CHAPTER 4

GEOLOGY

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addition to ground water migration through the coal seam may result in the accumulation of sulfur, uranium, selenium, cadmium and other trace elements.

Conditions for widespread peat accumulation were optimal during the regressive phases of the Western Interior epicontinental seaway. Basin subsidence was in equilibrium with sediment loading, and sedimentation rates generally declined along the western margin of the seaway. The coastal wetlands left behind the regressing sea became the site of extensive peat accumulation. The ultimate demise of the peat forming basins was the terminal regression of the Cretaceous seaway, and the eventual advancement of the freshwater fluvial processes.

Geology of the Subareas

Introduction. Subsurface exploration of the Black Mesa leasehold by Peabody Western Coal Company began in the early 1960's and mining began in 1970. Beginning in 1977, a series of core holes were drilled and overburden samples were taken in each of the areas projected to be mined. In addition to the overburden and parting analyses, coal samples were also taken from the same core hole and analyzed. The "Drill Hole Collar Location Map", Drawing No. 85351, is located in Volume 20 and the typical geologic cross sections are located in Volumes 13 and 14.

In 1978, a comprehensive exploration program was initiated to accurately define coal reserve parameters throughout the leasehold. At this time, a consistent correlation model has been established for all coal horizons encountered. It must be pointed out that the color designations pertain to coal horizons which may contain one or more coal benches and sub-benches. For the purpose of this report, a coal horizon is defined as a sequence of one or more coal beds which may be time-related as well as having a common environment of deposition.

J-19, J-21, J-23 Subareas. Due to the lateral continuity of the coal horizons and the interrelated stratigraphic and structural fabric of these subareas, J-19/20 and J-21 will be considered as one coal reserve "area".

Located in the southeast portion of the leasehold, this area is delineated on the south and east by Dinnebito Wash, on the north by Reed Valley, and on the west by coal exposures which have burned along the outcrop, forming bright red sequences of resistant shale and sandstone "clinker" material. Local occurrences of burnt coal and clinker material are

also found within the interior of the area. These occurrences are limited in their vertical and lateral extent but do serve to hinder the minability of a given coal horizon as well as alter the natural stratigraphic sequence which, in turn, may affect the topography due to the more resistant nature of the clinker material. In general, the area is characterized by rolling topography slightly dissected along its margins by minor tributaries of the above-mentioned washes.

At the northern and western margins of the area, a series of roughly parallel trending anticlines and synclines have developed. These folds are oriented in a northwest-southeast direction, and exhibit limited axial length. The remaining portions of the area exhibit less structural deformation, with only minor folding developed. Anticlines and synclines in the central portion are oriented in an east-west direction, while the folds in the southern portion exhibit a northeast-southwest orientation. Most folds throughout the area are inconspicuous in the field and seldom have dips which exceed 3°. Though the folds exhibit relatively minor dips, they do, however, influence local surface and ground water flows. A number of apparent, high angle faults with displacements ranging from a few feet to 30 to 40 feet have been identified while small north-south linearities, interpreted as faults have been photo-mapped west of the area. Except for a small remnant of resistant Yale Point Sandstone in the northeastern corner of the area, the Wepo Formation is the only exposed sequence. Within the Peabody Western Coal Company leasehold, the Wepo Formation consists of continental and near-shore sediments which includes seven recognizable and correlatable coal horizons. Each horizon may consist of one or more coal benches or sub-benches. Within the area, these coal horizons vary in thickness, quality and lateral extent. The minability of each horizon is dependent upon the topographic relief and the thickness and quality of the coal, which in turn is largely dependent on the geologic structure, susceptibility to erosion of the overlying strata, and environment of deposition of each coal horizon.

All seven coal horizons occur in the area; however, locally they may not all be present in minable thickness, occur at minable depths, or some horizons may be totally absent due to erosion or nondeposition. In descending order, the coal horizons are designated as: (1) violet; (2) green; (3) blue; (4) red; (5) yellow; (6) brown; and (7) orange. The violet is the uppermost coal horizon and, due to its stratigraphic position, it is the first horizon to be removed by erosional forces. For this reason, the violet is present in a limited portion of the northeast corner of the area. The violet is overlain by a series of continental sediments including paludal and overbank shales and siltstone as well as by

J-2 Coal Reserve Area. The J-2 reserve area is delineated on the west by the outcropping of coal seams along Wild Ram Wash, and on the north, east and south by the economical recovery limits and outcropping of one or more of the minable seams. Dips in the area are generally less than 2 degrees to the east with a strike orientation of N59E. The area is characterized by gently rolling hills usually capped by the more resistant red shale and sandstone associated with the burning of coal seams of the red horizon, and to a limited extent, the uppermost coals of the yellow horizon.

From their outcrop to a depth of up to 140 feet, the first recoverable coals occur within the yellow coal horizon. These two seams, averaging 2.5 and 4 feet in thickness are frequently burnt near their outcrop, limiting their aerial extent while lending the distinctive red color to the strata above the seams. Gradually increasing from west to east, a complex sequence of continental shale, mudstone and thin sandstone lenses separates the yellow horizon coals from those of the underlying brown. The most laterally consistent coals of the J-2 reserve occur within the brown horizon; ranging in thickness from 2.5 feet at its outcrop, to over 13 feet towards the northern margin of the area. Due to the influx of clay to silt size overbank sediments into the paludal environment, the single brown seam diverges into two benches of 2.5 and 6 feet within the central portion of the reserve; separated by less than 2 feet of carbonaceous shale. The orange horizon consists of three recoverable coal seams ranging in average thickness from 2.5 to 5.5 feet. The presence of a sandstone channel, migrating vertically up section, displaces coal seams of the orange horizon in the north; while increasing the non-coal interval separating the brown from the orange coals to the south by as much as 65 feet.

J-4 Coal Reserve Area. The J-4 coal reserve area is truncated by outcrops of the recoverable coal seams to the west, east, and north, and by the economical recovery limits to the south. The area is one of gently rolling topography incised by a major tributary of Moenkopi Wash on the east; with the development of small hills capped by resistant "clinker" material in the south. The general strike within the area is N27W, with dips rarely exceeding 2 degree to the west. Coal seams reaching recoverable thickness and lateral extent occur in the yellow, brown, and orange coal horizons. The coals of the violet, green, and blue horizons have been removed by erosion, while the coal seams of the red horizon have burnt in place and are responsible for the limited development of scoria lithology. From its outcrop to an average depth of 58 feet, the single minable coal seam within the yellow horizon varies from 2 to 8 feet thick. Separated by a 20 to 25 foot thick sequence of interbedded continental shale, mudstone and sandstone, the two

recoverable coal seams of the brown zone each average less than 4 feet thick throughout the reserve. An intercalated layer of shale to carbonaceous shale, generally less than 2 feet thick, separates the two coal benches of the brown horizon. As evidenced by the lateral and vertical continuity of the coal seams and interrelated lithologic units, the J-4 area is characterized by its relatively stable environment of deposition. Two coal seams of the orange horizon, averaging 2.5 and 8 feet in thickness are separated from the overlying brown coals by a relatively thin series of overbank clays, silts and sand with a slight increase in thickness from west to east. The development of a large distributary channel sandstone in the southwest portion of the reserve has displaced, and in a limited area completely removed three coal seams of the lower orange horizon, none of which occur at economically recoverable depths.

J-6 Coal Reserve Area. Coal outcrops, including areas of burnt coal, restrict the economically recoverable coal seams on all sides of the J-6 area. Topography of the reserve is that of gently rolling hills capped with the distinctive red clinker material commonly associated with the in-place burning of coal beds. Contrary to the general overall structural fabric of the southern portion of the Peabody leasehold, most likely due to localized events, the apparent strike of the strata is N89E with dips less than 2 degrees to the east. Coals of the upper Wepo Formation; the violet, green, and blue horizons have been removed by erosion, while the lower red horizon coal seams have burnt in-place along the eastern margin of the reserve. From their outcrop to the east, to a maximum of approximately 110 feet of overburden the first recoverable coals, averaging 6.5 and 3.5 feet thick, occur within the yellow coal horizon. The upper coal bed of the yellow is often described in sub-surface investigations as being "smutty" or "baked"; most likely caused by the oxidation of the seam due to the depth of weathering and the intense heat generated at one time, from the combustion of overlying coals. Averaging less than 10 feet in thickness throughout much of the eastern portion of the reserve, a simple series of shale, mudstone, and discontinuous non-minable coal underlie the yellow coal horizon. Towards the center of the area, this sequence becomes much more complex, with the development of a channel sandstone in excess of 50 feet thick. At its margins, this channel sand increases the yellow to brown interval up to 44 feet; at the channels greatest stage of development the coals of the brown horizon have been completely removed or are absent due to non-deposition. Where present, the brown coal horizon consists of one minable seam, ranging in thickness from 2.5 feet at its outcrop in the west, to in excess of 10 feet towards the eastern margin of the reserve. This same trend of increasing seam thickness towards the east continues with the single coal seam present

within the orange horizon. Laterally the most extensive coal bed of the J-6 reserve area, this seam ranges in thickness from 5 to 16 feet, averaging over 9 feet. A relatively consistent thickness of shale, mudstone and sandstone separates the orange coal horizon from that of the overlying brown. Averaging approximately 50 feet thick, the slight variation in the intervals thickness across the reserve appears to be dependent upon the percentage of sandstone present, with the increase usually at the expense of the overlying brown coal seam.

J-8 Coal Reserve Area. The J-8 coal reserve, situated in the southwest corner of Peabody's leasehold, is truncated on the west, north, and east by the outcropping and/or the burning of the upper recoverable coal seams, and on the south by the lease boundary. The topography is characterized by gently rolling terrain with limited drainage development. The major structural feature, the Oljeto Syncline occurs just east of the reserve and has had apparently little influence; with the overall strike of the strata oriented N52W, with dips less than two degrees to the west.

Coals of economical thickness, lateral continuity and depth occur within the red, yellow and brown coal horizons. The lowermost coals of the Wepo Formation, designated as the orange horizon, are present within the reserve, but do not attain minable thickness or depth; while the upper coal horizons have been eroded, or have burnt in-place and are responsible for the limited exposure of scoria material. From its outcrop to a maximum depth of cover in excess of 60 feet, the single recoverable coal seam within the red horizon averages 3.5 feet in thickness and occurs in the southern two-thirds of the reserve. The most laterally consistent seams, ranging in thickness from 1.5 feet up to 9 feet are present within the yellow coal horizon. Stratigraphically 5 to 68 feet below the red, the two recoverable seams of the yellow converge, attaining a maximum thickness of approximately 14 feet in the central portion of the reserve. This decreasing interburden trend from north to south continues with the merging of the yellow seam with the single recoverable coal of the brown horizon, with a combined thickness ranging from 7 to 19 feet. The variability of the thickness of non-coal lithology between the yellow and brown horizon appears to be dependent upon the influx of clay to silt-sized sediments into the paludal environment at time of deposition; while the large variation in interburden thickness separating the red and yellow horizons is largely due to the percentage of sand size material, and the sediments inherent differences in compaction rates.

J-9 Coal Reserve Area. Located in the southwest portion of the leasehold, the J-9 coal reserve area is delineated on the north, east and west by Yucca Flat Wash and its

tributaries, and on the south by the Peabody Lease Boundary. The area is characterized by rolling topography, incised by minor tributaries of the above-mentioned wash. Structurally, the coal bearing strata dips gently to the west, typically less than 2 degrees, with a strike of N14W. Minor changes in dip due to localized structure or differential compaction of the finer-grained sediments often occur. To date, sub-surface investigation within the area has not revealed any faulting. Faults with a vertical displacement of less than 20 feet may be present but are not readably discernable with the current sub-surface data density.

Economically recoverable coal in the J-9 reserve occurs within three coal horizons; in descending order these are the red, yellow, and brown. The coal seam nomenclature used in this area is representative of those correlations used throughout the lease, with the exception of the J-7 reserve. Typical of the southern portion of the Peabody lease, the upper coals of the Wepo Formation; the violet, green and blue horizons have been removed by erosion. In isolated areas coal seams of the red horizon have burnt in-place and account for the presence of heat-altered mudstone and sandstone. Extending from the horizon's outcrop to a maximum overburden depth of approximately 65 feet, the first recoverable coal seams, averaging 4 to 7 feet thick, occur within the red horizon. Gradually increasing from south to north, a sequence of strata consisting predominately of distributary channel sandstone, channel fill siltstone, overbank shale and mudstone and thin coals separate the red horizon from the underlying yellow. The yellow and brown horizons exhibit extensive variability in coal thickness as well as the intervening non-coal strata between horizons. Ranging in thickness from 2 to 10 feet, up to four individual benches of yellow and brown horizon coals converge and diverge throughout the reserve. The yellow and brown coal seams merge within the western portion of the reserve, attaining a thickness of up to 23 feet; with the non-coal parting interval between these horizons gradually increasing towards the east. The predominant non-coal rock strata consist of paludal, overbank, fluvial and near marine shale, siltstone and fine-grained sandstone. Coals of the lowermost orange horizon, while laterally continuous throughout the reserve, fail to attain economical thickness or depth of cover.

J-10 Coal Reserve Area. Separated from the J-7 and J-9 coal reserve areas by Yucca Flat Wash and it's tributaries, the J-10 reserve exhibits lateral continuity of coal horizons, and is considered an extension of the above mentioned reserve areas. The coal seam nomenclature for the J-10 reserve is consistent with that used for the J-9 reserve, while the J-7 area has maintained the original coal horizon designation first employed by

Peabody. The geomorphology of the reserve is that of gently rolling hills, incised by tributaries of Yucca Flat Wash. The apparent strike of N21W, with dips of less than 2 degrees to the west is consistent with the general structural fabric of the southern portion of the leasehold, with minor variations attributed to localized features and/or differential compaction.

Erosion has removed the upper coal horizons; the violet, green and blue, from much of the southern extent of the Peabody leasehold. Within the J-10 reserve the red, yellow and brown coal horizons contain coals of minable thickness, depth and lateral extent. In isolated areas, coals of the red and yellow horizon have burnt in-place, limiting the seams lateral extent and recoverability, as well as establishing zones of scoria development. Overburden ranging from 7 to 50 feet in thickness and consisting primarily of shale and mudstone with sandstone lenses overlie the first recoverable coal seams of the red horizon, averaging 2.5 and 3.5 feet thick respectively. Underlying these seams is a sequence of mudstone, sandstone, and non-minable coals of continental to marginal marine deposition, ranging in thickness from 4 to 80 feet; increasing from west to east across the reserve. The yellow horizon consists of two recoverable coal seams ranging in thickness from less than a foot, to a maximum of 7 feet. The presence of a distributary channel sandstone in the northern portion of the reserve has by the process of erosion, or non-deposition, limited the extent of the upper yellow coal seam. The brown horizon is comprised of a single recoverable coal seam ranging in thickness from 1 to 14 feet. This variation in thickness, increasing from east to west, is inversely proportional to the thickness of non-coal sediments separating the yellow and brown coals. This relationship, based upon the environments of deposition and the subsequent differential compaction ratio of sediments, is common throughout the coal bearing strata within the Peabody lease. As much as 58 feet of shale, mudstone and intercalated sandstone lenses separate the brown horizon from three non-economical coal seams within the orange horizon.

J-14 Coal Reserve Area. The J-14 coal reserve area is truncated on the northwest and northeast by Peabody's leasehold boundary, on the north-central by the previously mined J-3 area, and on the west, south and southeast by the economically recoverable coal limits, and/or outcropping of the recoverable coal seams. In general, the northern portion of the reserve area is flat lying, grading into a more gently rolling terrain to the south with the development of steep sided hills, capped by the more resistant red scoria lithology created by the in-place burning of the yellow and brown horizon coals. The occurrence of scoria within the blue and red coal horizons in the northern margins has limited the

success of obtaining sub-surface geological data; however the development of the typical scoria capped butte topography is not evident. The apparent strike of the coal bearing strata is N52E, with dips less than two degrees to the east.

Economically recoverable coal seams, present in descending order include the red, yellow, brown, and orange coal horizons. Due to their stratigraphic position, the coals of the red and yellow horizons have been exposed to greater erosion, and therefore exhibit limited lateral continuity. An average of 65 feet of shale, sandstone and scoria overlie the first recoverable coal seams within the red horizon. Averaging 2.5 to 4 feet thick these coals are separated from the underlying yellow horizon by a relatively consistent sequence, averaging 35 feet thick, of mudstone and intercalated fine-grained sandstone. The yellow horizon, represented by a single seam ranging from 7 to 16 feet in the northwest portion of the reserve, diverges towards the east into two minable benches, averaging 6 feet and 4 feet respectively. The non-coal interval separating the yellow from the underlying brown horizon is a consistent 5 to 10 feet of predominately mudstone with minor occurrence of fine-grained sandstone. Of notable exception is a single sub-surface data point, located at the eastern margin of the reserve, indicating the presence of a channel sandstone in excess of 40 feet, displacing the upper coal seam of the brown horizon. Continuing with the depositional trend of a more static paludal environment to the northwest, the brown horizon consists of a single minable seam, averaging 9 feet in thickness, diverging to the east into two benches ranging in thickness from 1 to 6 feet. Erosion, or less likely, non-deposition has resulted in the absence of the upper brown coal seam in the southern portion of the reserve area. The variation, from 36 to 77 feet, of the non-coal interval between the orange and the overlying brown horizon appears to be dependent upon the percentage of sandstone present in the continental to marginal marine sediments. One coal seam of the orange horizon is considered recoverable, averaging 7.5 feet thick. Shale, mudstone, siltstone, sandstone and thin coal seams complete the stratigraphic section in this area.

J-15 Coal Reserve Area. The J-15 area is delineated on the west and north by the leasehold boundary, and on the east and south by outcroppings and/or burnt sequences of the yellow and brown coal horizons. The general topography is that of rolling hills moderately incised by tributaries of Coal Mine Wash. The apparent strike of the area is N75E with dips generally less than 2 degrees to the east. However, small localized folds, and differential compaction of the fine grain sediments may alter the apparent strike and dip of individual lithologic units. Due to their stratigraphic position within the coal

bearing sequence, the coals of the violet, green and blue horizons have been removed by erosion, with isolated areas of scoria present due to the in-situ burning of coals located in the red and yellow zones. Coal seams of economical interest occur within the red, yellow and brown horizons. Coal beds of the orange horizon are present in the area, however these tend to be relatively thin, deep, and discontinuous. From its outcrop to a maximum depth of approximately 80 feet, the overburden material above the red coal horizon consists of interbedded shale, siltstone and sandstone, with isolated areas of scoria development. Two recoverable coal seams of the red horizon, averaging 3 and 5.5 feet thick are separated from the underlying yellow by a sequence of predominantly fine-grained sandstone, with minor shale and non-minable coal strata, with a total interval thickness ranging from 40 to 100 feet. The coal seams of the yellow and brown horizons as well as the intervening rock sequences exhibit lateral continuity throughout the J-15 reserve area. Two recoverable coal seams of the yellow horizon range in thickness from 1.5 to 6.5 feet; while up to four individual benches of the brown horizon, averaging between 2.5 and 7 feet thick coalesce towards the northeast to form one seam of approximately 12.5 feet thick. A thin sequence of overbank to paludal shale and carbonaceous shale, averaging less than 6 feet thick, separates the yellow from the underlying brown coal horizon. The lateral continuity of the yellow and brown horizons within the J-15 reserve can be attributed to a time of stability within the swamp environment, with relatively uninterrupted accumulation of fresh water vegetation and only minor influxes of fine sediments.

J-28 Coal Reserve Area. Located in the northeast corner of the leasehold, the J-28 coal reserve is delineated by economical recovery limits based upon the ratio of coal to non-coal waste as well as other mining constraints. The reserve is characterized by moderately to steeply rolling hills incised by tributaries of Moenkopi and Reed Valley Wash. East of the reserve and extending in to the interior, steep sided hills capped with scoria derived from the in-place burning of the blue, red and yellow horizon coal dominate the terrain. With apparently little or no influence from localized structure or differential compaction of sediments, the overall strike and dip, N29W and 2 degrees west, is consistent throughout the reserve.

Coal seams of the upper Wepo Formation, designated by Peabody as the violet and green horizons, are absent from the J-28 reserve; most likely removed by the forces of erosion. Underlying the green, the burnt coals of the blue and red horizons, and their associated red scoria lithology, occur to the south and east, but are not present within the reserve

area proper. Up to three coal benches of the yellow horizon are present within the southern portion of the reserve, however these seams were developed in an environment of deposition unfavorable to the accumulation of organic material and are thin and discontinuous. In isolated areas, the lateral extent of the yellow horizon coals are further limited by the process of in-situ burning. Approximately 25 feet of predominantly clay to silt-sized sediments separate the thin coals of the yellow horizon from the first economically recoverable coal seams, ranging in thickness from 1 to 8 feet, present within the brown horizon. Limited to the southern portion of the reserve, these seams are separated from the underlying orange horizon by a highly variable thickness of continental to marginal marine sediments consisting of shale, mudstone and channel sandstone. Up to four minable seams are present within the orange coal horizon. Averaging from 3 to 6 feet in thickness, the coals of the orange and their associated non-coal intervals exhibit extensive lateral and vertical variability. The upper two coal seams, separated by as much as 50 feet of mudstone and channel sandstone in the western portion or the reserve, converge to the east and attain a maximum thickness of 16 feet. Interbedded shale, siltstone, sandstone and thin coals complete the lower sequence of the coal bearing Wepo Formation.

N-9 Coal Reserve Area. This most northern coal reserve area within Peabody Western's lease is bounded on all sides by Yellow Water Canyon Wash and it's tributary, Yazzie Wash. In general, the structural fabric of individual coal reserve areas becomes more complex towards the northern escarpment of Black Mesa. Folds within the N-9 area are typically oriented in a northeast direction. The general strike and dip of the strata is N76E, 1.5 degrees to the east.

The minable coal horizons within the N-9 area in descending order include the red, yellow, brown and the uppermost coal seam of the orange sequence. The coals of the violet, green and blue coal horizons have been removed by erosion and/or the in-situ burning of the coal. The lower coals of the orange horizon are highly variable both in lateral extent and in thickness and are not economically recoverable. From the red horizon's outcrop to as much as 100 feet; interbedded sandstone, shale, thin coal, and scoria overlie the first recoverable coal seams in the N-9 reserve. The red horizon consists of up to five individual benches, ranging in thickness from less than one foot to a maximum of 7 feet. The two lowermost seams converge in the southern portion of the reserve and attain an average thickness of over 6 feet. A sequence of predominately mudstone, shale and sandstone of continental to marginal marine deposition separates the yellow coal horizon

from the overlying red. This coal horizon is comprised of two individual seams each averaging approximately 3 feet thick. Underlying the yellow horizon is a sequence of strata, up to 50 feet thick, dominated by the presence of sandstone interbedded with shale and minor beds of coal. The most laterally consistent horizon, the brown, consists of an upper seam averaging 7.5 feet thick, with a thinner and somewhat discontinuous lower seam ranging in thickness from 1 to 6 feet. This same lateral consistency is exhibited in the non-coal interval separating the brown and orange horizons, maintaining an average thickness of 16 feet of shale and sandstone. The lowermost coal horizon, the orange, consists of one seam of recoverable thickness, ranging from 2.5 to 7 feet, with a slight thinning trend towards the northern extent of the reserve. This trend corresponds with the gradual increase of brown to orange interburden in the same direction; indicating that at time of deposition, this portion of the reserve area was subjected to an influx of clay to silt-sized sediments. The most consistent lithologic unit within the N-9 coal reserve area, as well as throughout most of the Peabody lease, is a blanket sandstone believed to be deposited in a shallow embayment; bringing to a close the paludal environment responsible for the deposition of the orange coal horizon.

N-10 Coal Reserve Area. The N-10 coal reserve area is bounded on the west and south by lands reclaimed due to mining activities, on the east by a tributary of Coal Mine Wash, and on the north by Yellow Water Canyon Wash. Along the margins of these washes, the coal has burned extensively. The resultant "clinker" material, and remnants of the Yale Point Sandstone lend a distinctive break, marked by resistant cliffs, to the generally rolling topography of the area.

Because of the area's location, near the northern escarpment of Black Mesa, the structural fabric, resulting from the gentle uplift and tensional release, is considerably more complex. The western margin of the area is dominated by a set of parallel trending anticlines and synclines. These folds are oriented in a north - south direction, exhibiting limited axial length, plunging towards the south. These folds are inconspicuous in the field, with the overall strike and dip of the coal bearing strata being N16W and 2 degrees to the west. Faults, while not numerous, are present from the northern section of the area, northwards toward the Black Mesa escarpment. These faults are oriented in a northwest - southeast trend with the down-thrown blocks positioned to the northeast.

Mining in the southern and western portions of the N-10 area began in 1979 and was

discontinued in 1981 with a total coal production of approximately 500,000 tons. The recoverable coal horizons, in descending order are the red, yellow, brown and orange. Although the upper coal horizons are present in this area, they have either burned in place, or are too thin and laterally variable to be of economical quantity and quality. A sequence of continental to marginal marine shale, mudstone and sandstone up to 130 feet thick overlie the two recoverable coal seams of the red horizon. Averaging 4.5 and 3.0 feet in thickness, the coals of the red horizon are separated from the two minable coal seams of the yellow horizon by a relatively consistent interval of sediments averaging about 40 feet thick. The coals of the minable yellow horizons average 4.0 and 2.0 feet thick. Within the N-10 reserve area the coals of the brown horizon have converged into a single minable seam ranging in thickness from 5 to 14 feet. The orange horizon is comprised of up to three coal seams of recoverable thickness, ranging from a minimum of 2 feet to a maximum of 10 feet. The innerburden material between the yellow, brown and orange horizons consists of intercalated continental shales, siltstones, sandstones and coal, formed in interdeltaic to alluvial environments, with minor marine sequences containing the diagnostic liguloid brachiopod fossil.

N-12 Coal Reserve Area. Stratigraphically and structurally similar, the N-12 coal reserve area is considered an extension of the N99 reserve to the southeast and the N-11 reserve to the east. The N-12, N-99, and N-11 reserve areas are all one contiguous coal reserve. The N-12 coal reserve area is bounded on the west, south, and east by lands reclaimed due to mining activities, and on the north by Coal Mine Wash. As typically found throughout the Peabody leasehold, the upper coal horizons present in any given area have burned at their outcrop, forming the distinctive red scoria lithology responsible for much of the topographic highs. Within the N-12 reserve, the coals of the red and yellow horizons have burnt in-place, forming surface deposits of scoria material; however, the absence of large-scale erosion has limited the presence of the exaggerated highs prevalent in the N-99 reserve area. The estimated strike and dip of the coal bearing strata is N12W, 2 degrees to the west.

The recoverable coal seams are confined to the red, brown and orange horizons. Although present throughout much of the reserve, the coals of the yellow horizon are thin and discontinuous, averaging less than 2 feet thick. Restricted to the southern portion of the reserve, under an average overburden of 50 feet of predominately mudstone, shale and scoria, a single marginally economical coal is present within the red horizon, averaging less than 2.5 feet thick. A series of interbedded shale, thin coal and sandstone lenses averaging 80 feet thick separate the red horizon from the single recoverable coal seam of

the brown horizon. This interburden sequence maintains a relatively consistent thickness due to the absence of distributary channel sandstone development. This trend in lateral consistency continues with the brown coal seam maintaining an average thickness of 11 feet throughout much of the N-12 reserve. A highly variable thickness of shale, mudstone and sandstone, of probable continental to marginal marine deposition, separates the orange coal horizon from the overlying brown. Ranging in thickness from 19 to 63 feet, with a thickening trend to the south, this variability is most likely due to the development of a distributary channel prior to the deposition of the brown coal seam. The lower most coal horizon, the orange, consist of three minable seams averaging 3, 8, and 3.5 feet respectfully, with the two uppermost seams converging to the south, reaching a maximum thickness of approximately 12 feet.

N-99 Coal Reserve Area. The N-99 coal reserve is bisected, into roughly equal areas, by the present alignment of Peabody's overland coal conveyor. If the Kayenta Mine coal supply agreement with the Navajo Generating Station extends beyond 2011, PWCC will relocate the overland coal conveyor and adjacent facilities and mine the N-99 coal reserve as one mining block. The northern reserve is bounded on the east and west by the geologic extensions of the N-11 and N-14 coal reserve areas and their associated reclaimed lands, and on the north by the current leasehold boundary. The southern reserve area is delineated on the east and south by the development of extensive scoria lithology, resulting in topographic highs with deeply incised drainages, and by the J-1/N-6 reclaimed lands to the west. The overall strike of the area is N26W, with dips less than 2 degrees to the west.

The uppermost coal horizons of the Wepo Formation, due to non-deposition or most likely erosion, are absent from the N-99 coal reserve. Much of the distinctive "clinker" or heat-altered lithology present throughout the area owes its origin to the in-situ combustion of the uppermost coals of the red horizon. One coal seam of the red horizon, attaining a maximum thickness approaching 5 feet, is considered recoverable where depth of cover has prevented combustion or oxidation. A complex sequence of continental and marginal marine sediments ranging in thickness from 15 to 110 feet separate the red horizon coal from the underlying yellow. This interval increases from west to east and is largely a function of the percentage of sandstone present. Within the northern portion of the N-99 reserve, sub-surface investigations have identified a distinct geophysical signature interpreted to be a blanket sandstone of marginal marine deposition. The occurrence of this lithology within the coal sequence has been utilized in identifying the three minable seams, each 2.5 to 3.5 feet thick, of the yellow horizon. A laterally and

vertically consistent series of strata, predominately shale and mudstone with lenses of sandstone, separate the brown horizon coals from the overlying yellow. The two coal seams of the brown, averaging 5.5 and 4 feet thick respectively, merge towards the boundaries with the N-11 and N-12 reserve areas, attaining an average thickness of approximately 10 feet. Within the northern portion of the N-99 coal reserve area, the non-coal interval between the brown and the underlying orange coal horizon is a fairly consistent sequence; 18 to 20 feet thick, composed of shale, mudstone and intercalated sandstone. Trending to the south this interval increases to as much as 65 feet, most likely due to the process of differential compaction of sediments and the presence of a distributary channel sandstone. The introduction of fine sediments into the paludal environment during deposition has caused the coals of the orange horizon to converge and diverge over relatively short distances. From two to four seams of recoverable thickness may be present in any given area of the reserve. The two uppermost coals of the orange, averaging 4 and 8 feet thick respectfully, converge near the southern margin of the reserve, attaining an average thickness in excess of 13 feet. To the north, an influx of fine sediments of probable overbank origin is responsible for the development of an in-seam parting, splitting the second orange horizon coal seam into two distinct benches, ranging in thickness from 1.5 to over 6 feet. Present throughout much of the N-99 reserve area, the lowest recoverable coal seam within the orange horizon varies in thickness from less than 2 feet up to a maximum 6 feet. A series of mudstone, shale, sandstone and thin coal seams, of continental to marginal marine deposition completes the lowermost sequence of the coal bearing Wepo Formation.

Exploration Drilling and Sampling Practices

PWCC periodically conducts exploration drilling and sampling to characterize geologic and hydrologic conditions and to delineate and characterize coal, overburden, and interburden materials in both active and proposed mining areas. Exploration drilling and sampling are the primary means of determining the depth, thickness, physical and chemical characteristics, and degree of saturation of the geologic materials to be disturbed or otherwise affected by mining. Although each exploration program may involve a different area and slightly different objectives, all exploration programs will generally involve the same activities including:

- Establishment of exploration staging areas (for temporary storage of drilling equipment and supplies)

- Construction of temporary exploration roads

- Drilling, sampling, and geophysical surveying of completed drillholes

- Subsequent reclamation of all exploration disturbance outside of the five-year affected lands area

The following describe these components of exploration drilling and sampling programs as a basis for understanding the equipment and activities involved and the practices used to assure the integrity of the resulting sampling information. Exploration applications for J-21 and J-23 are presented in Attachment 4-1 and applications for N-6/N-11, N-9, and N-10 are presented in Attachment 4-2.

Exploration Staging Areas. Given that exploration activities may occur at the same time and in proximity to ongoing surface mining operations, a reasonable effort will be made to utilize existing mining disturbance areas or facilities areas. If necessary, separate staging areas will be developed for temporary storage of drilling equipment and supplies. The drilling contractor(s) may also have a temporary office trailer, fuel tank, and other temporary ancillary facilities in the staging area(s). Existing equipment parking areas or other existing disturbance areas may be used as staging areas or new staging areas may be constructed adjacent to existing roads.

If new staging areas are developed, surface disturbance will be minimized to the extent possible and they will be located adjacent to existing roads and well away from natural drainages. Staging area development will involve removal of available soil material and placement in windrows on the perimeter of the area, establishment of temporary drainage features (berms or ditches) to effectively control site drainage, and placement of surfacing material (granular spoils, scoria, or gravel) where appropriate. Contractors will be responsible for full compliance with all applicable regulatory requirements including fuel storage and containment requirements, waste collection and handling, and surface drainage and sediment control. On completion of drilling activities, staging areas will be reclaimed if outside of the five-year affected lands area.

Exploration Access. To the extent possible, exploration sites will be located adjacent to existing roads or trails. If existing access is not available and ground conditions are favorable, exploration equipment may move across undisturbed terrain to access exploration

sites. In the case of access across undisturbed terrain, equipment movements and other related traffic will be kept to an absolute minimum. In most cases where access does not exist, it will be necessary to establish temporary exploration roads. Where road construction is necessary, roads will be constructed to the minimum practical width and will be aligned to minimize total length and limit erosion to the extent possible.

Temporary exploration roads will be constructed ten to fifteen feet wide using a tracked dozer or rubber-tired loader. Road construction will involve clearing any trees or large shrubs, removing and windrowing available soil material to the side of the road, establishing appropriate temporary drainage (ditches, berms, and minor drainage control structures), and grading to provide a smooth stable operating surface. On completion of drilling activities, temporary exploration roads will be reclaimed if outside of the five-year affected lands area.

Exploration Drill Sites. Most drilling can be conducted with minimal site preparation, since the drill can be set-up and leveled using self-contained hydraulic jacks. Where site preparation is necessary due to the topography or the need to utilize drilling fluids, a pad having maximum dimensions of approximately 75 feet in width and 100 feet in length will be established. Pad preparation will involve the use of a tracked dozer, backhoe, or rubber-tired loader to recover and windrow available soil material on the pad perimeter and establish a level drill site. If feasible, based on hole depth and drilling conditions, portable tubs will be utilized to mix and contain necessary drilling fluids.

If greater pit capacity is required than would be feasible using portable tubs, mud pits for the containment of drilling fluids and cuttings will be excavated within the pad area. Maximum disturbance area for each drill site is expected to be approximately 0.17 acres. On completion of drilling activities, all mud pits will be backfilled and drill sites outside of the five-year affected lands area will be reclaimed.

Drilling and Related Activities. In general, PWCC's exploration drilling activities fall into three categories; boreholes, cropholes, and coreholes. At borehole and crophole locations the drill rig is set up on the drill site, leveled with hydraulic jacks mounted on the truck, and a single boring (typically 4.5 to 5 inch diameter) is drilled to intercept the lowest potentially mineable coal seam or an individual seam at the crop locations. At corehole locations, the drill rig is set up on the drill site, leveled with hydraulic jacks, and a "pilot" or borehole is drilled to intercept the lowest potentially mineable coal seam (or pre-determined horizon) to determine its depth at that location.

Once the target depth is determined, a second drillhole is off-set five to ten feet from the pilot hole and is drilled to just above the coal seam or horizon of interest. The coal seam or horizon of interest is then core-drilled using a diamond core bit and split-tube core barrel assembly.

Drilling activities will utilize one or more truck-mounted rotary drills capable of achieving depths up to 500 feet. In order to minimize the potential for sample contamination, drillholes will be drilled using air, air/foam, or water as the circulation medium. If the use of drilling muds is necessary to maintain circulation and drillhole integrity, polymer muds free of metallic compounds will be used. Each drill will be supported by a water truck (minimum capacity of 1,000 gallons) and at least one pickup truck. All drilling and related operations will be conducted by an experienced driller in such a way as to minimize potential environmental impacts and will be supervised by a qualified geologist, hydrologist, soil scientist, environmental coordinator, or engineer.

During drilling operations, water levels and flows in the drillholes will be closely monitored in order to characterize hydrologic conditions. Samples of surficial materials and sub-surface rock and coal materials may be collected and logged during drilling for subsequent analysis. Samples may be either chip or cutting samples or core samples. Chip or cutting samples are obtained during normal rotary drilling operations using specially designed buckets with extended handles. The buckets are often placed at the collar of the drillhole where the air or air/foam circulation medium carries cuttings to the surface from the drill bit. When sampling using this method, samples are obtained at regular intervals corresponding to progressive drilling advance, bagged, and labeled for physical and/or chemical analysis.

Core sampling is used to recover relatively intact samples of coal, overburden, or interburden materials. Core samples are obtained using a diamond core bit and split-tube core barrel assembly. Generally, core sampling proceeds in ten-foot intervals and the core samples are separated every two-feet, bagged in plastic core sleeves, labeled, and boxed. An exploration geologist, hydrologist, soil scientist, or environmental coordinator examines the core, logs and characterizes the cored materials by litho-type based on appearance (color, grain size, bedding, mineralogy, hardness) and field tests, and then selects and ships representative core samples to the analytical laboratory for physical and/or chemical analysis. Selection of core samples for analysis is generally based on PWCC's requirements for characterization of coal and overburden/interburden

materials, with core samples being segregated by litho-type as previously determined.

Downhole geophysical surveys may be conducted on all or selected drillholes following drillhole completion using a truck-mounted logging system. Geophysical surveys will result in a suite of logs including, but not limited to natural gamma, high-resolution density, and resistance that can be used in conjunction with driller's logs, lithologic descriptions, and sampling information to accurately characterize geologic, hydrologic, coal, and overburden occurrence and characteristics.

During drilling, PWCC will control dust from drilling and related activities, divert and control both natural runoff from disturbed areas and fluid loss from drilling, and will clean-up any trash or debris. If air is utilized as the circulation medium, dust from drilling will be controlled by a flexible shroud at the drill collar. Drill cuttings and drilling fluids will be effectively controlled and contained by portable tubs, mud pits, or berms within the drill pad area.

Drillhole Sealing, Abandonment, and Reclamation of Drilling Disturbance. On completion of drilling, sampling, and logging for each exploration drillhole, PWCC will proceed with either temporary plugging or permanent sealing unless it is advantageous to complete the drillhole as a monitoring well. Completion of any drillhole as a monitoring well will involve the well completion procedures outlined in Chapter 16, Hydrologic Monitoring Program and well completion information will be provided to OSM following completion of the drilling program. Because they will be mined through within a relatively short time-frame, drillholes within the five-year mining area will be temporarily plugged rather than permanently sealed. Temporary plugging will involve placement of drill cuttings to within one foot of ground level and filling the remainder of the drillhole with cement to the ground surface to prevent surface or other materials and surface water runoff from entering the drillhole. Drillholes outside of the five-year mining area will be permanently sealed. Permanent sealing will involve backfilling the drillhole with drill cuttings to within five feet of ground level and filling the remainder of the drillhole with cement to the ground surface. Drillhole locations are marked by a metal tag with the PWCC drillhole number which is attached to a wooden surveyors stake set in the concrete surface plug. The time interval between completion of drilling operations and completion of temporary plugging or permanent sealing is normally approximately three to five days.

Areas disturbed by exploration activities including temporary staging areas, temporary exploration roads, and drill sites will be stabilized or reclaimed following completion of drilling activities. Exploration disturbance areas within the five-year affected lands area will be stabilized to minimize erosion during the interim period before these areas are mined through. Stabilization measures will include removal of all trash and debris from the drill site for disposal, spreading any excess cuttings over the site, and backfilling of any excavations, including mud pits. Where mud pits are necessary, they will be fenced as needed, allowed to dry, and later backfilled with drill cuttings and/or previously excavated material.

Exploration disturbance areas outside the five-year affected lands area will be reclaimed. All trash and debris will be removed from drill sites for disposal; excess cuttings will be spread over the site; excavations, including mud pits, will be backfilled; disturbance areas will be regraded; drainage will be reestablished; soil material will be replaced; and vegetation will be reestablished. Where the creation of a drill pad results in a bench which exceeds four feet in height, the bench will be reduced to a maximum slope of 3h:1v. Where construction of temporary exploration roads results in minor cuts and fills, a track-hoe or similar equipment will be used to pull fill material back onto the road bench and grade the road surface to blend with the surrounding terrain. Available soil material will be replaced on disturbed areas if soils existed prior to the disturbance and were recovered during construction. The surface will be scarified to a depth of approximately four inches or more. Water bars or berms will be constructed to control drainage on and from the reclaimed areas and to aid in surface water retention. The disturbed areas will be seeded using broadcast seeding techniques using the Special Stabilization Mix described in Chapter 23, Revegetation Plan.

Generally, reclamation will be coordinated for all areas disturbed by exploration activities within a calendar year. Reclamation and revegetation will be contemporaneous with drilling as much as possible with exceptions due to extreme weather (snow, rain, mud) conditions and activities will be completed within six months following initiation consistent with seasonal reclamation planting considerations as outlined in Chapter 23, Revegetation Plan.

Exploration applications for J-21 and J-23 are presented in Attachment 4-1 and applications for N-6/N-11, N-9, and N-10 are presented in Attachment 4-2.

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