226-20 GENWAL Main West Barrier Mining Analysis DRAFT.pdf klg 9-21-07

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July 20, 2006

226-20

Mr. Laine Adair
Andalex Resources, Inc.
195 North 100 West
Huntington, UT 84520

Re: **DRAFT—GENWAL Crandall Canyon Mine Main West Barrier Mining Evaluation**

Dear Laine,

Agapito Associates, Inc. (AAI), has completed the geotechnical analysis of GENWAL Resources, Inc.'s (GENWAL) plan for room-and-pillar mining in the Main West barriers at the Crandall Canyon Mine (Figure 1). Current plans include developing four entries in the barriers north and south of the existing mains in the area west of the 1st Right/2nd North submains under cover ranging from about 1,300 ft to 2,200 ft. Barrier mining is also planned to the east between the 1st Right/2nd North and 1st North submains under generally shallower cover. Figure 1 shows the existing mine in green and planned mining in black. The objective of the analysis was to evaluate the potential for high-stress conditions caused by a combination of deep cover and side-abutment loads from the adjacent longwall gobs, and any load transferred onto the barriers from the existing pillars in Main West. Findings of the analysis and implications for pillar design and ground control are discussed.

CONCLUSIONS

Conclusions are that the proposed Main West 4-entry layout with 60-ft by 72-ft (rib-to-rib) pillars should function adequately for short-term mining in the barriers (i.e., less than 1 year duty). Model results indicate that planned mining in the barriers will avoid the majority of the side-abutment stress transferred from the adjacent longwall panel gobs. Stress conditions are expected to be controlled by the depth of cover and not by abutment loads.

The proposed 60-ft by 72-ft pillars are not intended for long-term performance and, therefore, can accept a reduced design safety margin compared to typical life-of-mine mains pillars. Analytical results indicate that the proposed pillars result in only incrementally more geotechnical risk than associated with the historical pillars in Main West. The historical 70-ft by 72-ft pillars in Main West have performed adequately for many years longer than will be required for mining the barriers. Because rib yielding and roof sag are time-dependent effects, it is probable that mining will be completed in the barriers before rib and roof conditions show advanced deterioration. The modern mining practices of GENWAL, including systematic bolting rapidly after excavation, bolting with 6 bolts per row, tight geometric control, mining with narrow entries (18 ft wide), and mining to rock instead of leaving top coal, should make this a workable design and limit geotechnical risk to an acceptable level. Increasing crosscut spacing is not expected to significantly improve ground control.

ANALYSIS

Ground conditions were simulated using the NIOSH displacement discontinuity code, LAMODEL.[1] The approach involved two stages of modeling, first, simulation of historical mining in the 1st North Left block of room-and-pillar panels and, second, simulation of future conditions in Main West. The historical and future mining areas modeled are highlighted in Figure 1. The models were 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.

Both models (historical and future mining areas) incorporated the mining geometry, sequence of mining, and variable depth of cover. To provide realistic pillar behavior, a high-resolution model was created using 5-ft-square elements. Coal strength was specified for eight levels of increasing confinement based upon depth into the rib, ranging from 2.5 to 37.5 ft.

In LAMODEL, the "method of slices" is applied to approximate the load bearing capacity of the pillars. This method assumes that the strength of any pillar element is a function of its distance from the nearest pillar rib and element size by:

$$\sigma_v = S_l[0.71 + 1.74(x/h)] \qquad \text{(Eqn. 1)}$$

where
σ_v = Confined coal strength
S_l = In situ rock mass unconfined strength
x = Distance from the nearest pillar rib
h = Pillar height

Peak strain in each element is calculated by:

$$\varepsilon_v = \sigma_v / E \qquad \text{(Eqn. 2)}$$

where
ε_v = Peak strain
E = Coal elastic modulus

Upon yielding, the residual stress and residual strain within a pillar element are calculated by:

[1] Heasley, K.A. (1998), *Numerical Modeling of Coal Mines with a Laminated Displacement-Discontinuity Code*, Ph.D. Thesis, Colorado School of Mines, 187 p.

$$\sigma_r = 0.2254 \times \ln(x) \times \sigma_v \qquad \text{(Eqn. 3)}$$

and

$$\varepsilon_r = 4 \times \varepsilon_v \qquad \text{(Eqn. 4)}$$

where σ_r = Residual stress
ε_r = Residual strain

The in situ unconfined coal strength and elastic modulus are estimated to be 1,640 psi, and 0.5×10^6 psi, respectively, for a 5-square-ft element. An average 8-ft pillar height, representative of actual and planned mining, was used in all models. The eight levels of confined coal strength and corresponding strain for a typical pillar, using Equations 1 through 4, are listed in Table 1.

Table 1. LAMODEL Confined Coal Strength

Confined Coal Distance into Rib (ft)	Confined Strength (psi)	Peak Strain	Residual Strength (psi)	Residual Strain
2.5	2,059	0.004	425	0.017
7.5	3,845	0.008	1,746	0.032
12.5	5,631	0.012	3,206	0.047
17.5	7,417	0.016	4,785	0.062
22.5	9,203	0.019	6,459	0.077
27.5	10,989	0.023	8,209	0.092
32.5	12,775	0.027	10,025	0.107
37.5	14,562	0.031	11,896	0.122

Other model properties are summarized in Table 2 and are based principally on previous modeling studies for the Crandall Canyon Mine.[2,3,4,5]

1st North Left Panels Back-Analysis

The historical mining area is relevant for calibrating the model for predicting future conditions in Main West because of (1) similar geologic conditions to that in Main West,

[2] Agapito Associates, Inc. (1995), "Technical Review of Longwall Feasibility," prepared for GENWAL Resources, Inc., November.

[3] Agapito Associates, Inc. (2000), "Barrier Pillar to Protect Bleeder for Panel 15, South of West Mains," prepared for GENWAL Resources, Inc., May 5.

[4] Agapito Associates, Inc. (1997), "Panel 6th Right Experiment Back Analysis and Model Calibration," prepared for GENWAL Resources, Inc., November 20.

[5] Agapito Associates, Inc. (2004), "GENWAL South Crandall Canyon Mine Gateroad Alternatives Geotechnical Study," prepared for GENWAL Resources, Inc., December 17.

Table 2. Input Parameters for LAMODEL

Overburden	
Deformation Modulus of Roof Rock (psi)	2,000,000
Poisson's Ratio of Overburden	0.25
Lamination Thickness of Overburden (ft)	25
Unit Weight of Overburden (pcf)	158
Coal	
Elastic Modulus of Coal (psi)	470,000
Poisson's Ratio of Coal	0.34
Strain Hardening Gob	
Initial Modulus (psi)	100
Final Modulus (psi)	76,000
Final Stress (psi)	4,000
Gob Height Factor	1
Poisson's Ratio of Gob	0.25

(2) significant depth of cover (up to 1,800 ft), and (3) similar mine geometry. The historical model area includes a barrier separating the mains from gob in the 9th Left panel at depths reaching 1,800 ft, which represents the same type of high-stress, side-abutment load transfer onto a barrier mechanism anticipated in Main West.

The 1st North Left model describes an area where room-and-pillar panels were retreated under relatively deep cover during the late 1990s. Ground conditions are reported to have been good during primary mining even with side-abutment loading from adjacent gob. Occasional pillars were left behind during retreat because of locally difficult ground conditions, mainly related to peeling top coal. This was compounded by large center-entry roof spans (reaching 22 to 23 ft) mined to accommodate the continuous haulage system in use at that time. Also, short 5-ft bolts and only 5 bolts per row were used in the panels, which is considered substandard for retreat mining compared to the mine's current practice. Conclusions are that, while retreat mining was overall successful, ground conditions could have been improved by mining the top coal. It is believed that this would have eliminated the need for leaving pillars in some locations.

Main West was recently mined northward into the barrier separating the mains from Panel 9th Left—1st North, leaving a 145-ft to 170-ft-wide barrier at a depth of about 1,600 to 1,800 ft. Ground conditions in the new entries are reported to be very good with no obvious effects of side-abutment load override across the barrier. Good conditions are also attributed to better mining practices than used in the historical panels to the north, including mining the top coal (rock roof), narrower entries (nominally 18-ft wide), and better roof bolting (6 bolts per row).

Modeling results presented in Figures 2 through 10 show vertical stress, coal yielding, and convergence for three stages of mining in Panel 9th Left, (1) when the panel was fully mined on the advance, and after the panel was (2) partly and then (3) fully retreated.

Figures 2, 3, and 4 show vertical stress, yielding, and seam convergence, respectively, during the first stage. Almost all remnant pillars in the north panels are shown to be fully yielded. The stresses in the centers of these pillars exceeded 10,000 psi, resulting in convergence greater than 2.0 inches. Pillars in Panel 9th Left show limited rib yielding. Seam convergence in the panel is computed by the model to be less than 1.6 inches and average vertical stresses within the pillars around 3,000 psi, reflecting an increase of about 800 psi above in situ stress levels.

At the second mining stage, pillars next to the gob at the retreat line are shown to be yielded (Figure 6) and converged more than 2.0 inches (Figure 7) in response to abutment stresses. Based on the experience in the panel with peeling top coal, 2.0 inches of convergence is considered an indicator of potential roof and rib instability in the model.

The third stage of mining in Figures 8, 9, and 10 shows 9th Left fully retreated and Main West mined into the barrier per the current geometry. The results show no significant side-abutment stress override across the barrier on to the mains pillars, consistent with actual conditions. Pillar rib yielding is shown to be minimal and roof convergence less than 1.0 inch in the vicinity of the barrier. This behavior is considered an indicator in the model of good ground conditions.

Main West Barrier Mining Predictive Model

Future mining in the north barrier of Main West was simulated using the same model properties from the back-analysis model. The Main West model was adjusted to include the actual depth of cover which ranges from about 1,600 to 2,200 ft. The area encompassed by the model is considered representative of the range of conditions expected throughout Main West, including planned mining in the barrier south of the mains.

Results of the model are shown in Figures 11 through 19. Mining was simulated in three stages: (1) current conditions before any new mining (Figures 11 through 13), (2) early during planned mining with development part way into the barrier (Figures 14 through 16), and (3) after the barrier is fully mined (Figures 17 through 19). Planned mining includes 18-ft-wide rooms with 60 ft by 72 ft (rib-to-rib) pillars. These dimensions were rounded to 20 ft and 60 ft by 70 ft, respectively, in the model because of the 5-ft element size. Notably, the models show mining into the existing Main West entries. This may or may not be the final design. This is a conservative assumption useful for analyzing the highest pillar loading.

For the current geometry, the model shows side-abutment stresses reaching as high as 30,000 psi in the northern interior of the existing 450-ft-wide barrier. Figure 20 shows two stress profiles (A-A′) through the barrier, one for the current geometry (magenta) and a second with planned mining in the barrier (blue). The location of Profile A-A′ is shown in Figure 14. For the current geometry, stress levels taper to near pre-mining (in situ) stress levels approximately 100 ft into the barrier, indicating that the proposed 130-ft-wide barrier will limit exposure of the planned entries and pillars to most of the abutment. Mining conditions are expected to reflect stress levels normally associated with development mining away from abutment stresses. Stress levels are expected to be controlled by the depth of cover, and not side-abutment stresses. This is consistent with the recent experience mining across the barrier from Panel 9th Left.

The proposed 60-ft by 72-ft (rib-to-rib) mains pillars are predicted to be about 7% weaker on average than the existing 70-ft by 72-ft pillars in Main West. This is based on five widely recognized empirical pillar strength formulas which show anywhere from a 1% to 12% drop in pillar strength with the 10 ft narrower pillar. Pillar strengths predicted by the various methods are summarized in Table 3.

Table 3. Reduction in Pillar Strength Based on Empirical Design Formulas

Empirical Formula	Pillar Design Strength: Existing 70-ft × 72 ft Pillars	Pillar Design Strength: Planned 60-ft × 72-ft Pillars	Existing to Planned Pillar Strength Change	
1,600 ft Deep				
Wilson Method	4,960 psi	4,800 psi	-160 psi	-3%
Abel Method	5,740 psi	5,690 psi	-50 psi	-1%
Bieniawski Method	3,910 psi	3,450 psi	-460 psi	-12%
ALPS-Bieniawski Method	3,410 psi	3,010 psi	-400 psi	-12%
Holland Method	3,060 psi	2,830 psi	-230 psi	-8%
			Average	**-7%**
2,200 ft Deep				
Wilson Method	6,730 psi	6,510 psi	-220 psi	-3%
Abel Method	7,370 psi	7,290 psi	-80 psi	-1%
Bieniawski Method	3,910 psi	3,450 psi	-460 psi	-12%
ALPS-Bieniawski Method	3,410 psi	3,010 psi	-400 psi	-12%
Holland Method	3,060 psi	2,830 psi	-230 psi	-8%
			Average	**-7%**

This reduced strength translates to slightly increased rib yielding (sloughage) and increased roof convergence. Figure 18 shows rib yielding predicted by the model. In the figure, rib yielding is limited to the corners of the existing 70-ft by 72-ft pillars (bottom two rows of pillars). In the proposed smaller pillars (top four rows of pillars), yielding occurs in the skin all the way around the pillar. However, the pillar cores are shown to remain competent in all locations, indicating acceptable pillar performance.

Figure 19 shows predicted roof convergence. Figure 21 compares centerline convergence along an entry in the existing mains (Profile B-B′) with an entry central to the new mining (Profile C-C′). Profile locations are shown in Figure 19. The figures show that the proposed smaller pillars result in up to a 0.15 inch increase in roof convergence in the intersections, or about a 15% increase, compared to historical conditions in Main West. This reflects the increased rib yielding around the smaller pillars.

Based on modeled convergence, ground conditions are expected to be heavier compared to conditions in the mains across from Panel 9th Left, and only slightly heavier than conditions in the existing Main West entries. This suggests there will be an increased reliance on roof support, particularly under the deeper cover (>1,800 ft). However, convergence is far below the 2.0-inch level associated with roof and rib instability established by the back-analysis model.

The existing 70-ft by 72-ft pillars in Main West have performed reliably over the long-term (several years) and are considered a successful design, including under the deepest 2,200-ft cover. Some deterioration has occurred locally in Main West. This is attributed to the same historical mining practices responsible for poor roof conditions in the 1st North panel, namely, leaving variable top coal, mining extra wide entries to accommodate the continuous haulage system, using short bolts, and only bolting with 5 bolts per row. Also, where angled crosscuts were mined, disintegration of the sharp pillar corners produced spans 10 to 20 ft wider than normal. In spite of some localized time-dependent roof falls, the 70-ft by 72-ft pillar design has demonstrated it success for ensuring long-term stability when properly mined. Given the reliability of the existing mains pillars and the results of modeling, the narrower 60-ft by 72-ft pillars are not expected to substantially increase geotechnical risk for short-term mining.

Model results indicate that increasing crosscut spacing does not significantly improve conditions. Figures 22 through 24 show stress, yielding, and convergence for a 60-ft by 80-ft pillar, representing about a 20-ft increase in pillar length (between crosscuts) over the proposed design. The increased length only incrementally reduces rib yielding, corresponding to a modest decrease in entry convergence of about 2% to 4%, as shown by comparison of convergence profiles in Figure 21.

Please contact me to discuss these results, at your convenience, or if you have any questions.

Sincerely,

[signature]

Leo Gilbride
Principal
gilbride@agapito.com

LG/smvf
Attachments(24): Figures 1–24

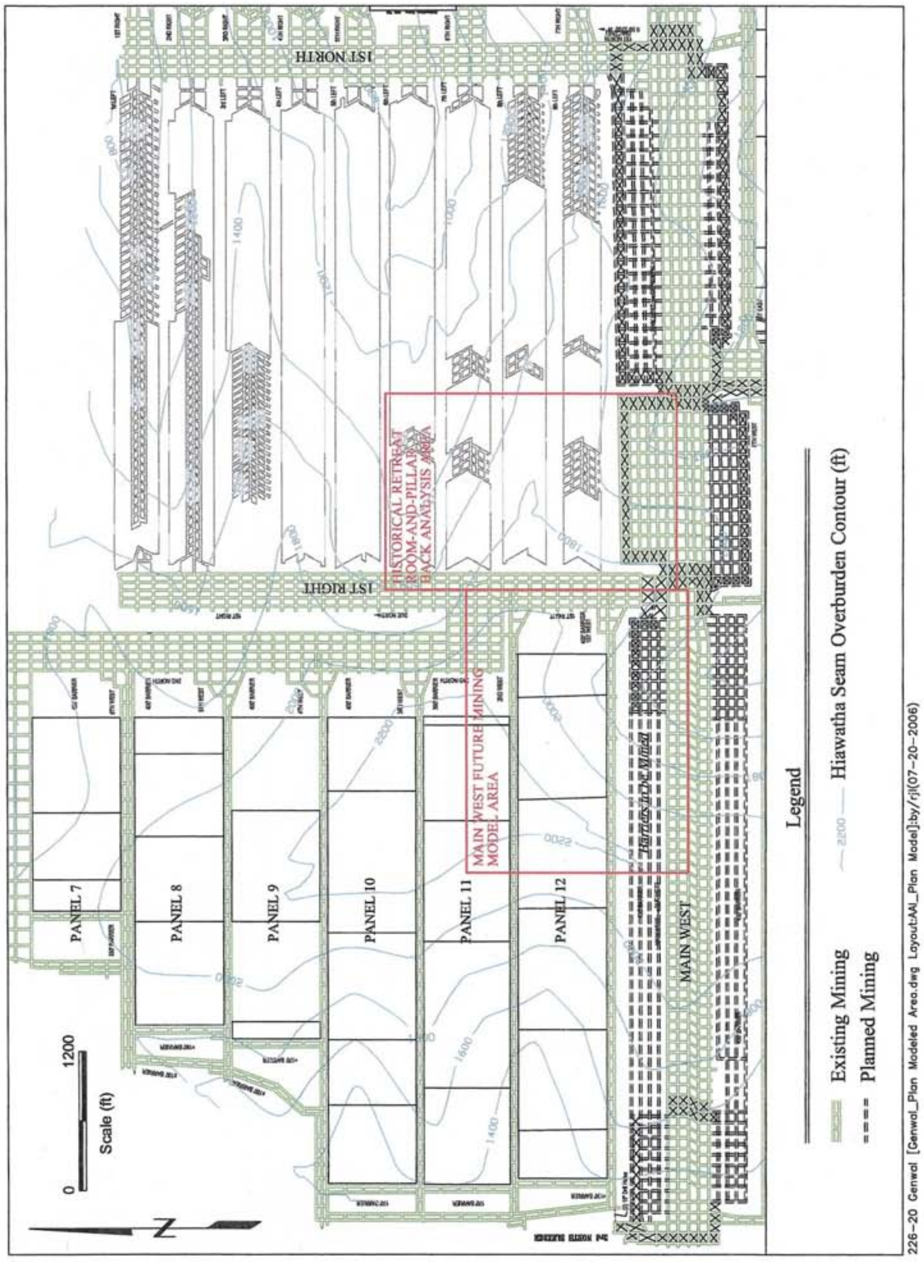

Figure 1. Main West Location Map Showing Existing and Future Mining and Modeled Areas

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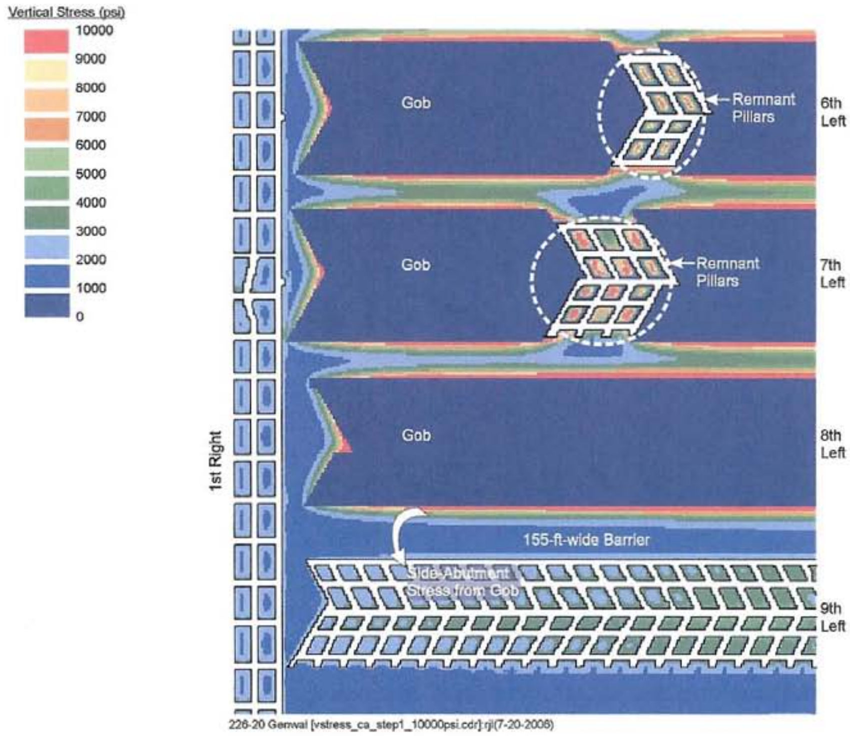

Figure 2. Modeled Vertical Stress—Primary Mining Completed in Panel 9th Left—1st North

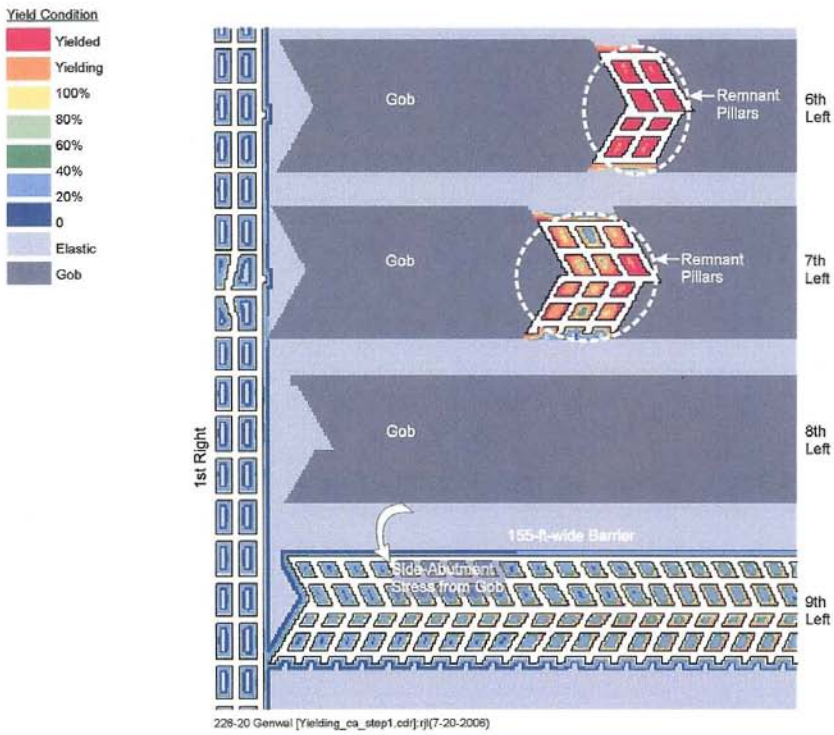

Figure 3. Modeled Coal Yielding—Primary Mining Completed in Panel 9th Left—1st North

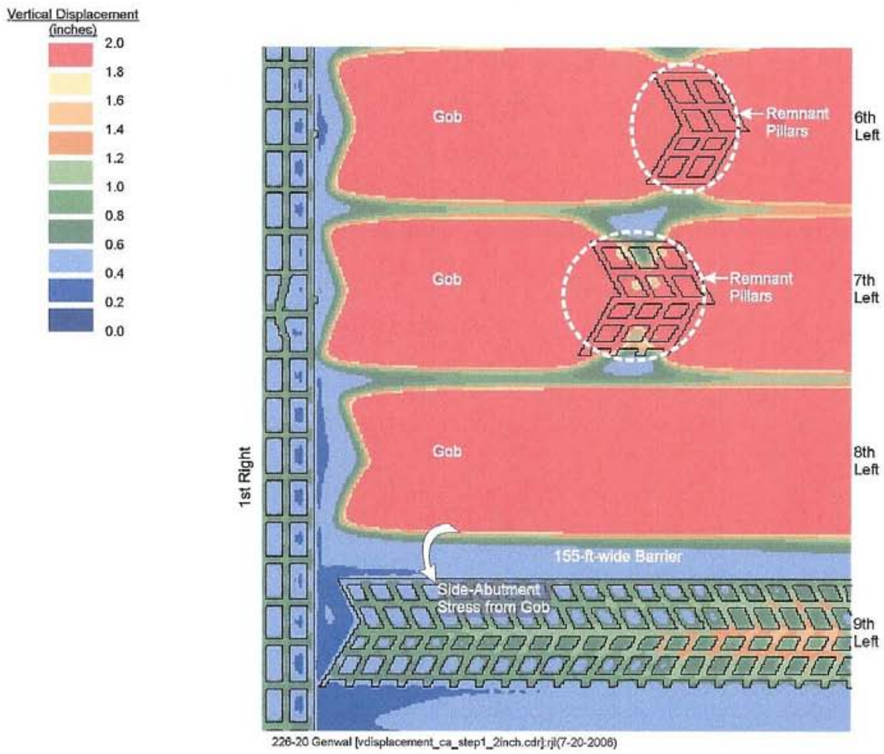

Figure 4. **Modeled Roof-to-Floor Convergence—Primary Mining Completed in Panel 9th Left—1st North**

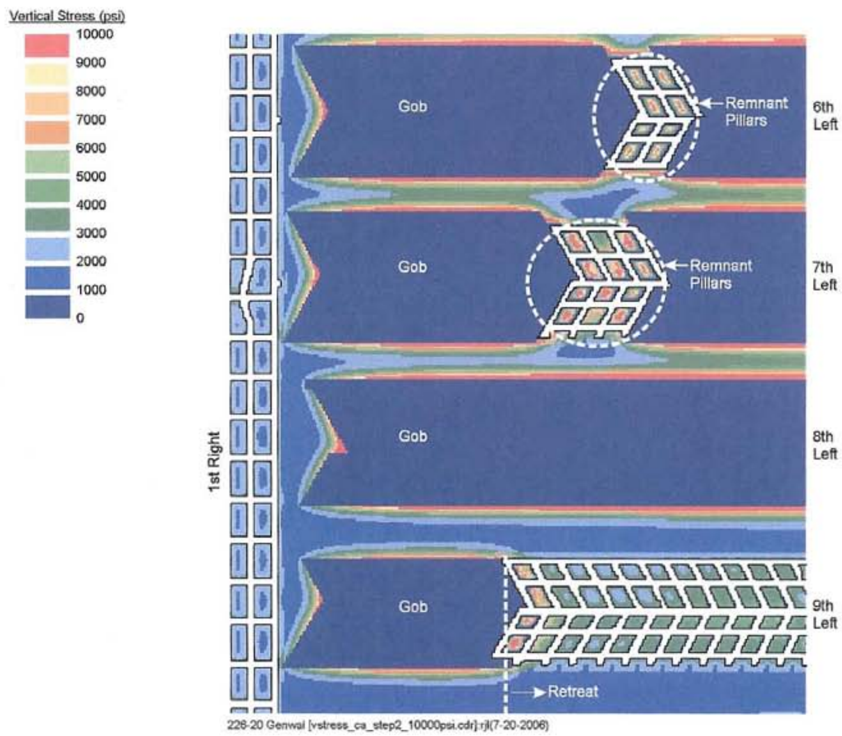

Figure 5. Modeled Vertical Stress—Partial Retreat in Panel 9th Left—1st North

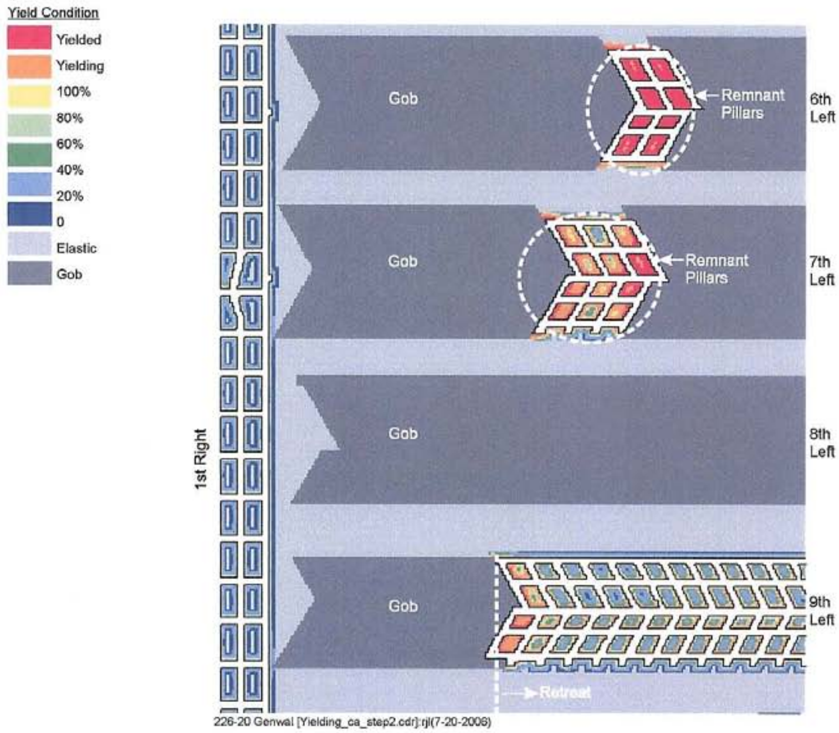

Figure 6. **Modeled Coal Yielding—Partial Retreat in Panel 9th Left—1st North**

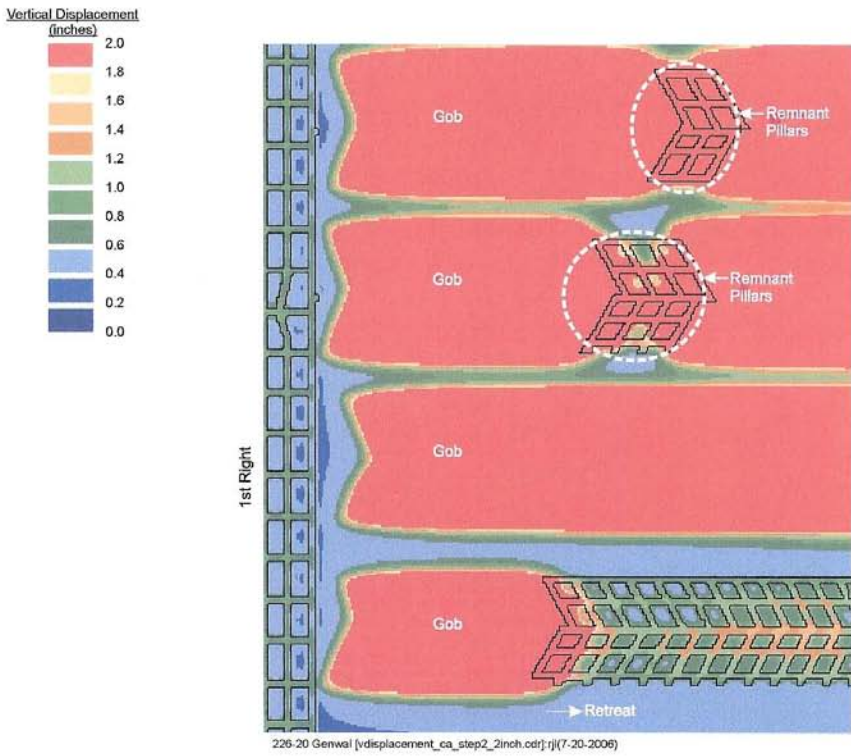

Figure 7. Modeled Roof-to-Floor Convergence—Partial Retreat in Panel 9th Left—1st North

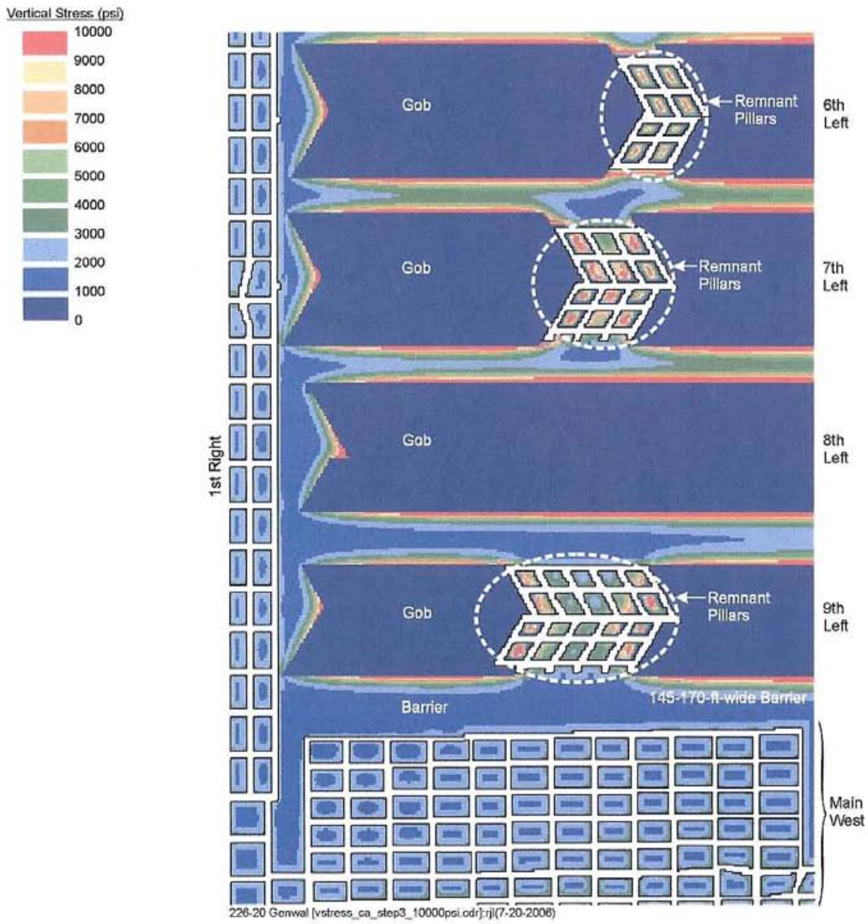

Figure 8. Modeled Vertical Stress—Retreat Completed in Panel 9th Left—1st North

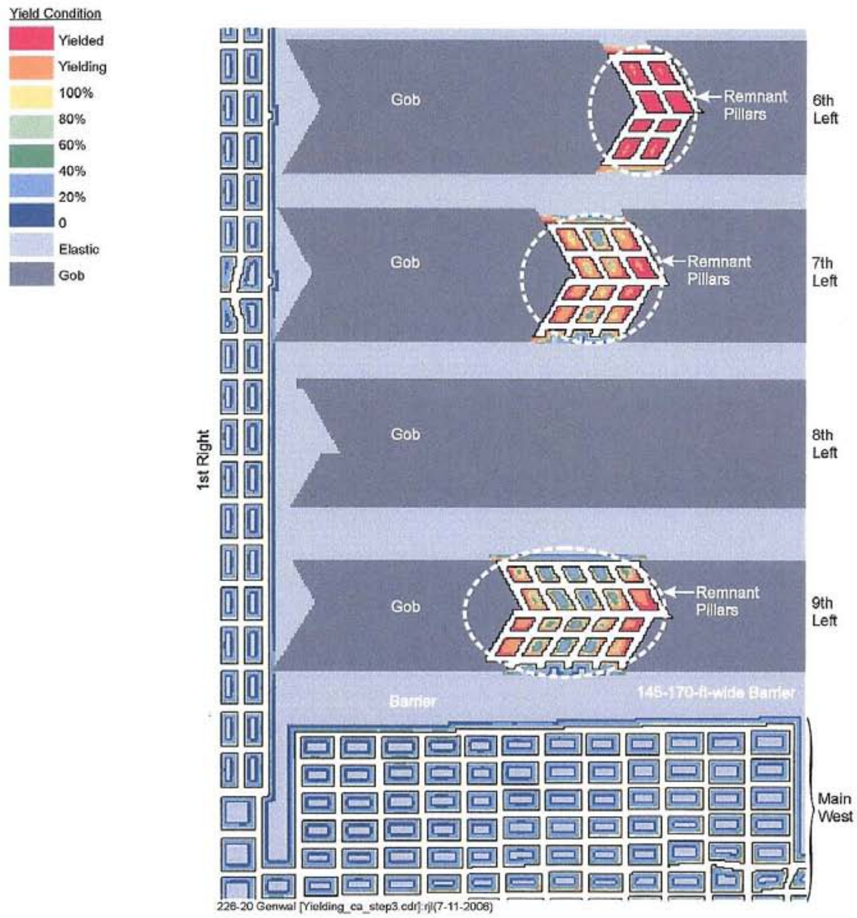

Figure 9. Modeled Coal Yielding—Retreat Completed in Panel 9th Left—1st North

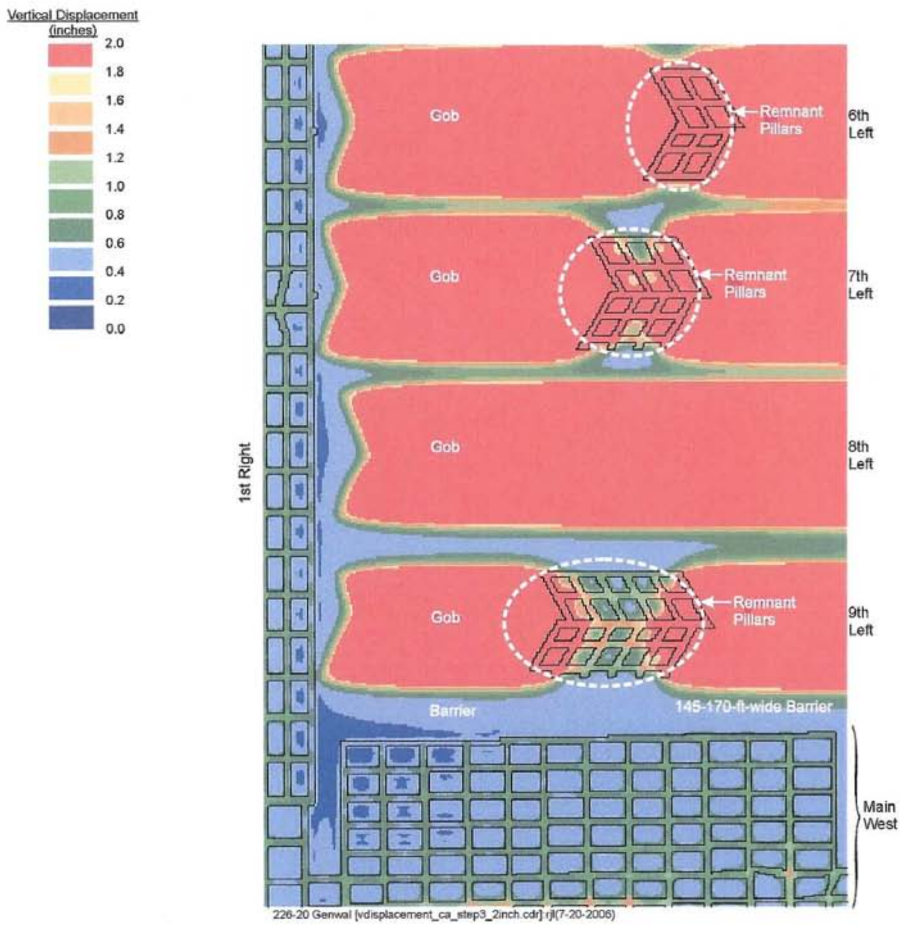

Figure 10. Modeled Roof-to-Floor Convergence—Retreat Completed in Panel 9th Left—1st North

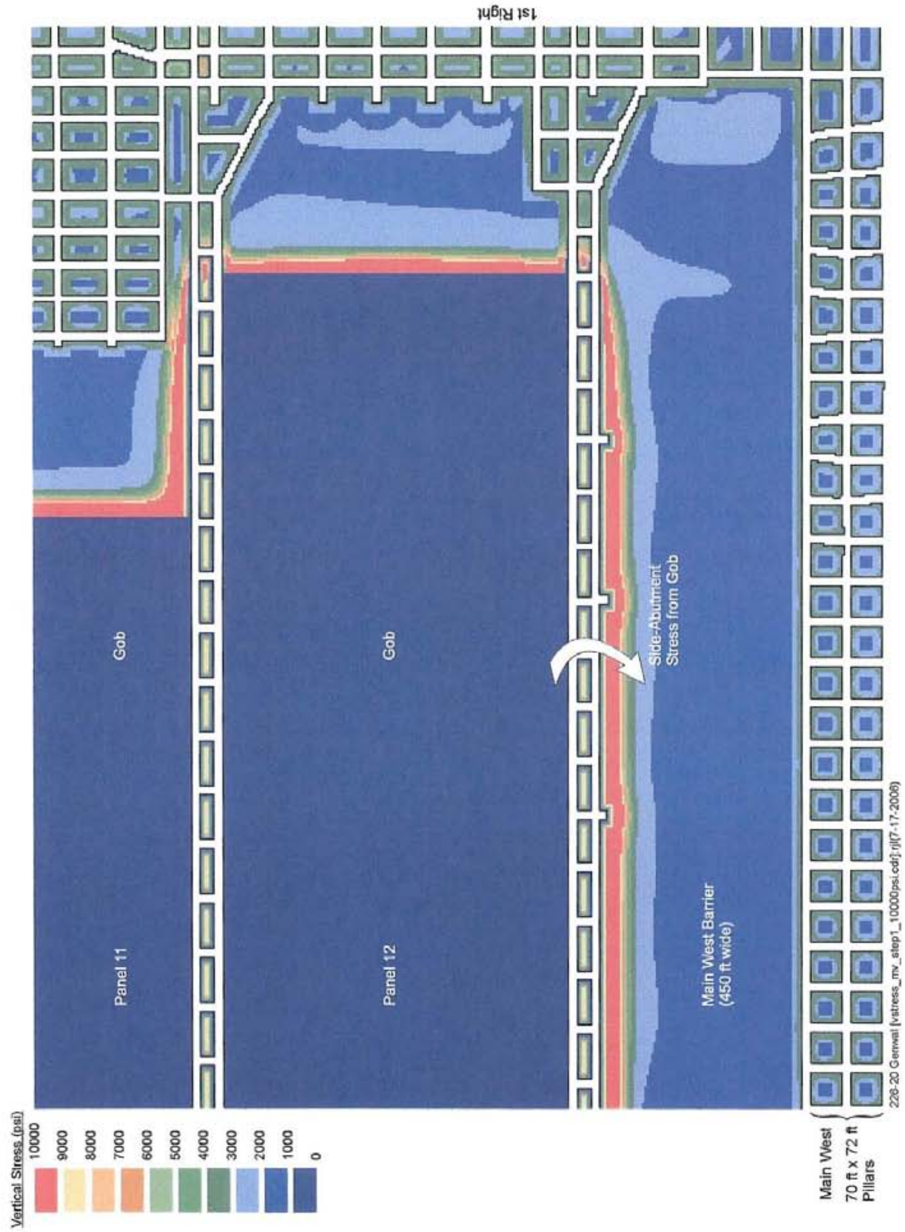

Figure 11. Modeled Vertical Stress—Current Conditions in Main West Barrier

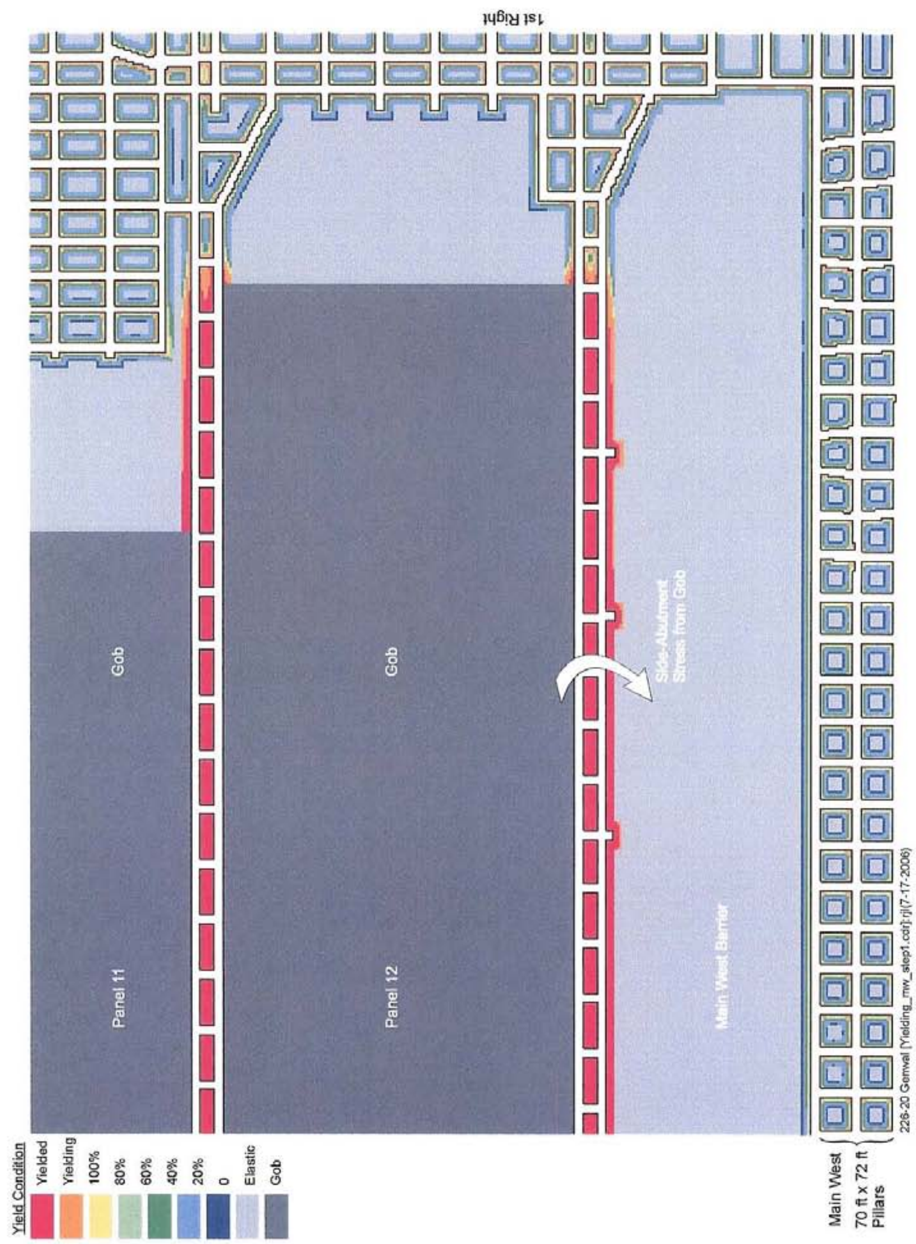

Figure 12. Modeled Coal Yielding—Current Conditions in Main West Barrier

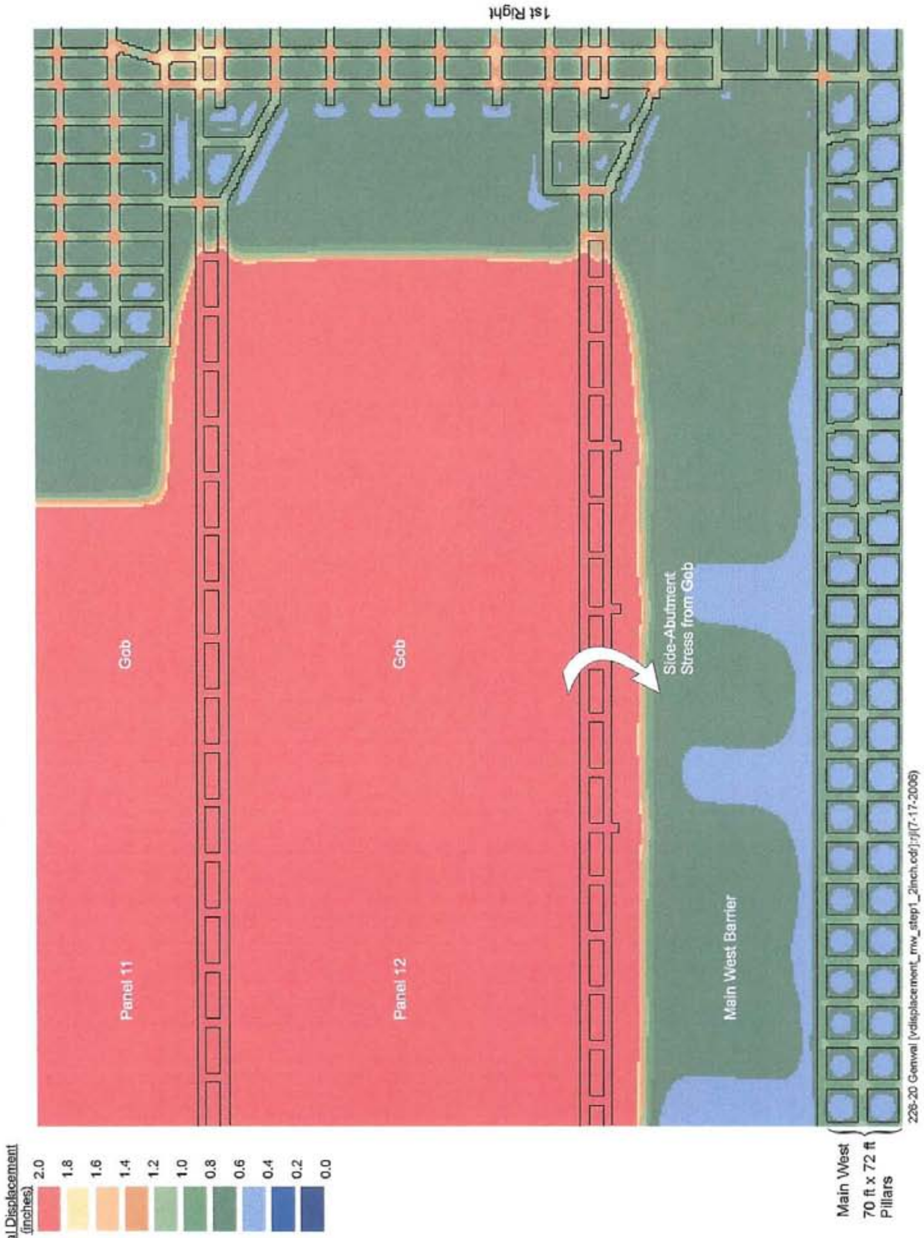

Figure 13. Modeled Roof-to-Floor Convergence—Current Conditions in Main West Barrier

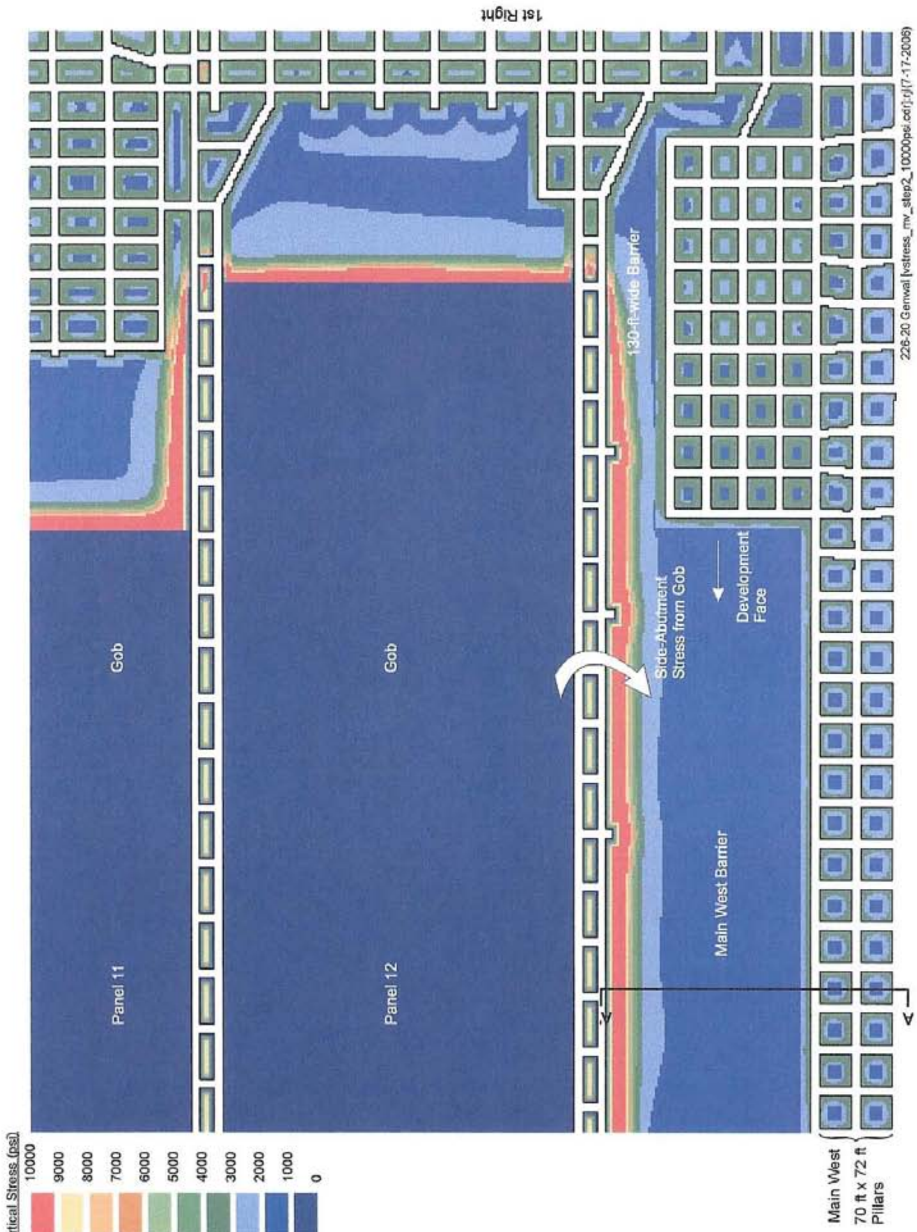

Figure 14. Modeled Vertical Stress—Partial Mining in Main West Barrier

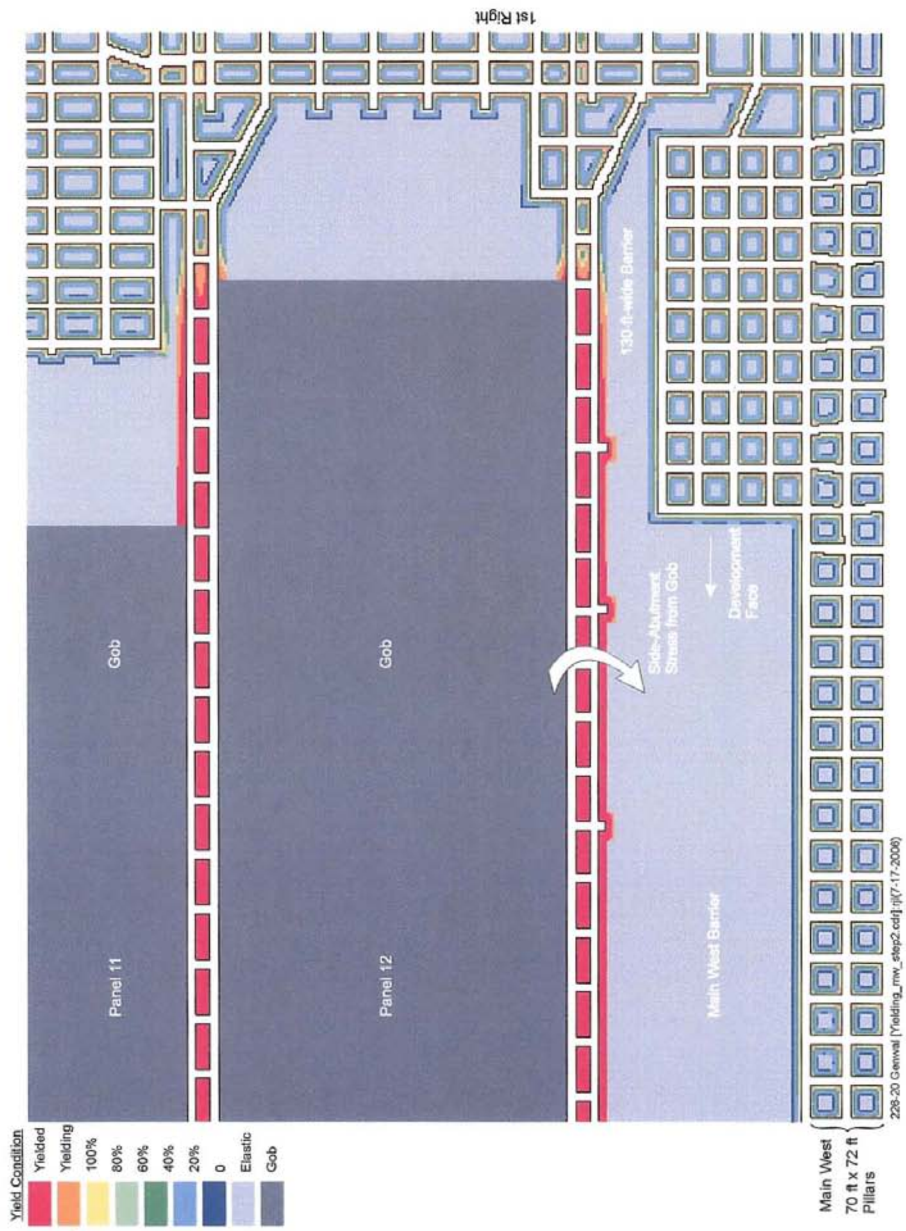

Figure 15. Modeled Coal Yielding—Partial Mining in Main West Barrier

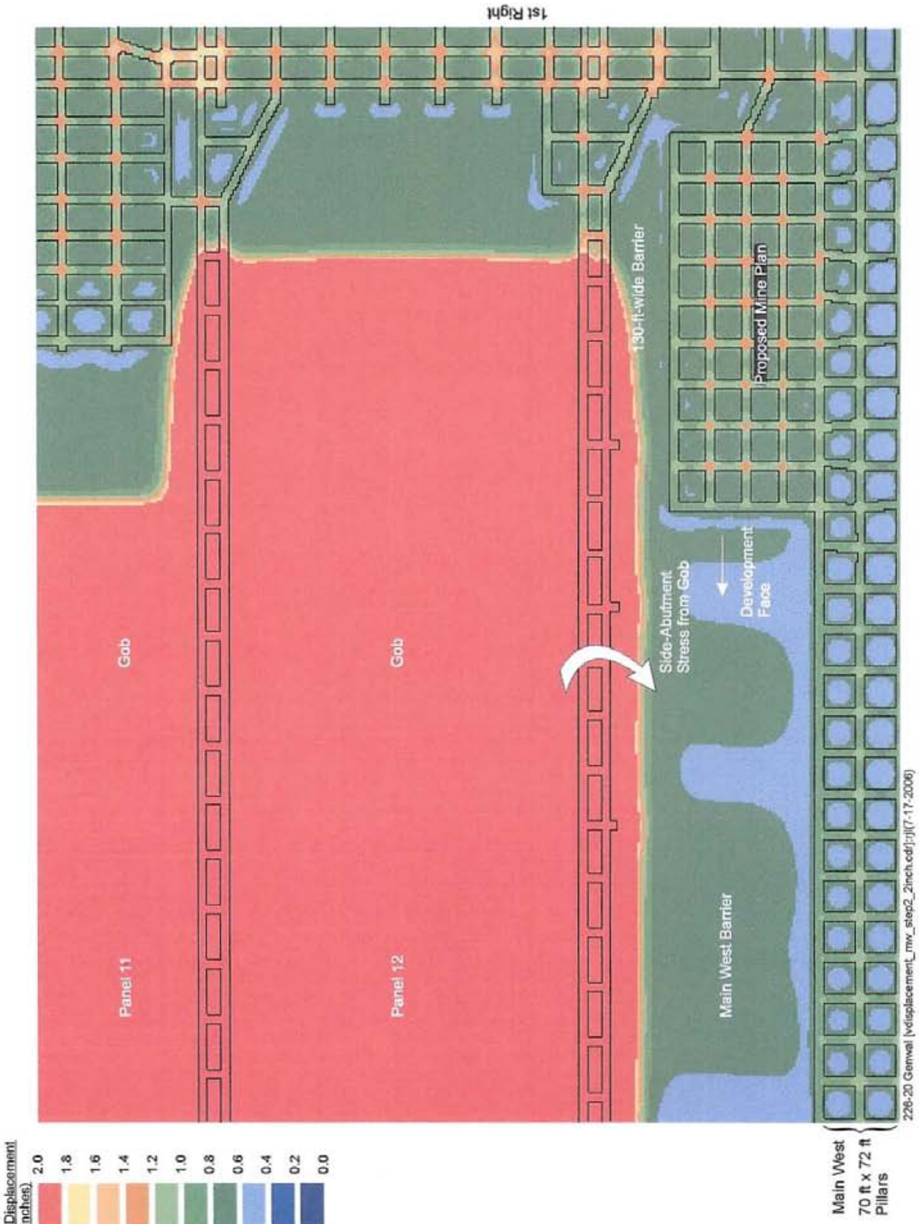

Figure 16. Modeled Roof-to-Floor Convergence—Partial Mining in Main West Barrier

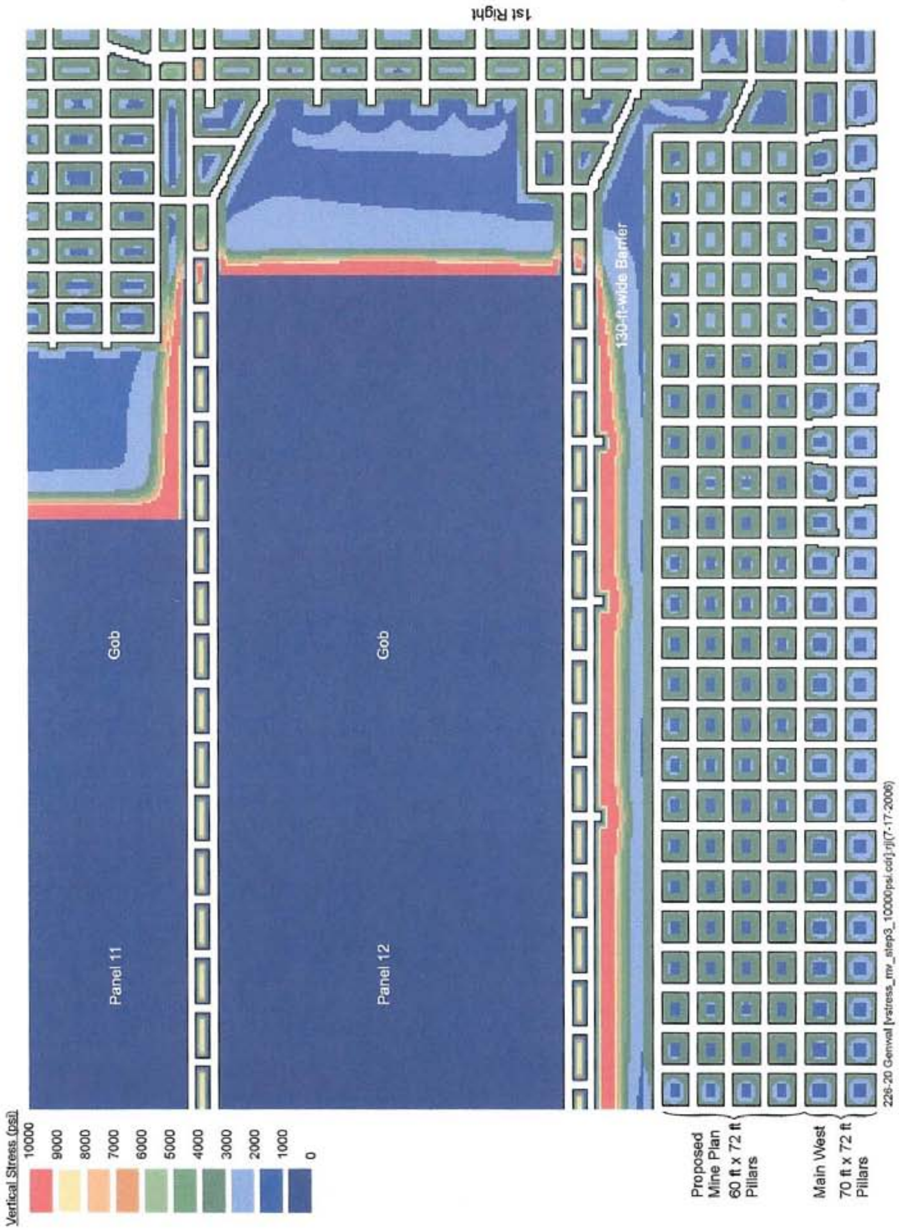

Figure 17. Modeled Vertical Stress—Mining Completed in Main West Barrier

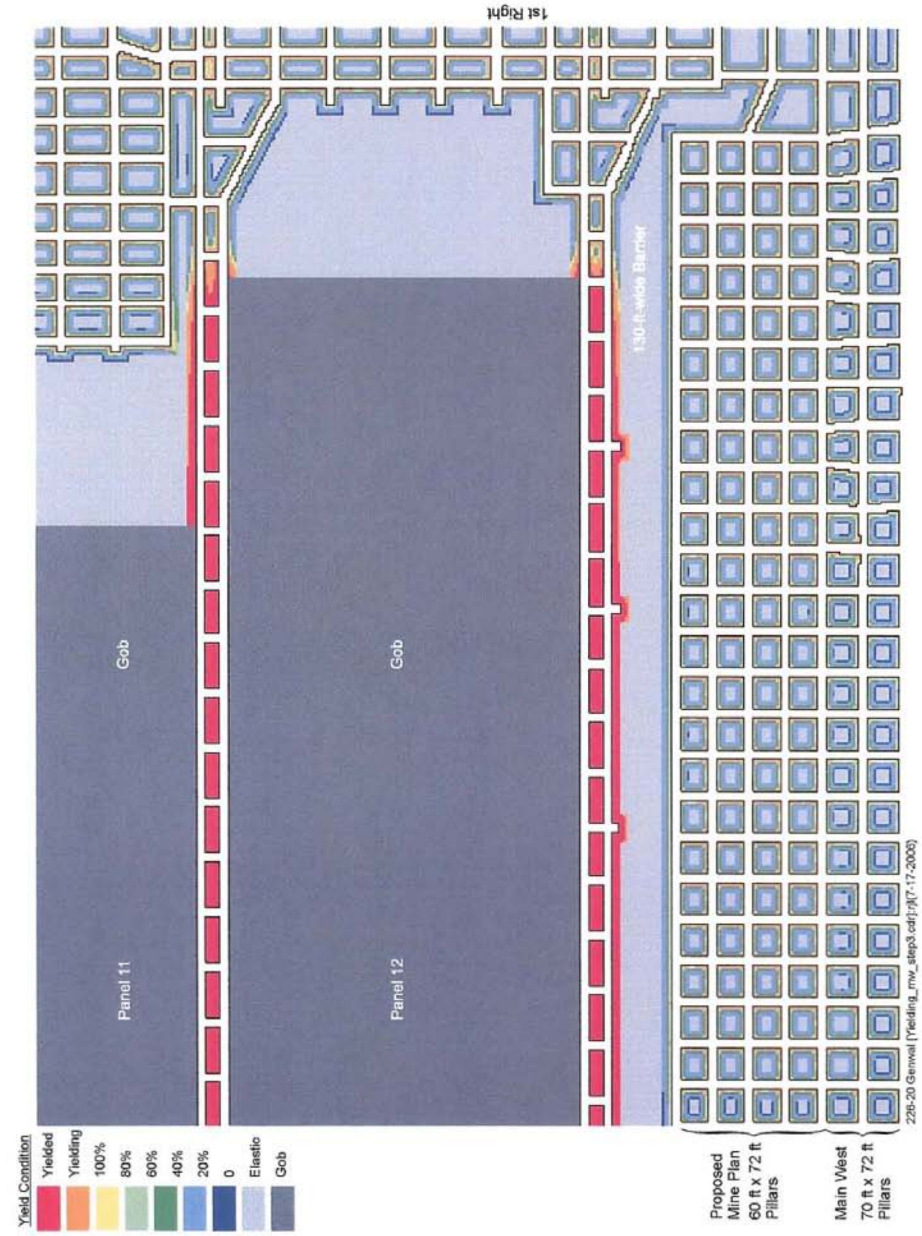

Figure 18. Modeled Coal Yielding—Mining Completed in Main West Barrier

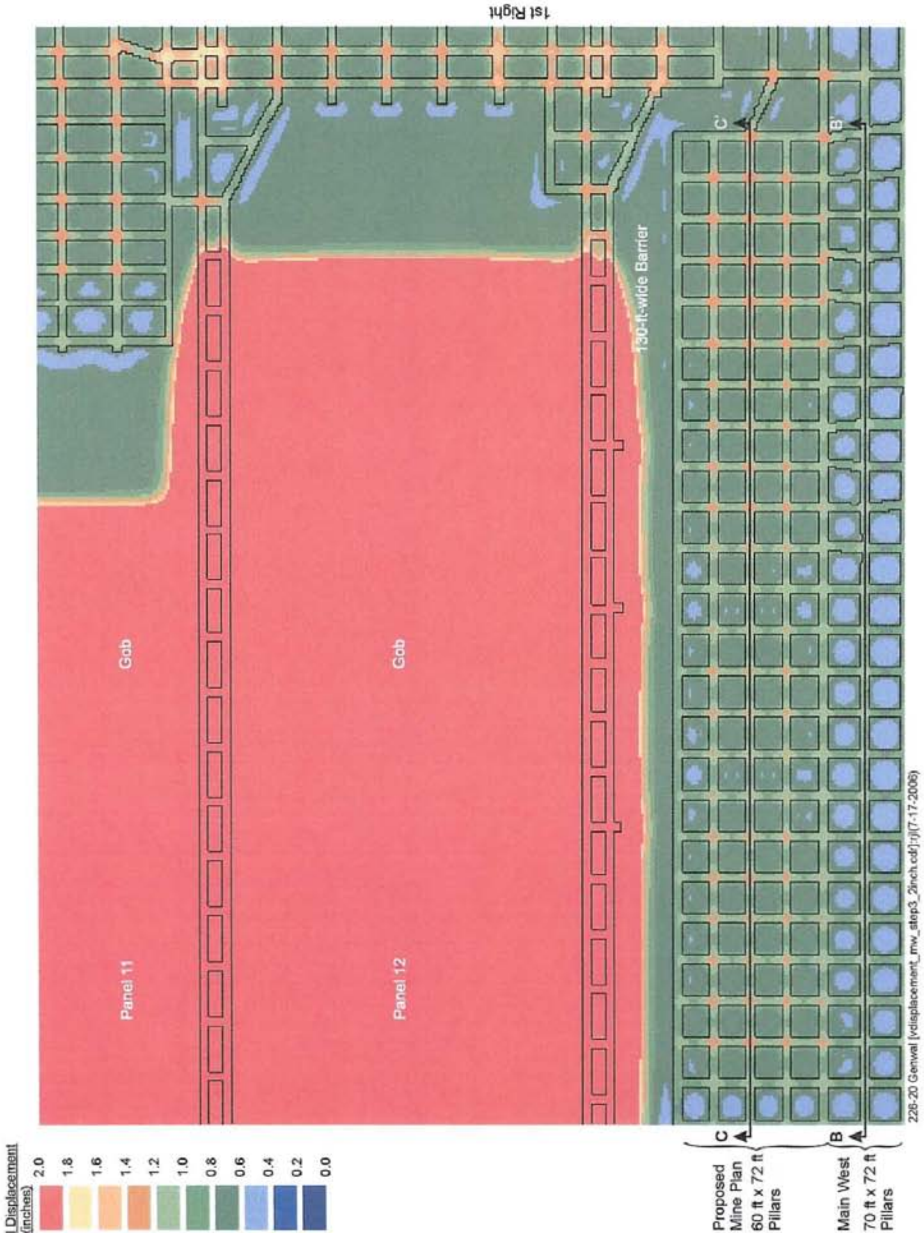

Figure 19. Modeled Roof-to-Floor Convergence—Mining Completed in Main West Barrier

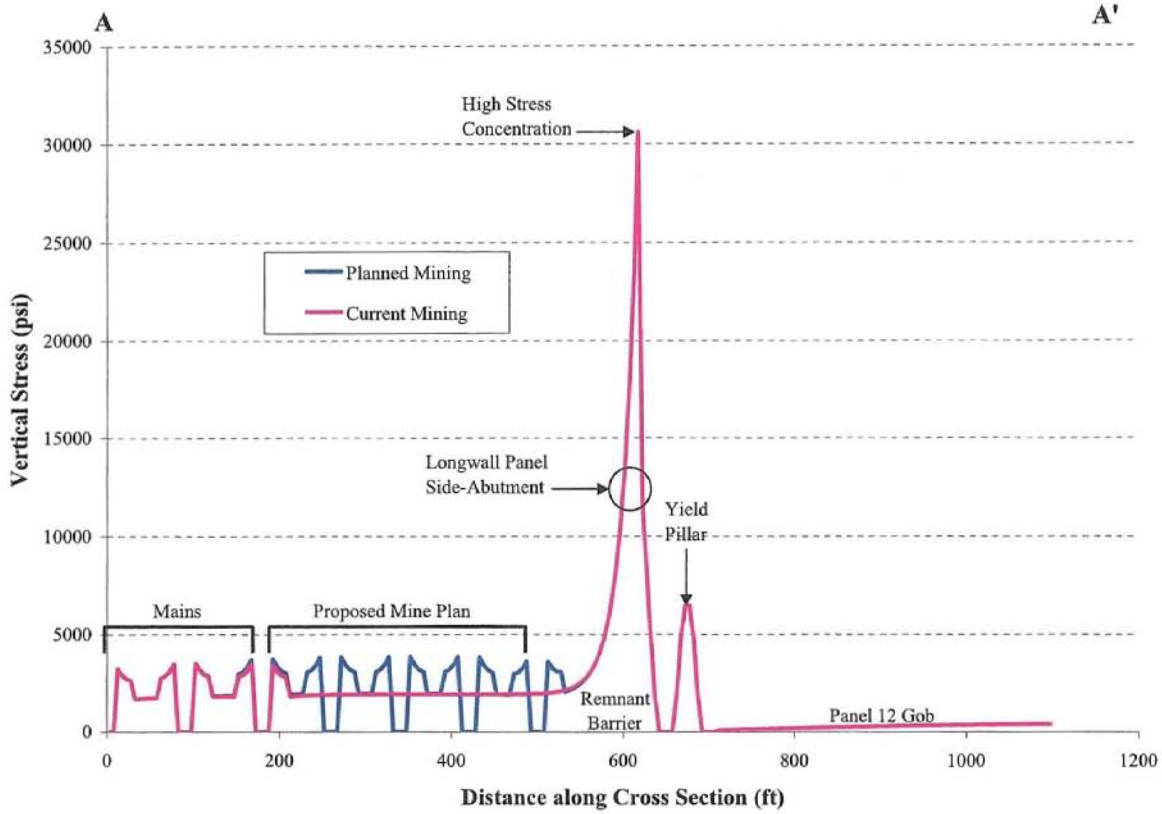

Figure 20. Modeled Vertical Stress Profiles Across Main West Barrier—Profile A-A' *(profile location shown in Figure 14)*

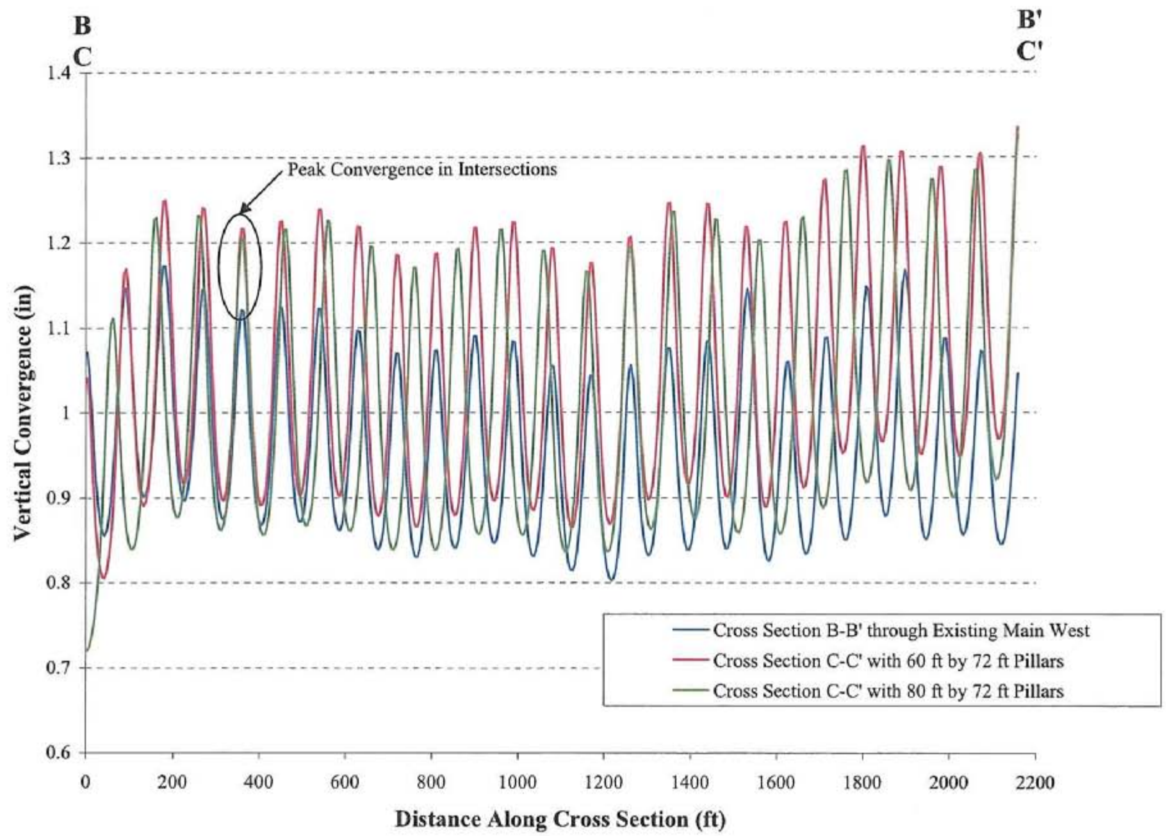

Figure 21. **Modeled Roof-to-Floor Convergence Profiles Along Main West Entries—Profiles B-B′ and C-C′** *(profile locations shown in Figure 19)*

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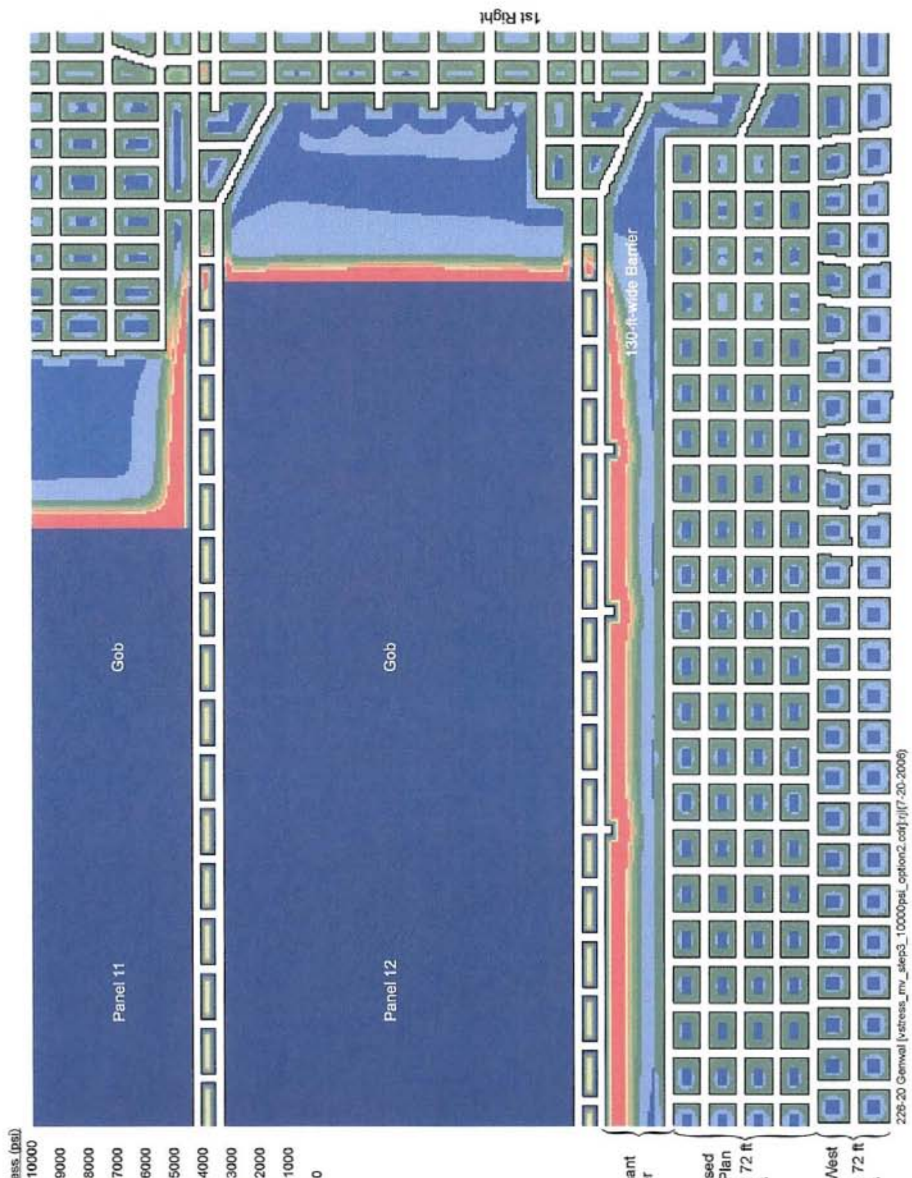

Figure 22. Modeled Vertical Stress—Main West Barrier Mining with 60-ft by 80-ft Pillars

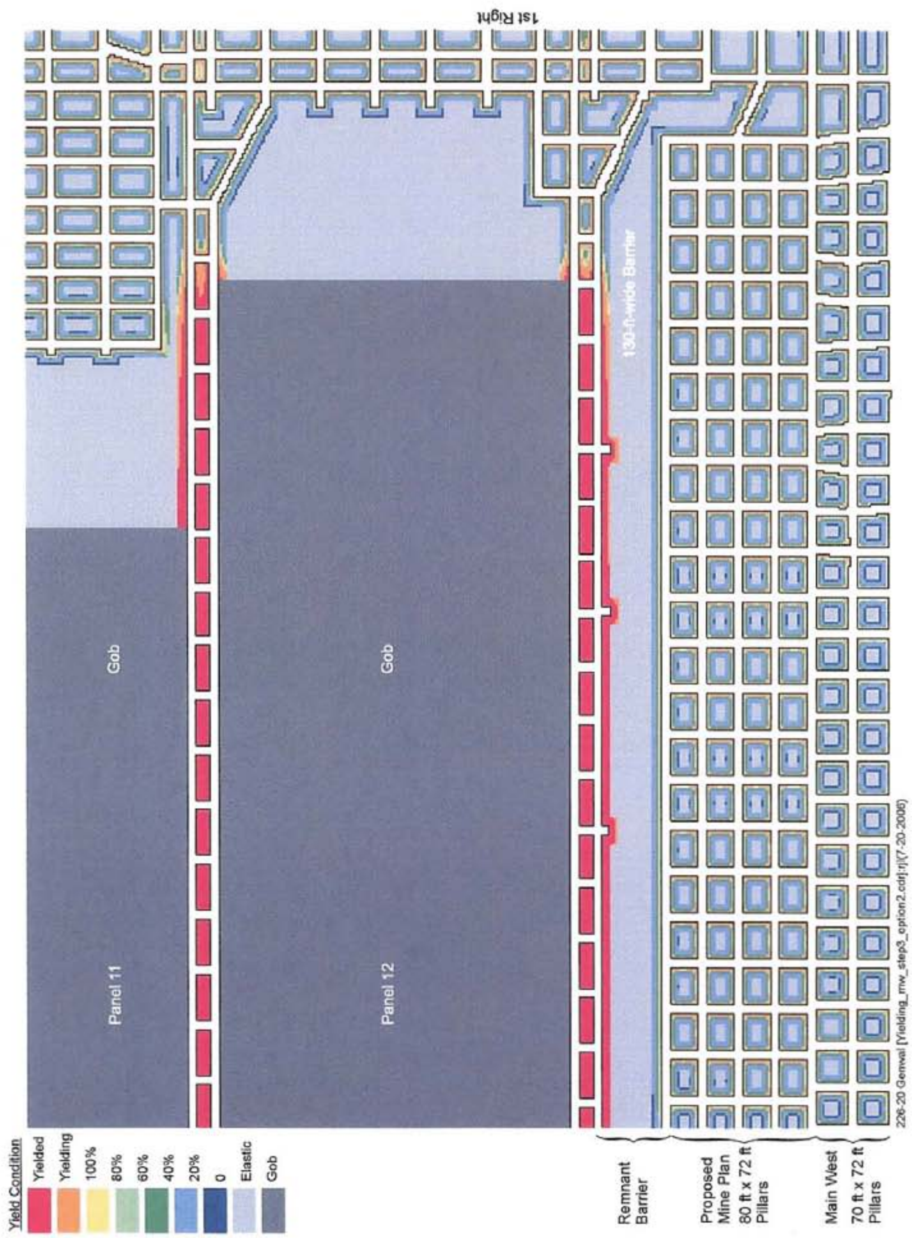

Figure 23. Modeled Coal Yielding—Main West Barrier with 60-ft by 80-ft Pillars

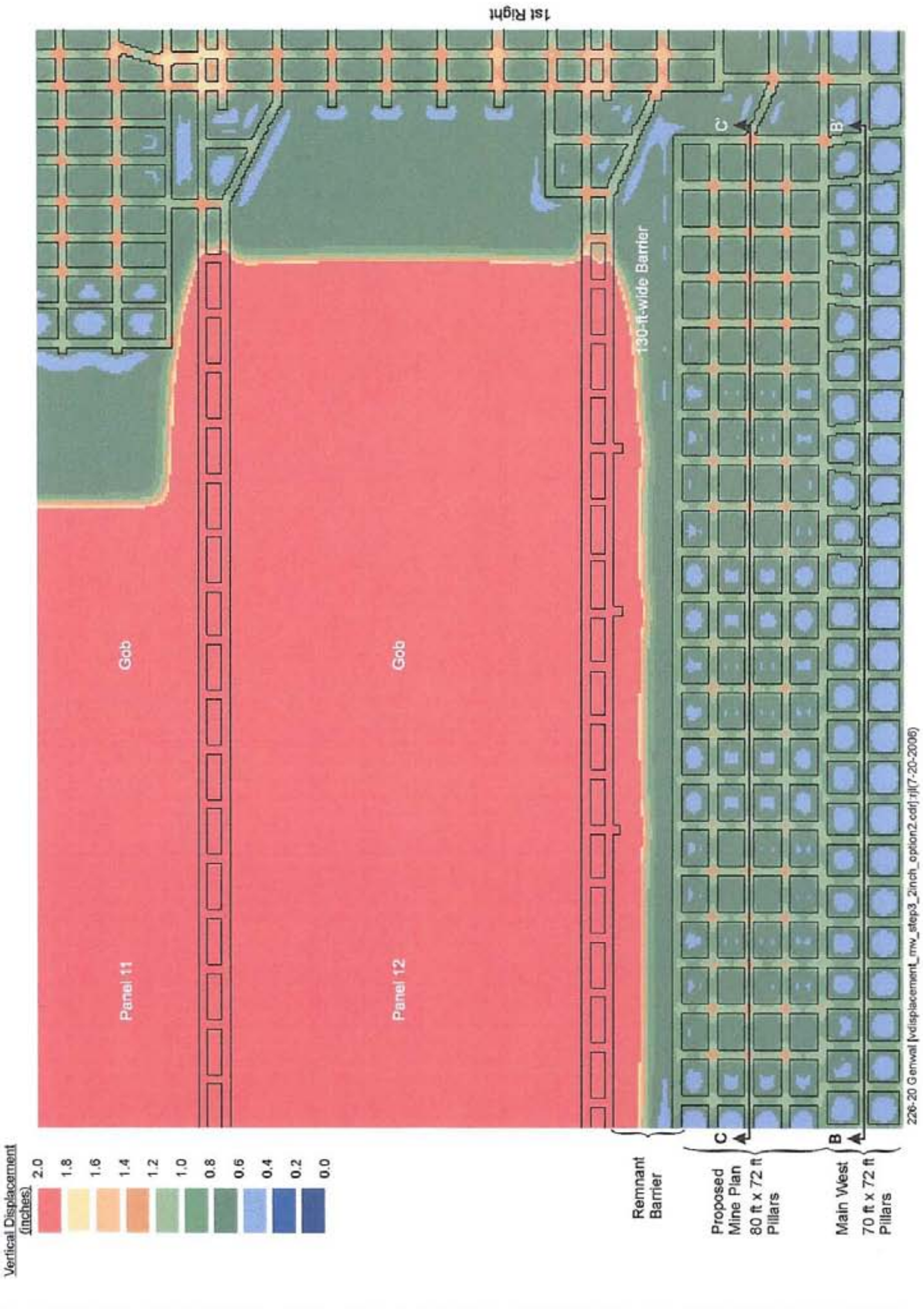

Figure 24. Modeled Roof-to-Floor Convergence—Main West Barrier with 60 ft by 80 ft Pillars