

Surficial Fracture Patterns in the Niobrara-Mancos Shale of Eastern Rio Arriba County, New Mexico and Applicability to Four Corner Basins*

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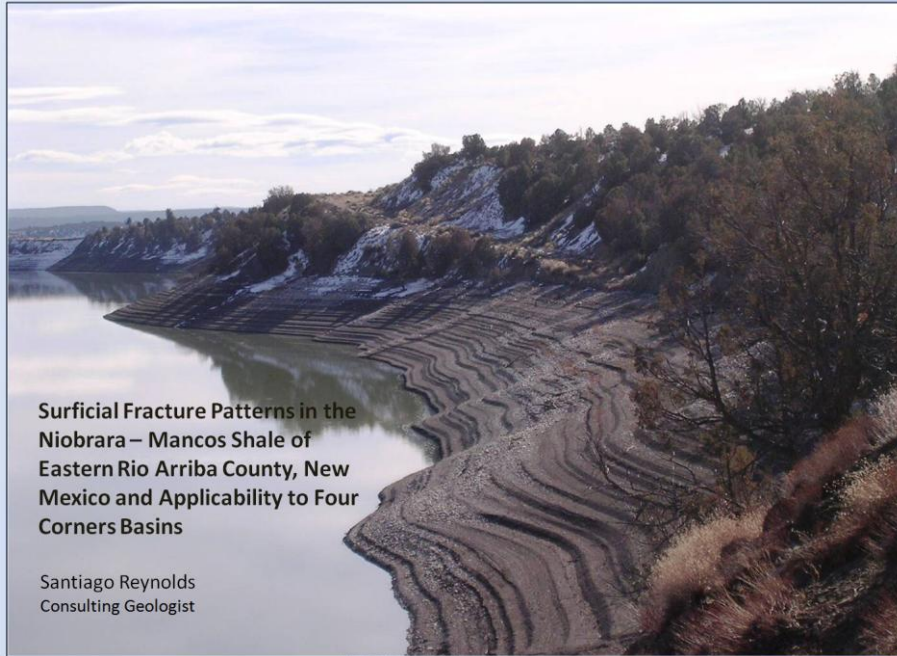
Abstract

Oil production attributable to fractured shale and siltstone of the Niobrara-Mancos is found in the Puerto Chiquito, East Puerto Chiquito, and Boulder Mancos fields of eastern Rio Arriba County, New Mexico. In order to understand the possible controlling influence of surficial fractures to reservoir fractures, the author identified fractures observable on aerial photographs and then posted them to 7.5 minute topographic quadrangles with a 1:24,000 scale. The alignment of fracture segments enabled a continuity interpretation, indicating the orientation of large primary fractures versus many smaller localized ones. Surficial drainage patterns were grouped and used to delineate related areas that likely reflect higher elevation bedrock surfaces under alluvium. Plotting the fracture and geomorphic information together shows that areas of fracture intersection correlate reasonably well to known oil fields with fracture controlled production, and similar patterns elsewhere might indicate other areas that have yet to be explored with surficial fracture trends in mind. Lacking dense vegetation, the basins of the Four Corners area lend themselves to surficial fracture assessment. The aerial photographic method of identifying surficial fractures is not new, though it typically is not mentioned in the context of petroleum E&P. The author first used the method while employed by Pemex in 1970 to successfully position gas/condensate wells in northern Mexico adjacent to Maverick Co., TX, and again in the mid-80's in South Africa to investigate anomalous shallow gas from crystalline rocks of the Transvaal. Fracture distribution is not the end point of any exploration effort, although in the areas of fracture-enhanced production, it can be a useful tool to better delineate areas worthy of further investigation with subsurface geology and geophysics.

References

Foster, N.H., and E.A. Beaumont, (compilers), 1992, Photogeology and photogeomorphology: AAPG Treatise of Petroleum Geology, Reprint Series, No. 18, 555 p.

Wermund, E.G., J.C. Cepeda, and P.E. Luttrell, 1978, Regional distribution of fractures in the southern Edwards Plateau and their relationship to tectonics and caves: Bureau of Economic Geology, University of Texas at Austin, Austin, Texas, Geological Circular, v. 78-2, 24 p.



**Surficial Fracture Patterns in the
Niobrara – Mancos Shale of
Eastern Rio Arriba County, New
Mexico and Applicability to Four
Corners Basins**

Santiago Reynolds
Consulting Geologist

Presenter's notes: My favorite subjects – fracture identification and aerial photography. The subjects are not new. I first used them professionally as a geologist for PEMEX in the early 1970s in order to spot wells in the tight rocks of northern Mexico adjacent to Maverick County, Texas. Throughout my career, I have used photogeology around the world, typically for specialized situations; e.g., to locate helium in fractured Precambrian rocks in South Africa. I think photogeology is under-used in our current quest to exploit tight rock reservoirs, like those present in the Four Corners area. For the non-initiated, the subject become confusing; therefore, I shall first define terms and topic particulars.

Preface:

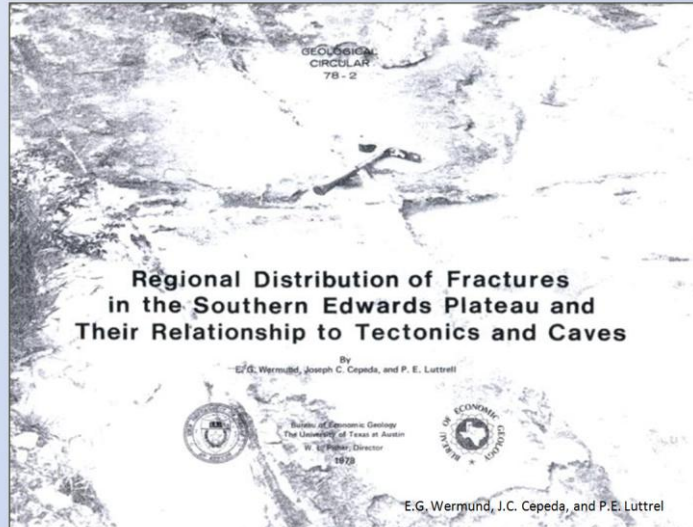
I use the trendy term “fracture” to encompass natural rock breaks and features, such as fissures, faults, joints, lineaments, and rock cleavage.

My focus is the reconnaissance detection of surface fractures of sufficient length to be identifiable from aerial photographs.

My primary tools are photogeology and geomorphology.

The end result is a map showing fracture trends imposed upon geomorphic features suggestive of structures at depth that are worthy of additional investigation with subsurface methods.

Presenter's notes: Fracture is general field geology term that covers several structural features resulting from rock breaks due to stress and strain.



A significant case study from 1978.

Presenter's notes: This study by the University of Texas Bureau of Economic Geology is regional in scope, but it used many of the photo interpretation techniques that I have found valuable in mapping surface fractures. Following are illustrations from this BEG study.

Fractures visible in a photograph of a portion of the sparsely vegetated Edwards Plateau of central Texas.

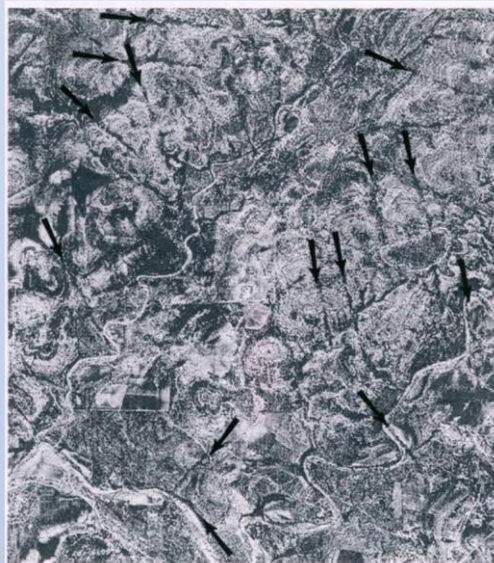


Figure 3. A part of a controlled mosaic of black-and-white aerial photography on which arrows indicate the limits of fracture zones.

Presenter's notes: The study identified surficial fractures and marked them on air photos.

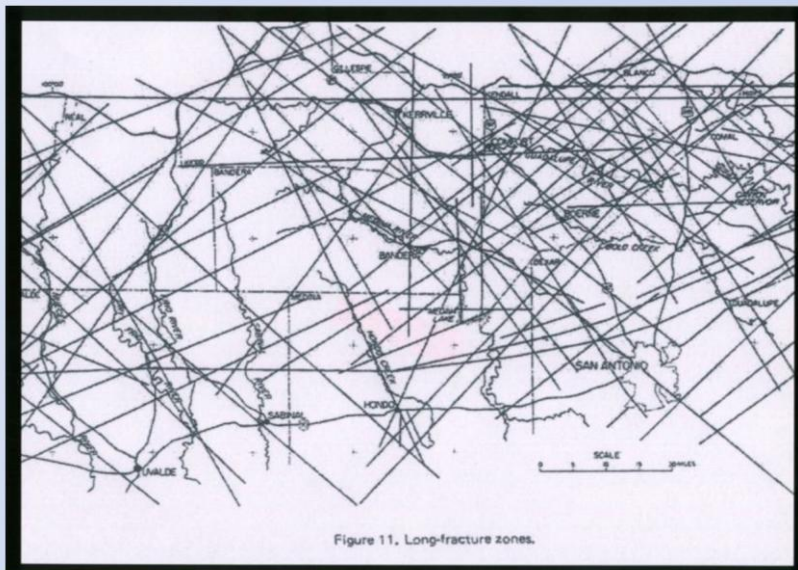


Figure 11. Long-fracture zones.

The final product – a map of large-scale intersecting fractures

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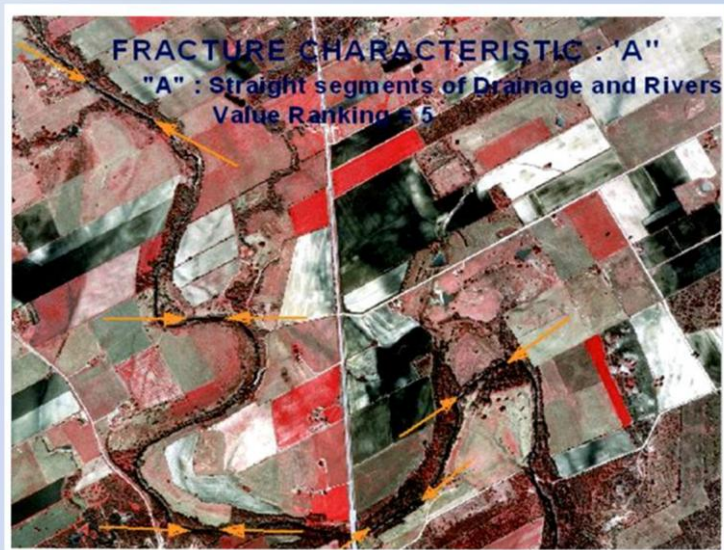
Presenter's notes: The final product was a map of intersecting regional fractures. This is the same result I strive for with my work, though on a more detailed and localized basis.

Surface Evidence of Fractures

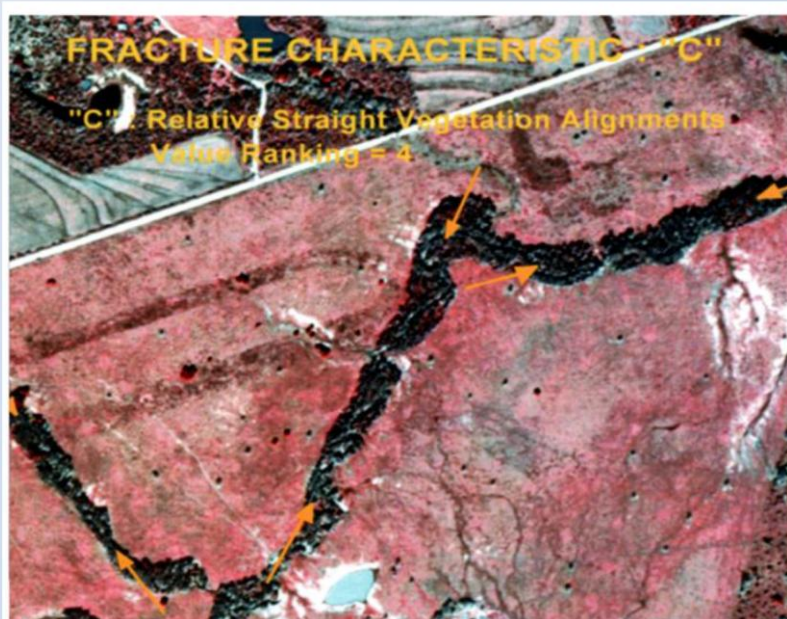
- Segmented drainage courses
- Visible fractures in rock
- Vegetation trends
- Meandering arroyos
- Tonal linear anomalies
- Tree alignment
- Straight edges

Examples>

Presenter's notes: These items enable the mapper to locate fractures, extrapolate their trends, and develop a coherent interpretation. They are ranked according to reliability.



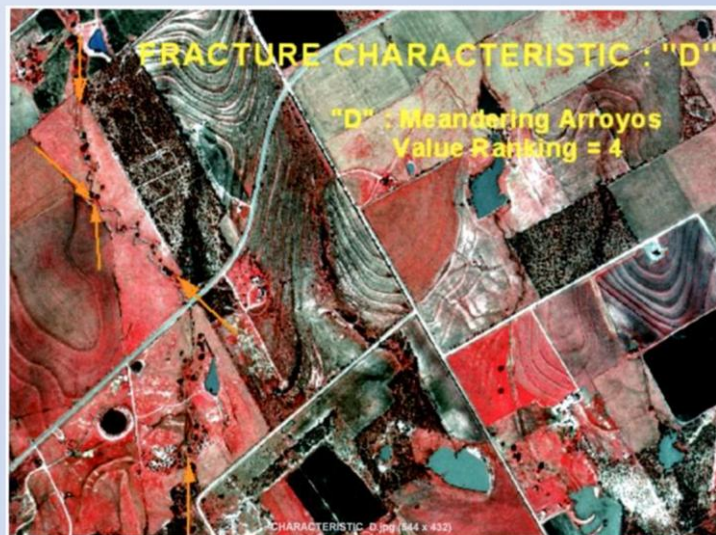
Presenter's notes: Stream courses are one of the best indicators of possible fractures.



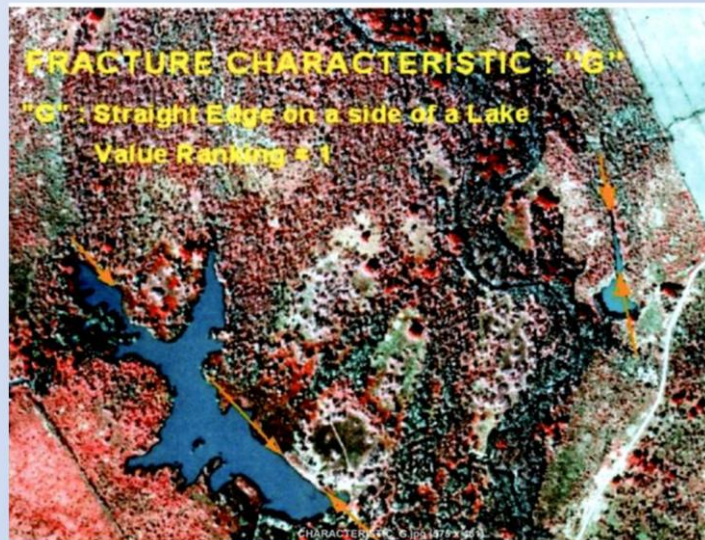
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Presenter's notes: In some cases, the trend of vegetation is a fracture indicator. Water fills fractures and the vegetation follows.



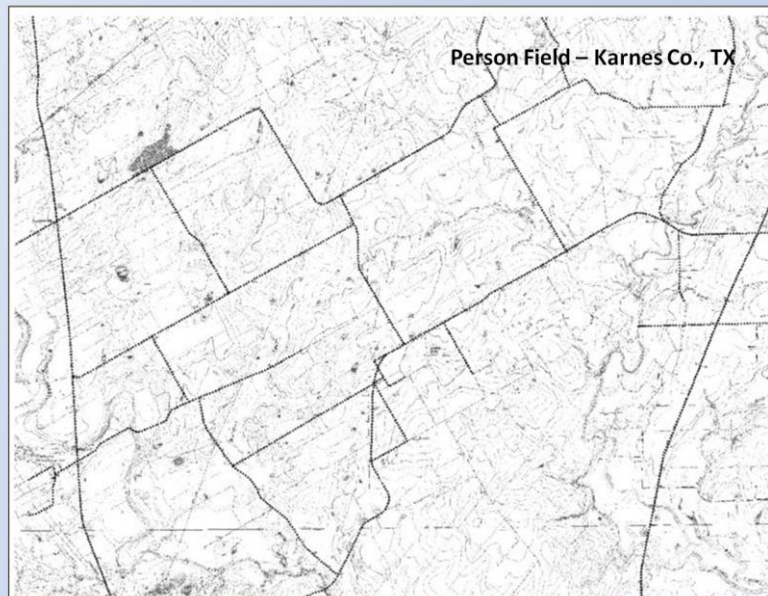
Presenter's notes: Meandering arroyos do not necessarily mean their course is fractured, but they can.



Presenter's notes: Irregular bodies that have a seemingly anomalous "straight segment" can be a fracture indicator.

A Quick Case Study – Person Field, Texas

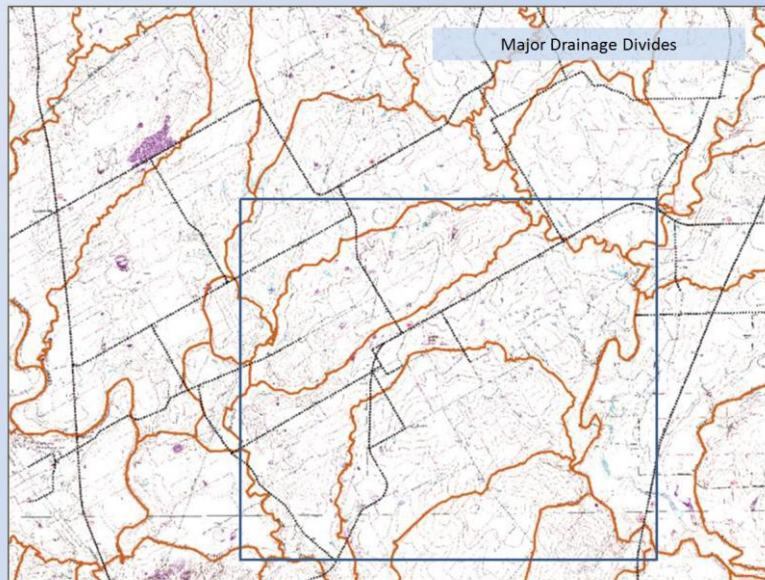
Presenter's notes: All the techniques discussed can be seen in this tightly controlled case study.



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Presenter's notes: This topographic map covers the prolific Person Field, discovered in 1959. The Lower Cretaceous Edwards carbonate reservoir produced 1.5 million barrels during the first three years of its history.



Presenter's notes: The orange lines mark major drainage, some lines coincide with large faults; dip of some is up-to-the-coast; others are down-to-the-coast. Drainage "closures" are apparent subsurface structures that cannot be classified at this point. Next are illustrations of area in the blue square.

STRUCTURES

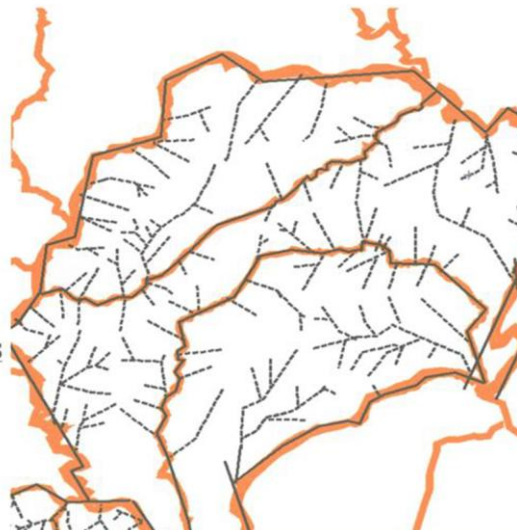
IN ORANGE LINES

PRIMARY FAULTS

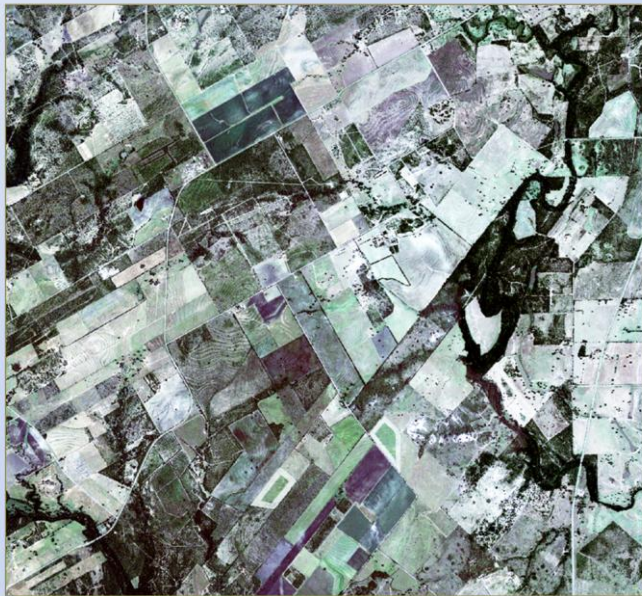
IN SOLID BLACK
LINES

SECONDARY FAULTS

IN BROKEN
BLACK LINES

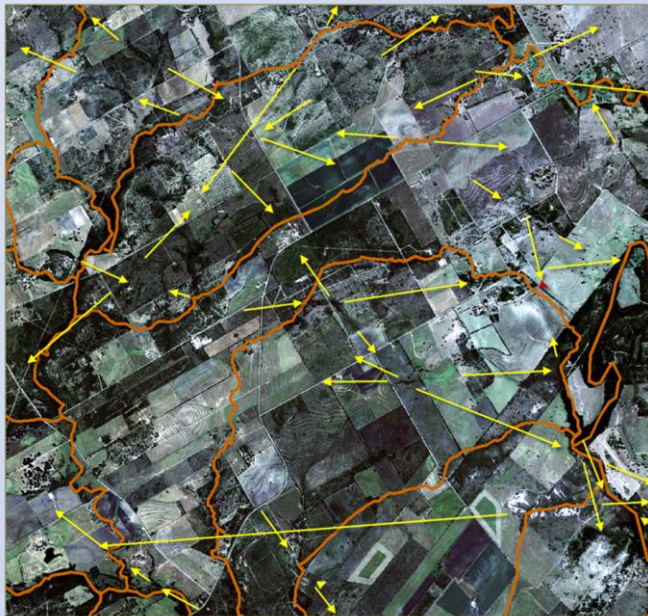


Presenter's notes: Marked here are the major drainage divides, some of which coincide with primary faults. Marked also are straight stream segments that might be fracture segments or small faults. This is a geomorphic interpretation based upon topographic data. Air photo of the same area is shown next.



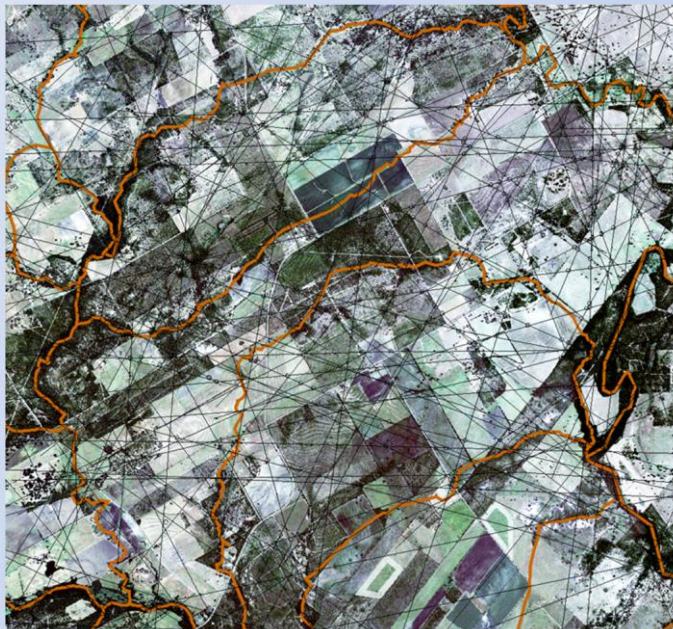
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Presenter's notes: Uninterpreted aerial photo of the Person area; this was used to find fracture indicators.



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Presenter's notes: This is the same photo with some of the stream segments marked, along with tree trends, tonal variations, and other fracture indicators.



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Presenter's notes: This is the final interpretation of the surface fractures. I have extrapolated the visible evidence of fractures segments like those shown on the previous slide to produce the overall fracture pattern. This kind of work requires the ability to interpret and extrapolate.

MAIN STRUCTURES

MAIN FAULTS

SECONDARY FAULTS

AXIS

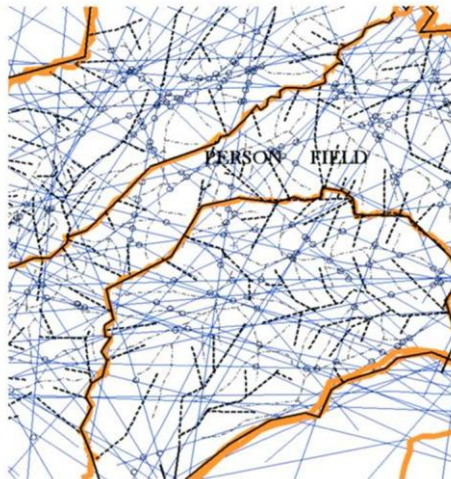
FRACTURES

FRACTURE INTERSECTIONS

BLACK CIRCLES ON TWO OR MORE INTERSECTIONS, NEAR OR ON THE PALEOGEOMORPHIC AXIS.

THESE INTERSECTIONS COULD BE THE OPTIMUM DRILLABLE LOCATIONS ON THE STRUCTURES.

THIS PROCEDURE WILL ENHANCE HORIZONTAL DRILLING, WHEN DIRECTING THE WELL TOWARD AREAS WITH MORE FRACTURES OR FRACTURE CLUSTERS, INCREASING CUMULATIVE PRODUCTION.



Presenter's notes: This is a composite map with the topographic interpretation showing faulting, upon which I added the fracture interpretation from the aerial photos. Fracture intersections are noted with the small circles. Intersections tend to be more favorable drilling locations, and dense clusters of intersections are best.

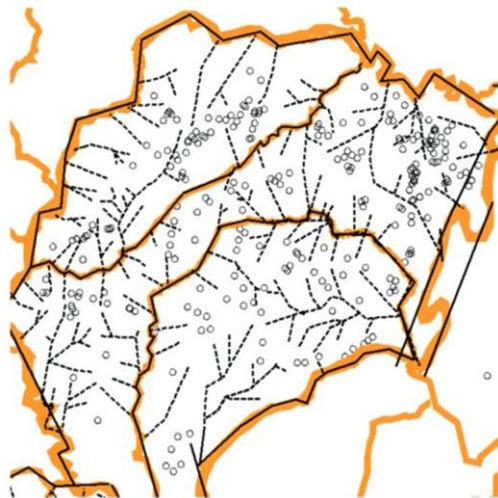
PERSON FIELD

STRUCTURES

PRIMARY FAULTS

SECONDARY FAULTS

FRACTURE
INTERSECTIONS



Presenter's notes: To simplify the picture, I removed the fracture traces and left the intersection points. The final map shows the key surface elements of fractures (including faults), and hints of subsurface structure. The specific type of structure (anticline, fault blocks, diapir, etc.), requires additional assessment using subsurface data.

Person Field Insights

- Photogeology can be used to:
 - Identify apparent subsurface structures
 - Trace fractures at the surface
 - Determine areas of high fracture density and intersection.

Apparent structures with a high density of intersecting fractures tend to be favorable for further assessment using subsurface methods.

Fully integrated surface and subsurface data will produce the most favorable drilling targets in tight-rock plays.

Presenter's notes: This sums up the value of photogeology and fracture identification. The question is often asked "Do the fractures extend down to reservoirs at depth?" In my opinion they probably do. Conversely, they could have originated at depth and propagated to the surface. The genetic classification of fractures is a complex subject. My reconnaissance efforts are to find them and get them on a map. Next is the study of the Four Corners area.

The Four Corners Area

San Juan Basin

New Mexico

Basin Margin

Niobrara – Mancos Shale

Eastern Rio Arriba County

North Central Basin

San Juan County

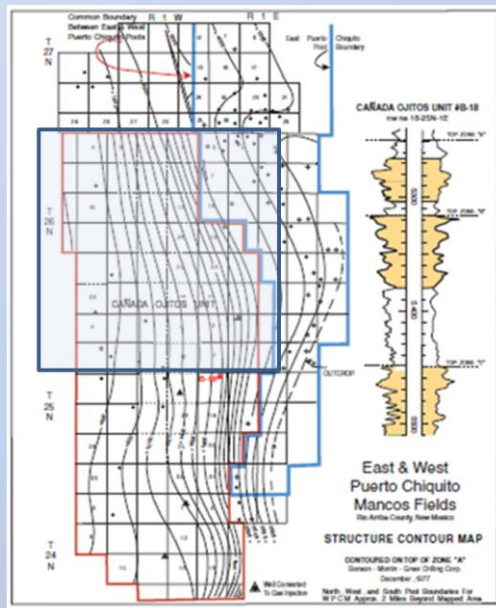
Presenter's notes: First is a reconnaissance look at aerial photos.

Niobrara-Mancos Area of Rio Arriba County, NM
A Fracture Overview at the Basin Margin

Presenter's notes: First are the fracture trends in the area of the Mancos Field – a classic fractured reservoir.

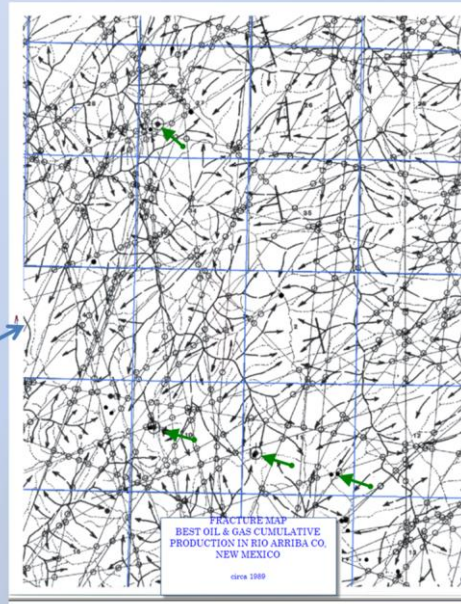
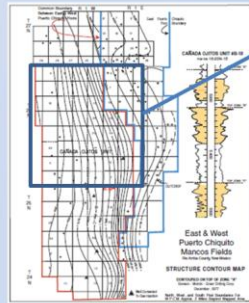
There is a reasonably good fit of fracture intersections along the trend of these fields, the structure of which is shown in this *Benson - Montin - Greer* map from 1977.

The area in dark blue is covered in the next slide.



Presenter's notes: This dated, but useful, map published by the Benson - Montin - Greer company shows the general structure over the fractured Mancos.

Mancos Field Area
Rio Arriba County, MN



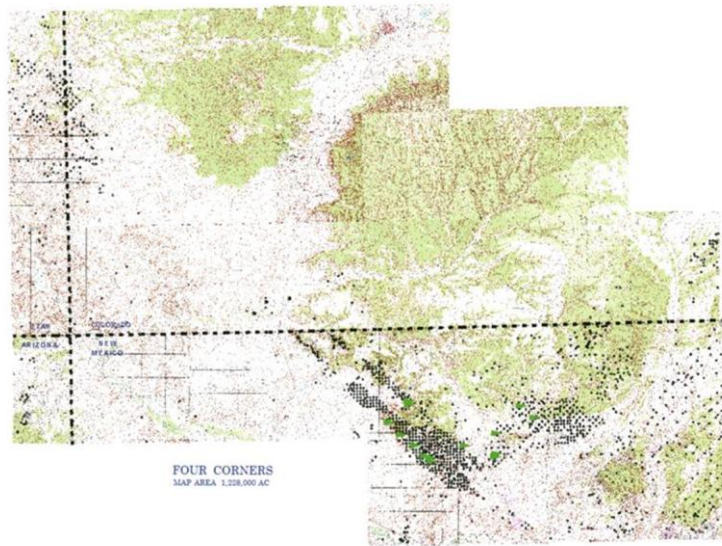
Presenter's notes: The Mancos Field appears to be in an area of intersecting fractures with sufficient density to suggest that they influence permeability at depth in the reservoir. Because of the documented fracture production, this area remains an interesting target for a more detailed assessment; it is one of my areas of focus.

North Central San Juan Basin Fractures San Juan County, NM

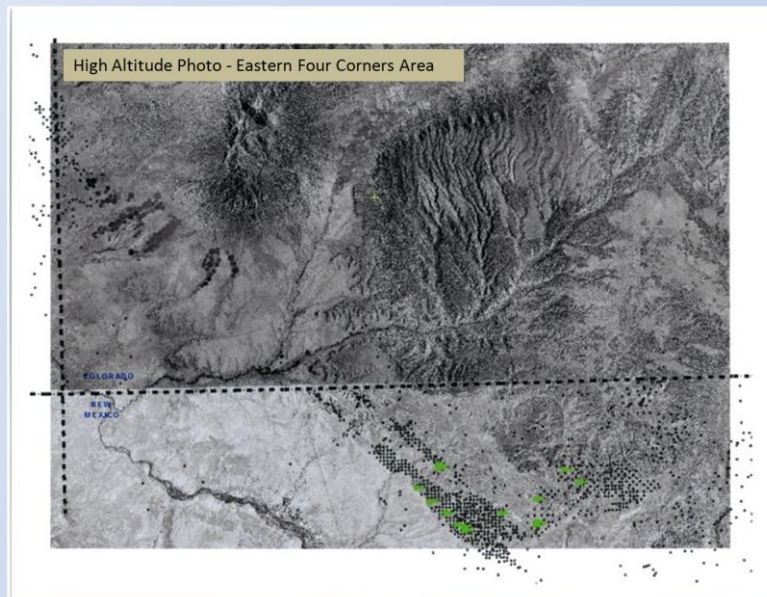
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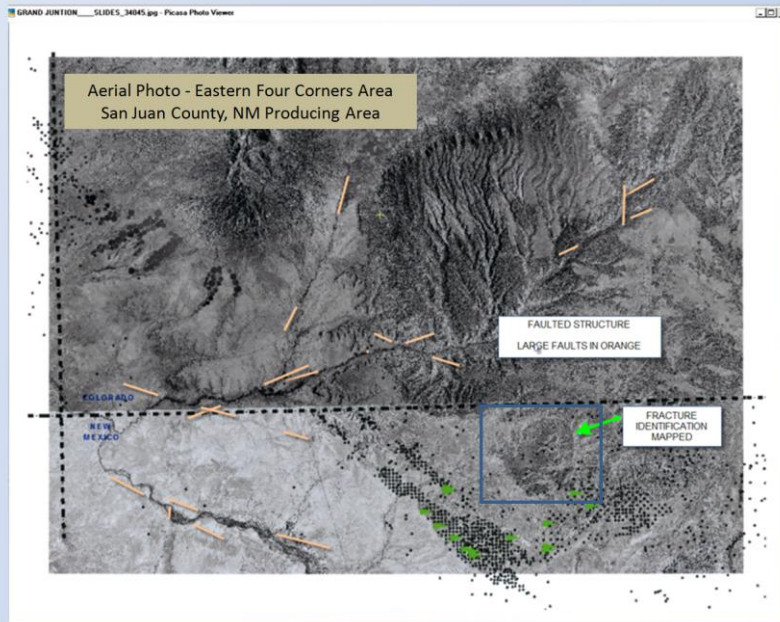
Presenter's notes: This example is significantly west of the Mancos basin margin area and near the center of the northern part of the San Juan Basin, an area populated by several large fields.



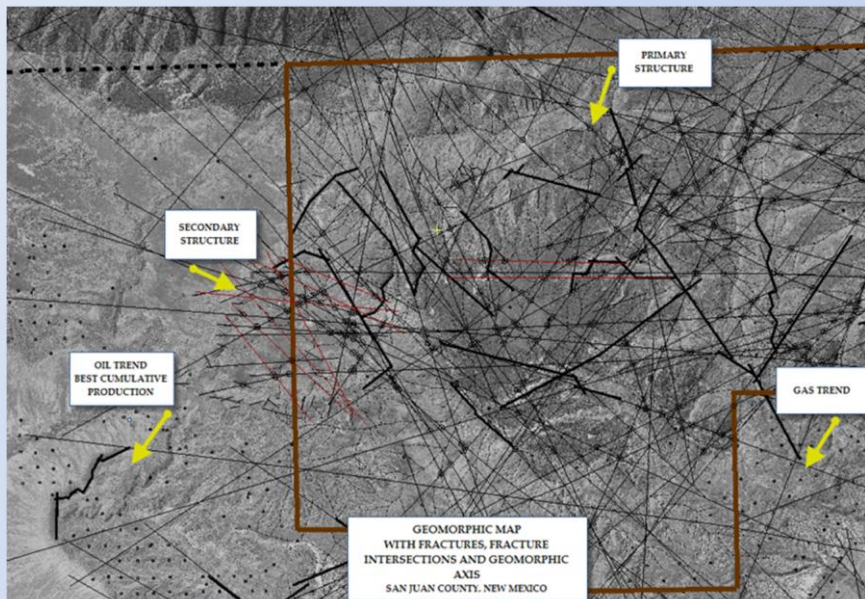
Presenter's notes: This topographic mosaic shows the setting. We are interested in the area near the major oil and gas fields.



Presenter's notes: This is an uninterpreted high-altitude photo of the same area. Note the large structures and the oil fields.



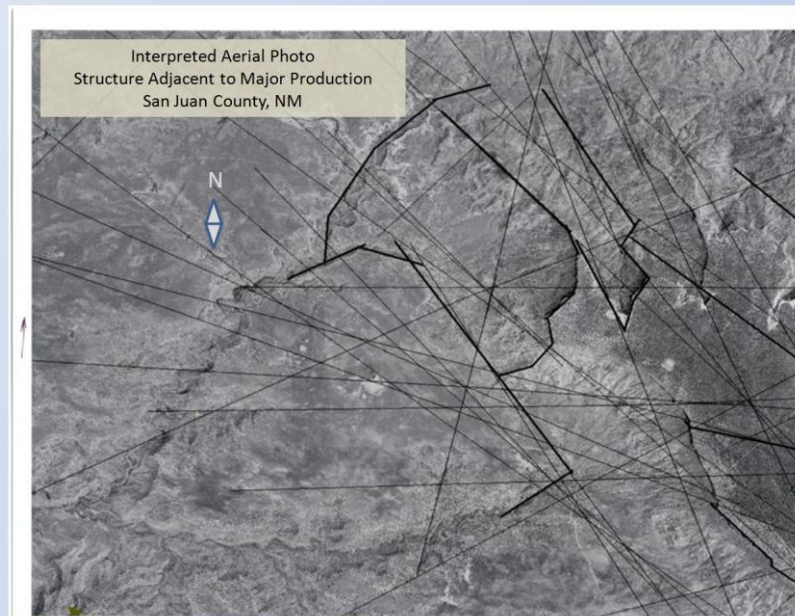
Presenter's notes: This is the same photo with some initial interpretation. The green areas mark wells that were exceptional producers. Next are illustrations of the area noted in blue.



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Presenter's notes: An interpreted view.



Presenter's notes: At a smaller scale is my interpretation of a nearby structure and associated fractures.

An excellent compilation of papers by experienced photo geologists.

**Thank
you!**

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PHOTOGEOLOGY AND PHOTOGEOMORPHOLOGY

COMPILED BY
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EDWARD A. BEAUMONT

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Presenter's notes: For more information and methods used by photogeologists, this AAPG publication is excellent.