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GEOTECHNICAL ISSUES FOR US 641

From Eddyville to North of Fredonia
Lyon and Caldwell Counties, Kentucky
QORE Project No. 24302831
July 19, 2004

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Wilbur Smith Associates
465 East High Street, Suite 100
Lexington, KY 40507-1938

Attention: Mr. Carl Dixon, P.E.

Reference: **Geotechnical Issues for US 641**
From Eddyville to North of Fredonia
Lyon and Caldwell Counties, Kentucky
QORE Project No. 24302831

Dear Mr. Dixon:

QORE, Inc. reviewed the eight proposed corridors for the section of US 641 from Eddyville to North of Fredonia. This report explains our understanding of the project, documents our findings, and presents our conclusions and engineering recommendations.

QORE appreciates the opportunity to be of service to you. We look forward to helping you through project completion. If you have any questions, please call.

Respectfully submitted,
QORE, Inc.

Bruce L. Hatcher, P.E.
Senior Geotechnical Engineer
Licensed KY 14527

Craig S. Lee, P.E.
Senior Engineer

24302831 GEO Report

Attachments: Index Map
Proposed Corridors (Sheets A - D)
Geology Column (2 Sheets)
Geology Explanation
Proposed Corridors Geology (Sheets A - D)

GEOTECHNICAL ISSUES FOR US 641

From Eddyville to North of Fredonia
Lyon and Caldwell Counties, Kentucky
QORE Project No. 24302831

Introduction

QORE, Inc. reviewed the proposed corridors for US 641 between Eddyville and north-northwest of Fredonia in Lyon and Caldwell Counties. The West Kentucky State Penitentiary Farm is located near the southeastern corner of the project area.

The project begins near Eddyville and heads northerly to a terminus point about 1.5 miles north-northwest of Fredonia. At present, there are eight proposed corridors (Alternates 1 through 4 and Alternates 1A through 4A). Each of the eight corridors terminates at the same point. However, there are four different beginning points. Alternates 1 and 1A begin at the Wendell H. Ford Parkway (Western Kentucky Parkway) where it crosses the Caldwell/Lyon County line. Alternates 2 and 2A begin at the intersection of US Highways 62 and 641 in the community of Fairview. Alternates 3 and 3A begin at Interstate 24 about 2 ¼ miles west of its intersection with US Highway 62. Alternates 4 and 4A begin where US Highway 62 intersects the Wendell H. Ford Parkway (Western Kentucky Parkway).

The eight corridors consist of various sections, some of which overlap with other corridors. As such, the eight corridors are color coded on the attached drawings. The following list of corridors indicates the applicable color coding for each proposed corridor

Corridor Identification

Color Coding

Alternate 1	Gold
Alternate 1A	Gold-Yellow-Green
Alternate 2	Pink-Green
Alternate 2A	Pink-Blue-Gold
Alternate 3	Green
Alternate 3A	Green-Blue-Gold
Alternate 4	Yellow-Pink-Green
Alternate 4A	Yellow-Blue-Gold

Due to the large scale of the project and the overlapping nature of the proposed corridors, four base maps (Sheets A through D) are needed to cover the project area. Please reference the attached Index Map for details of the four base maps.

General Topography

All eight proposed corridors lie within Lyon and Caldwell Counties. The proposed corridors (or corridor sections) which lie along the eastern side of the project area will be located within the Fredonia Valley. The Fredonia Valley is characterized by gently rolling hills. The majority of the Fredonia Valley is comprised of farmland, pastures, or forest. The proposed corridors (or corridor sections) which lie along the western side of the project area will be located in

moderately sloping terrain with narrow valleys. The terrain is steeper and more hilly west and directly north of Eddyville. Depending upon the selected corridor, the project could be constructed across four USGS (United States Geologic Survey) quadrangle maps. General location and topographic information about the proposed corridors across each quadrangle is listed below. Elevation ranges are within the potential construction areas only.

<u>Quadrangle</u>	<u>Location on Quadrangle</u>	<u>Elevation Ranges</u>
Fredonia	Majority	375 to 530 feet
Eddyville	Northern portion	400 to 610 feet
Grand Rivers	Northeast corner	450 to 520 feet
Princeton West	Northwest corner (barely)	570 to 620 feet

General Geology

We reviewed the geologic information along the proposed corridors from the four USGS Geologic Quadrangles. The major rock formations encountered are discussed separately in the following paragraphs.

Rosiclare Sandstone and Fredonia Limestone Members of the Saint Genevieve Limestone – The majority of the Fredonia Valley is underlain by the Rosiclare Sandstone and Fredonia Limestone Members of the Saint Genevieve Limestone. The Rosiclare Sandstone Member is comprised of 5 to 10 feet of sandstone and shale. The Fredonia Limestone member is comprised of limestone and shale. The Fredonia Limestone member is prone to sinkholes.

The Upper and Lower Members of the Saint Louis Limestone - To the west and south of the Fredonia Valley, the project area is underlain by the Upper and Lower Members of the Saint Louis Limestone. These rocks are comprised of medium to light gray limestone.

Gravel – Gravel is noted in the southwestern portion of the project area near the beginning of Alternates 3 and 3A along the north side of Interstate 24. The gravel is mostly pebbles with cobbles as large as 5 inches.

Alluvium – The valley bottoms are typically comprised of alluvium (i.e. – water transported soils). The alluvium is typically thicker along the banks of the larger streams and rivers, and less thick along the minor creeks or streams. Alluvium in this general area is comprised of varying combinations of sand, silt, clay, and gravel.

Tuscaloosa Formation - A small area of the Tuscaloosa Formation is present within the eastern edge of Alternates 1 and 1A corridors near the intersection with the Western Kentucky Parkway (Wendell H. Ford Parkway). However, it is unlikely that this formation will be encountered during construction.

The local geology changes drastically north of Fredonia as each of the eight proposed corridors crosses the Tabb Fault System within the final 3500 to 5000 feet. North of the Tabb Fault System, there are several types of bedrock encountered. These rock types are discussed briefly in the following paragraph.

The **Hardinsburg Sandstone** is comprised of sandstone and shale. As much as 2 feet of coal occurs near the middle of the formation. The **Saint Genevieve Limestone** is mapped as one

unit in the fault area. However, it is likely that the lower portion of the Fredonia Limestone Member will be encountered in this area. The **Menard Limestone** is comprised of limestone and shale. The **Palestine Sandstone** is comprised of sandstone and shale. The **Kinkaide Limestone**, **Degonia Sandstone** and **Clore Limestone** are mapped as one unit within this area. However, it is likely that the Clore Limestone will be encountered since it lies directly on top of the Palestine Sandstone. The Clore Limestone is comprised of limestone and shale. A small area of **Waltersburg Sandstone** and **Vienna Limestone** occurs west of centerline along the northwestern leg of some of the corridors. The Waltersburg Sandstone is comprised of sandstone, siltstone, and shale. The Vienna Limestone is comprised of limestone and shale.

Please reference the attached Sheets A through D, US 641 – Proposed Corridors Geology. Also, please reference the attached Geology Column drawings for descriptions of the applicable geologic units.

The local dip varies by quadrangle and generalized dips within the project areas are listed below:

<u>Quadrangle</u>	<u>Dip Direction</u>	<u>Dip (percent)</u>	<u>Dip (feet per mile)</u>
Fredonia - South of Tabb Fault System	Northeast or East	0.6-2	30-100
Fredonia - North of Tabb Fault System	Southwest	3-5	150-280
Eddyville	North	2	120
Grand Rivers	North-Northwest	1	60
Princeton West	North	2	120

Typically, groundwater flow is in the dip direction until it reaches daylight where it would then flow downhill to the valley bottoms and creeks. However, in Karst areas the groundwater system consists of underground conduits, caves, and underground streams.

Closed depressions (sinkholes), caves, and other underground indications of Karst topography are common in areas underlain by potentially soluble bedrock such as limestone and dolomite. According to a generalized Karst map of Kentucky published by the Kentucky Geological Survey, the project area is characterized as an area of high potential for Karst. The map indicates that the project area is underlain by pure limestone in which Karst is well developed. No detailed maps of Karst activity are available for this specific area.

Numerous closed depressions are noted on the Fredonia topographic and geologic quadrangle maps. It appears that they are highly concentrated within the Fredonia Valley area. A few closed depressions were noted near the northwest corner of the Eddyville topographic and geologic quadrangle maps. The closed depressions occurred at elevations ranging from 380 to 460 feet MSL, with the majority occurring in the 410 to 450 feet range. No closed depressions are noted within the project areas on the Grand Rivers or Princeton West topographic or geologic quadrangle maps.

Two major fault zones were identified on the geologic maps. One unnamed fault zone lies along the southern edge of the project area. These faults are northeast-southwest trending. The Tabb Fault System is an east-west trending series of faults less than 1 mile north of Fredonia. The Tabb Fault System is labeled on both the topographic and geologic maps (both Sheet D). It is advisable for the corridors to cross faults perpendicularly. Each of the proposed corridors crosses the faults at nearly perpendicular angles.

Review of USGS Maps for Mining Activities

We also reviewed the USGS topographic and geologic maps for each of these quadrangles looking for mine adits (openings) or other signs of mining activities.

The review of the USGS **topographic maps** for each quadrangle revealed the following data:

Fredonia Quadrangle – no adits observed, one quarry observed
Eddyville Quadrangle – no adits or quarries observed
Grand Rivers Quadrangle – no adits or quarries observed
Princeton West Quadrangle – no adits or quarries observed

The review of the USGS **geologic maps** for each quadrangle revealed the following data:

Fredonia Quadrangle – one mine shaft observed, one quarry observed
Eddyville Quadrangle – no adits or quarries observed
Grand Rivers Quadrangle – no adits or quarries observed
Princeton West Quadrangle – no adits or quarries observed

Previous Surface Mining

Based on our review of the topographic and geologic maps, no strip mining has occurred within the proposed construction area. However, there is an active rock quarry located southeast of Fredonia on the east side of US Highway 641.

We met with quarry personnel to discuss their mining activities. The quarry mines limestone in an open pit configuration. Presently, the quarry bottom is about 100 to 110 feet below the existing ground level. No deep mining is proposed in this quarry.

Previous Deep Mining

The Kentucky Department of Mines and Minerals in Frankfort, Kentucky has published public records for underground coal mining. This data is available on the internet at the web site minemaps.ky.gov. No data is available for the proposed project area.

We also contacted the Kentucky Department of Mines and Minerals in Frankfort, Kentucky to verify that coal was not present within the project area. Mr. Dan O'Canna verified that there are no records of coal mining within the applicable quadrangles. Our review of the geologic quadrangles did not reveal the presence of coal within the project area except for the possibility of coal within the Hardinsburg Sandstone. The Hardinsburg Sandstone occurs as an east-west trending band along the north side of the Tabb Fault System north of Fredonia.

There is a mine shaft symbol located north of Fredonia, along the Tabb Fault System. We have indicated this symbol on both the topographic and geologic maps (both Sheet D). We believe

that this mine shaft symbol is indicative of a fluorspar deep mine within this area. Although the mine shaft symbol is located outside of the corridor boundary, it is likely that deep mining may have occurred within the project area. According to the *Economic Geology* section of the Fredonia geology quadrangle, fluorspar mining has occurred along the Tabb Fault System. Mining occurred between the late 1890's and the 1950's; therefore, no mining maps are readily available for these areas. None of the mines in the quadrangle is now active. Lead contamination of soil and/or water is a concern due to the processing of the fluorspar ore.

Gas and Oil Wells

Gas and oil wells (active and abandoned) have been mapped based on available public records. However, this data indicates that there are no active oil or gas wells within any of the eight proposed corridors. One abandoned well is located west of Eddyville along the edge of Alternates 3 and 3A. Three abandoned wells are located near the end of the project, north of US Highway 641 and west of Kentucky Highway 902. Please reference the attached *Sheets C and D, US 641 – Proposed Corridors* for details.

Geotechnical Issues

Our field reconnaissance was confined to public right-of-ways in and around the eight proposed corridors. Because some corridors (or portions thereof) are located on private property, they were inaccessible.

Based on our visual observations of the project area and our review of available mapping, we have noted three geotechnical issues which could impact the proposed construction.

Karst activity – Numerous sinkholes were noted in the northern and eastern portions of the project area. Typically, these sinkholes lie within the Fredonia Valley. The majority of the bedrock underlying the Fredonia Valley is comprised of limestone capped with 5 to 10 feet of sandstone. However, where the sandstone cap is absent there is considerable Karst activity as evidenced by the numerous sinkholes within this area. In general, the entire Fredonia Valley is in a high risk of Karst activity area.

An existing quarry (Fredonia Quarry) is located southeast of Fredonia along the east side of the existing US Highway 641. This quarry is an open pit mining operation which is currently about 110 feet below the existing grade. Several of the proposed corridors pass near the existing quarry. Mineral rights may have been split from the surface land ownership in this area. Additionally, blasting for road cuts near the quarry may present some concern for the miner's safety.

We did not observe the four abandoned wells during our review of the project area. Again, oil and gas rights may have been split from the surface land ownership in this area. Since there are no active wells within the project area, we do not believe that this will be a major issue for the project. However, future wells present constructability (blasting, etc.) and monetary issues.

An abandoned mine shaft was observed on the geologic map north of Fredonia. We believe that this mine shaft is a remnant of fluorspar mining activities in the general vicinity. Although the mine shaft is not located within the proposed corridors, there could be underground mining located within the proposed corridors. During the processing of fluorspar, the generation of lead is a byproduct. As such, there is a likelihood of soil or water contamination due to the processing of the fluorspar.

Conclusions

From a geotechnical and constructability standpoint, we believe that the selected corridor should avoid certain problem areas or potential geotechnical problems discussed above. The project faces constructability issues (i.e. – sinkholes) which are inherent to the local terrain. These issues cannot be eliminated; however, sound engineering solutions are available to address them.

We believe that the most favorable corridor should avoid construction along the existing US Highway 641 and the railroad track north of Fairview. Additionally, we believe that the most favorable corridors should avoid closed depressions (sinkholes) by proper alignment selection. From a constructability standpoint, the most favorable corridors should be in the flatter terrain to reduce the amount of cutting and filling required. Additionally, shallower cuts and fills lessen the likelihood of cut or fill slope instability problems.

Based on our evaluation of the eight proposed corridors, we have listed them in order from most desired to least desired. Portions of each route are located within Karst areas. Remediation of Karst areas can quickly become expensive; therefore, it is best to avoid areas underlain by Karst activity. In general, the ranking of the following corridors also ranks the likelihood of encountering Karst activity. The ranking of the following corridors also ranks the amount of overlap of the existing US Highway 641. Houses and numerous underground utilities are located along this existing highway, both of which will greatly impact the constructability and cost of the project.

We have ranked the eight corridors and listed our major comments for each of the proposed corridors.

Alternate 3 (Green) – This route is least likely to encounter Karst terrain. It includes more hilly terrain and is generally longer than the following corridors. The area to the west of Eddyville appears to be more populated than other rural areas. The corridor does not involve the existing railroad track or any portion of the existing US 641.

Alternate 4 (Yellow-Pink-Green) – This route includes some hilly terrain in the yellow section and lies within sparsely populated areas. The corridor does not involve the existing railroad track; however, it will cross the existing US 641 at one location.

Alternate 2 (Pink-Green) - This route involves a major portion of the existing US Highway 641 and a railroad crossing (i.e. – bridge) just north of Fairview. However, a large portion of this route avoids probable Karst areas.

The following routes involve the gold corridor (which is the highest probability for Karst activity), although to different degrees.

Alternate 4A (Yellow-Blue-Gold) – This route involves a minor portion of the existing US Highway 641. The corridor does not involve the existing railroad track.

Alternate 3A (Green-Blue-Gold) - This route involves a significant portion of the existing US Highway 641. The corridor does not involve the existing railroad track.

Alternate 2A (Pink-Blue-Gold) - This route involves a major portion of the existing US Highway 641 and a railroad crossing (i.e. – bridge) just north of Fairview.

Alternate 1A (Gold-Yellow-Green) – This route will cross the existing US 641 at one location. The corridor does not involve the existing railroad track. This route travels through rolling hills and sparsely populated areas.

Alternate 1 (Gold) – This route will impact the existing US 641 at one location, near the Fredonia Quarry. The corridor does not involve the existing railroad track. This route travels through rolling hills and sparsely populated areas.

Recommendations

The following general recommendations are applicable to the selected corridor:

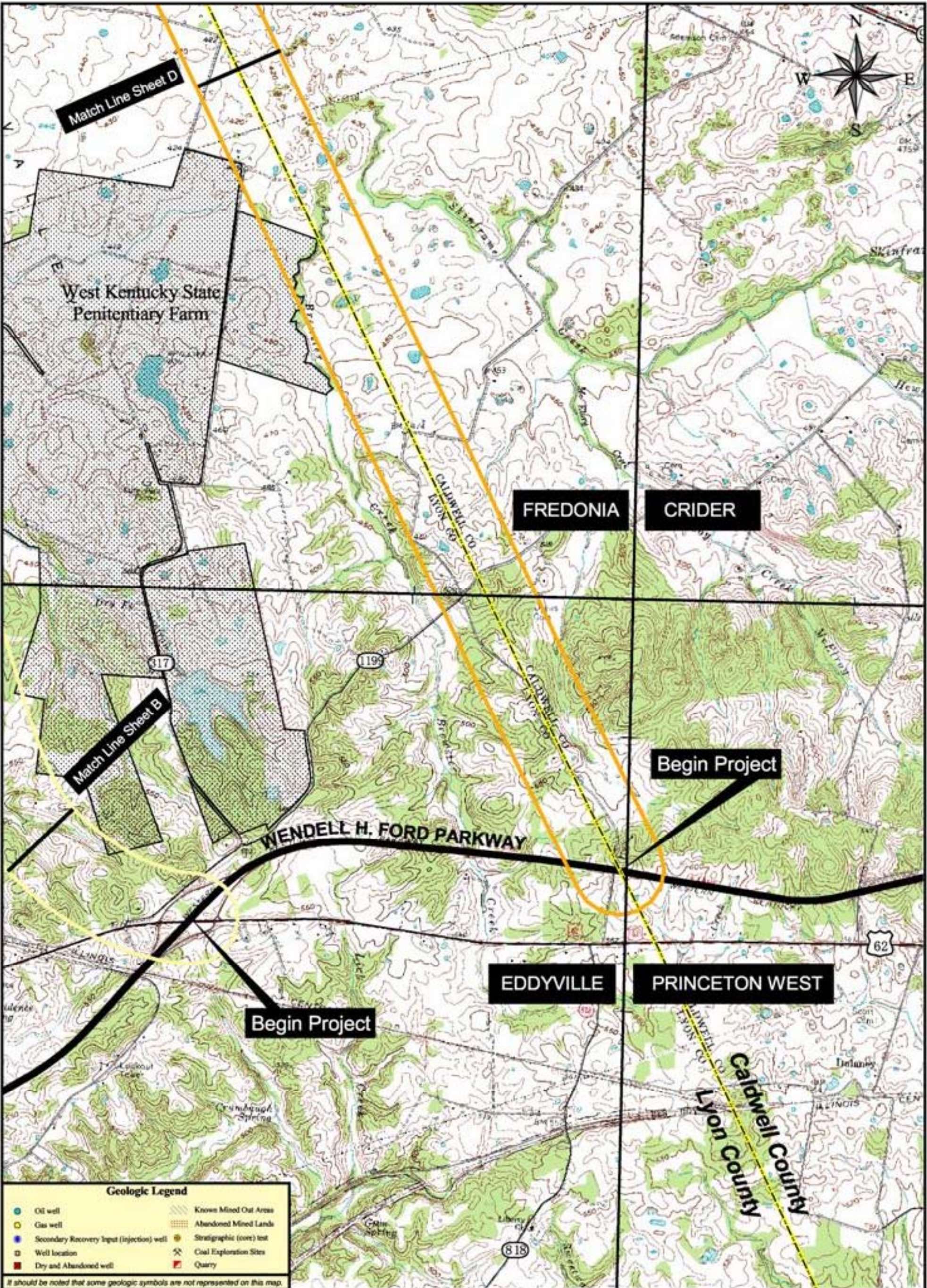
1. We expect that the cut soils will be used as fill material for this project. We also expect some rock excavation in deep cut areas. Based on the local geology, we anticipate that the soil will be low to high plasticity mixtures of silt and clay. Chert fragments will also be likely. We expect the rock from deep excavations to consist of limestone, shale, or sandstone. Soil or shot rock fill should be placed according to requirements as specified in the Kentucky Transportation Cabinet, Department of Highways, Standard Specifications for Road and Bridge Construction (latest edition).
2. Shrink/swell of newly placed fill should not be of significant concern in most areas. Newly placed fill will need to be placed with proper moisture control and compactive effort. However, consolidation of soft, alluvial soils near the valley bottoms may present some settlement concerns for embankments or for box culverts or other drainage structures. Undercutting and stabilization of soft/wet alluvial soils will likely be required when the roadway crosses alluvial areas.
3. We expect that the majority of the cutting and filling of the proposed corridor will be in soil. Therefore, we expect the majority of the cut and fill slopes to be in soil. For preliminary planning purposes only, expect 2.5H:1V (horizontal to vertical) cut and/or fill slopes. Obviously, no geotechnical work has been performed for this project. Shear strength testing of residual and compacted fill soils will be required so that specific cut and fill slope recommendations can be presented. Rock toe buttresses may be required at the toe of fill slopes in deep alluvial soil areas.
4. Depending upon the final selected grades, we expect a few cut slopes in rock. Cut slopes in massive, durable sandstone or limestone are typically stable on cut slope angles greater than ¼H:1V. Cut slopes in durable shale, poor limestone, or fractured sandstone are typically less stable and require cut slope angles at ½H:1V. Cut slopes in non-durable shale will require even flatter cut slopes – typically flatter than ½H:1V. Pre-splitting will likely be required below the rock disintegration zone (RDZ). An overburden bench and flattened cuts slopes will be required above the RDZ. Obviously, no geotechnical work has been performed for this project. Rock coring and a geologic evaluation will be required before specific cut slope recommendations can be presented.
5. Groundwater seeps or springs should be expected in down-dip cut areas, especially those cuts that intersect the soil/rock interface. Special construction considerations will likely be

required to collect and pipe groundwater in these areas if significant groundwater flows are anticipated or encountered.

6. We expect that low to high plasticity soil will be used for the majority of the roadway subgrade. Chemical stabilization of the soil subgrade should be expected for this project. The roadway subgrade could be constructed with durable rock if a more stable road base is desired. Depending upon the final selected grades, some shot rock fill may be available as fill material. The local geology suggests that there may be some durable limestone or sandstone available within certain portions of the proposed corridor; however, we doubt that there will be sufficient volume to provide a durable rock roadbed without importing additional material.

7. We expect box culverts (or other minor structures) can be founded on shallow foundations bearing on either stiff soil or rock. We expect bridge foundations will need to bear on rock, either shallow foundations on rock or through driven steel piling or drilled shafts. The presence of Karst activity will complicate the installation of rock bearing foundations. Some modifications of designed foundations are anticipated if pinnacled rock and/or voids are detected in the rock beneath the foundations. In addition, large chert boulders can be present in the soil mass that can deflect driven piles. A detailed geotechnical exploration is warranted in Karst areas to assess the foundation bearing conditions.

8. The project site is located in western Kentucky about 100 miles east of the New Madrid Fault Zone. Seismic loads are presented in the Kentucky Building Code (2002 Edition), Table 1608.2, page 232 for Caldwell County and page 233 for Lyon County. In general, the project area is located in a seismic zone which indicates moderate to severe damage to structures during large earthquake events.



Geologic Legend

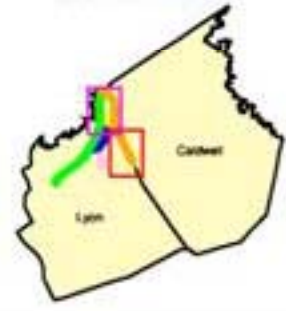
Oil well	Known Mined Out Areas
Gas well	Abandoned Mined Lands
Secondary Recovery Input (Injection) well	Stratigraphic (core) test
Well location	Coal Exploration Sites
Dry and Abandoned well	Quarry

It should be noted that some geologic symbols are not represented on this map.

LEGEND
(Corridors oriented south to north)

- ALT. 1	- ALT. 3
- ALT. 1A	- ALT. 3A
- ALT. 2	- ALT. 4
- ALT. 2A	- ALT. 4A

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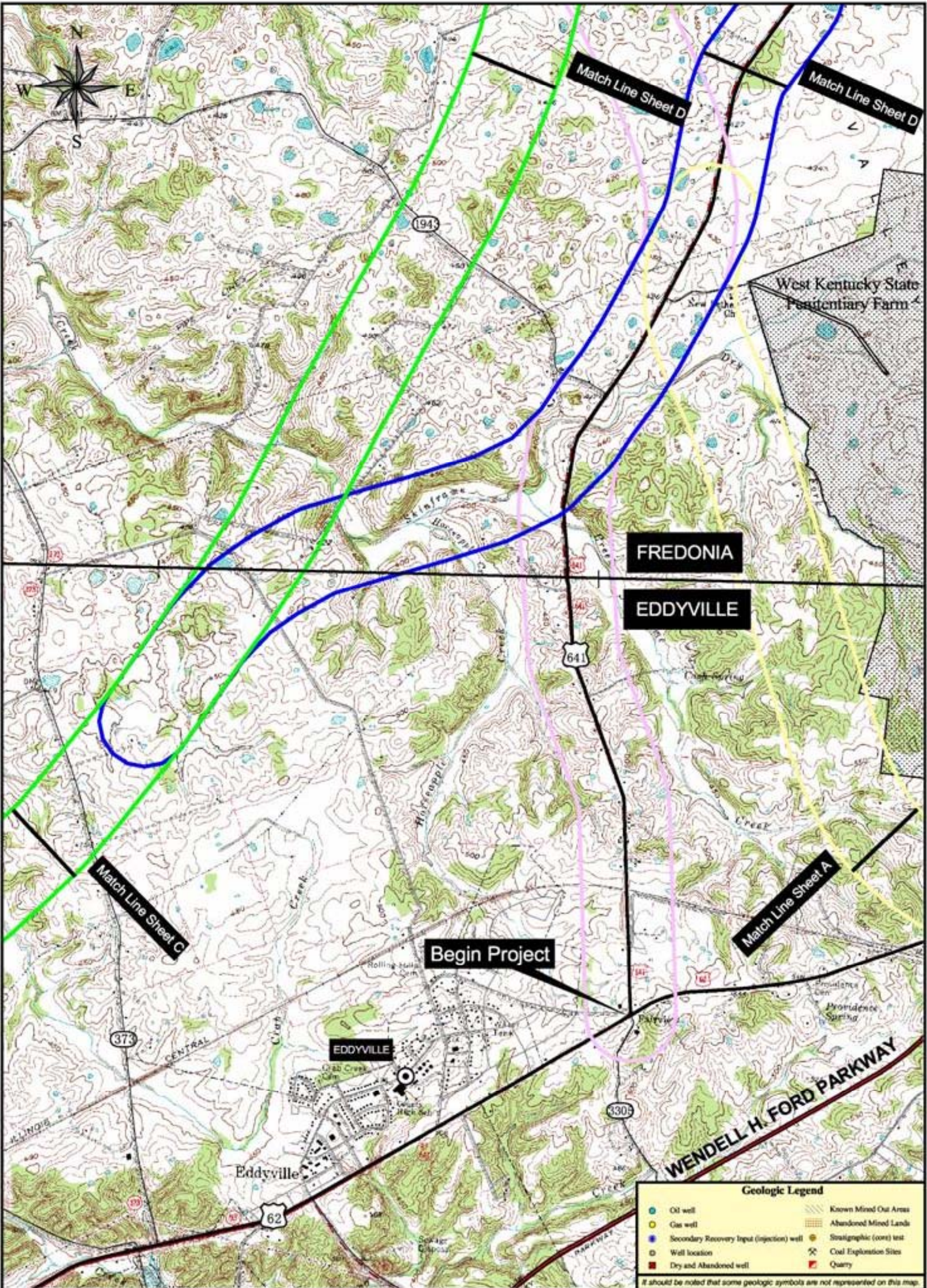


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US 641 - Proposed Corridors
(Eddyville to Fredonia)

Sheet A

Corridor Study
Lyon and Caldwell Counties



Geologic Legend

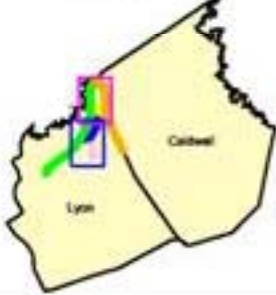
Oil well	Known Mined Out Areas
Gas well	Abandoned Mined Lands
Secondary Recovery Input (injection) well	Stratigraphic (core) test
Well location	Coal Exploration Sites
Dry and Abandoned well	Quarry

It should be noted that some geologic symbols are not represented on this map.

LEGEND
(Corridors oriented south to north)

- | | |
|-----------|-----------|
| - ALT. 1 | - ALT. 3 |
| - ALT. 1A | - ALT. 3A |
| - ALT. 2 | - ALT. 4 |
| - ALT. 2A | - ALT. 4A |

SCALE: 1" = 2000'

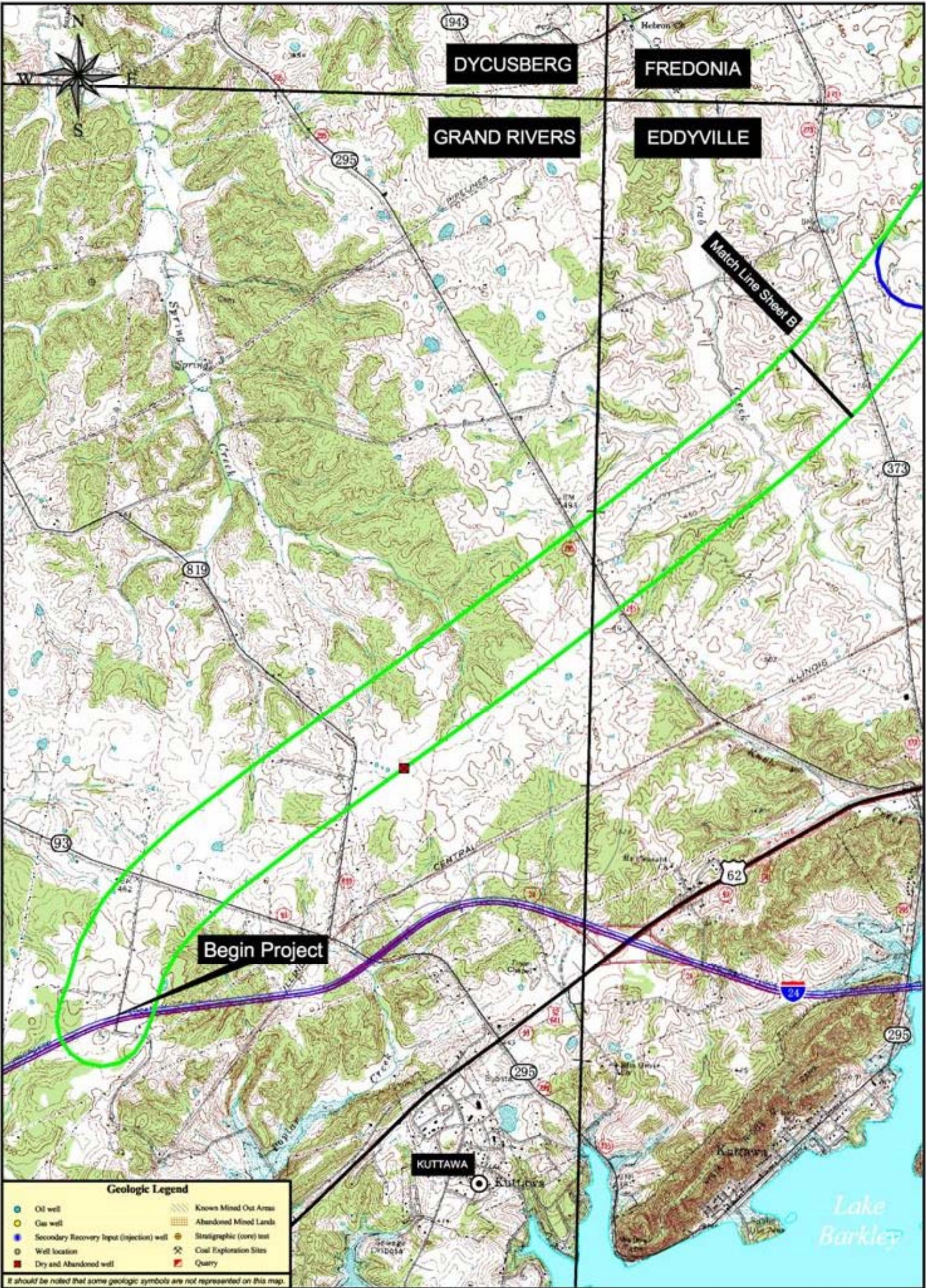


US 641 - Proposed Corridors
(Eddyville to Fredonia)

Sheet B

Corridor Study
Lyon and Caldwell Counties

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QORE PROJECT # 2400351



LEGEND
(Corridors oriented south to north)

- ALT. 1	- ALT. 3
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- ALT. 2	- ALT. 4
- ALT. 2A	- ALT. 4A

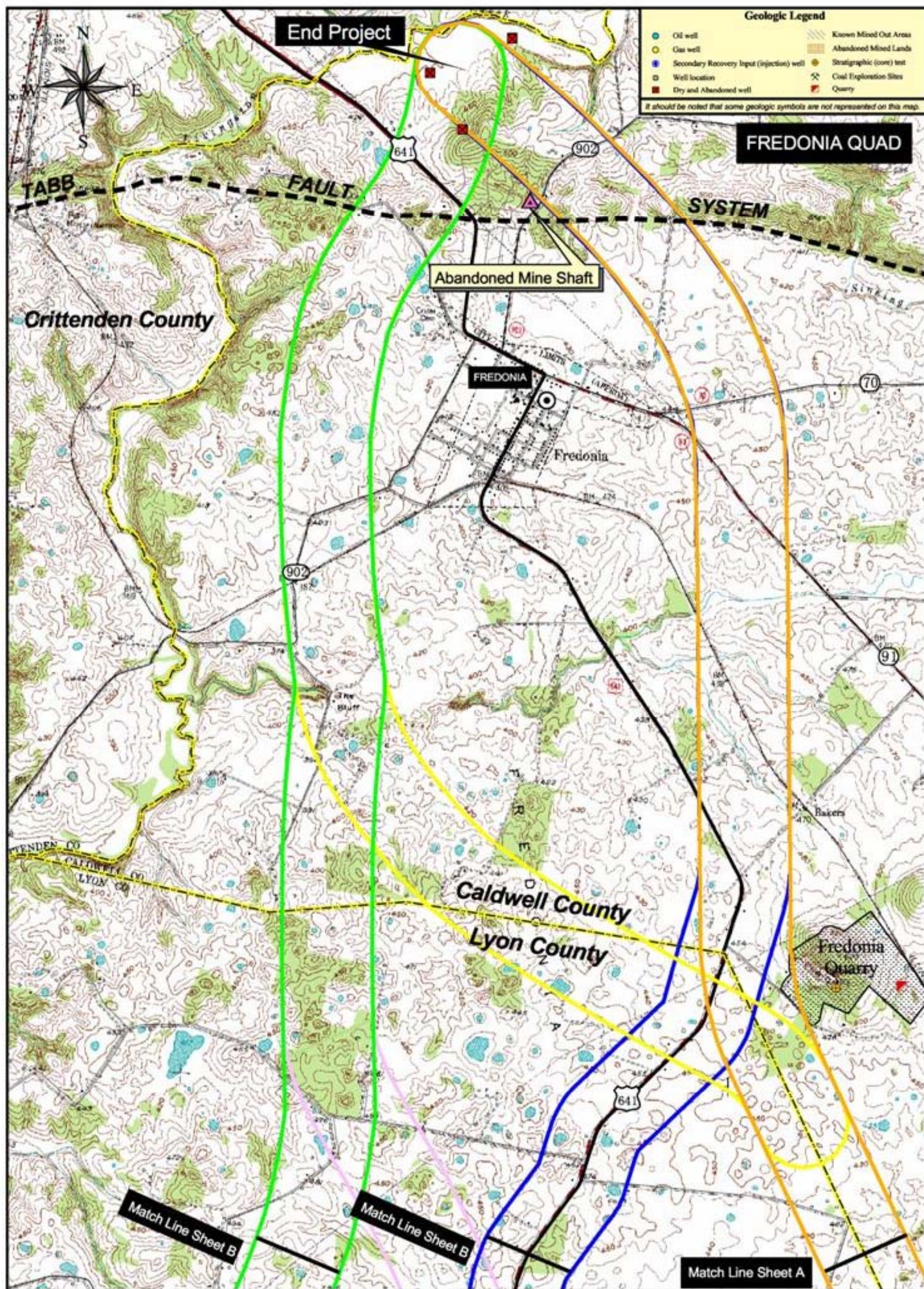
SCALE: 1" = 2000'

US 641 - Proposed Corridors
(Eddyville to Fredonia)

Sheet C

Corridor Study
Lyon and Caldwell Counties

QORE
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QORE PROJECT # 24000351



Geologic Legend

Oil well	Known Mined Out Areas
Gas well	Abandoned Mined Lands
Secondary Recovery Input (injection) well	Stratigraphic (core) test
Well location	Coal Exploration Sites
Dry and Abandoned well	Quarry

It should be noted that some geologic symbols are not represented on this map.

FREDONIA QUAD

Match Line Sheet B

Match Line Sheet B

Match Line Sheet A

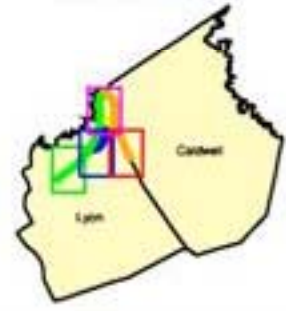
LEGEND
(Corridors oriented south to north)

SCALE: 1" = 2000'

US 641 - Proposed Corridors
(Eddyville to Fredonia)

Sheet D

- | | |
|-----------|-----------|
| - ALT. 1 | - ALT. 3 |
| - ALT. 1A | - ALT. 3A |
| - ALT. 2 | - ALT. 4 |
| - ALT. 2A | - ALT. 4A |



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Corridor Study
Lyon and Caldwell Counties

SYSTEM	SERIES	FORMATION AND MEMBER	LITHOLOGY	THICKNESS, IN FEET	DESCRIPTION
QUATERNARY	Recent	Alluvium		0-10	Clay, silt, sand, gravel, and chert rubble.
	Pleistocene	Loess		0-5	Silt and clay; yellowish-brown, wind-deposited; once blanketed entire area, partially removed by erosion, now remains principally on hilltops and gentle slopes. Not mapped.
PENNSYLVANIAN	Lower Pennsylvanian	Caseyville Formation		40+	Sandstone, very light gray and light-brown to reddish-brown; locally heavily iron stained; fine to medium grained, well sorted, generally clean and porous. Locally contains light-gray clay flakes and blebs, firm to friable, thick to thin bedded. Thinner beds generally ripple marked and more firmly cemented. Impressions of bark of scale tree <i>Lepidodendron</i> locally abundant. Probably some gray shale interbedded. Poorly exposed.
		Upper member		0-40	
		Middle member		0-40	Shale, siltstone, and sandstone: Shale, medium- to dark-gray, variably sandy or silty; locally contains small siderite nodules, especially near base of unit. Siltstone, very light gray; 1- to 2-inch irregular beds, some of which contain abundant impressions of the large horsetail rush <i>Calamites</i> ; occurs locally in units as much as 15 feet thick. Sandstone, light-brown to light-gray, very fine grained, very thin bedded, ripple-marked; interbedded and intergraded with shale. Poorly exposed. Unconformity at base.
				40-50	
		Lower member		40	Limestone, medium- to light-gray, very coarse to fine-grained; consists of calcarenite, composed largely of crinoid fragments, interbedded with and intergrading to microgranular limestone with sparse fossil debris. Generally contains sparse layers of flattened nodules of very dark gray chert as much as 6 inches thick. Locally removed by pre-Caseyville erosion. Well exposed in two places on north side of Moore Hill.
				35-40	
		Degonia Sandstone		30	Limestone, dolomitic limestone, dolomite, and shale: Limestone, medium- to dark-gray, microgranular, locally argillaceous or sandy. Dolomitic limestone and dolomite, very light gray, very finely granular. Interbedded shale, medium- to dark-gray. Poorly exposed.
		Clore Limestone		90-100	Sandstone and shale: Sandstone, light-gray to tan, very fine to fine-grained, well sorted, very thinly crossbedded; and sandstone, brown, very fine to medium-grained, argillaceous; contains abundant shale partings and clay pebbles, locally heavily iron stained. Shale, medium- to dark-gray, interbedded. Poorly exposed.
					Limestone, medium- to dark-gray, microgranular, with sparse to abundant fossil fragments. Partly argillaceous or with shaly partings. Brachiopods and gastropods locally abundant. Unit contains interbeds of calcarenite, medium- to dark-gray, fine- to very coarse grained, well sorted and clean to poorly sorted and argillaceous. Poorly exposed.
		Palestine Sandstone		50-60	Sandstone, siltstone, and shale: Sandstone, dark-greenish-gray, very fine grained, argillaceous, hard; and light-greenish-gray, very fine to fine-grained. Siltstone, greenish-gray; has closely spaced shaly partings. Shale, greenish-gray, interbedded; locally sandy, near base slightly calcareous. Unit poorly exposed.
		Menard Limestone		105-120	Limestone and shale: Limestone, medium- to dark-gray, microgranular; some coarse-grained calcarenite near base; some sandy beds, especially near base and top, some other beds dolomitic or argillaceous. Contains sparse crinoidal and other fossil fragments; brachiopods, as much as 1½ inches wide, irregularly distributed, locally abundant in thin layers. Shale, medium- to greenish-gray, partly calcareous. Scattered exposures of lower half of formation in north-central part of quadrangle; upper half poorly exposed.
					Sandstone and shale: Sandstone, light-gray, yellowish-gray, grayish-orange, or light-brown, very fine to fine-grained, partly silty, quartzose, porous, thinly crossbedded to thick-bedded, generally with shaly partings. In part, clean sandstone grades laterally to shaly sandstone and sandy shale. Shale, dark-gray to greenish-gray, generally sandy and very silty. Sandstone outcrops fairly numerous.
Chester		Waltersburg Sandstone		20-40	Limestone and shale: Limestone, medium- to dark-gray, some brownish-gray; microgranular to fine grained with sparse to abundant fossil fragments. Some limestone argillaceous or shaly, locally dolomitic, bedding thin and irregular to thick and even. Locally contains abundant brachiopods, as much as 1½ inches wide, and abundant gastropods. Small chert nodules rare. Beds of medium- to very coarse grained calcarenite composed of fossil fragments or oolites, commonly with many grains stained orange brown, cemented by microcrystalline or clear calcite, occur locally near top of formation. Outcrops fairly numerous. Shale, medium- to dark-gray, partly fossiliferous or calcareous, interbedded.
		Vienna Limestone		20	Sandstone, siltstone, and shale: Sandstone and siltstone, greenish-gray to light-brown, very fine grained, argillaceous, very hard to firm, slightly carbonaceous or calcareous locally; bedding is generally very thin and irregular with abundant closely spaced wispy shaly partings; bedding surfaces mostly rough and hackly, locally smooth. Some beds, especially harder ones, weather into small rhombohedron-like blocks. Shale, dark-gray, fissile, locally sandy and very silty. Small siderite nodules rare.
		Tar Springs Sandstone		90-120	Limestone and shale: Limestone, medium-gray, some light-gray and brownish-gray; consists of medium- to very coarse grained crinoidal calcarenite cemented with clear calcite, interbedded with microcrystalline limestone containing sparse to common fossil fragments. Chert common as thin irregular nodules or rounded nodular layers as much as 4 inches thick. Shale, dark-gray, fissile, mainly calcareous, fossiliferous. Unit weathers to reddish-brown clay generally containing abundant angular blocks of crinoidal chert.
		Glen Dean Limestone		40-50	Sandstone, shale, and siltstone: Sandstone, very light gray, grayish-orange, and dusky-yellow, mostly very fine grained, partly fine, generally quartzose, locally argillaceous. Beds 2 inches to a foot thick; many shaly partings; laminae, cross-laminae, and ripple marks locally abundant. Shale, medium- to dark-gray, commonly with green or olive tint, noncalcareous; commonly includes laminae and thin beds of sandstone and siltstone and locally includes nodules and layers of brown-weathering siderite. Siltstone, medium-gray; locally replaces sandstone in middle of formation. Sandstone at base commonly crops out.
					Limestone and shale: Limestone (calcarenite), medium-dark- to medium-light-gray, mostly fine- to coarse-grained; includes a little microgranular limestone; shaly in part; fossiliferous. Shale, medium- to dark-gray, locally with green tint, mainly calcareous; commonly inter-layered with limestone. Outcrops rare.
		Hardinsburg Sandstone		130-150	Sandstone and shale: Sandstone, mostly very light to light-gray, very fine to fine-grained, quartzose. Beds thick near base, thin to medium above; crossbeds common. In upper part of formation, much sandstone is greenish gray, partly silty, somewhat micaceous, with many shaly, micaceous partings; laminae and cross-laminae locally prominent. Shale, medium- to dark-gray, partly with green tint, locally reddish-gray near top; commonly includes laminae and lenses of sandstone and siltstone; partly calcareous at top. As much as 2 feet of coal locally near middle of formation; thinner beds rare at other levels. Lower sandstone commonly crops out. Base of formation slightly disconformable.
		Golconda Formation		100-140	Shale, limestone, siltstone, and sandstone: Shale, medium- to dark-gray, partly with green tint, locally reddish-gray near middle and top, partly silty, partly calcareous; some siderite nodules. Limestone, medium- to medium-light-gray, very fine to coarse-grained, mostly calcarenite, partly shaly; some oolitic limestone near middle and top; locally fossiliferous; commonly interbedded with shale. Medium-dark- to light-gray siltstone and silt shale and light-gray very fine grained sandstone form evidently discontinuous layers as thick as 25 feet near middle of formation. Outcrops rare. Locally thinned by shearing near faults.
		Cypress Sandstone		90-120	Sandstone, shale, and siltstone: Sandstone, very light to light-gray and grayish-orange; mostly very fine to fine-grained, partly medium-grained near base; quartzose; locally calcareous. Beds mostly medium to thick. Shale, medium-gray to black, partly with green tint, noncalcareous; forms thin partings and beds in upper half of formation. Interval near middle of formation consists of partly sandy shale, siltstone, mudstone, silty and muddy sandstone, and discontinuous coal beds. Coal generally 1 to 2 feet thick, rarely as thick as 4 feet. Outcrops uncommon except in lower sandstone.



EXPLANATION



ECONOMIC GEOLOGY

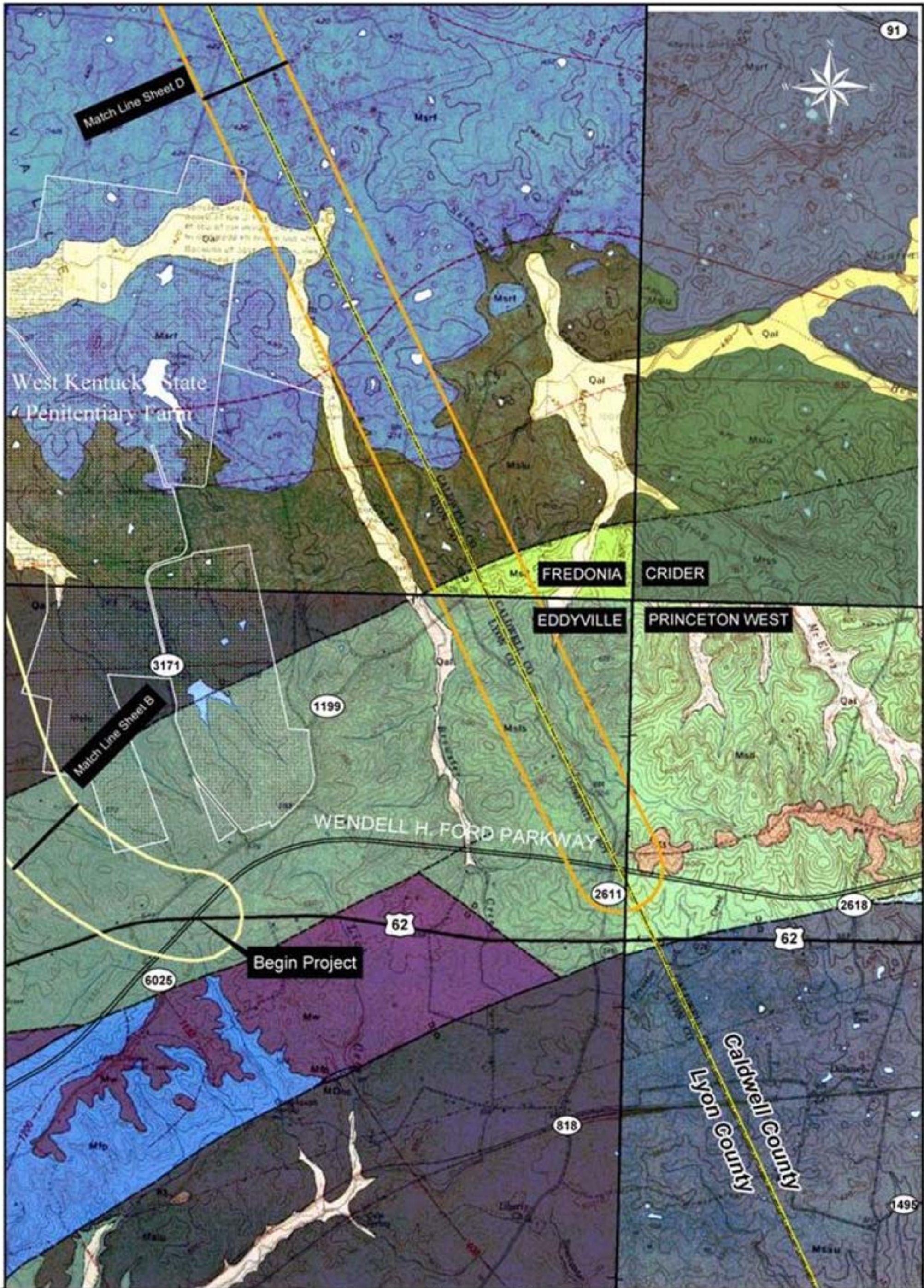
This quadrangle includes part of the southern edge of the Western Kentucky fluorspar mining district. The mines along the Tabb Fault system west of Livingston Creek were among the most productive fluorspar mines in Kentucky. Between the late 1890's and the 1950's, these mines produced several hundred thousand tons of crude ore. Fluorite, the principal ore mineral, is associated with considerable sphalerite, galena, and barite, but fluorite only was recovered by the milling processes used during much of the mining. Most of the barite occurs in the weathered part of ore deposits. Open pits in weathered material produced both barite and fluorite in the Pygmy mine area, southeast of the town of Mexico, from the 1950's until 1964. None of the mines in the quadrangle is now active.

Fault zones, generally much more complex than can be shown on this map, contain most of the ore deposits. Most large deposits have been found where the wall rock consists of the St. Louis and Ste. Genevieve Limestones or lower Chester limestone units.

The Fredonia Valley quarry, in the east central part of the quadrangle, produces high calcium limestone, agricultural limestone, and crushed limestone aggregate from the middle of the Fredonia Limestone Member of the Ste. Genevieve Limestone. Stokley and McFarlan (1952) report two limestone units in this quarry 30 to 36 feet thick that average over 97 percent calcium carbonate. Limestone with similar high calcium carbonate content may occur in this stratigraphic interval to the east-northeast of this quarry along the west side of Nelson Hill and at the northern edge of the quadrangle near Clement Creek.

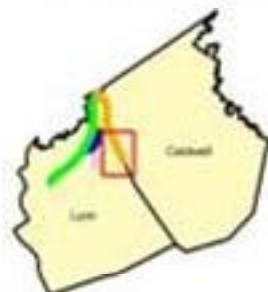
Much of the Palestine Sandstone tends to break into flat-surfaced slabs, 1 to 6 inches thick. It has been quarried northeast of Mexico for local construction of houses.





LEGEND (Corridors oriented south to north)

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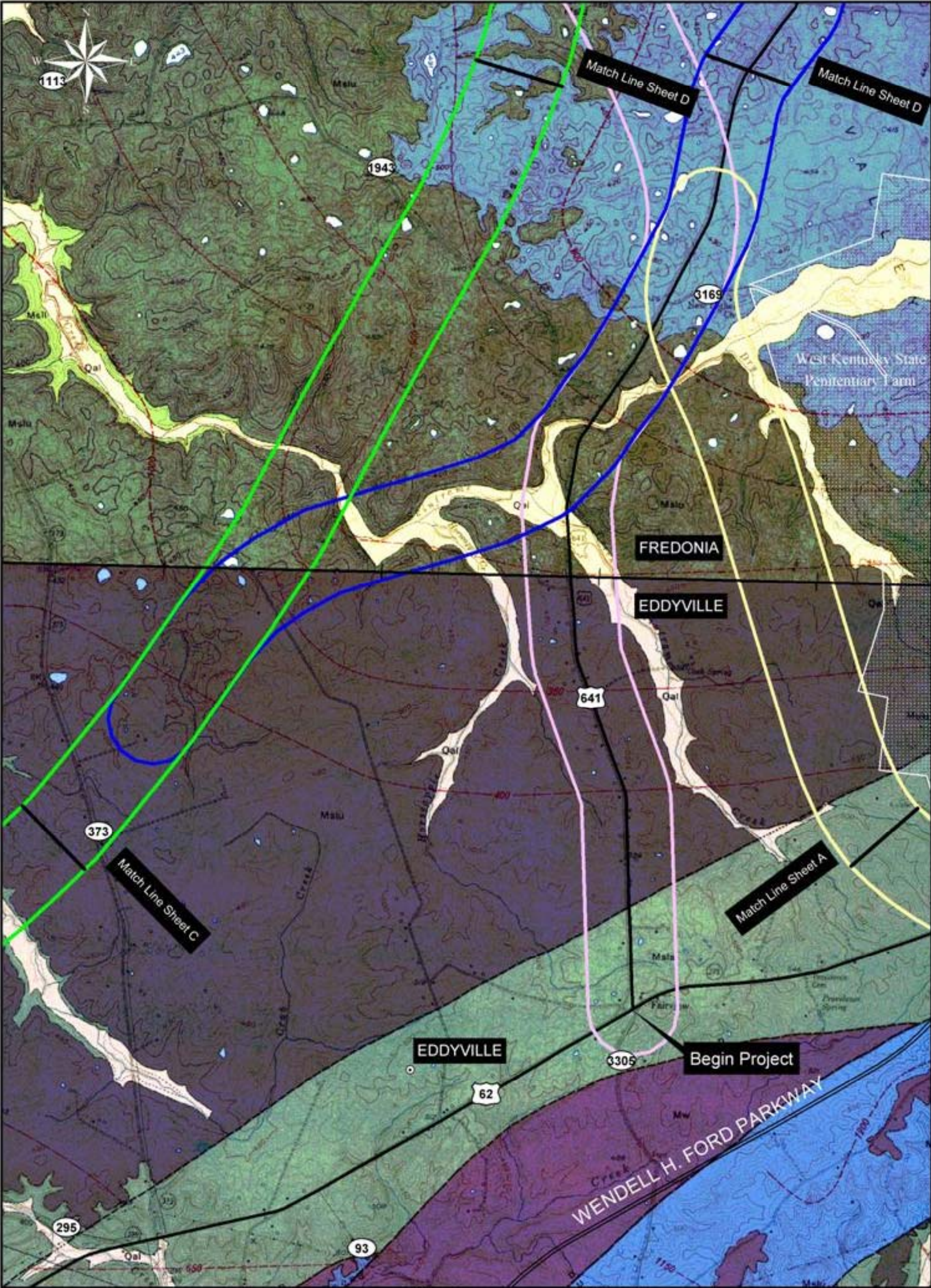


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Sheet A

Corridor Study
Lyon and Caldwell Counties



LEGEND
(Corridors oriented south to north)

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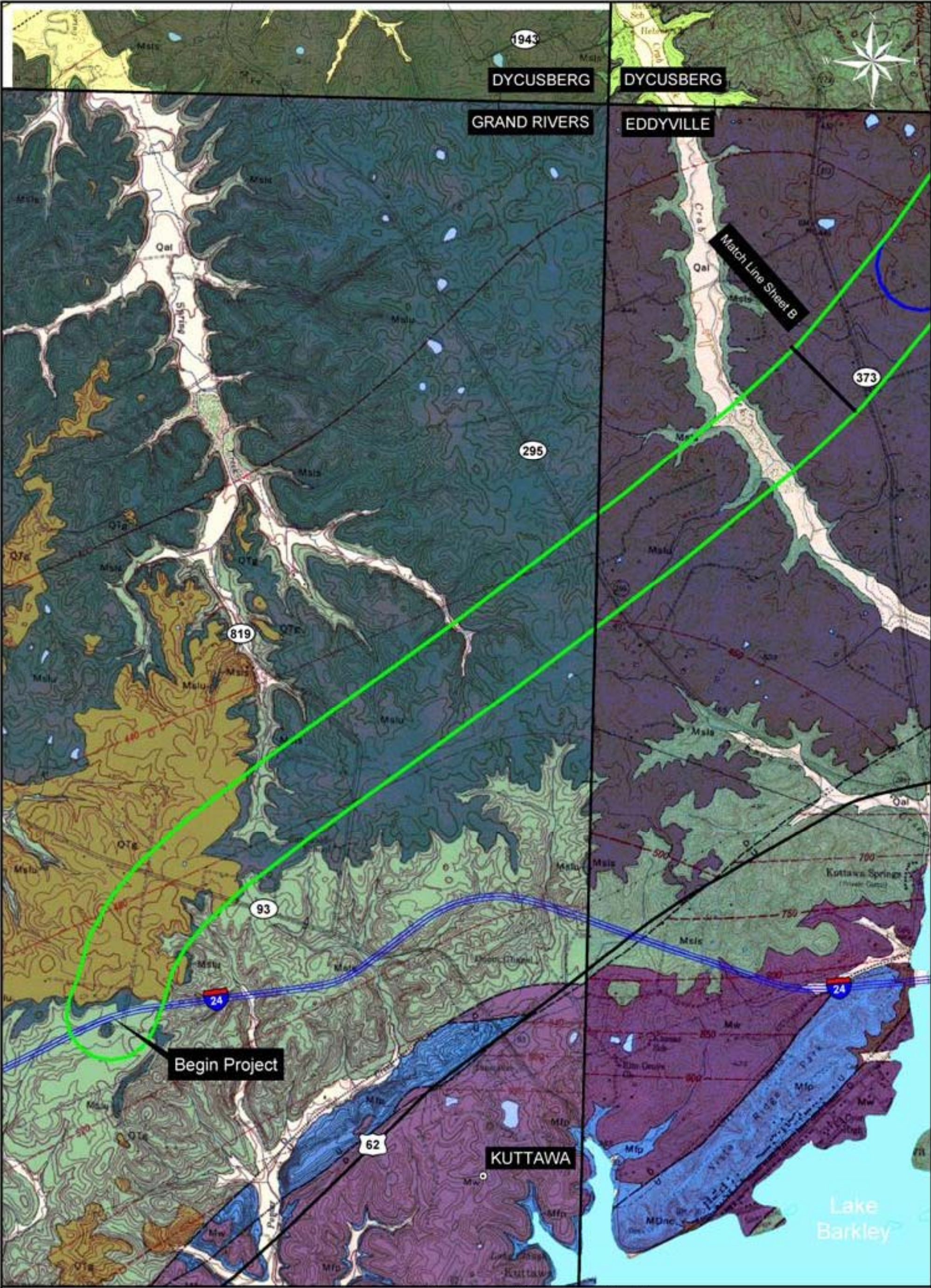


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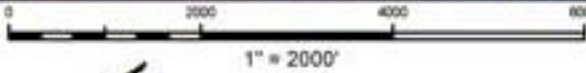
Sheet B

Corridor Study
Lyon and Caldwell Counties



LEGEND
(Corridors oriented south to north)

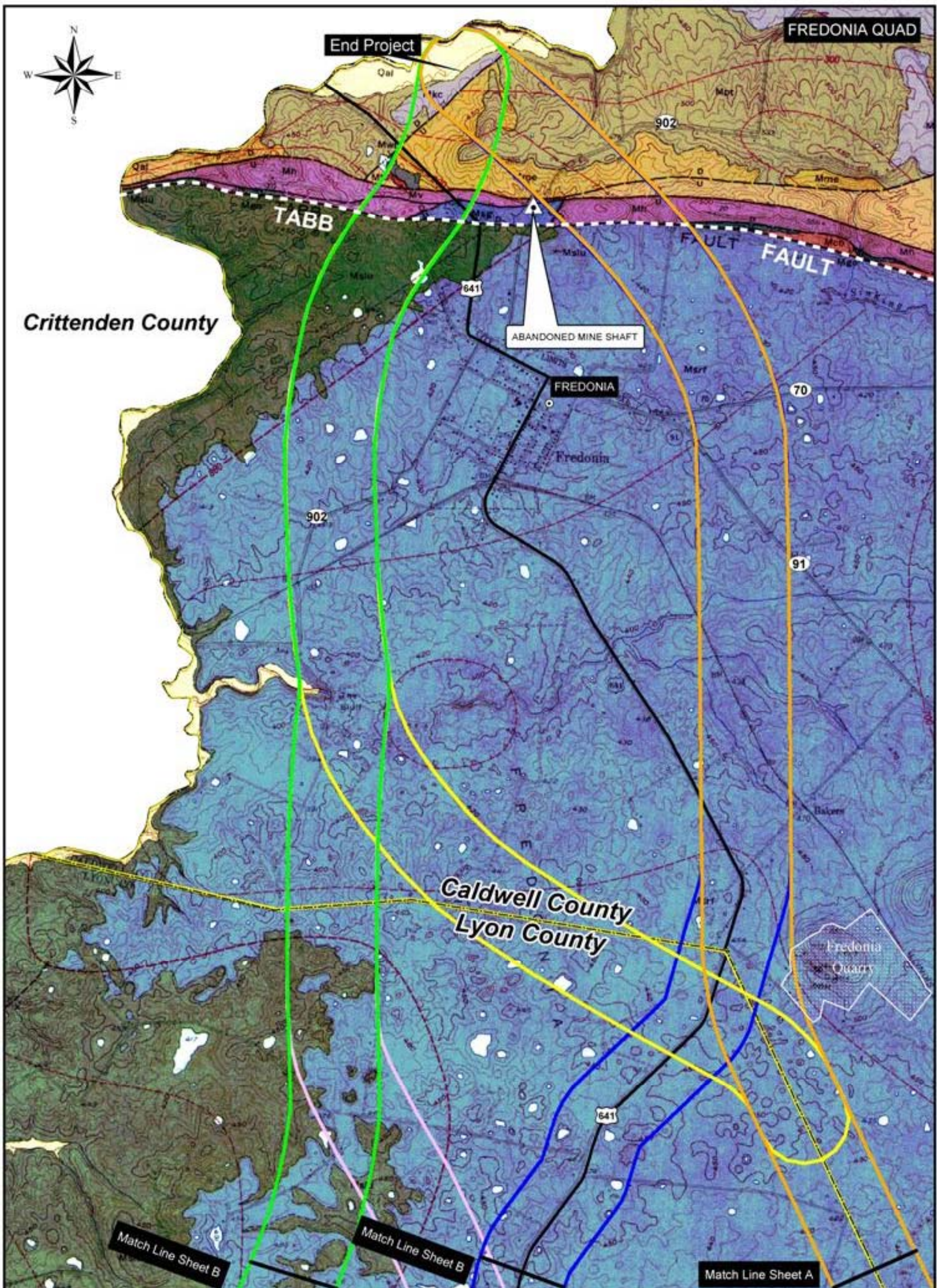
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(Eddyville to Fredonia)

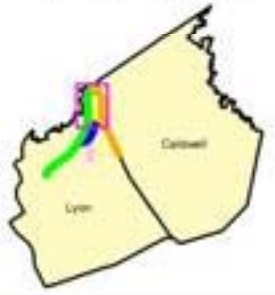
Sheet C

Corridor Study
Lyon and Caldwell Counties



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(Corridors oriented south to north)

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Sheet D

Corridor Study
Lyon and Caldwell Counties