

F. MAPS AND CROSS SECTIONS OF GEOLOGIC STRUCTURE OF AREA

Submit maps and cross sections detailing the geologic structure of the local area (including the lithology of injection and confining intervals), and generalized maps and cross sections illustrating the regional geologic setting.

The original Wells' (EDS) permit application for Well #1-12 and Well #2-12, submitted in 1996, contains detailed information about the regional and local geology of the area, including the structure and stratigraphy, as well as information about the injection interval, the injection zone, and the confining zone. A discussion of the depositional history of the region is provided below. Structure and isopach maps from the 1996 permit application are included in this document as Figures F-1 through F-13.

The Precambrian basement rock that underlies the southeastern part of the Michigan Basin is part of the Grenville Province, which is 0.8 to 1.0 billion years old (Lilienthal 1983, page 27). The Precambrian surface is interpreted as a complexly faulted series of uplifted and down-dropped blocks. The basement rock was fractured and faulted during the Precambrian. Regional stresses, both compressional and tensional, that were imposed on the North American continent during the Paleozoic reactivated movement along the ancient faults and fractures.

During and after the Grenville Orogeny, the Precambrian highlands eroded and basins filled intermittently with sediments. "Granite wash" detrital deposits and the Jacobsville Sandstone were deposited during the Precambrian in parts of the Michigan Basin. Drilling evidence indicates that the Jacobsville was deposited on a very irregular erosional surface (Dorr and Eschman, 1970, page 91). Across southern Michigan, the granite wash detritus is as thick as 30 feet (Fisher, 1988, page 368).

A gradual marine transgression occurred during the Late Cambrian (Dorr and Eschman, 1970, page 93), with the deposition of clastic sediments in marine environments. Late Cambrian deposits including the Mt. Simon, Eau Claire, Dresbach, and Franconia are probably marine deposits, with the source of material to the northeast (Dorr and Eschman, 1970, page 93). By the end of the Cambrian Period, most of the United States was under water.

The Ordovician began with the Michigan Basin still submerged. The Trempealeau Formation and Prairie du Chien Group were deposited in a marine environment. A regression followed the deposition of the early Ordovician Prairie du Chien Group, removing much of the deposits in southeastern Michigan. Deposition of the offshore marine shale and carbonates of the Trenton and Black River Formations was followed by another regression, with an accompanying unconformity. The Late Ordovician Richmond Group, which includes the Utica Shale, is composed of shale that was deposited in a deep-water environment.

The Howell Anticline of southeastern Michigan extends from northwestern Wayne County for approximately 50 miles northwest across Livingston County and plunges to the northwest toward the center of Michigan. The southwestern flank of the anticline is faulted. The fault terminates near the northwestern corner of Wayne County. No evidence for the fault is found within at least 12 miles of the EGT site. The EGT site is located in a broad gentle syncline on the southwestern flank of the updip extension of the Howell Anticline.

Isopach maps of late Cambrian and Ordovician sediments show thinning and thickening of these sediments in the vicinity of the Howell Anticline. These changes in thickness indicate that the structure was an active topographic feature early in the Paleozoic (Fisher et al., 1988, pages 375-376).

During the Silurian, the Michigan Basin was submerged. The sea was surrounded by low-lying land areas that partially isolated the sea from other bodies of water. In the absence of a significant nearby source of clastic material, the main deposits of the Silurian were evaporite and reef deposits.

The Middle Silurian Niagara Group, which was deposited throughout the Lower Peninsula, contains reef carbonate deposits. The Niagara contains very little clastic material. The deposits indicate that the environment was a shallow warm sea, far from any significant sediment source. Connections with other seas were not restricted during Niagara time.

After the Niagara, the Salina Formation was deposited. The Salina contains a great thickness of evaporite rock, including anhydrite and halite that was deposited while the inland sea was connected to other bodies of water only by narrow waterways. Evaporation in the basin caused the concentration of dissolved salts in the water to rise, resulting in the precipitation of those salts.

During the Silurian, over 3000 feet of sediment were deposited in the center of the basin, indicating subsidence of approximately that extent. Although individual reefs grew above sea level (Cercione, 1988), the area as a whole remained submerged.

The Devonian Period began with the land emergent, which resulted in an unconformity. The area was submerged prior to the Middle Devonian.

The Devonian Detroit River Group is entirely a marine deposit, consisting of carbonates and evaporites and with some shale. The Dundee Formation, and then the Traverse Group, which consist of limestones and dolomites, were deposited on top of the Detroit River Group.

In the Late Devonian, uplift in the Appalachian Region to the east created a source of clastic sediments. The dark shales of the Antrim Formation and the Mississippian Coldwater Formation indicate deposition on a deep, poorly oxygenated sea floor (Doff and Eschman, 1970).

Significant thinning of Mississippian sediments by erosion occurred at the end of Mississippian time (Fisher et al., 1988, page 376), indicating relative uplift of the Howell Anticline at that time. Much of the Michigan Basin may have been uplifted in the late Mississippian, as few rocks of this age are present in the Lower Peninsula (Dorr and Eschman, 1970, page 125). No consolidated rocks younger than Mississippian are preserved in the region of the EGT site.

During the Pleistocene Epoch, a series of glacial advances caused the bedrock surface of southwest Michigan to be scoured by ice, then covered with a varying thickness of glacial till, glaciofluvial deposits, and glacial-lake deposits.

Injection Zone Description

The injection zone must have reservoir strata with sufficient permeability, porosity, thickness, and areal extent to allow the injected fluid to be distributed through a significant volume of rock so that there is a manageable long-term increase of pressure within the injection zone. Above the injection interval, the injection zone must have strata that have relatively low vertical permeability and are continuous across the area within which the reservoir strata will be affected by injection. This overlying arrestment interval must be sufficient to prevent upward movement of wastes from the injection zone into USDWs or other formations above the injection zone. Figures 14 thru 24 of the original May 28, 1996 permit applications for the EGT #1-12 and #2-12 wells present maps of the formations that comprise the injection zone and confining zone in the vicinity of the site. These maps have been reviewed and found to be representative of local conditions.

The injection zone for the EGT Romulus facility is between approximately 3,369 and 4,468 feet below the surface at Well #2-12. It includes upper Precambrian rocks at the base and the Mt. Simon, Eau Claire, Franconia-Dresbach, Trempealeau, Glenwood, and lower Black River Formations (See Figure 1). EGT has subdivided the injection zone into an injection interval and an arrestment interval. The Mt. Simon, Eau Claire, and Franconia-Dresbach Formations at depths from 3,937 to 4,550 feet BGL will directly accept injectate from the wells and comprise the injection interval. The Trempealeau, Glenwood and Black River Formations between approximately 3,369 and 3,937 feet below the surface at Well #2-12 will prevent the waste from moving upward. These formations comprise the arrestment interval. Based on regional literature, each of these formations is known to extend far beyond the vicinity of the EGT facility.

The Mt. Simon and Eau Claire Formations are composed of sandstones interbedded with siltstone, limestone, dolomite, and shale. These formations contain a number of intervals that are capable of accepting injected waste. Based on testing reported in the land ban petition, the lower limit for porosity of rock, which seems to accept injected liquids, is 12%. The open-hole geophysical logs identified a total of 255 feet of section with porosity greater than 12%.

Overlying the injection interval will be the remainder of the Eau Claire, which demonstrates vertical permeabilities on the order of fractions of a millidarcy in the area, along with the Franconia-Dresbach, Glenwood, and Black River Formations, which have a thickness in excess of 500 feet. The Munising Group formations are expected to show several "streaks" with horizontal permeability, but nearby core demonstrates that the layered nature of the units typically have permeabilities that are only a fraction of a millidarcy. The Glenwood formation, the 5-foot thick basal member of the Black River Group, is composed of dense dolomite and has very low vertical permeability. The remainder of the Trenton and Black River Groups also has low vertical permeabilities.

The effective average permeability for the receptive intervals of the Eau Claire and Mt. Simon as a whole has been calculated by analyzing the pressure changes occurring during injection tests. A two-layer model was required in order to simulate the pressures actually recorded. The two layers are actually a summation of the effects of numerous layers, some with higher permeability and some with lower. The zones with higher permeability can be described as 33 feet in thickness with an average permeability of 400 millidarcies (md). The zone with lower permeability can be described as 190 feet thick with an average permeability of 63 md.

The arrestment interval is the portion of the injection zone above the injection interval that contains dense carbonates and shale units with relatively low permeability along with porous carbonates and sandstones. These limited intervals are pressure bleed-off units. An average permeability was assigned for the arrestment interval in the original land-ban exemption petition by calculating the harmonic average of vertical permeability measurements from core samples. That analysis concluded that the effective vertical permeability of the arrestment interval is less than 0.005 md.

Fracture logging of the three wells originally drilled by EDS indicated several sub-vertical fractures in the arrestment interval. These fractures have limited height and appear to be filled by mineral deposits, and do not compromise the integrity of the arrestment interval. Because there are no known transmissive fractures or faults in the arrestment interval, it is suitable for long-term waste containment.