Response to October 27, 2007, MSHA Questions

Where technical papers have been referred to, if not already transmitted to MSHA, the complete reference has been included at the end of this document. Due to copyright laws, these publications cannot be provided in their entirety.

1. Provide a curriculum vitae for AAI employees (past and present) that have performed ground control work at Crandall Canyon Mine.

   Attached are resumes for Gilbride, Mike Hardy, Bo Yu, Joe Agapito, Archie Richardson, Rex Goodrich, Brian McGunegle, Dave Conover and Hua Zhao.

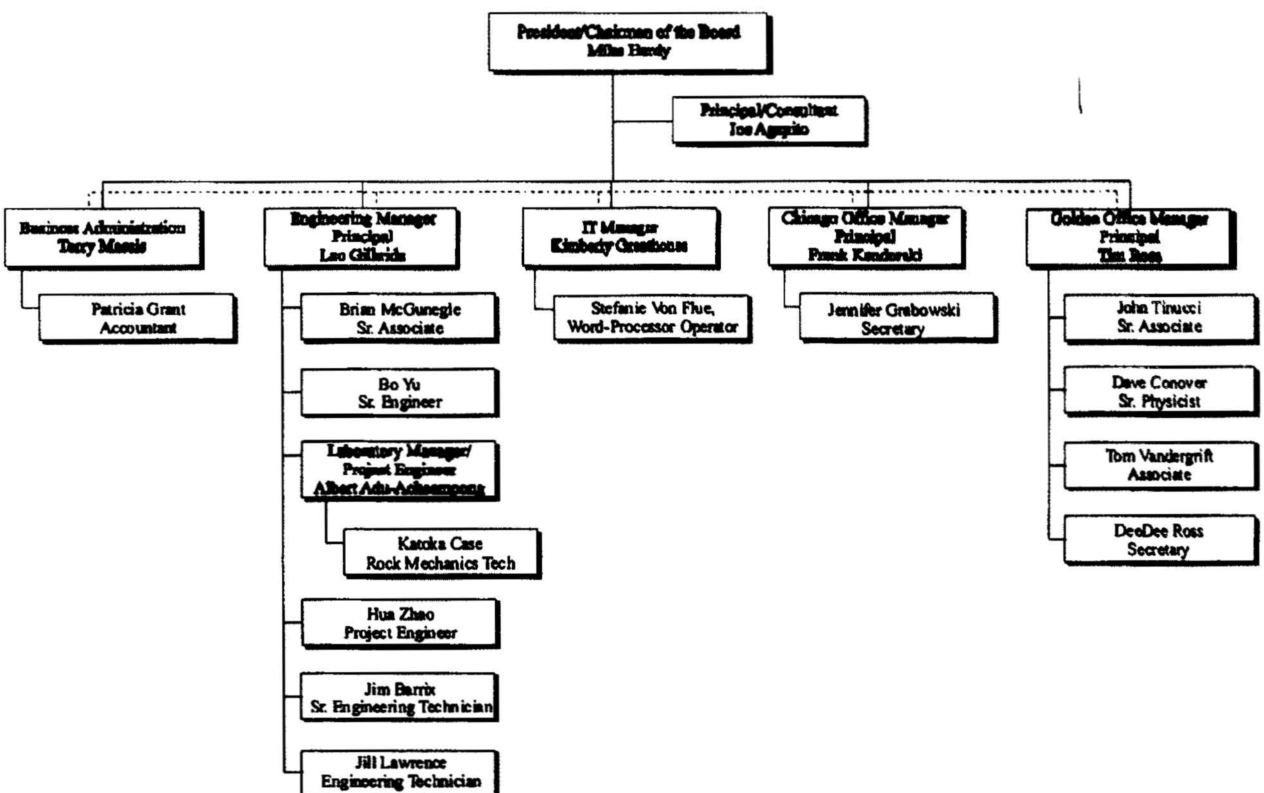
2. Describe the nature of the work performed on Crandall Canyon Mine projects by each of these employees as listed in No. 1.

   Refer to the AAI email with attached letter transmitted to MSHA September 21, 2007.

3. Describe the management structure at AAI.

   Following are organization charts that were in effect during the summer of 2006 and March 2007.

AGAPITO ASSOCIATES, INC.
(effective Summer 2006)

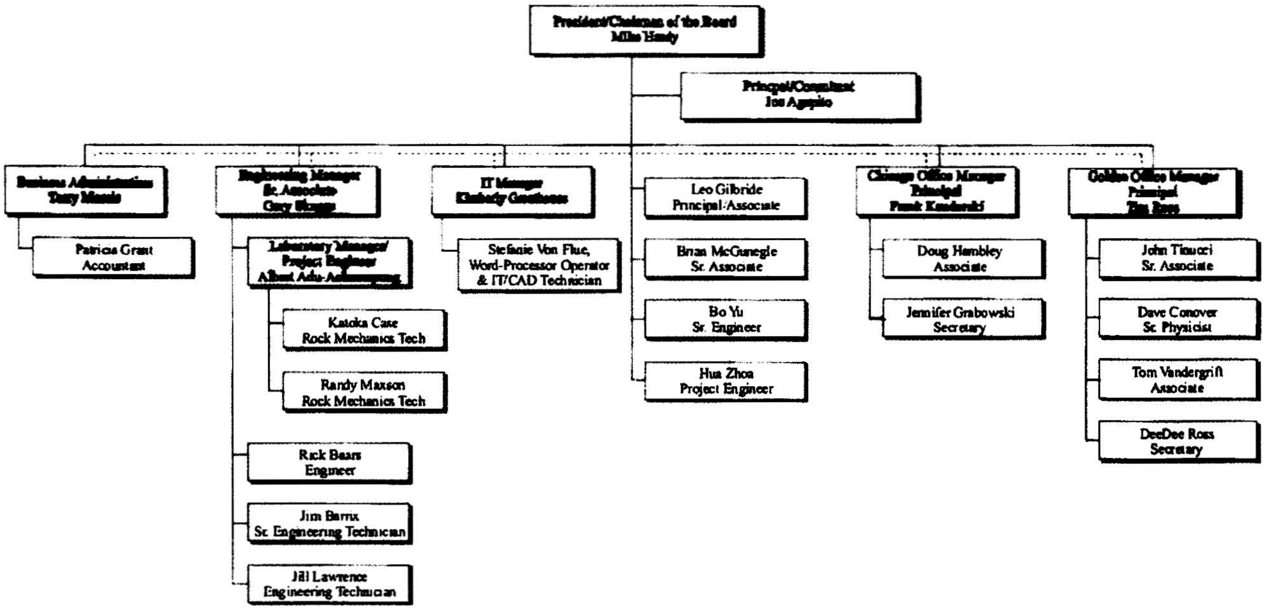


AAI009948

EXHIBIT
1
Hardy
PENGAD 800-631-6989

AGAPITO ASSOCIATES, INC.

(effective March 2007)



4. Describe the project management process at AAI, including project oversight and any formal or informal review procedures.

   A project is assigned to an Engineer who is responsible for establishing the scope of work and cost estimate. The final product is reviewed by a Principal.

Ventilation

5. Are you aware of any work that has been done to evaluate the inherent gases present in the Hiawatha seam? If so, please reference.

   No.

6. Are you aware of a tendency for the mine atmosphere at Crandall Canyon to become oxygen deficient other than normal oxidation? If so, explain any causes that you know of.

   No.

Ground Control Questions

7. Panels in the north central portion of Crandall Canyon Mine (Section 36) were developed and retreated using a mobile bridge conveyor (MBC) system.

AAI009949

a. Describe any involvement that AAI personnel had with mine design or site investigations in these panels.

   None during development. An area to the East of 1st North was back-analyzed during the assessment of the mining in the West Main barrier pillars, see AAI July 20, 2006 DRAFT letter report (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

b. Describe the extent to which previous AAI work in this area was considered during the design of workings in the Main West Barrier sections.

   See AAI DRAFT letter report dated July 20, 2006 (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

c. Describe the extent to which ground conditions or mining experience in this specific area were considered during the design of workings in the Main West Barrier sections.

   i. Identify AAI personnel who observed these conditions (and approximately when) or, if AAI did not make these observations, list the names and positions of persons who described the conditions/experiences to AAI.

      AAI did not observe these conditions. Laine Adair, General Manager at UtahAmerican, described the conditions to AAI.

   ii. Describe the relevant conditions or experience.

      See AAI DRAFT letter report dated July 20, 2006 (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

8. Twenty-two longwall panels were extracted at Crandall Canyon Mine.

   a. Describe any involvement that AAI personnel had with the design of longwall gate roads and/or barriers at this mine.

      See list of reports dating from November 1995 in letter to Richard Gates from Kimberly Greathouse dated September 21, 2007.

   b. Describe the extent to which this previous AAI work was considered during the design of workings in the Main West Barrier sections.

      See Table 2 in July 20, 2006 DRAFT letter report (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

   c. Describe the extent to which ground conditions or mining experience related to longwall mining at Crandall Canyon Mine were considered during the design of workings in the Main West Barrier sections.

AAI009950

i. Identify AAI personnel who observed these conditions (and approximately when) or, if AAI did not make these observations, list the names and positions of persons who described the conditions/experiences to AAI.

   Site visits were made during the mining of the panels to the north and south of West Mains. The personnel and places visited are included in AAI's September 21, 2007 letter to Richard Gates.

ii. Describe the relevant conditions or experience.

   Caving and subsidence was good.

9. After many years of longwall mining, pillar recovery operations were reinitiated at Crandall Canyon Mine in the south/southeast (vicinity of 6th East) area of the mine.

   a. Describe any involvement that AAI personnel had with the design related to pillar mining in this area.

      None; Mike Hardy and Leo Gilbride visited the areas in 2002 before retreat mining occurred but no design, analysis, or report was initiated by AAI.

   b. Describe the extent to which previous AAI work is this area was considered during the design of workings in the Main West Barrier sections.

      The retreat mining in the 1st North Left panels was considered more relevant because of depth.

   c. Describe the extent to which ground conditions or mining experience in this specific area were considered during the design of workings in the Main West Barrier sections.

      i. Identify AAI personnel who observed these conditions (and approximately when) or, if AAI did not make these observations, list the names and positions of persons who described the conditions/experiences to AAI.

         Laine Adair described the conditions. No AAI employee observed the pillar recovery operations.

      ii. Describe the relevant conditions or experience.

         See AAI DRAFT letter report dated July 20, 2006 (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

10. Main pillars and portions of barrier pillars were recovered in the South Mains at Crandall Canyon Mine.

   a. Describe any involvement that AAI personnel had with mine design in this area.

      None

AAI009951

b. Describe the extent to which previous AAI work in this area was considered during the design of workings in the Main West Barrier sections.

See c.

c. Describe the extent to which ground conditions or mining experience in this specific area were considered during the design of workings in the Main West Barrier sections.

Retreat conditions were reported to be good. Geomechanical relevance to Main West included the successful retreat of mains pillars and end-panel barrier pillars subject to longwall abutment loads under variable cover ranging from 1,000 to 1,400 ft.

ii. Identify AAI personnel who observed these conditions (and approximately when) or, if AAI did not make these observations, list the names and positions of persons who described the conditions/experiences to AAI.

Laine Adair described the conditions. No AAI employee observed them directly.

i. Describe the relevant conditions or experience.

See above.

Main West North Barrier Section

11. When did the main operator first contact AAI regarding plans to develop barriers adjacent to the Main West inby crosscut 118? Which personnel for both parties were involved?

April 23, 2006, John Lewis to Leo Gilbride by email (Bates numbers AAI000055 and AAI000056 submitted in hard copy September 28, 2007).

12. Did the mine operator initially limit AAI to an evaluation of development mining only?

Yes

a. If yes, why?

As a phased approach.

b. How was the AAI design for the North Barrier optimized for development mining?

AAI presented (July 20, 2006 DRAFT letter report, Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007) an analysis of a plan with 60 ft by 72 ft rib-to-rib pillars and concluded that the pillars should function adequately for short-term mining in the barriers. They were not for long-term performance.

13. Was AAI later asked to evaluate pillar recovery in the barrier sections?

Yes

AAI009952

a. If so, what date was the additional analysis requested? Was this before, during or after the time the Main West North Barrier was developed?

   See August 9, 2006, email to Laine Adair from Leo Gilbride (Bates number AAI000135 thru AAI000166 transmitted in hard copy September 28, 2007).

b. What concerns did AAI have that the design for development mining would be unacceptable for pillar recovery?

   A preliminary analysis was completed dated August 9, 2006 (Bates number AAI000135 thru AAI000166 transmitted in hard copy September 28, 2007) and emailed to Genwal. No significant issues were raised. The Safety Factor was lower than recommended by NIOSH ARMPS method but were acceptable relative to past experience in the 1st North Left Block at Genwal.

c. How would the design have been different if pillar recovery had been considered initially?

   Refer to UtahAmerican Energy who prepared the original design.

14. What was the basis for recommending the mine design implemented for development and pillaring in the Main West North Barrier section (empirical or numerical analyses, past experience, etc.)?

    A combination of past experience at 1st North Left Block, empirical comparison, and Lamodel numerical analysis of both old and proposed workings.

15. In what way(s) if any, did the mine operator deviate from AAI's recommendation for mining in the Main West North Barrier section?

    See April 18, 2007, letter report to Laine Adair (Bates numbers AAI000213 thru AAI000222 transmitted digitally September 20, 2007, and in hard copy September 28, 2007). To our knowledge they implemented the plan analyzed by AAI with the exception of leaving pillars between crosscuts 135 and 138.

16. Did AAI visit the North Barrier section as it was being developed?

    Yes

    a. If so, when and what was the purpose of each visit?

       December 1, 2006, when development mining was approaching the deepest cover, see AAI letter report dated December 8, 2006 (Bates numbers AAI000171 thru AAI000176 transmitted digitally September 20, 2007, and in hard copy September 28, 2007). Conditions were good with roof, floor, and rib conditions consistent with analytical predictions.

    b. What did AAI conclude from each visit?

       See above.

AAI009953

c. Did AAI personnel note any deviations in the way that the mine operator was implementing the recommended design?

No.

d. How were concerns with any deviations addressed by AAI? By the operator? (see report?)

17. Did AAI visit the North Barrier section as it was being retreated?

Yes, on March 16, 2007.

a. If so, when and what was the purpose of each visit?

To inspect the conditions after the bump that occurred on March 12th. The purpose was to reassess the design for mining in the South Barrier.

b. What did AAI conclude from each visit?

The bump occurred in a limited area possibly triggered by leaving the pillars between crosscuts 135 and 138.

c. Did AAI personnel note any deviations in the way that the mine operator was implementing the recommended design?

The section was shut down when we visited. No further mining was attempted in the North Barrier. Changes to the design for development in the South Barrier were recommended.

d. How were concerns with any deviations addressed by AAI? By the operator?

AAI recommended not leaving pillars in the gob.

18. Did AAI provide input regarding pillar sequence, cut sequence, stump size, etc.?

No

19. Was second mining of bottom coal considered when preparing AAI's recommendations? If so, how?

No

20. As the North Barrier section pillars were being recovered, difficult ground conditions were encountered.

a. How and when did AAI become aware of this?

By phone call from Laine Adair on March 14, 2007.

AAI009954

b. Describe the ground control problems.

Prior to the bump on March 12th, we were told there had been problems with a local roof fallout contained by the mesh, straps and bolts.

21. AAI's field notes contain a sketch (Figure 1) of an area around several rows of skipped pillars in the North Barrier section (see AAI000927).

a. Who wrote these notes?

Leo Gilbride

b. What do the markings labeled "A" in Figure 1 identify?

The markings are lines indicating the approximate location of the intact pillar ribs, as estimated by observation. The distance between the original pillar outline and the markings represents the approximate depth of rib sloughage.

c. Provide typed notations in place of all handwritten notations included on the original sketch (Figure 1)?

See table and annotated map as follows

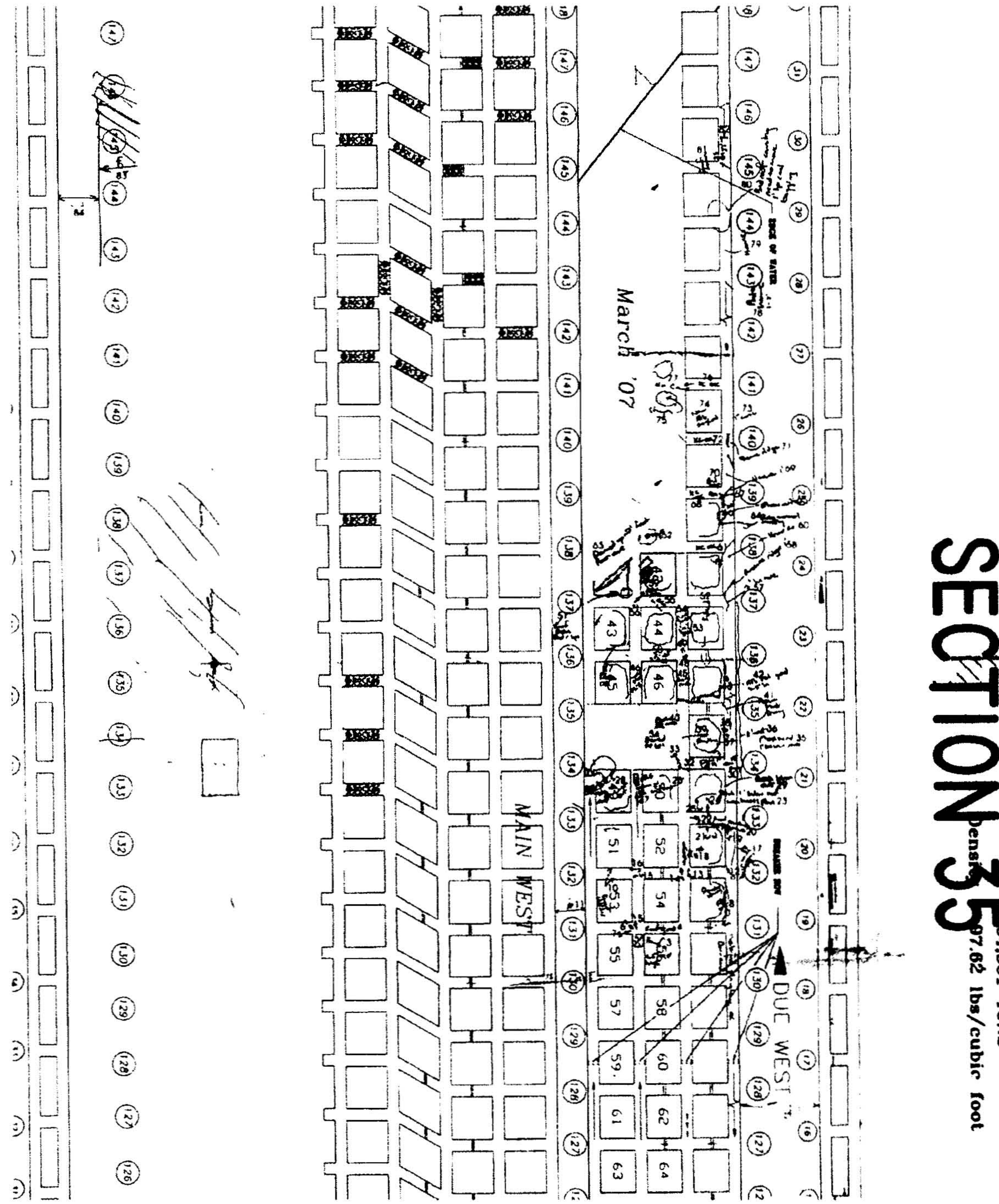
Marker	Exact Text	Comment
1	130'	130 ft
2	Normal sloughage OK Dev-cond.	
3	Transf 6.5-7' high	
4	Roof good	
5	1	photo location
6	2	photo location
7	3	photo location
8	Rib out	
9	Crushed sideways	
10	Bigger blocks	
11	55'	55 ft
12	13	photo location
13	6	photo location
14	7	photo location
15	5	photo location
16	4	photo location
17	Safety line down	
18	Sig. rib yield	Significant rib yield
19	14	photo location
20	Roof excellent large spans	
21	Solid	
22	8	photo location
23	Slick 1' below weakness plane	
24	9	photo location
25	20'	20 ft
26	MRS 2' on floor	Mobile roof support; 2 ft heave on floor
27	12	photo location
28	MRS Last cut	Mobile roof support; last cut location

AAI009955

Marker	Exact Text	Comment
29	Fresh blow out	
30	15 Gary	photo location
31	Filled up 4'	Filled up 4 ft
32	11	photo location
33	10	photo location
34	Domed to 10'	Domed to 10 ft
35	1" ash band 1' below rock	1inch ash band 1ft below rock
36	3' out	3 ft out
37	17	photo location
38	16	photo location
39	Roof standing	
40	Cave line	
41	Heave crack drummy	Floor heave with crack, "drummy" floor
42	Rib rel. good 4-5' in	Rib relatively good 4 to 5 ft in
43	18	photo location
44		Shows location of three wooden breaker posts
45	Less rash	
46	Ribs less rash	
47	Ribs OK	
48	20	photo location
49	19	photo location
50	2' filled	2 ft filled
51	Roof slabs bad 1' top	
52	Filled	
53	3'-4' filled	3 ft to 4 ft filled
54	Fine rash	Rib rash rubblized to a fine consistency
55	Ribs in 10'+	Ribs in 10 ft plus
56	21	photo location
57	2' heave	2 ft heave
58	Pressure ridge 1'	Pressure ridge 1 ft
59	Post on rock	
60	Heave <6"	Heave less than 6 inches
61	XC OK	Crosscut okay
62	Stump	
63	Domed up ~7' feet poor cave	Domed up approximately 7 ft poor cave
64	Ribs normal mostly	
65	Blow out	
66	22	photo location
67	Bagging	Bagging behind roof mesh
68	XC OK	Crosscut okay
69	Heave 1'	Heave 1 ft
70	Bad top	
71	Heave ridge	
72	XC OK	Crosscut okay
73	1" conv.	1 inch roof-to-floor convergence
74	New rib sloughed	
75	Stumps?	
76	XC OK	Crosscut okay
77	No cave	
78	Plate heave 1-2'	Plate in floor heaved 1 to 2 ft
79	Heave	
80	Rib roof crushing need to move 1' top coal bagging	Rib roof crushing, need to move 1 ft, top coal

AAI009956

Marker	Exact Text	Comment
		bagging behind roof mesh
81	Roof down	
82	23 Bagging	photo location
83	40'	40 ft; not actual mining, shows concept of slabbing barrier
84	?	Literally "?"



22. What conclusions did AAI personnel draw from the conditions observed on the North Barrier section regarding the adequacy of the section design?

    At the time of the bump, the cave was reported to be lagging inby XC 138. Also, the new start-up cave was minimally developed above the two pillars pulled between XCs 134 and 135. These lagging caves were simulated in the model by limiting load transfer through the gob, which causes higher abutment loads to be transmitted to surrounding pillars. The lagging caves can be recognized in Figure 1 [in the AAI April 18, letter report to Laine Adair (Bates numbers AAI000213 thru AAI000222 transmitted digitally September 20, 2007, and in hard copy September 28, 2007)] by the white-colored gob areas.

    Model results show that high stresses were placed on the pillars from three contributing sources: (1) abutment loads from the main cave (inby XC 138), (2) abutment loads from the start-up cave (between XCs 134 and 135), and, to a lesser extent, (3) abutment loads from longwall Panel 12. Peak stresses were concentrated on the pillars located between the two caves (between XCs 135 and 138). Figure 3 shows significant yielding in these pillars indicative of overloading. Modeling suggests that the start-up cave contributed on the order of 5,000 psi additional stress to some parts of the surrounding pillars. This, coupled with the other abutment loads, is believed to have created a high-stress region that allowed a localized bump in the pillars somewhere between XCs 134 and 135 to propagate to pillars over a much wider area.

23. What conclusions did AAI personnel draw from the conditions observed on the North Barrier section regarding the adequacy of the design process (e.g. models) that had been used?

    The bump occurrence in the North Barrier was limited to six or seven pillars and did not extend outby. The observation of this condition seemed to be consistent with the modeling results, i.e. bump occurred only around the edges of the pillars. Based on the observations in the North Barrier, further analysis was completed using the established models and a change in the plan for mining the South Barrier was recommended to reduce bump risk.

Main West South Barrier Section

24. What was the basis of AAI's recommendations for mining the Main West South Barrier (empirical or numerical analyses, past experience, etc.)?

    Back-analysis of the bump in the North Barrier, see AAI April 18, 2007 letter report to Laine Adair (Bates numbers AAI000213 thru AAI000222 transmitted digitally September 20, 2007, and in hard copy September 28, 2007).

25. In what way if any did the mine operator deviate from AAI's recommendation for mining in the Main West South Barrier section?

    We have not visited the mine since March 18, 2007, so do not know specifically the mine geometry and sequence of mining.

AAI009958

26. Did AAI visit the South Barrier section as it was being developed?

    No

    a. If so, when and what was the purpose of each visit?
    b. What did AAI conclude from each visit?
    c. Did AAI personnel note any deviations in the way that the mine operator was implementing the recommended design?
    d. How were concerns with any deviations addressed by AAI? By the operator?

27. Did AAI visit the South Barrier section as it was being pillared?

    No

    a. If so, when and what was the purpose of each visit?
    b. What did AAI conclude from each visit?
    c. Did AAI personnel note any deviations in the way that the mine operator was implementing the recommended design?
    d. How were concerns with any deviations addressed by AAI? By the operator?

28. Was second mining of bottom coal considered when preparing AAI's recommendations?

    No

29. Did AAI provide input regarding pillar sequence, cut sequence, stump size, etc.?

    No

30. How did AAI anticipate that the conditions (e.g. stress and geology) in the South Barrier would be similar or different than the North Barrier?

    See the AAI letter report of April 18, 2007 (Bates numbers AAI000213 thru AAI000222 transmitted digitally September 20, 2007, and in hard copy September 28, 2007).

31. List specific recommendations that were made to improve ground conditions in the South Barrier section?

    Increase pillar length to 110 ft, to mine on 80-ft by 129-ft centers. Slab the South Pillar by approximately 40 ft to increase the panel span to improve the caving conditions relative to the mining in the North Pillar. Pillars should be robbed as completely as is safe to promote good caving. Skipping pillars should be avoided in the South Barrier, particularly under the deepest cover.

AAI009959

Mine Design Analysis

32. Did AAI communicate with MSHA on behalf of Crandall Canyon Mine, Describe?

    No

33. Did AAI communicate with any other government agency on behalf of Crandall Canyon Mine? Describe?

    No

34. How many mine operators/mines have consulted with AAI specifically regarding the design of room-and-pillar retreat operations?

    Soldier Creek Mine, Andalex Tower Division, Cobra (Arch Mingo Logan). If additional examples emerge from discussion with former employees, we will forward references.

35. How many of these designs have been employed in overburden in excess of 2,000 ft?

    None

36. How many of these designs involved the extraction of barrier pillars adjacent to or between gobs (longwall or pillar retreat gobs)?

    Andalex Tower Division

37. What methods has AAI typically used to design room-and-pillar retreat operations?

    Numerical analysis using EXPAREA or Lamodel.

ARMPS

38. AAI employed the Analysis of Retreat Mining Pillar Stability (ARMPS) software in the Main West design. How long has AAI been using ARMPS for making recommendations to operators?

    Since 2006.

39. How did the AAI personnel who performed and/or interpreted ARMPS analyses learn to use the software (e.g. did they attend seminars on the use of ARMPS, rely on the software and accompanying documents, etc.)?

    Training based on ARMPS literature, software documentation, published case histories, and attendance at professional conferences.

40. An e-mail dated August 9, 2006, from Leo Gilbride to Laine Adair indicates that AAI did an ARMPS analysis for the Main West barrier section.

a. Was any back analysis done with ARMPS later to evaluate the failed experience in the North Barrier section (i.e. the conditions that forced the section to be abandoned)?

   No. Back-analysis was completed with Lamodel. The ARMPS back-analysis of the 1st North Left Block indicated that an ARMPS SF of 0.37 was satisfactory in the retreat mining in that section. The pillars for the North Barrier were designed with a SF of 0.53. The Lamodel numerical modeling of the pillar conditions in the North Barrier on March 12th indicates that the skipped pillars in the North Barrier may have contributed to the bump condition. That condition was to be avoided in the South Barrier Pillar and the pillar size was increased to reduce the potential for bump/burst conditions while mining the South Barrier.

b. If so, how was this analysis used in the design of the South Barrier section?

   Refer back to (a)

Boundary Element Modeling

41. It appears that earlier AAI analyses at Crandall Canyon used another Boundary Element Model (BEM) program call EXPAREA.

a. Approximately how long did AAI use this program?

   This program was developed at the University of Minnesota by Dr. S. Crouch and Dr. Starfield (Starfield and Crouch 1973, St. John 1978). It was initially used for Project Salt Vault in the early days of the Nuclear Waste program. It uses the displacement-discontinuity method. The development of the program and later variations such as MULSIM were further developed at the University of Minnesota under funding from the USBM. AAI has used the program since 1979 for design of underground thin-seam mines, particularly for coal mines.

b. Is EXPAREA commercially available to the mining community today? If so, from whom?

   No

c. It is still used by AAI?

   Yes

i. If not, when and why was its use discontinued?

ii. If so, why was Lamodel used for the Crandall Canyon Mine analysis instead of EXPAREA?

   Lamodel and EXPAREA have been used at Crandall. Lamodel is less demanding of computer time.

AAI009961

42. Approximately how long has AAI used Lamodel?

    Since 2003. Personnel in our Golden office have used it before 2003 when with a prior employer.

43. How did the AAI personnel who performed and/or interpreted Lamodel analyses learn to use the software (e.g. did they attend seminars on the use of Lamodel, rely on the software and accompanying documents, etc.)?

    Dr. Bo Yu and Dr. Hua Zhao attended Lamodel classes and seminars.

44. For the Crandall Canyon analysis, did AAI use elastic, plastic or strain-softening properties for the coal? Which variety were conclusions drawn from?

    Strain-softening properties were used for pillar ribs. Elastic properties were used for the other grids. The conclusions of yield conditions were drawn from the plastic conditions of the pillar ribs.

45. For each model at Crandall Canyon, were topographic contours (or overburden variations) incorporated?

    Yes.

    a. What was the source of this information?

       We extracted the topographic data from the AutoCAD file that Crandall Canyon Mine sent to us.

    b. How were these overburden variations incorporated into the models?

       The topographic data were first extracted from AutoCAD, and then Surfer was used to convert the contour lines to a topographic grid. The topographic input file was used in Lamodel to model the overburden variations.

46. A July 20, 2006, AAI report indicates that coal strength and modulus values of 1640 psi and 500,000 psi, respectively, were used in the Lamodel analyses. How were these parameters determined?

    The coal strength was calibrated from three mining stages in the south panel of Section 36. The coal strength was incrementally increased from 900 psi to 1,640 psi until modeling results were consistent with actual conditions. The average cover depth in this calibration panel was about 1,700 ft. We were told that all the pillars during retreat mining were stable and only limited yielding occurred at some pillar ribs. The coal modulus of 500,000 psi was based on the previous EXPAREA model calibration report (Agapito Associates, Inc., Panel 6^{th} Right Experiment Back Analysis and Model Calibration, report to GENWAL Resources, Inc. October, 1997—Bates numbers AAI003903 thru AAI003012 transmitted digitally September 20 and October 25, 2007).

AAI009962

42. Approximately how long has AAI used Lamodel?

    Since 2003. Personnel in our Golden office have used it before 2003 when with a prior employer.

43. How did the AAI personnel who performed and/or interpreted Lamodel analyses learn to use the software (e.g. did they attend seminars on the use of Lamodel, rely on the software and accompanying documents, etc.)?

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AAI009962

47. Mechanical testing for the Hiawatha seam from a January 2006, report shows values from SM-38-72, SM-26-72, and block samples. Where in the mine were these samples taken?

    This report is actually dated January 1996 (Bates numbers AAI002423thru AAI002450 transmitted digitally September 20, 2007, and October 25, 2007). AAI records do not reveal the location of the samples.

    a. This report indicates that other properties were based principally on four previous studies for Crandall Canyon Mine. Were these projects done using Lamodel or EXPAREA?

       These projects were all done using EXPAREA.

    b. List any significant differences between the Lamodel and EXPAREA programs.

       Both programs calculate the displacements and stresses for user-defined pillar geometries in flat-lying seams using the displacement-discontinuity version of the boundary-element technique. The major difference is that Lamodel uses laminated overburden while EXPAREA assumes intact overburden which influences the effective stiffness (modulus) of the overburden. Both models can be used to achieve similar results by adjusting overburden parameters. Lamodel yields faster computer run times.

    c. Were material properties developed from calibrated EXPAREA models modified in any way for use in Lamodel? If so, how?

       (1) Roof rock modulus was modified to 2,000,000 psi from 1,000,000 psi to account for the reduced stiffness introduced by the laminated roof.
       (2) Strain-hardening gob was used in the Lamodel model, in which the initial gob modulus was assumed to be 100 psi and the final modulus to be 76,000 psi. In EXPAREA, a constant gob modulus of 67,000 psi was used after critical closure of 0.7 ft into the gob.
       (3) A method of slices was used for the coal strength in the pillar in the Lamodel model. Strength of the 30-ft pillar was established at 5,000 psi from the calibration analysis using EXPAREA. Based on the "New Mark-Bieniawski" (Mark 1999) pillar strength formula (see below), in-situ coal strength should be about 2,000 psi. This coal strength was used as a guideline for coal strength input in Lamodel model.

       The new Mark-Bieniawski formula is expressed as:

$$S_p = S_I\,(0.64 + 0.54w/h - 0.18(w^2/(Lh)))$$

       where S_p = Pillar strength
       S_I = In-situ coal strength
       w = Pillar width
       L = Pillar length
       H = Pillar height

48. Did AAI ever run models to compare results of EXPAREA and Lamodel?

    Yes.

AAI009963

a. Are you aware of comparisons that others have made? If so by whom?

No.

49. Does EXPAREA use a laminated overburden?

No.

50. AAI reports appear to indicate that a 25 foot lamination thickness was used in Lamodel analyses for the Main West Barrier Section designs.

a. Were other thicknesses evaluated also?

A 50-ft lamination thickness was also evaluated.

b. How was this value selected?

Based on experience, a 25-ft to 50-ft lamination thickness is generally suitable for western coal seams.

51. The July 2006 report indicates that models are used to calculate three parameters: (1) in-seam vertical stress, (2) roof-to-floor convergence, and (3) pillar (coal) yielding. "These parameters provide the principal quantitative basis for comparing historical and future conditions."

a. Explain how each of these parameters was used in the Main West Barrier Section designs.

Refer to the AAI July 20, 2006 (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007), August 9, 2006 (Bates number AAI000135 thru AAI000166 transmitted in hard copy September 28, 2007) and April 18, 2007 (Bates numbers AAI000213 thru AAI000222 transmitted digitally September 20, 2007, and in hard copy September 28, 2007) reports.

b. Were multiple runs made to adjust the output to observed behavior?

Yes

c. Which parameters were adjusted?

The coal strength was adjusted from 900 psi to 1,640 psi until the modeling results were consistent with actual conditions.

d. Were runs also made to gauge the sensitivity of results to various input parameters?

Yes

i. Which parameters were varied?

See below.

AAI009964

ii. To what degree was each varied above and below those used in the final Crandall Canyon model?

The coal strength was adjusted from 900 psi to 1,640 psi until the modeling results were consistent with actual conditions. Lamination thicknesses of 50 ft and 25 ft were evaluated.

e. Did the calibration simultaneously fit all three parameters well (stress, convergence, and yielding)?

Yes, the description is in the report portion of 1st North Left Panels Back-Analysis in the July 20, 2006 report (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

f. Were the areas used for calibration observed by AAI personnel?

No.

g. Did AAI rely on one parameter more than the others? If so, which one?

No.

52. A July 2006 AAI report states that "convergence is far below the 2.0-inch level associated with roof and rib instability established by the back-analysis model." Please explain how that criterion was established.

Based on the mining experience in the section with peeling top coal, 2.0 inches of convergence in the model is considered a site-specific indicator of potential roof and rib instability.

53. How is "Yield Condition" (included in the legend shown in some AAI Lamodel output) computed?

The yield condition is only calculated for strain-softening materials. For each element, a stress and a displacement data value are read from the Lamodel output file. The strain is calculated as the displacement value divided by the seam thickness. If the strain is less than the peak strain for the material assigned to the element, the element is in the elastic range and the color (in 20% intervals) is determined by the ratio of the stress value divided by the peak stress for the assigned material. If the element strain value is greater than the peak strain but less than the residual strain, the element is considered to be in the "yielding" state and assigned the color orange. If the strain is greater than the residual strain, the element is considered to be in the "yielded" state and is assigned the color red.

a. Describe how various model output (e.g. yield condition, convergence, and in situ vertical stress) was evaluated for design (e.g. visual analysis of color or line plots or other subsequent post-processing steps).

The description is in the July 20, 2006 report (Bates numbers AAI000095 thru AAI000125 transmitted digitally September 20, 2007 and again in hard copy September 28, 2007).

AAI009965

North Barrier Section Lamodel Analysis

54. It appears that AAI's Lamodel analysis for the North Barrier section included both the Section 36 MBC panels and the North Barrier in the same model. Were the boundaries of the model symmetrical or rigid?

    The section 36 MBC panels and North Barrier section were analyzed in two different models. Symmetrical boundary conditions were applied for the four model boundaries for both models.

55. Were different widths of pillars modeled? Were different lengths of pillars modeled?

    The only pillar width modeled in the north main was 60 ft. Two pillar lengths of 70 ft and 80 ft were modeled in this area.

    a. If so, how was the final pillar design selected?

       Model results indicated that increasing the pillar length from 60 ft to 70 ft does not significantly affect ground conditions; 60-ft by 72-ft pillars were recommended for the final design.

    b. Was mining efficiency considered in the design?

       No

56. In the May 3, 2006, proposal to Genwal, AAI stated that "Concern exists for potentially high stress caused by a combination of deep cover and side-abutment loads from the adjacent longwall gobs, and to a lesser extent, load transferred onto the barriers by time-dependent pillar convergence in Main West."

    a. How did AAI account for load transferred onto the barriers by time-dependent pillar convergence in Main West?

       No time-dependent load transfer from Main West was incorporated in the model. AAI is not aware of any data indicating that there was significant time-dependent load transfer onto the barriers from Main West. Problematic load transfer was not observed on development in the North or South Barrier.

    b. If AAI opted not to consider load transfer, please explain the basis for this decision?

       It is impossible to quantify the load transfer onto the barriers by time-dependent pillar convergence in Main West based on the information about Main West at that time. The existing 70-ft by 72-ft pillars in Main West have been maintained over the long-term (12 plus years) and have required additional roof support at some locations. No significant pillar failures have been reported. Their performance has been satisfactory for ventilation and bleeder access. Genwal elected not to use the West Mains for men and materials and haulage as they reoriented the longwall panels after the West Mains were developed. Excessive convergence in the West Mains has not been reported so it was a reasonable assumption that the pillars were supporting the overburden load without significant load transfer onto the barriers due to time-dependent Main West pillar convergence.

57. The July 2006 report concluded that "Stress conditions are expected to be controlled by the depth of cover and not by abutment loads." This conclusion contradicts earlier concerns about stress conditions (see previous questions). What was the basis for this conclusion?

    Modeling results and mining experience at Crandall Canyon indicated that the depth of cover would have a far more significant influence on stress levels than abutment loads from gob that was separated by 100 ft or more across a barrier. For this reason, abutment loading was regarded as a secondary, not primary, influence. The model stress profile across the 450-ft barrier pillar showed stress levels tapering to near pre-mining (in situ) stress levels approximately 100 ft into the barrier, indicating that the proposed 130-ft-wide barrier would shield the new pillars from the largest part of the abutment load.

58. Subsequent to the July 2006 report, models were run to evaluate pillar mining in the Barrier sections (North and South in the same model). Were the model boundaries symmetrical or rigid?

    All four boundaries are symmetrical in that model.

59. A December 2006 report indicates that "The rib was mildly yielded, but showed no evidence of blowouts, indicating that the 130-ft wide remnant barrier pillar is wide enough to accommodate the load transfer from Panel 12 for short-term mining."

    a. Define short-term and long-term mining.

       Pillar mining in the barriers was proposed to be carried out within 1 year. We define this as short-term mining. Long-term mining implies a service life of several years or more, such as typical mains pillars.

    b. Explain how the distinction between the two impacted the design for Main West Barrier mining at Crandall Canyon Mine.

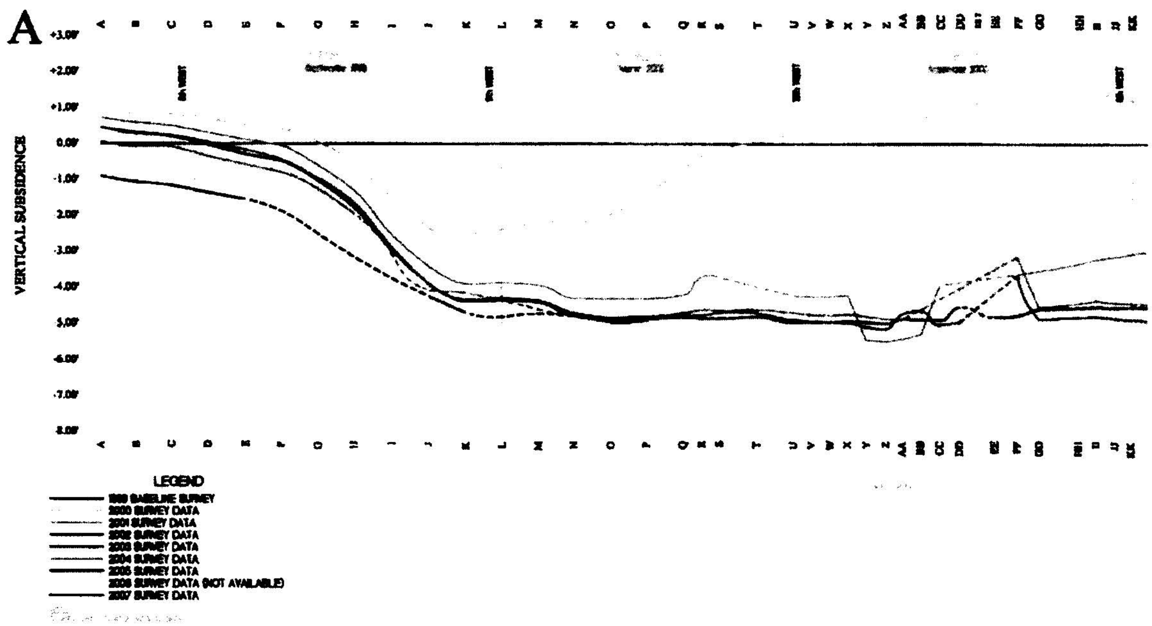
       Long-term entries and pillars were never considered in the 450-ft barriers.

60. The same report states that "The abutment load is expected to have alleviated since the time that Panel 12 was pillared in 1999 due to ground settlement and subsidence." Explain the basis for this observation and cite references.

    It is generally understood in mining geomechanics that overburden subsidence interrupts strata arching over gob and alleviates abutment loads. Longwall abutment loads are generally at their peak at the time of retreat and decay somewhat thereafter as a result of strata settlement into the mined seam. The subject is treated in numerous publications on mine subsidence (S. S. Peng and H. S. Chiang, "Longwall Mining" John Wiley & Sons, Inc.1984; S. S. Peng, "Surface Subsidence Engineering," SME, 1992). Rib conditions observed on development in the North Barrier would appear worse than expected had there been a poor cave in Panel 12. The good conditions were attributed, in part, to a relatively mature cave in the north panels resulting in partial alleviation of the original peak abutment loads.

61. Did AAI have access to subsidence data from panels adjacent to Main West? How was this data used in the Main West Barrier Section designs?

    Surface subsidence data were limited over the western half of the mine due to difficult terrain. Survey monuments over the panels north and south of Main West typically showed 5 to 6 ft of subsidence, indicating good caving (see below). This understanding contributed to the basis discussed in 60.



South Barrier Section Lamodel Analysis

62. Was the initial plan for the South Barrier section the same as the one implemented in the North Barrier?

    Yes.

63. Was the plan changed as a result of the conditions encountered in the North Barrier?

    Yes.

    a. What conditions specifically did the changes seek to address?

       A bump occurred between XCs 133 and 139 in the North Barrier section in early March 2007.

64. After the March bounce in the North Barrier section, additional Lamodel analyses were conducted.

AAI009968

a. Were these models used to develop a design specifically for the South Barrier section?

Yes, the models were used to evaluate a design nominated by UtahAmerican.

b. How were they different than earlier models?

There was no significant difference in the model or its parameters. The same model was used to simulate alternative mining geometries, namely, pillar size and barrier slabbing.

c. What was the basis for making these changes?

See b.

d. Explain how the models were used to redesign the South Barrier section.

The mining geometry at the time of the bump in the North Barrier was modeled. The simulated stress conditions were post-processed and compared to stress conditions simulated for various mining geometries modeled in the South Barrier. The modeling showed that lengthening the South Barrier pillars by an extra cut (approximately 37 ft), resulted in lower average vertical stresses within the pillar cores and more isolation between the retreat face and inby crosscuts.

e. What was the basis for design (vertical stress, yielding, or convergence)?

The modeling results indicated the benefit of increasing pillar size from 60-ft by 72-ft to 60-ft by 109-ft rib to rib. The added 37 ft length, approximately equivalent to an extra full cut, increases the size and strength of the pillars' confined cores, which helps to isolate bumps to the face and reduce the risk of larger bumps overrunning crews in outby locations. For conservatism, a lagging cave was also assumed in the south panel. Plans were to slab the south barrier to a depth of about 40 ft. The wider span was expected to improve caving conditions compared to the north panel and reduce concentrated loads at the face.

The south barrier will be mined to about 97 ft wide (rib-to-rib) after slabbing. The slabbed barrier will be subject to side abutment loads from gob on both sides, resulting in elevated stress levels through the core.

Model results indicated that the barrier will yield to a depth of about 20 ft along the ribs, but the core will remain competent. Model results also indicated that the maximum convergence in the entries and crosscuts was alleviated to 1.6 inches after the pillar size was increased to 60 ft by 109 ft.

f. Was mining efficiency considered in the design?

Only to the extent that adding 37 ft to the pillar length is approximately the length of a full mining cut and, therefore, compatible with the routine mining sequence.

65. A proposal for this work mentions elastic strain energy.

AAI009969

a. Did AAI use this parameter in this project or why did you opt not to?

   We did not calculate elastic strain energy because of insufficient site-specific supporting data .

b. Has elastic strain energy been used by AAI in other similar projects?

   Yes, for yield pillar and longwall face evaluation.

66. An April 2007 AAI report states that "...two pillars were simulated in the same model for convenience, which is possible because the two areas are geomechanically isolated from one another in the model." What does geomechanically isolated mean?

    The misquote should correctly read " two retreat areas were simulated..." Geomechanically isolated means that the two areas are far enough separated from one another that they have no significant ground control influence on the other. This can be quantified in the model by showing that significant abutment loads from one area do not reach the other area.

67. In the revised design, crosscuts were lengthened to ~130 ft. How were these model results different from earlier ones that indicated that "increasing crosscut spacing is not expected to significantly improve ground control"?

    The original statement referred contextually to ground conditions affected by pillar strength under static loading conditions. Pillars are designed for static loading by standard practice. Most design methodologies stipulate that pillar strength is principally controlled by the narrowest pillar dimension, in this case the width. By comparison, increasing pillar length will result in only a modest increase in static strength. Pillars were observed to perform well under static loading in the North Barrier. However, dynamic loading (i.e., bumping) occurred in the North Barrier as a result of pillars left in the gob. AAI recommended increasing pillar length as a precautionary measure in the South Barrier to expand the separation distance between the cave line and crosscuts, thereby improving the safety of outby mining operations from potential bumps near the face. The numerical models demonstrated that high-stress areas most vulnerable to bumping near the face were better isolated from outby crosscuts with longer pillars.

Barrier Pillar Design

68. AAI designed barriers for longwall panels at Crandall Canyon and it appears that several methods were used to estimate barrier widths (North American method, Holland Rule of Thumb, Holland Convergence method, PA Mine Inspectors formula). How were these formulas considered when evaluating mining in the existing barriers or why were they not considered?

    These methods are limited to cover less than 2,000 ft.

AAI009970

69. A March 25, 1998, AAI report indicates that the 2nd North Mains showed evidence of abutment load overriding a 400 ft barrier pillar. Was this information considered in designing the Main West North and South Barrier pillar mining plans or why was it not considered?

    No, this was an observation of minimal evidence of abutment load that may be of importance for a long-term permanent structure at the 2nd North mains. The subsidence data indicated a good cave and the mining conditions observed during the site visit of December 1, 2006, did not support the concept of a poor cave and significant overload from the gob to the north.

70. A November 1995 AAI report for Crandall Canyon Mine indicates that pillar widths ranging from 40 to 80 ft are bounce/bump prone in Wasatch Plateau mines when subjected to excessive loading. How was this considered in the Main West North and South Barrier pillar mining plans or why was it not considered?

    This quote refers to gateroad designs in three-entry systems. The loading on the gateroads during panel mining are excessive and can lead to bounces near the stage loader or inby. The conditions in the West Main Barriers at Crandall Canyon were analyzed with realistic assumptions for the load transfer from the gob, and field observations during development in the North Barrier confirmed that load override from the gob was minimal and within expectations. The burst during retreat mining in the North Barrier was limited and aggravated by a poor cave and the influence of the remnant pillars within the panel.

August 6 Accident

71. How was AAI notified of the August 6th accident at Crandall Canyon Mine?

    We became aware of the accident through the news media. We were not notified by UtahAmerican Energy.

72. Who notified AAI?

    Nobody

73. When was AAI notified?

    We were not notified.

74. Did AAI notify anyone else? If so, who?

    No.

75. Was AAI asked to provide assistance? What type?

    No.

76. Have AAI personnel visited the mine site since August 6th?

    No.

77. What aspects of the August 6 event at the Crandall Canyon Mine have AAI discussed with mine personnel?

    This request seeks information which is privileged as attorney work product, attorney-client communications, and also protected by a joint defense privilege. There have been no communications which are not covered by such privileges.

78. Does AAI disagree with any aspects of NIOSH's report on the Crandall Canyon accident (www.cdc.gov/niosh/mining/NIOSHCrandallCanyonReport.pdf)? If so, explain.

    (1) We understand that NIOSH's report is preliminary. For NIOSH's ARMPS analysis, the author first claimed that "recommendations from ARMPS should be considered as first-approximation guidelines, which should be tempered with site specific data and engineering judgments" (NIOSH report page 8). However, no sound site-specific data and engineering judgments were presented in their report to verify their data accuracy. For the Lamodel model conducted by NIOSH, the author only used default values of material properties in Lamodel for the coal seam, overburden strata, and gob, which directly contradicts the claim the author made on Lamodel that "it is usually necessary to employ past experience both in the selection of material properties and the interpretation of the results" (NIOSH report page 3). In fact, material calibration is the most important step in numerical modeling. Therefore, we think that all NIOSH conclusions drawn should be considered only as *first approximations* and not complete or necessarily accurate findings.

    (2) ARMPS has less relevance for deep mine design. In the ARMPS database, 70% of the case histories deeper than 900 ft are successful with a stability factor less than 1.0 (Heasley 2000). Site-specific data and previous mining practice should be used to calibrate ARMPS.

    NIOSH's report did not mention that we calibrated Lamodel with previous mining conditions. If a 900-psi in-situ coal strength was used, the historical mining in the 1st North Left Panels and Mains would be predicted to be unstable and could not be safely developed. Actual mining in that area, including both development and retreat mining, was successful at an average depth of approximately 1,700 ft.

    (3) NIOSH's report used an in-situ coal strength of 900 psi in ARMPS and Lamodel (NIOSH report page 17). However, previous laboratory tests showed higher than normal coal strengths at the Crandall Canyon Mine. The average uniaxial compressive strength for coal conducted by Neil & Associates, Inc. (Bates numbers AAI003181 thru AAI003244 transmitted digitally October 25, 2007) was 4,512 psi, with values ranging from 3,550 psi to 5,600 psi. In contrast, typical average coal strength values for local coal seams range from 2,000 to 3,500 psi. Mechanical testing of core samples from Holes SM-38-72 and SM-26-72 conducted by AAI (Bates numbers AAI002423thru AAI002450 transmitted digitally September 20, 2007, and October 25, 2007) showed an average uniaxial compressive strength for coal of 3,519 psi for five coal samples in which two samples were damaged during transport and preparation.

AAI009972

The average uniaxial compressive strength became 4,367 psi without the two damaged samples.

(4) Ground pressure measurements at Crandall Canyon Mine conducted by Neil & Associates, Inc. (Bates numbers AAI003181 thru AAI003244 transmitted digitally October 25, 2007) further confirmed that the coal strengths were higher than normal. The pressure measurements were conducted in the 6th Right gate-road yield and abutment pillars utilizing hydraulic borehole pressure cells (BPCs). Before yield pillar core failure occurred, the vertical stress in the center of the 30-ft yield pillar reached, or exceeded, 10,000 psi (10,000 psi is the upper limit of the BPC instrument). The in-situ coal strength should be 2,132 psi if the Mark-Bieniawski (Mark 1999) stress function is used. The Mark-Bieniawski's pillar stress function is:

$$S_v = S_I\,(0.64 + 2.16x/h)$$

where S_v = Vertical pillar stress
S_I = In-situ coal strength
x = Distance from pillar rib
h = Pillar height

(5) Even using the default in-situ coal strength of 900 psi, NIOSH's Lamodel analysis predicted the stability factor (SF) for the South remnant barrier to be close to 4, and the SF for the North remnant barrier to be more than 4 (NIOSH report Figure 13 on page 22). This result confirms that both the South and North remnant barriers were substantial.

(6) NIOSH's report refused to acknowledge the fact that partially yielded pillars can carry very high loads. In our Lamodel model, the coal elements were assumed to retain most of their load after failure. This was exactly based on NIOSH's research on pillar design. Papers that NIOSH published about pillar design on their web page (www.niosh.org) all emphasized that the pillar width-to-height ratio is the most important factor for predicting not just the pillar strength, but the pillar failure mode. The pillar dimensions used at Crandall Canyon mine were 60 ft by 72 ft (rib to rib) within the North barrier and 60 ft by 109 ft within the South barrier. The mining height was planned to be 8 ft. Thus, the pillar width-to-height ratio (w/h) was 7.5. For the pillars whose w/h ratios fall between 4 and 10, NIOSH categorized them as intermediate pillars. These pillars do not shed their entire load when they yield, but neither can they accept more load. This indicates that slight strain-softening should occur in these pillars. Figure 1 shows the effect of pillar-to-height ratio on the behavior of coal pillars (after Christopher Mark, Rock Mechanics Section Chief at NIOSH, 2006).

AAI009973

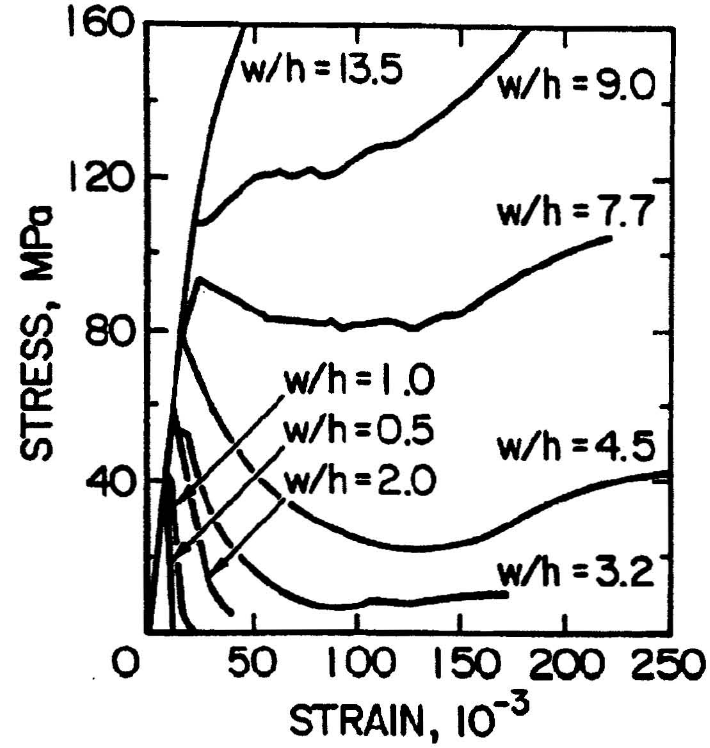


Figure 1. Effect of Pillar to Height Ratio on the Behavior of Coal Pillar (from Mark 2006)

(7) We think that our model reasonably represented the stress distribution in the mine based on the stress measurements conducted by Koehler, et al. (1996) (Bates numbers AAI005167 thru AAI005185 transmitted digitally October 25, 2007). Based on the stress measurements during Panel 6 mining, they found that the magnitude and location of the highest pillar stresses are near to the gob-line rib. They also found that under 1,100 ft of cover, the ground pressure in the yield pillars can reach 10,000 psi and that stress levels rise and drop off sharply across the pillar. This behavior was very well represented in our model.

(8) NIOSH's statistical approach to assess pillar stability is insufficient for many pillar design problems. The Crandall Canyon Mine is just one example. NIOSH has attempted to quantify the conditions when massive sudden pillar collapses have occurred (see Mark 2006). The NIOSH database includes case histories for 12 massive pillar collapses, each of which occurred so suddenly that they generated powerful air blasts (Mark 2006). This pillar failure mode is similar to what happened in the Crandall Canyon mine based on media reports. However, the database (Figure 2) shows no massive pillar collapse occurred involving pillars whose w/h was more than 3. At the Crandall Canyon West Main the pillars had a w/h ratio of 7.5 or more, hence one could assume that NIOSH would not have predicted that a massive sudden pillar collapse was imminent.

AAI009974

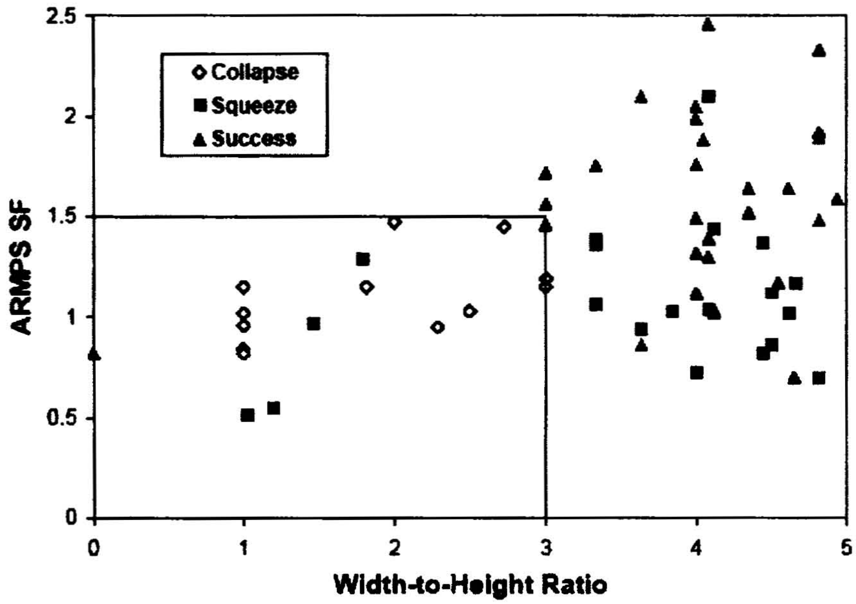


Figure 2. NIOSH's Database for Sudden Massive Collapse (from Mark 2006)

(9) We believe that the NIOSH report is preliminary and did not take into account or utilize site-specific data and mining experience from at the Crandall Canyon Mine. The NIOSH data base is primarily from shallower deposits and has been demonstrated to be inaccurate in estimating pillar performance at the Crandall Canyon mine.

(10) AAI may have additional comments regarding the validity of the NIOSH report should additional information become available.

79. Based on AAI's knowledge and experience, what is AAI's understanding of what caused the ground failure experienced at the mine on August 6th?

AAI has not participated in field observations since March 2007, the post-collapse data gathering nor the review/analysis of the collapse at the Crandall Canyon Mine. It would be premature to speculate on the cause of the collapse until all the MSHA investigations are complete.

References

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Starfield, A. M. and S. L. Crouch (1973), "Elastic Analysis of Single Seam Extraction," *New Horizons in Rock Mechanics, Proceedings, Fourteenth Symposium on Rock* Mechanics, ASCE, pp. 421–439.

ATTACHMENTS

RESUMES

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Rex Goodrich
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Dave Conover
Hua Zhao
Gary Skaggs

AAI009977

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Principal

Education

M.S.	(Mining Engineering) Mackay School of Mines, University of Nevada, Reno, 1995 *U.S. National Committee for Rock Mechanics M.S. Thesis Award 1996*
B.S.	(Civil Engineering) California Polytechnic State University, San Luis Obispo, CA, 1992 *(Summa Cum Laude)*

Professional Memberships/Certifications

Registered Professional Engineer, State of Colorado (#33329)
Member, American Society of Civil Engineers
Member, Society for Mining, Metallurgy, and Exploration, Inc.

Chronology

2004–Present	Principal, Agapito Associates, Inc.
2003	Senior Associate, Agapito Associates, Inc.
2001–2002	Associate, Agapito Associates, Inc.
1999–2000	Senior Engineer, Agapito Associates, Inc.
1997–1998	Project Engineer, Agapito Associates, Inc.
1995–1997	Engineer, Agapito Associates, Inc.
1992–1995	Graduate Student/Teaching Assistant, University of Nevada, Reno.
1993	Apprentice Miner, Bullfrog Mine, Lac Minerals, Beatty, NV.
1988–1992	Undergraduate Student, California Polytechnic University, San Luis Obispo, CA.
1987–1988	Undergraduate Student, University of California (UCLA), Los Angeles, CA.

Experience Summary

Experience spans from mining to civil engineering projects, with particular emphasis on underground geomechanical design and ventilation. Engineering experience also includes mine economic evaluation, conventional and geostatistical ore reserve estimation, mine planning, equipment selection, map construction, and open-pit blast design. Consulting services have been performed for mining operators in the hard-rock, coal, industrial mineral, and subsurface quarrying industries, and the nuclear waste isolation industry.

Consulting experience extends from on-site surveys and data collection, to office research and analysis and, ultimately, to direct client presentation of project findings, technology transfer, and personnel training. Project responsibilities include supervision of subordinate engineering staff, quality assurance of technical contributions, auditing of numerical simulations, and report production.

Geomechanical Experience: Geomechanical engineering projects have addressed ground support design, barrier and yield pillar design, entry stability, ground subsidence, mine sequencing, shaft and decline design, entry orientation, longwall shield capacity selection, underground storage bin design, ground failure investigation, *in situ* stress determination, identification of geological hazards, slope stability analysis, mine sealing, structural core logging, and laboratory rock mechanics property testing. Supporting numerical analysis has included both two- and three-dimensional linear and non-linear computer simulation using the commercially-available codes FLAC, FLAC^{3D}, UDEC, UNWEDGE, XSTABLE, and EXAMINE^{2D}, and the AAI proprietary codes EXPAREA and Basin. Mining projects have been performed for underground room-and-pillar, longwall, undercut-and-fill, sub-level stoping, and block caving operators, and, on the surface, strip coal and open-pit precious and base metal mines.

AAI009978

Ventilation Experience: Ventilation experience consists of underground pressure/quantity surveys, fan testing and performance surveys, computer network simulation, control device specification, fan selection, methane degassification consulting, ventilation troubleshooting, remote monitoring, and economic trade-off studies. Ventilation surveys, including altimeter and magnehelic pressure traverses, have been conducted in underground hard-rock, coal, and industrial mineral mines. The use of network simulation software includes VnetPC, MFIRE, and the AAI proprietary post-processing code WINDY.

Selected Publications

"Discontinuum Modeling of Block Cave Subsidence," 40th U.S. Symposium on Rock Mechanics, Anchorage, AK, June 25–29, 2005.

"Interpanel Barriers for Deep Western U.S. Longwall Mining," 23rd International Conference on Ground Control in Mining, Morgantown, WV, 3–5 August 2004.

"Ground Support Design Using Three-Dimensional Numerical Modeling at Molycorp, Inc.'s Block Caving Questa Mine," MassMin Chile 2004, Santiago, Chile, August 2004.

"Horizontal Stresses as Indicators of Roof Stability." 2002 SME Annual Meeting & Exhibit, Phoenix, AZ.

"Time-dependent Stability Implications for Planned Two-seam Mining at the OCI Wyoming, L.P., Big Island Trona Mine." Proc. 38th U.S. Rock Mechanics Symposium, DC Rocks: Rock Mechanics in the National Interest, Washington, DC, 7–10 July 2001.

"Rock Mechanics Issues in the Trona Patch." Proc. 18th Int'l Conf. on Ground Control in Mining, Morgantown, WV, 3-5 August 1999.

"A Study of Periodic Weighting of Longwall Supports." Proc. 17th Int'l Conf. on Ground Control in Mining, Morgantown, WV, August 1998.

"Use of Block Models for Longwall Shield Capacity Determinations." Proc. of the 3rd North American Rock Mechanics Symp., ISRM, Paper No. USA-716, Cancun, Mexico, 3–5 June 1998.

"Rock Movement Induced by Bench Blasting." Proc. '96 Int'l Symp. on Mining Science and Technology, Xuzhou, China, October 1996.

"The Influence of Massive Sandstones in the Main Roof on Longwall Support Loading." Proc. 15th Int'l Conf. on Ground Control in Mining, Golden, CO, August 1996.

"Ventilation Planning at the Aberdeen Mine." Proc. 6th Int'l Mine Ventilation Congress, Pittsburgh, PA, May 1996.

"Rock Movement Induced by Bench Blasting." Proc. 13th Annual Workshop, Generic Mineral Technology Center Mine Safety & Environmental Engineering, Blacksburg, VA, 22–24 October 1995.

"Blast-Induced Rock Movement Modeling for Nevada Open Pit Mines." M.S. Thesis, Mackay School of Mines, University of Nevada, Reno, May 1995.

"Blast-Induced Movement Modeling for Nevada Gold Mines." Mineral Resources Engineering, 4(2), Imperial College Press, April–June 1995.

"Blast Rock Movement and Its Impact on Ore Grade Control at the Rain Mine, Newmont Gold Company." Proc. 3rd Int'l Symp. on Mine Planning and Equipment Selection, Istanbul, Turkey, October 1994.

"Blast-Induced Movement Modeling for Nevada Gold Mines." Proc. 12th Annual Generic Mineral Technology Center Mine Systems Design and Ground Control Workshop, Fairbanks, Alaska, September 1994.

Revised 1/10/05

AAI009979

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Principal

Education

B.E./Honors	(Civil Engineering) University of Adelaide, 1968
Ph.D.	(GeoEngineering) University of Minnesota at Minneapolis, 1973

Professional Memberships

Member, Society for Mining, Metallurgy, and Exploration, Inc.
Registered Professional Engineer, State of Colorado
Member, American Society of Civil Engineers
Past Chairman, Underground Technical Research Council, a Joint AIME/ASCE Committee

Experience

1994–Present — President, Agapito Associates, Inc. Manage staff of engineers, technicians, and support personnel to achieve the mission of AAI to provide the highest quality consulting services to the mining industry. Project manager of mine development projects including PRC solution mine potash project and Kazan trona (solution mining) project for Rio Tinto, Hampton Corners Project for Akzo Nobel Salt, Inc., shaft and mine planning for Wold Benetron Project and solution mine feasibility study for Wold, solution mine feasibility for American Soda, LLP, resource assessment for solution mining for AmerAlia, Inc, reserve assessment for Intrepid Potash, authored 43-101 resource assessment for potash projects; ISX in Saskatchewan, and reviewed 43-101 for proposed solution mine plan for MagIndustries. Committee member National Academy of Science (NRC) committee on the Waste Isolation Pilot Plant, and NAS/NRC sub-committee on the United States Bureau of Mines. Coordinated projects involving underground mines in coal (burst-prone conditions), trona, nahcolite, borate, gold, and oil shale in the United States, Europe, and North Africa.

1979–1993 — Principal and Vice President, J.F.T. Agapito & Associates, Inc. Manager of projects involving field geotechnical data gathering, numerical modeling, and design of underground mines and nuclear waste repositories. Typical projects include management of preconceptual design effort and site characterization plan development for nuclear waste repository in basalt and design analysis of repository in tuff. Design of underground mines in oil shale, copper, molybdenum, limestone, coal, and trona. Rock support selection using rock bolts, shotcrete and steel sets for a variety of tunnels, declines and mine openings. Manager for characterization studies, including coring, geophysical logging, rock mechanics testing, gas monitoring, and resource evaluation. Design of large-scale tests involving thermal loading for ***in situ*** oil shale mining and nuclear waste disposal. Evaluation of alternate mining methods for underground gold deposit, design and selection of cemented backfill for high extraction mining, and structural evaluation of solution mine cavities. Coordinate business development and corporate quality assurance program.

1976–1978 — Assistant Professor, Department of Civil and Mineral Engineering, University of Minnesota. Teaching assignments, advanced rock mechanics, and mine plant engineering. Research activities, principal investigator on hydraulic fracturing, field and laboratory study for USGS, numerical modeling of nuclear waste repository in basalt for DOE, and application of numerical modeling for underground mine design

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	as applied to CuNi mining in northeast Minnesota for USBM. Consultant activities included design of underground oil shale and trona mines.
1974–1976	Senior Engineer, Golder Associates, Inc., Golder Brawner and Associates, Grand Junction, CO and Vancouver, B.C. Mine design activities for Mufulira, Zambia, underground copper mines; rock mechanics characterization of C-b oil shale tract, Colorado; preliminary structural mine design for C-b; and mine design for post-pillar mining of tungsten, Canada. Evaluation of rock and backfill interaction.
1969–1974	Research Fellow, University of Minnesota. Application of hybrid computers to room-and-pillar design evaluation of coal mine bumps, investigation of fracture initiation and propagation in hydraulic fracturing, blasting, and chip information. Thermal cracking of granite tanks. Rock mechanics test facilities.
1969	Mining Engineer, Broken Hill South Ltd., Broken Hill, Australia. Responsible for initiation and testing of trial cement fill system, rock mechanics testing of ore.
1964–1969	Summer employment, underground mines, Broken Hill, Australia.

Publications

Dr. Hardy has published over 50 papers on a wide range of geotechnical and mining issues. The following is a limited selection. A complete list of publications can be provided on request.

"An Overview of the Geology of Solution Mining of Potash in Sasketchewan," 2007 Solution Mining Research Institute Technical Meeting, Halifax, Nova Scotia, Canada, Fall 2007.

"A History of Solution Mining at the Cane Creek Mine, Moab, Utah," 2006 Solution Mining Research Institute Technical Meeting, Rapid City, South Dakota, Fall 2006.

"Cavity Shape Characterization of a Rubble-Filled, Solution-Mine Cavity," 2005 Solution Mining Research Institute Technical Meeting, Sycracuse, New York, Spring 2005.

"The History and Performance of Vertical Well Solution Mining of Nahcolite ($NaHCO_3$) in the Piceance Basin, Northwestern Colorado, USA" 2004 Solution Mining Research Institute Technical Meeting, Berlin, Germany, Fall 2004.

"Solution Mining of Nahcolite at the American Soda Project, Piceance Creek, Colorado." 2003 SME Annual Meeting & Exhibit, Cincinnati, OH, 24–26 February 2003.

"Geotechnical Characterization and Structural Mine Design at the Murray Mine, Northeastern Nevada." Fourth North American Rock Mechanics Symposium, July 31–August 1, 2000.

"Hydrologic Stability Study of the Crown Pillar, Crandon Deposit, in Support of Mine Permit Application." 37th U.S. Rock Mechanics Symposium "Rock Mechanics for Industry," Vail, CO, 6–9 June 1999.

"Design of Pillars with Backfill Interaction: A Case Study." Comprehensive Rock Engineering, Principles, Practice & Projects, 2(27), Pergamon Press, New York, 1993.

"Solution Mining Cavity Stability: A Site Investigation and Analytical Assessment." Proc. Int'l ISRM EUROCK '92 Symp. on Rock Characterization, Chester, U.K., September 1992.

"Application of High-Strength Backfill at the Cannon Mine." 4th Int'l Symp. on Mining with Backfill, Montreal, Quebec, October 1989.

"Geotechnical Mine Design of the Foidel Creek Mine." 7th Int'l Conf. on Ground Control in Mining, University of West Virginia, May 1988.

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"Impact of Mechanical Bolt Installation Parameters on Roof Stability." 27th U.S. Symp. on Rock Mechanics, 1986.

"A Study of Ground Control Problems in Coal Mines with High Horizontal Stresses." 21st Annual U.S. Symp. on Rock Mechanics, Rolla, MO, May 1980.

"Geotechnical Analysis of Underground Mining Methods for the Copper-Nickel Ore Bodies of NE Minnesota." Proc. 20th U.S. Symp. on Rock Mechanics, Austin, TX, June 1979.

"Pillar Design in Underground Oil Shale Mine." Proc. 16th U.S. Symp. on Rock Mechanics, University of Minnesota, MN; entitled "Design Methods in Rock Mechanics," September 1975.

Revised 11/29/07

AAI009982

BO YU
Senior Engineer

Education

B.S.	(Mining Engineering) Beijing University of Science and Technology, 1991
M.S.	(Mining Engineering) Beijing University of Science and Technology, 1994
Ph.D.	(Mining Engineering) West Virginia University, 2005

Experience

2005–Present Senior Engineer, Agapito Associates, Inc. Provides consulting engineering services to the mining and civil engineering industries in reserve/resource study, numerical modeling, in situ stress measurements, ground support design for underground mines, slope stability analysis, and geological modeling in dam design. Typical reserve/resource study projects include Anderson mine uranium resources project, General Chemical Anpeng alkali resource estimation project, PRC potash resource project for Rio Tinto, Potash resource estimation for Intrepid Potash-Wendover. Typical geotechnical modeling projects include Molycorp LHD ground support evaluation, PRC cavern stability study, U1A drift stability analysis.

2000–2005 Research Assistant, Department of Mining Engineering, West Virginia University, Morgantown, West Virginia. Assisted in designing the cutting head and cutting bits for continuous miners. Built the three-dimensional rotary cutting drum model and rock model in LS-DYNA3D to predict the interaction of a cutting drum with the rock/coal. Designed, installed, and tested a data recording system to acquire the cutting parameters (i.e. cutting force, penetrating force, vibration, noise, etc.) for a rotary cutting experiment. Designed the experiment procedure to evaluate the young's modulus of rock/coal on MTS without using strain gages.

1999–2000 Consultant, China Society of Hydroelectric Engineering. Developed concrete information system for Three-Gorges Construction Department of China. The objective was to visually manage the concrete placing procedure during dam construction. Implemented three-dimensional geological and GIS models for the design of Xiluodu Dam. Offered GIS lectures to engineers at Chengdu Hydroelectric Investigation and Design Institute of State Power Company, China.

1998–1999 Engineer, Beijing Fegen Finite Element Software Company, Beijing, China. Developed finite-element procedure and carried out numerical analysis of the deformation/stress distribution in pressure vessels. Participated in customer service, product support, and product training.

1994–1998 Lecturer and Engineer, Beijing University of Science and Technology, Beijing, China. Analyzed high, steep slope stability in an open pit mine using numerical simulation code. Carried out field experiments to evaluate the in situ stress in Chinese metal mines. Both hydrofracturing and overcoring techniques were used in these measurements. Evaluated the underground cut-and-fill mining methods adopted by Jinchuan Nickel Mine, which is the largest underground nickel mine in China. Predicted the possibility of sudden ground subsidence in a gold mine. Conducted geological field investigation, instrumented multi-point displacement gages in underground observation borehole to monitor the surrounding rock movement. Developed two-dimensional finite-element model for rock excavation. This program was combined with AutoCAD for mining or civil engineers to estimate the stress and strain distribution around an underground opening.

Publications

"Numerical Modeling of Rock Ridge Breakage in Rotary Cutting," *Proc. of the 1st Canada-US Rock Mechanics Symposium*, Vancouver, Canada, May 27–31, 2007.

"Analytical Investigation of Shaft Damage at West Elk Mine," *Proc. 25th International Conference on Ground Control in Mining*, Morgantown, West Virginia, August 1–3, 2006.

"Evaluation of Ground Support Requirements for D Orebody LHD Block, Molycorp," *Proc. 41th U.S. Rock Mechanics Symposium*, Golden, Colorado, June 17–21, 2006.

"Transient Study of Continuous Miner Rock Cutting Process," *Proc., 3rd International Conference Mining Techniques 2003*, Krakow, Poland.

"Numerical Simulation of the Effects of Cutting Parameters on Rock/Coal Fragmentation," *Proc. 2nd International Conference Mining Techniques 2002*, Krakow-Arnica, Poland, September 2002.

"Effects of Dynamic Bit Impact and Contact on Rock," *ISRM International Symposium on Rock Engineering for Mountain Regions*, EUROCK 2002, Fundhal, Portugal, November 25–28, 2002.

"Results of In-Situ Stress Measurements and their Application to Mining Design at Five Chinese Metal Mines," *International Journal of Rock Mechanics and Mining Sciences*, April 2000.

"Field Investigation and FEM Analysis of Ground Subsidence in a Chinese Underground Gold Mine," *Journal of University of Science and Technology*, 7(1): 1–78, 2000.

"Experience of In-Situ Stress Measurement with Hydrofracturing and Overcoring Techniques in Ekou Mine, China," *International Journal of Rock Mechanics and Mining Sciences*, 34(2): 299–302.

Revised 10/19/07

J.F.T. AGAPITO
Principal

Education

A.C.S.M.	(Mining Engineering) Camborne School of Mines, England
M.S.	(Mine Ventilation/Mining Engineering) University of Missouri at Rolla
Ph.D.	(Rock Mechanics/Mining Engineering) Colorado School of Mines

Professional Memberships

Member, Society for Mining, Metallurgy, and Exploration, Inc.
Fellow, Institute of Mining and Metallurgy, England
Member, International Society for Rock Mechanics
Professional Engineer, States of Colorado and Washington

Experience

1994–Present	Principal, Agapito Associates, Inc. Involved in reviewing a wide variety of underground mining projects and in providing expert witness services in cases related to mine stability.
1978–1993	President, J.F.T. Agapito & Associates, Inc. Established geotechnical and ventilation consulting firm with gross sales exceeding one million dollars per year. Has worked on many projects for underground mines, both in soft and hard rock, has conducted research programs for government agencies, and was an expert witness in cases relating to ground stability. Extensive experience on ground control issues in longwall coal mining.
1976–1978	Independent consultant mining engineer. Responsible for projects in operating copper, trona, molybdenum, uranium and potash mines, and the evaluation of plans for large oil shale mines and the disposal of nuclear waste in deep geologic formations.
1974–1976	Associate, Golder Associates, Inc. In charge of the Grand Junction, CO office. Responsible for geotechnical projects in oil shale, coal, copper, trona, and scheelite underground mines.
1972–1974	Senior Rock Mechanics Engineer, Atlantic Richfield Company, Grand Valley, CO. Responsible for the organization and implementation of a rock mechanics program in a test mine for obtaining basic information for the structural design of a 66,000 tons per day oil shale mine. Design of ventilation plans for a commercial-scale oil shale mine.
1968–1972	Instructor, Colorado School of Mines, Golden, CO. Organization and teaching of Ventilation and Rock Mechanics courses, senior level.
1966–1968	Mine Research Engineer, White Pine Copper Company, White Pine, MI. Analysis of blasting and rock bolting problems. Design of mine openings and mining methods to efficiently exploit large, low-grade copper deposit.
1964–1966	Ventilation Engineer, White Pine Copper Company, White Pine, MI. Responsible for ventilation of large mine and surface plant. Design and monitoring of air distribution systems, and evaluation of subsurface air quality.
1958–1960	Miner and Technician, Beralt Wolfram & Tin, Ltd., Portugal and South Crofty, Ltd., England. General underground work, rock drill maintenance, and mining geology.

Selected Publications

"Stress Issues Impacting Design and Stability at OCI Wyoming's Big Island Trona Mine." 2003 SME Annual Meeting & Exhibit, Denver, CO, 23–25 February.

"Horizontal Stresses as Indicators of Roof Stability." 2002 SME Annual Meeting & Exhibit, Phoenix, AZ.

"Pre-failure Pillar Yielding." Mining Engineering, November 2002, and 2001 SME Annual Meeting & Exhibit, Denver, CO, 26–28 February.

"Five Stress Factors Conducive to Bumps in Utah, USA, Coal Mines." 19th Conference on Ground Control in Mining, Morgantown, WV, August 8–10, 2000.

"Dealing with Coal Bursts at Deer Creek." Mining Engineering, 31–37, July 1997.

"Recent Developments in Practice and Technology of Ground Stability Monitoring in Underground Mining." McGraw-Hill Yearbook of Science and Technology, 1995.

"Depth and Horizontal Stress Challenges at White Pine." SME Annual Meeting, Reno, NV, February 1993.

"Economic Benefits Gained by Rock Mechanics: Three Case Studies." Mining Engineering, 215–219, February 1991.

"Stability Evaluation During Bench Cut-and-Fill Mining of the B-Neath Zone at the Cannon Mine." SME Annual Meeting, Las Vegas, NV, February 1989.

"Two-Entry Longwall Gateroad Experience in a Burst-Prone Mine." American Mining Congress, MINExpo Int'l '88, Chicago, IL, April 1988.

"Improvements in Resource Recovery at Stauffer's Big Island Mine." Int'l Journal of Mining Engineering, 6:195–214, March 1988.

"Mine Design at the Cannon Mine: Integration of Operational Planning and Geomechanical Design." 1st Int'l Conf. On Gold Mining, Vancouver, B.C., Canada, November 1987.

"Ground Stability and Support in Block Caving Operations at Molycorp's Questa Mine." 28th U.S. Symp. on Rock Mechanics, July 1987.

"Pillar Stability in Large Underground Openings: Applications from a Case Study in Competent, Jointed Rock." Quarterly, 81(3), Colorado School of Mines, Golden, CO, July 1986.

"Construction and Geological Engineering of an Underground Ore Bin." 1985 RETC Proceedings.

Revised 4/23/2004

ARCHIE M. RICHARDSON
Principal

Education

B.S.	(Geological Sciences) Pennsylvania State University, 1974
M.S.	(Mining Engineering) Pennsylvania State University, 1978
Ph.D.	(Mining Engineering) Colorado School of Mines, 1986

Professional Memberships

Registered Professional Engineer, State of Colorado (#22294)
Member, Society for Mining, Metallurgy, and Exploration, Inc.

Experience

1998–Present — Principal and Manager of Engineering, Agapito Associates, Inc. Supervises group of civil/mining engineers, geologists, and engineering technicians. Provides consulting services in mining engineering with specialties in rock mechanics, mine ventilation, and mine access design for clients in hard rock, coal, stone, and industrial minerals industries. Performs due diligence reviews and provides expert witness testimony.

1990–1998 — Associate promoted to Senior Associate, Agapito Associates, Inc. Primarily assigned to management of mining projects. Involved in numerous coal projects including longwall rock mechanics to 2500-ft depths, longwall mine feasibility studies, ventilation, panel orientation studies; shield design, subsidence analysis, technical support for permitting, and coal reserves assessment. Managed design of three large-diameter shafts in support of a major mine expansion project. Participated in metal mining projects including ventilation design for a multilevel zinc mine, rock mechanics and ventilation consulting for several underground gold mines, ventilation design for a deep base metal mine with climate problems, and rock mechanics for an underground block caving molybdenum mine. Typical industrial minerals projects included production system simulations, ground control studies, ventilation engineering and ore bin design in support of major trona mine expansion project, longwall feasibility studies for two room-and-pillar trona mines, and shaft design and bid package preparation for proposed new trona project.

1988–1989 — Professional Associate, Parsons Brinckerhoff Quade & Douglas, Inc., San Francisco, CA. Acting Supervisor of geotechnical design projects for Yucca Mountain Project (YMP) repository. Task Leader for various mining and geotechnical projects including evaluating proposed technology for sealing underground openings. Participated in cast-in-place and precast concrete liner design for the Boston Outfall Project.

1986–1988 — Lead Engineer, Parsons Brinckerhoff Quade & Douglas, Inc., San Francisco, CA. YMP Task Leader for various tasks including a multi-organizational effort to develop design methodology for concrete shaft liners. For a joint U.S./Canadian project at the Underground Research Laboratory in Manitoba, participated in the design of a heated block test. Participated in a technical feasibility study regarding reopening a large underground copper mine.

1982–1986 — Instructor and Research Associate, Colorado School of Mines, Mining Department, Golden, CO. Exxon Educational Foundation Instructor of Mining. Instructed a required undergraduate course in mine ventilation and supervised the mine ventilation laboratory. Principal Investigator on an underground research project to develop excavation technology in crystalline rock. Technical accomplishments included

	conducting and analyzing an *in situ* block test at the CSM Experimental Mine as part of Doctoral research.
1979–1982	Associate Project Engineer promoted to Project Engineer, Dravo Engineers and Constructors, Denver, CO. Project engineering in support of major shaft sinking project. Participated in full-scale feasibility studies for oil shale mine layouts. Performed ventilation analysis for several mines including a uranium mine and a proposed million ton per year coal project in Bulgaria.
1978–1979	Research Assistant, Pennsylvania State University, Mining Department, University Park, PA. In this full-time Post-Masters research-faculty position, managed rock mechanics research project involving underground natural gas storage in salt formations for the American Gas Association. Assisted with various laboratory and field-oriented research projects and with undergraduate rock mechanics courses.
1973–1975	Summer employment as Coal Miner (Greenwich Collieries), Geological Field Assistant (Johns Manville Exploration), and Driller's Helper (Pennsylvania Drilling Company).

<u>Selected Publications</u>

"Rock Mechanics Issues in the Trona Patch" 18th Int'l Conf. on Ground Control in Mining, Morgantown, WV, in press.

"A Study of Periodic Weighting of Longwall Supports." 17th Int'l Conf. on Ground Control in Mining, Morgantown, WV, August 1998.

"Use of Block Models for Longwall Shield Capacity Determinations." Proc. of the N. American Rock Mechanics Symp., ISRM, Cancun, Mexico, June 1998.

"Ventilation Planning at the Aberdeen Mine." 6th Int'l Mine Ventilation Congress, Pittsburgh, PA, 1997.

"The Influence of Massive Sandstones in the Main Roof on Longwall Support Loading." 15th Int'l Conf. on Ground Control in Mining, Golden, CO, 1996.

"Recent Developments in Practice and Technology of Ground Stability Monitoring in Underground Mining." McGraw-Hill Yearbook of Science and Technology, 1995.

"Ventilation Planning for the El Mochito Mine." Proc. 6th U.S. Mine Ventilation Symp, Salt Lake City, UT, June 1993.

"Application of Numerical Methods in Design of Mining Shafts and Tunnels: Selected Case Histories." Tunneling '91 Conf., London, April 1991.

"Considerations for Selecting Shaft Linings." Proc. Int'l Conf. on Shaft Drilling Technology, Las Vegas, May 1990.

"Seismic Design of Shaft Linings." Proc. Symp. on Recent Developments in Lifeline Earthquake Engineering, Honolulu, July 1989.

"An Interpretation of Widely Scattered Stress Measurements in Jointed Rock." Symp. on Stress Measurements, Stockholm, September 1986.

"A Mechanical Study of the Influence of Joints on Block Test Results." Proc. Int'l Symp. on Fundamentals of Rock Joints, Bjorkliden, September 1985.

"Design of Permanent Ground Support Structures for Shafts at Cathedral Bluffs Project." Trans AIME, Vol. 274, 1984.

Revised 3/18/99

REX R. GOODRICH
Associate

Education

B.S.	(Geology) Mesa College
B.S.	(Computer Science) Mesa College
M.S.	(Mechanical Engineering/Computational Solid Mechanics) Colorado State University

Professional Memberships

Registered Professional Engineer (Civil) (PE)
Registered Professional Geologist (PG)
American Rock Mechanics Association
American Society of Civil Engineers
Society of Mining Engineers

Experience

2/98–Present	Associate, Agapito Associates, Inc.
6/94–1/98	Senior Engineer, Agapito Associates, Inc.
Jan–May 1994	Project Engineer, Agapito Associates, Inc.
1984–1993	Geotechnical Computer Analyst, J.F.T. Agapito & Associates, Inc.
1983–1984	Hydrologic Technician, U.S. Bureau of Reclamation, Grand Junction, CO.
1981–1983	Junior Geologist, J.F.T. Agapito & Associates, Inc.

Experience Summary

Eighteen years cumulative experience with Agapito Associates, Inc. as engineer, computer analyst, and geologist. Primary duties are engineering, analyses, marketing, planning, and management of small groups involved with specific engineering and geological projects. Projects include engineering, numerical analysis, geological interpretation, and data collection related to underground stability. Experience includes stability evaluations for underground excavations in soft and hard rock, subsidence, solution mining, and geological interpretation. Soft rock experiences include longwall and room-and-pillar mining in coal, trona, and salt. Hard rock experiences include block caving, open stope, cut-and-fill, and stope-and-fill. Solution mining experiences include salt, nahcolite, potash, and secondary recovery of copper. Stability evaluations for solution mining include cavern spacing, protection of subsurface resources, and subsidence; also heat transfer and thermal- mechanical issues related to rock. Geological experiences include resource evaluation and structural evaluation and interpretation. Experience also includes part-time marketing and sales for Agapito Drilling, Inc.

Solution Mine Design Experience: Conducted stability evaluations for cavern/leached zone stability. Issues related to stability include cavern dimensions, cavern roof and walls, well-field layout, well spacings, placement of barrier pillars, and potential impacts to overlying resources such as aquifers, mineable seams, and subsidence. Stability issues for several clients include thermal-mechanical effects; thermal calculations of energy losses of a heated injection liquor in well bores and during cavern development; optimization modeling for cavern growth; and core hole summary reports of exploration holes and resource evaluation. Nahcolite clients include American Soda, Dennison Resources, AmerAlia, and White River Nahcolite. Potash and halite clients include Intrepid Oil and Gas and Vulcan Chemicals.

Underground Mine Design Experience: Areas of design experience include structural mine design and layout of longwall mining in coal and trona; structural mine design of room-and-pillar mining in coal, trona, oil shale, and hard rock; structural mine design for open stope and overhand and underhand stope with cemented and uncemented backfill; stability evaluation and design of solution-mined cavities; and structural design of tunneling for a nuclear waste repository with thermal-mechanical loading. Other design experience includes tunnel support systems, foundation design in underground mining, mine production optimization and simulation, and mine ventilation design and simulation.

Computational Experience: Much of the design experience includes computer modeling and numerical analysis. Experienced using elastic and nonlinear constitutive models with finite-element, boundary-element, finite-difference, and distinct-element methods. Model development experience includes the implementation of plasticity, joint, and bolt models. Computer modeling experience includes surface water discharge, confined and unconfined aquifers, and contaminant transport in groundwater. Proficient in computer software engineering and development, including computer graphics. Developed and implemented several large computer graphics programs designed for data reduction and pre- and post-processing results from numerical analysis computer models.

Field Experience: Field experience includes site visits to various mines for observations of conditions with respect to stability and structural design. Conducted overcoring stress measurements and installed and monitored stress and deformation instrumentation in rock. Geological and hydrological field experience consists of lithological and structural core logging, data collection, and hydrological well site tests.

<u>Selected Publications</u>

"Five Stress Factors Conducive to Bursts in Utah, USA, Coal Mines." Proc. 9th Int'l Congress on Rock Mechanics, August 1999.

"Long Load Transfer Distances at the Deer Creek Mine." Proc. 37th U.S. Rock Mechanics Symp., June 1999.

"Subsidence Behavior at the SUFCO Coal Mine, UT." Proc. 37th U.S. Rock Mechanics Symp., June 1999.

"Long-Term Stability for Two-Seam Mining at OCI's Big Island Mine." SME Annual Meeting and Exhibit, March 1999.

"Longwall Mining Through a Graben with Anomalous Stresses at the Deer Creek Mine." NARMS 98, Cancun, Mexico, June 1998.

"Dealing with Coal Bursts at Deer Creek." Mining Engineering, July 1997.

"The Effect of Entry Spacing, Rock Strength and Horizontal Stress on the Roof Stability of Multiple Parallel Excavations." Colorado State University, Mechanical Engineering Dept., M.S. Thesis, 1994.

"Yucca Mountain Site Characterization Project: New Three-Dimensional Far-Field Potential Repository Thermomechanical Calculations." SAND92-0589, Sandia National Laboratories, Albuquerque, NM, 1993.

"Fault Stress Analysis for the Yucca Mountain Site Characterization Project." Proc. Annual Nuclear Waste Conference, Las Vegas, April 1992.

"Solution Mining Cavity Stability: A Site Investigation and Analytical Assessment." Proc. Int'l ISRM EUROCK '92 Symp. on Rock Characterization, Chester, U.K., 1992.

"Documentation and Verification of STRES3D, Version 4.0." SAND89-7023, Sandia National Laboratories, Albuquerque, NM, 1991.

"Preliminary Drift Design Analyses for Nuclear Waste Repository in Tuff." Proc. 31st Rock Mechanics Symp., Golden, CO, June 1990.

Revised 3/10/99

BRIAN F. McGUNEGLE
Senior Associate

Education

B.S.	(Mining Engineering) Michigan Technological University, 1966
M.S.	(Rock Mechanics/Mining Engineering) Michigan Technological University, 1970

Professional Memberships

Member, Society for Mining, Metallurgy, and Exploration, Inc.
Member, Colorado Mining Association
Registered Professional Engineer, State of Colorado (#30961)

Experience

1998–Present Senior Vice President and Senior Associate, Agapito Associates, Inc. Conducted engineering studies and mine planning projects for clients in Mexico, Russia, and China. Continued activities performed as an Associate.

1991–1998 Associate, Agapito Associates, Inc. Provide consulting engineering services to the mining industry in the areas of mine engineering, mine planning, rock mechanics design, material handling, mine ground control, and general mine operations. Client projects include ground control problem resolution for operators in coal, limestone, fertilizer and industrial minerals, evaporite, and hard rock mines. Studies and reviews of mine designs and backfill systems for room-and-pillar, open stope and slot-and-fill mining methods. Reviews and investigations have been completed addressing coal bounce events and bounce potential. Conducted inspections and reviews of ground conditions and provided ground control recommendations for coal longwall and pillar recovery operations. Mine plan reviews applying longwall techniques and coal mine subsidence and ventilation studies have also been performed. Developed short- and long-range mine plans, prepared operating and capital cost estimates, and made equipment selection recommendations.

1980–1991 Manager, Technical Services, Unocal Corp., Energy Mining Division, Oil Shale Operations, Parachute, CO. Management of mine engineering and planning, project engineering, process engineering, construction, metallurgical engineering and inspection, computer service, and analytical laboratory functions supporting the start-up and operation of a grass roots syncrude production facility.

Superintendent, Mining Engineering and Planning. Developed preliminary staffing plans for the Mine Engineering and Planning Department. Reviewed mine geotechnical designs, equipment requirements, and mine production plans and schedules for the development and operation of an underground room-and-pillar mine to supply 14,000 TPD of oil shale for processing.

1973–1980 Manager, Technical Services, White Pine Copper Division, Copper Range Company, White Pine, MI. Responsible for the direction of the engineering, analytical laboratory, product quality control, and metallurgical research functions to support mining, milling, and smelting operations. The Technical Services Department consisted of the Plant Engineering, Electrical Engineering, Industrial Engineering, Mine Planning and Engineering, Metallurgical Research, and the Analytical and Quality Control Laboratory groups.

Manager of Mine Engineering and Planning responsible for directing the mine engineering efforts including surveying, rock mechanics, ventilation, long- and short-

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range mine planning, and the design of mine conveyor systems to support mine production operations.

Superintendent of Crushing and Conveying responsible for safe operation, maintenance, and construction of crushing and conveying facilities to transport the ore from the faces to the surface.

Ground Control Supervisor responsible for the direction of the applied rock mechanics program supporting an underground room-and-pillar copper mine production up to 25,000 TPD. Conducted interfaces with MSHA and county regulatory personnel concerning ground control issues.

1971–1973 Mine Engineer, Union Carbide Corp., Mining and Metals Division, Bishop, CA. Responsible for production and development layouts, surveying, long hole drilling patterns, and implementation of a shotcrete application system for an underground tungsten mine utilizing long hole sublevel open stoping methods. In addition, coordinated the layout and start-up of a sublevel caving mining system.

1970–1971 Senior Mining Engineer, Jackson County Iron Company, Subsidiary Inland Steel Company, Black River Falls, WI. Supervised engineering, surveying, and engineering technician functions in support of open pit iron mining and processing plant operations. Developed plans and layouts for the open pit mine, tailings disposal, and waste placement operations.

1968–1969 Senior Mining Engineer, Inland Steel Company, Ore Mining Division, Iron River and Crystal Falls, MI. Supervised the general mine engineering support for two underground iron ore mines producing 1000 to 1200 TPD utilizing sublevel open stoping methods.

1966–1968 Junior Mining Engineer, Inland Steel Company, Ore Mining Division, Iron River and Crystal Falls, MI. Conducted routine underground mine surveying, mapping, and grade control sampling. Developed long hole drill patterns, conducted surface subsidence surveys, and shaft alignment surveys.

1965–1966 Mine Engineer, Copper Range Company, Champion Division, Painesdale, MI. Provided surveying, incentive measurements, bonus calculations, and general engineering services for an underground copper mine producing 800 to 1000 TPD utilizing shrinkage stoping methods.

Selected Publications

"Rock Mechanics/Ground Control Methods, Unocal Long Ridge Mine." American Mining Congress, 1990.

"Union Oil Company's Parachute Creek Shale Oil Program." 15th Oil Shale Symp., Golden, CO, 1981.

"Utilization of Rock Mechanics by Management." 15th Symp. on Rock Mechanics, Rapid City, SD, 1973.

"Restricting Structural Damages Caused by Mining." Michigan Technological University, M.S. Thesis, 1970.

Revised 2/21/03

DAVID P. CONOVER
Senior Physicist

Education

B. S. (Engineering Physics) Colorado School of Mines, 1973.

Experience

7/2004–Present Associate, Agapito Associates, Inc. Similar responsibilities and work assignments as previously performed at NSA Geotechnical Services, Inc.

1996–7/2004 Senior Mining Engineer, NSA Geotechnical Services, Inc., Golden, CO. Developed embedded system softwar3e and interface designs for microcontroller-based seismic sensors associated with the ATP resea4rch and development project. Expanded the GeoGuard™ system into an integrated package for monitoring and predicting longwall shield pressures through an Allen-Bradley monitoring network. Developed other Windows-based software for clients, involving the evaluation of performance and costs for roof support systems (STOP), longwall shield supports (SHIELD), and trenching machine projects (K-Trench). Developed techniques for estimating mechanical miner (roadheader, TBM, and bore-miner), production and production rates, and operating costs. Developed other in-house software for data conversion, processing, analysis, and display. Conducted GPS surveys with error-correction analyses for various RockVision™ projects. Developed ground control designs relating to pillar sizing, roof support systems, and panel layouts for coal mines throughout the U.S. and in Australia. Conducted numerical modeling analyses of various mine structures using MULSIM/NL, UDEC, and FLAC models and applied established empirical methods for evaluating ground stability. Conducted overcoring stress measurements using USBM borehole deformation gauge and hollow-inclusion strain cells.

1984–1996 Mining Engineer, U.S. Bureau of Mines, Denver, CO. Was instrumental in research and development of the GeoGuard™ ground control management system for real-time monitoring and evaluation of geotechnical stability. Accomplishments included installation improvements, operating enhancements, and development of software for processing, evaluating, and presenting real-time monitored data. Adapted artificial intelligence (neural network) and virtual reality technology for ground control applications. Conducted ground control evaluations of longwall and room-and-pillar coal mining operations in Colorado, Utah, Illinois, West Virginia, and Alabama. Applied numerical modeling techniques to assist in ground failure analyses. Had a key role in installing the GeoGuard™ system at the DOE/WIPP nuclear waste repository and provided technical review of ground control issues for NRC relative to the Yucca Mountain nuclear waste repository. Was project leader for initial GeoGuard™ installation, and laboratory and field investigations.

1979-1984 Mining Engineer, Science Applications, Inc., Golden, CO. Conducted feasibility analyses for oil shale projects in Colorado, Utah, Canada, and Morocco, consisting of engineering designs, rock mechanics evaluations, equipment selection, and cost estimates. Participated in a groundwater study for monitoring hazardous waste migration. Developed blasting design and explosive selection software. Operated an oil shale research mine involving hands-on mining activities and documentation of production statistics.

1976-1979 Mining Engineer, Bedix Field Engineering Corporation, Grand Junction, CO. Conducted monitoring of 43 DOE uranium lease tracts in Colorado, Utah, and New Mexico for verification of royalty production and compliance with environmental and reclamation requirements. Reviewed mining and reclamation plans for technical feasibility. Collected and maintained surveying data for each tract.

1973-1976 Mining Engineer, Occidental Oil Shale, Inc., Grand Junction, CO. Directed a rock fragmentation research program consisting of underground blasting and screening tests and numerical modeling studies. Maintained production statistics for both research- and commercial-scale operations. Ensured that both operations complied with MSHA regulations. Conducted ventilation surveys and designed ventilation systems for both mines.

Selected Publications

"The NIOSH Shield Hydraulics Inspection and Evaluation of Leg Data (Shield) Computer Program," Proceedings of 21st International Conference on Ground Control in Mining, Morgantown, WV, August 2002.

"Three-Dimensional Tomographic Imaging of Geologic Structure in Exploratory Studies Facility," 38th Rock Mechanics Symposium, Washington D.C., July 2001.

"Application of Advanced Technologies in Delineate Hazardous Geologic and Stress Conditions in Coal," 17th International Mining Congress, Ankara, Turkey, June 2001.

"Shield Monitoring to Forecast Severe Face Weightings at the South Bulga Colliery, NSW, Australia," Proceedings of 18th International Conference on Ground Control in Mining, Morgantown, WV, August 3–5, 1999.

"Shield Pressure Monitoring—A Key to High-Production Longwall Mining Systems," Proceedings of 8th International Symposium on Mine Planning & Equipment Selection, Dnipropetrovsk, Ukraine, June 15–18, 1999.

"Shield Pressure Monitoring—A Key to High-Production Longwall Mining Systems," Proceedings of Advanced Tools & Monitoring Techniques for Mechanized Longwall Mining Conference, Katowice, Poland, October 1998.

"Identifying Physical Property Trends in Coal Mine Structures Using Portable On-Site Devices," USBM Information Circular 9598, 1995.

"Evaluation of an Alternative Longwall Gate Road Design," USBM Report of Investigations 9541, 1995.

"Integrated Shield and Pillar Monitoring Techniques for Detecting Catastrophic Failures," Proceedings USBM Technology Transfer Seminar, USBM Special Publication 01-95, 1995.

"Integrated Monitoring and Analysis Techniques for Detecting Longwall Panel Ground Hazards," Proceedings 3rd International Symposium on Mine Mechanization and Automation, 1995.

"Computer-Assisted Ground Control Management System," USBM Information Circular 9408, 1994.

"Shield Pressure Monitoring to Detect Longwall Ground Control Hazards," Proceedings of 4th Conference on Ground Control for Midwestern U.S. Coal Mines, 1992.

"Ground Control Management System for High Speed Longwall Mining," Proceedings of 1st International Symposium on Mine Mechanization and Automation, 1991.

"Mine-Wide Physical Property Trend Identification Using Portable, On-Site Test Devices," Proceedings of 10th International Conference on Ground Control in Mining, 1991.

"Mine-Wide Monitoring Applications in Ground Control Research," Proceedings of 9th International Conference on Ground Control In Mining, 1990.

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HUA ZHAO
Project Engineer

Education

B.S.	(Applied Mechanics) Beijing University of Science and Technology, 1993
M.S.	(Applied Mechanics) Beijing University of Science and Technology, 1997
	(Mining Engineering) West Virginia University, 2005
Ph.D.	(Applied Mechanics) West Virginia University, 2005

Experience

2006–Present Project Engineer, Agapito Associates, Inc.

2003–2005 Graduate Research Assistant, Department of Mining Engineering, West Virginia University, Morgantown, West Virginia. As part of a team, conducted research on in-mine validation of method determining characteristics of coal seam using electromagnetic transmission. Project won the prestigious *R & D 100 Award* for 2004 from R&D Magazine. The honor is for the year's 100 most important projects from science and industry.

- Validated the radio imaging method (RIM) interpretations against the collected geological data using the electromagnetic theory and statistic methods.
- Built 3D models of geological anomalies using AutoCAD.
- Created geological anomaly contour maps using Surfer.

2001–2005 Graduate Research Assistant, Mechanical and Aerospace Engineering Department, West Virginia University, Morgantown, West Virginia. Conducted research for dissertation on Friction Stir Welding (FSW) for joining the same and dissimilar aluminum alloys.

- Developed three-dimensional (3D) finite element models to simulate the large deformation dynamic FSW process using an Arbitrary Lagrangian-Eulerian (ALE) moving mesh approach. Commercial software used: LS-DYNA and ANSYS.
- Provided a mesh motion scheme for simulating the large deformations of the work pieces being joined during FSW.
- Predicted the material flow behavior in the friction stir welds of the same and dissimilar aluminum alloys using the moving mesh approach.
- Assessed the material flow patterns in the different material models.
- Analyzed friction effect on the material flow patterns.
- Verified finite element simulation results with experimental data.

1997–2000 Software Engineer, Beijing FEGEN Software Co., Ltd., Beijing, China. Worked with a team of engineers to develop softwar package for finite element analysis, Vessel Analysis System (VAS).

- The work included developing thermo-mechanical, contact, fatigue models. Programming the pre-processor to generate a library of part models for different geometric vessels. Programming multifunctional interactive graphics display system. Programming postprocessor for automatically generating a report of finite element results.

1994–1997 Graduate Research Assistant, Mechanical Engineering Department, University of Science and Technology, Beijing, China. Developed 3D finite element models to analyze the strength and deformation of several types of rolling mill housings using finite element code, ALGOR. Designed new rolling mill housing and screw-down equipment with software, ALGOR and AutoCAD.

- Developed my own research project as first graduate student for my advisor.
- Successfully passed five tests to enter into the graduate program: Mathematics, English, Political, and two related to my major.

1993–1994 Mechanical Engineer, Jilin Ferroalloy Factory, Jilin, China.

- Designed machinery for electric furnaces using CAD software.
- Renovated equipment to make it more efficient.

1989–1993 Undergraduate Student, Mechanical Engineering Department, University of Science and Technology, Beijing, China.

- Designed a rolling mill stand for a special purpose.

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GARY L. SKAGGS, P.E., P.ENG.
Senior Associate

Education

B.S.	(Mining Engineering) Virginia Polytechnic Institute, 1969
MBA	University of Denver, 1986

Professional Memberships

National Society of Professional Engineers
Colorado Society of Professional Engineers
Society for Mining, Metallurgy, and Exploration, Inc. (SME)
- Professional Engineers Exam Committee (Past chair)
- Subcommittee on Accreditation and Curricular Issues
- Council on Accreditation and Education
- ABET Inc. Visitors Selection Committee

SME Foundation Board of Trustees—Professional Engineers Exam Committee Representative
Engineering Accreditation Commission–ABET, Inc. (Commissioner for SME representing mining engineering)

Association Memberships

Rocky Mountain Coal Mining Institute
Colorado Mining Association
National Mine Rescue Association (Life Member)

Experience

2006–Present	Senior Associate, Agapito Associates, Inc. Direct projects for new mine development in coal, limestone, and similar minerals. Develop mining strategies, shaft and access designs, select mining equipment, develop mine plans, prepare man-power estimates, and capital and operation costs. Optimize existing mine plans and mining operations. Support due diligence and provide consulting support to clients for evaluation of geologic prospects or operating mines.
2000–2006	Vice President and Senior Mining Consultant, Marston and Marston, Inc. Directed projects for coal and limestone development to prefeasibility and feasibility level. Provided high-level consulting services for strategic planning and served as expert witness, performed due diligence reviews of multi-mine operation targets, and supported mine permit applications. Conducted stand-alone, cash-flow analysis, risk assessment, and screening of potential acquisition prospects. Design and analysis of mining systems and infrastructure, mine safety audits, implementing productivity improvements and operation turn-arounds, and evaluating companies for merger and acquisition potential. Experience in eastern, mid-western, and western U.S. underground mine operations, and international experience in Australia, Canada, Mexico, and Ukraine.
1997–2000	Vice President Engineering, Stagg Engineering Services, Inc. Directed the engineering work for the company. Engaged in mine planning activities for coal and stone industries, conducted operations and safety audits, analyzed and prepared litigation support work for various projects, evaluated coal selling price models, benchmarked Utah/Colorado coal mines, and performed equipment analysis and replacement justifications for a large trona mining complex.

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1993–1997 Business Owner. Engaged in the practice of management and engineering consulting. Consulting assignments included projects in Ukraine, Mexico, Canada, and the United States. Principal projects have included:

- Evaluation of a subsidiary company President for performance and capability of position.
- Operation/production improvement audits for two large, multiple unit operations.
- Safety audits for a major eastern U.S. coal company embarked upon changing its safety culture.
- Multiple projects developing long-range business and operating plans.
- Equipment and facilities appraisals for an international bank.
- Operation assessments, safety, and production improvement, mining system infrastructure upgrade recommendations to double annual production at several Mexican operations.
- Cost model development for coal bed degasification.
- Development of plans to support expert witness testimony.
- Recommended belt conveyor system design changes for a new longwall mine.
- Evaluated longwall roof control issues for an undersea mine in Nova Scotia.

1991–1993 Vice President and General Manager–Potomac Division, Island Creek Corporation (Subsidiary of Occidental Petroleum Corp. that was acquired by CONSOL, Inc., in July 1993). Promoted to Vice President and General Manager of this $120 million (divisional) producer of bituminous coal as part of a mid-1991 restructuring program. This division was on the verge of losing one of its two major customers, representing 45% of the division's sales volume, due to product quality and production scheduling problems. In addition, efficiency improvements were required for cost reductions necessary to remain a competitive, profitable operation while absorbing a scheduled, mid-1993 sales price reduction of 22% from its other major customer.

The customer relations objective was achieved resulting in the operation winning this customer's "Quality Supplier of the Year" award for 1992, beating out all six other suppliers. The production efficiency objective was achieved by consolidating the three mines and their three separate local labor unions into one facility and one local labor union. To achieved the production efficiencies required, a complete rehabilitation and upgrading of the mine's infrastructure was accomplished, while maintaining operations and profitability. This consolidation permitted cost reductions of $3–$4.00/ton in late 1993. Initiated programs resulting in continuous miner unit productivity improvements of 44%. MSHA citation reductions of 50%, and environmental citation reductions of 89%.

1988–1991 Vice President Engineering, Island Creek Corporation. Recruited by the chairman and CEO to take over the corporate-wide engineering function of a $600 million plus mining company. Managed a functional budget of $10–$11 million and 165 employees, and annual construction and equipment budgets of $50 million plus, in a matrix organizational environmental.

Technological improvements introduced between 1988 and 1993 through team-oriented operations and engineering work groups improved longwall productivity at

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the corporation's longwall mines by over 77%, introduced continuous miners to West Kentucky Division with a cost savings of over $3.00/ton, and improved belt conveyor availability by over 20%.

Led the introduction of CAD, computer-aided mine planning, statistical and geostatistical analysis and quality forecasting. Implemented higher professional engineering and construction standards than was the previous norm.

1986–1988 Senior Staff Engineering Consultant, Cyprus Coal Co. Reported to the manager of mining and environmental engineering for this 14 Mtpy mining company. Primary responsibility was evaluation of underground mining merger and acquisition candidates from the operating, technical, safety, cost of production, and capital needs aspects. Identified improvements possible for economic evaluations. Team member of a profitable, union-free acquisition made in 1987.

1985–1986 Graduate Student/Part-time Consultant.

1982–1985 Manager Underground Engineering, Sunedco Coal Co. Recruited by the company's president to head an underground mining engineering design group for a newly acquired 230 million ton deep mine reserve in Utah. Design planning included capital, operating cost, and economic analysis for stage growth from 300,000 to 5 Mtpy levels. Supervised a staff of four professionals.

1979–1982 Manager Mining Engineering, The Youghiogheny and Ohio Coal Co. Recruited by the vice president of operations and engineering. Supervised a staff of eleven professional and technicians. Devised system and equipment changes resulting in 30% productivity improvements of mining units.

1976–1979 Senior Staff Engineer/Senior Engineer, Monterey Coal Co. Engineering design for two large (2–4 mm tpy, $90 to $140 million project capital) underground coal mines, including start-up activities. Served as mining advisor to civil, mechanical, and electrical design engineers. Joined company because of its ambitious growth plans and no expansion plans at UCC.

1966–1972
1973–1976 Assistant Mine Superintendent, Union Carbide Corporation. Responsible for mine management of three-unit mine employing 137 personnel (1975). Chief Industrial Engineer/Mining Engineer/Co-op Student (1966). Various engineering projects and first level supervision of production units.

1972–1973 Permit approvals. Initiated computer reporting of industry records. Technical advisor to the director.

Publications

In the course of his industry employment and consulting work, Mr. Skaggs has authored numerous unpublished papers and reports. As a member of SME's Professional Engineers Exam Committee, he has authored numerous engineering problems for use on the National Council for Examiners and Surveyor's national mining/mineral engineering Professional Engineer Principals and Practices (Part 2) engineering licensing examinations.

"Clean Air Act Amendments of 1990: An Eastern Coal Producer's View," (co-author), *Mining Engineering*, Littleton, CO, August 1992, pp. 994–998.

"Mine Design—Preparing for the Competition," Generic Minerals Technology Center, Virginia Polytechnic Institute and State University, Blacksburg, Virginia.

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