Iowa Geological Survey
Resource Information Fact Sheet 2006-2

Our Common Ground

Iowa Department of Natural Resources

Exploring the Midcontinent Rift

Twenty years ago the farm fields of Iowa played host to an unusual group of visitors. Geologists, land agents, and seismic survey crews crisscrossed the state gathering information on the oil and natural gas potential of some of Iowa's most deeply-buried rocks, the rocks of the Midcontinent Rift System (MRS). The MRS is a failed rift, a great rip through the earth's crust, that stretches for a thousand miles from eastern Lake Superior, across the center of Iowa, and south into Kansas (Fig. 1). The rift formed about 1.1 billion years ago, and had it continued to spread, it would have formed a new ocean. But the rifting stopped as suddenly as it started, and a new sequence of events reversed the rifting process producing a unique geologic structure – one that potentially contains significant oil and gas reserves.

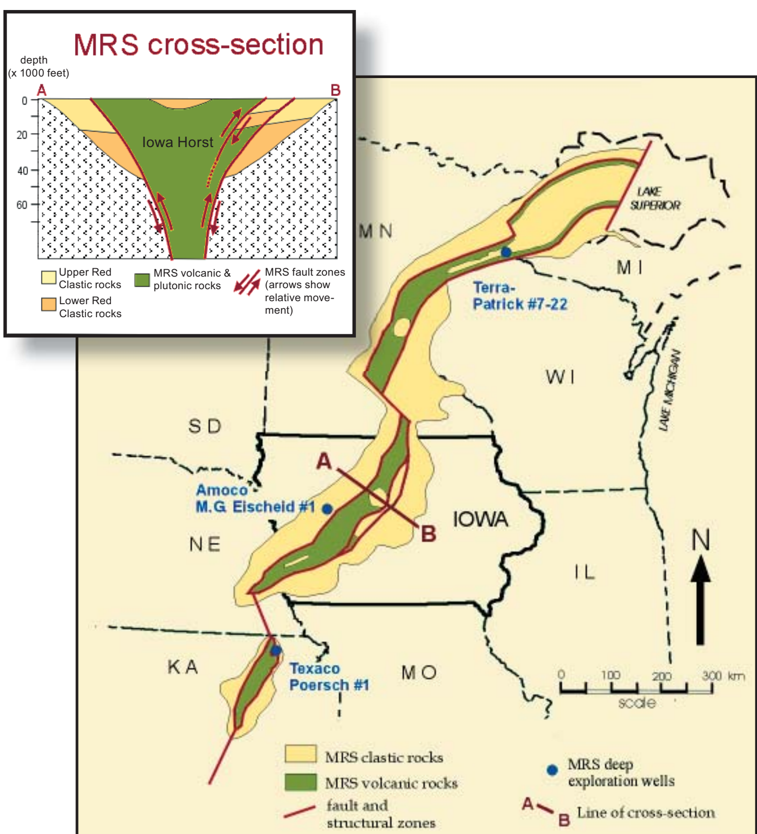


Figure 1. Location of the Midcontinent Rift System, major deep petroleum exploration wells, and cross-section in the upper left-hand corner.

Origin of the Midcontinent Rift

The Midcontinent Rift that exists today formed during two distinct stages. Stage 1 began with extensional forces stretching and pulling the crust until a rip opened across much of the continent. Rather than a single rip, the crust developed two parallel faults that bounded a series of wedge-shaped blocks along the axis of the rift. As the rift spread wider the central block slid downward, forming a graben. Dense, black basaltic lava erupted, rising from deep within the crust along the faults and flowing out onto the central block. Huge volumes of basalt erupted, its heat softening the crust and its weight causing the rift to further subside. When the volcanism stopped, the rift continued to sink and rivers carried sand, gravel, and mud into the deepening valley. The river systems evolved into a rift lake teaming with bacteria and algae, with countless

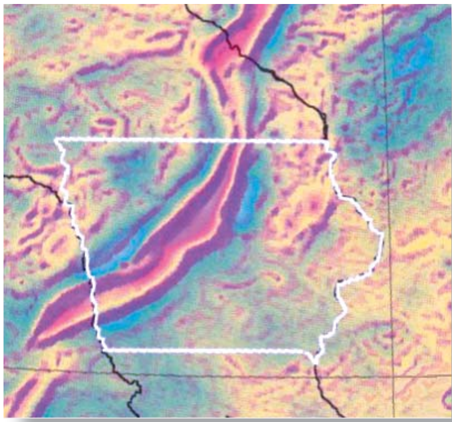


Figure 2. *Geophysical map of Iowa and surrounding region showing the Bouguer gravity anomaly. Reds and yellows indicate values higher than regional values. Greens and blues identify areas of lower values.*

generations flourishing, dying, and sinking into black, organic ooze at the lake bottom. As the lake filled in, rivers again flowed down the rift, depositing sand, gravel, and clays. The resulting suite of rocks is called the Lower Red Clastics. The organic-rich lake sediments represent potential petroleum source rocks, while the overlying coarser clastics may serve as reservoir rocks.

The second stage of rift development resulted from a shift to compressive continental stresses. Pressure on the rift from the southeast and northwest squeezed the wedge-shaped central block, pushing it upward along with overlying basalt, lake, and river sediments. As this horst continued to rise upward the clastic sediments were eroded, filling basins on the rift margins. This suite of eroded clastic rocks is called the Upper Red Clastics. Eventually almost all of the clastics were eroded off the volcanic rocks on the uplifted horst in Iowa, with only a few clastic-filled horst basins remaining. Figure 1 (inset) shows a cross-section of the Midcontinent Rift in Iowa, with the volcanic rocks of the Iowa Horst flanked by deep basins filled with Lower Red Clastic rocks deposited in the subsiding rift, which are overlain by Upper Red Clastic rocks that were eroded off the uplifting horst.

Interpreting the Rift in Iowa

The rocks of the Midcontinent Rift System are exposed at the land surface in the Lake Superior area. Volcanic rocks can be seen along the north shore in Minnesota and Ontario as well as on the west side of Michigan's Keweenaw Peninsula. The clastic rocks can be seen on Wisconsin's Bayfield Peninsula, on the east side of the Keweenaw Peninsula, and along the lake's south shore on the Upper Peninsula of Michigan. Within the clastic sequence resides the black, organic-rich Nonesuch Shale, which drips oil into a northern Michigan copper mine. In southern Minnesota, Iowa, and further south the rift rocks are buried by younger sedimentary rocks. However, the distribution of these buried rocks can be followed by their gravity (Fig. 2) and magnetic signatures. The gravity anomaly map shows the dense volcanic rocks of the MRS central horst as gravity highs (red) and the low-density clastic rocks of the flanking basins as gravity lows (blue). On this map the rift can be seen trending southward into Iowa near the center of its border with Minnesota,

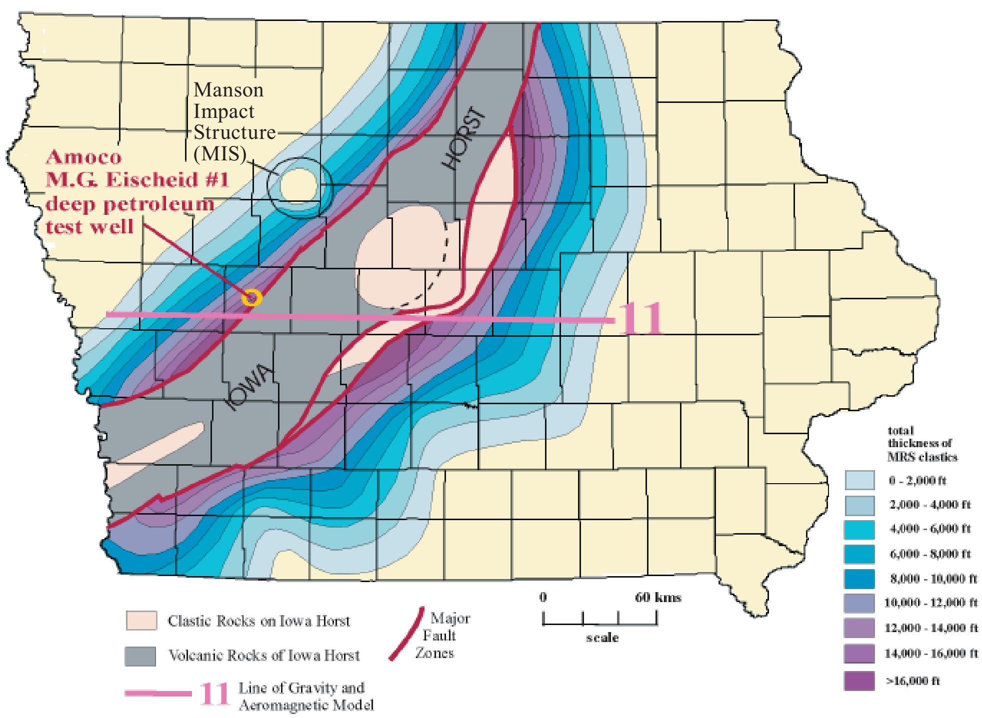


Figure 3. *Map of thickness of clastic rocks in MRS flanking basins in Iowa, produced by gravity and magnetic anomaly modeling and seismic interpretation.*

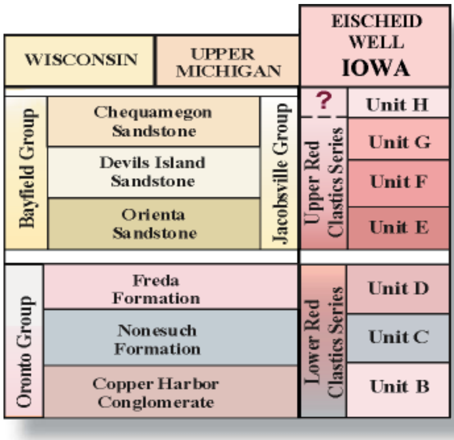


Figure 4. *Correlation of MRS units in Wisconsin and Upper Michigan with units encountered in the M.G. Eischeid #1 well in Iowa*

then curving westward and passing into Nebraska near Omaha.

To understand the MRS in Iowa, gravity and aeromagnetic anomaly data were analyzed and interpreted using 2-dimensional geophysical modeling. The model consists of a series of 2-D polygons representing various rock types, with assigned density and magnetic values. Petroleum industry seismic profiling of the rift in the 1980s was used to assist in defining the polygons, which increased the accuracy of the model. By modeling a series of 2-D profiles along the trend of the rift, a 3-D model was created, providing a close approximation of the geometry of the MRS in Iowa. Maps such as the thickness of clastic rocks in the MRS horst-flanking basins (Fig. 3) were produced using this modeling technique. This map shows that clastic-filled basins on both sides of the Iowa Horst attain depths in excess of 16,000 feet.

Testing the Interpretation – Drilling the Rift

Industry exploration for oil in the Midcontinent Rift in the 1980s led to the drilling of 3 deep petroleum test wells: the Texaco Poersch #1 in Kansas, the Amoco M.G. Eischeid #1 in Iowa, and the Terra-Patrick #1 in Wisconsin (Fig. 1). The deepest of these, Eischeid #1, reached a depth of 17,851 feet. This well, described in IGS Special Publication #2 (available at www.igsb.uiowa.edu/gsbpubs/pdf/SR-02.pdf), penetrated 14,898 feet of MRS clastic rocks. The Upper Red Clastic Sequence (Fig. 4 and 5) is dominated by feldspathic sandstones interbedded with red-brown siltstones and shales. The Lower Red Clastic Sequence also contains red-brown sandstones, siltstones, and shales, but at Eischeid #1 it contained 600 feet of gray to black shales and siltstones as well (Fig. 5). The Upper Red Clastic Sequence has been informally divided into 3 formations (Units E, F, & G) which appear to correlate with the 3 formations of the MRS Bayfield Group in Wisconsin (Fig. 4). The Lower Red Clastic Sequence is also composed of 3 formations (Units B, C, & D) which correlate to the 3 formations of the Oronto Group of Michigan. The middle formation of the Lower Red Clastics in the Eischeid well, Unit C, is dominated by gray to black shales and siltstones, like its correlative unit, the Nonesuch Formation in the middle of the Oronto Group.

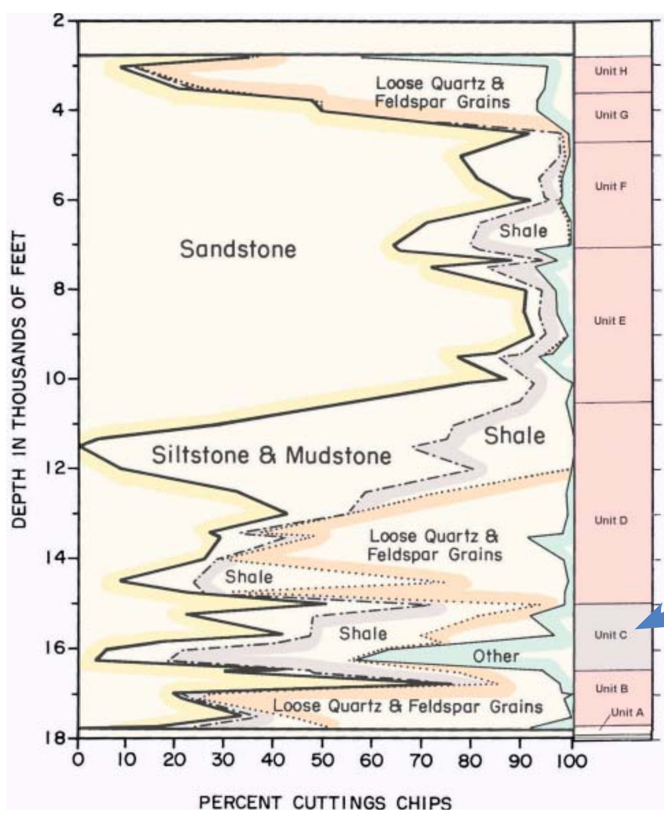
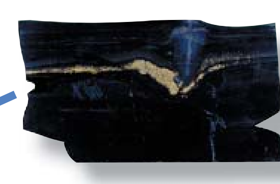


Figure 5. *(Left) Major rock lithologies penetrated by the M.G. Eischeid #1 well.*

(Below) Sample of drill core collected from Unit C (15,027 feet) during drilling of the M.G. Eischeid #1 well. The core is dominated by black shale, featuring a band of pyrite mineralization.



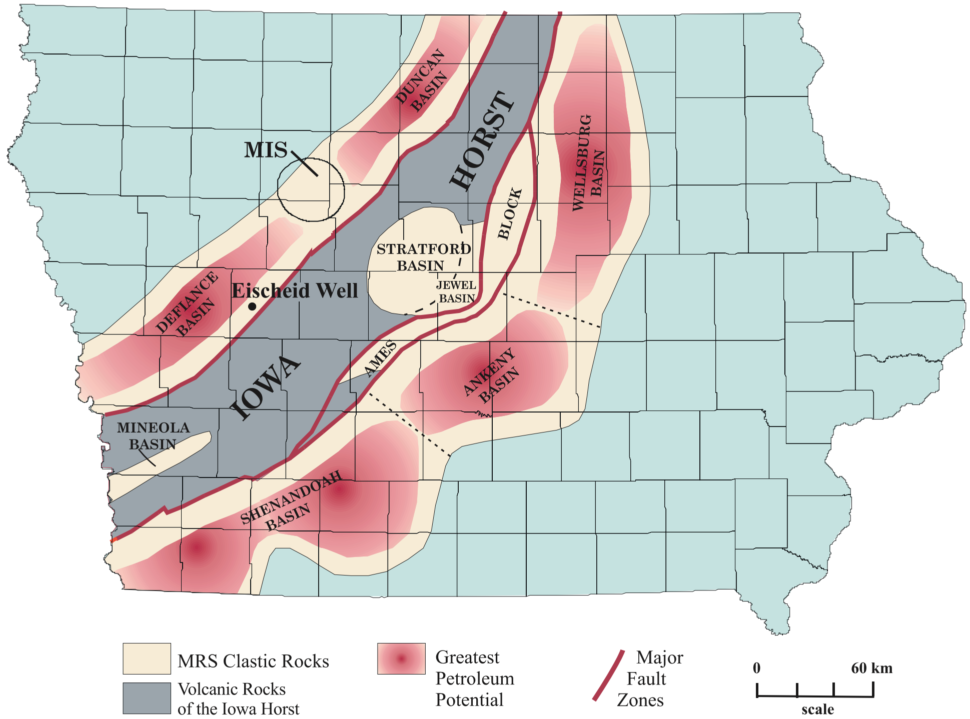


Figure 7. *Major features of the Midcontinent Rift in Iowa and identification of areas of greatest petroleum potential.*

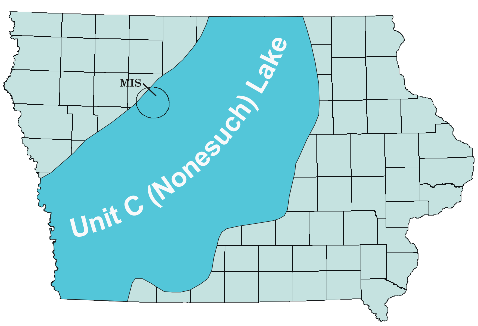


Figure 6. *Possible extent of Unit C (Nonesuch) lake in Iowa.*

Oil and Gas Potential in Iowa

The Nonesuch Formation in the Lake Superior area is composed of dark shales and siltstones, rich in organic materials, which under the right conditions have potential as an excellent petroleum source rock. Those conditions include sufficient burial depths to produce petroleum (5,000 – 20,000 feet) and a sufficient volume of organic-rich rocks to produce economic volumes of petroleum. Past interpretations had the Nonesuch Formation deposited in relatively small lakes within the subsiding graben of the early rift. The presence of 600 feet of similar Unit C rocks in the Eischeid well challenged this view, as the Eischeid well was drilled 5 miles outside of the graben. Additionally, Unit C rocks have been encountered in several wells drilled in the Manson Impact Structure (MIS) over 20 miles beyond the graben. The Nonesuch Lake must have been huge, possibly 100 miles wide and extending along most of the rift (Fig. 6), with the 600 feet of black siltstones and shales in the Eischeid well attesting to the volume of organic rich rocks that were deposited. In Iowa these rocks are currently buried beneath up to 15,000 feet of sedimentary rocks, easily sufficient for petroleum generation. These sediments also include potential reservoir rocks – thick sequences of sandstones, with highly porous and permeable strata, only weakly cemented, and identifiable as zones with abundant loose quartz and feldspar grains in Figure 5. These strata alternate with less permeable siltstones and shales that could serve as impermeable cap rocks. The key target areas for oil or gas exploration in Iowa are areas with sufficient thickness of potential reservoir rocks and of sufficient distance from the axis of the rift to reduce the effects of early high heat flow. Figure 7 identifies such targets in red.

Come explore the Rift in Iowa! For more information contact Ray Anderson at the Iowa Geological Survey.

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