right? -- so that they could fall, if that didn't get removed, there would be no stress change in that top zone.

Q I see.

A That stress change is mining-induced stress.

Q Very good.

A All right.

Q A question for you on Exhibit 592, which is your report on the evaluation of possible hydraulic conductivity changes due to mining-induced stress effects, when were you asked to prepare that report?

A Late last year in about around Christmastime.

Q So this was a request that was made to you to prepare the report, this particular report, Exhibit 592? You were asked to do that right around the holidays of 2007?
A Yes.
Q Okay. Why did it take you until April to finish it?
A The data from which I needed to build was not immediately available and had to be provided. And the development of the responses from Kennecott were timed, I guess, to work within that. I wasn't given a time line to produce it by.
Q Well, I was going to ask you whether you were given any specific due date for that report?
A Not that I recall.
Q When did you provide it to whoever you -- who did you provide this report to initially?
A The report was provided to legal counsel.
Q To Mr. Lewis --
A Yes.
Q -- or his firm? When did you provide it to Mr. Lewis' firm?
A It was dated in March, I believe, right at the end of March.
Q So it could have been March 25th, 26th?
A I can't remember if there's a covering letter on it.
(Witness reviews documents)
A No. It's dated April.
Q The report itself is dated April?
A Yes.

Q Do you know when you actually gave it to Mr. Lewis?
A I can't remember.
Q Was it before April or was it --
A No; no. It was in April.
Q How long have you had a relationship with Kennecott, with any of the Kennecott companies? Is this your first project for Kennecott?
A I think so, yes.
Q Okay. Is that true for your firm, or is it true for you?
A No. I think it's the first time I've worked for Kennecott. The firm has worked for them for many years.
Q So the firm has worked for Kennecott many years?
A Uh-huh (affirmative).
Q Okay. Have people been called upon to testify previously for Kennecott?
A I'm not aware.
Q What exactly did Mr. Wozniewicz do for this project?
A I do not know and can't answer exactly.
Q Well, what do you understand was the work that he did?
A I understand that he prepared the reports on the bedrock hydrogeology.
Q Okay. What about are you familiar with a person named Willy Zawadzki?
A Yes, I am.
Q Who is he?

A He's one of our numerical modelists and he --
Q And what do you understand that he did?
A I understand that he is the main numerical modeler for all the hydrogeological work.
Q Very good. Just one question or two finally. This 90 -- you said that one of your conclusions is that this crown pillar is going to be essentially compressed and is going to close the fractures that occur as a part of mining?
A Yes.
Q Okay.
A To the permitted level.
Q But did I also understand you to say that at about that time that that's happening that the walls of the mine will actually become more permeable? In other words, as you compress the crown pillar, the sidewalls actually become more permeable?
A Let me just go back a bit. What we looked at for passing through to numerical modeling folk was the worst case for both situations. And if you remember, I said ten meters up into the crown and 20 meters out into the sidewalls.
Q Yes, I do remember that.
A If you take the best estimate, which is a k ratio of about 1.5, you get less than five meters of damage into the crown and only about ten meters into the sidewalls. So for the best estimate it's much better than the situation that we've

passed through to the modelers. So does that answer your question?
Q Not really. I'm asking a very simple question. When the crown pillar is compressed and it, as you describe, it's compressed and closes up, these fissures and crevices had to close up as a result of -- as a result of activity, it sounds to me like the sidewalls open up a little bit; is that fair?
A That is correct. And that's because of the geometry of the excavation shape.
Q Understood.

MR. EGGAN: Okay. I don't think I have any additional questions. Thank you.

MR. LEWIS: I have nothing further, Your Honor.

MR. REICHEL: May I have just a moment?

JUDGE PATTERSON: Sure.

MR. REICHEL: Good afternoon, Dr. Carter. My name is Bob Reichel. I represent the Department of Environmental Quality in this proceeding.

CROSS-EXAMINATION

BY MR. REICHEL:
Q I just wanted to follow-up briefly with a portion of the PowerPoints that you used to illustrate your testimony this morning. Perhaps it was me or perhaps just the pace at which we were going or the amount of information projected,

but I have to confess, sir, that looking at what I believe is slide 23, there's several different pieces of information layered on there. And if we could, I know there are different stages in this. If you could back up to the steps? I'd just like to run through --
A Certainly.
Q -- this document again to make sure I understand what you're attempting to illustrate here.
A Certainly. Which slide are you after?
Q Okay.
MR. REICHEL: That one, 23. Thank you.
Q Just looking back in my notes, could you explain again briefly, sir, what you were attempting to illustrate with this slide?
A Okay. I'll go through it slowly. We have a little time. If you go to the next -- first I've put on here the -- this chart is from the Q system, which is the Norwegian system, and first let me explain what the gray area is. This is the area in which we put -- we considered that the rock mass is in a zone which would be lower than the factor of safety of 1; that we can put rock bolts and Shock-Crete and other things into those to stabilize the tunnel or the excavation that we're working in.
So if I look at this very carefully -- and I'm going to look at my copy here, because it's easier for me to

read with my glasses -- the lines that we have -- this line here is 25 centimeters of Shock-Crete. This line in the middle here that goes up where it says "supportable" is 5 centimeters of Shock-Crete.
Q Okay. May I interrupt you there? So basically, in this shaded area, the lines -- the curved lines you're pointing to correspond to different levels specific support measures?
A Correct. This is like putting a zone of support around the excavation. So from this we can design bolts, the Shock-Crete, the supports that we need to put in for that rock mass quality.
Q So this illustrates design tools that mining engineers could use to plan mine support?
A And what Mr. Beauchamp used is the two bands across here, which is what he decided was the range that the drifts and excavations for the Eagle Mine would be. So this defines his rock classes for support.
Q And as you proceeded through with this graphic, you layered on some additional information. This Table 13, could you explain again, sir, what the function of that is?
A Okay. This comes again from the Q system. And if I take this axis here, this is the span, the width of that tunnel. Okay? So if I look at this table here and I go for power stations, major road and railway tunnels, civil defense chambers and portal intersections, I see 1.0 for this

parameter called ESR, which is the denominator of the side.
Q I'm sorry. That's what I was -- "ESR" stands again --
A ESR.
Q -- stands for what?
A Excavation support ratio.
Q Okay. So that's the axis there on the left?
A Right. So if I was deciding that I was going to build a civil engineering tunnel and I want to use this chart, I would take the raw numbers here. So I would go across the chart on 10, if I was going to make a 10-meter-diameter tunnel, to whatever the rock quality was, and that would give me my support that I needed.
Q Okay.
A If I go into a mining situation and it's a temporary excavation like the top drifts will be for one of the lower sills -- not for the crown pillar but one of the lower levels where they're going to be backfilled and mined out completely, it's a temporary excavation. For that temporary excavation, I can go into here and look at the next level down here, which is "permanent mine openings water tunnels for hydro power," and I would be using 1.6 temporary mine openings 2 or 3 to 5. I can't quite read this. And if we just said for simplicity it was 2, which would take you up into that temporary range, I would take this span, and that 10 there would now mean that that would be here at 5. Okay?

Q So you've just reduced it by that value?
A Essentially, yes. So I'm allowing it to be less stable, if you like, for a temporary excavation. Then I --
Q Okay. And again --
A Okay.
Q I'm sorry. Again, this table is from the cited reference, Orton, et al., or adapted from that, --
A Yes.
Q -- where they published their recommendations as to what these ESR values would be under different scenarios; is that correct?
A Correct.
Q And so your point here in bringing this to bear is to illustrate or -- is to illustrate the need or lack of need for support measures under certain scenarios that might be present at the Eagle Mine Project?
A That and also that, however poor the rock mass is, we can develop support measures that it can control and deal with those rock mass conditions.
MR. REICHEL: And could you bring up the next feature? There's another box.
Q Could you explain what that is, sir? Because my notes were not clear on that -- this additional box that appears in the overlay.
A This comes from page 16 of the report, and it is the three

gram classes that Mr. Beauchamp has identified for the Eagle Mine. So if we are in this zone -- this first one is Q greater than 4. And if I look at the chart here, at Q greater than 4 would be about an RMR of about 55. So anything greater than 55 would have spot bolting or pattern support bolting as a routine operation in all the drifts. Okay?

The next class he has is between a Q of 1 and a Q of 4, so that's between about 45 RMR and 60 RMR. And for that he's saying pattern support bolting and 4 to 10 centimeters of fiber-reinforced Shock-Crete, which means that I go in, and I put roof bolts in, and I spray the outside of the tunnel with Shock-Crete. And then the last class is for lower than that, which would be pattern support and screen and 4 to 10 centimeters of Shock-Crete. So these are three levels of support that he's saying should be used on the mine drifts.

Q Depending upon what conditions are actually encountered?

A Depending on the rock conditions.

Q And again, I just want to make sure I understand this. So if I understand you correctly sir, that, during the normal development in mining process as the rock is encountered and you have in situ information about what its characteristics are, various support methods can be applied as appropriate to the actual rock conditions encountered?

A That's absolutely correct.
Q Let me just look at my notes for a moment.
(Counsel reviews notes)
Q And just following up further on this point, I believe you indicated in testimony just a few minutes ago that, based upon your experience in the mining industry, that there are certain practices or conventions as to types of support that are routinely -- or ground support measures that are routinely employed in mines; is that correct?
A That is true.
Q It's a matter of sort of industry practice; is that correct?
A It is industry best practice.
Q And again, what would those be, sir?
A They variability from mine to mine and depend on the local rock conditions. So typically on most mines they will have a series of class 1, 2, 3 and 4 support patterns, which they will have agreed as to the standards for that mine. And usually the Ministry of Labor or the responsible government body that polices the underground operations will check off to agree to those support patterns, and then they will be used routinely.
Q And again, when you're talking about in that context, you're talking about essentially mine safety regulations?
A Yes.
MR. REICHEL: Nothing further. Thank you, sir.

MR. HAYNES: Your Honor, just some follow-up on Mr. Reichel's question.

RECROSS-EXAMINATION

BY MR. HAYNES:

Q Dr. Carter, on slide 23 -- slide 23, which is also Figure 19 from Appendix C-2, relates only to the drifts and not to the crown pillar; correct?

A That is correct.

MR. HAYNES: Thank you. Nothing further.

MR. LEWIS: Nothing further, your Honor.

MR. WALLACE: Nothing further.

JUDGE PATTERSON: Thank you, Doctor.

THE WITNESS: Thank you.

MR. LEWIS: You have to leave at 4:30?

JUDGE PATTERSON: I have to leave at 4:30, and it's 11 after.

MR. LEWIS: I suggest we break.

JUDGE PATTERSON: Call it a day?

MR. LEWIS: Yes.

MS. HALLEY: Just for the record, your Honor, I just wanted to make sure we don't lose sight of Dr. Stone's cross-examination. We are negotiating about when Dr. Stone is available to be present telephonically.

JUDGE PATTERSON: Okay. See you tomorrow.

(Hearing adjourned at 4:13 p.m.)

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