

LEGEND

- Lithostratigraphic Contact
- - - Approximate Lithostratigraphic Contact
- - - Inferred Lithostratigraphic Contact
- ▭ Study Area
- ▭ Permit Boundary
- ▭ Mine Pit Boundary
- - - Match Line
- Railroad
- Paved Road
- - - Unpaved Road
- - - Trail
- Drainage Way
- Township and Range
- Section
- Index Contour - 20 Ft Interval
- Contours - 5 Ft Interval

Map Unit Descriptions

The description for the rock color is based on Munsell Color 1998 color soil chart system, soil descriptions are based on ASTM-D2488-00 (ASTM International 2000), grain size descriptions for soil are based on engineers grain-size, grain size for rocks is based on geologist grain size descriptions.

Qf Artificial fill deposits: Consists of engineered fill and occurs in areas disturbed by construction activities such as roads, bridges, earthen dams, and areas to create level building sites.

Qal Modern alluvial deposits: Sand, silt, and clay deposited by modern streams and rivers and include river channel and floodplain sediments (Biek and Murphy 1995). Locally it is similar to the Sentinel Butte and Golden Valley Formations since the material is derived from these formations. The thickness varies from 2 feet to 28 feet.

Qoa Older alluvial deposits: Sand, silt, and clay deposited by streams and rivers and usually occur in terraces and slopes above the modern channel and floodplain sediments. Similar to the modern alluvial deposits but located above these deposits. Locally similar to the Sentinel Butte and Golden Valley Formations since the material is derived from these formations.

QTg Sand and gravel deposits: Sand and gravel deposits. The gravel deposits consist of rounded coarse gravel and angular siltified wood and siltstone. May occur as veneer on the ground surface and recognized by scattered gravel on the ground surface.

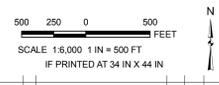
QTC Clinker (Scoria by locals): The clinker age is not known and could be Tertiary to Holocene. Clinker is sediment that has been heated by burning of underground coal. The range of heating of clinker may range from completely melted (a slag-like mass of dark rock that contains numerous voids caused by escaping gases) to rock that is heated just enough to change density and color (Biek and Gonzalez 2001). This rock will still have original sedimentary structures, fossils, and grain-size.

Tgv Golden Valley Formation: The basal contact of the Golden Valley Formation is conformable with the Sentinel Butte Formation. The Golden Valley Formation consists of claystone, mudstone, siltstone, micaceous sandstone, micrite, and coal. The Golden Valley is recognized by a slight change in topographic slope and is weathered at the surface. The Formation is usually covered, however, where sandstone outcrops occur the sandstone is usually a well sorted fine- to medium-grained sandstone and may be cemented with calcium carbonate, but is usually poorly cemented. Poor crossbeds may also be present. Color is variable from pale olive (2.5Y 8/2), yellowish brown (10YR 5/8), light olive brown (2.5Y 5/6), or very pale brown (10YR 7/3).

Tsb Sentinel Butte Formation: The Sentinel Butte Formation consists of silty very fine- to fine-grained sandstones (occasional medium- to coarse-grained sandstone), siltstone, mudstone, claystone, shale, and coal. These rocks are usually not well cemented; the more cemented beds are usually channel sandstones that form ledges or cap rocks. Ripple marks and crossbeds may occur in the channel sands. The claystone may be laminated. Color is predominantly gray and varies between light gray (N6 to N8), olive brown (5Y 5/6) medium olive brown (5Y 4/4) grayish olive (10Y 4/2), pale olive (10Y 6/2), olive gray (5Y 4/1), greenish gray (5GY 4/1), or light olive brown (2.5Y 5/4). May contain calcium carbonate and siderite nodules, and pyrite is commonly associated in vicinity of the coal. Fossils may include wood fragments, seeds, and plant leaves. Carbonaceous layers or stringers are also present.

REFERENCES

Study Area: Golder, 10/18/2007.
 Permit Boundary: IEI, 11/12/2009.
 Mine Pit Boundary: Norwest, 1/20/2010.
 Township, Range and Section: ND HUB, 6/20/2006.
 Roads, Railroad, Drainage Ways: Digitized from aerial photography, 6/19/2006.
 Contours: Generated from aerial photography stereo pairs, 6/19/2006.
 Projection: StatePlane, North Dakota South, NAD27, Feet.



STUDY AREA GEOLOGY SHEET 3 OF 3

Golder ASSOCIATES
 Denver, Colorado

FIG 2.3-2D

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