CHAPTER 6

GEOLOGY

(R645-301-600)

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GEOLOGY

6.10 Introduction

This Chapter presents discussion of geologic conditions within and adjacent to the Genwal Mine Permit Area, which consists of Lease Areas SL062648 and U054762, the Right-of-Way N-66838, State Lease ML-21569 and State Lease ML-21568. Conclusions herein are based on field reconnaissance, exploratory drilling and previous documentation. Report references are shown at the end of this chapter.

6.11 General Requirements

The geology within and adjacent to the permit area is discussed in Sections 6.21 through 6.27 of this chapter. Plans for casing and sealing of exploration holes and for subsidence monitoring are discussed in Sections 6.30 through 6.32.

6.12 Certification

All required maps, plans and cross-sections presented in this chapter have been certified by a registered professional engineer.

6.20 Environmental Description

This section presents a description of the geologic resources in, and adjacent to the permit area.

6.21 General Requirements

Regional Geology

The Wasatch Plateau consists of Tertiary and Cretaceous strata, mostly limestone, sandstone, and shale that differ in resistance to erosion (Davis and Doelling, 1977). Limestones and sandstones generally form cliffs, whereas the shales form recessive slopes.

Stratigraphic units present in the vicinity of the Crandall Canyon area include from youngest to oldest (1) the North Horn Formation (slope-forming mudstone and sandstone). (2) the Price River Formation which consists of the basal Castlegate Sandstone Member (cliff-forming sandstones, conglomerates and minor amounts of shale, of deltaic origin) and the Upper Price River Member (steep slope-forming sandstone with minor interbeds of pebble conglomerate and shale, of fluvial origin). (3) the Blackhawk Formation (cliff-forming sandstone underlain by slope-forming mudstone, shale and coal, of paludal origin). (4) the Star Point Sandstone (cliff-forming sandstones consisting of deltaic and beach

deposits), and (5) the Masuk Shale Member of the Mancos Shale (slope-forming marine shales), refer to Appendix 6-3 and 6-4 and Plate 6-1. The Star Point Sandstone contains several shale tongues of the underlying Masuk Shale in the Wasatch Plateau region.

The stratigraphic record produced by these units indicates that deposition up through the Blackhawk Formation consisted mostly of fine-grained detritus under conditions of relatively quiet and uniform sedimentation (Davis and Doelling, 1977). An erosional disconformity exists at the top of the Blackhawk Formation, which is overlain by coarse clastics of the Castlegate Sandstone. These coarse continental sediments suggest tectonic movement to the west and probably mark the onset of the Laramide orogeny (Davis and Doelling, 1977).

The Wasatch Plateau lies in a transition zone between the relatively stable Colorado Plateau to the east and the relatively complex and unstable Basin and Range province to the west (Davis and Doelling, 1977). Strata of the western Wasatch Plateau dip into a complexly faulted monocline, whereas strata on the east side have predominantly gentle dips and faults are less numerous (Davis and Doelling, 1977).

Major faults present within the region of the coal fields are north-trending with maximum displacements of up to 2,300 feet (Davis and Doelling, 1977). Many north-trending faults with minor displacements are present and few east-trending faults, most of which have displacements of less than 100 feet, are also present locally.

Most of the strata in the coal field form broad anticlines and synclines that trend northeast or are roughly perpendicular to the principal fault zones (Davis and Doelling, 1977).

Geology of Project Vicinity

The drainage basin of Crandall Canyon covers approximately 5.7 square miles and exposes six geologic units which range in age from Cretaceous to Tertiary. Surface lands within the permit area consist entirely of outcrop exposures of sandstones, mudrocks and coal of the Castlegate Sandstone, Blackhawk Formation, Star Point Sandstone, Price River Formation, and North Horn Formation are shown on Plate 6-1.

The Hiawatha and Blind Canyon coal seams, which will be of importance in the permit area are present at or near the base of the Blackhawk Formation (Campanian in age). Several other thin lenticular coal seams are present at the property, but none are of significant thickness or of probable lateral extent to be of economic interest. Only the Hiawatha seam is of sufficient thickness to be economically recoverable.

The Hiawatha coal seam has been mined and is exposed at an approximate elevation of 7900 feet amsl (Appendix 6-1). Mining overburden above the Hiawatha coal seam in the permit area consists of the Blackhawk Formation, Castlegate Sandstone, and the Upper Price River Member and the North Horn Formation. Surface outcrop of these formations rise from approximately 7900 feet amsl to approximately 10,400 feet amsl in the center of State Lease ML-21568. This results in a maximum overburden of approximately 2100 feet and an average overburden of approximately 1,000 feet. The entire area is underlain by the Star Point Sandstone.

The coal-bearing unit is the Upper Cretaceous Blackhawk Formation. The Blackhawk Formation is composed of grey sandstone, siltstone, shale, and coal; it is composed of about 50% fine-grained sandstone and is present in thicknesses of 650 to 1000 feet at Crandall Canyon. The Hiawatha coal bed is the thickest coal bed present (10 feet at Crandall Canyon), and is found near the base of the Blackhawk (Lines, 1985).

The Upper Cretaceous Star Point Formation underlies the Blackhawk Formation. It is predominately composed of massive tan medium-grained sandstone with minor interbeds of shale and siltstone near its base. This formation outcrops east of the Crandall Canyon Mine and reaches a thickness of 350 to 450 feet. At the southeast end of Trail Mountain, where the Star Point is exposed, it is about 500 feet thick (Lines, 1985). This formation is of significance since it and the saturated portions of the Blackhawk Formation comprise a regional aquifer present at both mine sites.

The Upper Cretaceous Castlegate Formation overlies the Blackhawk Formation and is dominated by massive tan medium-grained massive sandstone. It has a thickness of about 170 to 200 feet at Trail Mountain, and is 250 feet thick at Crandall Canyon (Lines, 1985).

The Castlegate is overlain by the Upper Cretaceous Price River Formation, a grey medium - to coarse - grained sandstone interbedded with several thin shale beds at both mine sites. The Price River is about 700 feet thick at the Trail Mountain Mine (Lines, 1985), and is about 600 feet thick at the Crandall Canyon Mine.

Overlying the Castlegate is the North Horn Formation of Upper Cretaceous and Tertiary age. It is composed of interbedded shales, siltstone, sandstones, and limestones. At the Trail Mountain mine it reaches a thickness of about 1000 feet, although thicknesses of only several hundred feet are present at Genwal, due to erosion. The North Horn Formation caps the mountain ridges in the Crandall Canyon area, and serves as a recharge unit to underlying formations and supplies water to springs within the formation.

The Joes Valley Fault breaks the continuity of these geologic units at both the Trail Mountain and Crandall Canyon Mines. The Joes Valley Fault lies along the west base of Trail Mountain, and along the west base of East Mountain at the Crandall Canyon Mine (Davis and Doelling, 1977). The Joes Valley Fault forms the eastern boundary of a graben about 3 miles wide which extends north and south of both mines (Davis and Doelling, 1977). Davis and Doelling (1977) estimate approximately 2300 feet of vertical displacement along the fault in this area. Stratigraphic dip at both mine sites is approximately 2 to 3 degrees to the southeast (Lines, 1985).

As discussed in Section 5.25, mining-induced subsidence will not intersect the Joes Valley Fault. The maximum limit of subsidence in Section 2 is depicted on Plates 5-2, 5-2C, and Figure 5-9, and subsidence-induced hydrologic effects are discussed in Section 7.0.

Geologic inspection of the property indicates that prior mining of the Hiawatha Seam did not encounter subsurface water. The maps submitted in Appendices 6-3 and 6-4 and Plate 6-1 are included to show the relative location of the geologic formations to the mine permit area.

6.22 Cross Sections, Maps and Plans

Stratigraphic sections are shown in Appendices 6-1 and 6-4. Drill hole results and cross sections are shown in Appendix 6-5. The Geologic map is on Plate 6-1. Coal seam isopachs for the Hiawatha, Blind Canyon and Bear Canyon Seams are shown on Plates 6-3, 6-4 and 6-5, respectively. Overburden is shown on Plate 6-6. Structure is shown in Appendix 6-3. A structure contour map of the top of the Hiawatha seam is shown on Plate 6-7. Plate 6-2 has been eliminated from the plan.

6.22.1 Test Borings and Coal Sampling

Genwal has included two lithologic, depth correlated sections to show thicknesses of interburden and coal from the Star Point Sandstone to the surface. These geologic sections are provided in Appendix 6-1. The lithofacies of the Blackhawk Formation in the vicinity of the mine area are shown in stratigraphic section within Appendix 6-1. Two additional holes have been drilled in State Section ML-21569. These sections should provide sufficient technical information to determine the nature, depth and thickness of the coal seams, rider seams, overburden and interburden strata for the permit area. The thickness and extent of all formations in the area adjacent to the mine area are shown on Plates 6-1 through 6-6, with related discussion in Section 6.21. Borehole locations are shown on Plate 5.2. The locations of in-mine up-drilled borings discussed in Section 14.1 are shown on Plate 5-2B.

The drilling results obtained during 1985 indicate the presence of the Blind Canyon seam although it is of unminable thickness (Appendices 6-1 and 6-5). The upper seam will be called the Blind Canyon Seam at the request of DOGM to simplify discussion. The same seam has been referred to as the "upper Hiawatha Seam" and the "lower Bear Canyon Seam" at various other locations.

Analysis of coal samples collected from the Hiawatha Seam indicate that it is a high volatile bituminous coal with a BTU content ranging from 12,500 to 13,000 BTU, ash content of 6% to 8%, moisture of 3% to 5%, volatile matter from 40% to 44%, fixed carbon from 43% to 46% and sulfur from 0.3% to 0.8%. Forms of Sulfur average 0.20% pyritic sulfur, 0.09% sulfate sulfur, and 0.50% organic sulfur.

6.22.2 Coal Seams, Overburden, Stratum Coal Seams

Additional technical information has been submitted to determine the nature, depth and thickness of the coal seams, rider seams, overburden and interburden strata for the permitted mine area based upon drilling completed to date (Appendices 6-1 and 6-5 and Plates 5-2 and 5-2C). There is insufficient evidence to support the presence of the Blind Canyon Seam in Crandall Canyon, but it thickens southward to the Mill Fork area, beyond which it again is of little value (Doelling, 1972, p. 189). The old workings can provide information on the lower seam (Hiawatha) and some ground water information but nothing about the other seams. Additional geologic information was submitted by Mr. Wollen, a former operator of the Genwal property, which contained specific lithologic characterizations of the interburden, and the strata immediately above and below the coal seams (Appendices 6-1 and 6-2).

Coal Reserves. Coal-seam data for lease area SL 062648 indicates that approximately 840,000 tons of coal are in place, of which 400,000 tons are recoverable. Lease area U 54762 contains approximately 2.5 million tons of coal in place, of which approximately 1.5 million tons are recoverable. Approximately 0.5 million tons will be left in place for final retreat, leaving approximately one million tons minable during advance.

Coal reserves in the Right-of-Way U-66838 are estimated at 1,400,000 tons in place from which 203,000 were recovered to gain access to State Leases. No other mining will be done here per agreement of B.L.M. and Genwal, until LBA #9 has been awarded if Genwal Coal is the successful bidder. In-place tonnage for State Leases ML-215688 and ML-21569 is estimated at 18,000,000 tons, of which 8,000,000 tons are considered recoverable.

There are no reserves considered minable or recoverable in the upper seams (Plates 6-4 and 6-5). The Hiawatha seam is the only

seam in the mine plan area that is of minable thickness. The Hiawatha seam isopach map is shown on Plate 6-3.

The information obtained from drill holes 1 and 2 show the Blind Canyon to be approximately 59 and 40 inches thick, respectively, which makes this seam unminable and of no economic value. Drill holes 3 and 4 indicate the Blind Canyon seam is 54 and 40 inches thick, respectively, in those areas. The Blind Canyon seam is located approximately 40 to 60 feet above the Hiawatha seam. Refer to Plate 5-2 for locations. The Blind Canyon is present on approximately 60 acres of the property and has an average thickness of 4 feet, equivalent to approximately 418,000 tons of coal in place. This seam remains fairly continuous across the property.

Additional drilling information has been provided for the State Leases. This information is included in Appendix 6-1. The seam information has been translated to the isopach maps, Plates 6-3, 6-4 and 6-5. As shown on the isopach maps, the Hiawatha Seam is the only seam which is considered economically recoverable.

Reserve Classifications. A map is provided delineating coal outcrop lines from the Hiawatha and Blind Canyon seams with the strike and dip indicated at one point, refer to Plate 6-1.

Stratigraphy. The Blackhawk Formation is comprised of approximately 1000 feet of gray carbonaceous shales, siltstones, coals and thin interbedded sandstones. The coal beds to be mined near the base of the formation are 6 to 11 feet thick and are generally classified as a high volatile bituminous coal. The Blackhawk Formation is underlain by the massive cliff-forming Star Point Sandstone, which is 200 to 400 feet thick.

Appendix 6-1 includes two stratigraphic sections which were obtained by traversing the stratigraphic column from Crandall Creek to the Castle Gate Sandstone. The entire stratigraphic column is shown in Appendix 6-1 for the permit area. A generalized stratigraphic section is provided in Appendix 6-4. This section has been confirmed by field analyses of distances between coal seams and the thickness of the overburden in the mine area, as described above. The stratigraphic section accompanies this chapter as part of Appendix 6-4.

A coal isopach (Plate 6-3) and overburden isopach map showing the depth to the minable Hiawatha Seam is included as Plate 6-6 to support extrapolation of ground water hydrology projections from nearby mines to the Crandall Canyon Mine and to support projections of subsidence.

Structure. Formations in the central Wasatch Plateau generally dip 1-3 degrees to the west. This regional structural attitude is broken by several north-south trending, high angle

normal faults which offset the rocks from less than 10 feet to approximately 250 feet or more. As mapped, there are no major faults present within the boundaries of the permit area. Springs are present in the upper reaches of the canyon near the Castlegate Sandstone-Blackhawk Formation contact. Several seeps have been noted in the Crandall Canyon area issuing from the Star Point Sandstone. A complete discussion of the springs and seeps encountered within the permit area is in Chapter 7.

6.22.3 Coal Outcrop / Strike and Dip

Coal outcrops are shown on the isopach maps (Plates 6-3, 6-4 and 6-5) and on all mine plans and progress maps (Chapter 5). Plate 6-7 is a structure contour map of the top of the Hiawatha seam.

Plates 5-2, 5-2C and 6-1 show strike and dip providing an average strike over the entire area where the coal outcrop data have been obtained. An average strike designation was necessary due to the severe erosional and geographic conditions of the area, which would make anything but an average direction highly inaccurate. This dip is to the southeast, and varies slightly from the regional dip due to local geologic conditions.

6.22.4 Gas and Oil Wells

There are no gas or oil wells known to exist within, or adjacent to, the permit area.

6.23 Geologic Determinations

The acid- or toxic-forming characteristics of the strata are discussed in Sections 6.24.32 and 6.24.33 and in Appendix 6-2.

The subsidence control and monitoring plans are discussed in Section 5.25 and in Chapter 5.

6.24 Geologic Information

(1) Information presented in Section 7 indicates that the water table in the Star Point Sandstone is below the coal seams of the lower Blackhawk Formation. The flow of ground water in the formation is toward Huntington Creek.

(2) The Star Point Sandstone, which underlies the Hiawatha seam, is predominantly a light-gray massive sandstone with minor interbedded layers of shale and siltstone near its base (Doelling, 1972). In the vicinity of the mine, the Star Point Sandstone is 200-400 feet thick. The Star Point Sandstone serves as an important regional aquifer (Danielson et al., 1981) yielding water to several minor and some major springs where fractured and jointed.

(3) The Blackhawk Formation (at the base of the Hiawatha seam) could contain perched aquifers in lenticular sandstones interbedded within the shales. The shales of the Blackhawk Formation are only slightly permeable; consequently, ground water within the formation is perched. The shales of the Blackhawk Formation are bentonitic and swell when wet; therefore, faults and fractures in the Blackhawk tend to seal, limiting secondary permeability, refer to the exceptions itemized in Section 7.

If perched water is encountered from the Blackhawk Formation, due to drilling or from the strains associated with subsidence, its vertical flow to deeper strata would be altered. Some perched aquifers which release water under topographic conditions (springs) may be affected.

Detailed Columns of Interest and Cross Sections. See Appendix 6-1 included with this chapter. Stratigraphic section A was taken at the portal area and stratigraphic section B was taken 500 feet east of the portal area.

Additional information on the regional and permit area geology is presented in Section 6.21, and on maps, cross-sections and plans presented in this chapter and in Chapters 5 and 7.

Geologic literature and practices are discussed throughout this chapter and in the list of references at the end of the chapter.

6.24.2 Chemical Analyses of Overburden

N/A - Strata above the coal seam will not be removed by underground mining.

6.24.3 Chemical Analyses / Lithology

Strata above the coal seam will not be removed. Samples have been collected and analyzed as required.

6.24.31 Drill Hole Logs

Drilling results and details are summarized in Appendix 6-5. Additional information on lithology and potential impacts of mining on ground water is provided in Section 6.24 and in Chapter 7.

6.24.32 Chemical Analyses - Strata

Alkalinity. The pyrite, alkalinity and clay content information is from samples taken by applicant and submitted to Standard Laboratories, Huntington, Utah for chemical analysis. The lab reports are included with this document as Appendix 6-2.

The pyrite content and alkalinity content of the stratum immediately above the coal seams are as follows:

	Hiawatha	Blind Canyon
Pyrite	0.03%	0.09%
Paste pH	7.6	7.25
Alkalinity	63.3 mg/1	87.4 mg/1

The pyrite content, alkalinity and clay content of the stratum immediately below the coal seams are as follows:

	Hiawatha	Blind Canyon
Pyrite	0.06%	0.07%
Paste pH	3.95	3.90
Alkalinity	4.0 mg/1	0.0 mg/1
Clay Content	9.5%	10.5%

As discussed in Section 5.28.30, waste rock is not produced during mining operations. When incidental quantities of rock are encountered, the rock is left in the mine and will not be removed at any time in the future; thus, no negative effects are expected from the acid-forming potential of strata which overlie and underlie the Hiawatha seam. However, to further characterize the acid-forming potential of strata immediately above and below the Hiawatha seam, the applicant will collect additional roof- and floor-rock samples from three equally spaced locations within the current mine workings (including the state leases and right-of-way areas). Analytical results from these three sets of samples will be used to evaluate the need for additional sampling to adequately characterize the acid-forming potential of the strata.

6.24.33 Chemical Analysis - Coal

The total sulfur content of the Hiawatha coal has been analyzed at 0.58%, and the acid-base potential determined for the coal is -11 tons $CaCO_3$/1000 tons (Appendix 6-2). Under the current operation plan only a small quantity of coal is temporarily stockpiled on-site. The amount of coal remaining at the time of reclamation is likely to be insignificant; thus, no negative effects are expected from the acid-forming potential of the coal.

Future determinations of acid-base potential will be based on pyritic and organic sulfur content, rather than total sulfur content.

6.24.34 Properties of Strata Above and Below Coal

This mine employs standard room and pillar mining operations; however, the stratigraphic sections (Appendix 6-1) and drilling results (Appendix 6-5) do not show any clays or soft rock immediately above or below the coal seam to be mined.

6.25 Additional Information

Additional information will be provided if determined necessary by the Division.

6.26 Waiver of Requirements

Not applicable.

6.27 Overburden Thickness and Lithology

Provided in Appendix 6-1 and Plate 6-6.

6.30 Operation Plan

6.31 Casing and Sealing of Exploration Holes and Boreholes

Exploration holes, boreholes, or other holes will not remain open for use as water supply wells or ground water monitoring wells and will normally not be completed with casing. These holes will be plugged, capped, sealed, backfilled or otherwise managed to protect water resources without the use or installation of casing, but casing will be used if it is needed to maintain boring wall integrity.

The measures to be used to close the holes will include filling the hole or opening with cuttings or inert material until it is level with the surface. Those holes which flow or might flow as a result of artesian conditions will be cemented, and any holes which penetrate two or more aquifers with significantly different ground water quality will be cased or cemented.

Installation and abandonment of monitoring wells (and other wells) will be done by a licensed driller following Division of Water Rights rules and procedures.

6.31.1 Temporary Casing and Sealing of Drilled Holes

Those holes which remain open for use as water supply wells or for use as ground water monitoring well will be completed with

casing or piezometers at a sufficient height above the land surface to prevent drainage of surface water or entrance of other material into the well. In addition, they will be fitted with caps to prevent introduction of foreign objects, other than monitoring and sampling equipment, into the well. When ground water monitoring wells are no longer needed or required for any purpose, each well will be sealed in accordance with the measures described above by a licensed driller following Division of Water Rights rules and procedures.

6.31.2 Permanent Casing and Sealing of Exploration Holes and Boreholes

When no longer needed for monitoring or other use approved by the Division upon a finding of no adverse environmental or health and safety effect, or unless approved for transfer as a water will under R645-301-731.400, each exploration hole or borehole will be plugged, capped, sealed, backfilled or otherwise properly managed under R645-301-631 and consistent with 30 CFR 75.1711. Permanent closure methods will be designed to prevent access to the mine workings by people, livestock, fish and wildlife, and machinery and to keep acid or other toxic drainage from entering water resources.

6.32 Subsidence Monitoring

Subsidence monitoring is carried out on an annual basis and includes aerial surveys and visual surveys of the mine permit area. As required by R-645-301-525, a complete subsidence control plan addressing the regulations can be found in section 5.25 of this document

6.40 Performance Standards

6.41 All Exploration Holes and Boreholes

All exploration holes and boreholes will be permanently cased and sealed according to the requirements of R645-301-631 and R645-301-631-200.

6.42 Monuments and Surface Markers

All monuments and surface markers used as subsidence monitoring points and identified under R645-301-200 will be reclaimed in accordance with R645-301-521-210.

References

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