CHAPTER

II

GEOLOGY

WBH 2009 Update

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1.0 INTRODUCTION

The Wishbone Hill Coal District is 1 of the 4 coal districts of the Matanuska Coal Field. It is approximately 2 miles wide and 8 miles long and takes its name from the prominent conglomerate capped hill that occupies its central part. Figure II-1 displays the regional location of the Wishbone Hill Coal District and the Matanuska Coal Field. This district has the greatest coal development potential of the 4 districts because of its relatively simple structure, good coal quality, close location to existing infrastructure, and surface mineable reserves. As a result of these favorable attributes, the Wishbone Hill District has produced more coal than the other districts combined.

The location of the Wishbone Hill District is determined by the known extent of the coal-bearing

Chickaloon Formation which extends eastward from Moose Creek to the head of Knob Creek. Its northern extent is defined by the Castle Mountain Fault which separates the lower Matanuska Valley from the Talkeetna Mountains. The southern boundary of the district is generally masked by glacial gravel, but lies a few miles north of the Glenn Highway.

Coal was first discovered in the Wishbone Hill District in the late 1800's, and by the early 1900's all major geologic features had been described by federal government geologists. The first mining began in the southwestern portion of the district in 1916 at the Doherty Mine, which supplied coal to the newly formed Alaska Railroad. As coal demand for the railroad grew, emphasis shifted to the better quality reserves in the east-central part of the field.

To secure a constant supply of coal, the federally directed Railroad Commission opened the Eska Mine and operated it until a major private mine, the Evan Jones, could meet railroad demand. There were a number of small, underground prospects during this time along Moose Creek, within close proximity to the proposed mine permit boundary. However, only the Premier and Buffalo Mines within the proposed permit boundary produced any notable quantities of coal. For 40 years the coal produced was used by the Alaska Railroad, but with conversion of locomotives to diesel fuel in the mid-1950's, coal use shifted temporarily to military bases near Anchorage. After the bases converted to natural gas in 1963, the domestic market was insufficient for the large Evan Jones Mine, and that mine closed in 1968. The entire district's production is uncertain, but probably totals about 7 million tons, of which 6 million came from the Evan Jones Mine.

The involvement of the federal government in developing this district was extensive. The dedication and ability of government geologists and engineers, as well as private industry, is highly evident in the development and history of the Wishbone Hill District. The geologic section of this chapter builds on the early government investigations.

2.0 REGIONAL OVERVIEW OF GEOLOGY

2.1 General Geology

The present day Matanuska Valley is a narrow structural trough 5 to 10 miles wide and 50 miles long where upper Mesozoic and Tertiary sedimentary rocks have been down dropped along faults and sharp flexures. Older, more resistant rocks of the Talkeetna and Chugach Mountains flank the valley on the north and south respectively. The sedimentary rocks in the valley generally have been complexly faulted, tilted and folded. The Wishbone Hill project lies in the western or lower portion of the Matanuska Valley structural trough and typifies the valley's structurally complex geology.

Many sedimentary formations have been identified within the Matanuska Valley structural trough. The Tertiary Chickaloon Formation is of particular interest because it contains four economic coal zones. The Chickaloon Formation is of continental origin and consists of a sequence of claystone, shale, siltstone, sandstone, coal and a few thin beds of pebble conglomerate. It is characterized by its stratigraphic variability both laterally and vertically, with facies and thickness changes over fairly short distances. The extent of economically surface mineable coal in this formation defines the boundaries of the proposed surface mining areas within the proposed permit area.

Economically mineable coal beds are contained in the upper 1,000 to 1,500 feet of the Chickaloon Formation, where they are concentrated in four major "zones". The coal zones vary in thickness from 20 to 130 feet in thickness and contain 3 to 15 individual coal seams. The coal seams in most zones grade in and out of coal, bone and shale with often imperceptible boundaries. The coals are generally high volatile bituminous B in rank, and are low in sulfur content.

The dominant structural feature of the Wishbone Hill area has been described in the geologic literature as a northeastward-trending canoe-shaped structure (Wishbone Hill syncline). Simplistically, the skin of the canoe contains the coal bearing upper Chickaloon strata, and the interior of the canoe is filled with non-coal-bearing conglomeratic formations. Several major

transverse faults bisect the syncline and are present in the project area. The economical coal seams of the project area lie on the northern limb of this syncline where they dip from 5 to a maximum of 80 degrees. Locally, a few high angle reverse faults and low angle thrust faults have caused repetition and omission of coal bearing stratigraphic sections.

Five Pleistocene glacial advances have been recognized in the Cook Inlet region; at least three of these have affected the present day topography of the Lower Matanuska Valley. These glacial advances have deposited a mantle of unconsolidated clay, silt, sandstone, cobbles and infrequent boulders on the project area. This mantle of glacial material varies from 0 to 130 feet in thickness within the project area.

2.2 Regional Stratigraphy

The present day Matanuska Valley is a northeast trending structural trough composed predominately of Mesozoic and Tertiary sedimentary rocks. The sedimentary rocks are underlain by metasedimentary rocks of Jurassic and Cretaceous age which are exposed south of the valley in the Chugach Mountains. North of the valley, intrusive rocks of the Talkeetna Mountains form a complex batholith comprised of quartz diorite, alaskite, and granodiorite mainly of Jurassic age.

Of the many sedimentary formations which have been identified in the lower Matanuska Valley trough, the Tertiary Chickaloon Formation is of particular interest because it contains four economic coal zones in its upper section. The coal bearing portion of this formation is discussed in detail in sections 3.3 and 3.4. Shorter descriptions of the other, non-coal-bearing formations follow, beginning with the oldest. The general succession of sedimentary rocks identified in the western half of the Wishbone Hill District from oldest to youngest is as follows: Matanuska Formation, Chickaloon Formation, Wishbone Formation and Tsadaka Formation. A generalized stratigraphic section of these formations is displayed in Figure II-2. A short description of the Arkose Ridge Formation is also provided since it could arguably be a part of the lower Matanuska Valley trough sequence.

Matanuska Formation

The Cretaceous Matanuska Formation in the lower Matanuska Valley consists of a basal dark shale unit overlain by a sequence of interbedded sandstones, shales, and siltstones. A few lenticular

conglomeratic beds have been observed in the Matanuska Formation along the Glenn Highway in the vicinity of Granite Creek and the Matanuska River. The sandstone beds are generally thin (<1.0 feet) and predominately a graywacke with fine-grained detrital quartz. The upper sandstone/graywacke and shale sequence in the vicinity of Wishbone Hill is fairly hard and has a platy fracture pattern. The formation is more than 4,000 feet thick at its type section along Granite

Creek (T. 19 N., R. 3 E.) and ranges in age from early to late Cretaceous (Grantz, 1964). Rocks of this formation are the most widely exposed formation in the valley today, and presumably underlie the entire area of Tertiary deposition. Fossil mollusks found within this formation indicate a middle-to-outer sublittoral to outer bathyal or abyssal depositional environment (Grantz, 1964).

Arkose Ridge Formation

The Arkose Ridge Formation of Paleocene Age is composed of highly indurated dark brown to gray conglomerates, feldspathic sandstones, and a few thin shale beds. A greenish tinge in color was observed in a few outcrops which is probably a result of the presence of chlorite. The Arkose Ridge Formation is thought to be over 2,000 feet thick in the lower Matanuska Valley. Although little is known of this formation, its restricted outcrop distribution and composition suggest a fanglomerate deposit of local origin (Clardy, 1974). This formation is arguably a part of the Matanuska trough sequence, however, is only exposed on the southern flank of the Talkeetna Mountains. It is juxtaposed to the Castle Mountain Fault on its north side where the formation unconformably overlies the plutonic rocks of the Talkeetna batholith. Its similar age and proximity to the Chickaloon Formation suggests a sequential stratigraphic relationship; however, the right-lateral movements along the Castle Mountain Fault have probably brought the two formations together from widely separated depositional areas (Clardy, 1974).

Chickaloon Formation

The coal-bearing Chickaloon Formation unconformably overlies the Matanuska Formation and is at least 5,000 feet thick. Mineable coal beds are contained in the upper 1,000 to 1,500 feet of this formation, where they occur in four major groups and one isolated seam. Potassium Argon and fission-track aging techniques from two volcanic ash partings in upper Chickaloon Formation coals range from 53.3 plus or minus 1.5 million years to 55.8 plus or minus 1.7 million years. (Triplehorn and others, 1984). These dates place the Paleocene-Eocene boundary (55 m.y.) somewhere within the upper part of this formation.

There are discrete and sometimes subtle lithologic differences between the lower, middle, and upper Chickaloon strata. In general, there is a decrease in grain size in gross aspect from the bottom to top of this formation. The overall decrease in grain size indicates the energy associated with the depositional environment of Chickaloon sediment was decreasing. A decrease in energy regime coupled with a warm, humid, temperate continental environment was conducive to peat (coal) deposition, hence the major coal groups are located in the upper Chickaloon Formation. The depositional environment of the lower Chickaloon has been interpreted to be fluvial with braided and meandering stream deposits. The sediments in the upper section appear to have been deposited in a meandering stream and paludal environment.

Various portions of the Chickaloon Formation in the western Wishbone Hill District have been observed in outcrop at three general localities:

1. Southern flanks of the Talkeetna Mountains north and west of Wishbone Hill
2. Tsadaka Canyon
3. Periphery of the Wishbone Hill

The Chickaloon strata, exposed in the small stream valleys on the flanks of the Talkeetna Mountains, is generally coarser grained than the Chickaloon strata in Tsadaka Canyon. Many covered intervals prevent accurate determination of thickness. Unless faulting and folding have caused duplication in strata, at least 2,500 feet of Chickaloon section is partially visible along some stream valleys. These sections are believed to comprise the lower Chickaloon Formation because of their stratigraphic proximity to the Matanuska Formation. The lower Chickaloon section in these stream valleys consists of dark shale, gray siltstone, tan and gray fine- to medium-grained sandstone, and occasional conglomeratic beds. No coal beds were identified within this strata. Plant fossils within this stratigraphic section are sparse compared to middle and upper Chickaloon sections. Sandstone and conglomerate appear to constitute approximately 50 percent of the visible section.

The Chickaloon strata exposed in Tsadaka Canyon appear to lie below the upper coal-bearing section in the middle of the formation. This stratigraphic section is fairly well exposed in the canyon and totals approximately 1,400 feet in thickness. In Tsadaka Canyon, the middle Chickaloon Formation consists of dark gray shale, carbonaceous black shale, thin coaly beds, gray

siltstone, and tan fine-grained sandstone. The sandstone beds in the middle Chickaloon Formation are generally massive, reach a maximum thickness of 25 feet, and appear to be laterally continuous up to a mile. No coarse-grain sandstone or conglomerate were observed in the middle Chickaloon Formation of Tsadaka Canyon. There is an abundance of plant fossils within most of the lithologic units found in the middle Chickaloon Formation.

A few scattered thin coal beds, generally less than 3 feet thick, are present in the middle Chickaloon Formation. Outcrop examinations and geophysical log interpretation of these coaly beds indicate they contain numerous boney coal, bone, and carbonaceous shale partings. The only known seam in excess of 3 feet thick was mined in the abandoned Doherty Mine. This seam, where observed in outcrop and penetrated by drilling, is 4.4 feet and approximately 6.0 feet, respectively. The seam contains numerous bone and carbonaceous shale partings.

The upper Chickaloon Formation in the Wishbone Hill District is exposed on the northern and western flanks of Wishbone Hill. This section of the formation contains the only known economic coal deposits, and consequently has been evaluated more than the lower and middle Chickaloon sections. The predominant lithologic units found in the upper Chickaloon Formation are dark gray shale, carbonaceous black shale, light and dark gray claystone, bone, thick coal zones, gray siltstone, tan and light gray fine- to coarse-grain sandstone, and thin conglomeratic lenses. A detailed description of the Upper Chickaloon stratigraphy can be found in Section 3.3 (Overburden and Interburden Stratigraphy) and Section 3.4 (Coal Stratigraphy and Characteristics).

Wishbone Formation

The name "Eska conglomerate" was given to a thick sequence of conglomeratic beds on Wishbone Hill by Martin and Katz in 1912. Barnes and Payne subdivided the Eska conglomerate into the Wishbone and Tsadaka Formation based on contrasting beds. The maximum thickness of the Wishbone Formation is 1,800 to 2,000 feet in the Wishbone Hill area. The synclinal structure of Wishbone Hill is made easily visible by the resistive concentric ridges and cliffs composed of this formation.

The boundary between the Wishbone Formation and Chickaloon Formation has previously been considered conformable and gradational through several feet (Barnes, 1956). An exposure of the Chickaloon/Wishbone Formation contact, located approximately 600 feet east of the abandoned

Premier Mine entry, shows a definite angular unconformity between the two formations. U.S. Bureau of Mines drill holes located on the southern limb of the Wishbone Hill syncline also indicate an angular unconformity exists between the relatively flat-lying Wishbone Formation conglomerate and the more steeply dipping upper Chickaloon Formation.

The Eocene Wishbone Formation consists of thick sequences of massive to poorly stratified conglomerate beds, lenticular sandstone and siltstone beds, and a few thin lenses of claystone. Conglomerate clasts are well rounded and range in size from pebble to boulder. Wishbone Formation sandstones are generally brown to tan in outcrop, coarse- to very coarse-grained, subangular, poorly sorted, and fairly well lithified. These sediments were derived from a predominantly volcanic source terrain located to the north of the Matanuska Valley (Clardy, 1974). This fact is supported by paleocurrent data and the high percentage of mafic rock fragments found in the Wishbone Formation. Pebbles and boulders of granitic rock are extremely scarce. The Talkeetna Formation probably comprised the source area because Wishbone Formation conglomeratic clasts are lithologically similar to Talkeetna Formation rocks. Sedimentary texture and structures suggest the Wishbone Formation was deposited in an alluvial fan and braided stream environments. Clardy (1974) suggested that the relief of the source area and gradient of the source area stream system was controlled by tectonic activity along the Castle Mountain Fault.

<u>Tsadaka Formation</u>

The overlying Tsadaka Formation of Oligocene Age is composed of poorly indurated very coarse conglomerate, fine- to coarse-grain sandstone, siltstone, silty carbonaceous shale, and thin layers of bone. On Wishbone Hill, the Tsadaka is poorly exposed because of its soft, very friable nature. The best and most complete exposure of Tsadaka Formation is located in Tsadaka Canyon. In Tsadaka Canyon, this formation is more than 500 feet thick, and contains a continuous basal conglomerate which is approximately 50 feet thick. The massive basal conglomerate contains well rounded clasts that range in size from pebble to boulder. Thin pebble conglomerates, sandstone, and siltstone with occasional thin layers of carbonaceous shale and bone overlie the basal conglomerate unit. The overlying lithologic units are very lenticular, discontinuous, and contain many scour and fill features.

On Wishbone Hill the gently dipping Tsadaka Formation rests unconformably on the Wishbone Formation which dips into the Wishbone Hill syncline. In Tsadaka Canyon, the basal Tsadaka

Formation conglomerate lies directly on steeply dipping middle Chickaloon strata. The Wishbone Formation and upper Chickaloon Formation have apparently been removed by erosion in this area prior to Tsadaka deposition. The extent and thickness of strata eroded during this period is largely unknown due to the lack of drilling and outcrop control.

Clardy (1974) suggests the Tsadaka Formation was derived from a felsic igneous source terrain, as indicated by the high percentage of quartz and feldspar. Conglomerate clasts are composed of diorite and granodiorite on Wishbone Hill. Clardy (1974) indicates the Tsadaka Formation contains a "volcanic clast tongue" which is composed of basalt and andesite fragments. This tongue, which is present in the vicinity of Tsadaka Canyon, is probably a result of the reworking of the totally eroded Wishbone Formation.

The Tsadaka Formation, like the Wishbone Formation, was deposited in an alluvial fan and braided stream environment. The texture and structure of the basal conglomerate suggests sheet flood deposition near the apex of an alluvial fan (Clardy, 1974).

Quaternary System Deposits

Quaternary deposits of the lower Matanuska Valley consist of glacial deposits, alluvial deposits, colluvial deposits and terrace sands/gravels. These deposits cover most of the lower Matanuska Valley except for cliffs, steep valley sides and the higher topographic areas. The Quaternary deposits, especially those of glacial origin can reach thicknesses greater than 150 feet.

2.3 Regional Geologic Structure

The dominant structural feature of the Wishbone Hill District is a northeastward-trending canoe shaped syncline: the Wishbone Hill syncline. The depth, width, and traceable length of the Wishbone Hill syncline exceeds that of other known synclinal structures in the district. The northeast end of this syncline is located near Knob Creek, and the southwest end was believed to lie near the abandoned underground Premier Mine. Simplistically, the skin of the canoe contains the coal-bearing upper Chickaloon strata, and the interior of the canoe is filled with Wishbone and Tsadaka Formations. Several major transverse faults and many minor faults bisect the limbs of the syncline into many displaced segments. The transverse faults could represent either secondary shears related to the deformation along the Castle Mountain Fault system, or primary shears which developed during folding. The Castle Mountain Fault lies approximately 1 mile north of the district at the base of the Talkeetna Mountains.

The dip of the coal beds in the east-central part of the district range from 30 to 45 degrees, although dips as low as 12 degrees near the synclinal axis have been reported in underground mines. In the east central part of the district, the Wishbone Formation conglomerate is confined to the trough of the syncline where it appears to lie conformably above the upper Chickaloon strata. The two largest abandoned underground mines are located in that portion of the district, hence the geology of that area is known in more detail than elsewhere.

The northern limb of the Wishbone Hill syncline can be traced along the entire length of the district. Upper Chickaloon strata, although bisected by a few major transverse faults and many smaller faults, appear to be present and correlatable along the entire northern limb of the syncline. The largest identified block of potentially strippable coal lies on the northern limb of the syncline on the Idemitsu Alaska leases and within the proposed permit area. The coal in this block is continuously mineable for 1.2 miles, and dips 40 to 80 degrees.

In the eastern portion of the district, faulting with vertical displacement prevents the coal-bearing strata from wrapping around the eastern end of the Wishbone Hill syncline. These faults, whose southeast sides are down thrown, have the effect of extending the coal-bearing strata of the Wishbone Hill syncline eastward. The Wishbone conglomerate and the very upper portions of the Chickaloon Formation have been removed by erosion in the extreme eastern portion of syncline.

In the western part of the district, the Wishbone and Tsadaka Formations are not always confined to the trough of the Wishbone Hill syncline. The Wishbone and Tsadaka Formations truncate the coal bearing upper Chickaloon Formation at depth on portions of the Wishbone Hill syncline's northern limb. The angular unconformity resulting from the erosion of the slightly deformed upper Chickaloon strata prior to Wishbone and Tsadaka deposition is visible in outcrop and can be inferred from drilling data. The net economic effect of the erosion of the coal bearing upper Chickaloon Formation is the decrease in potentially surface mineable coal.

In the northwestern part of the district, the Chickaloon Formation has been compressed and broken into tight folds and fault blocks. In most instances, the northwest limbs of the synclines dip more steeply than the southeast limbs, creating asymmetrical folds. Numerous faults, including thrust and reverse faults, are present in this tightly folded area. The thrust and reverse faults cause both duplication and omission of stratigraphic sections.

3.0 STRATIGRAPHY AND STRUCTURE OF PERMIT AREA

3.1 Bedrock Stratigraphy

The majority of the bedrock within the proposed permit area is masked by Quaternary glacial deposits which obtain a maximum thickness of 120 feet. Bedrock exposures within the proposed permit area are limited to those within the abandoned surface mining pits and those along the southwest side of Moose Creek. Because of the extremely limited bedrock exposures, the majority of stratigraphic knowledge of the proposed permit area has been gained through drilling. The drilling density is sufficient to accurately understand the stratigraphy of the permit area. Plate II-1 displays the bedrock geology of the proposed permit area.

The predominant bedrock unit of the proposed permit area is the upper Chickaloon Formation. Generally, this unit lies below the glacial and alluvial gravels in the northwestern half of the proposed permit area. As a result of faulting, the lateral and vertical stratigraphic continuity of the upper Chickaloon in this area is often interrupted, thus complicating stratigraphic interpretation. A major offset in the Upper Chickaloon Formation occurs in the central portion of the proposed permit area. In this area, the Wishbone Formation has been thrust over the Upper Chickaloon Formation. Overall, the Upper Chickaloon Formation is easily identified in drill hole cores and cuttings through it's abundance of carbonaceous rock and thick coal groups.

The bedrock formation in the south central and southwestern portions of the permit area is generally the Tsadaka Formation. Drill holes that have penetrated the Tsadaka Formation in the areas near its contact with the Chickaloon Formation often encountered the lower basal coarse conglomerate unit. This lower unit is well indurated, thus significantly inhibiting drilling penetration rates. The middle portions of the Tsadaka Foundation contain fairly soft sandstone and siltstone which can be quickly penetrated through drilling.

In the south central and southwestern portions of the permit area the Wishbone Formation has apparently been eroded prior to the deposition of the Tsadaka Formation. Drilling information indicates an angular unconformity exists between the Chickaloon and Tsadaka Formations.

Approximately one half mile west of the permit area, in Tsadaka Canyon, the basal Tsadaka conglomerate can be seen lying unconformably on middle Chickaloon Formation strata. In this area, the Wishbone and upper Chickaloon Formations have apparently been removed by erosion prior to Tsadaka deposition. Drill holes in the south central portion of the permit area often encounter a mantle of Tsadaka Formation prior to penetrating the steeply dipping coal-bearing upper Chickaloon strata.

The Wishbone Formation lies under the glacial gravels in the northeastern and central portions of the proposed permit area. This formation is easily identified in drill cuttings by its abundance of mafic rock fragments. The color of these cutting fragments is generally gray to green. In the central portion of the permit area the Wishbone Formation has been thrust over the Chickaloon Formation. The contact between the Chickaloon and Wishbone Formations in the northeastern portion of the permit area is believed to be a slight angular unconformity.

Core samples of the Wishbone Formation in the permit area indicated it generally consists of pebble conglomerates and medium to coarse grained sandstones. Occasional cobble conglomerate lenses are also encountered and appear to increase in thickness and frequency in the eastern portions of the permit area. Similar to the Wishbone Formation's drilling cuttings, the core also has a green to gray color.

3.2 Quaternary Stratigraphy

The glacial gravels generally cover the bedrock of the permit area and tend to thicken toward the southern and eastern portions of the proposed permit area. The deposits are assumed to be all of Late Stade Naptowne in age (approximately 10,000 to 30,000 years B. P.) however, no radiocarbon dates are available from the site or adjacent areas. The following is a list and description of glacial and alluvial deposits identified in or closely surrounding the proposed permit area. The location of these deposits are displayed on Plate II-2 entitled "Surficial Geology".

Outwash and Glacial Drift

The oldest exposed late Quaternary glacial deposits are the unconsolidated gravels immediately overlying the Tertiary Wishbone and Tsadaka Formations. They are best exposed in the canyon walls of Tsadaka Canyon. The deposits generally underlie all of the younger glacial deposits in the

area and represent an environment during rapid recession when melt water was at high levels and braided stream channels covered a large part of the Matanuska Valley floor. With the exception of the Tsadaka Canyon walls, exposures of this unit exist only in limited areas on either side of Moose Creek at the northern end of Tsadaka Canyon. The unit is characterized by relatively smooth, level topography and heavy tree cover. The materials composing the unit are generally sands, gravels and sandy gravels. Silt content is low (<5 percent) and, although cobbles are frequent, large boulders are rare. The thickness of the unit is generally greater than 20 feet, and commonly greater than 50 feet. Differentiating overlying deposits is often difficult, as in most cases the outwash unit has simply been reworked to form the new deposit. Southwest of the project area, the outwash and drift unit become much more extensive.

Old Ice-Marginal Deposits

These deposits are younger than the outwash and contemporaneous with the esker-kame terrace deposits. The unit is exposed along the Buffalo Mine Road approximately one mile south of the proposed permit area. The unit is composed of very similar materials to both the Outwash and esker units, but is much less stratified and characterized by pothole and kettle topography. The unit represents both recessional, ice-marginal deposits, as well as intra-eskerine deposits. The sand and gravels of this unit may have a slightly higher silt content, more boulders, and a generally less classified nature than most of the other deposits.

Esker-Kame Terrace Deposits

The eskers in the Wishbone Hill area are perhaps its most prominent and easily recognized surficial deposit. The long (up to 6 miles), snake-like ridges stand above the surrounding landscape by as much as 200 feet. The ridges are sinuous and intertwine with one another forming a braided channel in reverse relief. These deposits, which begin near Wishbone Hill, extend outward across the broad Matanuska-Knik lowlands, forming some of the most extensive and classically shaped eskers in Alaska. The term "kame terrace" is used here to denote the less well-developed yet still well-stratified portions of the esker-kame complex.

The esker-kame unit represents a stage during recession when the terminus of the Matanuska Glacier still reached well out into the Matanuska-Knik lowlands. The eskers formed primarily as subglacial channels but also within the glacier and on top of the ground ice. The ice cavities

contained the agrading stream channel gravels as the stream continued to melt away the overlying roof. Eventually, all of the ice of the glacier melted away leaving the ridges of alluvium. In some cases, the eskers insulated ground ice beneath them so that eventually, as this ground ice melted, it allowed the center of the esker to sink. This phenomenon can be noted at certain localities where cross-sections of an esker show concave upward stratified material.

The associated kame terrace deposits are formed when a stream channel is trapped between stagnant ice and a valley wall - or in this case, a previously formed esker. Such deposits could be formed in innumerable ways at or near the ice margin. An important characteristic which is always present, however, is the stratified nature of both the esker and kame terrace.

The esker-kame terrace deposit sprawls over the southern half of the proposed permit area and access corridor. The sandy gravels of the unit are well washed and sorted and are perhaps the best source of clean gravels in the proposed permit area.

Young Ice-Marginal Deposits

One of the strongest topographic features in the map area is a scarp which runs southwestward along the southern edge of Wishbone Hill, through Elks Lake, and continues across Moose Creek Valley where it runs parallel to the first mile or so of the Buffalo Mine Road. On the southeast side of this feature, the esker-kame terrace deposit has been sharply eroded away. The generally level but heavily kettled topography to the southeast is interpreted as the base of a minor readvance of the main valley glacier and is referred to as young ice marginal deposits.

The advance must have been short lived and receded very rapidly, as the erosion surface was not entrenched very deeply, and the extremely pitted and hummocky nature of the deposit suggest abundant stagnating ice. The deposits are exposed in the valley walls of Moose Creek near the highway bridge and are composed primarily of sandy gravels. Stratification is generally poor; however, the deposit is somewhat better layered on the southwest side of Moose Creek.

Old Channel Deposits

Two distinct former channels of Moose Creek can be mapped in the proposed permit area. Channel 2 (see Plate II-2) is the older of the two, more extensive, and takes a radical departure from the

existing Moose Creek drainage in the northeastern portion of the permit area. This former channel runs south to Elks Lake from the northeastern portion of the permit area. The direction of past flow at Elks Lake appears to be southeast. The former channel was probably a short lived phenomenon, but yet it must also have carried substantially more water than the present day Moose Creek. During the waning phases of the late stade of the Naptowne glaciation, Moose Creek's base level was believed to be from 200 to 300 feet higher. This deposit was believed to be formed when water from the Talkeetna Mountains' portion of Moose Creek began to run against the flank of Wishbone Hill. The water first carved more directly around the base of Wishbone Hill, flowing through much of the eastern portion of the permit area, then cutting through portions of the esker-kame terrace deposit, flowing down across the present position of Elks Lake, and on to the main channel of the Matanuska. As the channel converged on the area south of Elks Lake, it actually melted a channel through the then existing stagnant ice and created an irregularly shaped but relatively flat floodplain. Later, the confining walls of ice melted and the landscape surrounding the channel sunk into the hummocky terrain we see today, but with a base level actually below that of the channel. In its heyday, this channel may have received flow from the basin of Wishbone Lake as well, and coarse material was periodically flushed into its upper reaches by flooding and outbursts on both Moose and Buffalo Creeks. Subsequently, the channel was diverted by multiple channels to the southwest and finally it was abandoned altogether as Moose Creek adopted its current drainage system.

Channel 1 is contemporaneous and essentially equivalent to the oldest Moose Creek Terrace deposits. It is a meander remnant that occurs on the east bank of Moose Creek just above Tsadaka Canyon. It carved into the esker-kame terrace unit and probably caused a minor outburst flood after it eroded into the side of a small lake captured within the braided esker deposit.

Neither channel deposit is well exposed; however, drilling in the northern part of Channel 2 has encountered frequent bouldery sections. From Moose Creek to Elks Lake, Channel 2 very likely contains significant coarse materials; from Elks Lake to the Matanuska River, the materials are more likely to be sands and gravels. Since Channel 1 appears to be a gentle meander, it is probably composed of sands and sandy gravels.

Moose Creek Terrace Deposits

Based on height above the present floodplain, three distinct terrace levels have been recognized. Martin & Katz (1912) observed six terraces within the Moose Creek Valley. The terraces lie from 10 to 130 feet above the present Moose Creek floodplain.

All the terraces appear to be younger than the glacially derived deposits. Some of the terraces are well exposed and, for the most part, are reworked sands and gravels. The terraces are occasionally cut into Tertiary-aged rocks, and the deposits are generally shallow (5 to 15 feet) in depth.

Modern Alluvium

The modern alluvium of Moose Creek is characterized by boulder-rich sandy gravels. The floodplain of Moose Creek, though heavily forested in some areas, is still prone to occasional flooding. Drilling in the floodplain indicates the alluvium is very thin and the creek essentially lies on the bedrock.

Aeolian Loess

A thin blanket of aeolian loess and sand was recognized along the northeast bank of Moose Creek Valley just below Tsadaka Canyon. The deposit boundaries are very uncertain as the shifting sands have been overgrown. Shallow cuts indicate at least a few feet of the material has accumulated, and perhaps there area areas where the deposit is as thick as 20 feet. The wind-carried material was probably derived directly from the canyon walls of Moose Creek and drifted over the edge of the esker-kame terrace deposits.

3.3 Overburden and Interburden Stratigraphy

The overburden and interburden of the coal groups consist of glacial gravels, Tsadaka Formation, Wishbone Formation and Upper Chickaloon Formation. As discussed in the overburden characterization chapter of this permit, glacial gravels and conglomerates of the Wishbone and Tsadaka Formations consist of approximately 34 percent of the overburden material. Stratigraphic descriptions of these formations and gravels are contained in Sections 3.1 and 3.2 of this chapter. The remaining 66 percent of the overburden material lies in the upper Chickaloon Formation.

The predominant lithologic units found in the upper Chickaloon Formation are olive gray to dark gray shale, carbonaceous black shale, light and dark gray claystone, bone, thick coal zones, gray siltstone, tan and light gray fine- to coarse-grain sandstone, and thin conglomeratic lenses. The coarse-grain sandstone and pebble conglomerates contain abundant irregular carbonaceous fragments. The lithologic character of these coarse units, coupled with their relatively localized

lateral extent, indicate they were deposited in or in close proximity to fluvial channels. The sandstones are generally moderately indurated and contain more than 50 percent feldspathic detritus. As displayed in Figure 3-2 in the overburden characterization section of this permit, the most frequent overburden unit is gray shale which represents 41 percent of the overburden/interburden above the proposed surface mining areas. Siderite (ironstone) concretions are common within every lithologic unit, including coal.

Individual lithologic beds within the upper Chickaloon Formation tend to intergrade and vary in thickness within relatively short distances. Coal beds within the well defined coal zones tend to grade laterally into carbonaceous shale and claystone. The coal zones, however, persist in varying thicknesses around the northern and western flanks of Wishbone Hill.

3.4 Coal Stratigraphy and Characteristics

The upper 1,400 to 1,600 feet of the Chickaloon Formation is coal bearing in the western part of the district (see Figure II-3). The rank of the coal throughout the Wishbone Hill District is high volatile, bituminous B. The coal seams are not spread throughout the upper portion of the formation but are concentrated into four discreet groups. The following names have been given to the four groups in order from youngest to oldest: Jonesville, Premier, Eska and Burning Bed. While individual coal beds within the groups may be hard to correlate between locations, the groups themselves seem to be persistent from one end of the permit area to the other. In addition to the four main groups, there are a few thin unnamed seams. The Midway seam is the only surface mineable seam which does not lie within a coal group.

Jonesville Group

The Jonesville group is named for a persistent group of coal beds in the Jonesville area at the eastern end of the Wishbone Hill District. Within the proposed permit area, the Jonesville coal group is thinner than at Jonesville and can be easily traced within the proposed permit area. Within that area, the group is commonly made up of 3 to 6 coal seams (see Figure II-4) gradationally interbedded with highly carbonaceous shale. In the SW/4 NW/4 of Section 27, the Pioneer Mining Company mined the Jonesville coal group with a small dragline in the 1950's. In this area, the Jonesville group has a stratigraphic thickness of approximately 75 feet. Drill holes in close proximity to the Pioneer Mining pit suggest the Jonesville coal group also has an additional coal section about 50

feet above the main coal section. This upper Jonesville coal group is limited to the western part of the permit area and does not appear to extend as far east as the abandoned Buffalo Mine. Where penetrated in drill holes, the Jonesville coal group lies 50 to 350 feet below the base of the Wishbone conglomerate.

Generally, the Jonesville coal group is stratigraphically situated about 350 to 420 feet above the easily identified Premier coal group. However, in the eastern portion of the permit area the apparent stratigraphic distance between the Premier and Jonesville coal groups increases to greater than 600 feet. This increase may not be entirely stratigraphic and could be a result of strike parallel faulting.

Premier Group

The principal coal group in the Wishbone Hill District is the Premier; it is named for its occurrence at the western end of the district in the abandoned underground Premier Mine. Throughout the proposed permit area, the Premier group maintains a thickness of 70 to 130 feet and consists of 10 to 13 discreet coal beds (see Figure II-5). Only one of these seams was clean enough to allow extensive mining in the past. This seam that can be correlated with acceptable certainty across the entire proposed permit area.

In the western part of the district, the Premier coals commonly contain hard ironstone concretions, and the coals are cleaner near the bottom than higher up in the section. The coal beds in the upper section grade in and out of coal, bone, and shale with almost imperceptible boundaries. The large seam near the base of the Premier group was named the No. 3 bed in the

Premier Mine and the No. 2 bed in the Buffalo workings. This seam averages approximately 7 feet thick in the proposed permit area. Most of the other seams have too many in-seam partings to be worked underground, although in a few cases they were worked for a few hundred feet, especially in the Premier Mine.

Midway Seam

As far as is presently observed, the Midway seam is the only coal bed that extends over the entire district as an isolated, discreet bed. Generally it is 3.8 to 8.8 feet thick (see Figure II-6), usually with a boney or shaley section in the middle and occurs between the Premier and Eska coal groups. It was called the No. 5 bed at the Premier Mine and the No. 1 bed at the Buffalo Mine. As a single coal seam, the Midway is perhaps the most persistent in the Wishbone Hill District. The

stratigraphic position of the Midway seam in the proposed permit area is 55 to 95 feet below the Premier coal group.

In the western portion of the permit area, a group of 2 to 8 thin coal and bone seams lie approximately 21 to 48 feet stratigraphically below the Midway seam. These seams are referred to as the below Midway seams and are not present in the eastern portion of the permit area.

Eska Group

The Eska coal group generally occurs about 190 to 250 feet stratigraphically below the base of the Premier coal group. The interval between these two groups is quite variable, with no identifiable trends. The Eska coal group was named for a prominent group of coals in the eastern portion of the district, but the Eska group in the proposed permit area is much thinner (see Figure II-7). Where encountered in drill holes, the Eska coal group is made up of a number of thin coal beds interbedded with carbonaceous shales and has an average thickness of approximately 47 feet. Because of the thinness of the seams and the degraded quality due to the shales, this group was never extensively mined in the western part of the district.

In the central portion of the proposed permit area, the Eska coal group has been divided into two separate coal groups: Eska and Sub-Eska coal groups by a shale unit. This unit tends to increase in thickness towards the northeast and has a maximum defined thickness of 55 feet.

Burning Bed Group

The Burning Bed group was named for a group of coals that occur in the western portion of the proposed permit area in the vicinity of the abandoned surface mining pits. Until the group was removed by mining, one bed in an isolated fault block had burned for a number of years, hence the name. At one time this group was exposed on both limbs of an anticline of that name, but most of that coal has been either mined or covered with spoil. Its occurrence is now known from drilling information, all of which lie within the central portion of the proposed permit area. Whether these coals are the same as those in the type section is unknown.

The drilling data from the central portion of the proposed permit area indicates that the complete Burning Bed section is approximately 86 feet thick and is made up of 9 coal and boney coal beds

(see Fig. II-8). The upper half of this group contains the majority of the thicker coal seams and less interburden material. The Burning Bed group within the proposed permit area lies approximately 130 feet below the Eska coal group.

3.5 Geologic Structure

The overall geologic structure of the proposed permit area is fairly complicated for an economic coal mining area. Interpretation of the structure is difficult and hindered by the lack of outcrops. The coal-bearing strata is generally masked by conglomerate, glacial gravel and dense vegetation. Drill hole spacing is presently sufficient to provide fairly conclusive structural information in this geologically complex area.

Recent drilling and field mapping in the western half of the district, on or near the Idemitsu Alaska leases, indicate significant structural variations exist from what has been previously cited in the geologic literature. The structure of the western half of the district is characterized by a series of steeply dipping folds and numerous faults. The relationship between the folding and faulting is complicated by the fact that the faults both parallel and bisect the folds' axes.

The economically mineable coal of the proposed permit area is confined to two surface mining areas which are characterized by diagnostic structure and bedding attitudes. Plate II-3 displays the location of the two mining areas and also serves as a cross section index. Specifically Mine Area

1 predominantly contains relatively shallow (250 to 90 feet below ground surface) 5 to 35 degree dipping coal; Mine Area 2 contains generally parallel northeast-southwest striking beds of coal dipping from approximately 50 to 80 degrees.

The collective structural geologic evidence from these sites include:
* folding
* repetition or omission of stratigraphic section
* steeply dipping bedding
* faulted juxtaposition of stratigraphically discordant lithologies * high angle reverse faults
* low angle thrust faults
* dragged bedding

The above structural characteristics suggest that the site has undergone a complex tectonic history consistent with an accretionary tectonic model characteristic of fore-arc regions typified in south central Alaska.

The local structural setting of Mine Area 1 and Mine Area 2, in the framework of an accretionary tectonic model, are distinctly different, but are believed to have resulted from forces associated with the similar tectonic episodes. Ramping and imbricate stacking of reverse fault bounded stratigraphic sequences, typical of Mine Area 2, is characteristic of layer parallel shortening and associated crustal thickening at continental accretionary margins bordering subduction zones. Plates II-8 and II-9 are cross sections through Mine Area 2 which display the ramping and imbricate stacking of reverse fault bounded stratigraphic sequences. The local isolated occurrence of essentially flat lying Premier coal in Mine Area 1 is conceivably an allocthonous block transported and "piggy-backed" along a basal thrust or decollement. Cross sections through Mine Area 1, which display the flat lying Premier coal group, are displayed in Plates II-5 and II-6.

The sharp, low angle, 40 degree, southeastward dipping contact between the overlying Wishbone Formation and Chickaloon Formation observed in the southeast wall of the Omlin East pit was interpreted as a thrust fault by Barnes (1956) who initially defined portions of this major structural feature. Exploratory and geotechnical drilling has helped determine the existence of this thrust where Barnes was unable to trace it, specifically along the northern central boundary of Mine Area 2. Successively repeated Premier coal groups with near parallel dips to the southeast in Mine Area 2 are believed to have resulted from stacking along high angle reverse faults which are possibly listric (concave downward) and sole into the main thrust. Plate II-7, displaying cross section D-D', displays the repeating Premier coal group separated by a high angle reverse fault.

The hangwall of the sole thrust which constitutes a substantial portion of the mine site has been dissected by several near vertical, sometimes arcuate east-west trending strike slip faults which may represent syntectonic "tears" in the leading edge of the major thrust. Mine Area 1 is bounded on the southeast and northwest by two of these faults. Mine Area 2 is bounded by the thickening Tsadaka conglomerate and the Buffalo Fault and centrally transected by a genetically similar fault trending east-west coincident with the base of the topographic slope break west of exploration drill hole PB-103 (see Plate II-3).

Accretionary tectonic terrains and associated tectonic melanges characterized by high angle reverse faults, sole thrusts and strike slip faults are well documented in fore-arc basins including the coastal and near interior margins of south central Alaska (Coney et al., 1983; Jones et al., 1979; Saleeby, 1983; Silberling et al., 1980; Dickinson et al, 1979).

4.0 GEOLOGY OF PROPOSED SURFACE MINING AREA

The boundaries of the two proposed surface mining areas are defined by the geologic structure, stratigraphy and the Moose Creek flood plain. Since the two mining areas are predominately covered by glacial gravels, the structure and stratigraphy have been defined by drill hole information. Drilling density within the two surface mining areas is approximately one drill hole per 6 acres. Plate II-1 (Bedrock Geology), as well as Plates II-4 through II-10 (cross sections) display the structural and stratigraphic features of the proposed surface mining areas.

Mine Area 1 is divided by a major transverse fault known as the Premier Fault. The location of this fault is displayed on the bedrock geology map, (Plate II-1). This fairly well defined fault is nearly vertical and strikes N70^{o}W. The fault is encountered in the Premier Mine and is visible in outcrop on both sides of Moose Creek.

The section of Mine Area 1 that lies southwest of this fault contains the southwestern limb of a northeastern plunging synclinal structure. This synclinal structure contains the abandoned underground Premier Mine as displayed in Plate II-4 (cross section A-A').

Previous geologic literature suggested that the syncline in which the Premier Mine lies is an offset extension of the Wishbone Hill syncline. If this assumption is correct, the Wishbone Hill syncline would have to be displaced more than 4,000 feet to the northwest by the Premier Fault. This large amount of horizontal fault displacement is suspect. A comparison of the geologic structure from one side of the Premier Fault to the opposite side suggests the syncline in the Premier area is not an offset of the Wishbone Hill syncline. The structural geometries and amount of overlying conglomerate within the center of the Premier area and Wishbone Hill synclines are considerably different. The synclinal structure that contains the Premier Mine most likely lies in the footwall of the large thrust fault which is visible 2,000 feet northeast of this area. What has been previously called the Wishbone Hill syncline in the Premier Mine area, is referred to as the Premier syncline in this permit application.

The Premier coal group and Midway seams will be mined in the section of Mine Area 1 that lies southwest of the Premier Fault. The coal bearing strata in this area dips approximately 35^{o} northwest and is shown in Plate II-4 (cross section A-A'). Surface mining in this area will encounter the abandoned underground Premier Mine workings. Drilling and mine information indicate only one thick (7.2 feet) coal seam in the basal portion of the Premier coal group was extracted by room and pillar mining. The underground mine maps of the Premier Mine, which are displayed in Chapter XII of this application, indicate no major faults exist on the southwestern limb of the Premier syncline.

The portion of Mine Area 1 that lies northeast of the Premier Fault contains two economically mineable coal groups; Jonesville and Premier. The outcrop of the Jonesville coal group defines the northwestern boundary of Mine Area 1 in the area northeast of the Premier Fault. In this area, the Jonesville coal group was surface mined to approximately a 40 foot depth by the Pioneer Mining Company in the mid 1950's. The dip of the Jonesville coal group at the contact with the Premier Fault is 50^{o} southwest and gradually increases to the northwest until it is near vertical. Outcrop and drilling data indicates that the dip of the Jonesville group rapidly decreases with depth. At a depth of approximately 200 to 250 feet the Jonesville coal group is truncated by a reverse fault which is displayed in Plate II-5 (cross section B-B'). This fault dips to the southeast and has a north-easterly strike which approximately parallels the Jonesville coal group's strike. On the opposite side of the reverse fault lies an area which contains relatively flat lying Premier coal group. The Premier coal group in this area is bounded by faults. The southeastern boundary is defined by a reverse fault similar to the one that truncates the Jonesville group (Plate II-5). The southeastern and northwestern sides of the block are defined by the Premier Fault and an unnamed transverse fault respectively. This relatively flat lying block is structurally unique for the Wishbone Hill District.

The Premier coal group within this block is also unique from a stratigraphic standpoint. The northeastern portion of the Premier coal group block contains an anomalously large shale parting. This shale parting increases in thickness towards the northeastern boundary and reaches a maximum thickness of 55 feet. The shale parting is shown in Plate II-5 (cross section B-B'). In the central portion of the block, the Premier coal group also contains an additional few boney coal seams. These additional seams stratigraphicly lie directly above the typical Premier coal group sequence and were also encountered in a few holes outside of the flat lying Premier block. The typical

Premier coal group within this area is shown in the geophysical log of drill hole PB-86 (Chapter III, Appendix E).

Mine Area 2, like Mine Area 1 is bisected by an unnamed transverse fault. The trace of this fault although slightly curved is approximately east-west. The coal bearing strata on both sides of this fault dip to the southwest. This transverse fault is displayed on Plate II-1.

The surface mining area southwest of the transverse fault is bounded on the west by a reverse fault which separates the coal bearing strata from the Wishbone Formation. The southwestern boundary is determined by mining economics and is formed by the increasing thickness of Tsadaka Formation, which unconformably overlies the coal bearing Chickaloon Formation strata. The upper Chickaloon Formation in this block contains, from west to east, the Burning Bed coal group, Sub
Eska coal group, Eska coal group and the Premier coal group as shown in Plate II-7, cross section D-D'. Representative geophysical logs of the majority of the stratigraphic section from the Burning Bed group through the Premier group are displayed in the logs of holes PB-48, PB-100, PB-92, and PB-13 contained in Chapter III, Appendix E. A reverse fault that lies east of the

Premier coal group results in the repetition of the Premier coal group (see Plate II-7). The geophysical log of PB-73A (Chapter III, Appendix E) shows the lower portion of the repeated Premier coal group. Wishbone and Tsadaka Formations lie east of the repeated Premier coal group. The dips of the coal bearing strata southwest of the transverse fault gradually increase from north to south from 55^{o} to 80^{o}.

The surface mining area northeast of the transverse fault contains a reverse fault in its southwest corner. This fault is most likely a segment of the Moose Creek thrust fault and is shown in Plates II 8 and II-10 (cross sections E-E' and G-G'). The exact dip of this fault has yet to be defined, which inhibits the determination of fault type. If this fault is indeed the Moose Creek Thrust Fault, then the Premier, Eska and Sub-Eska coal groups that occur west of this fault lie in the footwall of the thrust fault. The geophysical log of drill hole PB-69A (Chapter III, Appendix E) shows the interval between the Midway seam and the Eska coal group in this area.

The majority of the proposed surface mining area that lies northeast of the transverse fault consists of the normal stratigraphic sequence of coal groups. The coal groups which will be mined in this area consist of the Sub-Eska, Eska, Premier and Midway seams. Representative geophysical logs of these groups and their overburden are shown in drill holes PB-70, PB-74, PB-107, PB-108, PB-109,

and PB-19 (Chapter III, Appendix E). Reverse faulting appears to be present in the northwest portion of this area as displayed in Plate II-9 (cross section F-F'). These reverse faults, because of their location, should not significantly affect the surface mining operation. Since these reserve faults were not encountered in drill holes and are being inferred based on known stratigraphic and structural relationships, they may in fact not exist. The changes in stratigraphy and structure may be a result of rolls in the northern limb of the Wishbone Hill syncline.

Glacial gravel thicknesses rapidly increase in the northeastern portion of this proposed mining area. The northeastern boundary is determined by the economic limit of mining the gravel and underlying coal bearing strata. Economic mining depths define the southwestern limits of Mine Area 2. As a result of the stratigraphic distance between the Jonesville and Premier coal groups, the Jonesville coal group can not be economically mined in Mine Area 2.

5.0 GEOLOGICAL EXPLORATION AND DEVELOPMENT METHODS

With the outbreak of World War II, the demand for both military and civilian coal in Alaska increased dramatically. Since the Matanuska Field was the closest coal field to the population, the U. S. Bureau of Mines conducted several exploration programs to delineate coal reserves for mining.

From 1942 through 1944 the Bureau of Mines drilled 11 holes in or within close proximity to the proposed permit area. Those holes were all core holes and are designated "DDH" holes on the drill hole plan map (Plate II). All but 2 of those holes were angle holes with the total footage amounting to approximately 6,600 feet. The location of these holes is uncertain as they were not surveyed. The placement of all "DDH" holes, with the exception of DDH-1, DDH-10 and DDH-11, should be considered approximate as they were located by enlargement of the 1956 USGS report map (see Barnes 1956). Holes DDH-1, DDH-10 and DDH-11 were approximately located by the presence of a sinkhole around the apparent drill site.

From 1945 through 1950, the U. S. Bureau of Mines shifted its interest to the eastern and southern portions of the district where four drilling programs were conducted during this period. These programs were primarily conducted in the areas of the now abandoned Evan Jones and Eska Mines. In addition, a few holes were drilled west of the abandoned Evan Jones Mine on the southern limb of the Wishbone Hill syncline.

In 1953 and 1954 the Bureau turned their attention back to the western end of the field and drilled 8 additional holes designated MC-1 through MC-7 and P-1. P-1 was located on the east side of the Premier Fault and represented an attempt to trace the Premier syncline toward the east. The majority of the MC holes were drilled in the Buffalo Mine area in an effort to trace the stratigraphy across the Wishbone Hill syncline. Total footage in that program amounted to approximately 8,400 feet, all of which was cored. P-1 was the only angle hole drilled.

All of the "MC" series holes were surveyed, but the coordinates were based on section corner monuments. Since the section corners have not been surveyed, hole locations should be considered approximate unless they were positively identified on the ground. In the case of holes MC-13, 14, 15 and 17, casing was located, so a positive identification was possible.

In June, 1983, Union Pacific and Hawley Resource Group acquired four State coal leases in the western portion of the Wishbone Hill Coal District. After approximately 30 years of no exploration drilling activities, these two companies initiated a drilling program in the area in and closely surrounding the proposed permit area. This drilling program was the first drilling program to use modern down hole geophysical logging techniques. The intent of this drilling program was to delineate the lowest cost surface mineable coal reserves in the western portion of the district. While there are certainly significantly sized underground reserves, such reserves would be more costly to produce. Therefore, the drilling activities were concentrated in areas where topography was conducive to surface mining.

The areas immediately surrounding the abandoned underground mines were believed to be the least geologically complicated, so most holes were placed in those areas. A number of additional holes were drilled in the intervening area and south of the abandoned Premier Mine in an attempt to trace the Wishbone Hill syncline and locate additional surface mineable reserves. In areas where coal zone data were available, holes were sited in order to penetrate the group as shallowly as possible. There were also a few holes placed in areas where no information was available.

The 1983 program consisted of 29 open rotary holes and 9 continuous core holes. Two bulk samples for washability testing were also extracted during the 1983 field program. All holes were cased through the glacial gravel, surveyed and given a "PB" designation. The rotary holes were

completed using 2 tire-mounted rigs with casing hammers. The nine continuous core holes were drilled with a Longyear 28, a skid-mounted wireline rig.

In 1984, Union Pacific and Hawley Resource Group conducted a second drilling program. The goal of the drilling program was to find additional recoverable reserves in close proximity to the reserves defined in the 1983 drilling program. These new reserves hopefully would be in areas of less gravel cover and less complex structure. The program consisted of 22 rotary holes. There was no core drilling. Two Mayhew 1000 drill rigs mounted on FN110 Nodwell tracked carriers were used during the entire 1984 drilling program. The majority of the holes were "wildcat" holes in areas where little or no geological data previously existed.

In 1983 and 1984, drilling and evaluation programs were successful in confirming the existence of sufficient economically mineable reserves for a surface mine. These programs indicated significant structural and stratigraphic variations existed in the western portion of the district than were previously indicated in the geologic literature. Coal quality data from the coring and bulk sampling programs indicated that a high quality bituminous coal can be produced for the export market.

In December, 1984, the Alaska Department of Natural Resources, Division of Mining, offered nine coal lease tracks for competitive sale in the Wishbone Hill Coal District. Union Pacific was the successful bidder on three contiguous tracts located in the central and eastern portions of the Wishbone Hill District. At the time of acquisition by Union Pacific, very little geologic information existed to define the amount and location of surface mineable coal within these tracts. Therefore, exploration efforts during the time period of 1985 to 1987 focused on better defining the potentially surface mineable coal in the areas south and east of the proposed permit area.

In 1988, Idemitsu Alaska, Inc. acquired all Union Pacific and Hawley Resource Group's Wishbone Hill coal leases and conducted a drilling program in both the western and eastern portions of Wishbone Hill District. The majority of drilling activities were conducted in the western portion of the district in the proposed permit area. These drilling activities were conducted to better define the surface mineable reserve, geotechnical and geochemical characteristics of the overburden/interburden and ground water hydrology. Within the proposed permit area, 32 exploration/ development drill holes and eight continuous core holes were completed with a combined rotary and core footage of approximately 12,780 feet. Two Mayhew 1000 drill rigs mounted on FN110 Nodwell tracked carriers were used to complete the exploration and

development drill holes. Continuous core holes were completed with Nodwell mounted Acker and Failing core rigs.

Following is a summary of all holes known to have been drilled in the western part of the Wishbone Hill Coal Field through 1992:

Drilling Summary Through 1992

Time Period	Responsible Party	Holes Series	No. of Holes	Approximate Footage
1942-1944	U.S.B.M.	DDH	11	6,600
1953-1954	U.S.B.M.	P, MC	8	8,400

1956-1958	U.S.B.M.	MC	11	7,100
1983	Union Pacific/Hawley	PB	38	9,490
1984	Union Pacific/Hawley	PB	19	5,940
1988	Idemitsu Alaska	PB	40	12,780
1988	Idemitsu Alaska	H88	17	2,570
1989	Idemitsu Alaska	PB	31	9,544
1989	Idemitsu Alaska	H89	2	403
1990	Idemitsu Alaska	PB	28	11,495
1990	Idemitsu Alaska	BH	9	490
1991	Idemitsu Alaska	PB	18	7,185
1992	Idemitsu Alaska	PB	7	2,717

All holes drilled during the 1983, 1984, 1988, 1989, 1990, 1991, and 1992 exploration drilling programs were geophysically logged unless adverse down-hole problems existed. The chip or core samples from these holes were also megascopically described by a field geologist. The drill holes were geophysically logged with the following two tools:

* resistivity sonde
* coal combination sonde (CCS)

The coal combination sonde (CCS) provided the following three geophysical logs:

Gamma The natural, low-level radioactivity all rock units display. Shales have a higher natural radioactivity than coals and sandstones, hence, kick higher to the right on the paper displays.

Density A radioactive (gamma emitter) source irradiates the surrounding rock, and the rock's response gives a measurement of the in-place density. Since coal is considerably lighter than either shale or sandstone, the log shows coal plainly as a kick to the left.

Caliper Drill holes are not the same diameter from top to bottom, and the caliper measures that change. Other measurements, especially density, are affected by changes in hole size.

The resistivity sonde provided a log of the resistance of the lithologic units between a down hole electrode and a surface ground point. This is a useful qualitative log for defining all lithologic units.

All the log data was recorded on magnetic tapes. These tapes were replayed later to create an additional coal quality log for accurate determination of in-place coal and parting densities.

In a number of holes where structural information was poor or lacking, an additional log was run. In those cases, a dipmeter sonde was used to measure the strike and dip of lithologic units, as well as the variance of the drill hole from true vertical. The tool consists of three separate resistivity pads that press against the drill hole wall. In addition, there are very sophisticated circuits that measure

the tilt of the instrument as well as the direction of magnetic north. All of these values were evaluated with a computer to generate two types of logs:

Dipmeter Log Analysis: a vertical plot every 2 feet throughout the hole that shows the dip angle and direction.

Verticality Log Analysis: a plot of the actual drill hole in relation to the surface opening that shows drill hole drift.

Because the dipmeter and verticality logs are generated by computer, there is no accurate means of determining if the geophysical dipmeter tool is operating properly in the field. The following is a listing of all the holes that had dipmeter and /or verticality logs. The holes in which the instrument malfunctioned are noted.

Drill Holes With Dipmeter and /or Verticality Logs

Drill Hole No.	Collar Elev.	TD	Verticality Log	Dipmeter

				Log Quality
PB-2A	868.5	298.4	Yes	Fair
PB-7	930.1	368.0	Yes	Poor
PB-8	905.2	331.0	Yes	Poor
PB-8rd	905.2	336.0	Yes	Malfunction
PB-12	1094.3	289.0	Yes	Excellent
PB-18	1032.1	348.0	Yes	Excellent
PB-20	839.7	362.0	Yes	Poor
PB-24	1012.0	319.4	Yes	Excellent
PB-38	809.7	567.0	Yes	Poor
PB-40	1066.6	540.0	Yes	Fair
PB-61A	901.5	299.0	Yes	Fair
PB-74	1009.9	400.0	Yes	Malfunction
PB-76	1086.1	414.0	Yes	Malfunction
PB-78	872.7	334.0	Yes	Malfunction
PB106	1035.0	514.0	Yes	Malfunction
PB-107	1025.0	515.0	Yes	Malfunction
PB-108	1048.0	550.0	Yes	Malfunction

All lithologic descriptions and geophysical logs for the above drill holes are kept on file in the project office in Palmer, Alaska.

6.0 GEOLOGICAL REFERENCES

There are approximately 350 known geologic references for the Matanuska Coal Field. Most of the references refer, in part or in whole, to the more past productive eastern end of the Wishbone Hill District. The eastern end of the district contained the Eska and Evan Jones Mines. Of the 125 references known to deal with the western end of the field, many are either quite old or are very general. In addition, there are a large number of references in federal archives in Seattle, Juneau, or Washington that are of limited use and consist mainly of Alaska Railroad memoranda. The list that follows is a compilation of the most pertinent and useful geologic references. A complete listing can be found in Alaska Coal - A Bibliography, 1982, by Julia Triplehorn.

Selected Matanuska Coal Field Geologic References

Apell, G. A., 1944, Moose Creek District of Matanuska Coal Fields, Alaska: U.S. Bureau of Mines Report of Investigations 3784.

Barnes, F. F., 1962, Geologic map of the lower Matanuska Valley, Alaska: U.S. Geological Survey, Inv. Map I-359, scale 1:63,360.

________________, 1966, Geology and coal resources of the Beluga-Yenta region, Alaska: U.S. Geological Survey Bulletin 1202-C, 54 p.

Barnes, F. F., and Payne, T. G., 1956, The Wishbone Hill District Matanuska Coal Field, Alaska: U.S. Geological Survey Bulletin 1016, 46 p.

Barnes, F. F., and Sokol, D., 1959, Geology and coal resources of the Little Susitna District, Matanuska Coal Fields, Alaska: U.S. Geological Survey Bulletin 1058-D, 17 p.

Capps, S. R., 1927, Geology of the Upper Matanuska Valley, Alaska: U.S. Geological Survey Bulletin 791, 92 p.

Clardy, B. I., 1974, Origin of the Lower and Middle Tertiary Wishbone and Tsadaka Formations, Matanuska Valley, Alaska: M.S. Thesis, University of Alaska, Fairbanks, 51 p.

Geer. M. R., and Yancey, H. F., 1946, Washability Characteristics and washing of coals from the Matanuska Field of Alaska: U.S. Bureau of Mines Report of Investigations 3840.

Geer, M. R., and Fennessy F. D., 1962, Washability of coals from the Matanuska Valley and Beluga River Fields, Alaska: U.S. Bureau of Mines Report of Investigation 6017.

Grantz, Arthur, 1964, Stratigraphic reconnaissance of the Matanuska Formation in the Matanuska Valley, Alaska: U.S. Geological Survey Bulletin 1181-I, 33 p.

Grantz, Arthur, and Jones, D. L., 1960, Stratigraphy and age of the Matanuska Formation, south central Alaska in Geological Survey Research 1960: U.S. Geological Survey Professional Paper 400-B, p. 347-350.

Grantz, Arthur, Thomas, H. Stern, T. W., and Sheffey, N. B., 1963, KAr and Pb-alpha ages for stratigraphically bracketed plutonic rocks in the Talkeetna Mountains, Alaska: U.S. Geological Survey Professional Paper 475-B, p. 56-59.

Grantz, Arthur, and Wolf, J. A., 1961, Age of the Arkose Ridge Formation, south central Alaska: American Association Petroleum Geological Bulletin, v. 45, p. 1762-1765.

Hazen Research, 1983, Washability analyses and sample characterization studies on Alaskan coal, Consultant's Report.

Jolley, T. R., Toenges, A. L., and Turnbull, L. A., 1952, Bituminous coal deposits in the vicinity of Eska, Matanuska Valley Coal Field, Alaska: U.S. Bureau of Mines Report Inv. 4838, 82 p.

Martin, G. C., and Katz, F. J., 1912, Geology and coal fields of the Lower Matanuska Valley, Alaska: U.S. Geologic Survey Bulletin 500, 98 p.

Rao, P. D., and Wolff, E. N., 1979, Characterization and evaluation of washability of Alaskan coals, Phase 1 Report, University of Alaska, Mineral Industry Research Laboratory.

_______________________, 1982, Characterization and evaluation of washability of Alaskan coals, Phase 4 Report, University of Alaska, Mineral Industry Research Laboratory.

Triplehorn, J. H., 1982 Alaska coal - a bibliography, University of Alaska, Mineral Industry

Research Laboratory Report 51.

Triplehorn, D. M., Turner, D. L., and Naeser, C. W., 1984, Radiometric age of the Chickaloon Formation of south central Alaska: Location of the Paleocene-Eocene boundary, Geological Society of America Bulletin, v. 95, p 740-742.

U.S. Bureau of Mines, 1946, Analyses of Alaska coals, U.S. Bureau of Mines Technical Paper 682.

Various Authors, 1976, Focus on Alaska's coal, '75, University of Alaska, Mineral Industry Research Laboratory Report 37.

Various Authors, 1982, Focus on Alaska's coal, '80, University of Alaska, Mineral Industry Research Laboratory Report 47.

Warfield, R. S., 1962, Bituminous coal deposits of the Matanuska Coal Field, Alaska: central and western parts, Wishbone Hill District: U.S. Bureau of Mines Report of Investigations 5950, 190 p.

Waring, Gerald, 1934, Core drilling for coal in the Moose Creek area, Alaska: U.S. Geological Survey Bulletin 857-E.

Williams, Jerry, 1983, Seismic refraction survey of Wishbone Hill coal property, Palmer, Alaska: C. C. Hawley and Associates, Inc.

Accretionary Tectonics

The following is a list of selected references related to accretionary tectonics:

Ben-Avraham, Z., Nur, A., Jones, D., Cox, A., 1981, Continental Accretion: From oceanic plateaus to allocthonous terranes. Science 213: 47-54.

Coney, P. J., Silberling, N. J., Jones, D. L., 1983, Oceanic crustal telescoping and the growth of continents; accretionary tectonics in Alaska. Abstracts with Programs - Geological Society of America 15: 5, 427 p.

Dickinson, W. R. and Seeley, D. R., 1979, Structure and stratigraphy of fore-arc regions. Bulletin of the American Association of Petroleum Geologists, v. 63, no. 1, 2-31.

Jones, D. L., Silberling, N. J., Mesozoic accretionary tectonics of southern and central Alaska: Geological Society of America, Abstract Programs 11: 7, 1979, 452 p.

Noklenber, W. J., Plafker, G., Roeske, S., Structural analysis and accretionary tectonics of Cretaceous and early Tertiary flysch sequences juxtaposed along the Contact Fault, eastern Chugach Mountains, Alaska: The Geological Society of America, Cordilleran Section, 82nd annual meeting. Anonymous.

Silberling, N. J., Jones, D. L., Mesozoic accretionary tectonics of Alaska. AAPG Bulletin 64: 5, 1980, 784 p.

Quaternary Geology

The following is a list of selected references pertaining to the Quaternary geology of the Matanuska Valley. It is worthy to note that many of the Matanuska Coal Field geologic references discuss certain aspects of the quaternary geology. Those references that were used in preparing both the Quaternary Geology and Pre-Quaternary Geology sections of this report can be found in both reference lists.

Barnes, F. F., and Payne, T. G., 1956, The Wishbone Hill District, Matanuska Coal Field, Alaska: U.S. Geological Survey Bulletin 1016, 87 p.

Capps, S. R., 1927, Geology of the Upper Matanuska Valley, Alaska: U.S. Geological Survey Bulletin 791.

Clardy, B. I., Hanley, P. T., and LaBelle, Joe, 1982, Field trip guidebook: Anchorage to Matanuska Glacier: Anchorage, Alaska Geological Society, 38 p.

Collins, S. G., 1975, Glaciers of the Talkeetna Mountains, Alaska, in Field, W. O., ed., Mountain glaciers of the Northern Hemisphere: U.S. Army Cold Regions Research and Engineering Laboratory Report, v. 2, p. 543-548.

Detterman, R. L., Plafker, G., Hudson, T., Tysdal, R. G., and Pavoni, N., 1974, Surface geology and Holocene breaks along the Susitna segment of the Castle Mountain Fault, Alaska: U.S. Geological survey Miscellaneous Field Studies Map MF-618, scale 1:24,000, 1 sheet.

Detterman, R. L., Plafker, G., Tysdal, R. G., and Hudson, T., 1976, Geology and surface features along part of the Talkeetna segment of the Castle Mountain - Caribou Fault system, Alaska: U.S. Geological Survey Miscellaneous Field Studies Map MF-738, scale 1:63,360, 1 sheet.

Karlstrom, T. N. V., 1953, Upper Cook Inlet region, Alaska, in Pewe, T. L., and others, Multiple glaciation in Alaska: A progress report: U.S. Geological Survey Circular 289, p. 3-5.

__________________, 1955, Late Pleistocene and recent glacial chronology of south central Alaska [abs.]: Geological Society of America Bulletin, v. 66, no. 12, pt. 2, p. 1581-1582.

__________________, 1957, Tentative correlation of Alaskan sequences, 1956: Science, v. 125, no. 3237, p. 73-74.

__________________, 1964, Quaternary geology of the Kenai Lowland and glacial history of the Cook Inlet region, Alaska: U.S. Geological Survey Professional Paper 443, 69 p.

_________________, 1965, Upper Cook Inlet area and Matanuska River Valley, in Pewe, T. L., Ferrains, O. J., Jr., Nichols, D. R., and Karlstrom, T. N. V., Guidebook for field conference F, central and south central Alaska, International Association for Quaternary Research, 7th

Congress, Fairbanks, 1965: Lincoln, Nebraska Academy of Science, p. 114-141 (reprinted 1977, College, Alaska Division of Geological and Geophysical Surveys).

Martin, C. G., and Katz, F. J., 1912, Geology and coal fields of the Lower Matanuska Valley, Alaska: U.S. Geological Bulletin 500.

Pewe, T. L., 1975, Quaternary geology of Alaska: U.S. Geological Survey Professional Paper 835, 145 p.

R & M Consultants, Inc., 1981, Geological and geotechnical investigations, Glenn Highway realignment study, Palmer to Mile 135: Anchorage, 146 p.

Reger, R. D., 1978, Reconnaissance geology of the new capital site and vicinity, Anchorage Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Open-File Report 113A, scale 1:63,360, 1 sheet.

_________________, 1981a, Geologic and materials maps of the Anchorage (C-8 SE) Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 65, scale 1:25,000, 2 sheets.

_________________, 1981b, Geologic and materials, maps of the Anchorage (C-8 SW) Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 68, scale 1:25,000, 2 sheets.

_________________, 1981c, Geologic and materials maps of the Anchorage (B-8 NE) Quadrangle, Alaska: Alaska Division of Geological and Geophysical Surveys Geologic Report 69, scale 1:25,000, 2 sheets.

Reger, R. D., and Updike, R. G., 1983, Upper Cook Inlet region and Matanuska Valley from Guidebook to Permafrost and Quaternary Geology along the Richardson and Glenn Highways between Fairbanks and Anchorage, Alaska, edited by Pewe, T. L. and Reger, R.

D., published by State of Alaska Division of Geological and Geophysical Surveys.

Warfield, R. S., 1962, Bituminous coal deposits of the Matanuska Coal Field, Alaska: Central and western parts, Wishbone Hill District: U.S. Bureau of Mines Report of Investigations 5950, 190 p.

Williams, J. R., and Ferrains, O. J., Jr., 1961, Late Wisconsin and recent history of the Matanuska Glacier, Alaska: Arctic, v. 14, no. 2. p. 82-90.

7.0 RESPONSIBLE PARTIES

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