2.04.6 Geology Description

Introduction

The following geologic description of the West Elk Mine permit area is based on publications by C.R. Dunrud (1976), W.R. Junge (1978), Ellis, Gaskill, and Dunrud (1987) C. Richard Dunrud (1989), A. Mayo and W. Koontz (2000), and A. Mayo et al (2004); unpublished reports by V. H. Johnson (1948), Geo-Hydro Consulting (1980), Dames & Moore (1983), Intrasearch, Inc. (1993), J. Corbett (1997), Mayo and Assoc (1998, 2000, 2004), and SRK Consulting (1998); considerable subsurface and surface investigations by ARCO (now MCC) and Ark Land/Arch Resources staff geologists, aerial photo and low altitude aerial and field reconnaissance studies by C.R. Dunrud and J.W. Rold (1994 to 2004), and results from more than several hundred drill holes on or near the property. The locations of these drill holes are shown on Map 8.

Holes that were designated "SOM" were drilled in Federal coal and "MG" were drilled in private coal. Four holes were drilled within the permit area by the U.S. Bureau of Mines (USBM) in the 1940's which were given a G designation. Twenty-five (25) holes were completed in 1963 by U.S. Steel Corporation and designated with the "CSM" prefix. Five additional holes were drilled by Grand Mesa Properties in 1981 and designated "MG-***-81." Grand Mesa Properties completed another hole (CP-82-1) in 1982. In 1992 and 1993, MCC completed 13 drill holes through the B-Seam and were given the designation "JMB." Three holes were drilled to the southwest of the mine site in 1994 and were designated "So.W." (These holes should not be confused with the shallow wells completed for the subsidence monitoring program and designated as "SW-1" through "SW-6"). Holes drilled from 1993 to 1995, to the east of the mine site, toward or on Raven Mesa have been designated "RAV". In 1996, 1997, and 2001, 21 holes were drilled and completed through the B-Seam. They are designated as 96 (or 97 or 01) -*-*. The first entry indicates the year that the hole was drilled. The second entry indicates the section in which the hole was drilled, and the third entry indicates the numbered hole in that section. Later B and E seam exploration used similar nomenclature.

Subsurface control; coal distribution, coal thickness, and quality; overburden and interburden thickness and chemical characteristics; structural geology and stratigraphy have been derived using information from all of the drill holes. The locations of drill holes are included on Map 8. All holes were drilled with permission of landowners and permits from appropriate state and federal regulators. Monitoring wells shown on Map 34 and other holes shown on Map 8 were completed or plugged and abandoned (P&A) and reclaimed in accordance with all regulations of the CDRMS and the State Engineer's Office (SEO) applicable at the time. Hole completion data were submitted to the CDRMS. P&A and completion data are also provided in Exhibit 12.

Normal practice from 1973 through 1991 entailed rotary drilling to approximately 250 feet above the E-Seam where casing was set and coring continued downward through the B Seam. Since 1992, procedures typically only included spot coring of the E and B Seams and immediately adjacent strata. The typical suite of geophysical logs run on each hole consisted of various combinations of gamma ray, neutron, density, resistivity, self-potential, temperature logs, and caliper. Since 2000, coal quality has been determined from laboratory analyses conducted by Standard Labs of Charleston, WV. Between 1992 and 2000, Commercial Testing and Engineering Laboratories of

Denver, Colorado conducted the laboratory analyses. Prior to 1992, several other laboratories performed laboratory analyses.

Stratigraphy

The general geology of this portion of the southeast Piceance Basin consists of gently north-northeast dipping beds of sandstone, shale, and coal of Upper Cretaceous and early Tertiary age. The main coal beds are found in the Upper Cretaceous Mesaverde Group which is overlain by the early Tertiary Ohio Creek Conglomerate and underlain by the Upper Cretaceous Mancos Shale. Locally, the Mesaverde Formation is about 2,500 feet thick. Figure 4, shows a generalized stratigraphic column. Map 9 shows the geology of the permit area, the coal outcrop line and strike and dip for the F, E, and B Seams. It has been modified after C. R. Dunrud's 1989 geologic map and incorporates more recent geologic mapping data (Intrasearch, Inc. 1993 and 1994). Although Dunrud placed the top of the Upper Coal Member above the F-Seam, MCC uses the top of the F Seam as the top of the member.

Stratigraphic cross-sections between drill holes show the subsurface geology through the permit area. The locations of these cross-sections are shown on Map 10. Figure 5A (Cross-Section A-A') crosses the lease area from north to south. Figure 5B (Cross Section B-B') crosses from the Fee land in the north through the Fee land in the south (including Federal leases C-56447 and C-1362. Figure 5C (Cross-Section C-C') crosses lease C-56447 from the north to C-1362 to the south in the eastern area of the leases. Figure 5D (Cross-Section D-D') crosses west to east over C-0117192 through C-044569 to C-56447. Figure 5E (Cross-Section E-E') runs west to east on the northern edge of the South of Divide permit revision area. Figure 5F (Cross-Section F-F') crosses the center of South of Divide permit revision area from west to east.

Characteristic lithologic logs have been included for core holes SOM 6, SOM 38, SOM 42, JMB 11, SOW-3, RAV-2, RAV-4B, and RAV-7 (Exhibit 12).

Mancos Shale

The Mancos Shale, the oldest formation exposed in the Paonia area, consists of a sequence of dark gray to buff marine shale approximately 2,000 to 3,000 feet thick.

Mesaverde Formation

The Mesaverde Group conformable overlies the Mancos Shale and is comprised in ascending order of these five stratigraphic units; the basal Rollins Sandstone Member, the Lower Coal Member, the Upper Coal Member, the Barren Member, and the Ohio Creek Member.

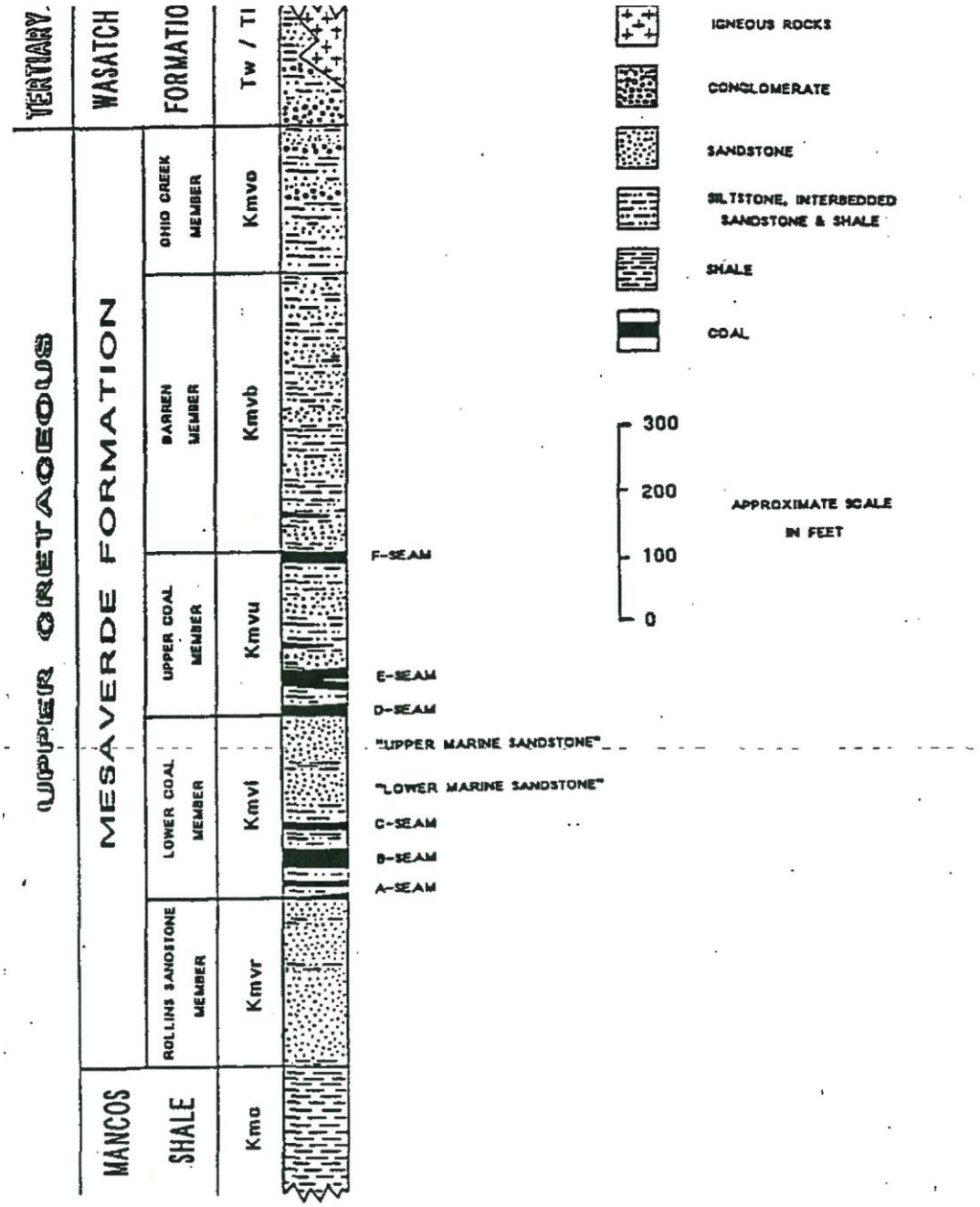

Figure 4, Generalized Stratigraphic Column of the Coal Bearing Strata of the West Elk Mine Area

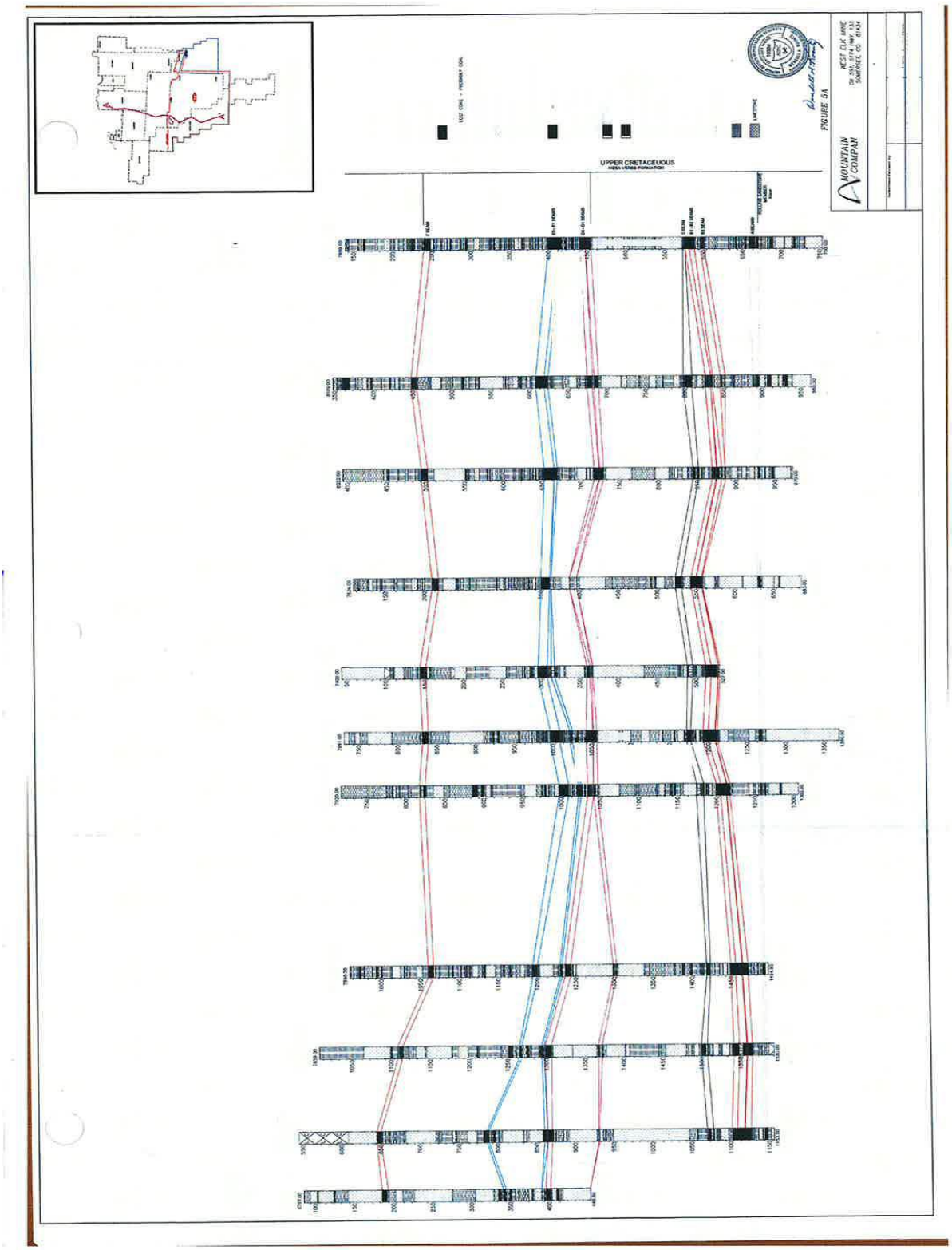

Figure 5A, Cross-Section A-A'

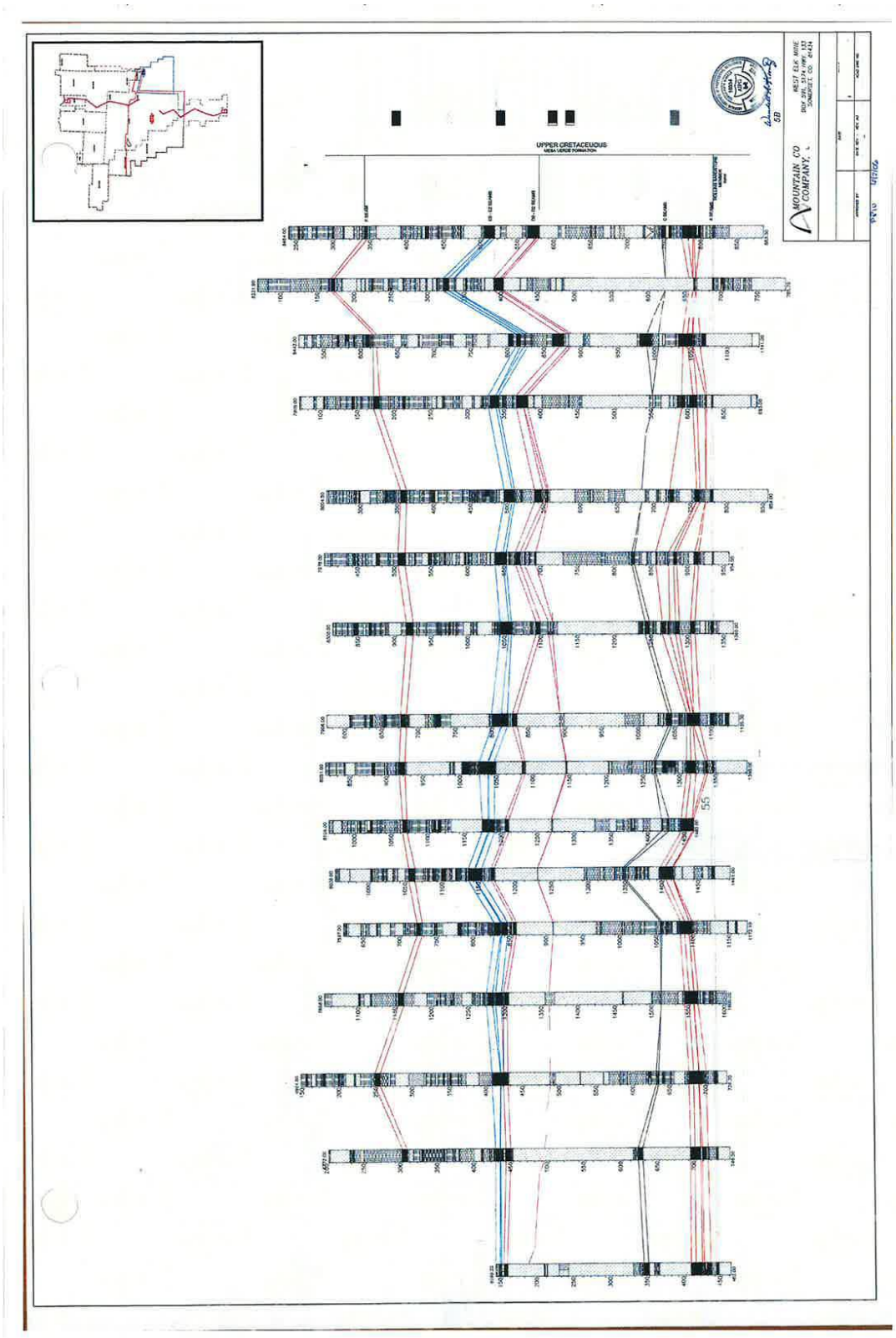

Figure 5B, Cross-Section B-B'

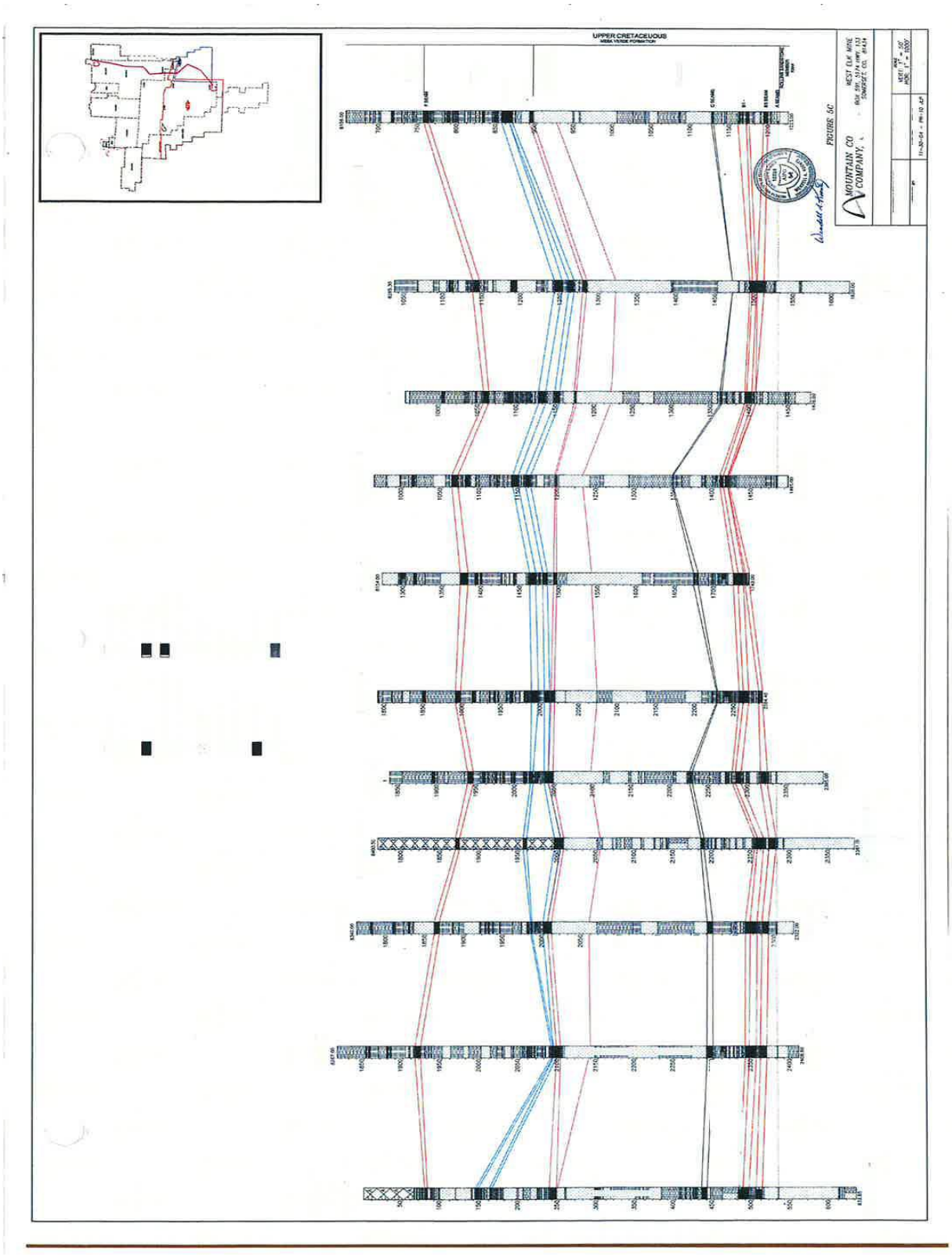

Figure 5C, Cross-Section C-C'

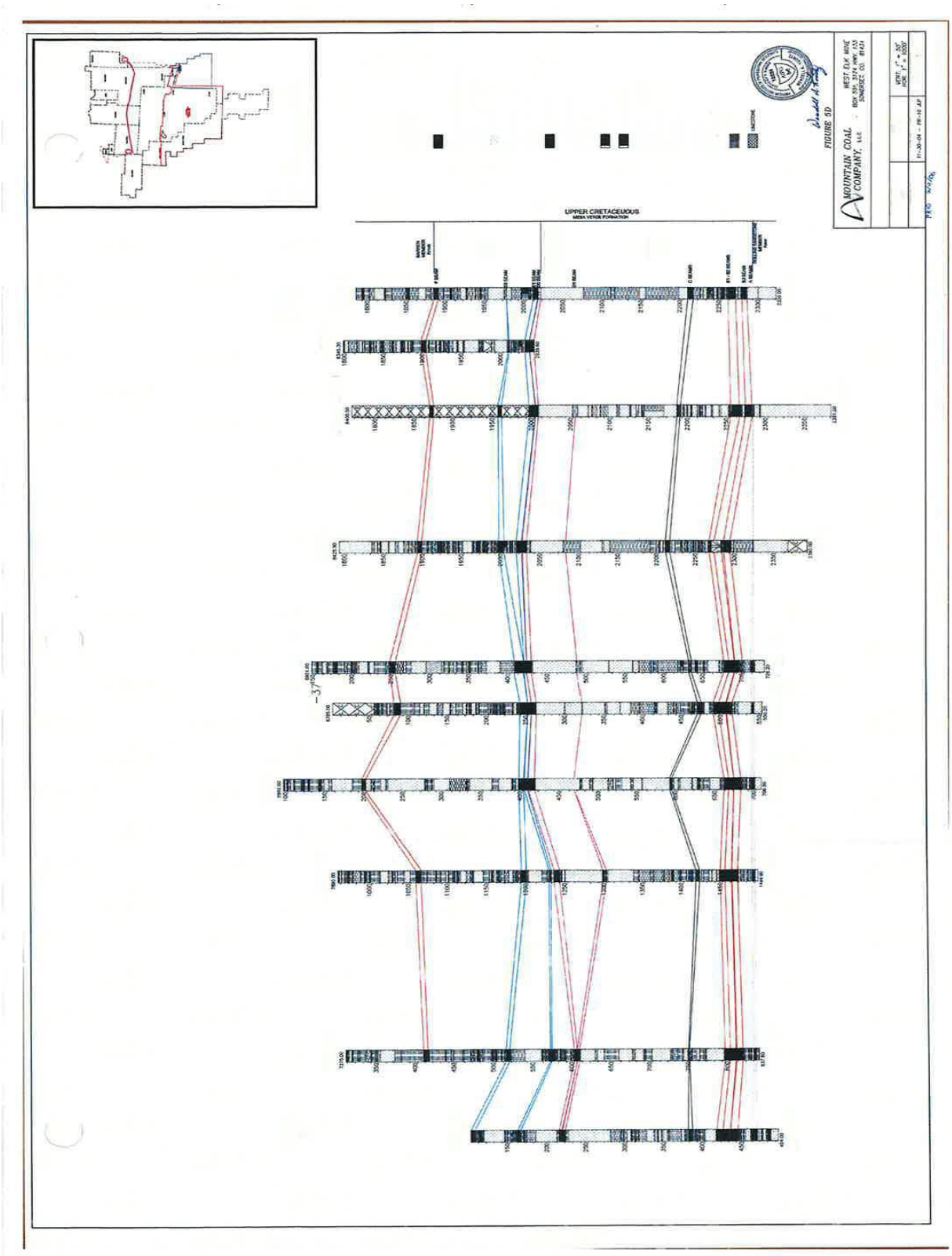

Figure 5D, Cross-Section D-D'

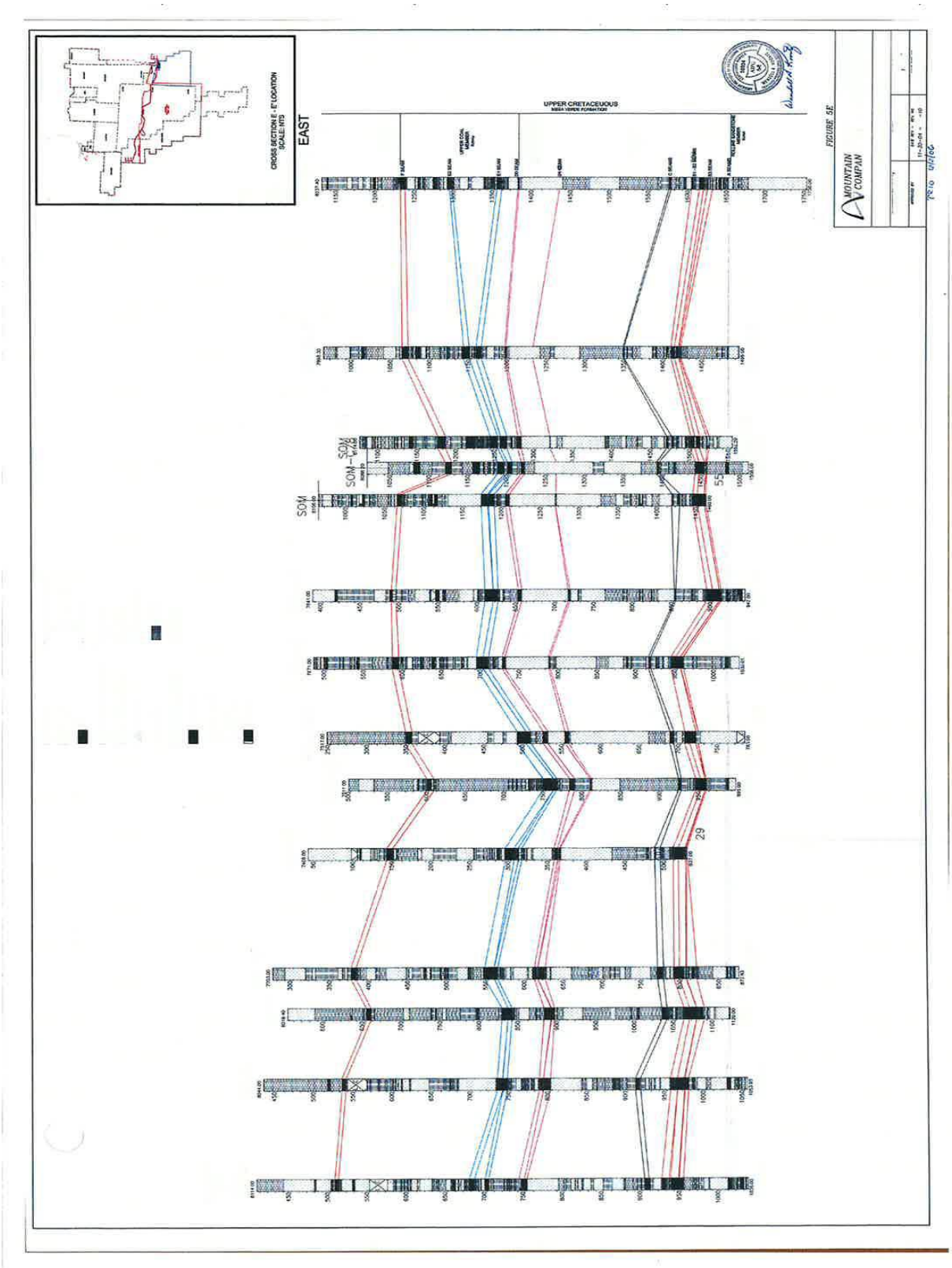

Figure 5E, Cross-Section E-E'

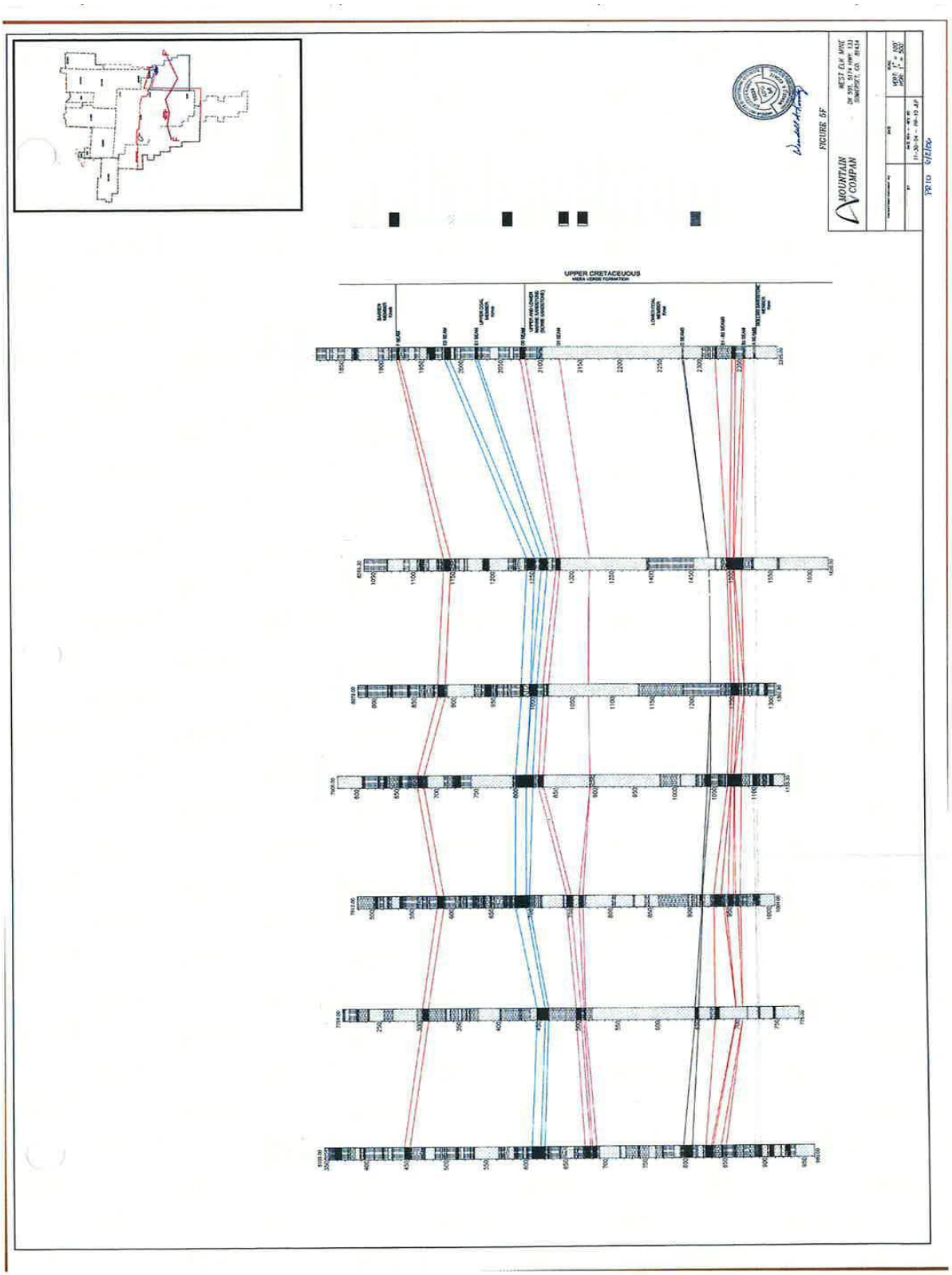

Figure 5F, Cross-Section F-F'

Rollins Sandstone Member

The Rollins Sandstone Member is conspicuous white to buff, well-sorted, fine to medium grained, massive cliff-forming sandstone of marginal marine origin, ranging in thickness from 150 to 300 feet in the area. Although this sandstone forms a good local subsurface marker, it is a poor regional marker because of lateral facies changes and intertonguing with shale. The Rollins Sandstone forms conspicuous cliffs in the area and is generally easily recognizable in cores. It has poor permeability and is considered an aquitard, and a few miles to the north has been given "tight gas sand" designation by the Colorado Oil & Gas Conservation Commission.

Lower Coal Member

The Lower Coal Member consists of interbedded sandstones, siltstones, shales, and coal. The unit averages 270 feet in thickness and contains three recognized persistent potentially mineable coals in its lower part; the A, B, and C Seams. The Lower Coal Member is almost always capped by massive Bowie Sandstone units which range in thickness from 20 to 225 feet (informally designated as the "Upper and Lower Marine Sandstones"). These sandstones appear similar in nature to the Rollins sandstone, but show much more variation in thickness. The top of this sandstone marks the base of the Upper Coal Member.

Upper Coal Member

The Upper Coal Member contains approximately 220 feet of shales, mudstones, siltstones, sandstones, and three persistent and potentially minable coals recognized as the D, E, and F Seams. The D and E Coal Seams locally merge to form a single coal seam of mineable thickness. The Upper Coal Member displays sequences of disturbed bedding (attributed to compaction and bioturbation) in the non-coal units. The shale to sandstone ratio increases relative to the Lower Coal Member, and the sandstones appear to be less continuous than those in the Lower Coal Member. This is probably due to a greater fluvial influence in the depositional regime of the Upper Coal Member.

Barren Member

The Barren Member of the Mesaverde Group lies above the F Seam and is approximately 1000 feet thick in the West Elk Mine coal lease area. This member consists of interbedded sandstone, siltstone, and shale with a few thin and discontinuous coals of no commercial importance. The Barren Member caps the highlands in the western, central, and southern portions of the mine property. The lenticular sandstones commonly form the uppermost cliffs in outcrop. Beneath the highest mesas occurring in the easternmost portions of the West Elk Mine coal lease area, the Barren Member is overlain by the Ohio Creek Member and the Wasatch Formation.

Ohio Creek Member

The Ohio Creek Member is the uppermost member of the Mesaverde Group. This unit is approximately 700 feet in thickness and consists primarily of interbedded sandstone, mudstone, and shale. The sandstones range from a few feet to more than 100 feet in thickness and are

generally lenticular in nature. Although typically fine to coarse-grained, the sandstones may locally be conglomeritic.

Tertiary Wasatch Formation

The Wasatch Formation of Tertiary age lies unconformably atop the Upper Cretaceous Mesaverde Formation. Rocks of the Wasatch Formation are only exposed in the easternmost portions of the West Elk Mine coal lease area where they cap the highest mesas, including West Flatiron in the Box Canyon permit revision area. Atop West Flatiron Mesa, the Wasatch Formation is represented by brownish-gray to reddish mudstone and its characteristic basal conglomerate of sandstone, chert, and volcanic rocks.

Other Rocks and Deposits

Further to the south and east, igneous intrusives of Tertiary age form the laccoliths of Mt. Gunnison and West Beckwith Peak. There is a low probability of intrusive dikes/sills within the permit area, based on an aerial magnetic survey completed in 1997.

Unconsolidated deposits of sand, gravels, and boulders (Pleistocene age) derived from the tertiary intrusives and Wasatch Formation may cover the Barren and Ohio Creek Members of the Mesaverde locally. These deposits are the result of more recent erosion and mass-gravity movements.

Coal Seams and Related Strata

B Seam

The B Seam is the lowermost mineable coal seam within the lease area. This seam constitutes a portion of the recoverable reserves and is of economic importance. Multiple rock partings and subsequent thinning of mineable B Seam coal benches cause challenging mining conditions in the South of Divide permit area. With the Coal Preparation Plant constructed in 2010, these B Seam reserves can be efficiently recovered.

The B Seam and adjacent strata gently dip to the northeast at approximately 3.5 degrees (Map 11). In the South of Divide permit area the strike is southeast to northwest. In the Box Canyon lease area, the strike swung to nearly east-west and the dip flattened to approximately two degrees to the north. This change of strike and lessening of the dip was significant because it reduced the concern about block glide instability over the Oliver No. 2 Mine and bedding plane failures in the Box Canyon area. Photo mapping by Intrasearch indicated numerous flat and even some gentle south dips of surface outcrops in the Box Canyon area. B Seam outcrops occur along the North Fork of the Gunnison River to the north and west of the mine portal and along Minnesota Creek. Some burning of the B Seam has occurred along outcrops on Jumbo Mountain and in the Minnesota Creek drainage, predominantly on south and west-facing slopes.

B Seam Lithology

The B Seam typically comprises three coal benches separated by persistent rock partings. The coal benches have been designated in descending sequence as B1, B2, and B3 (Figure 6). All three benches are present in the permit area with varying thickness.

In other areas of MCC's lease holdings the minable portion of the B Seam occurs at the top of the seam where the B1 and B2 benches are closely associated and attain sufficient combined thickness. In these areas, the upper coal benches are thinly separated by a parting informally called the "Marker Parting" and formally designated as the M1 Parting. The M1 Parting in the permit area varies from 0.2' in the north to 29.6' in the south at hole MG-15.

The M2 Parting is also present in the B Seam within the South of Divide permit area. The M2 Parting develops in the upper section of the B2 coal bench typically 1.5' to 2.0' below the M1 Parting, decreasing the mineable bench of coal to the lower B2 bench. The M2 Parting has been encountered previously in the B Seam reserve in the Jumbo Mountain and Box Canyon leases. Parting composition varies from bone and carbonaceous mudstone on the fringes to fine-grained siltstones and sandstones as the parting thickens. In the Box Canyon reserve, the M2 Parting at 0.5' or greater in thickness defined the mineable boundary for longwall mining.

Beneath the B2 coal bench, a thick rock parting separates the mineable portion of the B Seam from the lowermost, impure B3 coal bench (Figure 6). Because of its position near the base of the mining interval, this parting is informally called the "Lower Parting." The underlying B3 coal bench contains numerous bone and shale partings, and as a result, may not be of salable quality. This coal bench grades downward and laterally into a carbonaceous shale. The contrast in coal quality between the upper, mineable portion of the B Seam and the impure, lower bench is shown in Table 2, along with the average as-shipped quality of the B Seam from the Box Canyon reserve and the E Seam from the South of Divide coal reserves.

Table 2 Average Coal Quality

	Upper	**Lower**	**Product**	**Quality**	
Parameter	**B Seam**	**B Seam**	**B Seam**	**E Seam**	**F Seam**
	In situ	**In situ**	**Actual**	**Projected**	**Actual**
Moisture (%)	*7.7*	*7.8*	8.5	12.1	10.0
Ash (%)	*7.1*	*16.8*	9.5	7.2	9.7
BTU (%)	*11,900*	*10,800*	11,900	11,250	11,300
Sulfur (%)	*0.6*	*0.4*	0.7	0.4	0.5

Note: *As Received Basis*
As Shipped Basis

Because the coal benches split near the margins of the coal deposit, the B Seam ranges in total thickness (B1, B2, and B3) from 1.5 feet to 16.5 feet across the coal lease area (Map 13). Those areas where B Seam splitting, parting thickening, or coal bench thinning may preclude or limit

the economic recovery of the reserve, using current longwall technology, are identified (Map 13). In the permit area, the thickness of the B Seam reserve is highly variable because the upper and lower coal benches (B1 and B2) are split by both the M1 and M2 partings in an irregular manner. In this area the B Seam ranges from 1.0 feet to 16.5 feet in total thickness. Map 12 shows the combined total thickness of the B1 and B2 coal benches.

B Seam Reserves

The projected saleable reserves for the B-Seam at year-end 2021 are tabulated in Table 3 for the remaining B Seam reserves, as well as the E seam. Because the combined thickness of the B1 and B2 coal benches can exceed the maximum mineable thickness, a 12-foot maximum mining height is assumed. The maximum mineable thickness is controlled by operational and safety factors. The reserve estimate is based upon current mining plans.

Table 3 Projected Saleable Reserves (MM Tons)

Reserves	Leased	To Be Leased	Total
B Seam	31.7	0	31.7
E Seam	21.2	0	21.2
Total	52.9	0	52.9

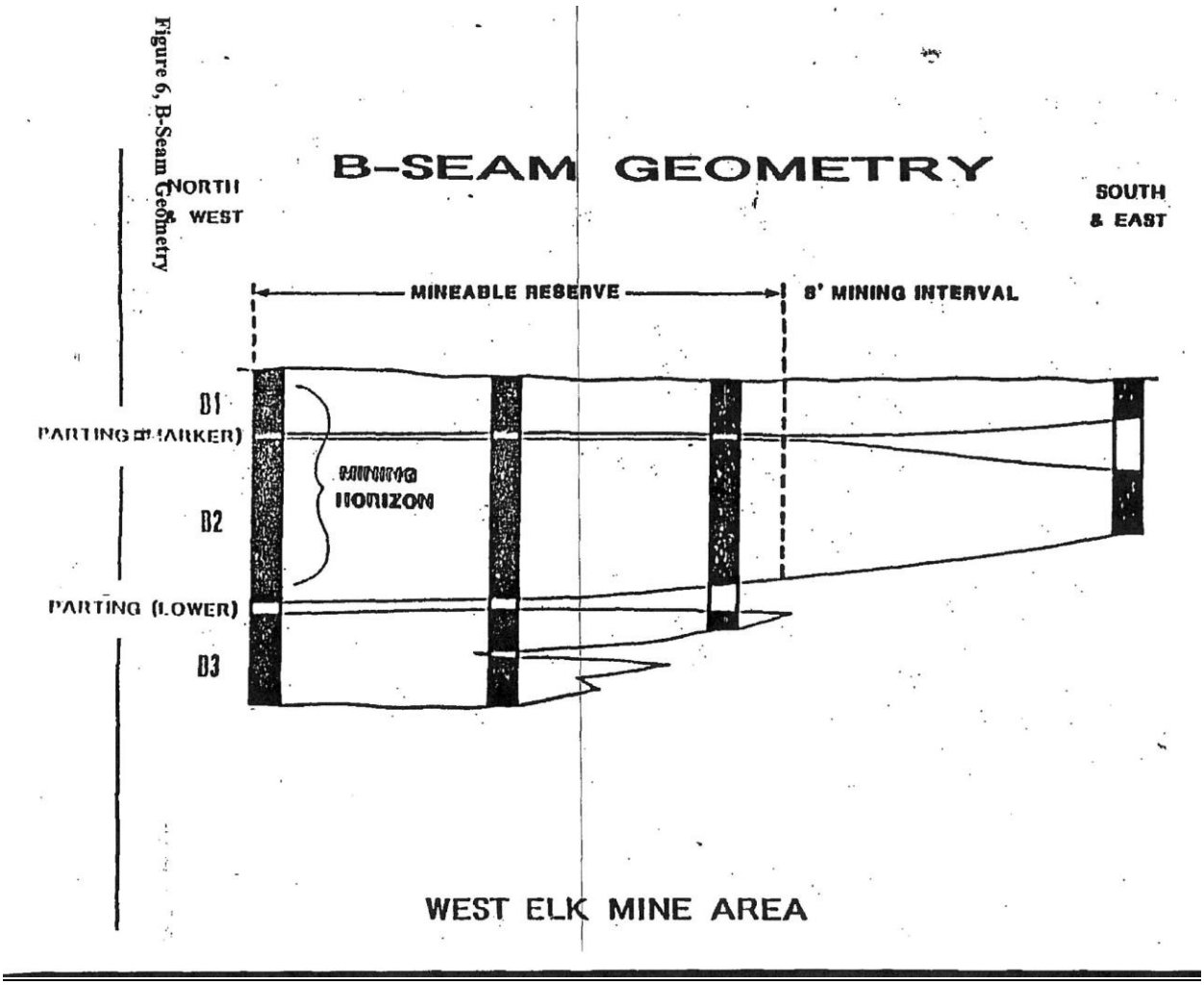

Figure 6, B-Seam Geometry

Several factors have limited the mineable B Seam reserve shown on (Map 13). On the north end of the coal lease area the recoverable B Seam reserve was limited by Bear Coal Company's abandoned C Seam mine workings. Because these mine workings closely overlie the B Seam (30 to 60 feet), the B Seam was considered un-mineable using longwall mining methods. This operating and safety limitation was designed to assure that no connection between the adjacent mines would occur as a result of undermining.

Other portions of the reserve were bounded by geologic factors. In the northern portions of the Jumbo Mountain lease tract area, the B Seam reserve was limited by an ancient landslide deposit. In that area, a massive slide removed the upper mineable portion of the B Seam. To the west, south, and east, the B Seam mineable reserve have been and may be constrained by increasing parting thickness as the B Seam coal benches diverge.

Access slopes from the F Seam workings enter the B Seam in the southwest quarter of Section 21, T13S, R90W, 6th P.M. This location provides ready access to the B Seam coal in the permit area.

B Seam Overburden and Interburden

B Seam overburden ranges from zero at the outcrop along the North Fork and Minnesota Creek drainages to 2,300 feet beneath West Flatiron Mesa, on the east side of the coal lease area. Within the existing West Elk Mine permit area, the average overburden thickness is about 1,000 feet (Map 14). Within the South of Divide and Southern Panels permit area, the overburden ranges from 200 feet to 2,300 feet and averages approximately 1,200 feet.

Interburden between the B Seam and the overlying E Seam ranges from 200 to 300 feet over the permit area (Map 15) and between 225 and 300 feet in the South of Divide permit area. The interburden between the B Seam and the overlying F Seam ranges from 320 feet to 450 feet (Map 16) over the current permit area and between 320 and 400 feet in the South of Divide permit area. The B/F Seam interburden includes the C, D, and E Seams, of which only the E Seam is of significant economic importance in the permit area.

Lithologies within the B/E Seam interburden consist of shales, siltstones, and coals. Sandstones are generally lenticular, with the exception of the massive Bowie Sandstone. This sandstone unit usually lies close under the bottom of the D Seam, and ranges from 20 to 225 feet thick. It can be divided into two laterally continuous sandstone bodies which have informally been designated as the "Upper Marine Sandstone" and the "Lower Marine Sandstone" (Figure 5A, Figure 5B, Figure 5C, Figure 5D, Figure 5E, and Figure 5F). In the western portions of the initial mining area and into the Jumbo Mountain lease tract, only the lower lobe of this sandstone body occurred.

B Seam Roof and Floor

Representative samples of the B Seam coal, overburden, roof, and floor strata have been collected and analyzed from core holes drilled within the mine permit area, and elsewhere around the lease holdings. The locations of these holes are shown on Map 8 and the analytical results are presented in Exhibit 13. Stratigraphic cross-sections and geochemical analyses

indicate that these results are representative of the existing conditions throughout the West Elk coal lease area and that the B, E, and F coal seams and associated roof and floor materials do not contain potential acid- or toxic-forming materials.

Core examination and actual observed conditions suggest that the B Seam has the most competent roof rocks of the three mined or minable seams. Immediately overlying the B Seam is from 1 to 2 feet of a dark gray mudstone. This lithology is generally competent, but may locally be weakened where slickensides, fossils, or joints disrupt bedding continuity and rock strength. Above this fine-grained "cap rock", a widespread sandy unit occurs which forms the main roof of the B Seam. This sandstone typically provides good anchorage for roof bolts and forms a strong beam above the mined entries. Locally, this sandy unit may be weakened by jointing or thin, fine-grained laminations, which commonly occur near the unit's base.

B Seam roof conditions have historically been excellent. From 1 to 2 feet of top coal is commonly left unmined in the roof to improve roof conditions by eliminating air slaking, which can weaken the immediate roof shale over time. In leaving top coal, sulfur in the coal product is also reduced by avoiding higher concentrations of sulfur that occur near the top of the seam.

The base of the B Seam is predominately comprised of siltstone and shale. Because all of the lower coal bench (B3) is left unmined and in place for quality reasons, floor conditions of the normal mining interval are generally excellent. On occasion, floor conditions degrade when mining inadvertently encounters the lower claystone parting (Figure 6).

E Seam

The E Seam is also an economically recoverable coal reserve in the South of Divide permit area. Like the B Seam, the E Seam and adjacent strata gently dip to the northeast at approximately 3.5 degrees (Map 17). The E Seam outcrops on the northern side of the coal lease area along the North Fork, and on the western side of the leases along Jumbo Mountain and Minnesota Creek, following the pattern of the B and F Seam outcrops (Map 9). Minor burn areas occur along the outcrop in this area. The E Seam is too low in elevation to outcrop in Sylvester Gulch; however, it does outcrop along the North Fork just to the east at the former Oliver No. 2 Mine portal.

E-Seam Lithology

The E Seam is a thick and widespread coal deposit of high economic importance within the West Elk Mine coal lease area. The E Seam is comprised of two coal benches, which are separated locally by a rock parting. The upper coal bench is informally denoted as the "E0" Bench and the lower bench as the "E1" Bench (Figure 7). MCC generically uses the E Seam designation for the upper (E0) coal bench or the combined upper and lower benches, where the rock parting is less than 0.5 feet thick.

The E Seam thickness is controlled by the splitting of the two coal benches (Map 18). In the central and southern portions of the coal lease area, both E0 and E1 coal benches are merged to form a thick coal body ranging from 15 to 21 feet in total thickness. To the east and west of the

central coal body, the E Seam splits into two distinct benches (E0 and E1) as the intervening rock parting thickens (Map 18).

Further to the east and west, the upper (E0) bench of the E Seam maintains mineable thickness, ranging from 8.0 to 12.0 feet. The E0 bench thins to its mineable thickness limit of 8.0 feet and continues splitting and thinning further to the east and west. Within the Jumbo Mountain and most of Box Canyon lease areas, the E Seam was split and comprised of several thin (<5 feet) coal benches that are separated by rock partings. In these areas, these splits collectively form the E Seam "zone" as shown on the stratigraphic cross-sections (Figure 5A through Figure 5F). Because of the thin and erratic nature of these coal benches, the E Seam was considered un-mineable in the Jumbo Mountain and most of the Box Canyon lease tracts.

Where the E Seam coal benches merge to form one thick seam, away from the influence of the split, the coal quality is generally good. This is because the upper (E0) bench is thicker and "cleaner" with fewer impurities than the lower (E1) bench, which frequently contains bony or shaley layers. The additional seam height will also allow top and bottom coal to be left during mining, which will improve product quality by reducing out-of-seam dilution. This thicker and higher quality E 100 Seam deposit was mined during the 1940's from the Oliver No. 2 mining operation (Map 18), and will likewise be mined locally within the South of Divide permit revision area.

E Seam Reserves

Mineable E Seam reserves are based on projected longwall mining heights ranging from 8 to 14 feet, dependent upon seam thickness and other operating constants due to reserve geology. As shown on the E Seam thickness map (Map 18), the mineable E Seam reserve is bounded on the northwest, east, and south by the thinning of the uppermost, E0 coal bench to 8 foot and less in thickness and the Mt. Gunnison laccolith. To the southwest, the E Seam reserve is restricted by outcrop. To the north, the E Seam merged with the underlying D Seam and was mined by the Oliver No. 2 Mine operation.

The existing mined slopes that were used to access the B Seam from the F Seam workings are located such that they pass through the northern-most extent of the mineable E Seam reserve. Access to E Seam reserves are from these slopes south to the main body of the reserve and east and north to the existing shaft ventilation facilities. Mining of E seam longwall panels LWE1 through LWE8 was begun in late 2008 and was followed by mining of the Sunset Trail longwall panels LWSST1 through LWSST4, and longwall panels LWE14 through LWE16 as depicted on Map 51. Future E seam mining plans include longwall mining reserves in longwall panels LWE10 through LWE12 that are located above longwall panels B12, B13, and B13A. Mining plans also include mining of longwall panels B26 through B29 under already mined E seam panels E1 through E6. Projected reserves and quality are shown on the tables above.

E Seam Overburden and Interburden

E Seam overburden (Map 19), ranges in thickness from zero at the outcrop to about 1,200 feet in the east central part of the permit area. Average overburden thickness is about 800 feet within the West Elk Mine permit area.

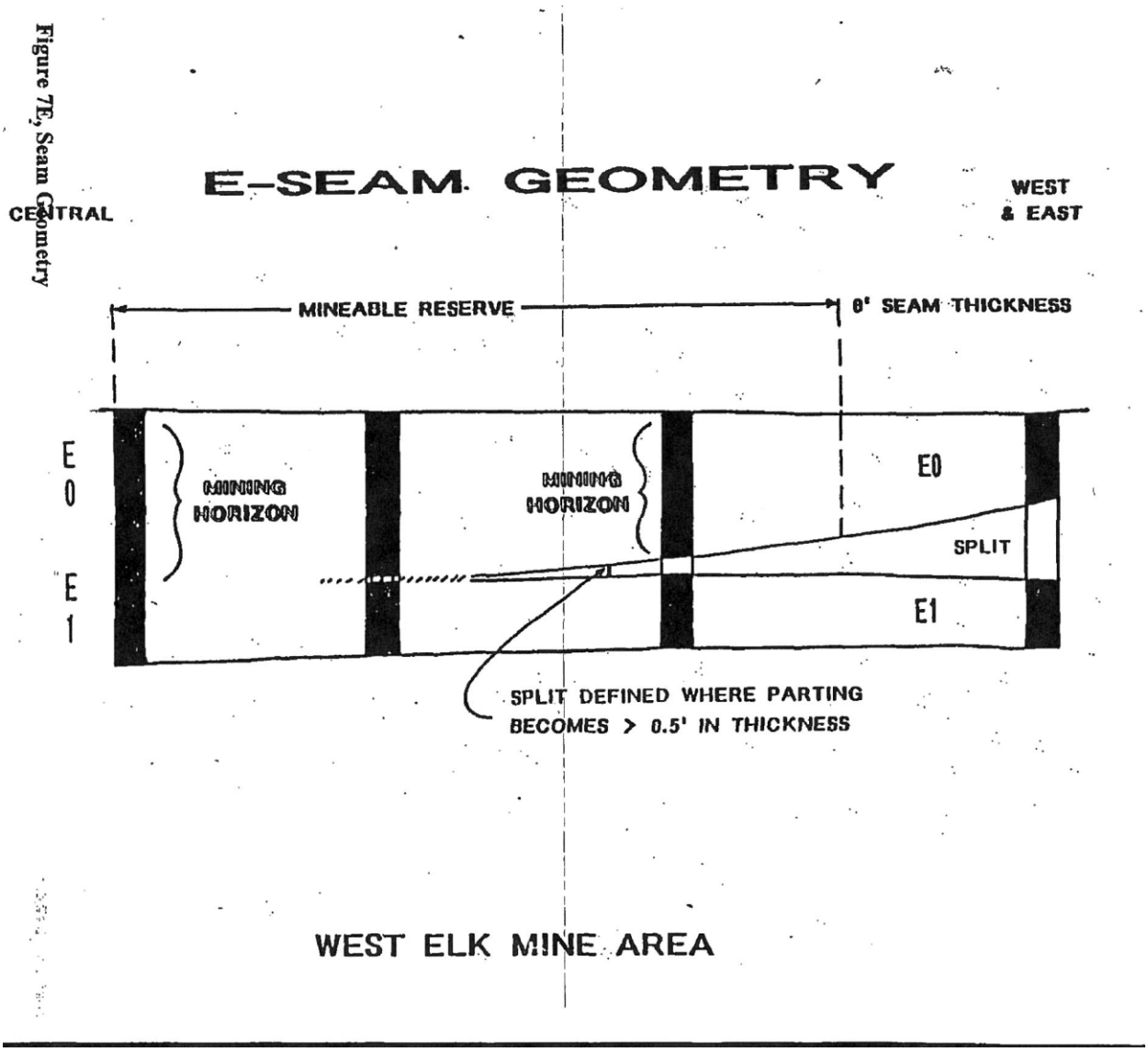

Figure 7, E Seam Geometry

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