

# **Silt Mesa Geology And Drilling Considerations**

**Prepared By: Bob Arrington, P.E.**

## Introduction

The old New Castle coal mine fire has burned for years. It caused the Coal Seam fire when it broke to the surface and ignited brush. In the aftermath of the resulting forest fires and property damage, calls were made to extinguish the source fire. The discussion centered on stopping air flow into the old mine. It was concluded to be near impossible to cement all the old faults and sources of air in the broken rock. This is the case in the Silt Mesa geology.

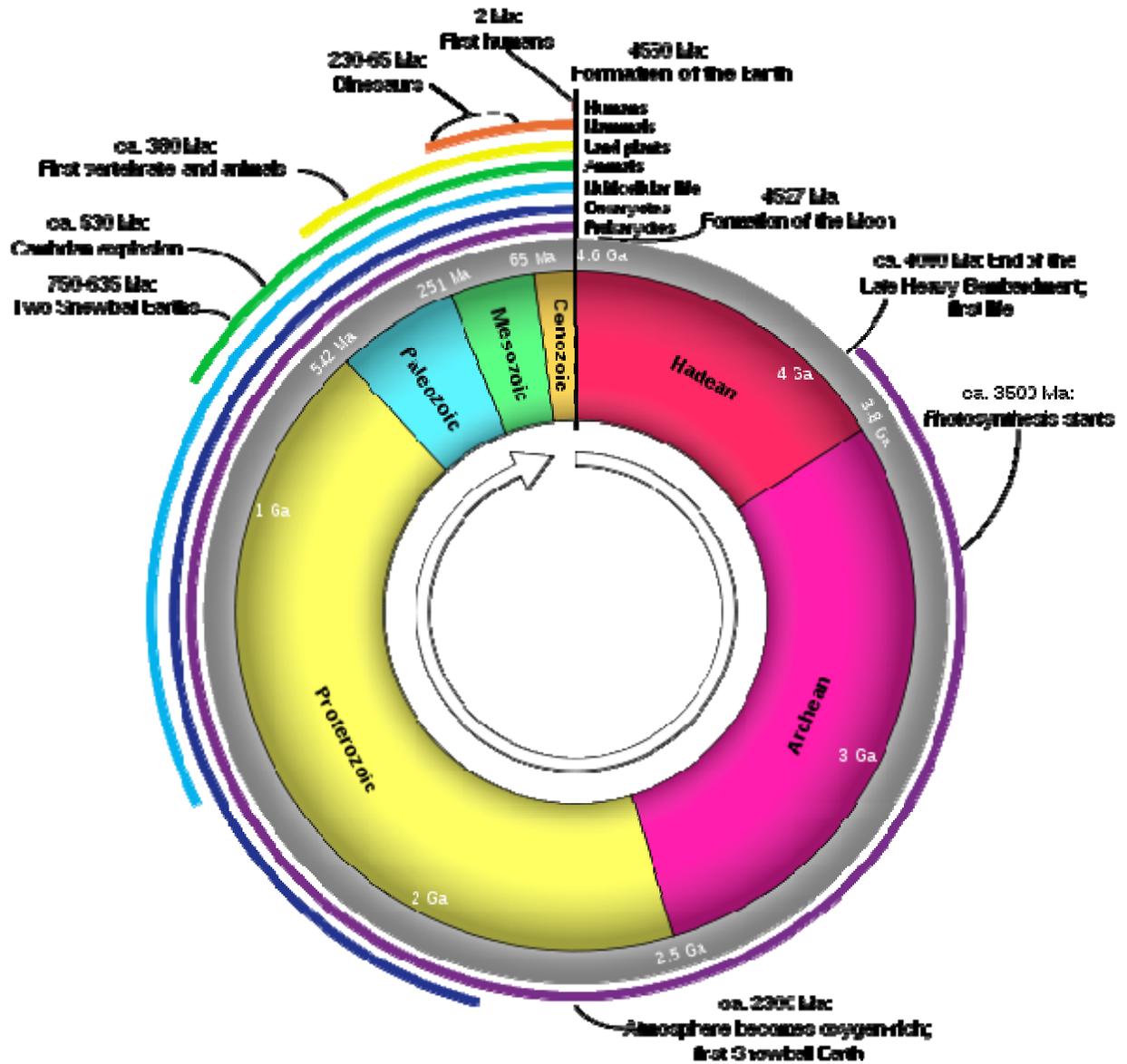
The beds turn up here in the Grand Hogback and have been pushed up in the Divide Creek anticline and pushed down in the Rifle – Grand Hogback syncline between them. The uplift has been on the North, East and South of Silt Mesa. There has been a volcanoclastic bed laid down underneath the planned beds of harvesting. This latter bed is very likely rich in sulfur and porous in composition.

URS Corporation engineering did an extensive study from Silt to Rifle South of the Colorado River as part of the Mamm Creek Study, Phase I. They prepared Figure 2-11 and 12 that illustrates the extreme faulting of the area. Entire blocks were pop-up from thrusting forces upward and horizontally. In addition to the crustal thrusting, erosion unloading has also taken place resulting in further bed fracturing.

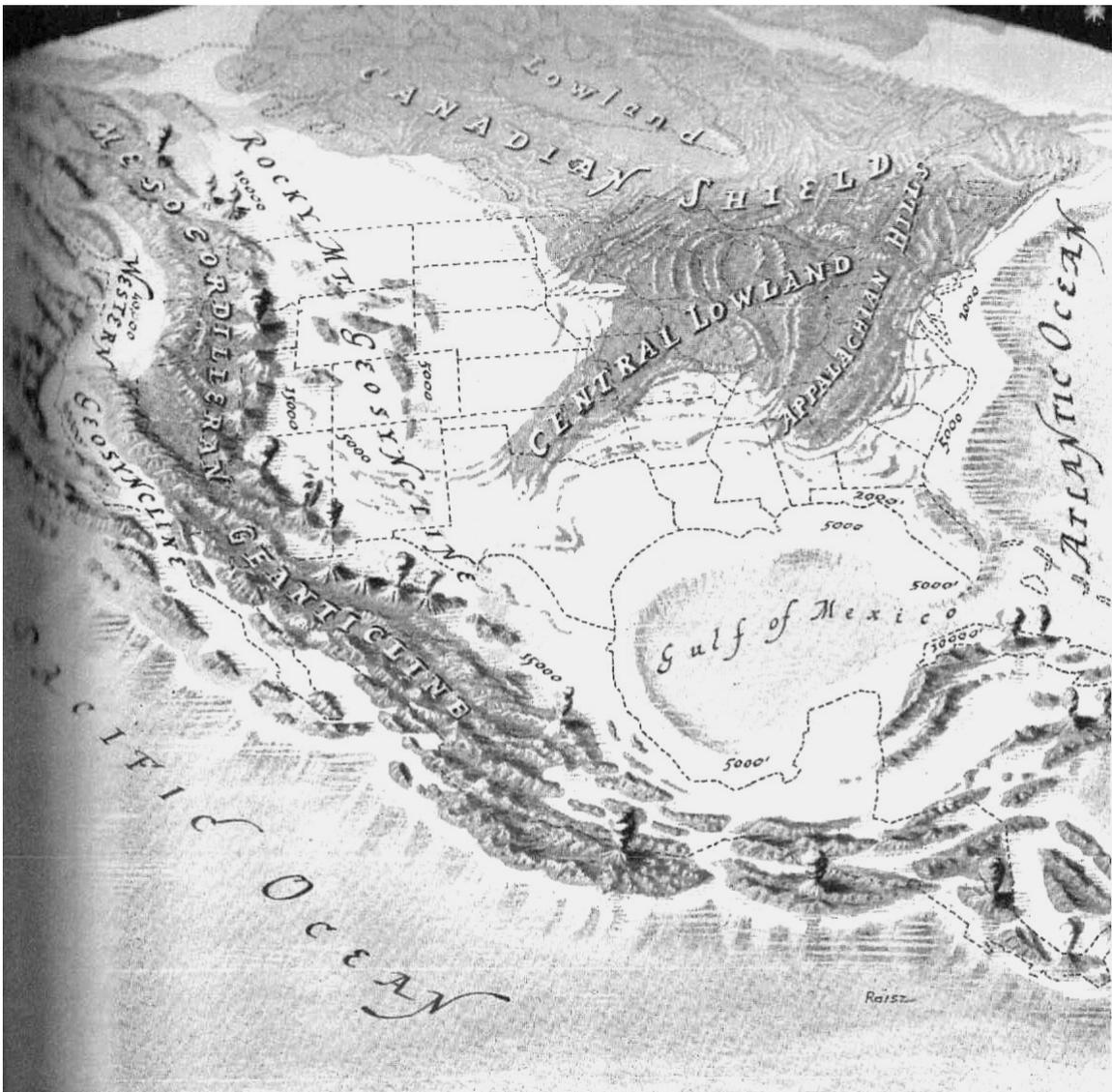
The relatively shallow drilling depths do not appear to be going for the Williams Fork formation that becomes exposed on the southern flank of the hogback and is the most common target for gas extraction. The harvesting appears to be in the Wasatch formation which is usually considered less adaptable to commercial extraction. This shallow depth is close to a point of overlayment pressure where fractures by hydraulic fracturing will change from vertical to horizontal and control techniques could rapidly change on a fracturing stage. The skill of fracturing technicians to quickly adjust to new parameters could be severely tested. Because all of these beds are surface exposed, water infiltration from irrigation, rainfall, and riverbed seepage can be expected to occur through any available migration path.

The magnitude of the uplift is from a sea level or below elevation to a mile high elevation and then having basement rock push through and lay back the edges of these sedimentary surfaces. The following pages will provide visual complement of the bending, uplift and break through discussed. These figures and maps from the United States Geological Survey, URS Mamm Creek Phase I, *The Principles of Historical Geology*, and my own design are presented to show the resultant geology of Silt Mesa and the forces that formed it in a relatively short time in Earth's history. This history supports the conclusion of extensive faulting and breaking of rock that could cause severe hydrogeological problems to the area's water tables and natural supply.

## GEOLOGIC TIME SCALE



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*The Cretaceous sea flooded the continent from the Gulf of Mexico. It joined a sea advancing south from the Arctic, producing one of the continent's most complete inundations. But by the close of the period the sea had almost completely withdrawn from the continent. In the West great batholiths were intruded, and in the geosynclines thick sediments were deposited. Ashes and lava covered much of Arizona, California, Mexico, and the Antilles. The Gulf of Mexico filled with sediments. The Laramide revolution completely reshaped the West.*

## MESOZOIC ERA<sup>1</sup>

<sup>1</sup> *The Principles of Historical Geology, J.W. Stovall and H.E. Brown, Ginn and Company. 1955*



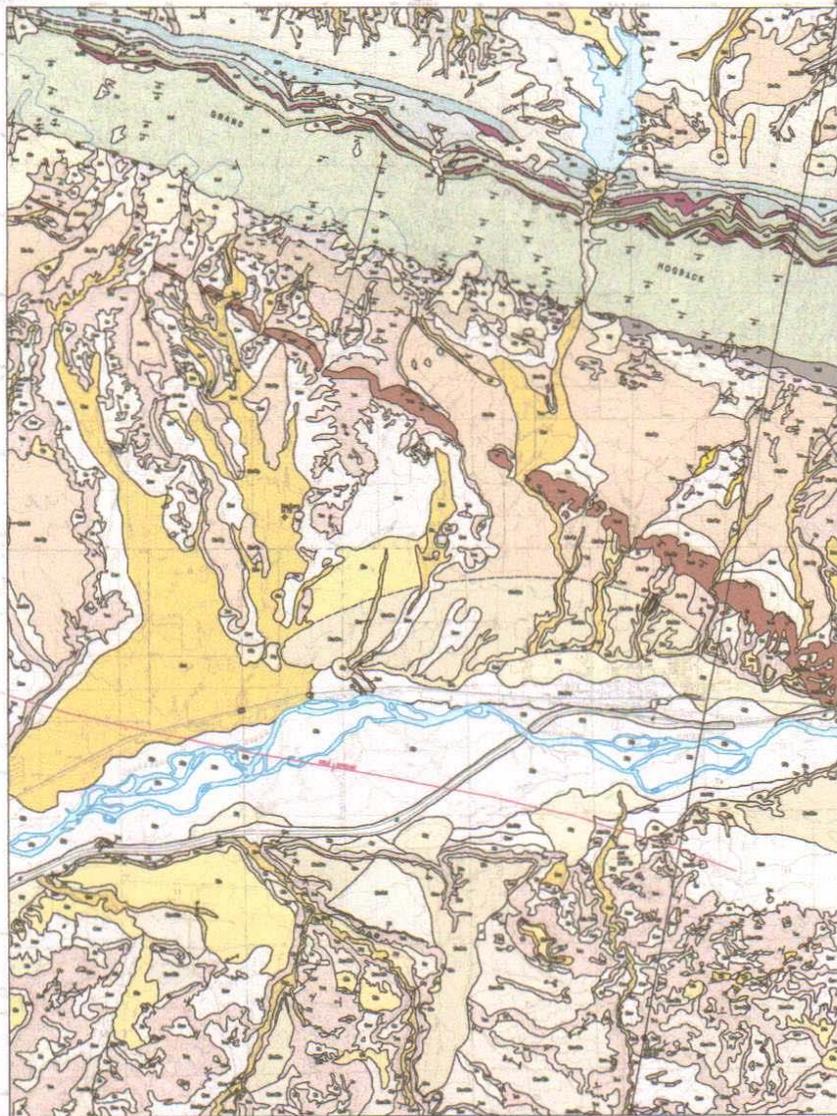
*With the Laramide revolution, Tertiary North America attained generally its present shape. The coastal plain was submerged. The Appalachians were repeatedly peneplained, uplifted, and redissected. The eastern slopes of the Rocky Mountains were covered by immense thicknesses of gravel, merging into sand and loess eastward. The volcanoes of the Pacific coast poured out thousands of feet of lava, from the Columbia River to Panama. At the end of the period, the Cascadian revolution raised the Sierras and the Rockies and up-arched the Appalachians. The period culminated in the Ice Age.*

## CENOZOIC ERA<sup>2</sup>

<sup>2</sup> *The Principles of Historical Geology, J.W. Stovall and H.E. Brown, Ginn and Company. 1955*



U.S. DEPARTMENT OF THE INTERIOR  
U.S. GEOLOGICAL SURVEY

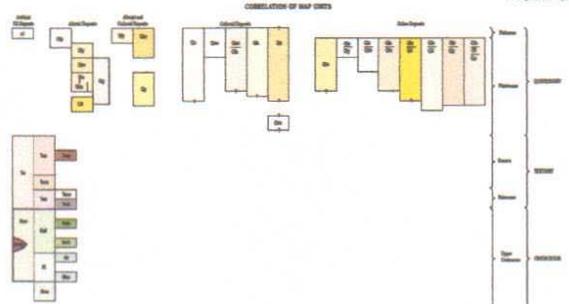


Base map U.S. Geological Survey 1987  
Reprints available, USGS Book Store Order

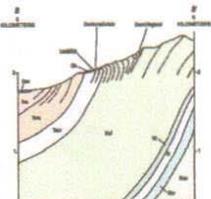
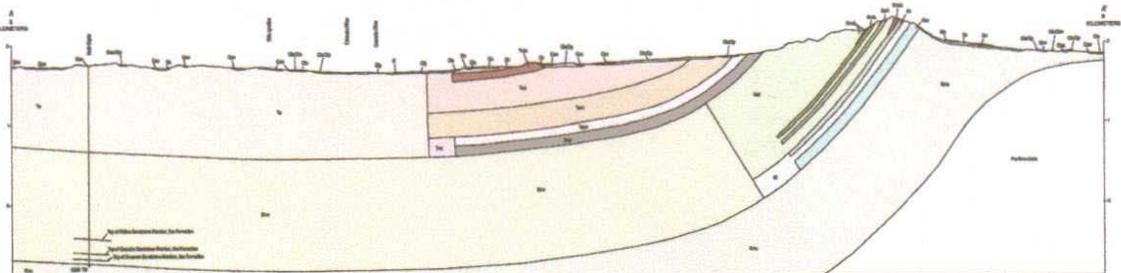
Scale 1:50,000

Geologic symbols as shown on the accompanying legend are used throughout this map. Symbols for faults, folds, and other structural features are shown as appropriate.

MISCELLANEOUS FIELD STUDIES MAP MF-2331  
Scale 1:50,000  
Partial reconnaissance map



- LIST OF MAP UNITS**
- | ARTIFICIAL DEPOSITS     | ALLUVIAL DEPOSITS        | ALLUVIAL AND COLLUVIAL DEPOSITS        | COLLUVIAL DEPOSITS       | COLLUVIAL DEPOSITS       | REWORKED UNITS           |
|-------------------------|--------------------------|--|--------------------------|--------------------------|--------------------------|
| Artificial fill (brown) | Recent alluvium (yellow) | Recent alluvium and colluvium (yellow) | Recent alluvium (yellow) | Recent alluvium (yellow) | Recent alluvium (yellow) |
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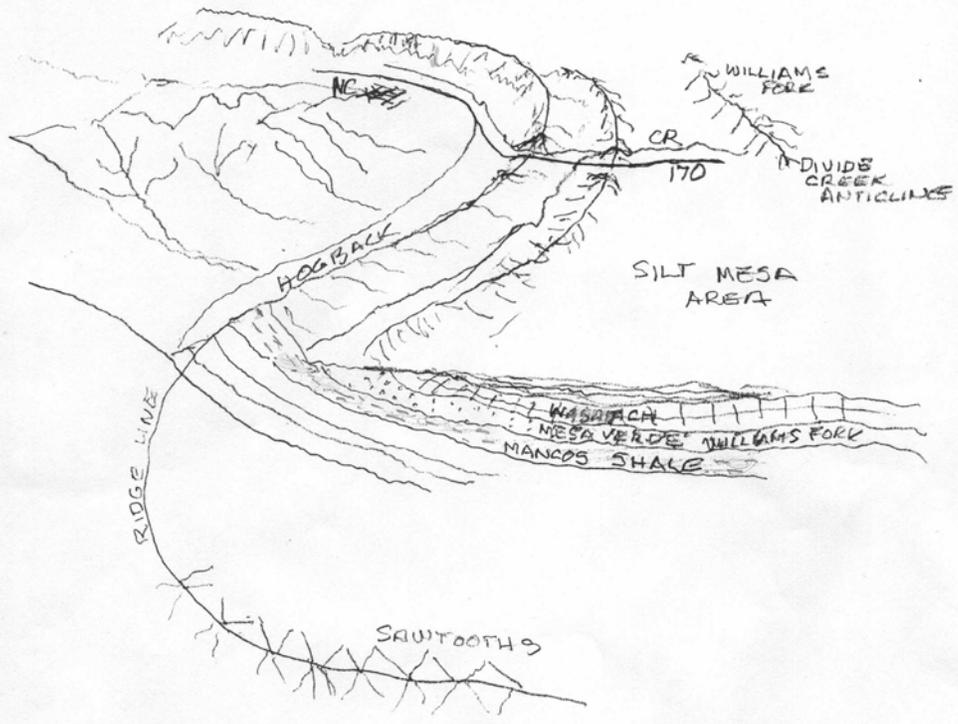


**GEOLOGIC MAP OF THE SILT QUADRANGLE, GARFIELD COUNTY, COLORADO**

By  
Ralph R. Stroba and Robert B. Scott

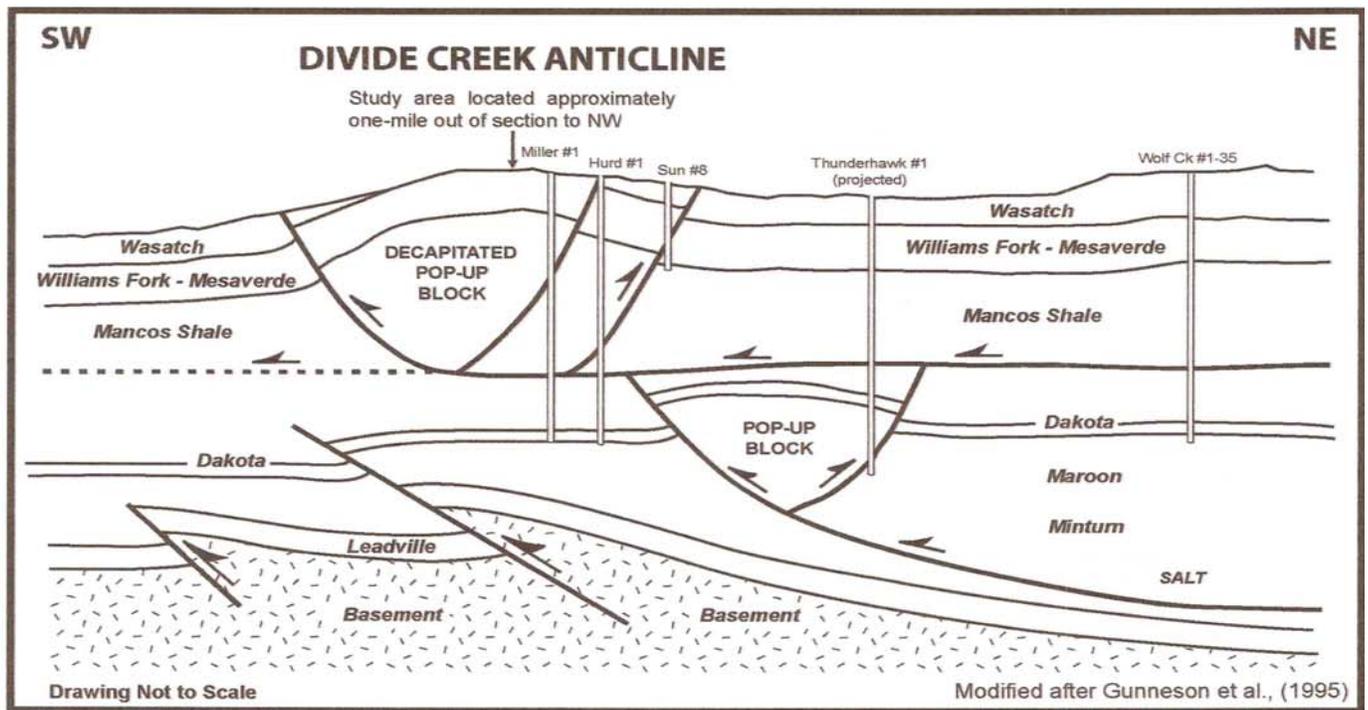
2001

This map is a partial reconnaissance map and is not suitable for engineering or other purposes requiring a high degree of accuracy. It is intended for general reference only.



Not to any scale - Generalization of area with view Southerly.  
 Divide Creek anticline is Northwest - Southeast alignment and Williams Fork - Mesa Verde formation of pop-up block.  
 Hogback bounds the East and North of Silt Mesa area. New Castle East of Hogback and Silt West.

Drawing by Arrington



Schematic interpretation of Divide Creek Anticline and related producing fields. In the interpreted sequence of structural development, the shallower pop-up anticline was decapitated and thrust westward due to later thrusting from the east along the Mancos detachment, leaving the deeper pop-up block to the east. A deeper, basement-involved structure is also present to the east.

**Legend**

Major Geologic Structures

- ▲— Syncline
- ▲— Basement Fault (Approximate)
- ▲— Anticline

Aeromagnetic Anomalies

- Shallow
- Transitional
- Basement

- F1 Joints
- F2 Joints
- F3 Joints
- F4 Joints

- ↔ Stress Orientation from Drill Hole
- ↔ Stress Orientation from Mine

Study Area

Source: Tremain and Tyler (1996),  
 Tyler, McMurtry and Zhou (1996)



**Figure 2-10**  
**Geologic Structures**

## Concepts Implied in O & G Geology

***In addition to the protections provided by multiple casings and cements, there are natural barriers in the rock strata that act as seals holding the gas in the target formation. Without such seals, gas and oil would naturally migrate to the earth's surface. A fundamental precept of oil and gas geology is that without an effective seal, gas and oil would not accumulate in a reservoir in the first place and so could never be tapped and produced in usable quantities. These sealing strata also act as barriers to vertical migration of fluids upward toward useable groundwater zones.***<sup>3</sup>

(This was formulated on geology of early oil and gas discovery sites. Moreover, water is often the agent to seal or impound in geological basins. *Arrington*)

The problem with this reasoning is in the tight sands and shale the gas is trapped interstitially in the matrix of the formation or even lenses of porosity (tight sands) within the bed and sealed by the bed structure itself. Theory has gas migrating to the lenses, but the lenses of porosity are more likely caused by gas being trapped in the bed during formation as opposed to migrating there. Leakage occurs in all after formation with geologic movement at a very low release rate from local faces of cracks and breaks like those introduced or stimulated by fracking. It also occurs when beds become exposed on the surface. In exposed beds, gas can still be found like the beds were closed cell foam, away a moderate distance from the exposure face. These beds are labeled “unconventional” beds. With fracturing, they are now finding oil can be harvested like gas from some shale like the Niobrara. In conclusion it can not be stated the overlay beds have kept the gas “trapped” and are a “seal”.

***The very fine sheet-like clay mineral grains and laminated layers of sediment result in a rock that has limited horizontal permeability and extremely limited vertical permeability. Typical unfractured shales have matrix permeabilities on the order of 0.01 to 0.00001 millidarcies<sup>76</sup>. This low permeability means that gas trapped in shale cannot move easily within the rock except over geologic expanses of time (millions of years).***<sup>4</sup>

Therefore, there is a basic fault of reasoning that upper beds will prevent gas migration once released from host bed. Any sealing is dependent on composition (imperviousness) and integrity. Even if it were axiomatic, there can be many faults, previously filled with gas or not, that will become conduits with the fracking of the laden beds and closer downhole spacing intersection. Truly, if probability were taken closer to zero leakage, the cementing would have to go to the laden bed and fracking could not be allowed into any ceiling bed. Leaving the fracking of ceiling beds to “poor economic practice” is not even utilizing the questionable protection of that sealing capability.

This brings the conclusion that in a densely faulted zone, much gas has found its way out over millions of years and has become stabilized. Any gas recovery operations will renew gas flow into old paths from new sources that were not originally depleted from natural fracturing. There is every indication the normally less productive Wasatch is saturated at its' lower depths and is the target for harvest. There are no “sealing” beds of consequence and USDWs (Underground Sources of Drinking Water) are sure to be compromised.

## Mitigations or Consequences

With directional drilling able to reach 5000 feet or more horizontally, the tendency of granting permits with more than one pad per square mile must be reviewed to much closer scrutiny and pooling arrangements utilized to assure all parties have fair distribution. The trend to more pads

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<sup>3</sup>*Modern Shale Development in the United States: A Primer; U.S. Department of Energy, Office of Fossil Energy, National Energy Technology Laboratory, April 2009*

<sup>4</sup> *Ibid.*

must be reversed to a measured necessity. Thusly, spills, ground and water contamination, stringing of pipelines, access roads and traffic, air pollution are all reduced. Inspected metering of a well gas flow must be required to assure fair distribution of economic gains.

Because drilling will be in zones sure to intercept faults, the release of gas into the hydrology can be reduced by requiring cementing of bore holes to the fracking zones. This will reduce the gas flow to faults through the annulus intersection of faults. After re-cementing in the Divide Creek release, gas seepage was reduced. Cementing will also reduce production waters and chemicals from exiting into bore hole/fault intersections. The hydraulic fractures intersecting faults will still allow such contamination.

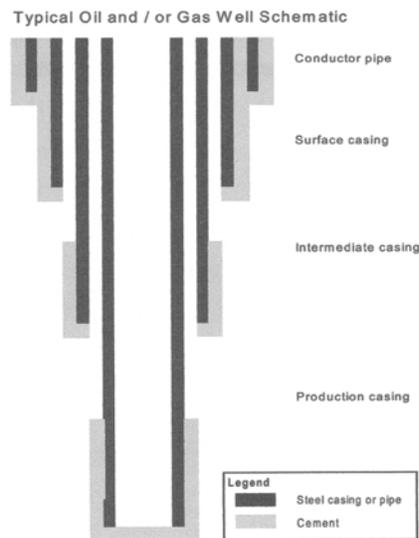
Two aspects here must be considered. The first being fresh water is a more valuable commodity and a priority resource above and beyond any rendering of making it unavailable or contaminated such that natural cleansing and rejuvenation can't be used to make it readily available in its flow system without significant loss. The other aspect is a loss of surface use that should be compensated fairly and that loss should be minimized to the greatest extent. Damage to water is a major consideration legally defining loss of property value. The loss of use land is balanced against lease gains, but it is a legal "stigma" effect for neighbors.

Since my first discourse on this likely water damage, The Silt Water District has proposed expansion into these areas. If the expansion were agreed to by residents before damage to the existing system, the residents receiving this service would be liable for the all expansion costs. If the existing USDW systems were damaged requiring replacement by such an expansion, the County and the gas drilling company could be liable for the system costs and the difference in water costs and limits of usage.

### **What is happening With Drilling?**

The next pages are intended to clarify some of the conversation that occurs about what is happening with drilling. I will take some simplified graphics and excerpts from publications to help define what terminology and reference is taking place.

From *Hydraulic Fracturing Operations – Well Construction and Integrity Guidelines*, API Guidance Document HF, First Edition, October 2009, pgs. 5, 6 (API – American Petroleum Institute, a standards organization). These are general representations and the document is not binding or minimum requirements, it is an industry Guidance only.



Casing used in oil and gas wells that will be hydraulically fractured should meet API standards, including API Spec 5CT. API casing specifications and recommended practices cover the design, manufacturing, testing, and transportation. Casing manufactured to API specifications must meet strict requirements for compression, tension, collapse, and burst resistance, quality, and consistency. The casing used in a well should be designed to withstand the anticipated hydraulic fracturing pressure, production pressures, corrosive conditions, and other factors. If used or reconditioned casing is installed in a well that will be hydraulically fractured, it should be tested to ensure that it meets API performance requirements for new built casing.

Casing and coupling threads should meet API standards and specifications to ensure performance, quality, and consistency, including API Spec 5B. If proprietary casing and coupling threads from a specialized supplier are used, these threads must also pass rigorous testing done by the supplier and should adhere to applicable subsets of the API qualification tests.

## 5 Cementing the Casing

### 5.1 General

After the casing has been run into the drilled hole, it must be cemented in place. This is a critical part of well construction and is a fully designed and engineered process. The purpose of cementing the casing is to provide zonal isolation between different formations, including full isolation of the groundwater and to provide structural support of the well. Cement is fundamental in maintaining integrity throughout the life of the well and part of corrosion protection for casing.

Cementing is accomplished by pumping the cement (commonly known as slurry) down the inside of the casing, and circulating it back up the outside of the casing. Top and bottom rubber wiper plugs should be used to minimize mixing of cement with drilling fluid while it is being pumped. A downhole schematic of a cement job in progress is illustrated in Figure 2.

Note: The surface casing is supposed to be deeper than the deepest well in the area. *Arrington*

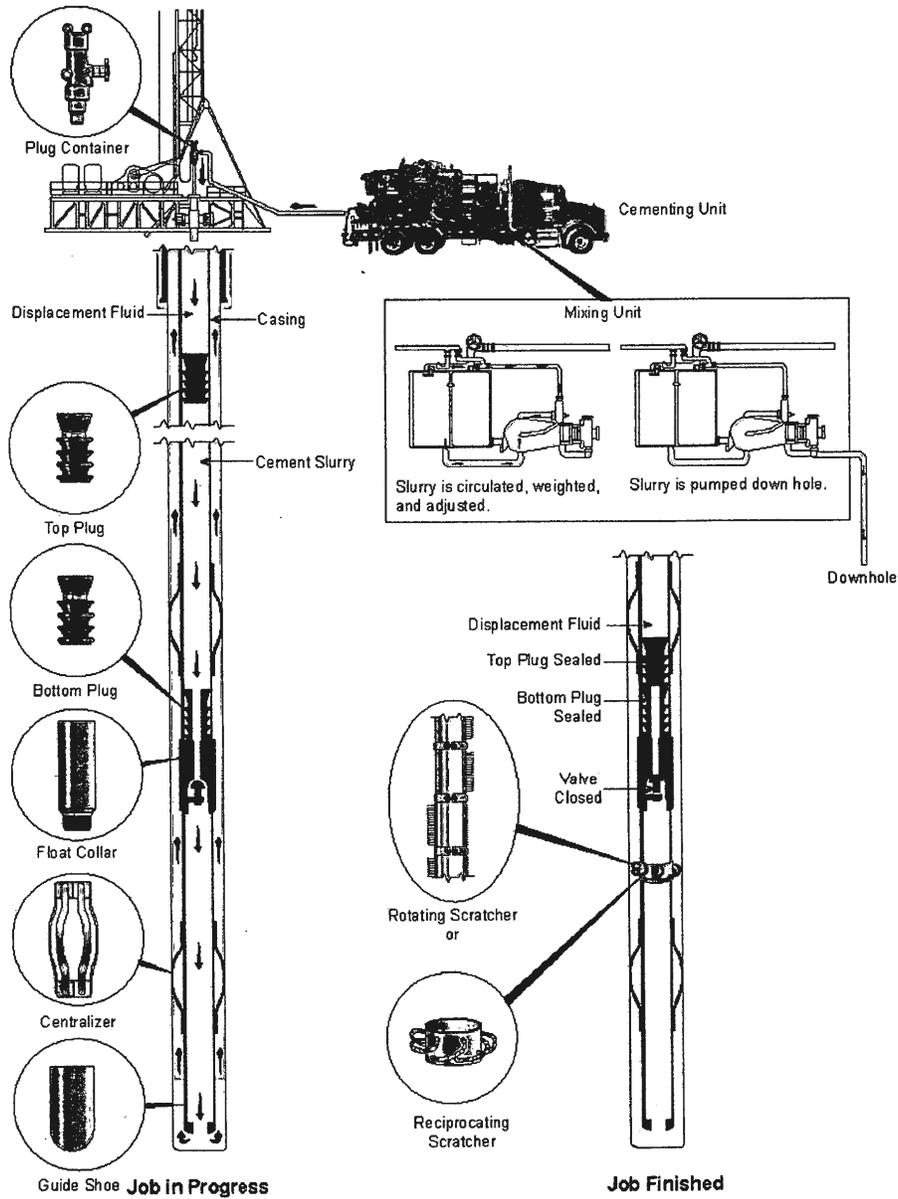
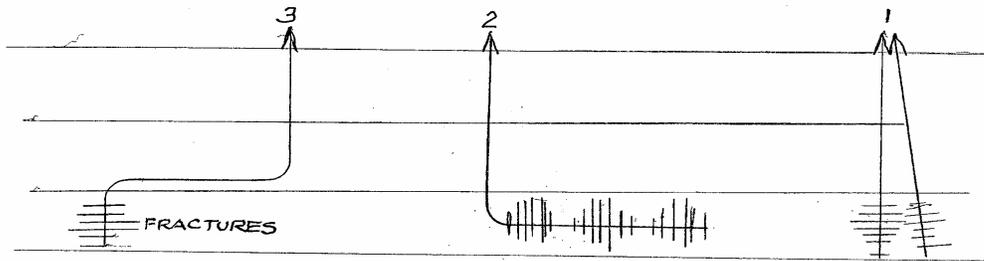


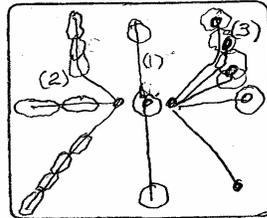
Figure 2—Cementing the Casing

Note: Chevron cements its' wells to the fracking zone and runs logs on the cement work with third party review. Directional drilling has a requirement for Centralizers to center casing on direction changes. *Arrington*

The following *Profiles* and *Patterns* exemplify how the bores may be guided to harvest locations. *Patterns* is a top view looking down. The common profile being used in directional drilling in this area is # 3. These profiles are represented by their numbers in *Patterns*.



**Profiles of Bores**



**Patterns of Directions**

Profile 1 - vertical or slant bore usually "targeting sweet spots".  
 Profile 2 - directional bore with fracture along horizontal run.  
 Profile 3 - directional bore down, horizontal, down with fracture on final down.  
 More turns increase drag on drill steel and increase cementing difficulty unless centering devices are used on casing.

*Chart by Arrington*

## Fracturing

This chart was used to determine practice of fracturing distances. A fracture half-length is the distance from the well bore outward. It is a half-length as it goes out each side of the bore.

The more common distance seemingly used, from discussion with engineers, for the Piceance formations appears to be up to ~300 feet.

TABLE 2—TIMES REQUIRED TO REACH LINEAR AND PSEUDORADIAL FLOW FOR A WELL CONTAINING A HYDRAULIC FRACTURE				
Formation Permeability (md)	Fracture Half-Length (ft)	Start of Linear Flow (days)	End of Linear Flow (days)	Start of Pseudoradial Flow (days)
0.001	100	341	1,752	4,545
	500	8,523	43,788	113,636
	1,000	34,091	175,152	454,545
0.01	100	34	175	455
	500	852	4,379	11,364
	1,000	3,409	17,515	45,455
0.1	100	3	18	45
	500	85	438	1,136
	1,000	341	1,752	4,545
1	50	0.1	0.4	1.1
	100	0.3	1.8	4.5
	250	2.1	10.9	28.4

Assumptions  
 Porosity = 0.1 (fraction)  
 Viscosity = 0.02 cp  
 Compressibility = 0.002 Psi<sup>-1</sup>

Society of Petroleum Engineers, “Distinguished Author Series”, Stephen A. Holditch, SPE, Texas A&M U., pg.88, <http://www.holditch.com/LinkClick.aspx?fileticket=VbXfjM52eWY%3d&tabid=2716&mid=4003>

Using a half-length of 325 feet would provide a 650 foot fracture centered by the well bore and this would approximate the radial distance of a 10 acre spacing. It must be realized that the 10 acre space will have almost complete coverage of fractures.

With a horizontal directional capability up to 5000 feet, a 3250 foot reach is all that is necessary to cover every 10 acre parcel in a section from a central point. This would require 64 wells to accomplish. This is supported in:

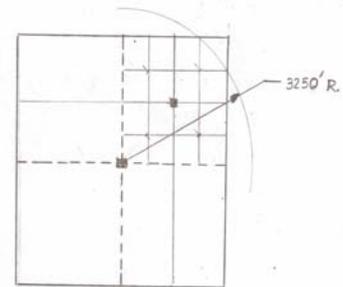
[www.pinedaleonline.com/socioeconomic/pdfs/tight\\_gas.pdf](http://www.pinedaleonline.com/socioeconomic/pdfs/tight_gas.pdf)

**Tight Gas Reservoirs – An Unconventional Natural Energy Source for the Future**  
**G.C.Naik**

**New Technology Concepts**

"Township Drainage" - The concept of draining an entire "township" with a single surface area of activity is required, in contrast to the multiple location approach. This can be achieved by "**Well Clusters**" in potential tight-gas productive areas.

The drawing represents a section. The quarter section has been sub-divided to quarters and 10 acre parcels. The 3250 foot radius shows the distance to the center of an extreme 10 acre parcel. The small black square is the relative position of a centered quarter section pad. The larger black square is the relative center of the section. To cover the quarter section from its' relative center would require 16 well bores for a total of 64 well bores for all for quarters.



## Fracturing Depth

The following is introduced to show that the 3000 foot depth of drilling is very close to the depth of 2000 feet that marks a general transition of vertical/horizontal cracking planes in formations. If from bottom of hole, fracturing is staged upward for a thousand feet in two overlaying beds, the lower fracturing can be vertical in plane and up well can change to horizontal. The control of the fracturing would be rapidly changing and the extent could easily escape control or fracture into faults or sloping upper bed. Figures 6 and 7 illustrating the change are on page following.

### **Hydraulic Fracturing Operations— Well Construction and Integrity Guidelines** API GUIDANCE DOCUMENT HF1, FIRST EDITION, OCTOBER 2009 Excerpt from page 16

#### **9.2 Horizontal Fractures**

Hydraulic fractures are formed in the direction perpendicular to the least stress. In Figure 6, an imaginary cube of rock is shown as having confining stress exerted on it in three dimensions. Each pair of opposing stresses must be equal in order for the cube to remain stationary in space. The relative size of the arrows represents the magnitude of the confining stress. In Figure 7, the least stress is in the vertical direction. This direction is known as the direction of overburden, referring to the weight of the earth that lies above. The Earth's overburden pressure is the least principal stress only at shallow depth. Based on experience, **horizontal fractures will occur at depths less than 2000 ft.** In this example, when pressure is applied to the center of this block, the formation will crack or fracture in the horizontal plane as shown, because it will be easier to part the rock in this direction than any other direction. In general, these fractures are parallel to the bedding plane of the formation.

#### **9.3 Vertical Fractures**

As depth increases, overburden stress in the vertical direction increases by approximately 1 psi/ft. As the stress in the vertical direction becomes greater with depth, the overburden stress (stress in the vertical direction) becomes the greatest stress. This situation generally occurs at depths greater than 2000 ft. This is represented in Figure 7 by the magnitude of the arrows, where the least stress is represented by the small red horizontal arrows, and the induced fracture will be perpendicular to this stress, or in the vertical orientation. Since hydraulically induced fractures are formed in the direction perpendicular to the least stress, as depicted in Figure 7, the resulting fracture would be oriented in the vertical direction. The extent that the created fracture will propagate in the vertical direction toward a USDW is controlled by the upper confining zone or formation. This zone will stop the vertical growth of a fracture because it either possesses sufficient strength or elasticity to contain the pressure of the injected fluids.

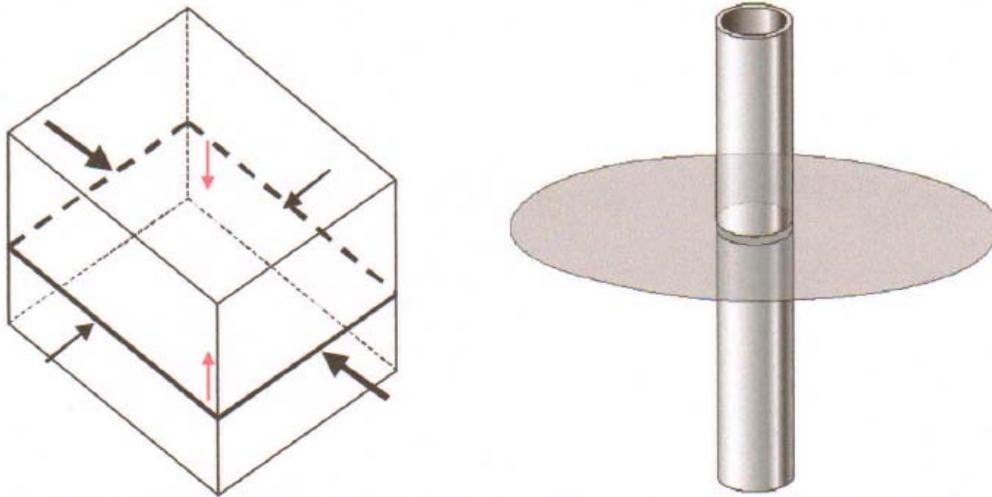


Figure 6—Least Principal Stress is in the Vertical Direction Resulting in a Horizontal Fracture

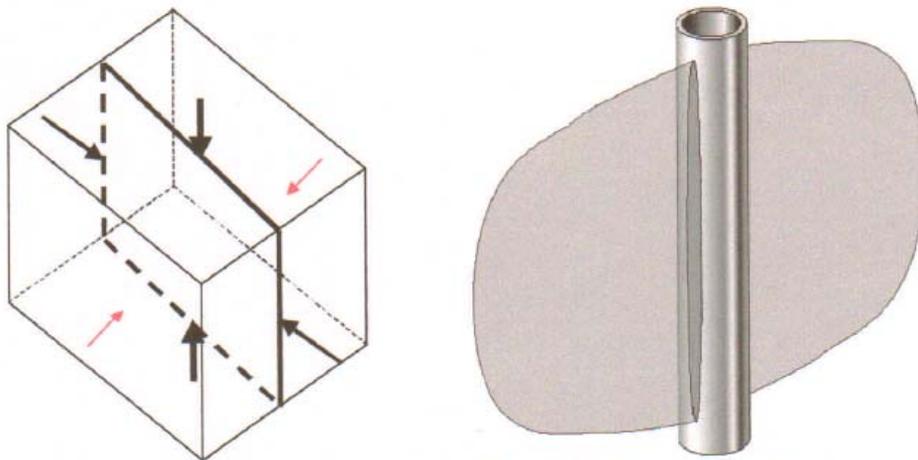


Figure 7—Least Principal Stress in the Horizontal Direction, Vertical Fracture

From information provided by the URS Corporation:

**Excerpt From (with *comments* and highlights added):**

PHASE I HYDROGEOLOGIC CHARACTERIZATION OF THE  
MAMM CREEK FIELD AREA IN GARFIELD COUNTY

*Prepared for*

Board of County Commissioners

Garfield County, Colorado

March 23, 2006

URS Corporation

8181 East Tufts Avenue

Denver, Colorado 80237

Project No. 22238121.00006

**4.1.1 Data Evaluation for Potential Gas Well Problems**

The data were reviewed from the perspective of activities associated with well drilling, completion and production that could potentially impact surface and groundwater resources.

There are several areas that are important:

- Integrity of the cementing job
- Height of cement above the top of gas
- Production casing integrity
- Depth of surface casing relative to depth of potable water
- Integrity of surface casing cement job
- Perforation and frac intervals and procedures
- Presence of significant subsurface fracture zones
- Bradenhead pressure measurements
- Well plugging and abandonment

Typically, a substantial interval of the annular space outside the production casing is not sealed with cement. There is no cement in the region located below the base of the surface casing down to the top of the cement used to seal the production (perforated) interval. Within this uncemented interval, gas pressure, if any, will be monitored at the wellhead as bradenhead pressure.

However, if a gas well production casing is adequately cemented to a height above the top of known gas occurrence, and the cement retains its structural integrity during the perforation and frac completion activities, then there should be no leakage of gas or other fluids into or up the annulus. If the cement does not extend above the depth of the uppermost gas occurrence, gas can flow into the wellbore and up the annulus. This gas, if present at sufficient pressure, can enter potable water supplies if the depth of the surface casing and cement does not extend below the waterbearing zone. This gas can also leave the wellbore and flow out into the surrounding formation, either through permeability within the rock matrix and/or along fractures that intersect the annulus.

*Or natural fractures that intersect the hydraulic fracturing of the gas formation. Arrington*

At the Schwartz 10-2B well, a faulty cement job allowed gas and associated hydrocarbons to migrate over 2,000 feet southeast of the well, evidently along a fracture system, and seep into

West Divide Creek. The failure of the cement job was attributed to an underpressured zone or a natural fault or fracture.

#### 4.2.4 Bradenhead Pressure

Bradenhead pressure is pressure in the annulus measured at the wellhead, and is indicative of gas under pressure within the well annulus. Although wells with measured bradenhead pressures may indicate micro-annular gas migration from completion problems (incomplete cementation of the well annulus), a slow leak in the production casing, or a wellhead seal leak, or the presence of thermogenic or biogenic methane present in shallower rock intervals (i.e. Wasatch Formation). Because the well annulus interval above the producing interval and below the surface casing is not sealed, if the cause of the elevated bradenhead pressure is not corrected through remedial cementing, gas and other formation fluids could move up the well annulus from the producing zone. There is a potential for fluids or gas to enter fractures (if present) below the base of the surface casing, within the overlying Mesaverde or Wasatch Formation and migrate outward from the borehole. These hydrocarbons could potentially reach a shallow groundwater aquifer or surface water body in the study area. The COGCC has encountered instances where bradenhead pressure originating in one well on a pad has charged one or more of the other wells present on that pad, indicating that gas can migrate within the shallow subsurface located above the gas producing zone.

*This does not account for fracking intersecting a fault and gas migration to surface. In this case, cementing can not halt the gas flow nor will sparging. Sparging will dilute the apparent gas for as long as the sparging is carried out, but as long as there is gas in the fracked area, gas will flow out. In this case, gas may have escaped via this route over eons and eventually stopped; but, the fracking allowed new gas and pressure to be introduced to the old route.*

*The information supplied by URS is supported by Dr. Tynes' review and study. Arrington*

#### Conclusion: Drilling, Fracturing and URS Report

“The West Divide Creek gas seep followed a fault 3000 feet to the surface and the creek.”<sup>5</sup>  
*The report indicates it entered the fault from the well bore annulus. Arrington*

Antero Resources has stated that their drilling in the Silt Mesa area will be in the 3000 foot range. This means faults of this area can be from surface to as deep or deeper than Antero is planning on drilling. A preventative measure that would not allow a seep into faults from the well bore annulus would be well bore cementing to the top of hydraulic fracturing. This will not prevent fracturing from opening other paths to other faults. These other faults may have seeped gas over the eons and are likely expended, but the fracturing could re-stimulate them just as done for a declining production well.

There is every indication that a problem of this nature is present in the Divide Creek seep, as in Thyne's report, evidenced by continued methane seepage after re-cementing.<sup>6</sup> Although benzene sampling showed reduced amounts, this could be in part by air sparging and seasonal water flow affecting sampling or that it was introduced originally in fracturing fluids.

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<sup>5</sup> Dr. G. Thyne, *Analysis of the West Divide Creek Seep, prepared report for Garfield County, 2010*

<sup>6</sup> *Ibid.*

## Summary

The forces on this geologic area of Silt Mesa are forces that reshaped the North American continent. Independent geologic and engineering studies, by URS and Thyne, have quite clearly defined and concluded there are unique problems in this area.

With up to 50% of drilling and fracking fluids left behind, it is quite improbable that these fluids didn't reach the surface in Divide Creek Seep. This would skew benzene testing results by denying the existence of such fluids and assuming a surge release of natural benzene. The lack of reporting on the other components of the BETX combination or any other chemicals does not support any interest in finding drilling contaminants. The air sparging is not reported constant, as opposed to increased or diminished, and levels of seasonal water flow are acknowledged but not quantified. With no establishing of diluting criteria, it can not be determined if contamination is declining. The rise reported in wells indicates otherwise.<sup>7</sup>

The Silt Mesa area is geologically compatible to the Divide Creek area in tectonic activity and the fault systems have every possibility of being greater than Divide Creek because the beds of gas play are turned upward on end with fold back creating far greater forces than the Divide Creek block uplift.

The shallower drill plan in Silt Mesa is courting intersection of faults. Ten acre spacing of bores virtually assures fracking will break into the entire subsurface of an entire section with average frac half-lengths. This will be compounded by the transition area of rock break going from vertical to horizontal as fracking proceeds upward in stages. Control will be very difficult, if possible.

One mitigation can be required cementing of bores to fracturing zones. This would at least have a chance of sealing any leakage into faults from the bore annulus.

It must be recognized that because beds are turned up on end, natural migration of water can be through all beds running over 5000 feet deep. The Hogback area is considered water source for the entire basin.

The potential of H<sub>2</sub>S is enhanced by a volcanoclastic layer at the base of drilling depth.

Destruction of a complete USDW system, well irrigation, and livestock watering is a distinct possibility.

Less drill pads are required with directional drilling and 4 pads per section are unnecessary. Every aspect of surface problems is mitigated by the reduction of 3 pads.

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<sup>7</sup> *Geoffrey Thyne PhD., P.G., Analysis of the West Divide Creek Seep, Prepared for Garfield County by Science Based Solutions LCC, Laramie, Wyoming, 2010 (?)*

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