

# **Divide Creek Area Joint Study Summary Report South of Silt, Colorado**

September 8, 2011

*Walter* Project No.: 237-02-003

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## DIVIDE CREEK AREA JOINT STUDY SUMMARY REPORT

### 1.0 PURPOSE AND SCOPE

**Walter Environmental Group, Inc. (Walter)** conducted a limited study of linear geologic and geomorphologic features in the vicinity of the Divide Creek Seep area south of Silt, Colorado (Figure 1). The study included the identification of the major lineaments and joint sets by reviewing United States Geologic Survey (USGS) topographic maps for the study area, and conducting site reconnaissance at three outcrop locations. These locations included the P3 (Arbaney) well pad outcrop, Brown (F11E) well pad outcrop, and the Bracken outcrop.

The goal of this study was to evaluate the orientation of these major lineaments and joint sets relative to the spatial relationship between impacted domestic water wells and natural-gas wells in the study area. The purpose of this report is to summarize the results of this study.

### 2.0 ASSUMPTIONS AND DEFINITIONS

#### 2.1 Joints

A joint is defined as a planar brittle-fracture surface in rocks along which little or no displacement has occurred. Joints can provide a preferred migration pathway for gas or liquids if the conductivity along the fracture is greater than the surrounding host rock. This preferential migration pathway is referred to as fracture porosity.

**Walter** considered the “primary” joint set to be the most common joint set observed throughout the outcrop. The term “secondary” joint set was assigned to the less common joint set. In both cases, the decision to assign the title was based on a subjective analysis of field observations. The age relationship between joint sets was based on observed joint intersections. **Walter** made the reasonable assumption that younger joint sets truncate against older joint sets.

#### 2.2 Lineaments

Over geologic time, wind, rain, and water’s freeze-thaw cycles erode even the most resistant mountains. These erosional forces take advantage of bedrock weaknesses. Joints often provide a source of readily-exploitable weaknesses. Since a joint is defined as a planar brittle-fracture surface in rocks, the resulting erosional signature is often planar.

Joints are typically planar features; therefore, their intersection with other generally planar features (i.e., the earth’s surface) often results in linear geomorphological features. These linear geomorphologic features are defined as lineaments. Lineaments can take the form of elongate hillsides or ridges, straight valley floors or drainages, and/or uniform “stair-stepped” mountains. These features are typically discernable in aerial photographs and topographic maps.

Based on this genesis, it is reasonable to assume that field-observed joint sets (discussed above) should generate a similar linear surface expression (lineament). Furthermore, inspection of topographic maps (or other representations of geomorphology, i.e. aerial photographic stereo-pairs) should reveal the resulting lineaments. In addition, it is *Walter's* opinion that analysis of topographic maps for lineaments should reveal not only joints, but other planar/linear structural weaknesses exploited by erosion. These weaknesses can include bedding planes, faults, and man-made features.

### 3.0 FIELD ACTIVITIES

*Walter* performed a field investigation on September 1, 2010 and November 11, 2010. The field investigation included an analysis of three bedrock outcrops west of the Divide Creek Seep (Figure 2). The analysis consisted of the identification of the major joint families at each of the three outcrops.

For the purpose of this effort, the three outcrops investigated were named (west to east):

- P3 (a.k.a. Albany) Well Pad Outcrop (approximately N39° 28' 15", W107° 38' 41" [NAD 83])
- Brown (a.k.a. F11E) Well Pad Outcrop (approximately N39° 27' 50", W107° 38' 12")
- Bracken Outcrop (approximately N39° 28' 4", W107° 37' 24")

#### 3.1 P3 (Arbaney) Well Pad Outcrop

The P3 Well Pad outcrop is located approximately 500-750 feet north of the P3 Well Pad. Viewed from the valley floor, the P3 Well Pad Outcrop presents itself as an elongate, east-west trending, vertical (and near vertical) planar feature (Figure 2).

Analysis of the outcrop resulted in the identification of two consistent vertical joint sets (Photographs 1 through 4):

- Primary Joint Orientation: 105 degrees east of north (N105E)
- Secondary Joint Orientation: 10 degrees east of north (N10E) (Older)

Based on observed joint intersections (Photograph 4), the N10E (secondary) joint set is older than the N105E (primary) joint set. These joint sets are illustrated in Figure 3.

#### 3.2 Brown (F11E) Well Pad Outcrop

The Brown Well Pad outcrop is located approximately 500-750 feet east of the Brown Well Pad (Figure 2). Outcrop on the hillside east of the Brown Well Pad is limited in quantity; as much of the hillside is covered by "float" (rock masses disconnected from the deeper bedrock mass).

However, inspection of the available outcrop resulted in the identification of two consistent vertical (and near vertical) joint sets (Photograph 5):

- Primary Joint Orientation: N130E
- Secondary Joint Orientation: N40E (Older)

Based on observed joint intersections (not documented with a photograph), the N40E (secondary) joint set is older than the N130E (primary) joint set. These joint sets are illustrated in Figure 3.

### 3.3 Bracken Outcrop

The Bracken outcrop is located east of the Bracken residence, on the cliffs overlooking West Divide Creek, south of the confluence of East and West Divide Creeks (Figure 2). The outcrop affords excellent exposure in both plan (Photograph 6) and cross-sectional (Photograph 7) views. Inspection of the outcrop resulted in the identification of two consistent vertical (and near vertical) joint sets (Photographs 8 through 10):

- Primary Joint Orientation: N40E
- Secondary Joint Orientation: N105E (Older)

Based on observed joint intersections (Photograph 9), the N105E (secondary) joint set is older than the N40E (primary) joint set. These joint sets are illustrated in Figure 3.

### 3.4 Field Investigation Summary

*Walter* identified a pair of (vertical or near vertical) orthogonal joints in outcrops within the study area. One set was oriented between N10E and N40E. The other set was oriented between N105E and N130E. The field-observed age relationship between the two sets is contradictory. The observations on the P3Well Pad and Brown Well Pad outcrops suggest the N10E to N40E set is older, the observations on the Bracken Outcrop suggest the N105E to N130E set is older.

## 4.0 LINEAMENT ANALYSIS

To identify lineaments in the Divide Creek area, *Walter* reviewed USGS topographic maps (USGS, 1987 and 1987a) for the study area. Lineaments were identified and shown highlighted in Figure 4. In general, the orthogonal joint sets observed in outcrop (N10E to N40E, and N105E to N130E) are expressed as lineaments on the topographic map.

A second pair of lineaments was identified that were oriented differently than the joints observed in outcrop (Figure 4). For this report, these lineaments will be termed “non-associated lineaments.” The more common set is estimated to be oriented N160E to N170E; the second set was only observed on the ridge that makes up the central portion of Section 11 at an orientation

of approximately N80E. An investigation of the cause of this second set of lineaments is beyond the scope of this investigation.

## **5.0 JOINT-SET ORIENTATION RELATIVE TO THE SPATIAL RELATIONSHIP BETWEEN IMPACTED DOMESTIC WATER WELLS AND NATURAL-GAS WELLS**

### **5.1 Joint and Lineament Orientation Summary**

In general, *Walter* identified a pair of (vertical or near vertical) orthogonal joints in outcrops within the study area. One set was oriented between N10E and N40E. The other set was oriented between N105E and N130E. The field-observed age relationship between the two sets is contradictory. The observations on the P3 Well Pad and Brown Well Pad outcrops suggest the N10E to N40E set is older, the observations on the Bracken Outcrop suggest the N105E to N130E set is older. A summary of the joint orientations observed is presented as Figure 5.

Lineaments were identified and shown highlighted in Figure 4. The orthogonal joint sets observed in outcrop (N10E to N40E, and N105E to N130E) are also expressed as lineaments on the topographic map. A second pair of lineaments (non-associated lineaments) was identified that were oriented differently than the joints observed in outcrop (Figure 4). The more common set is estimated to be oriented N160E to N170E; the second set was only observed on the ridge that makes up the central portion of Section 11 at an orientation of approximately N80E. A summary of the lineament orientations observed is presented as Figure 5.

### **5.2 Impacted Domestic Water Wells and Natural-Gas Wells**

COGCC has determined that two natural-gas wells in the study area have impacted nearby receptors. COGCC Order 1V-276 (COGCC, 2004) found that the Schwartz 2-15B Well impacted West Divide Creek (Figures 2 through 4). In addition, COGCC Order 1V-297 (COGCC, 2005) found that P3 Pad wells impacted the Dietrich (Moon area) water well (Figures 2 through 4).

### **5.3 Spatial Relationship**

Figures 3 through 5 illustrate the spatial relationship between the two well pads and their identified receptors.

#### **5.3.1 Schwartz Well and West Divide Creek Seep**

The compass bearing between the Schwartz 2-15B Well and the West Divide Creek Seep is approximately N130E (Figure 2). This compass bearing coincides with the orientation of the secondary joint set observed in outcrop in the study area (N105E to N130E).

The predominant lineaments identified in the immediate vicinity of the Schwartz 2-15B Well and the West Divide Creek Seep appear are believed to be associated with the observed N10E to N40E joint set. A non-associated lineament set (N80E) is interpreted to also be present nearby on the ridge that makes up the central portion of Section 11. These lineament orientations do not coincide with the compass bearing between the Schwartz 2-15B Well and the West Divide Creek Seep (N130E).

### 5.3.2 P3 Pad wells and Dietrich (Moon Area) Water Well

The compass bearing between the P3 Pad wells and Dietrich (Moon area) water well is approximately N150E (Figure 2). This measurement does not coincide with the orientation of either joint sets observed in outcrop in the study area (N10E to N40E and N105E to N130E). However, one non-associated lineament was identified on the southwestern end of the ridge in the center of Section 11 and was oriented approximately N145E. This lineament could be considered as nearly coinciding with the compass bearing between the P3 Pad wells and Dietrich (Moon area) water well.

## 6.0 INVESTIGATION SUMMARY AND CONCLUSIONS

*Walter* conducted a limited study of linear geologic and geomorphologic features in the vicinity of the Divide Creek Seep area south of Silt, Colorado. The study included the identification of the major joint sets and lineaments by reviewing USGS topographic maps for the study area, and conducting site reconnaissance at three outcrop locations. These locations included the P3 (Arbaney) well pad outcrop, Brown (F11E) well pad outcrop, and the Bracken outcrop. The goal of this study was to evaluate the orientation of these features relative to the spatial relationship between impacted domestic water wells and natural-gas wells in the study area.

*Walter* identified a pair of (vertical or near vertical) orthogonal joints in outcrops within the study area. One set was oriented between N10E and N40E. The other set was oriented between N105E and N130E. The field-observed age relationship between the two sets is contradictory. The observations on the P3 Well Pad and Brown Well Pad outcrops suggest the N10E to N40E set is older, the observations on the Bracken Outcrop suggest the N105E to N130E set is older.

To identify lineaments in the Divide Creek area, *Walter* reviewed the USGS topographic map for the study area. In general, the orthogonal joint sets observed in outcrop (N10E to N40E, and N105E to N130E) are expressed as lineaments on the topographic map. A second pair of lineaments was identified that were oriented differently than the joints observed in outcrop. The more common non-associated lineament set is estimated to be oriented N160E to N170E; the second non-associated lineament set was only observed on the ridge that makes up the central portion of Section 11 at an orientation of approximately N80E.

With the major joint sets and lineaments identified, *Walter* was able to evaluate their orientation relative to the spatial relationship between impacted domestic water wells and natural-gas wells



in the study area.

The compass bearing between the Schwartz 2-15B Well and the West Divide Creek Seep is approximately N130E. This compass bearing coincides with the orientation of the secondary joint set observed in outcrop in the study area (N105E to N130E). The observed non-associated lineament orientations in the Schwartz/Seep vicinity do not coincide with the compass bearing between the Schwartz 2-15B Well and the West Divide Creek Seep (N130E).

The compass bearing between the P3 Pad wells and Dietrich (Moon area) water well is approximately N150E. This measurement does not coincide with the orientation of either joint sets observed in outcrop in the study area. One non-associated lineament was identified on the southwestern end of the ridge in the center of Section 11 oriented approximately N145E. This lineament could be considered as nearly coinciding with the compass bearing between the P3 Pad wells and Dietrich (Moon area) water well.

## 7.0 REFERENCES

COGCC (2004), "Report of the Commission, in the Matter of Alleged Violations of the Rules and Regulations of the Colorado Oil and Gas Conservation Commission by Encana Oil & Gas (USA) Inc., Garfield County, Colorado; Order No. 1V-276." August 2004.

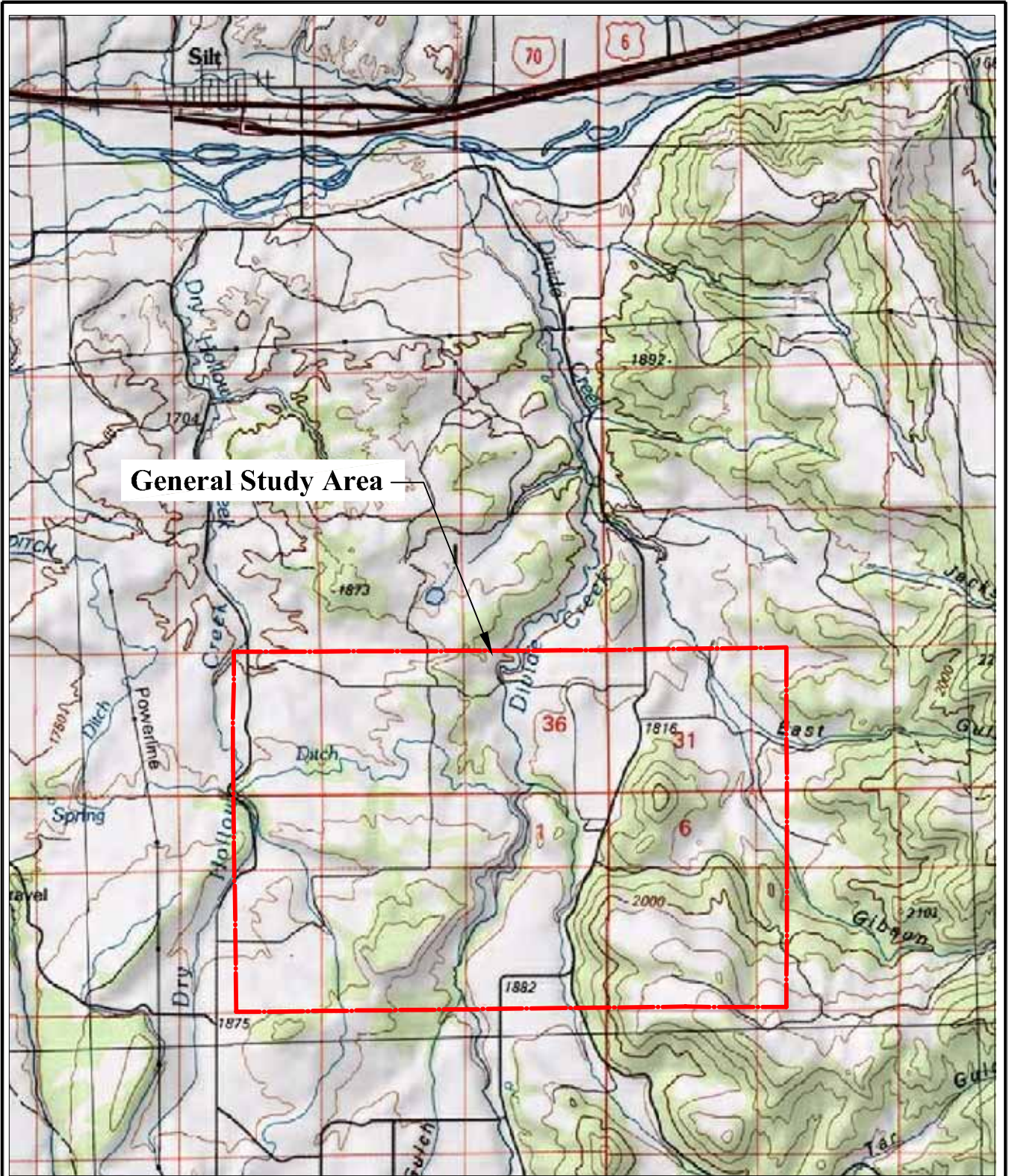
COGCC (2005), "Report of the Commission, in the Matter of Alleged Violations of the Rules and Regulations of the Colorado Oil and Gas Conservation Commission by Encana Oil & Gas (USA) Inc., Garfield County, Colorado; Order No. 1V-297." October 2005.

USGS (1987), "United States Geologic Survey, Topographic Map of the Gibson Gulch, Colorado Quadrangle." 1963, Photorevised 1987.

USGS (1987a), "United States Geologic Survey, Topographic Map of the Hunter Mesa, Colorado Quadrangle." 1963, Photorevised 1987.

**FIGURES**

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Base Map Source: National Geographic Holdings; 2000.



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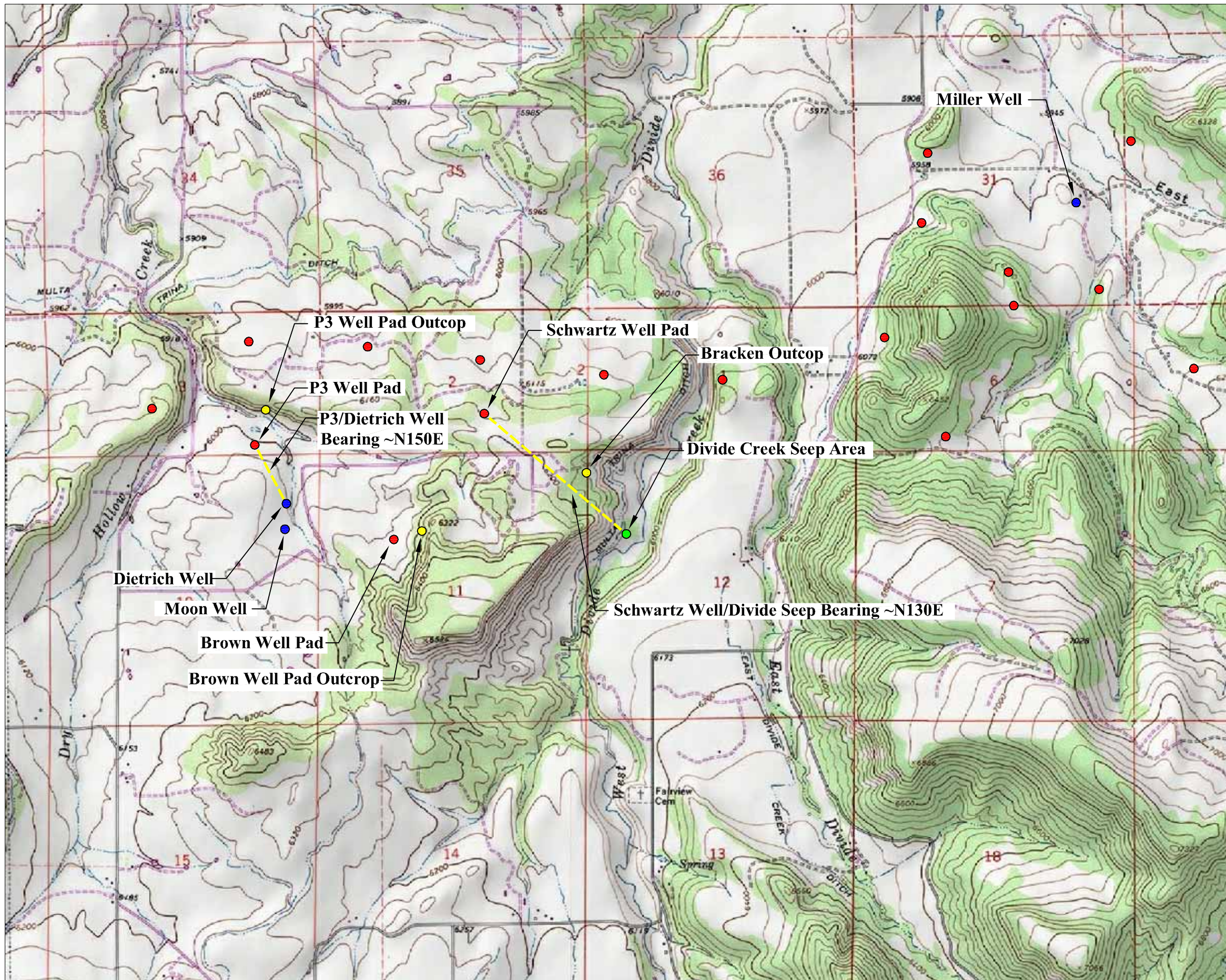
APPROXIMATE SCALE IN MILES

**WALTER ENVIRONMENTAL**  
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**Study Area Location Map**  
Divide Creek Area Joint Study  
South of Silt  
Silt, Colorado

03/03/2011  
Project No. 237-02-003

**Figure 1**



Explanation:

- Domestic Water Well Location
- Gas-Well Pad Location
- Gas Seep Location
- Outcrop Location

Data Sources:

USGS, Gibson Gulch Colo. Quadrangle; 1987.  
 USGS, Hunter Mesa Colo. Quadrangle; 1987.  
 COGCC Online Data; 2010.

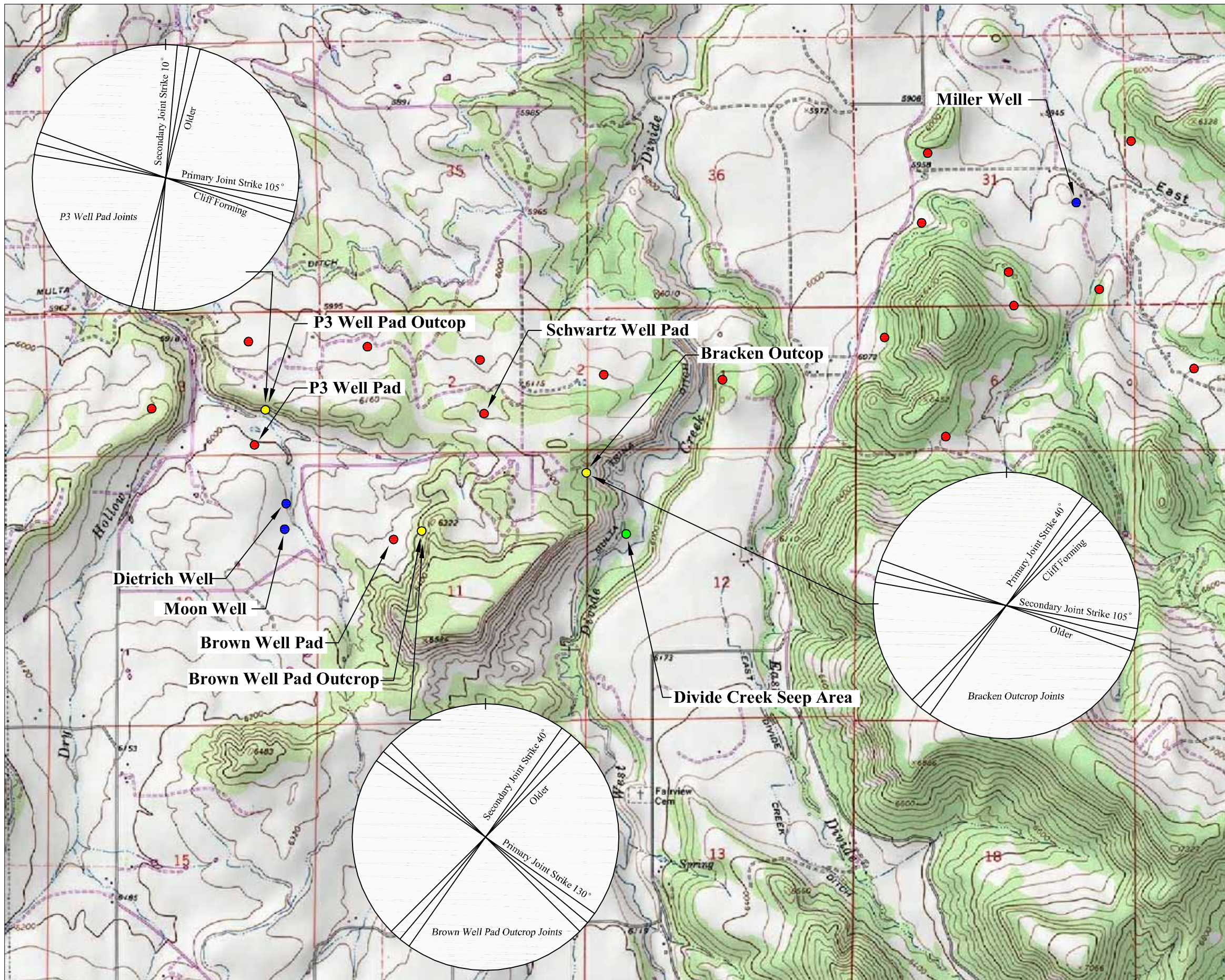
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**Study Area**  
 Divide Creek Area Joint Study  
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 Garfield County, Colorado

03/03/2011  
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**Figure 2**



**Explanation:**

- Domestic Water Well Location
- Gas-Well Pad Location
- Gas Seep Location
- Outcrop Location

**Note:**

Joint strikes are shown with 10 degrees of splay to enhance their appearance on the figure.

**Data Sources:**

USGS, Gibson Gulch Colo. Quadrangle; 1987.  
 USGS, Hunter Mesa Colo. Quadrangle; 1987.  
 COGCC Online Data; 2010.

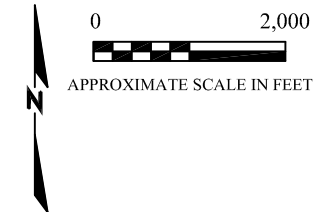
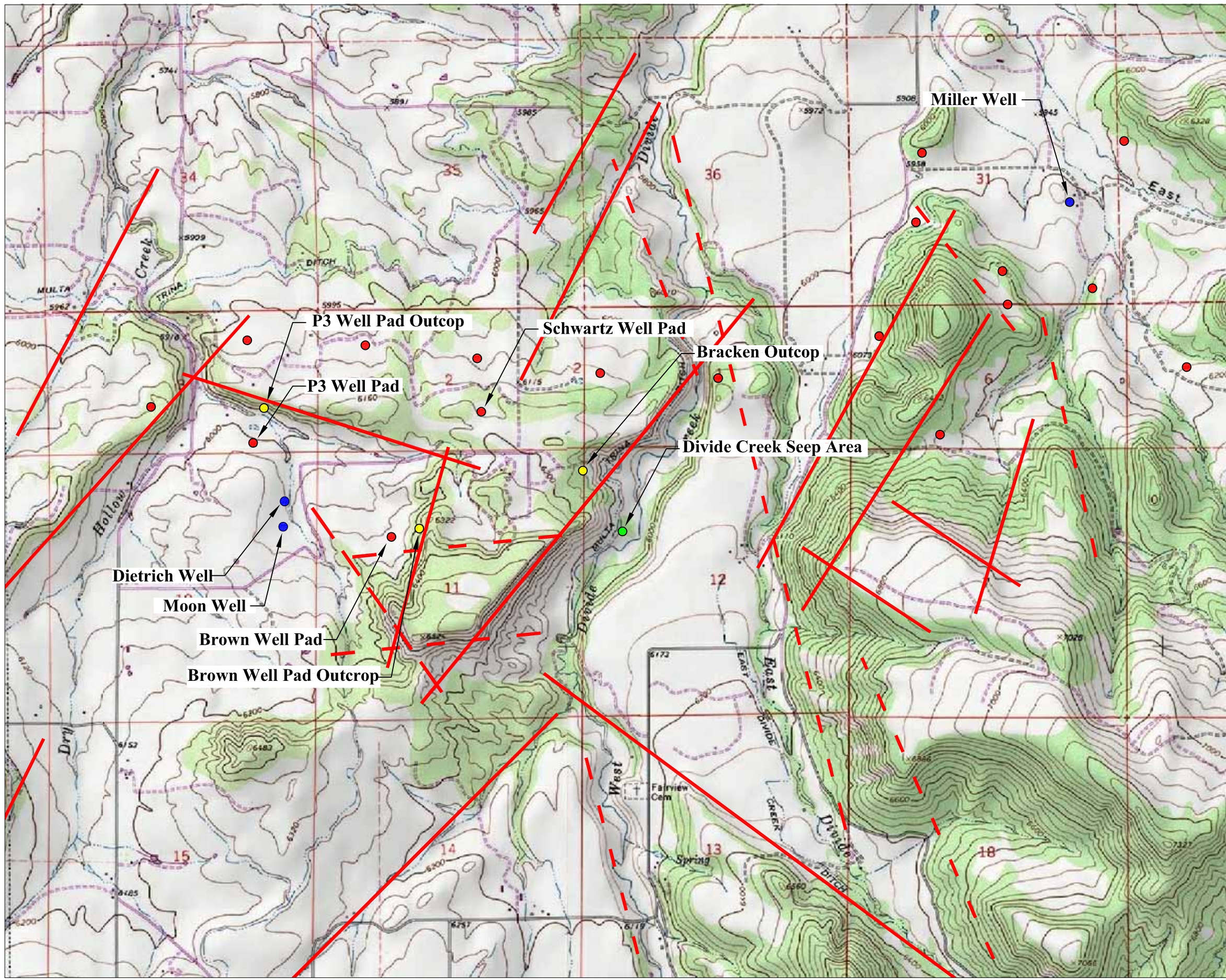
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**Joint Strike Measurements**  
**Divide Creek Area Joint Study**  
**South of Silt**  
**Garfield County, Colorado**

03/03/2011  
 Project No. 237-02-003

**Figure 3**



**Explanation:**

- Domestic Water Well Location
- Gas-Well Pad Location
- Gas Seep Location
- Outcrop Location
- / Lineament with similar orientation to observed joint sets.
- - - Lineament without similar orientation to observed joint sets.

**Note:**

The lineaments identified in this figure were determined by visual inspection of the topography illustrated in the USGS maps shown in this figure. As discussed in the accompanying report, lineaments may be interpreted as the topographic expression of joints.

**Data Sources:**

USGS, Gibson Gulch Colo. Quadrangle; 1987.  
 USGS, Hunter Mesa Colo. Quadrangle; 1987.  
 COGCC Online Data; 2010.

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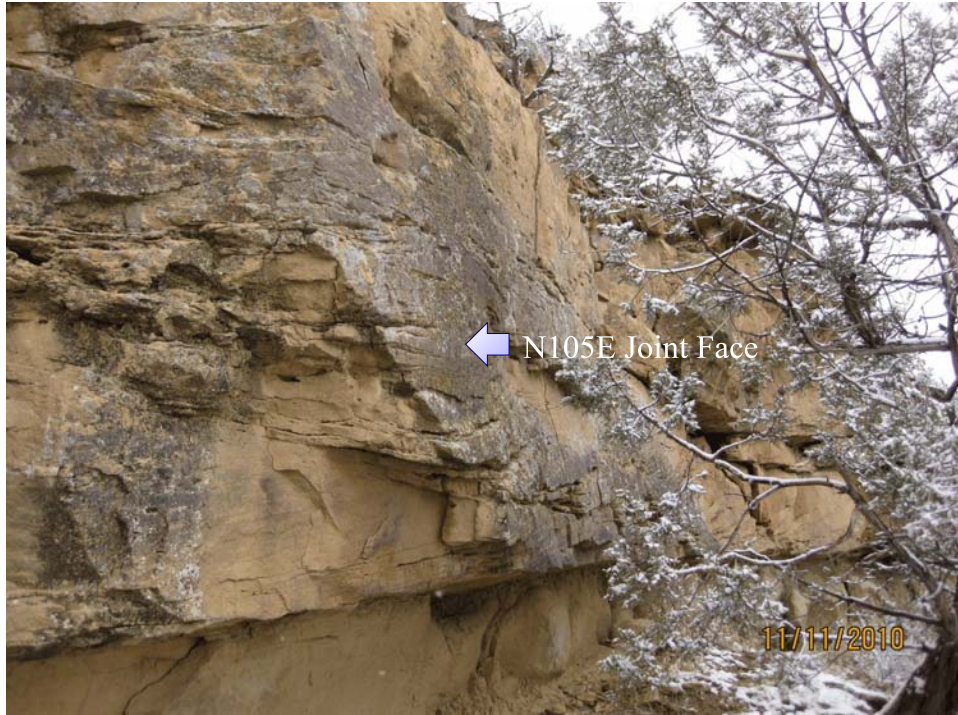
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**Lineaments**  
 Divide Creek Area Joint Study  
 South of Silt  
 Garfield County, Colorado

11/16/2010  
 Project No. 237-02-003

**Figure 4**

## **PHOTOGRAPHS**



Photograph 1 - P3 Well Pad Outcrop  
View to the east of primary vertical joint set; oriented N105E.



Photograph 2 - P3 Well Pad Outcrop  
View to the east of the primary vertical joint set; oriented N105E.





Photograph 3 - P3 Well Pad Outcrop  
View to the south of the secondary vertical joint set; oriented N10E.



Photograph 4 - P3 Well Pad Outcrop  
View of the N105E joint set truncating against the N10E joint set.



Photograph 5 - Brown Well Pad Outcrop  
View to the northwest of the primary vertical joint set; oriented N130E.



Photograph 6 - Bracken Outcrop  
View to the northeast from the top of the outcrop.



Photograph 7 - Bracken Outcrop  
View to the northwest from the road east of the outcrop.



Photograph 8 - Bracken Outcrop  
View to the southwest of the surface expression of the N40E joint set.



Photograph 9 - Bracken Outcrop

View to the southwest of the two pervasive joint sets. Note how the N40E joint set truncates against the N105E joint set.



Photograph 10 - Bracken Outcrop

View to the northeast of the cliff face formed by the N40E joint set.