3 GEOLOGY

The Project area is located on the upper Meade Thrust plate, one of several thrust plates developed as part of the Rocky Mountain overthrust belt, a zone of eastward compression associated with significant folding and faulting. These processes resulted in a series of northwest-to-southeast-trending anticlines and synclines that form northwest-to-southeast-trending ridges and valleys where exposed and shallow expressions of the Meade Peak Member of the Phosphoria Formation have been the target of phosphate mining in the region. The Project area occurs along the northeast dipping limb of the Dry Valley Anticline where the Phosphoria Formation outcrops along Dry Ridge. The Meade Peak Member outcrops between 7,550 and 8,260 feet above mean sea level at the H1 area and between 6,775 and 7,460 feet above mean sea level at the NDR area.

The phosphate mineralization is sedimentary in nature, occurring in a conformable sequence of alternating phosphatic and weakly- to non-phosphatic shale, mudstone, carbonate, and chert beds within the Meade Peak Member of the Permian Phosphoria Formation. The phosphate mineralization encountered in the Meade Peak Member is stratigraphic in nature, and the deposit type is considered a typical example of a marine sedimentary phosphate deposit. The phosphate mineralization occurred during the primary depositional processes, and there are no known secondary phases of phosphate mineralization or enrichment identified in the deposits.

The beds of the Meade Peak Member were deposited within a marine sedimentary basin within the Phosphoria Sea that marked the western margin of the North American craton approximately 250 million years ago. Depositional processes during the period in which the Meade Peak Member was being deposited resulted in alternating beds of phosphatic shale and mudstone with layers of non-phosphatic shale, carbonate, and chert beds. The phosphate mineralization within the Meade Peak Member consists of apatite pellets, oolites, and sand grains, some of which are further cemented together into clusters of pellets and grains in an apatite cement; the apatite within the Meade Peak Member is entirely in the form of carbonate fluorapatite (Altschuler et al. 1958). Individual beds of the Meade Peak Member are laterally continuous over significant distances, with some beds commonly found distributed over tens of thousands of square miles within the Western Phosphate Field (Sheldon and Davidson 1989); however, the thickness and geometry of the beds has been locally impacted on a deposit scale by both primary depositional variability and post-depositional structural modification due to both regional and deposit-scale faulting and folding.

3.1 Stratigraphy

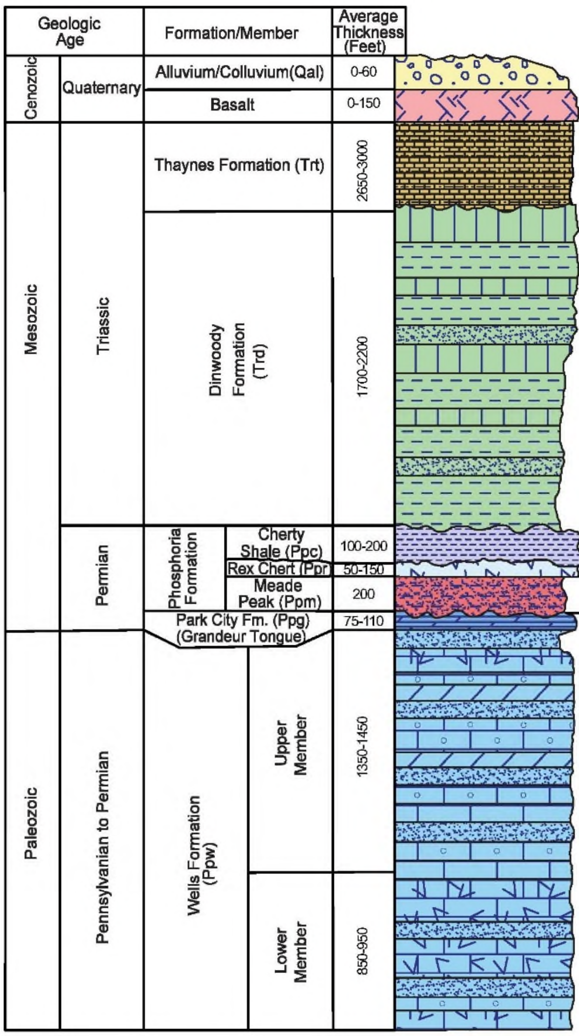
Rocks exposed at the surface at the Project range in age from Mississippian to Recent, and include Quaternary-age alluvium, colluvium, and sedimentary bedrock of Mississippian- to Triassic-age formations. A detailed list of the stratigraphic units of the area is provided below in reverse stratigraphic order and presented on Figure 3-1:

- *Alluvium/Colluvium – Quaternary*. Unconsolidated sand, silt, and gravel in drainages and along hillsides that averages 0 to 60 feet in thickness.
- *Basalt – Quaternary*. Dark gray olivine basalt that averages 0 to 150 feet in thickness.

- *Thaynes Formation – Triassic*. The Thaynes Formation was deposited during the Triassic Period and overlies the Dinwoody Formation. This formation is divided into four members and consists of gray fossiliferous limestone, calcareous siltstone, and black and gray shale with a total thickness of 2,650 to 3,000 feet.
- *Dinwoody Formation – Triassic*. The Dinwoody Formation outcrops on the eastern slope of Dry Ridge and is approximately 1,700 to 2,200 feet thick. This unit consists of thin-bedded tan siltstone, shale, and interbedded limestone. Surficial wreathing of the Dinwoody Formation forms dense, clayey soils.
- *Phosphoria Formation – Permian*. This unit forms the central-eastern portion of Dry Ridge. The Phosphoria Formation is divided into three members, described from youngest to oldest below:
    - *Cherty Shale Member*. The unit thickness ranges from 100 to 200 feet along Dry Ridge and is composed of thinly bedded dark brown to black, cherty mudstone, siliceous shale, and argillaceous chert.
    - *Rex Chert Member*. The Rex Chert Member is composed of thick-bedded black to bluish-white or occasionally reddish-brown chert with small amounts of interbedded mudstone and lenticular limestone. The unit thickness ranges from 50 to 150 feet along Dry Ridge. The Rex Chert Member is highly siliceous and resistant to weathering (Hein et al. 2002), often forming overhanging ledges above the less resistant Meade Peak Member.
    - *Meade Peak Phosphatic Shale Member (Meade Peak Member*). The Meade Peak Member is approximately 110 to 200 feet thick and consists of dark carbonaceous, phosphatic, and argillaceous rocks including shale, mudstone, and limestone. The upper contact of the Phosphoria Formation is marked by nodular phosphorite. The lower contact with the underlying Grandeur Tongue of the Park City Formation is marked by a phosphorite seam 4 to 6 inches thick containing abundant fossil fish scale and bones. The mineable phosphate rock occurs in two separate ore zones within the Meade Peak Member, identified as the lower ore and upper ore, which are separated by approximately 80 to 110 feet of sub-economic phosphoric shale. The lower and upper ore units vary in thickness throughout the leases but average approximately 40 feet and 15 feet, respectively.
- *Grandeur Tongue Member of the Park City Formation – Pennsylvanian*. This unit directly underlies the Phosphoria Formation and outcrops on the central-western portion of Dry Ridge. The Grandeur Tongue Member of the Park City Formation is typically mapped with the Wells Formation. It is composed primarily of gray to tan, thick to massively bedded, finely to coarsely crystalline dolomite and dolomitic limestone. The thickness of the Grandeur Tongue Member ranges from 75 to 110 feet along Dry Ridge.
- *Wells Formation – Pennsylvanian*. The upper member of the Wells Formation averages 1,350 to 1,450 feet thick and consists of buff-colored sandy limestone, gray to reddish-brown sandstone, dolomitic limestone, and interbedded gray limestone and dolomite. The lower member of the Wells Formation averages 850 to 950 feet thick and consists of thin- and medium-bedded, gray, silty limestone with cherty nodules, and flattened oolites, and some interbedded sandstone. The Wells Formation outcrops along the western side of Dry Ridge. The Upper Wells Formation member is typically a light gray to yellowish-orange sandstone with interbedded limestone and chert bands in the upper 50 feet.

- *Monroe Canyon Limestone Formation – Mississippian*. The Monroe Canyon Limestone (also known as the Brazer Limestone by Cressman and Gulbrandsen [1955]) is the oldest unit in the Dry Valley Quadrangle, deposited during the upper Mississippian Period. Only the upper 800 feet of the Monroe Canyon Limestone are exposed in this quadrangle, which is characterized by thickly bedded, light gray limestone containing corals and brachiopods, and interbedded limestone and sandstone. The Monroe Canyon Limestone is partly exposed in Dry Valley and forms the axis of the Dry Valley Anticline.

Figure 3-1. Typical Regional Stratigraphic Column



Meade Peak Member

Average Thickness (Feet)	
15-35 ft	Hanging Wall Mud
~15 ft	Upper Phosphate Zone - Low/Medium to High Grade (Interbedded Phosphorite Mudstone, Siltstone, Limestone, and Shale)
80-110 ft	Center Interburden - Mudstone and Shale
~40 ft	Lower Phosphate Zone - Low to High Grade (Interbedded Phosphorite Mudstone, Siltstone, Limestone, and Shale)
5-10 ft	Footwall Mud

NOT TO SCALE

ITAFOS
HUSKY 1 / NORTH DRY RIDGE PROJECT
CARIBOU COUNTY, IDAHO
MINE AND RECLAMATION PLAN

TYPICAL
REGIONAL STRATIGRAPHIC COLUMN

ARCADIS

FIGURE
3-1

References:
1. *Brown & Caldwell. 2013. Rasmussen Valley Mine Project, Geology Baseline Study Report. April 26.*
2. *Rioux, R.L., R.J. Hite, J.R. Dyni, and W.C. Gere. 1975. Geologic Map of the Upper Valley Quadrangle, Caribou County, Idaho. 1:24,000. U.S. Geological Survey Map GQ-1194.*

3.2 Structural Geology

The regional geologic structure is characterized by thrust faulting and folding into a series of northwest-to-southeast-trending folds (i.e., anticlines and synclines). Bedrock strata in the Project area form the eastern limb of the Dry Valley Anticline and generally dip northeastward. The Meade Peak Member is overturned at the NDR Lease and in the southern portion of the H1 Lease. Subsidiary folding and faulting are also found in the southern portion of the H1 Lease.

Two sets of faults were previously mapped in the Project area: a set of thrust faults with strike parallel to northwest-trending folds with relatively large displacements (up to 500 feet) and an orthogonal set of minor faults with normal displacements less than 25 feet. The Henry Thrust Fault parallels Dry Ridge on the east side, and the Dry Valley Thrust Fault parallels Dry Ridge on the west side. The Dry Valley Thrust Fault and Henry Thrust Fault are subsidiary to the Meade Thrust Fault and are contained within the Meade Thrust plate. The north end of Dry Ridge is terminated by the Blackfoot Fault, which is a left lateral tear fault with approximately 1 mile of left-lateral displacement and substantial normal vertical displacement with the north side downthrown.

The structural feature that dominates the NDR and H1 areas is the northwest-trending North Dry Valley Anticline. NDR and H1 are located on the northeast limb of the anticline and, as such, the strata of NDR and H1 dips very steeply to near vertical to the northeast. Faulting in the northern portion of the NDR Lease has forced the Meade Peak Member of the Phosphoria Formation to uplift to the overlying Dinwoody Formation, resulting in the absence of the Meade Peak Member north of the Blackfoot normal fault with in the NDR property. Additional folding and faulting are found in the southern portion of the H1 area (notably, the Stewart Anticline), which trends northeast-southeast. The axis of the Stewart Anticline is within the southern portion of the H1 property and allows for a large outcrop area of the Meade Peak Member.

3.3 Exploration

Exploration drilling at NDR was conducted in 1989 and 1990 and included 260 exploration borings. These activities occurred before Agrium's 1995 acquisition of Nu-West. In June 2010, the BLM Pocatello field office and the USFS Caribou Targhee National Forest completed an Environmental Assessment for the H1 and NDR Phosphate Exploration Project exploratory drilling in accordance with National Environmental Policy Act (NEPA) requirements. The BLM/USFS issued a Finding of No Significant Impact on June 16, 2010.

3.3.1 Husky 1 Exploration

The following timeline illustrates the chronology of exploration for the H1 Lease. An exploration drilling program was conducted from 1969 to 1970, 1974, and 1981. More than 175 exploration borings were drilled during these years. Fifty-six exploration holes were drilled in 2011, 92 were drilled in 2012, and 86 were drilled in 2014. In April 2009, Agrium submitted the H1 and NDR Exploration Drilling Plan of Operations to the BLM. Wireline Geophysical Logs were gathered for 235 drill holes at H1 and 253 drill holes at NDR.

3.3.2 North Dry Ridge Exploration

As part of the historical exploration work on the NDR property, 40 surface trench samples and 260 boreholes were collected during the 1989 and 1990 exploration campaigns. Before the 1989 and 1990 drilling program, no exploration activities had occurred on this lease by a non-government entity. The trenches were laid out at approximately 1,000-foot spacing on a surveyed grid across the property as a means of collecting initial geological and grade information before commencing with the drilling programs on the Project. The trenches were mechanically stripped using a dozer and were then surveyed by the mining surveyors. The Conda mining grade control technicians then sampled each trench, measuring thickness off the surveyed points. The samples were bagged and sent to the Conda Phosphate Plant on-site laboratory for analysis in the same manner as the drill hole samples from the 1989 and 1990 exploration programs. Both head grade and washed analyses were run for all samples.

The tables of analytical results for the NDR trench samples, as well as the surveyed coordinates, are stored in a binder at the Conda Phosphate Plant and have been converted to digital format. Selected trench samples were used to supplement drilling data to aid in modeling the bed roof and floor surfaces; however, given the potential base differences between the samples collected from the reverse circulation drill holes versus those collected from the NDR exploration trenches, the grade data from these samples were not used in the grade modeling process. For the purpose of structural modeling, the trenches were converted to horizontal pseudo-drill holes using the surveyed coordinates from the start and end points of the sample section lines.

In 2010, 23 exploration drill holes were completed at NDR to provide additional data for consideration.

Ten additional core boreholes were drilled in 2012 primarily to support geotechnical studies for the NDR Lease.

3.4 Digital Modeling

Geologic modeling and mineral resource estimation for H1 and NDR pits were developed as stratigraphically constrained grade block models using a combination of Sequent Leapfrog Geo and Maptek Vulcan modeling software. These modeling softwares are industry standard, computer-assisted, geological-grade modeling and reserve estimation software applications. The following sections provide a summary of the digital modeling completed for the H1 and NDR pits.

3.4.1 Husky 1

Digital models for the H1 were constructed from several sources of data or information. Vulcan mine modeling and design software was used to create three-dimensional solids representations of the upper and lower economic ore zones within the Phosphoria Formation. Where historical geological interpretations were derived as a result of the historical drilling, cross-sections were used to create new digital model solids. Where no historical geologic interpretations were available, surface geology maps were used to spatially locate subsurface phosphate ore zones using surface outcrops and projected dip angles. Using this surface geology map information, basic projections of ore were created and used to develop this MRP.

Areas where geologic projections were used are, for the most part, in the Off-Lease Area between the H1 Lease and the MCM Lease. Section 6.1 describes the proposed lease modification to the H1 Lease.

3.4.2 North Dry Ridge

As the 1989 and 1990 drilling information appears to be adequate for Itafos' modeling requirements, three-dimensional solids were created using these drilling data in Vulcan mine modeling and design software. Historical geologic correlations were also used, as these interpretations best fit the drilling data.

Appendices C1 and C2 contain cross-sections for both H1 and NDR.

3.5 Grade Classification

The digital models were used to produce resource models based on reasonable assumptions of lateral continuity of grade and reasonable prospects for economic extraction. The resource models were used to determine pit designs and for general mine planning. These models are subject to updates based on additional drilling and observations made during mining operations.

3.5.1 Husky 1

The resource model or block model for H1 was assigned grades based on exploration and drill hole data and historical grades measured during mining of the SMCM. These grades were applied to each stratigraphic unit created for the model. As a result of this method of grade assignment, mineable tonnages and grades of ore, as well as the actual footprint of the mine disturbance for the H1 deposit, may be subject to change based on the results of additional exploration drilling. A phosphate recovery factor was applied to each mineable unit based on historical mining recoveries. These recovery factors simulate ore quality characteristics. Blocks within the model were subsequently assigned an ore type classification. Mining overburden was also modeled to predict overburden volumes requiring selective handling practices. The ore volumes include both Upper and Lower Ore Zones. Overburden has been classified as: Dinwoody, Chert (aka Rex Chert), Center Waste Shales (includes Meade Peak Member shales, muds, and ore-associated waste) and Limestone (Grandeur Tongue and Wells Formation).

An account of ore grades, ore classifications, and strip ratios are referenced in the Itafos NI 43-101 Technical Report (Minnes, et al. 2019). Overburden volume and classifications are detailed in Section 4.1.3.1.

3.5.2 North Dry Ridge

Grades were estimated into resource or block models from drilling data for NDR. Blocks within the model were subsequently assigned an ore type classification. Mining overburden was also modeled accurately to predict overburden volumes requiring selective handling practices. The ore types and overburden are classified in the same manner as those for H1.

3.6 Mineralized Inventory

Vulcan's pit optimizer (LG method) software was used to define various open-pit designs that would be optimal using different or variable strip ratios. Inputs to the optimization included economic and physical parameters provided by Itafos. Mineralization was modeled over a fixed outcrop strike length, and the ore deposit modeling used this strike length as a factor in optimizing the pit designs. In addition, Appendix E outlines the mining and ore recovery verification procedures used by Itafos and approved by the regulatory agencies.