# Geology
# Technical Report

*March 2005*

Submitted To:

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# TABLE OF CONTENTS

**1.0 INTRODUCTION TO ANALYSIS ..... 1**
**2.0 AFFECTED ENVIRONMENT ..... 1**
2.1 EXISTING CONDITIONS ..... 1
2.2 GEOLOGY ..... 1
2.2.1 Surficial Units ..... 2
2.2.2 Bedrock Units ..... 3
2.2.3 Geologic Hazards ..... 3
2.2.4 Mineral Resources ..... 4
2.3 C470 CORRIDOR ..... 4
2.3.1 Existing Pavement Conditions ..... 4
2.3.2 Existing Geology and Geologic Hazards ..... 5
**3.0 ENVIRONMENTAL CONSEQUENCES ..... 6**
3.1 METHODOLOGY FOR IMPACT EVALUATION ..... 6
3.2 FINDINGS ..... 6
3.3 IMPACT EVALUATION ..... 6
3.3.1 Alternative No. 1: No Action ..... 6
3.3.2 Alternative Nos. 2 and 3: Express Lanes and General Purpose Lanes ..... 6
**4.0 MITIGATION MEASURES (ALL ALTERNATIVES) ..... 7**
**5.0 SUMMARY/CONCLUSION ..... 9**
**6.0 REFERENCES ..... 10**

# 1.0 INTRODUCTION TO ANALYSIS

Information was gathered on geologic conditions, geologic hazards, and geologic factors that could potentially limit the proposed transportation alignment. While several geologic constraints have been identified along the corridor, no significant impacts to the geology, soils, or mineral resources are expected due to the proposed alternatives. Conditions that have been identified along the corridor that may require standard mitigation during construction include: expansive soils and bedrock, steeply dipping bedrock, corrosive soils, collapsible soils, and potentially unstable slopes.

Geology, soil, and mineral resources-related impacts that could be considered significant include the following:

- Topographic changes that lead to other adverse impacts (e.g., visual impacts or impacts on slope stability)
- Adverse affects on unique geologic or topographic features
- Exposing people or structures to major geologic hazards
- Causing substantial erosion or siltation
- Prevention of the recovery of significant mineral resources

The results of this analysis indicate the proposed alternatives will not significantly impact the construction along the C470 Corridor from Kipling Parkway to I-25.

# 2.0 AFFECTED ENVIRONMENT

## 2.1 EXISTING CONDITIONS

The general geology, soils, and mineral resources encountered along the corridor are introduced in the following paragraphs. Then, specific conditions for the C470 Corridor between Kipling Parkway and Interstate 25 are detailed in the next sections.

## 2.2 GEOLOGY

The geologic setting along the corridor includes bedrock and variable thicknesses of surficial deposits overlying bedrock (See Figures 1 through 6, Geology Map). The study area lies within the Colorado Piedmont, along the southwestern flank of the Denver Basin. Sedimentary rock layers dip steeply from the flank of the Front Range eastward into the Denver Basin, then rise much more gradually up the eastern flank of the basin in eastern Colorado. The regional structure of the bedrock along the corridor predominantly strikes north-northwest and is slightly dipping to the northeast. The bedrock typically is hard and indurated while the surficial deposits are unconsolidated and in a looser condition. The bedrock within the corridor is all of sedimentary origin. These sedimentary rocks represent former environments and conditions that existed along the Front Range during the Cretaceous and early Tertiary geologic times. These

environments include shallow inland seaways, near shore and terrestrial stream bed conditions. Overlying the bedrock formations are deposits of surficial material. These surficial deposits are the result of geomorphic activity that has shaped the present landforms and vary considerably in depth. This activity is primarily related to processes involving wind and water including former and modern streams and rivers. The surficial deposits are younger than the bedrock and are unconsolidated and loose by comparison. They are composed predominantly of boulders, cobbles, gravel, sand, silt, and clay deposited primarily by gravity (colluvium), streams (alluvium), wind (eolian sand and loess), or humans.

### 2.2.1 Surficial Units

Surficial geologic units along the corridor include artificial fill, colluvium, eolian sand, loess, and alluvium.

Artificial fill can be composed of various amounts of naturally occurring materials mixed with undocumented man-made materials such as concrete, brick, and trash. This unit includes highway and road fills, canal embankments, or trash dumps of various thicknesses. For construction, it is assumed that artificial fill is not suitable for use as backfill materials unless there are records of it's content and placement. It will probably need to be removed and recompacted to specified standards. At various locations along the corridor, the fill material ranges from the surface to approximately 10-15 feet deep.

Colluvial deposits typically consist of poorly sorted sandy gravel to silty clay on slopes adjacent to exposed alluvium and bedrock. Colluvial deposits may have low permeability and expansive clays, depending on site-specific soils. Generally, colluvium is less than 5 feet thick.

Eolian sands are wind-deposited materials that are generally very permeable with rapid surface drainage. Foundation stability is good under moderate static loads, but settling is common with heavy loads or vibrations. Eolian sand deposits have low swell potential and resistance to erosion is low on steep slopes and in cuts but moderate to high in flat areas because of high permeability.

Loess is wind-deposited material typically consisting of nonstratified fine sand and silt forming a mantle over bedrock and older alluvial surfaces. These materials are susceptible to hydrocompaction and to differential settlement. This unit can be found at many locations along the corridor and is generally 10 feet thick.

Alluvial stream-deposited materials within or adjacent to the corridor include the Post-Piney Creek Alluvium, Piney Creek Alluvium, Broadway Alluvium, Louviers Alluvium, and Slocum Alluvium. The oldest alluvial deposits lie several hundred feet above modern stream floodplains, while subsequent younger alluvial surfaces were cut at sequentially lower elevations, until modern floodplain levels were reached. Descriptions of the alluvial units from youngest to oldest follow. The Post-Piney Creek Alluvium is predominantly sand, silt, and clay with lenses of gravel that occurs in mordern stream channels, floodplains, and alluvial fills. Generally it is 5 to 10 feet thick. The Piney Creek

Alluvium typically consists of interbedded sand, silt, and clay, with organic material near the surface and with gravel in lower portion. It is generally up to 20 feet thick. The Broadway Alluvium generally consists of fine sand and sandy silt forming terraces generally up to 25 feet thick. The Louviers Alluvium consists of gravelly sand with scattered boulders and gravelly channels. This deposit usually forms terraces approximately 25 feet thick. The Slocum Alluvium generally consists of sandy gravel, pebbly sand, pebbly clay, and silty gravel with scattered cobbles and boulders. This unit can be 15 to 20 feet thick (Lindvall 1980).

### 2.2.2 Bedrock Units

Four major bedrock geology units are encountered in the area of the corridor. The Dawson/Denver Formation consists of interbedded lenticular sandstone, claystone, siltstone, shale, and conglomerate that are brown to yellow-brown and gray to blue-gray. These units may up to 1000 feet thick and contain fossil leaves, dinosaur and mammal bones, and petrified wood. The Laramie Formation consists of interbedded gray to brown shale, siltstone, lignitic claystone, coal, and light gray to light brown sandstone. This formation can be up to 600 feet thick. The Fox Hills Sandstone contains greenish buff crossbedded sandstone in lower part grading upward to light yellow and white sandstone. This bedrock unit can be up to 300 feet thick. The Pierre Shale is primarily dark gray to brown clayey shale with some siltstone, silty sandstone, and limestone beds. The upper part of unit contains highly expansive claystone and siltstone as well as bentonite. It is generally up to 8000 feet thick.

### 2.2.3 Geologic Hazards

A geologic hazard, as defined by Colorado House Bill 1041 (1974), is "a geologic phenomenon which is so adverse to past, current, or foreseeable construction or land use as to constitute a significant hazard to public health and safety or to property." Physical and/or chemical properties associated with the natural deposits, both bedrock and surficial, may impose risk or constraints to the corridor and the proposed improvements. Geologic hazards and engineering constraints along the corridor include expansive soil and bedrock, steeply dipping bedrock, corrosive soils, collapsing soil, and potentially unstable slopes.

Expansive soils and bedrock are widespread throughout the study area. The altered volcanic ash layers that are common in most bedrock units underlying the study area are composed primarily of swelling clay minerals. Soils that develop from and upon them tend to have elevated swell potential as well. Expansive soils and bedrock can repeatedly swell when wet and contract when dry, damaging man-made structures.

Steeply dipping bedrock units that contain layers with different swell potential occur west of the Wadsworth Interchange (See Figure 1, Geology Map: Kl, Kfh, and Kp). This geologic hazard is distinguished from relatively flat-lying expansive bedrock hazards due to the differential movement that can occur associated with steeply dipping bedrock. Heaving bedrock and surficial deposits that have significant swell potential but are relatively flat-lying generally expand in fairly uniform directions. On the other hand,

steeply dipping bedrock that contains layers with different swell potential can cause extreme structural damage by either heaving or rebounding along individual bedrock layers and/or by asymmetrical thrust-like heaving along bedding planes or fractures (Noe 1997).

Corrosive soils underlay areas of the corridor. Most of the soils in the Denver Basin area potentially produce high concentrations of sulfate salts and therefore can corrode metals and concrete in moist conditions. The degree of the corrosion can be determined in the future geotechnical exploration and laboratory testings. Parts of the Dawson Arkose, Laramie Formation, Fox Hills Sandstone, and Pierre Shale are units near the surface that are prone to corrosive behavior (See Figures 1 to 5, Geology map: TKda, Kl, Kfh, Kp).

Collapsing soils occur along the corridor in several surficial deposits. Upon inundation with water, these deposits undergo sudden changes in structural configuration with an accompanying decrease in volume that is expressed as settlement at the surface. Eolian sands, loess, and loose sands and silts are deposits near the surface that are prone to collapse (See Figures 1 to 5, Geology Map: Qes, Qol, and Qyl).

Potentially unstable slopes are defined as those slopes that in their current configuration are stable, but any modification to the slope through site grading, increase in water content, or erosion may cause the slope to become unstable and may initiate a slope failure. Identification of these slopes and their engineering characterization can be difficult. Grading cuts in the Laramie Formation and Pierre Shale, especially where overlain by alluvial terraces, should be individually analyzed for stability (See Figures 1 to 5, Geology Map: Kl, Kp).
The site is considered to be in a seismically inactive area. There are no known active faults either on, or adjacent to the project site, so the potential for surface fault rupture is considered to be low. Faults within the corridor are believed to have been inactive for at least the last 45 million years. Seismic hazards at this site are, therefore, a consequence of ground shaking caused by events on distant, active faults. Based on a review of seismic data available from the United States Geological Survey (2003), the peak ground acceleration (PGA) with a 10% probability of exceedance in 50 yrs., is approximately 0.02g at the site.

### 2.2.4 Mineral Resources

Mineral resources along the corridor are primarily aggregate resources near the Santa Fe Interchange. This includes aggregate recovery of sand and gravel from the Dawson/Denver Formation. In addition to the aggregate resources from the sedimentary units, sands and gravels have been produced from the current stream channels and older alluvial deposits near the corridor.

## 2.3 C470 CORRIDOR

### 2.3.1 Existing Pavement Conditions

The condition of the pavement along the C-470 between Kipling Parkway and I-25 was observed. The highway is constructed of concrete pavement over embankment cut or fill.

Due to the presence of expansive soils and rock in this area, we understand the upper 8 to 12 inches of subgrade beneath the pavement has been treated by subexcavating, reconditioning the soil, and adding lime. Recently, a two-inch asphalt overlay has been completed from Santa Fe to the Kipling.

Slab replacement, crack sealing, and area patches have been observed along the C-470 mainline area. The cracks appear to have resulted from a combination of localized consolidation and expensive soils or rock. We understand major repairs were conducted between Broadway and I-25 several years ago. Currently, three pavement distress areas were observed between Santa Fe Drive and Broadway, at University, and between Quebec and I-25. The conditions are summarized below.

#### 2.3.1.1 Santa Fe Drive to Broadway

Pavement distress including heaving and cracking was found in a few isolated areas. It appeared that it was caused by expensive soils or rock.

#### 2.3.1.2 University Interchange

Settlement and cracks were found on the westbound pavement near the east end of the bridge approach. This type of settlement could be a result of excessive wetting of the subgrade soils and improper compaction during construction.

#### 2.3.1.3 Quebec to I-25 Interchange

Several transverse cracks and a depression were observed on the eastbound off-ramp at the Quebec Interchange. The cracks have been properly sealed and the depressed area has been patched. It does not appear that further pavement movement has occurred.

We believe that most of the distressed pavement and subgrade soils have been stabilized. However, poor surface drainage around the distressed areas can cause severe roadway failure in the future. Extensive drainage improvement and major roadway repair are required.

### 2.3.2 Existing Geology and Geologic Hazards

#### 2.3.2.1 Segment 1: Kipling Parkway to Santa Fe Drive

This segment is underlain by bedrock of the Laramie Formation, Fox Hills Sandstone and the Pierre Shale. These formations are overlain in places by alluvium, wind blown sand, and loess. The alluvium is deposit from present day and former, higher river levels. There are several hazards and constraints associated with these geologic deposits, including expansive bedrock and soil, steeply dipping bedrock, corrosive soils, collapsing soils, and unstable slopes (See Figures 1 and 2).

#### 2.3.2.2 Segment 2: Santa Fe Drive to Broadway

This segment is underlain by bedrock of the Dawson/Denver Formation. This formation is overlain in places by alluvium deposited from former, higher river levels and wind-deposited sand and loess. Geologic hazards and constraints associated with these

geologic deposits include expansive soils and bedrock, corrosive soils, and collapsing soils (See Figure 3).

#### 2.3.2.3 Segment 3: Broadway to I-25.

This segment is underlain by bedrock of the Dawson/Denver Formation. This formation is overlain in places by colluvium, wind-blown sand, loess, and alluvium. Geologic hazards and constraints associated with these geologic deposits include expansive bedrock and soils, corrosive soils and collapsing soils. Specific areas of high to very high swell potential (Hart 1974) along the alignment include the Highlands Ranch residential area (See Figures 4 and 5).

# 3.0 ENVIRONMENTAL CONSEQUENCES

## 3.1 METHODOLOGY FOR IMPACT EVALUATION

Geologic conditions present along the corridor were identified using information from geologic maps, topographic maps, United States Geological Survey reports, Colorado Geological Survey publications, United States Department of Agriculture soil survey reports, and geotechnical consulting reports. This information was supplemented with field reconnaissance, communications with local engineering and planning personnel. Evaluation of existing geologic conditions was based on proximity to the corridor, history of occurrence, and impact of occurrence on transportation and mobility.

## 3.2 FINDINGS

There is no clear distinction between direct impacts to geology, geologic hazards, soils, or mineral resources associated with the C470 Corridor under any of the proposed build alternatives. Any alternatives (except Alternative 1: No Action) will require crossing surficial and bedrock geology units that may require standard mitigation during construction. There are no indirect effects associated with the geology, geologic hazards, soil or mineral resources identified within the project area.

## 3.3 IMPACT EVALUATION

### 3.3.1 Alternative No. 1: No Action

The No-Action Alternative would not have any direct or indirect effects associated with the geology, geologic hazards, or mineral resources identified within the project area.

### 3.3.2 Alternative Nos. 2 and 3: Express Lanes and General Purpose Lanes

Both alternatives were evaluated and considered to have the same impacts as follow.

Direct Impacts—Geologic conditions that have been identified along the corridor that may be directly impacted by the alternatives include: expansive soils and bedrock, corrosive soils, steeply dipping bedrock, collapsible soils, and potentially unstable slopes. None of these geologic conditions and aggregate resources along the corridor constitute a significant impact that should alter the location of any of the proposed build alternatives.

Expansive soils and bedrock as well as corrosive soils may cause increasing damage to transportation system components over a period of years. Steeply dipping bedrock has locally demonstrated severe damage to pavement and transportation structures from differential movement. Collapsible soils can damage the system infrastructure by either large settlement areas or differential settlement. Unstable slopes can also cause failure at the cuts and fills area.

Indirect Impacts—There are no indirect effects associated with the geology, geologic hazards, soil or mineral resources identified within the project area.

Cumulative Impacts—There are no cumulative effects associated with the geology, geologic hazards, soil or mineral resources identified within the project area.

# 4.0 MITIGATION MEASURES (ALL ALTERNATIVES)

Conditions that have been identified along the corridor that may require standard mitigation during construction include: expansive soils and bedrock, corrosive soils, steeply dipping bedrock, collapsible soils, and potentially unstable slopes. Mitigation of the direct impacts can be mitigated through several standard techniques and should conform to the Colorado Department of Transportation Standard Specifications for Road and Bridge Construction.

Expansive soils and bedrock as well as collapsible soils can be mitigated at structure locations by designing deep foundation systems, such as driven H-piles or drilled piers, rather than on shallow foundations. Foundation pads could also be designed to form a raft across any swelling or collapsing materials. Additionally, floating floor slabs can be designed instead of slab-on-grade construction. Structural Retaining walls, such as soil nail walls, ground anchors, mechanically stabilized earth (MSE) walls, cantilever walls, or reinforced soil slopes can be built to stabilize slopes when cut or fill slopes require steep gradients (3 horizontal: 1 vertical) or where potential slope failures may occur due to the presence of water and loose material.

Expansive subgrade soils under pavement sections can be stabilized with chemicals (lime), removed and recompacted, or removed and replaced with imported structural fill of better quality. For planning purposes, preliminary evaluations indicate the corridor will require up to 4 feet of overexcavation, moisture treatment and recompaction with up to 12-inch lime stabilization.

Collapsible subgrade materials under pavement sections can be mitigated by flooding, deep dynamic compaction, overexcavation prior to embankment placement, or additional loading with a thicker section of embankment material.

Steeply dipping bedrock areas requires alternative practices such as overexcavation with refill and compaction to remove the conditions that perpetuate heaving. A barrier between the subgrade material and the pavement section could be constructed out of imported structural fill materials that range in thickness of 3 to 5 feet. Under structures,

this depth of subexcavation and replacement could be as much as 10 feet under the base of the shallow foundation footer.

The collection and diversion of surface drainage away from paved areas is critical to the satisfactory performance of pavement. Proper design of drainage should include prevention of ponding of water on or immediately adjacent to pavement areas. All landscape sprinkler heads and lines adjacent to pavement areas should be frequently checked for leaks and maintained in good working order. It is also imperative that surface and subsurface water conditions be addressed in the design of any retaining wall systems. Any design should consider diverting and controlling surface water around or away from the wall areas and the wall designs should incorporate an internal drainage system. Horizontal drains may increase slope stability by reducing the seepage and freezing pressure acting within fractures in rock and within zones of weakness in the soil. Slopes and other stripped areas should be protected against erosion by re-vegetation or other methods.

Stormwater Management Plan (SWMP) that prescribe best management practices (BMP) to minimize potential soil erosion, and include prescriptions for monitoring of conditions before and after the completion of work (and for immediate post-restoration site stabilization) should be prepared and implemented. Measures that will be required are typical of erosion control procedures used in highway construction projects. The methods for controlling erosion will be as described in the Colorado Department of Transportation, Standard Specifications of Road and Bridge Construction, Section 208, Erosion Control.

The proposed mitigation measures are summarized in Table 1 below:

**Table 1:**
**Proposed Mitigation Measures**

| Impact | Impact Type, Responsible Parties | Mitigation (All Packages) |
|---|---|---|
| Expansive Soils | Construction, Designer and/or Contractor | Installation of deep foundations systems, raft foundations, floating floor slabs. |
| Unstable Slopes | Construction, Designer and/or Contractor | Design retaining walls, such as soil nail walls, ground anchor walls, MSE walls. |
| Expansive Subgrade Soils | Construction, Designer and/or Contractor | Stabilize with lime treatment, remove and recompact, or remove and replace with imported fill material. |
| Collapsible Subgrade Soils | Construction, Designer and/or Contractor | Stabilize by flooding, deep dynamic compaction, overexcavation, additional loading prior to construction. |
| Steeply Dipping Bedrock | Construction, Designer and/or Contractor | Stabilize by overexcation and replacement with imported fill materials. |

In addition to designing the appropriate mitigation measures, proper maintenance of the new roadway segments is very important. Surface and underground drainages must be properly maintained to keep water flowing away from the roadway and not ponding.

# 5.0 SUMMARY/CONCLUSION

Based on the impact evaluation, the geologic resources will not be significantly impacted by the proposed alternatives along the C470 Corridor from Kipling Parkway to I-25. However, geologic conditions that have been identified along the corridor that may be directly impacted by Alternative Nos. 2 and 3 include: expansive soils and bedrock, corrosive soils, steeply dipping bedrock, collapsible soils, and unstable slopes. Specific mitigation measures have been proposed to alleviate the identified impacts along the C470 Corridor.

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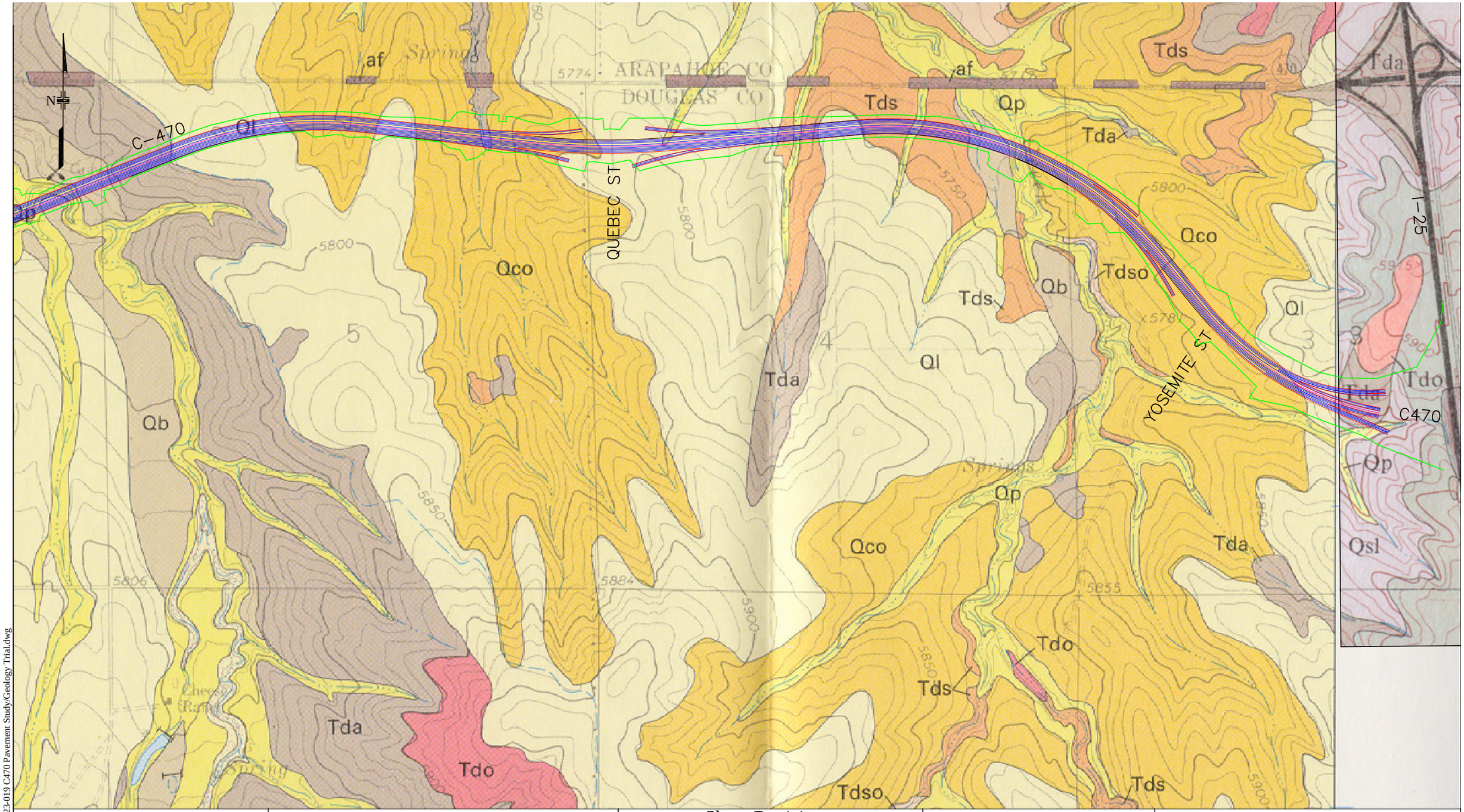


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Project Number: **23-019**

Drawn by: **JD**

Checked by: **SY**

Date: **February 15, 2005**

# Geology Map

Project: **C470 EIS**

Figure Number: **5**

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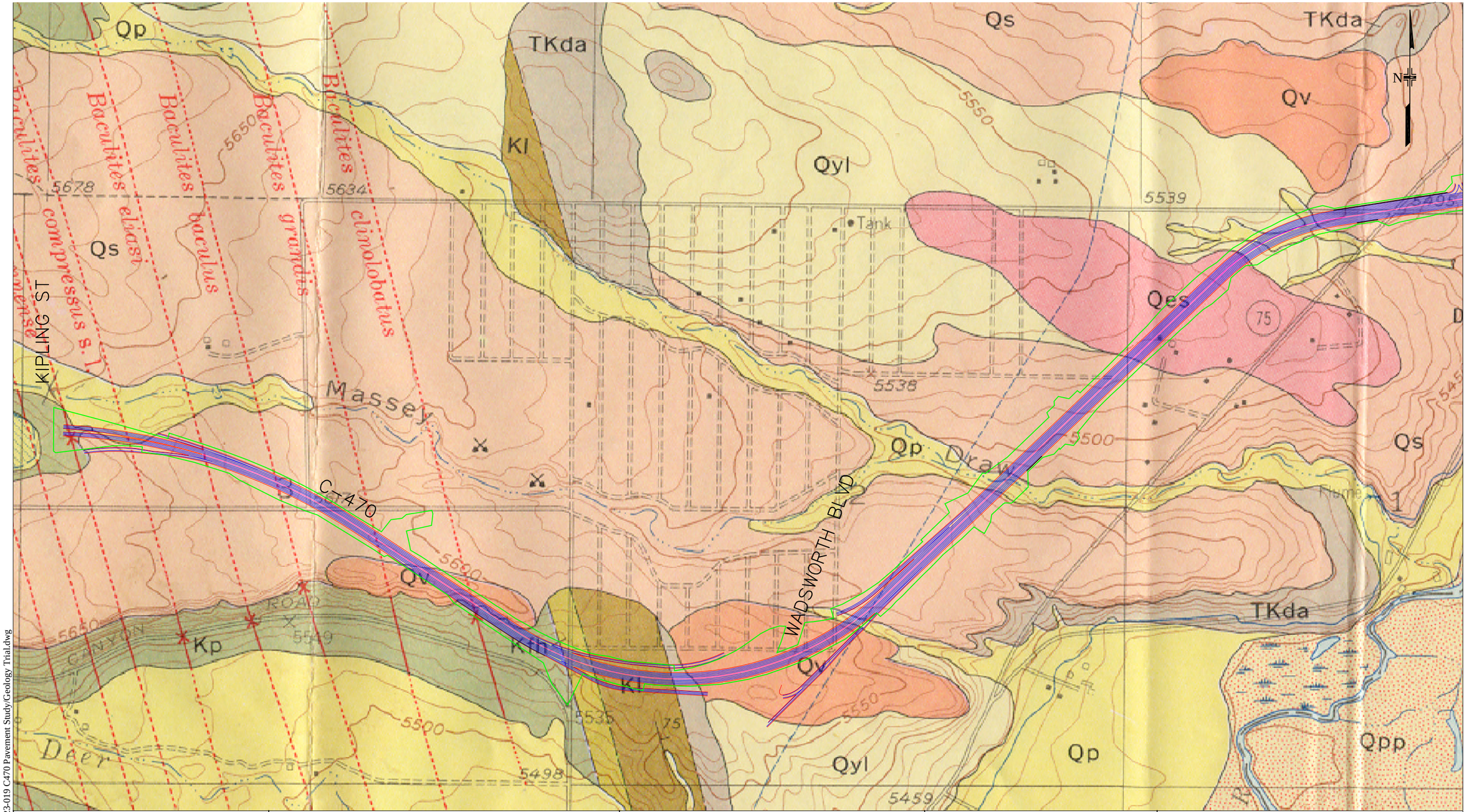


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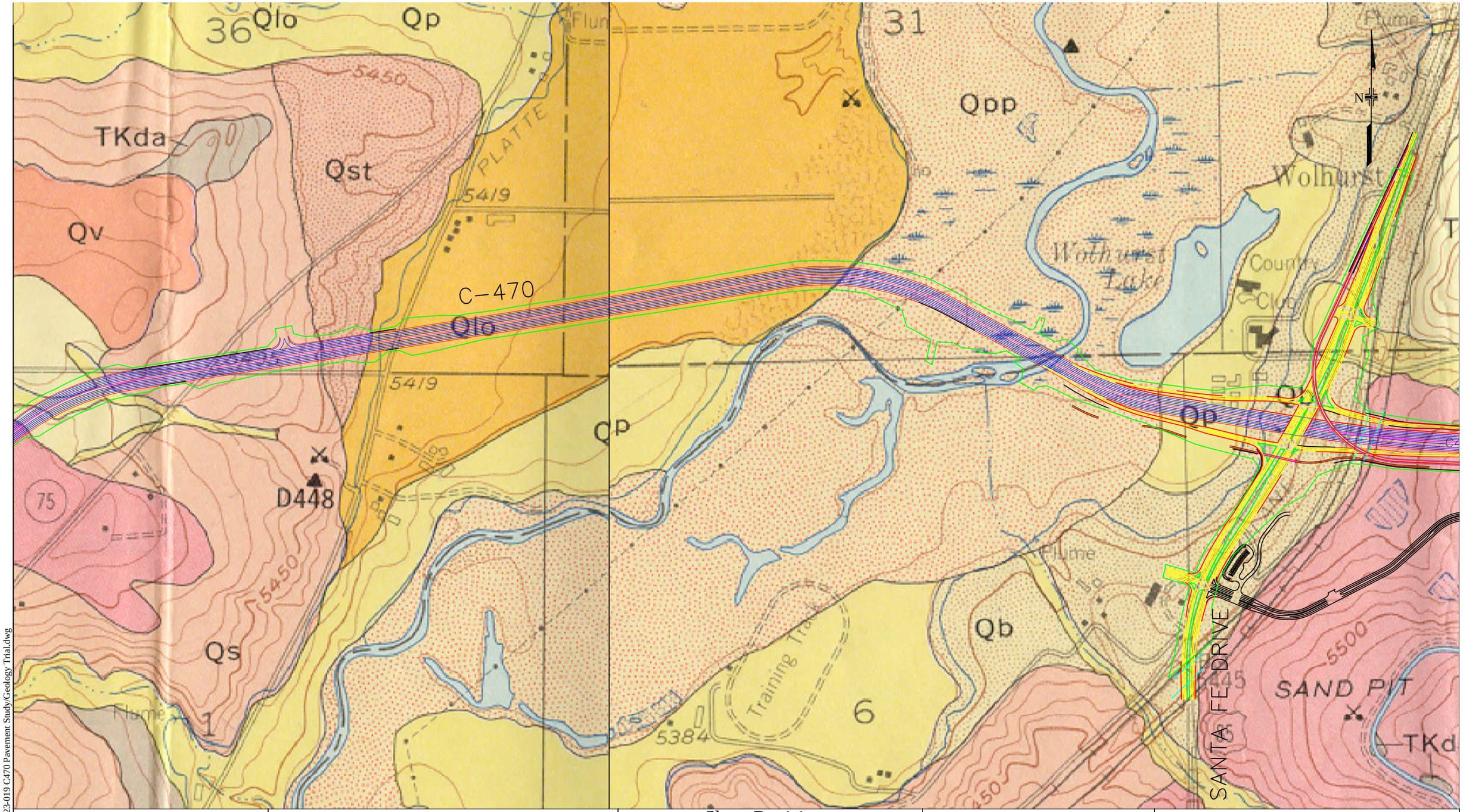
# Geology Map

Project: **C470 EIS**

Figure Number: **1**

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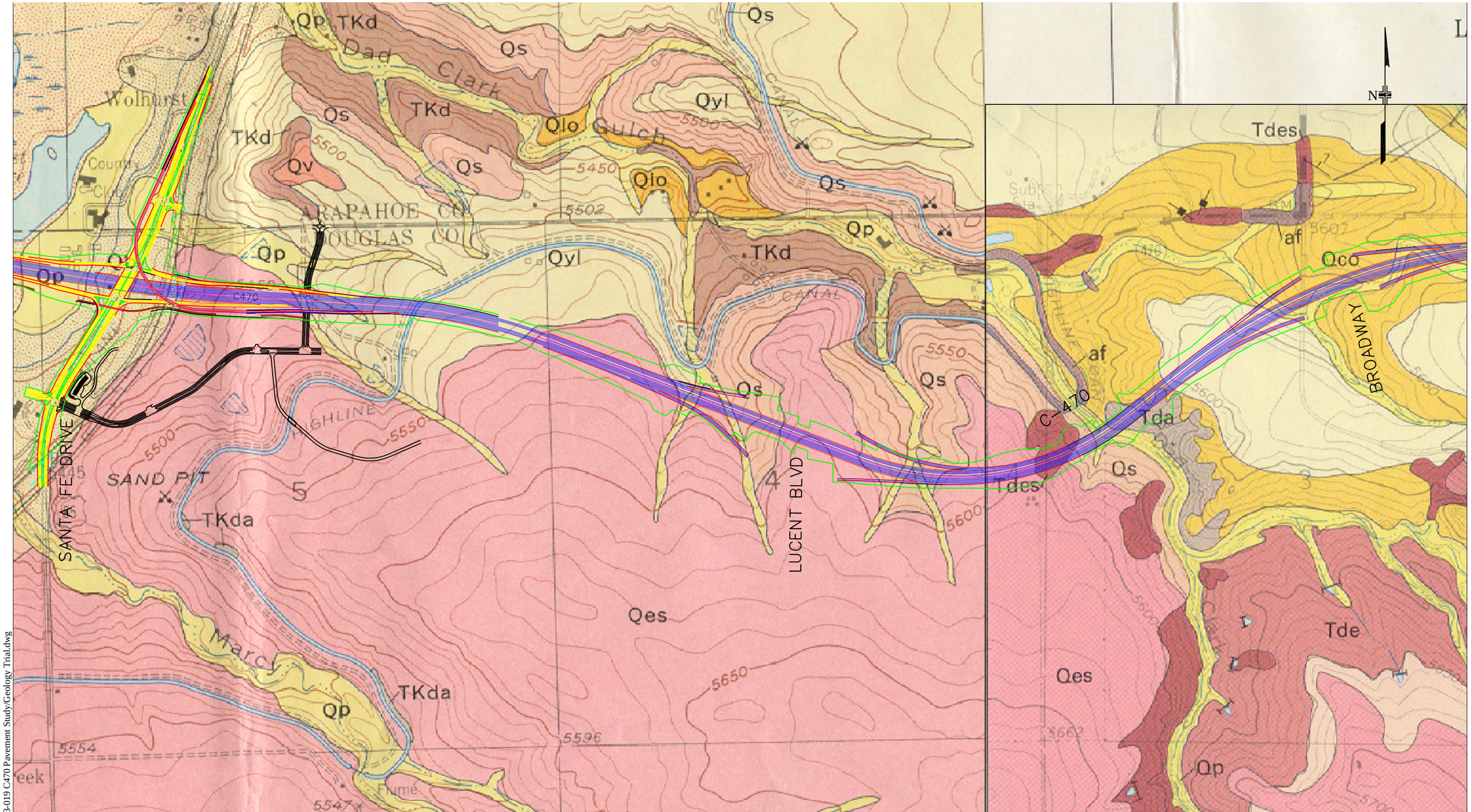
# Geology Map

Project: **C470 EIS**

Figure Number: **2**

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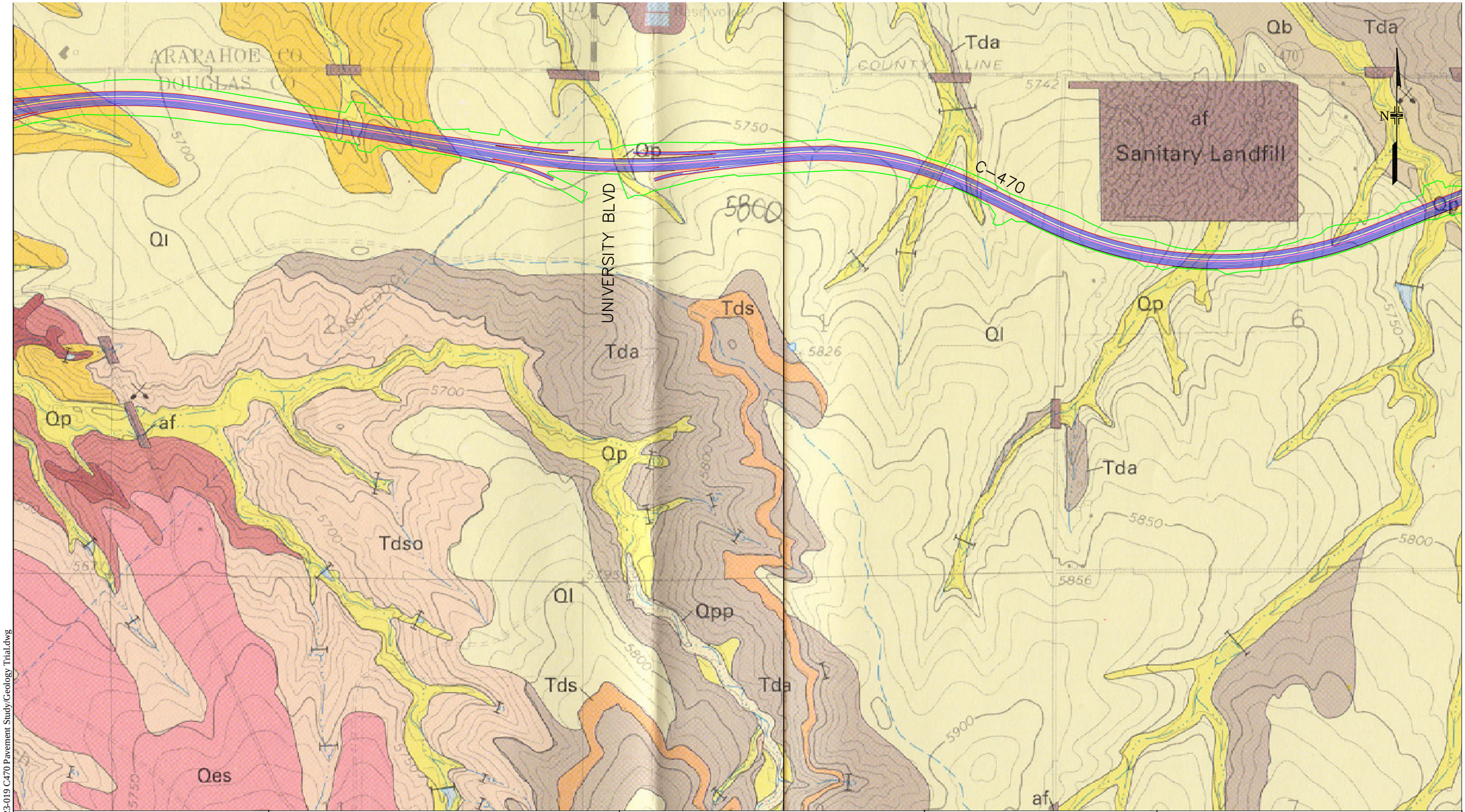
# Geology Map

Project: C470 EIS

Figure Number: 3

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# Geology Map

Project: C 470 EIS

Figure Number: 4

Qpp
Post-Piney Creek alluvium

Qp
Piney Creek alluvium

Qes
Eolian sand

Qpa
Pre-Piney Creek alluvium

Qb
Broadway alluvium

Qyl
Younger loess

Qlo
Louviers alluvium

Qol
Older loess

Qs | Qst
Slocum alluvium

Qv | va
Verdos alluvium
*Volcanic ash at base*, va

Qrf
Rocky Flats alluvium

TKda | TKd
Dawson arkose

Kl
Laramie formation

Kfh
Fox Hills sandstone

Kp
Pierre shale

Kns
Knf
Niobrara formation
Kns, *Smoky Hill shale member*
Knf, *Fort Hays limestone member*

Kc
Carlile shale

Kgh
Greenhorn limestone

Kg
Graneros shale

Ksp
South Platte formation

Kly
Lytle formation

Ply
Lyons sandstone

PIPf
Fountain formation

Qco
Colluvium

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# Legend

Project Number: **25-007**

Project: **C-470 EIS**

Drawn by: **JD**

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Figure Number: **6**