# Recent Diamond Exploration in Eastern North Dakota

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**Introduction**

Over the past several years, thousands of wells have been drilled in the exploration and development of North Dakota's subsurface natural resources. Nearly all of these wells have been drilled in the western half of the state, most targeting the oil- and gas-bearing Bakken and Three Forks Formations. However, in the northeastern corner of our state, far removed from any oil and gas activity, another mineral exploration test well was recently drilled.

In August of 2010, Kennecott Exploration Company (a subsidiary of Rio Tinto) drilled and cored the 10NDV001 in Pembina County in northeastern North Dakota (fig. 1). An exploratory well, the 10NDV001 was not drilled in search of oil, gas, potash, or uranium, but was drilled in search of a geological feature called a kimberlite. While most non-geologists may be unfamiliar with kimberlites, many people are likely very familiar with the mineral resource that can occur within them . . . **diamonds!**

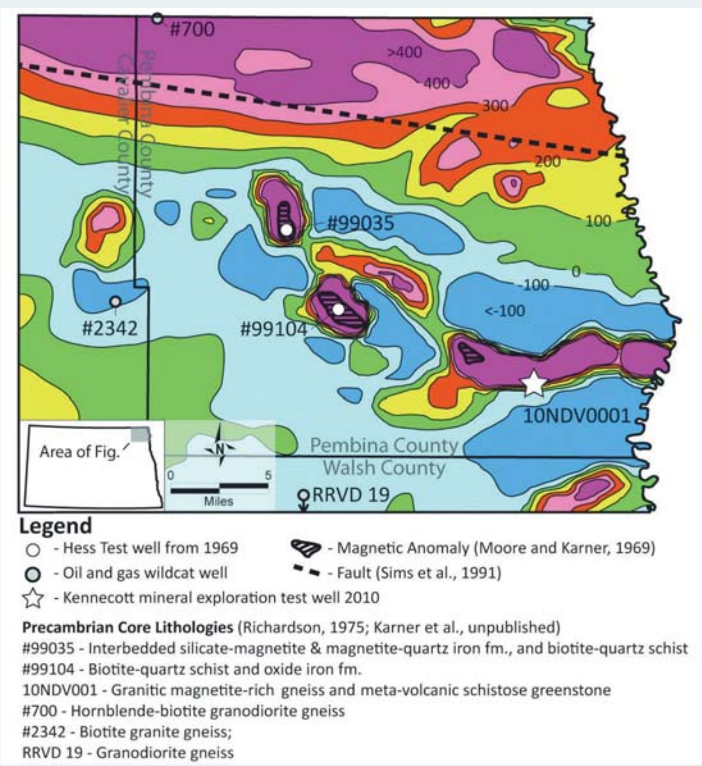


**Figure 1.** Aeromagnetic Anomaly Map of Pembina County with Precambrian well information. Aeromagnetic anomaly data was borrowed from Sweeney and Hill (2003) and was contoured in the Petra map module. Contour interval is in nanoteslas.

**Diamond Formation and Kimberlites**

While some diamonds on Earth form through tectonic plate subduction and meteorite impacts, the majority of naturally occurring diamonds form by a much different process. Most commercial gem quality diamonds form beneath older and thicker portions of Earth's continents (fig. 2) owing primarily to two factors: 1) older continental crust tends to exist at lower temperatures (colder) than newer continental crust, which causes the underlying mantle to also be colder, and 2) areas of mantle beneath thicker portions crust have higher pressures than areas beneath thinner portions of crust. This combination of old and thick continental crust creates the necessary pressure and temperature conditions in the underlying mantle needed to form diamonds.

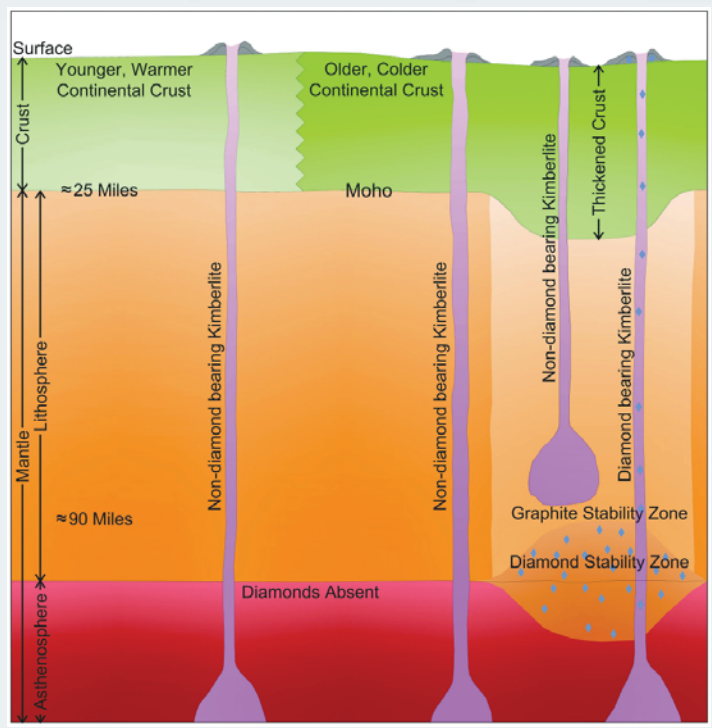


**Figure 2.** Schematic cross-sectional illustration of Earth's crust and upper mantle depicting diamond-bearing versus non-diamond-bearing kimberlitic eruptions.

Kimberlites are tube-shaped igneous features, hundreds of yards in diameter, which form through eruptions that originate very deep beneath the surface. Most volcanic eruptions consist of molten lava erupted from depths of several to tens of miles. Kimberlites, however, form through eruptions that originate at depths of over a hundred miles beneath Earth's surface (fig. 2), and can occur singly as well as in fields or clusters. During a

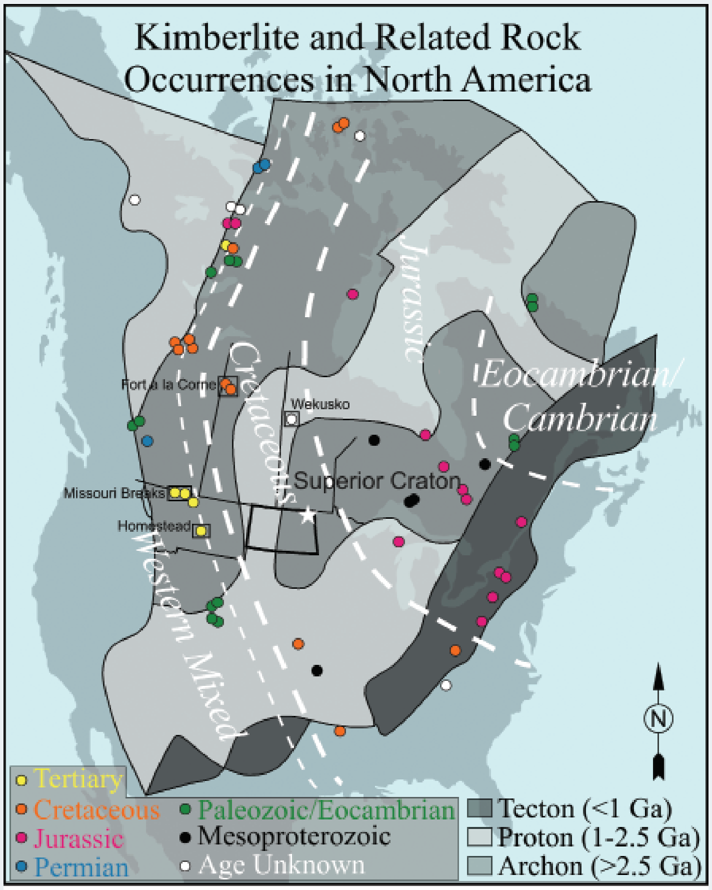


**Figure 3.** Kimberlite occurrence map of North America. Circles represent the approximate location of kimberlite and related rock occurrences. The white star represents the area of figure 1 and the location of 10NDV001. This figure is modified from Heaman et al. (2003) with additional kimberlite occurrences from Hearn (2004) and Kaszycki and Syme (2003). Coloring represents the geologic time period of eruption. The dashed white lines separate regions containing kimberlites with similar eruption ages, as interpreted by Heaman et al. (2003), which suggest that any kimberlites present in North Dakota would have erupted during the Cretaceous. Ga = billions of years ago.

**Figure 4.** Photograph of the drilling rig used to core the 10NDV001. Photograph by Kent Hollands.

kimberlitic eruption, peridotite magma (low silica, high iron and magnesium composition) from Earth's mantle erupts at or near Earth's surface, picking up numerous pieces of rock while passing through the overlying layers of lithosphere and continental crust (fig. 2). In some cases, one of these layers includes the diamond stability zone. Kimberlites can lack diamonds either because their eruption depth was above that of the diamond-bearing zone or if the eruption occurred within portions of Earth's subsurface that lack the diamond-bearing zone.

**Kennecott's Exploration Program**

Kennecott started their mineral exploration project in northeastern North Dakota/northwestern Minnesota in the early 2000s. The preliminary phase of investigation involved examining previously collected geomagnetic survey data in the project area, an area underlain by the Superior Craton (fig. 3). The Superior Craton is a piece of Earth's crust that is both old and tectonically stable, and therefore may be underlain by diamond stability zones. Initially forming around 2.7 billion years ago, the Superior Craton has not undergone any significant tectonic activity for approximately 2.4 billion years (Sims et al., 1991) and fulfills the criteria of being relatively old and cold continental crust.

After a preliminary evaluation of the region, Kennecott conducted an airborne magnetic survey of Walsh and Pembina counties in North Dakota, along with Kittson County in Minnesota. With their newly acquired magnetic survey data, geologists with Kennecott identified several potential locations to drill mineral exploration test wells. Typically, Kennecott mineral exploration programs involve field work prior to drilling. However, possibly due to the glacial till and other unconsolidated sediments covering the bedrock, Kennecott completed minimal field work in the project area. For the final phase of the project, Kennecott decided to drill the best-looking location identified by their magnetic data.

**Drilling of 10NDV001**

Kennecott's selected drill site, located in Section 3, T159N, R52W in southeastern Pembina County (fig. 1) was surveyed in early June of 2010. The drill site location was later adjusted prior to drilling, moving about 500 feet to the west-southwest in order

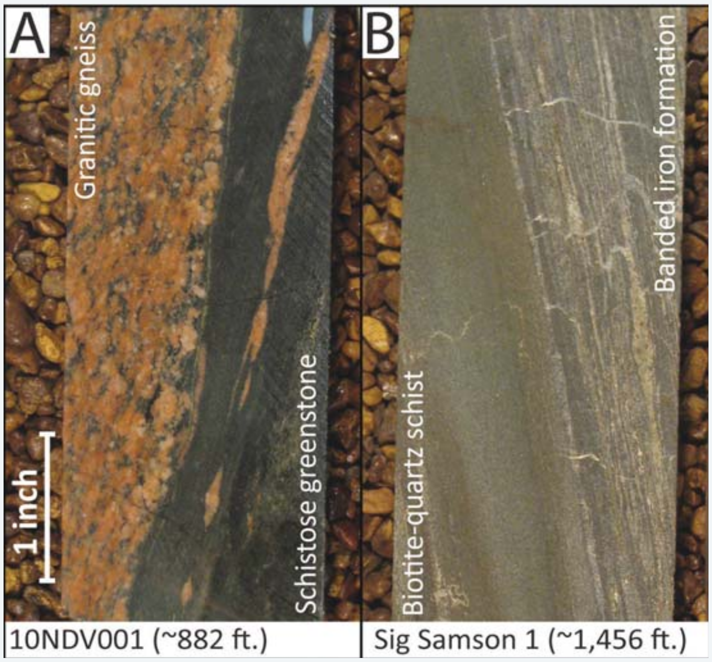


**Figure 5.** Photographs of Precambrian core samples from magnetic anomalies test wells in Pembina County, North Dakota. A) Precambrian core sample from Kennecott's 10NDV001, and B) Precambrian core sample from Amerada-Hess Corporation's Sig Sampson 1. Well locations for the core samples are shown in figure 1. Note the significant difference in rock types.

to better intersect the center of the magnetic anomaly being targeted. Later that summer, on August 17th, 2010, Kennecott spudded (began drilling) the 10NDV001.

Drilling operations began with a sonic drilling rig to drill the first 50 ft. After setting 7 5/8" casing to 50 ft., the sonic rig drilled to 300 ft., which was set with 5 ½" casing. After the second casing was set, the sonic rig was moved offsite and a different drilling rig (fig. 4) was brought in for coring purposes. The rig was run 24 hours a day, for approximately 3 days, cutting a core interval from 300 ft., (~Red River Formation top) to 999 ft. (Precambrian basement). During drilling operations, an approximately 1.5-foot-thick sandstone (Black Island Formation), with very high salt water flow rates, was encountered along the Paleozoic/Precambrian boundary. A blowout preventer, which the North Dakota Geological Survey had insisted be installed on the drill rig prior to drilling, was used to contain the saltwater flow. If a blowout preventer had not been installed, saltwater would have flowed out across the surrounding bean field and would have proved difficult to contain. After the 10NDV001 finished coring to 999 ft., the well was plugged on August 25th and the core interval collected was sent to Tamarak, MN for logging and sampling.

**Drilling Results and Future Potential**

Prior to drilling the 10NDV001, Kennecott announced on local news radio that their chances of encountering an economic ore body would be very low. Unfortunately, the 10NDV001 met such expectations and did not encounter a diamond-bearing kimberlite or another potential ore body. The well encountered about 295 ft. of glacial till and poorly lithified sediments, 409 ft. of limestone (Red River Formation), 110 ft. of green shale (Icebox Formation), about 1.5 ft. of sandstone (Black Island Formation), and 185 ft. of interlayered, magnetite-rich granitic gneiss and metavolcanic schistose greenstone (fig. 5a). The magnetite-rich granitic gneiss was noted to be fairly magnetically susceptible and may be the source of the magnetic anomaly that Kennecott identified.

Three other magnetic anomalies were previously identified in Pembina County (fig. 1) by Moore and Karner (1969) . Two of those anomalies were drilled by Amerada-Hess Petroleum Corporation in 1969, coring the Precambrian basement in search of economic ore bodies. As described by Richardson (1975), the Amerada-Hess cores found banded iron formation interbedded with biotite-quartz schist (fig. 5b). Richardson interpreted the banded iron formation as the source of the magnetic anomalies drilled by Amerada-Hess, which differs from the magnetite-rich granitic gneiss encountered by Kennecott's 10NDV001 (fig. 5).

While Kennecott's recent exploratory program did not find a kimberlite, the possibility of kimberlites existing within North Dakota remains. The entire eastern half of our state is underlain by the Superior Craton (fig. 3), providing the whole area with kimberlite potential. Both Canadian provinces along our northern border contain kimberlite fields, and Montana contains two sets of kimberlite fields, including the diamond-bearing Homestead kimberlite field that was discovered in 1999 (Hearn, 2004). Diamonds are forever, and forever is plenty of time to find diamonds, if present, in North Dakota.

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