# 5.0 GEOLOGY

## 5.1 TERRAIN AND GEOLOGY

The Project primarily traverses the Interior Plain Physiographic Province, crossing into the Laurentian Upland Province—Superior Upland in the eastern portion of its preferred route in Minnesota (USGS, 2004). The geologic terrain of both of these provinces is characterized by ancient pre-Cambrian igneous and metamorphic rocks that have been uplifted and eroded to a relatively low-relief plain, forming the stable geologic core of the North American continent, known as the craton. The North American craton has been tectonically stable for over 500 million years. The Superior Upland is a southern extension of the Laurentian Upland Province. The basement rocks of this province are associated with the 2.5-billion-year-old Kenoran Orogeny, a mountain-building event, and are part of the Canadian Shield. Basement rocks of the Interior Plains Physiographic Province were generally formed from the tectonic collision of smaller continental plates over one billion years ago that resulted in continental accretion and expansion of the North American craton.

The bedrock geology underlying the preferred route is illustrated in Figure 5.1-1 (after Jirsa and others, 2011). Very limited occurrences of Paleozoic and Mesozoic sedimentary bedrock units lie randomly over the pre-Cambrian basement rocks across northern Minnesota. Ordovician sedimentary bedrock occurs in the northwestern portion of Polk County, but lies to the north of the preferred route. However, relatively short segments (approximately 20 to 15 miles) of the preferred route cross Cretaceous sedimentary bedrock in both Aitkin and Cass counties. These sediments were deposited 65 to 136 million years ago and consist of sandstone lenses near the base of predominantly gray, soft, argillaceous shale (solidified mud and clay) sections.

Surficial geology along the preferred route is characterized by unconsolidated deposits from Pleistocene continental glaciation. In the Project area, these sediments were deposited primarily during four major episodes of glaciation of variable provenance. The sediments are comprised of both ground and end moraine, outwash deposits, ice-contact stratified drift (e.g., kames and eskers), and lacustrine sediments, including lake bottom and beach ridge deposits. Additionally, there are more recent deposits of alluvium in river channels and peat in the pothole depressions that are characteristic of the interrupted drainage of glaciated terrain. Figure 5.1-2 is a simplified map (after Hobbs and Goebel, 1982) of the surficial geology in relation to the preferred route.

Topography across the preferred route varies widely given the variable nature of glacial deposition. The interrupted drainage of glacial terrain can be of low relief and include wetlands, lakes, and gently rolling to undulating hills and ridges, as well as hummocky areas of high relief with steep hills and ridges associated with glacial end moraine deposits. Additionally, glacial erosion can remove unconsolidated deposits and scour bedrock, and glacial meltwater can incise significant valleys into bedrock (MNDNR, 1997). Elevations in

the Project area range from approximately 882-feet to 1,681-feet above mean sea level (see Table 5.1-1).

Regional maps of depth-to-bedrock coverage generally lack sufficient resolution to identify areas where bedrock occurs at specific depths (see Section 5.4). Accordingly, the depth to bedrock in a specific location is difficult to determine without sampling. Generally, depth to bedrock along the preferred route segments can exceed 450-feet; however, using digital coverage of depth-to-bedrock (Olsen and Mossler, 1982), the preferred route was found to cross an area of more or less continuous bedrock exposure from approximate MP 579.5 to MP 582.0. This area of shallow bedrock is located in Carlton County, and the bedrock geology is dominated by graywackes, slates, and metasediments. In areas where the pipeline is installed using HDD techniques, bedrock could be at a depth where it may be encountered during construction. These areas will be identified from geotechnical borings at the HDD crossings and will be factored into the design of the crossings.

As stated previously, the area crossed by the Project has been tectonically stable for over 500 million years. Therefore, there is a low probability of an earthquake of significant intensity or other seismic event in the Project area (National Atlas of the United States, 2013).

**Table 5.1-1**
**Elevation Along the Sandpiper Pipeline Project**

| County | Elevation Above Mean Sea Level (feet) | | |
|---|---|---|---|
| | Lowest | Average | Highest |
| Polk | 1,201 | 1,263 | 1,371 |
| Red Lake | 1,031 | 1,090 | 1,125 |
| Clearwater | 1,271 | 1,463 | 1,671 |
| Hubbard | 1,364 | 1,461 | 1,681 |
| Cass | 1,278 | 1,386 | 1,519 |
| Crow Wing | 1,335 | 1,375 | 1,421 |
| Aitkin | 1,201 | 1,263 | 1,371 |
| Carlton | 882 | 1,184 | 1,318 |
| **Average** | **1,145** | **1,283** | **1,423** |

**Figure 5.1-1**
**Bedrock Geology**

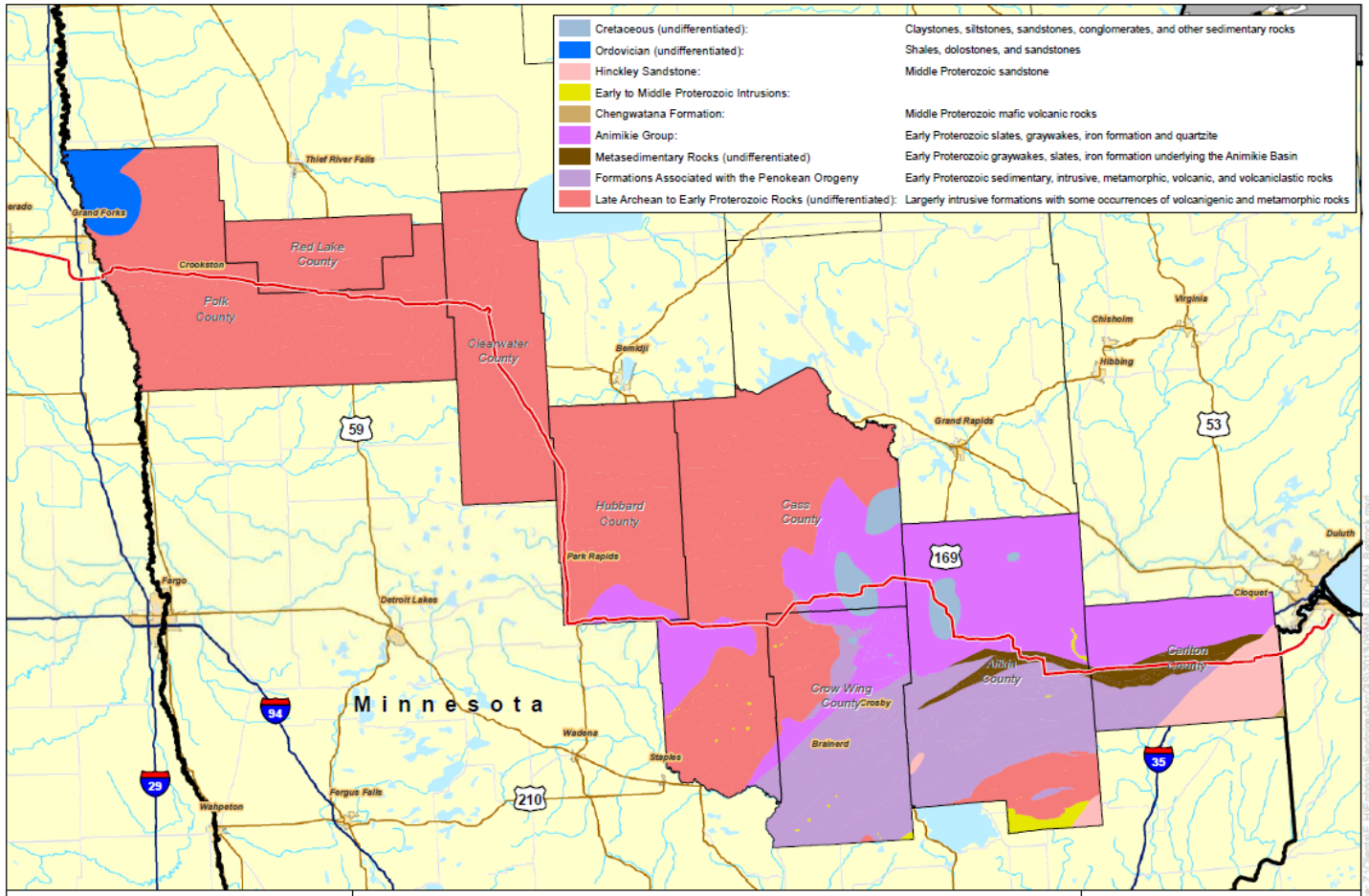

**Figure 5.1-2**
**Quaternary Geology**

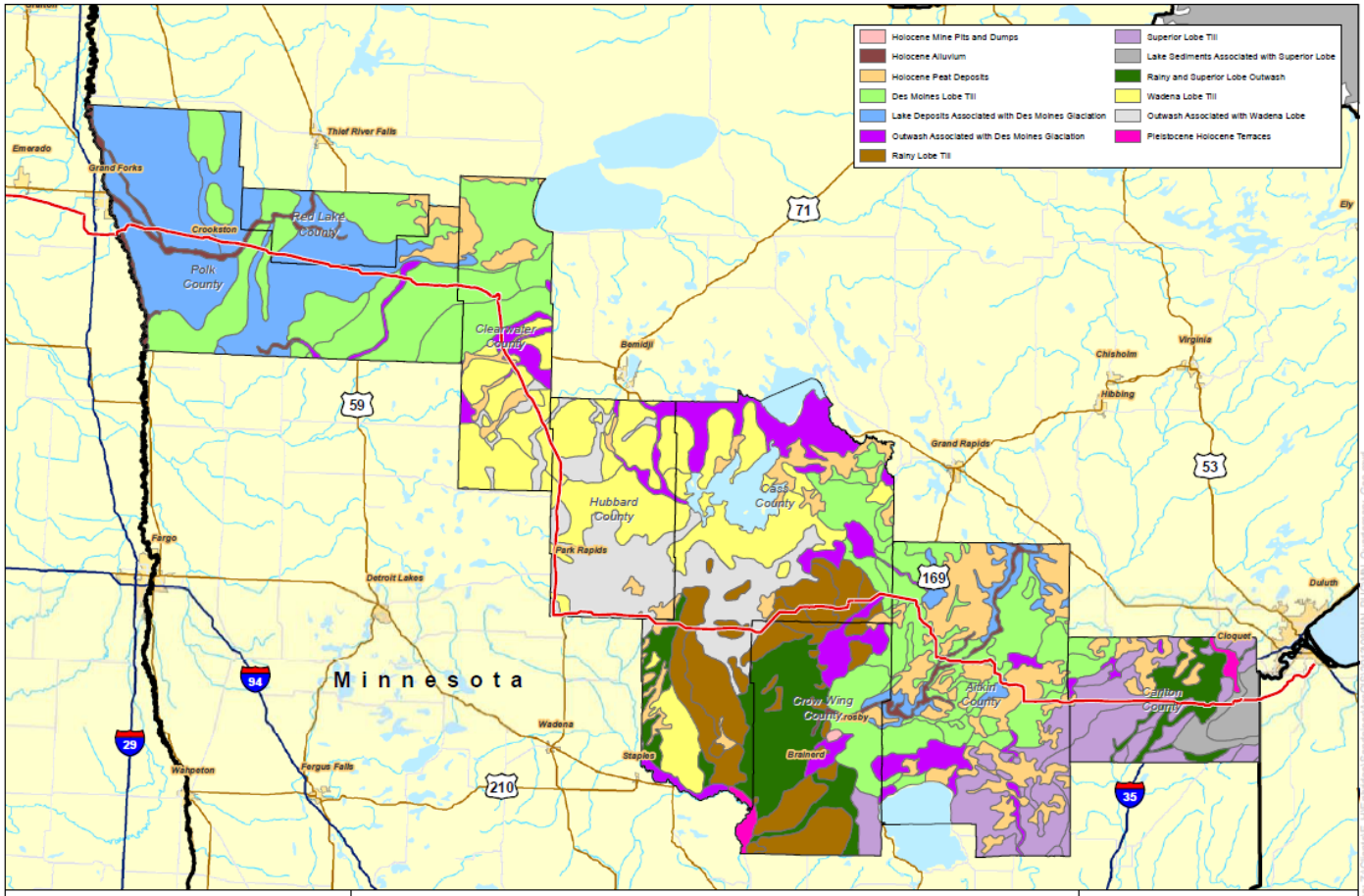


**Figure 5.1-2**
**Enbridge Pipelines (North Dakota) LLC**
**Sandpiper Pipeline Project**
**Quaternary Geology**
**(After Hobbs and Goebel, 1982)**

## 5.1.1 Mineral Resources

Mineral resources in Minnesota include industrial (e.g., sand, gravel, and crushed stone) and metallic (e.g., iron ore, nickel, and titanium) minerals. USGS topographic maps, 2013 aerial photography, and MNDNR spatial data for mineral leases on state lands (as of May 2013) were used to identify surface features associated with mining or mineral resources. Table 5.1.1-1 identifies possible mining and mineral resource areas within 1,500-feet of the construction workspace, in addition to known active state mineral leases. Of the localities listed, 19 sites are possibly associated with non-metallic resources (7 gravel pits and 12 sand/gravel pits) and 4 are associated with active metallic mineral leases. Three areas of active mineral leases on MNDNR land will be crossed by the Project's construction right-of-way in Aitkin and Carlton counties.

**Table 5.1.1-1**
**Mineral Resources within 1,500-Feet of the Sandpiper Pipeline Project** [a]

| County | Milepost | Operation | Distance and Direction from the Right-of-Way |
|---|---|---|---|
| Polk | 328.0 | Sand/Gravel Pit [a] | 1400 feet South |
| | 352.0 | Sand/Gravel Pit [b] | 820 feet Northwest |
| | 366.0 | Gravel Pit [b] | 870 feet North |
| Clearwater | 374.0 | Gravel Pit [b] | 1300 feet East |
| | 383.0 | Gravel Pit [b] | 970 feet Northwest |
| | 384.0 | Sand/Gravel Pit a | 1470 feet North |
| | 385.0 | Sand/ Gravel Pit [a] | 1300 feet East |
| Hubbard | 410.0 | Sand/Gravel Pit [a] | 790 feet East |
| | 451.0 | Sand/Gravel Pit [a] | 890 feet Southeast |
| Cass | 476.0 | Sand/Gravel Pit [a] | 300 feet Southeast |
| | 479.0 | Sand/Gravel Pit [a,b] | 610 feet Northwest |
| | 496.0 | Gravel Pit [b] | 230 feet East |
| Aitkin | 515.0 | Sand/Gravel Pit [a] | 420 feet Northwest |
| | 523.0 | Gravel Pit [b] | 1400 feet West |
| | 527.0 | Sand/Gravel Pit [b] | 150 feet West |
| | 528.0 | Gravel Pit [b] | 400 feet South |
| | 530.0 | Sand/Gravel Pit [a,b] | 380 feet Southeast |
| | 558.0 - 558.1 | Metallic Mineral Exploration [c] | 460 feet Southeast |
| Carlton | 560.4 - 561.6 | Metallic Mineral Exploration [c] | 0 - 458 feet/All directions |
| | 561.8 - 562.7 | Metallic Mineral Exploration [c] | 0 - 390 feet East |

**Table 5.1.1-1**
**Mineral Resources within 1,500-Feet of the Sandpiper Pipeline Project** [a]

| County | Milepost | Operation | Distance and Direction from the Right-of-Way |
|---|---|---|---|
| Carlton | 563.3 - 563.4 | Metallic Mineral Exploration [c] | 0 - 30 feet Northeast |
| | 565.0 | Sand/Gravel Pit [a] | 1400 feet South |
| | 586.0 | Gravel Pit [b] | 1350 feet Southeast |

[a] Based on a review of 2013 aerial photography
[b] Based on a review of USGS topographic maps
[c] Source: Minnesota Minerals Coordinating Committee, 2013. Does not include terminated or expired mineral contracts or leases.

In addition, the preferred route will cross two bedrock greenstone belt terrains in the western portion of Minnesota (MNDNR, 2013g). Greenstone belt terrains are zones of variably metamorphic rock that have undergone a change in existing rock structure or composition induced by location, chemicals, or temperature. Greenstone belt terrains have the potential to contain gold mineralizations.

### 5.1.2 Paleontology

Based on the thickness of the unconsolidated glacial material in the Project area, significant paleontological resources are not likely to be encountered during construction. Despite the fact that glacial deposits in Minnesota are of Pleistocene age, megafauna fossils tend to be scarce where glacial ice was present (Mather, 2009; Sloan, 2005). EPND consulted with the Minnesota Geological Survey ("MGS") and confirmed that paleontological finds are not common in the northern half of Minnesota. However, EPND has developed a Draft Unanticipated Discoveries Plan (included as Appendix D) that will be implemented in the event of an unanticipated paleontological find.

## 5.2 GENERAL CONSTRUCTION AND OPERATION IMPACTS AND MITIGATION

No unique geological features that have received state or federal protection will be disturbed by the Project. Construction and operation of the Project will result in minor impacts on topography and geology. Primary impacts will be limited to construction activities and consist of temporary alteration of slopes on the construction right-of-way due to grading and trenching operations. These disturbances will be necessary to create a level and safe construction area.

EPND will minimize impacts by returning contours to pre-construction conditions to the extent practicable. In addition, EPND will implement the erosion control measures described in the EPP (see Appendix A). These measures include the installation of slope

breakers, temporary sediment barriers, and permanent trench breakers, as well as the revegetation and mulching of the construction right-of-way.

Blasting may be required if bedrock is encountered within the depth of the trench. Only 2.5 miles of the preferred route will cross bedrock outcrops. If blasting is required, EPND will conduct these activities in accordance with applicable U.S. Occupational Safety & Health Administration regulations.

Based on USGS topographic maps, 2013 aerial photography, and MNDNR mineral lease spatial data, the preferred route is located within 1,500-feet of 23 mining operations. Three general areas of active metallic mineral leases on state lands will be crossed by the Project's construction right-of-way. The greenstone belt terrains crossed by the Project do not contain any known gold mineralizations or high gold potential zones and are currently unexplored due to immensely thick overlaying glacial materials. However, these areas may attract mineral exploration activities in the future. There is a potential that future use of sand and gravel or mineral resources will be precluded where the pipeline is installed across these resource deposits. In areas where the Project is located adjacent to any existing utilities, any sand and gravel deposits in the Project area will be unavailable for mining. Where existing surface mineral facilities exist and are directly crossed by the Project, EPND will be required to compensate for any encumbrance that precludes extraction activities due to the presence of the Project.

For mineral leases on state lands, Minnesota Rule 6125.0700 requires that the mineral lessee be consulted prior to issuance of any other surface leases, permits or licenses, and such leases, permits or licenses shall not unduly interfere with the exploration or mining operations conducted on the leased mining units. EPND will continue to consult with the MNDNR, Aitkin and Carlton counties, and affected private exploration companies concerning metallic mineral resources and active mineral leases that will be crossed by the Project.

Construction of the pipeline will not likely affect any significant paleontological resources; however, any unique resources exposed or excavated during pipeline construction will be recovered and studied for the scientific record and managed in accordance with EPND's Unanticipated Discoveries Plan.

EPND does not anticipate impacts associated with seismic activity within the Project area. Due to the limited potential for large, seismically induced ground movements, there is minimal risk of earthquake-related impacts on the pipeline. No additional mitigation beyond designing the pipeline to currently accepted industry specifications will be required.

No additional disturbance or loss of unique geological features, mineral resources, or scientifically important fossils will occur during operations because there will be no additional surface disturbance required beyond that used for construction.