APPENDIX D
MINE LEASE AND BACK ANALYSIS CASE STUDY DESCRIPTIONS

This appendix contains a brief accounting of each of the case studies used in the back-analysis. Each accounting includes a discussion of the mining activities on the specific lease and a description of the local geologic conditions. Detailed mine maps, drill-hole logs, Eagle-Picher's 1954 maps at a scale of 1 in. = 300 feet, and Weidman's (1932) descriptions of the mines were used to describe the geology and mining for the leases. Detailed mine-map scales varied from 1 in. = 40 feet to 1 in. = 100 feet.

Also included in each account is information regarding the map and drill logs used to determine the mine opening dimensions and geologic contacts, the complexity of the maps, comments regarding other sources of information where appropriate, and an assessment of the reliability of the information derived from the information sources. A qualitative judgment of high, medium, or low was applied to confidence in the stope dimensional data dependent on the age of the map and the degree of difficulty encountered by the back-analysis group in interpreting the map.

Preceding each case study description is a lease-scale index map showing the location of the case study (or studies) within the lease boundary. A detailed map showing the axes chosen to represent stope width and length as well as unsupported span follows each narrative description. The values of stope width and length, and unsupported span, are noted on the axes. The case history number and the identification number(s) of drill hole(s) used to determine the thickness of the overlying geologic units (and in some cases the stope heights) are shown in red on the detailed maps. The location and length of the maximum unsupported span within each stope is shown in green. In cases where the maximum unsupported span coincides with the stope width the maximum unsupported span is not indicated separately. The drill logs used in each case history are also included as separate figures with each case study. Each of the case study detail maps is overlain by the 2004 aerial photography, showing the relation of the mine working to surface features.

CASE STUDY # 1 - WOODCHUCK MINE, COLLAPSE

The Woodchuck mine is located on a 40-acre lease in the SE1/4 NE1/4 sec. 30, T. 29 N., R. 23 E. The ore was mined at several levels, the lowest about 283-feet and the highest at 245- to 250-feet below the shaft collar. The ore body was in the form of a large irregular run, 25- to 150-feet wide and 30-to 120-feet high. The orebody, in places, was continuous from the lowest to the highest level; where the roofs of the lower stopes were mined out created open chambers 118- to 120-feet high. In the west-central part of the mine, large fractures trend N. 25^{o} E. in the roofs of stopes. Fractures curve and dip at angles of 55^{o}-90^{o}. Ore beds were so broken that bedding planes of the rock formations were unrecognizable. The principal ore beds mined were M and G-H. Some E & Chester beds were mined near the tops of the high stopes. Thickness of the shale varies from 50- to 75-feet on the eastern side, and from 85- to 130-feet on the western side of the lease. About 40- to 50-feet of Chesterian strata occurs between the shale and underlying Boone Formation on this lease.

Collapse case study #1 is characterized by a 165 foot diameter circular surface subsidence that occurred prior to 1939 (Luza, 1988). The available mine maps show the subsidence feature as occurring above an unmined area of the main level. The subsidence is therefore inferred to have resulted from an upper level stope collapse. The most recent mine map dated 1965 does not show upper level workings in this area of the mine, but an earlier 1945 map does show an upper level of mining. The 1945 map was thus used to determine the upper level stope dimensions. Interpretation of the map was complicated by the quality of the map, the depiction of two levels of mining, and shading that was used to delineate zones of differing ore grade, making it difficult to follow the stope outline and visualize the three-dimensional configuration of the workings. The upper stope dimensions were ultimately selected to be 235-feet in length and 115-inches width, with the width also being the maximum unsupported span. The surface subsidence occurs at the northern end of the stope. Drill logs 19c and 21c were used to derive the thickness of the overlying geologic units. Because of the age of the map and the difficulty in determining the stope boundary the confidence in this data is considered to be medium.

CASE STUDY # 2 – WOODCHUCK MINE, NON-COLLAPSE

Non-collapse case study #2 is located just south of the collapse case study #1. The area was selected because of its proximity to that nearby collapse area case, and because upper level workings were present. The 1965 Woodchuck mine shows the upper level workings in this area and was used to obtain the stope data. Interpretation of the map was fairly straightforward, although the western boundary of the stope was somewhat uncertain and the elevation of the stope roof was inferred from assay data from drill log 37. Drill log 37 was also used to infer geologic contacts above the stope. Confidence in the stope dimension data is judged high based on the recent age and relative ease of interpretation of the map.

CASE STUDY #3 – WOODCHUCK MINE, NON-COLLAPSE

Case study #3 is a non-collapse example from the Woodchuck mine. The area was chosen because it is undermined by a relatively large and high stope with few pillars. There was mining only on the main (M) level, the 1965 map was unambiguous, and the stope boundary was easily determined. Roof and floor elevations were also clearly shown on the map, indicating a 77-foot high stope. Drill log 120 was used to determine the overlying geology. The stope is overlain by a moderate-sized chat pile, with the northern boundary of the stope corresponding with the northern edge of the chat pile. The recent age of the map, and its straightforward interpretation, results in a judgment of high confidence in the stope dimension data.

CASE STUDY #4 – DOMADO MINE, COLLAPSE

The Domado mine is located on a 40-acre lease in the SW1/4 NW1/4 sec. 29, T. 29 N., R. 23 E. The main mine level in the southwestern part of the lease is at 208-feet below the surface. Some stopes in this area reached a height of 80-feet. The ore was in "boulder ground" with angular "boulders" ranging in size from 3-4 inches to 4- to 5-feet in diameter. The ore was mainly in a jasperoid breccia that filled the space between "boulders." The ore body in the northern half of the lease was mined at 232 feet and at 217 feet below the surface. Stopes were about 300 feet wide and 60-to 80-feet high. Much of the ore in this part of the mine was in highly fractured chert. Fractures trend N. 20°-30°W. and N. 40°-50°E. Ore mined on this lease came from the M-bed; however, some ore was mined from the E and Chester and the G-H beds. The Hindsville limestone is overlain by 55- to 60-feet of alluvium and shale in places. The limestone is 30- to 50-feet thick and rests unconformably on the Boone Formation.

Case study #4 is a large 550- by 400-feet surface subsidence that overlies a large, well-defined stope area in the southwestern quadrant of the mining lease. An American Zinc 1966 map of the Domado Mine shows most of this stope as "this area caved to surface". A 1955 Rialto Mining map shows the stope and pillars, which indicates that the subsidence occurred after 1955. Although there were two or more ore horizons mined within this stope area they were apparently mined in one stope that exceeded 100-feet in height. Many pillars on the 1955 map are small in diameter compared to the height of stope, and thus may not have provided effective roof support. Some maps and other sources of information indicate that many of the pillars may have been shaved or removed. The 1955 map was used for stope dimension and extraction ratio data because the more recent 1966 map only shows an area of collapse without any mine working information. Drill log #32 was used to determine the overlying geologic contacts. A chat pile was located over the stope, and the western edge of the chat pile corresponds with the approximate western boundary of the stope. The extent of the stope boundaries are well defined and roof and floor elevation data are noted on the map, thus the degree of confidence in the stope dimensional data for this case study are rated high.

CASE STUDY #5 – DOMADO MINE, NON-COLLAPSE

Case study #5 is an area of the Domado Mine just north of the stope that produced the large surface subsidence feature of case study #4. The area was chosen as a non-collapse case because it is proximity to case #4, and because it is a relatively large area with high roof (71-feet) and few pillars. The area is well defined on the American zinc 1966 Domado Mine map, which was used to determine the stope dimensions. This map also suggests the shaving and removal of some pillars that are shown on the 1955 Rialto Mining Company map. Drill log Spry 1 was used to determine thickness of the overlying geologic units. Approximately the southern third of the stope area is overlain by a chat pile. The dark feature that appears over the stope on the air photo is believed to be a mill pond, and not a surface subsidence. Confidence in the stope dimension data is rated high based on the ease of interpretation of the map, the recent age of the map, and the notation of floor and roof elevation data on the map.

CASE STUDY #6 – METEOR MINE, COLLAPSE

The Meteor mine is located on a 40-acre lease in SW1/4 NE1/4 sec. 23, T. 29 N., R. 23 E. Mine levels are somewhat irregular and uneven, but at least three main levels were mined. The deepest level was at 239-feet, the middle level was at about 214, and the upper level was at 200-feet below the surface. Stope widths varied from 10- to 170-feet. Working heights, which were inferred from drill-hole logs, were 25-feet in the upper level, 10-feet in the middle level, and 20-feet in the lower level. The principal ore beds mined were M and G-H. Alluvium and shale, 75- to 80-feet thick, overlie 30-feet of Chester, mostly limestone on this lease.

Case study #6 is an approximately 300-by 170-feet surface subsidence that overlies the working of the Meteor Mine and a portion of the Aztec lease. The surface subsidence occurred sometime between 1939 and 1952, and it was later filled and the area reclaimed. The mine workings in this area are narrow (approximately 170-feet in width) and vein like, and trend northwest-southeast. It appears from the map that the mine workings also increase in elevation from southeast to northwest. Three levels were mined in the area of the subsidence. Mine floor and roof elevations are not noted on the available maps and the drill log from exploratory hole 4A was used to infer working elevations and heights. It is possible that two of the ore horizons were mined in one level. The 1956 mine map was difficult to interpret, and the confidence in the stope dimension data is rated as medium.

CASE STUDY #7 – RITZ, COLLAPSE

The Ritz mine is located on a 60-acre lease in the NE1/4 NW1/4 and the W1/2 NW1/4 sec. 30, T. 29 N., R. 23 E. The ore in the southeast part of the west forty acres and that of the east 20 acres was mined at a level 287-feet below the surface. Considerable ore also was mined 10- to 20-feet below the 287-feet level. Stope heights, in places, reached 80 feet. In most places, stopes were 20-to 35-feet high. Ore was mined mostly from the M-bed. E and Chester beds and G-H beds were mined mostly in the northwestern part of the lease. Ore bearing rock usually was highly fractured and contained numerous small cavities and few caves. The shale is about 100-feet thick in the southeast part of the lease. Where the Miami syncline crosses the northeastern part of the west forty acres, the shale is about 200-feet.

Case study #7 is a recently recognized subsidence that was not included in the Luza (1986) inventory. During the course of this study the question arose that two circular shaped ponds above the mine workings in the northwestern part of the lease might be subsidence features rather than mill or tailings ponds. A depth sounding of the ponds was from a canoe in March 2005, indicated them to be relatively deep (23-feet and 11-feet respectively) and steep sided. As such, the ponds are more characteristic of subsidence features than tailings ponds and were therefore included as a collapse case study in the back analysis. The subsidence features overlie an upper-level stope in the very northwest corner of the lease. Drill logs X-117 and X-120 were used to determine the geologic contacts. The shape of the stope was easy to determine from the 1956 map, but some uncertainty in the elevation of the top of the stope results in a medium level of confidence in the stope dimension data.

CASE STUDY #8 – RITZ, NON-COLLAPSE

Case study #8 is a non-collapse example located in the north central part of the lease. It was selected for inclusion in the back analysis because it is a relatively large stope in an area of multiple level mining. The stope boundaries on the 1956 map are relatively unambiguous, but are not entirely consistent with an earlier map. The later version of the map also indicates only two levels of mining.

CASE STUDY #9 – CRYSTAL MINE, COLLAPSE

The Crystal mine is on a 20-acre lease in the W1/2 SE1/4 SW1/4 sec. 19, T. 29 N., R. 23 E. Mine levels are somewhat irregular and uneven, but at least three main levels were mined. The deepest level was at 300- to 306-feet, the middle was at about 240- to 260-feet, and the upper was at 185- to 200-feet below the surface. The Crystal mine is on the west side and within the Miami Syncline. The lowest level was worked mainly on the southwest side of the lease. Stopes were generally from 25- to 75-feet wide and from 25- to 50-feet high. The middle level lies above most, but not all, of the ground mined on the lowest level. Stoped-out chambers were generally 50- to 100-feet wide and from 40- to 60-feet high. Upper level stopes varied from 25-to 110-feet wide and from 15- to 40-feet high. The ore-bearing rock was much crumpled, folded, and highly fractured. The ore-bearing rock in the upper two levels is mainly in Chesterian strata. The ore at the lower level was in the upper part of the Boone Formation. Numerous cave-ins have occurred on this lease.

Case study #9 is a large 170- by 200-feet surface subsidence located in the southwestern corner of the Crystal lease. The subsidence occurred prior to 1939 (Luza, 1986). According to the map there are three extensive levels of mining below the subsidence, and what appears to be an upper fourth level of limited extent. Two or more levels may have merged to produce a single stope. The minimum interburden thickness between levels was inferred to be 8-feet from the mine map and drill logs. Drill logs from exploratory holes 12, 13, and P-52 were used to infer geologic unit thicknesses. Because the surface subsidence feature is considerably larger than the limited-extent highest level workings, stope measurements were made in what was interpreted to be the next lower mining level, which may have included two or more ore horizons. There was confidence that the recent 1964 map provided a reliable representation of the current workings, but the interpretation of the map was complicated by the multi-level mining. For that reason the confidence in the stope dimension data is rated medium.

CASE STUDY #10 – CRYSTAL MINE, COLLAPSE

Case study #10 is a 160- by 72-feet surface subsidence located near the northeast corner of the Crystal lease. The surface subsidence and underground workings extend into the Harrisburg lease to the west. The Harrisburg mine is located on a 40-acre lease in the SW1/4 SW1/4 sec. 19, T. 29 N., R. 23 E. Two separate ore bodies were mined; one located in the northeast part and the other in the southwest part of the lease. The ore in the northeast part of the lease was mined from two levels. The lower level ranged from 246- to -262 feet below the surface. Stope widths varied from 25- to 50-feet and were usually 25- to 50-feet high. Ore in the lower level was mainly from the M bed in the Boone Formation. Upper ore zones in the northeastern part of the lease were mined at a level of 186- to 190-feet. Stopes in the upper level were 150- to 200-feet wide and 30- to 50-feet high. The main ore beds mined in the upper level were the G-H and E and Chester.

The ore body mined in the southwestern and western part of the lease was worked on one level. This level corresponds to lower level workings in the northeastern part of the lease. Lower level workings were 245- to 285-feet below the surface. Stope widths were generally 30- to 60-feet, but in places reached 200-feet. The height of the stopes varied from 20- to 30-feet. In the 200-feet-wide stopes, stopes were as much as 50-feet high. The principal ore bed mined was the M.

Alluvium and shale vary from 120-feet thick in the northwest to 170-feet thick in the southeast part of the lease. Ore bodies followed the Boone Formation and Chesterian strata that dip eastward toward the Miami syncline. The ore followed major fractures and faults which trended northwest-northeast.

According to available maps, the case study #10 surface subsidence occurred largely above an area of the Crystal and Harrisburg mines where the lower level was not mined. It is therefore assumed that the collapse occurred in the upper level workings. Determination of the stope dimensions from the 1964 Crystal map and the 1955 Harrisburg map appeared relatively straightforward, although complicated somewhat by the apparent merging of mine levels with an adjoining stope just to the northeast. The maximum unsupported span measurement was made in an area of the stope below the surface subsidence feature, although larger unsupported span occurred under the non-collapsed part of the stope. Confidence in the stope dimension data is considered medium to high based on the age of maps and relative ease of interpretation. Logs from drill holes H-3, on the Crystal lease and holes 50, 118, and 128 on the Harrisburg lease were used to establish the overlying geology.

CASE STUDY #11 - CRYSTAL MINE, NON-COLLAPSE

Case study #11 is located in the northeast corner of the Crystal lease. It was chosen for inclusion as a non-collapse case study because it is located above an area where two levels of mining apparently merged to form one large, open stope about 110-feet in height; thus it is an area that would normally be considered likely for collapse. Stope boundaries are well defined by the 1964 Crystal Mine map, and confidence in the stope dimensional data are judged to be high. The log from drill hole #37 on the Crystal lease was used to define the geologic contacts.

Case Study #12 - Blue Goose #1 Mine, collapse

The Blue Goose No. 1 (formerly Angora mine) is located in the SW1/4 NW1/4 sec. 30, T. 29 N., R. 23 E. Ore was mined at depths ranging from 155-to 330-feet below the surface. The main level of the mine is at 300-feet below the surface. Working heights ranged from 9- to 74-feet, and averaged 35-feet. Most of the ore was mined from the M bed. Other ore beds included G-H and sheet ground (O bed). Stope widths varied from 25- to 90-feet. The Miami syncline extends across the central part of the Blue Goose No. 1. Chesterian strata are found on both limbs of the syncline and overlie the Boone Formation. These formations dip steeply toward the center of the syncline.

Case study #12 is a large 300- by 300-feet subsidence that occurred under a 155-feet high chat pile. The subsidence occurred sometime between 1952 and 1964 (Luza, 1986). The subsidence occurred above a well defined 340-feet. wide stope that trends northeast-southwest. A 1956 mine map indicates one large, long pillar in the central part of the stope, and several small pillars dispersed throughout the stope. A 1965 mine map shows both a large area of underground caving and the outline of the surface subsidence. An upper level of mining occurred along the western side of the stope, and a small pocket of upper level mining also occurred on the southeastern part of the stope. These upper levels of mining were small compared to the main level stope, however, and the dimensions of the large main-level stope were used in the back analysis. Because stope boundaries were well defined and numerous roof and floor elevations were noted on the 1965 map, the confidence in the stope dimensional data are rated high. Drill logs from exploratory holes # 32 and #87 were used to determine the overlying geologic contacts.

Case Study #13 - Blue Goose #1 Mine, non-collapse

Non-collapse case study #13 is located just north of the collapse case study #12. This stope was chosen for a non-collapse example because it is located adjacent to the stope of case study #12. Although it is a smaller stope than case study #12, it is none the less a relatively large stope with few pillars, is in the same geologic setting, and a large part of the stope is under the same chat pile as case study #12. Only one level on mining occurred at this location. The stope boundaries are well defined and roof and floor elevation are available on a 1965 map. Confidence in the stope dimensional data is thus rated high. Drill hole #7 log was used to determine the thickness of geologic units above the stope.

Case Study #14 - Blue Goose #1 Mine, non-collapse

Case study #14 was chosen as another non-collapse example in the Blue Goose #1 mine because it is a large stope similar in dimension and pillar spacing to the collapse case study #12. The stope boundaries are well defined and confidence in the dimensional data is rated high. Drill log #78 was used to determine the overlying geology. This stope is also overlain by the same chat pile that overlies case study #12 and #13.

Case Study #15 - Farmington Mine, collapse

The Farmington mine (Lucky Jack) is located on a 100-acre lease in the S1/2 NE1/4 sec. 14, T. 29 N., R. 23 E. One main mine level at 172-feet below the surface was worked in the Lucky Jack mine. The floor on this level was very irregular and uneven. Stopes were highly variable both in width and height. The largest stope was at least 375-feet wide and 50-feet high. Main ore zones were the M and K beds. The large stopes occurred where the K bed overlies the M bed. About 95-feet of alluvium, shale, and boulders overlie 26-feet of limestone, limestone boulders, and shale. The Boone Formation, which contains the main ore zones, is brecciated and highly fractured.

Case study #15 is a large 120-feet diameter circular subsidence that overlies a large circular shaped stope. The subsidence occurred between 1964 and 1972. Three levels were mined in the stope area, but it appears that the mid-level stope is the large circular stope, with a lower-level ring-shaped stope on the south and east periphery and an upper-level ring-shaped stope on the north and west periphery. Because the surface subsidence is approximately centered on the large circular shaped mid-level stope, the dimensions of that stope were used for the back analysis. The stope boundaries are reasonably well defined on the 1956 map and the confidence in the stope dimension data is considered medium to high. Drill logs F-5 and F-11 were used to determine thicknesses of the overlying geologic units.

Case Study #16 - W.M. & W Mine, non-collapse

The W. M. & W. mine, which is adjacent to and west of the Lucky Jack, is on a 50-acre lease in the SE1/4 NW1/4 sec. 14, T. 29 N., R. 23 E. Mine workings only occur in the southeast corner of the lease. The mill shaft collar is at an elevation of 850-feet. The main mine level was at a depth of 213-feet below the surface. Ore from the M bed was mined from one large stope, which was 150- to 320-feet wide and 12- to 54-feet high. Part of this stope extended eastward into the Lucky Jack mine. Drill-hole log no. CC-3, which is on the adjacent Dobson lease south of the W. M. & W. mine, was used to describe the local stratigraphy. About 43-feet of alluvium and shale overlie 62-feet of interbedded limestone and shale. The contact between the Boone Formation and overlying Chesterian strata occurs at 105-feet below the surface.

Case study #16 was chosen as a non-collapse example because of it's proximity and similarity in size and pillar spacing to the collapse case study #15 just to the northeast. Stope boundaries are well defined, and the confidence in the stope dimension data is rated moderate to high.

Case Study #17 - Discard Mine, collapse

The Discard mine is located on a 47-acre lease in the SW1/4 NW1/4 sec. 17, T. 29 N., R. 24 E. The collar of the mill shaft is at an elevation of 837-feet. Two main mine levels, the upper level at 146-feet and the lower level at 180-feet below the surface, were worked in this mine. Upper level stopes were 100- to 150-feet wide and from 10- to 20-feet high. The ore body at the upper level was in thinly-bedded chert and finely-fractured chert of the Boone Formation. Stopes in the lower level were 60-to 80-feet high. The ore body mined at the lower level was mainly in “open boulder” ground. The boulders varied from 1- to 5-feet. in diameter. The ore was within the smaller boulders as well as in the matrix between boulders. About 26-feet of soil and clay overlie the Hindsville Limestone. The Hindsville Limestone is about 19- to 21-feet thick and rests on the Boone Formation at depths between 45 and 50-feet.

Case study #17 is a large 150- by 200-feet surface subsidence that overlies part of a circular shaped underground stope. Two levels were mined, and the subsidence roughly corresponds to the size of the upper level stope. It was therefore assumed that the subsidence resulted from the collapse of the upper level stope, and the upper level stope dimensions were therefore used in the back analysis. Assay data from drill logs in the area of the stope indicate that stope heights may have been highly variable due to varying levels of high-grade ore. The stope boundary is reasonably well defined on the 1955 map, so the confidence in the horizontal stope dimensions is medium to high. Stope height was inferred from drill logs, however, and due to the variability in elevation of the high grade ore between drill holes, the confidence in stope height and depth data is low. Drill hole C-4 was used as the primary drill log for determining stope height.

Case Study #18 - Discard Mine, non-collapse

Case study #17 was chosen as a non-collapse example for the Discard mine because it is over a large, well-defined stope located just to the northwest of case study #17. Only one level of mining occurred in this area of the mine. The mine map is easy to interpret with respect to the lateral stope boundaries. A 1929 map of the mine shows the stope boundaries as also displayed in the 1955 map shown here. The 1929 map had abundant floor elevations noted, but only one roof elevation. It was therefore assumed that the roof elevation was relatively constant throughout the stope. This floor and roof elevation data indicated the working to be only about 10-feet in height. No drill logs could be located for exploratory holes in the vicinity of the stope, so drill log C-51 located approximately 300-feet northwest of the stope was used to infer the overlying geologic contacts. Confidence in the stope dimensional data is considered high because of the ease of interpretation of the map. Confidence in the overlying geology is only rated as medium because of the distance between the stope and the drill hole log used to interpret the geology.

Case Study #19 – Martha B Mine, non-collapse

The Martha B. mine is located on a 47-acre lease in the SE1/4 NW1/4 sec. 17, T. 29 N., R. 24 E. The collar of the mill shaft is at an elevation of 844-feet. The main mine level occurred at 119- to 130-feet below the surface. Stopes were up to 50-feet wide and from 7- to 20-feet high. Ten-feet of soil and clay overlie the Hindsville Limestone, which is about 25-feet thick on this lease. The Boone Formation occurs at depths that range from 35- to 45-feet below the surface. Numerous sink holes have formed in Hindsville Limestone at the surface and extend downward to some unknown depth.

Case study #19 was included as a non-collapse example because it occurs in the same vicinity as the Discard collapse case study. It is a relatively large stope located to the north of the Discard subsidence. Only one level of mining occurred at this location, and the stope heights were only 15-feet or less. Confidence in the stope dimensional data are rated high based on the ease of interpretation of the maps. The log from drill hole #45 located near the center of the stope was used to determine the thickness of the overlying geologic units.

Case Study #20 – Admiralty #3 Mine, collapse

The Admiralty No. 3 mine is located on a 40-acre lease in SW1/4 SE1/4 sec. 29, T. 29 N., R. 23 E. The collar of the mill shaft is at an elevation of 828-feet. Three mine levels were developed on this lease. The deepest level was at 203- to 227-feet, the middle was at 172- to 198-feet, and the upper level was at 77- to 92-feet below the surface. Lower level stopes were 400-800 feet wide, and heights ranged from 10-to 33-feet. The M bed was mainly mined in the lower level workings. Middle-level stopes varied from 100- to 400-feet wide; heights ranged from 16- to 32-feet. The main ore horizon mined in the middle level was the G-H bed. Upper level workings overlie the middle level. These workings, which occur in the northeast part of the lease, had stope widths that varied from 150- to 200-feet and heights that ranged from 12- to 23-feet. The E and Chester beds were mined in the upper level stopes. Many upper level stopes are caved to the surface.

The Batesville Sandstone crops out near and southeast of the mill shaft. In the vicinity of the upper stope, there is about 20-feet of alluvium, mostly clay, which overlies a 20-feet thick limestone. Below the limestone is 30-feet of shale and "boulders."

Case study #20 is a 65-feet in diameter circular surface subsidence that occurs above a small area of upper-level workings on the eastern portion of the lease. Two levels were mined, but the surface subsidence occurred in an area where the upper level is above an unmined area of the lower level. Maps of this mine dated 1936 do not show an upper level of mining at this location of the mine, but the 1956 map does show a small upper-level mining area. The 1956 map does not provide roof and floor elevation data, so the log from drill hole #368 was used to infer the roof and floor elevations based on an interval of lead and jack shines. Drill logs also indicate thin shale overlying limestone and "boulders". There also appears to be considerable lateral variability in the geology and ore occurrence. Because stope height and depth was based on drill log interpretation in an area that appears to exhibit considerable lateral variability in geology, confidence in the stope dimension data is rated low to medium. It does seem apparent, however, that this is a small stope relative to the adjacent workings, and that subsidence at this particular location seems unexpected.

Case Study #21 – Admiralty Mine, non-collapse

Case study #21 was chosen as a non-collapse example because it is adjacent to and in the same upper level of mining as collapse case #22. Although this is a larger stope than the collapse case, it is at a somewhat greater depth. Two levels of mining are present under the majority of the stope area. The log of drill hole #350 was used to infer the roof and floor elevations of the stope based on the ore assay values. Confidence in the stope dimension data is considered to be low to medium based on the absence of map elevations and necessity to infer stope heights from drill log data.

Case Study #22 – Netta East Mine, non-collapse

The Netta East mine is situated on a 40-acre lease in NE1/4 NE1/4 sec. 20, T. 29 N., R. 23 E. At least three main levels occurred on this lease. Mining depths varied from 190- to 260-feet below the surface. Most of the ore was mined from the M and G-H beds. Ore also was mined from K and E and Chester beds, but in lesser amounts. The deepest level was at about 260-feet, the middle was at about 220-feet, and the upper was at 190-feet below the surface. Lower level stopes were 10-to 96-feet high and from 50-to 750-feet wide. Ore was mainly from the M-bed on this level. In the larger stopes, 60-to 96-feet high, a number of beds were simultaneously mined. Middle level stopes were 150- to 200-feet wide and 8-to 12-feet high. The principal ore bed mined on this level was G-H. The upper level workings were limited to the south end the lease. Stopes on this level were up to 200-feet wide and 9- to 10-feet high. Ore from E and Chester beds were mined on this level. Two large rock falls, which cover several acres, are located in the northeast corner of the lease. About 65-feet of alluvium and shale overlie the Hindsville Limestone on this lease. The Hindsville Limestone is 60- to 65-feet thick and extends across the entire lease.

Case #22 was included as a non-collapse example in the back analysis because a portion of the stope is a large, approximately 100-foot-high open room that would typically be considered a high risk for collapse. The stope is located under Reunion Park in the town of Picher, and has been a source of concern for some time because of the potential consequences should a collapse and sudden surface subsidence occur. The high stope was produced by the merging of three levels of mining. A large concrete pillar is noted on the map along the northeast side of the large open part of the stope. There is some evidence that the concrete pillar may have been removed and the tops of other pillars shaved or removed. Although the multiple levels of mining make interpretation of the map somewhat difficult, the stope boundaries seem well defined and the presence of roof and floor elevation data on the map results in a high confidence rating for the stope dimension data. The log of drill hole #59 was used to estimate thicknesses of the overlying geologic units.

Case Study #23 – Netta East Mine, non-collapse

Case study #23 is a non-collapse case located a short distance north of case study #22. It is in an area of single-level mining, where the tabular nature of the orebody resulted in large lateral expanses of random room-and-pillar mining. Stopes are thus not well defined in this area of the mine, and determining stope boundaries as the lateral extent of mining in mine areas like this results in very wide and long stope dimensions. Roof and floor elevations from the mine map indicate that the maximum height of the stope is 31-feet, with areas of the stope height as low as 15-feet. A large area of rockfall is noted on the mine map in the central part of this stope. Drill log #59 was used to determine the thickness of overlying units. Ease of map interpretation and presence of roof and floor elevations on the 1967 map results in a high confidence level for the stope dimensional data.

Case Study #24 – Netta West Mine, non-collapse

The Netta West mine is on a 40-acre lease in NW1/4 NE1/4 sec. 20, T. 29 N., R. 20 E. Mine-workings depths ranged from 165- to 270-feet below the surface. Ore was mined from three main levels. The lowest level was at 265-270 below the surface. Stope widths were up to 240-feet and working heights ranged from 12- to 22-feet. Ore was mined from the M bed at this level. Middle level workings occurred at about 236-feet below the surface. Middle level stopes were up to 200-feet wide and 8- to 33-feet high. Ore was mined from K bed at this at this level. The upper level workings are found on the east and west sides of the lease. Upper level workings occurred at 188- to 205-feet below the surface. Stopes on the upper level were up to 250-feet wide and from 7-to 20-feet high. The principal bed mined on this level was G-H. About 100-feet of alluvium and shale overlie the Hindsville Limestone. The Hindsville Limestone is up to 60-feet thick.

Case #24 was includes as a non-collapse example for the Netta West lease because it is a relatively large stope in an area of two-level mining. The boundaries of the upper level stope are reasonably well defined, and roof and floor elevations on the map result in high confidence in the stope dimensional data. the log from drill hole #190 was used to determine the overlying geology.

Case Studies #25a (non-collapsed) and #25b (collapsed), Netta White Mine

The Netta White mine is on a 40-acre lease in SW1/4 SE1/4 sec. 17, T. 29 N., R. 23 E. Three main mine levels were developed on this lease. The deepest level was at 242- to 244-feet, the middle level at about 190-feet, and the upper level at 150-feet below the surface. Lower level workings occurred in the central part of the lease. Stopes were up to 200-feet wide; working heights varied from 15- to 25-feet. K bed was mined in the lower level. Middle level workings, the main level in the mine, were developed in the western two-thirds of the lease. Middle level stopes were up to 280-feet wide and working heights varied from 12- to 25-feet. G-H beds were mined on this level. Upper level workings occurred on the western side of the lease. Stopes were 100- to 150-feet wide and 7- to 15-feet high. The E & Chester beds were mined on this level. The ore body, in places, was continuous from the middle level to the upper level where the roofs of the middle stopes were mined out to create open chambers 50- to 62-feet high. The M bed was also mined at a depth of over 270-feet below the surface in the southeastern corner of the lease. The thickness of the alluvium and shale is about 90-feet. The underlying Hindsville Limestone is 44- to 50-feet thick.

Case studies #25 a and b are the same stope and provide both a non-collapse and collapse case. A surface subsidence occurred above this stope in 1966 after gougers shot the shaft pillar or pillars located near the center of the stope. Until that time the stope had apparently been stable. The only conditions that therefore changed prior to collapse is the unsupported span that resulted from pillar removal. The subsidence reportedly occurred within hours of shooting the shaft pillar. It is undocumented which pillar or pillars were shot, so it was assumed that the three pillars shown on the map in the vicinity of the shaft were removed. This resulted in the unsupported span increasing from an estimated 96-feet to over 260-feet. Because of multiple level mining in this area, the mine map proved to be somewhat difficult to interpret. Although two mining levels are present in the area, it appears that the two levels merged in the central stope area to produce one level of mining with a stope height of about 50-feet. Because of the complexity of the map, confidence in the stope dimensional data for the non-collapse case is considered medium. Because of the uncertainty regarding which pillar or pillars were removed prior to the subsidence, the confidence in the stope dimensional data for the collapse case is low. The log from drill hole #2-F was used to derive the thicknesses of the overlying geologic units.

Case Study #26 – Cardin Townsite Mine, non-collapse

The Cardin Townsite mine is located on a 40-acre lease in the SE1/4 SE14 sec. 19, T. 29 N., R. 23 E. Separate mine workings were developed on the north and south halves of the lease. The main mine level at the north workings occurred 226-feet below the surface. Stopes were 80- to 370-feet wide and from 8-to 14- feet high. Workings were in sheet ground (possibly O bed). About 25- to 35-feet of alluvium and shale overlie the Hindsville Limestone. The Hindsville Limestone is 17- to 27-feet thick in this area.

One main mine level at 260-feet below the surface was developed at the south workings. Stopes were 120- to 280-feet wide and 16- to 50-feet high. The principal bed mined in the south workings was M. The Hindsville Limestone, which is 33- to 35-feet thick, is overlain by about 75-feet of alluvium and shale near the southern workings.

A relatively large, well defined stope was selected for inclusion as a non-collapse case study in the Cardin area. One level of mining is present in the stope with small pillars and a large, approximately 97 percent extraction ratio. The maximum height of the stope was only about eight-feet. The recent 1966 age of the map, well defined stope boundary, and ease of interpretation of the map gives a high level of confidence to the stope dimensional data. Drill hole T-43 was used to determine thickness of the overlying geologic units.

Case Study #27 - Cardin Townsite Mine, non-collapse

Case #27 was also selected as a non-collapse example from the Cardin area. It is a small stope containing only one pillar. Maximum height of the stope was 22-feet. Maximum unsupported span is taken as the stope width. The well-defined stope boundary and recent age of the 1966 map also results in a high level of confidence in the stope dimensional data for this case. The log from drill hole T-93 was used to determine the overlying geologic contacts.

Case Study #28 – Scammon Hill Mine, collapse case

The Scammon Hill mine is located on a 160-acre lease in the W1/2 SE1/4 and the E1/2 SW1/4 sec. 36, T. 29 N., R. 22 E. The axis of the Miami Syncline, which trends northeast-southwest, bisects the lease. At least 4 main levels were mined on the lease. The deepest level was at 300- to 330-feet, the middle level was at about 279- to 284-feet, and the upper two levels were at 251 and 205-feet below the surface. Stopes were generally long and narrow, 50- to 100-feet wide and up to 60-feet high. The principal ore beds mined included the M, G-H, E and Chester. On the west side of the lease, alluvium and shale are 158-feet thick and rest on about 17- to 20-feet of limestone. Numerous caves occur on this lease. One of the largest caves known in the Picher Field was 300-feet long and 45-to 50-feet high at a depth of about 240-feet.

Although the surface subsidence feature is small, case study #28 was initially included in the back-analysis because it is a relatively recent (post-1983 subsidence) and it was felt by the back-analysis group that a recent subsidence should be included in the analysis. The mine workings below the subsidence are narrow and at a depth of about 140-feet, so surface subsidence would not normally be expected. During initial statistical analysis of the back-analysis case studies, this case was consistently an outlier from the statistical trends suggested by the other case studies. On closer examination we became uncertain that the surface subsidence at this site was the result of collapse of the underground workings, at least in part because a shaft is located near the subsidence and the underground mine map also notes the presence of a cave at depth. Nearby drill logs also indicate the presence of "crevices" in the area. We ultimately decided to exclude this collapse case study from the analysis because of the uncertainty regarding the origins and mechanism of the surface subsidence. The case study was included in the tabulation, however, as a matter of record.