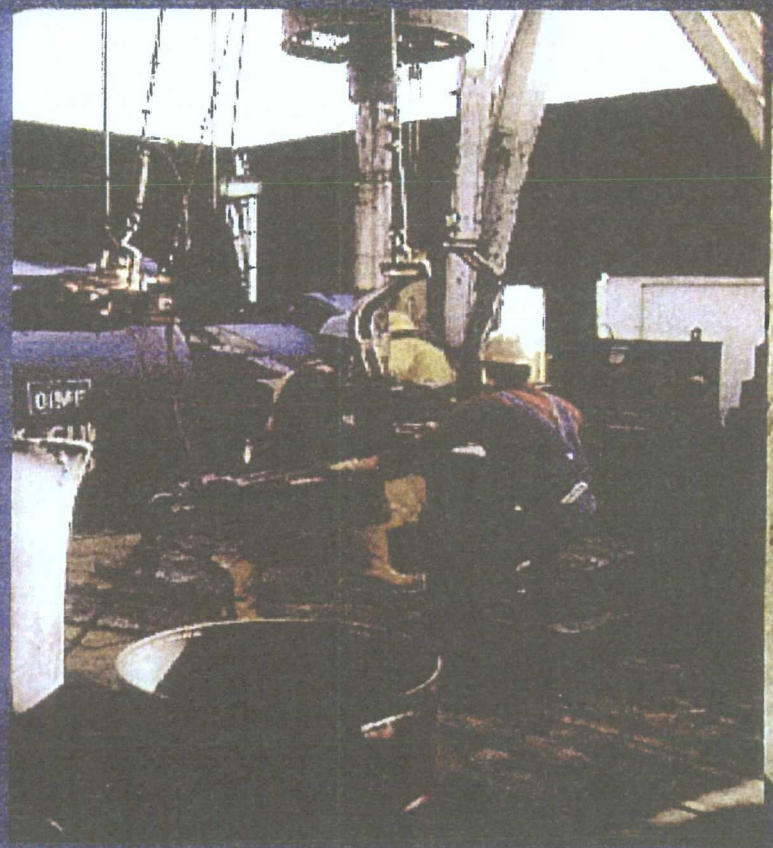
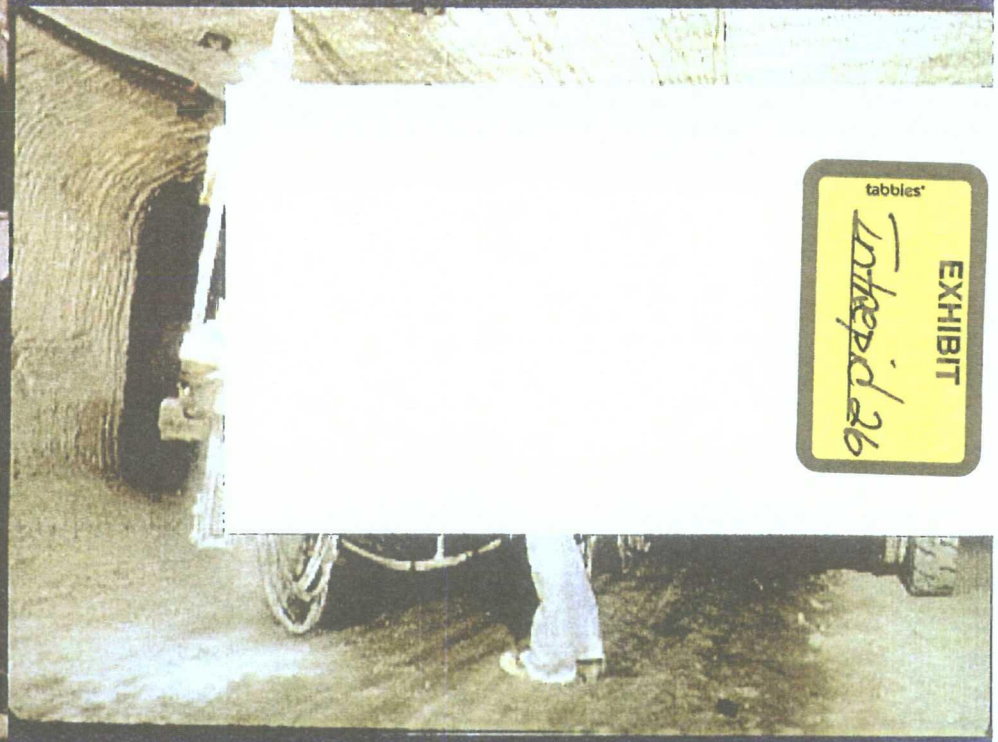
COINCIDENTAL DEVELOPMENT OF OIL AND GAS AND TRONA WITHIN THE GREEN RIVER BASIN OF SOUTHWEST WYOMING

Ted Murphy-Rock Springs Field Office





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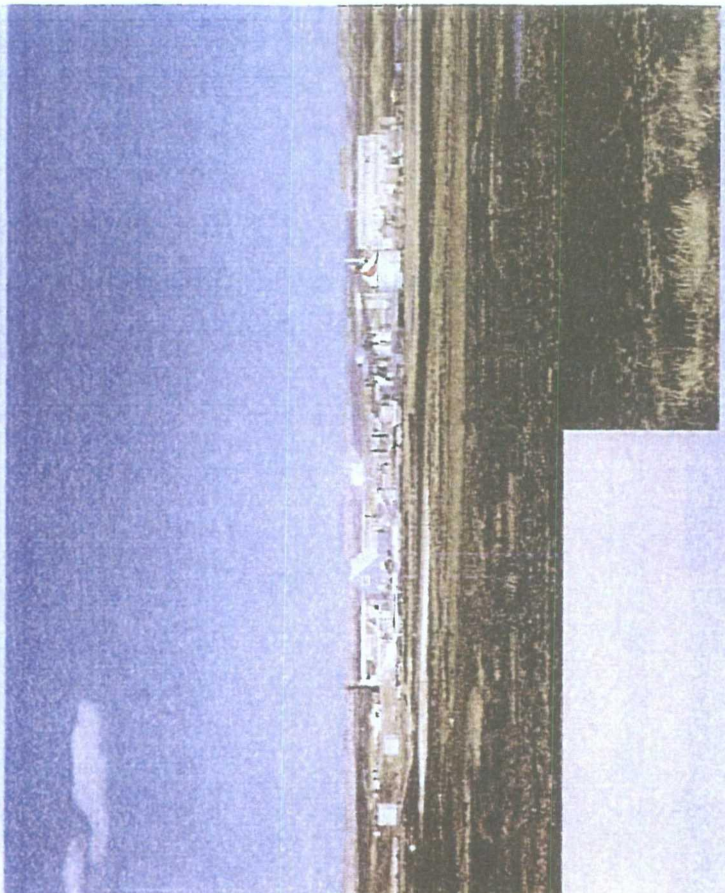
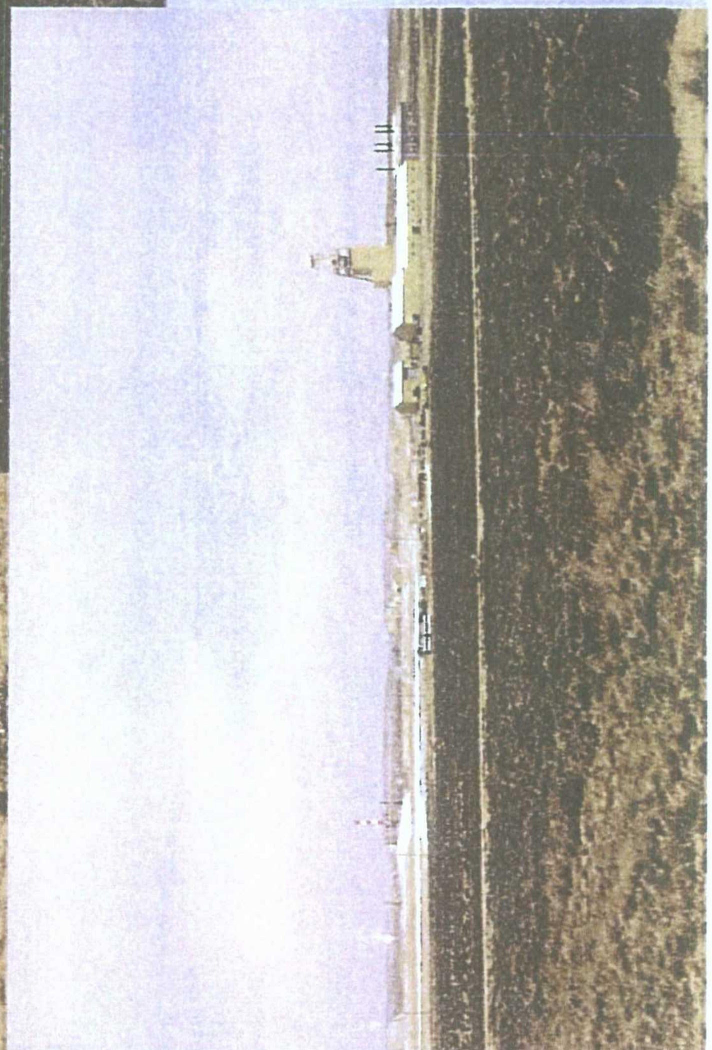
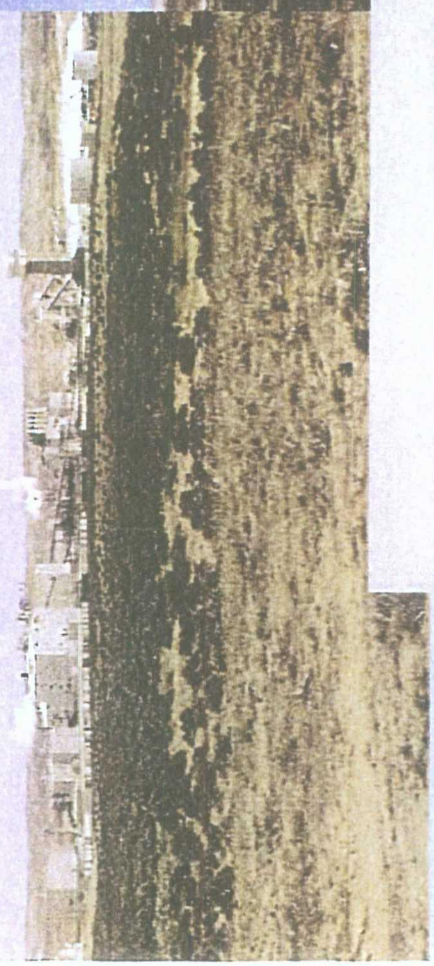






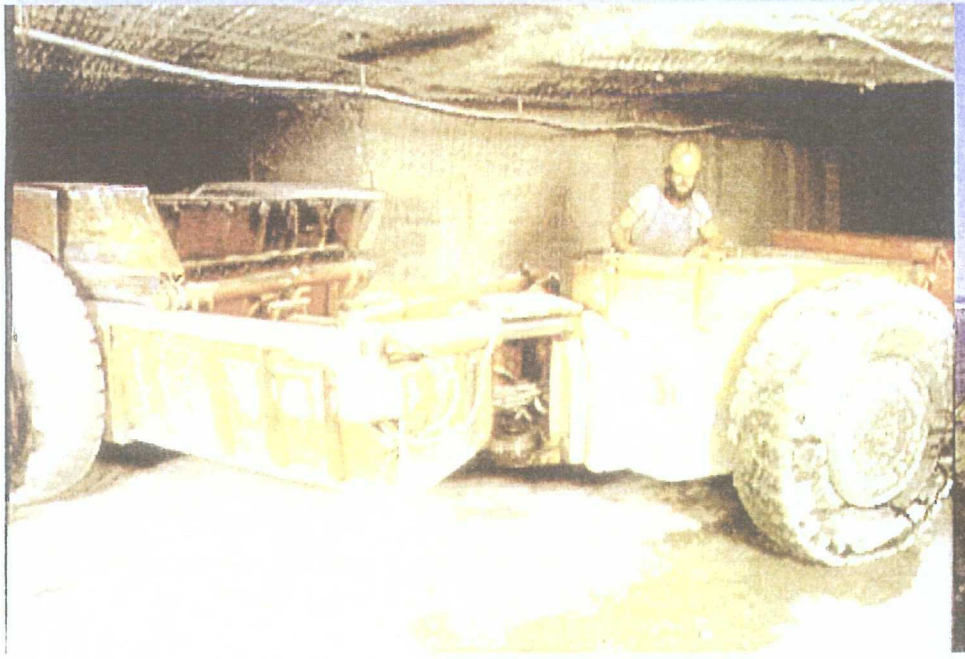
IP001289

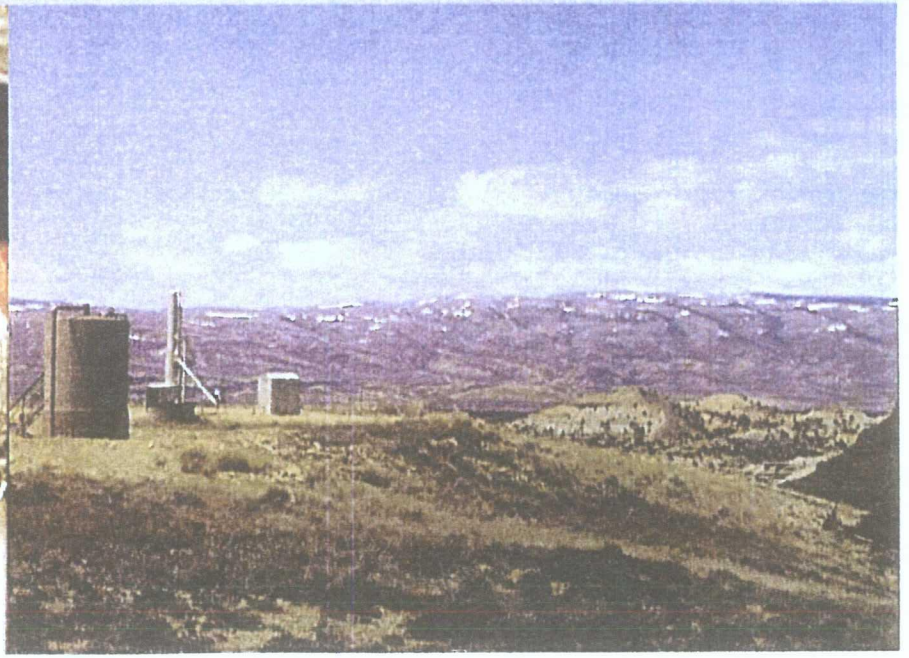
Coincidental Leasing of Sodium and Oil and Gas

38% coincidentally leased

89,200 federal acres leased for sodium

33,825 federal acres coincidentally leased for oil/gas





IP001290

IP001291

BIG OIL
BIG TOBACCO

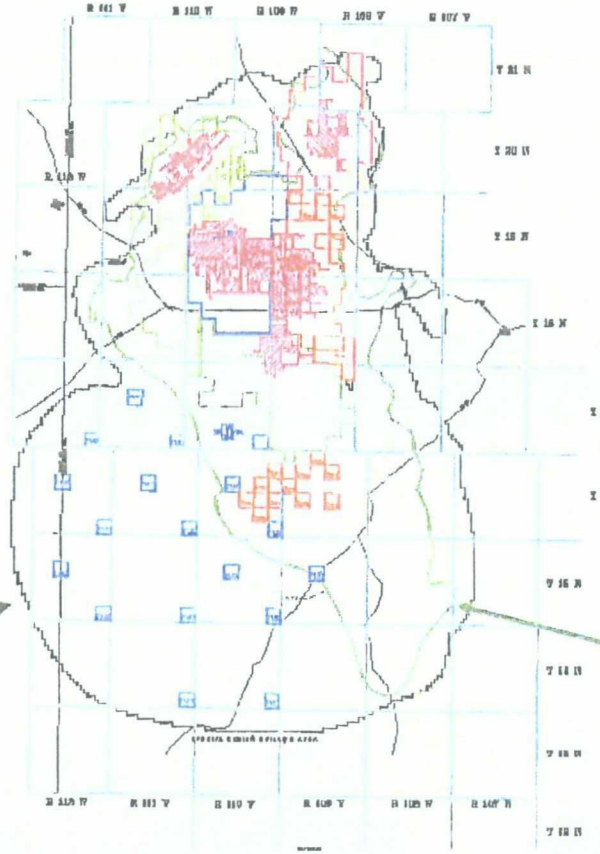
IP001293

Known Sodium Lease Area and Mechanically Minable Trona Area

Known Sodium Lease Area

397,122 Federal acres
263,157 private acres
33,967 State acres

Total 694,246 acres



Mechanically Minable Trona Area

218,614 Federal acres
223,873 private acres
30,959 State acres

Total 473,445 acres

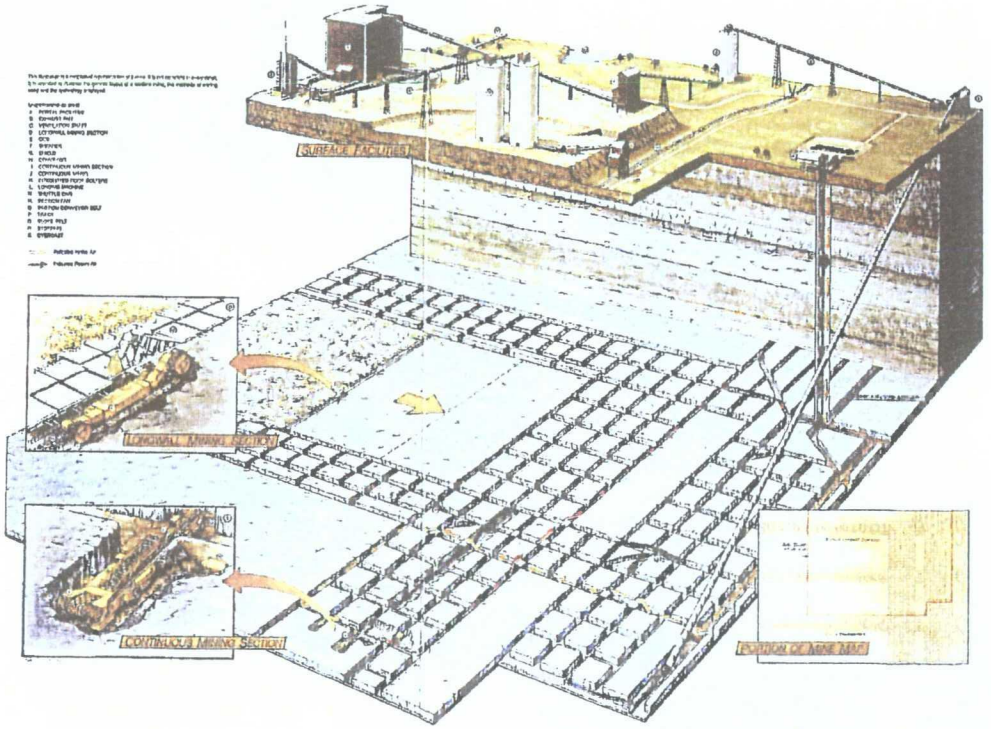
KSLA

MMTA

- The KSLA contains 127 billion tons of trona and mixed trona and halite.
- The MMTA contains an estimated 87 billion tons of mechanically minable trona.

Trona Mining in the Green River Basin

- The five underground mines in the district produce over 18 million tons of trona per year utilizing room & pillar and longwall mining methods.
- Room & pillar mining utilizes mobile continuous mining machines and shuttle cars to mine parallel, interconnected entries in the horizontal trona bed. The roof of the entries is typically supported with roofbolts. Conveyors, ventilation controls, and utilities are extended behind the mining face.



Longwall mining is used to fully extract large blocks (650'x10,000') of trona. The block is delineated by room & pillar workings. A longwall shearer (mining machine) operates in conjunction with a series of hydraulic roof supports and a chain conveyor to remove a narrow (3') strip from the longwall face. The supports advance under the newly mined roof, allowing the strata to cave behind the face.

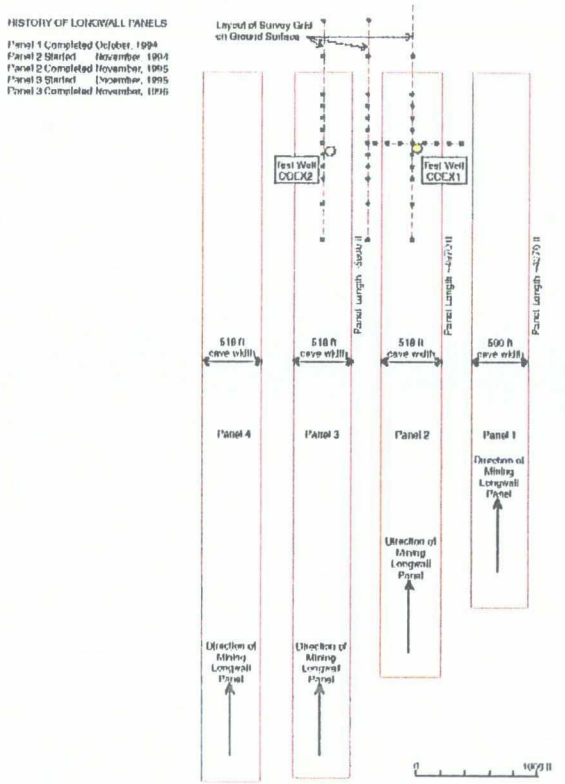
IP001295

JIC Technical Investigations

- Test well logging over FMC longwall
- Core testing for rock properties
- Surface subsidence monitoring at FMC
- Numerical analysis of subsidence
- Evaluation of tolerable casing deformation
- Natural gas isotopic "fingerprinting"
- Potential for fluid and gas migration

Test Well Program

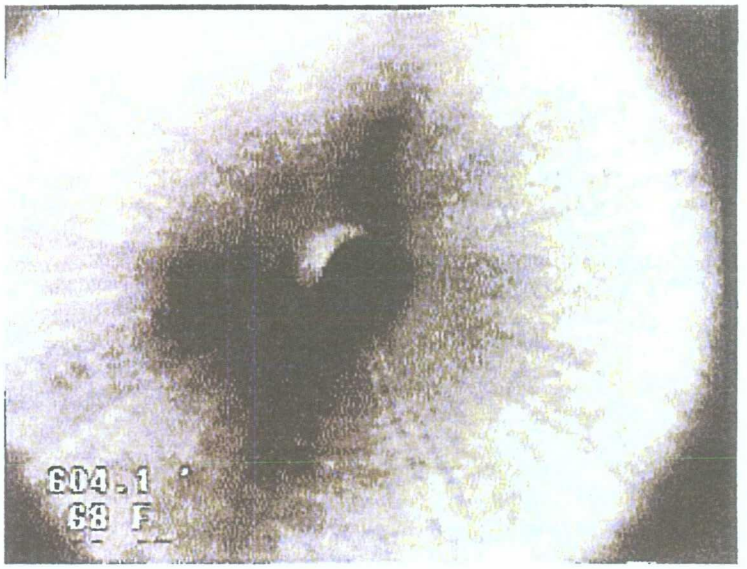
- Two test wells were drilled at FMC in advance of longwall mining.
- Caliper, CET, and camera logging provided information on casing failure vs distance from mine workings.
- Bedding plane slip was noted up to 1200 feet horizontally from the longwall.
- Lateral movement occurs at specific lithologic horizons.
- Permeability and mechanical property tests were conducted on selected core for modeling input.

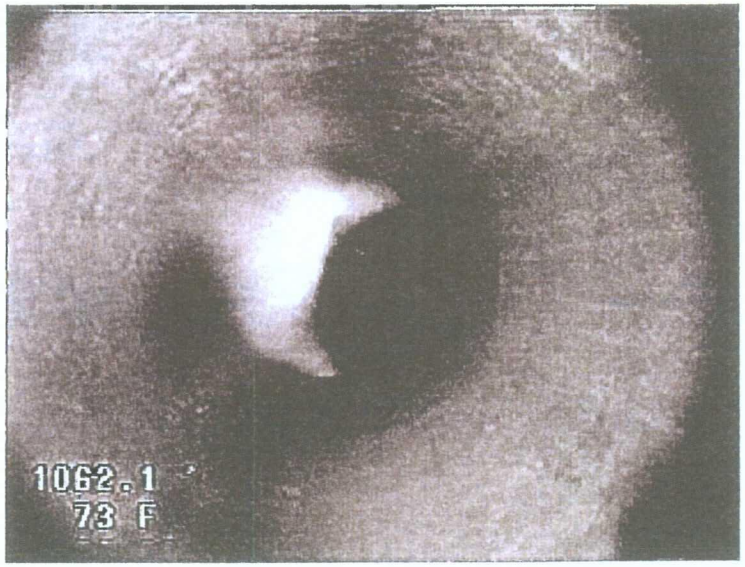


PLAN VIEW OF LONGWALL MINING PANELS

Test Well Program

- Video camera logging of the test wells was conducted several times as longwall mining approached.
- Logs identified nine major slip planes where significant casing deformations were noted.



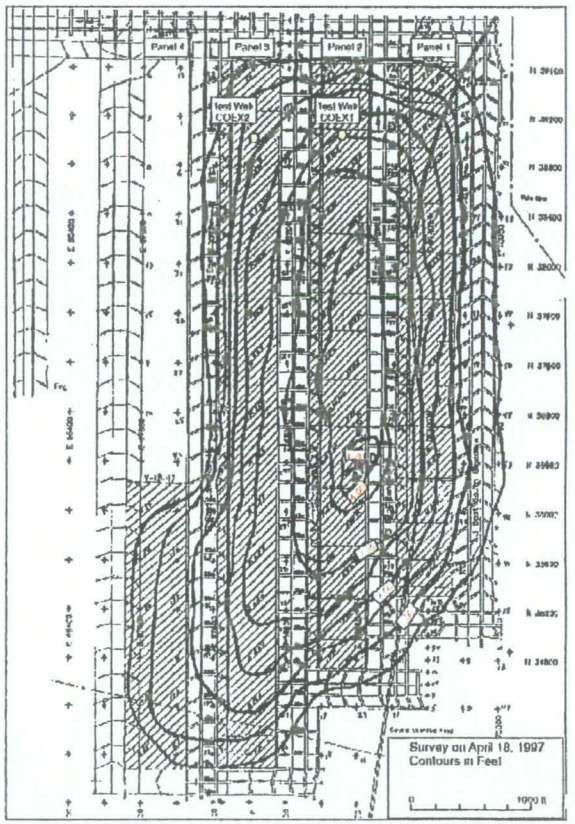


The location of the slip planes correlated with lithological breaks between stiff and softer formations.

Lateral deformation occurs over short (1.5-2.0 feet) lengths of the well, resulting significant angular offsets.

Surface Subsidence Monitoring

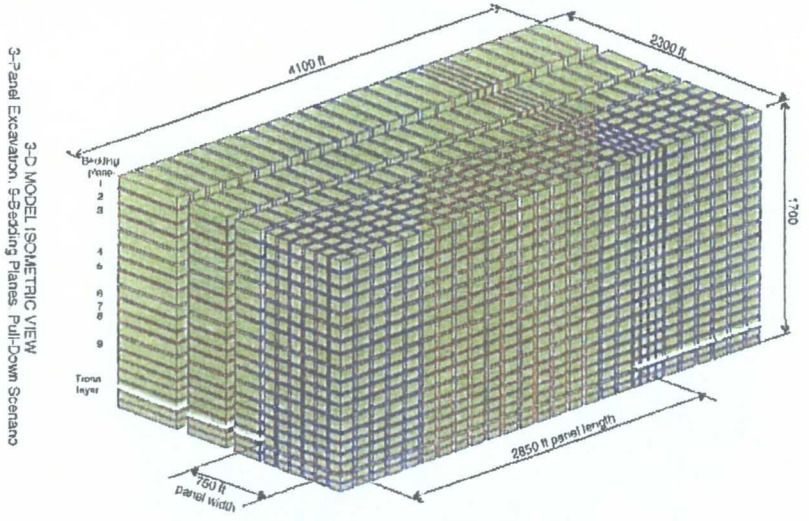
- The surface can subside up to 70% of the mined height.
- Subsidence is time-dependent, continuing at a declining rate for years after mining.
- Significant horizontal movement occurs at surface. The direction of horizontal movement is generally toward the mine void.
- Subsidence affects an area within a 38 degree vertical cone from the edge of the mine workings, or about 1250 feet horizontally from a 1600 foot deep mine.



GROUND SURFACE SUBSIDENCE CONTOURS AT FMC MINE

Numerical Analysis of Subsidence

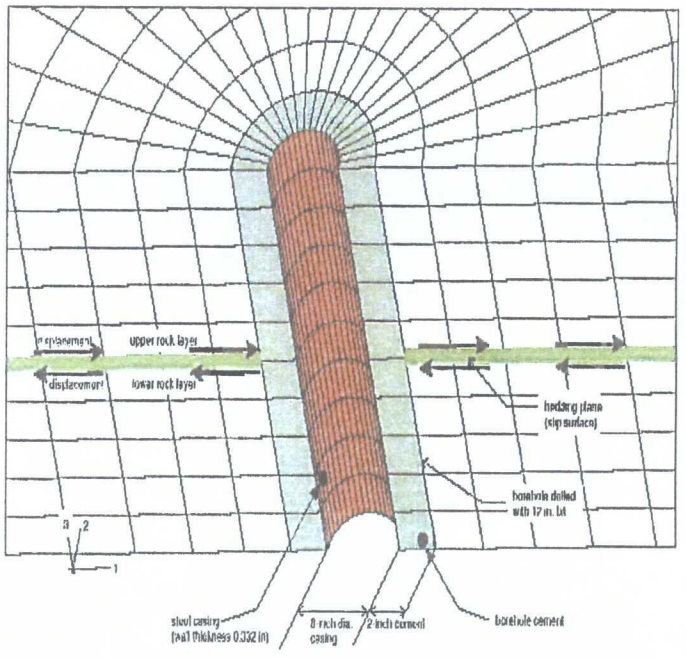
- Fugro-McClelland developed several numerical models to simulate the large scale effects of mining induced subsidence.
- The models confirmed the importance of lateral slip on well mechanical stability.
- Concluded that bedding plane slippage greater than 0.1 feet is "a major design concern for oil and gas wells".
- Lateral slippage of 0.1 feet occurs up to 1200 feet horizontally from mine workings.



Casing Deformation Analysis

- E^xponent-Failure Analysis Associates analyzed the relationship between bedding plane slip and casing deformation.
- Concluded "that increasing the wall thickness or…yield strength do not provide increased resistance to shear deformation."
- Tolerable lateral displacement in 8 5/8 inch casing is about 2 inches. This amount of shear can occur about 1000 feet from mines.
- Analysis did not consider threaded couplings.

CLOSEUP VIEW OF 3-D MODEL FOR ANALYSIS OF WELL DEFORMATIONS



Geochemical Fingerprinting of Natural Gas

- Isotech Laboratories analyzed 27 shallow and 4 deep gas samples.
- Isotopic analysis indicated that the shallow (mine level) gas is enriched in lighter hydrogen and carbon isotopes relative to deeper gas.
- Mixtures of shallow and deep gases can be identified.

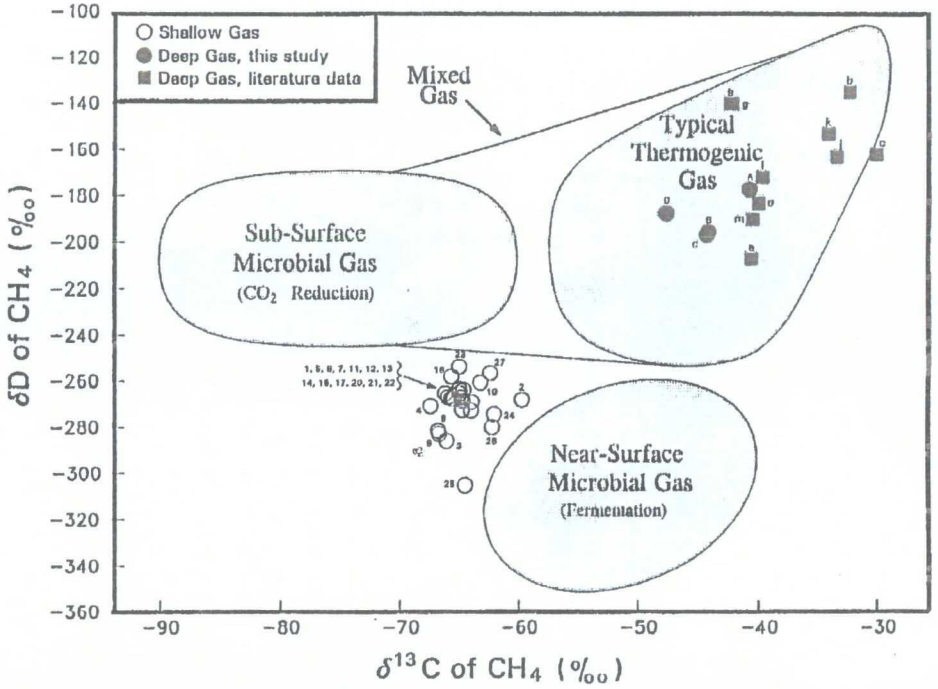


Figure 3. Carbon and hydrogen isotopic compositions of methane samples. Base figure after Coleman et. al, 1993. Literature data from Jenden and Kaplan, 1989.

IP001302

Potential for Fluid Flow from Gas Wells

- Van Kirk and Associates identified numerous case histories of uncontrolled fluid flow from gas/oil wells.
- The potential for undetected leakage from Green River basin wells is significant.
- A numerical fluid flow simulation was developed for the area near a well in Section 16 T18N R111W.
- The modeling concluded that fluids could migrate significant distances (>2 miles) with conservative assumptions about pressure and permeability.

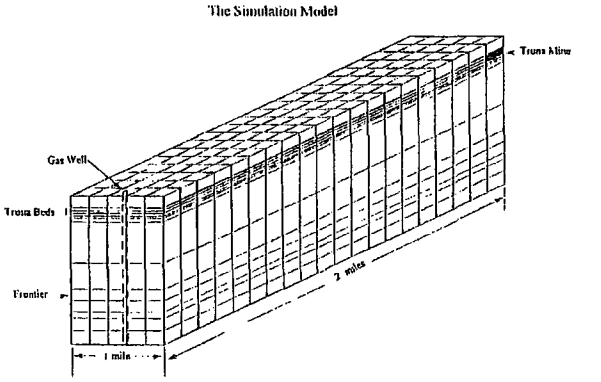
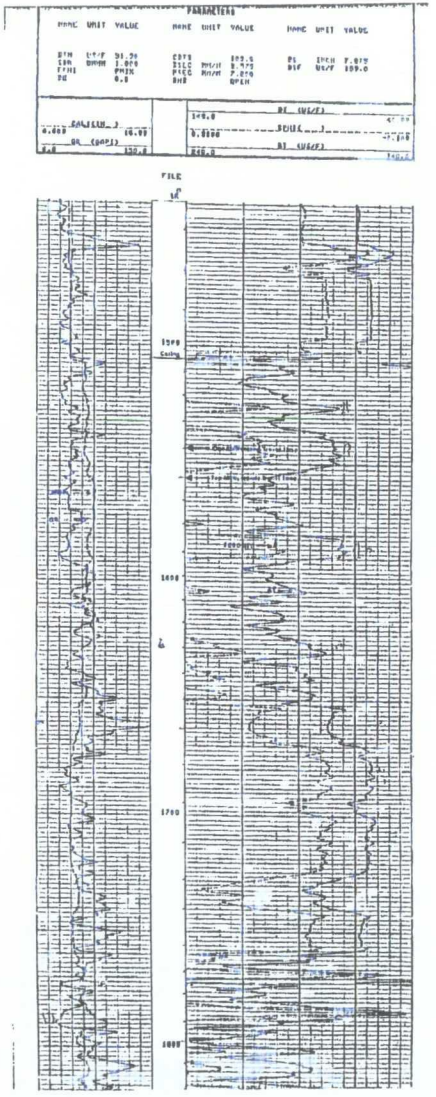


Figure 10

IP001303

Potential for Fluid Flow from Gas Wells

- In 1994 the BLM, PAW, and the WO&GCC formed a study group to investigate casing leaks in the Granger area.
- Over seventy wells were examined in the 20 section study area. A November 1994 report from the BLM stated that "A conclusion…was that 84% of the uncemented wells did appear to be in communication with a gas/water source."
- "Wells that had surface casing set to the top or into the Wasatch Formation and cemented to surface showed no signs of trona water flow or corrosion in this interval."
- The gas migration study focused on a gas well with shallow surface casing located on a sodium lease adjacent to the Granger study area.



IP001304

Conclusions

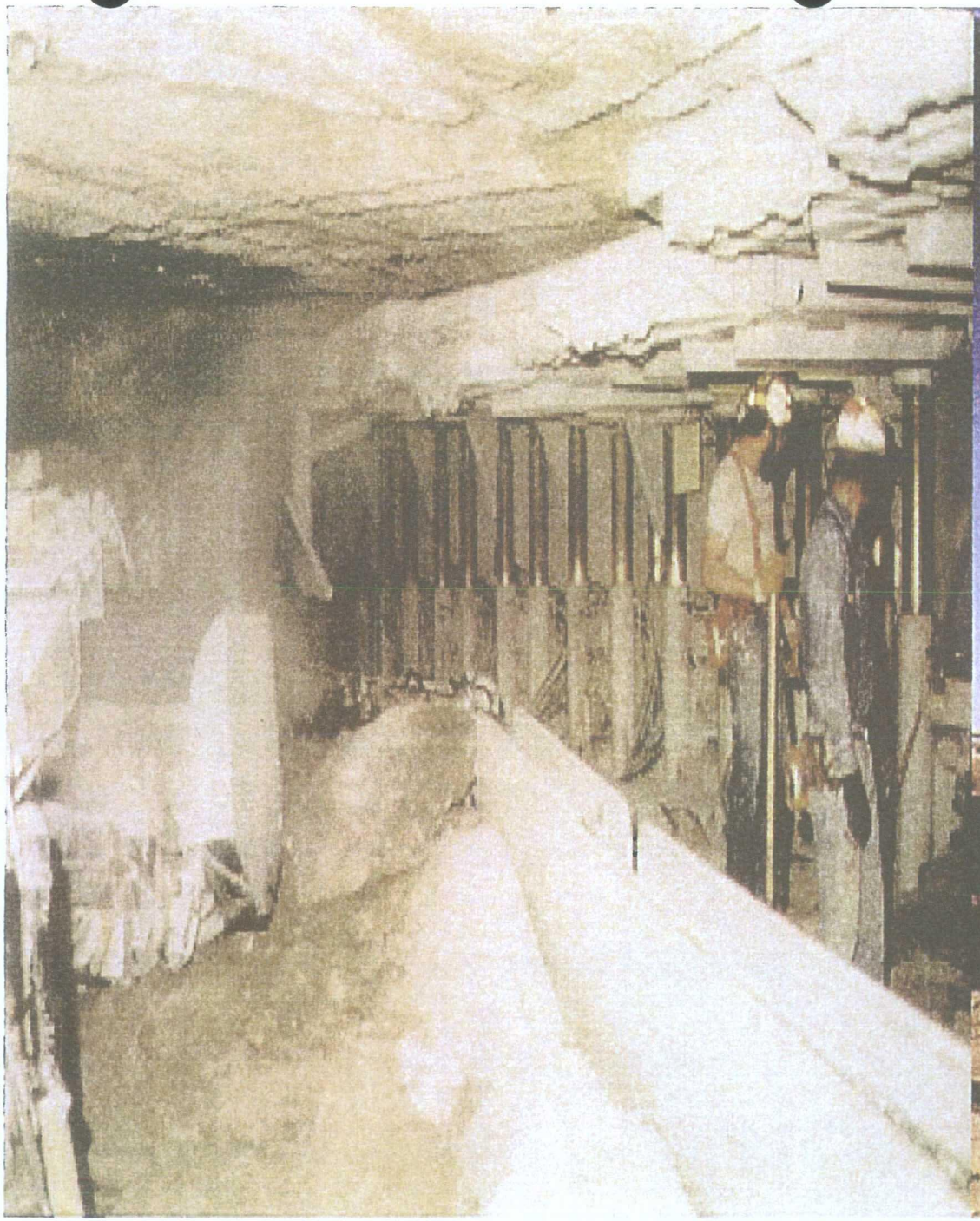
- Field and analytical studies indicate that underground trona mining has a horizontal zone of influence nearly equal to the depth to the mining horizon. Secondary solution recovery will compound subsidence effects.

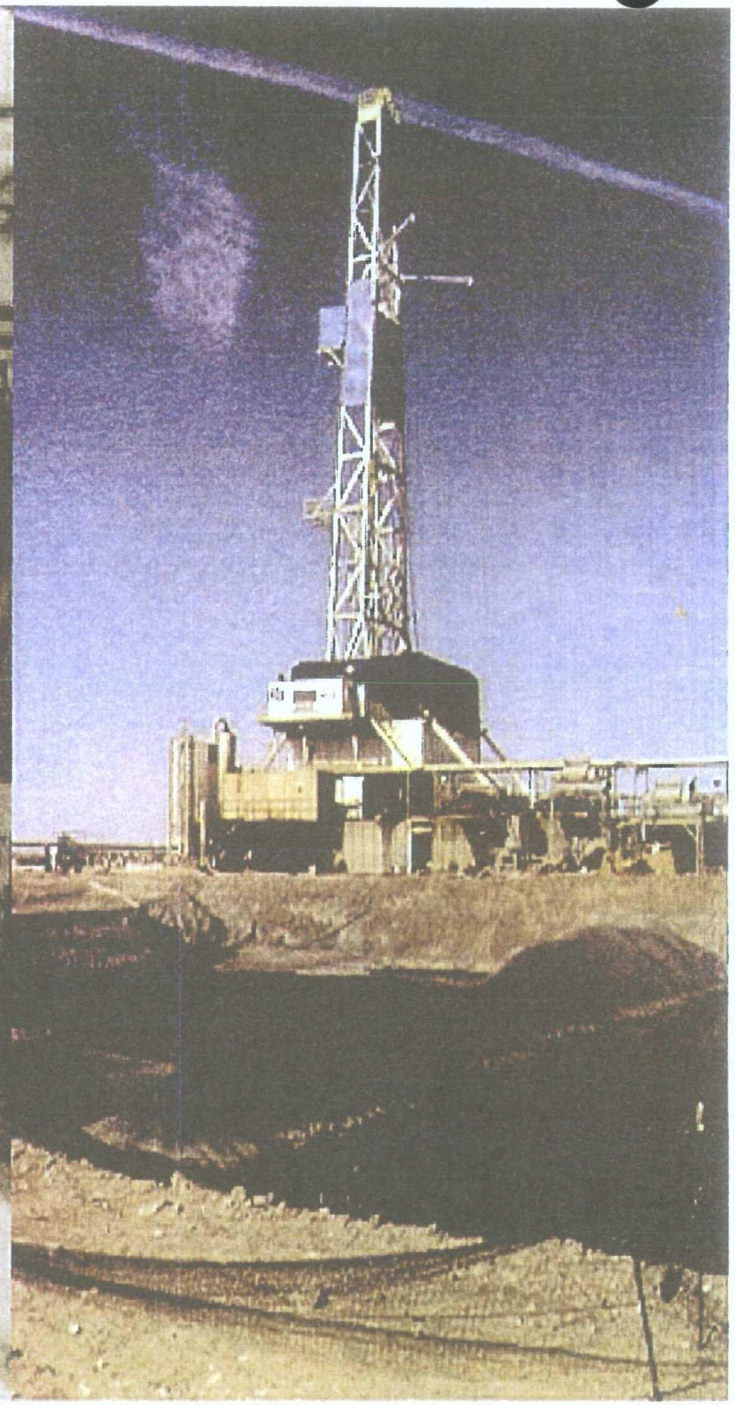
- A majority of the horizontal movement occurs at a relatively few horizons, resulting in high levels of lateral strain at the slip planes.

- Methane from the trona horizons is isotopically unique relative to deeper natural gas.

- Past casing and cementing practices have allowed communication between gas / water sources and the trona deposits.

- Postponing deep gas development will maximize the recovery of both resources.



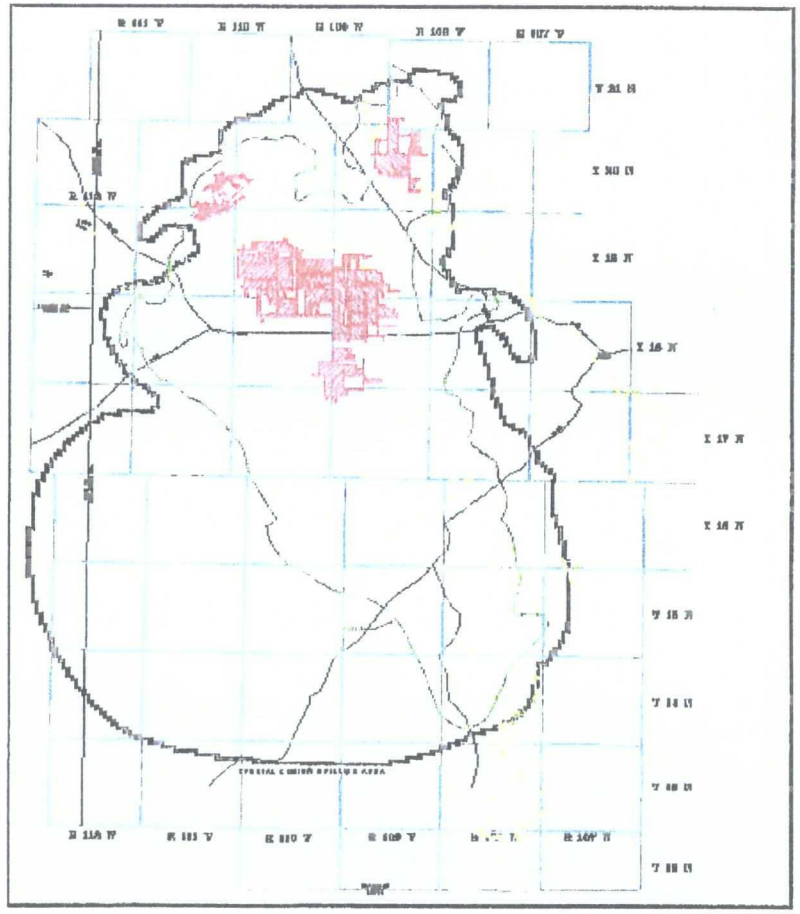


IP001307

Special Rules Area

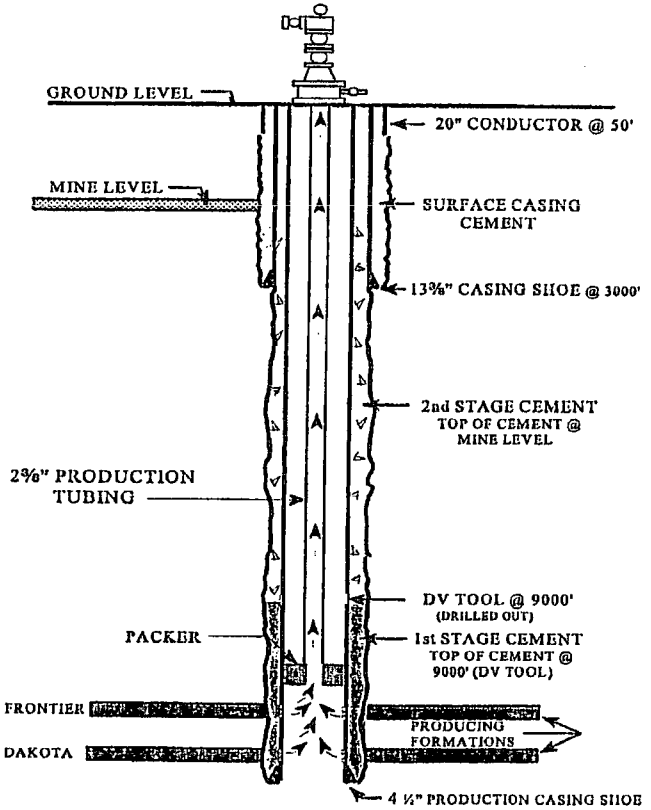
- 383,283 Federal acres
- 267,552 Private acres
- 42,879 State acres

- 693,714 acres



General Drilling Rules
(Chapter 3 Section 22)

PROPOSED KSLA COMPLETED WELL BORE DIAGRAM WITH TUBING & PACKER



Received at meeting in Green River, Wyoming on March 26, 1998 from Union Pacific Resources as part of document titled "Draft Proposed KSLA Drilling Prodedures".

Figure 17

- Run deviation surveys to confirm down-hole location.
- Set surface casing below base of Green River Formation and cement to surface.
- Pressure test cement shoe.
- Cement production casing to 200 feet above mine level.

Plugging of Wells

(Chapter 3 Section 18)

- Set 100 foot cement plugs in casing every 2500 feet.
- Cement production casing 100 feet above and below surface casing cment shoe.

PROPOSED KSLA COMPLETED WELL BORE DIAGRAM WITH TUBING & PACKER

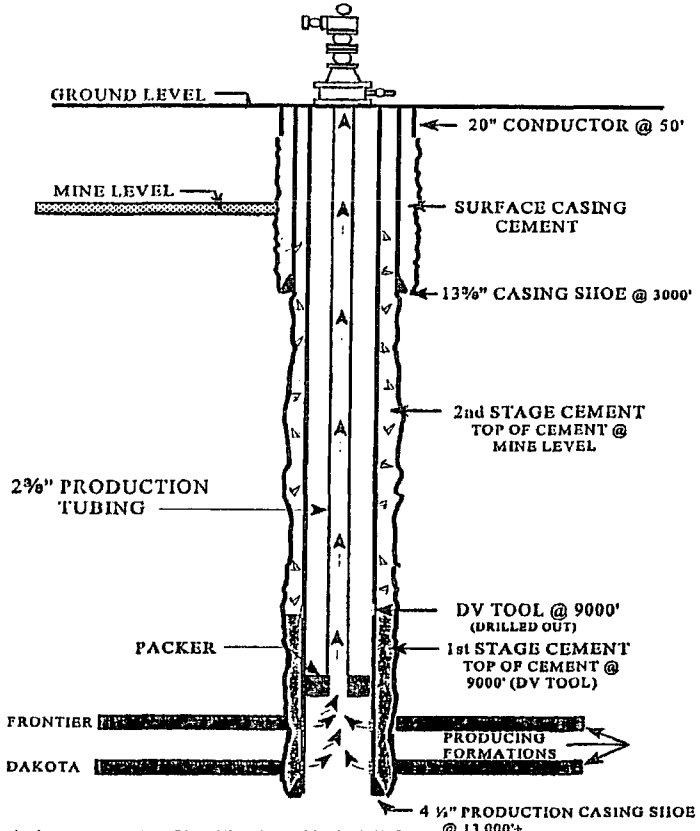


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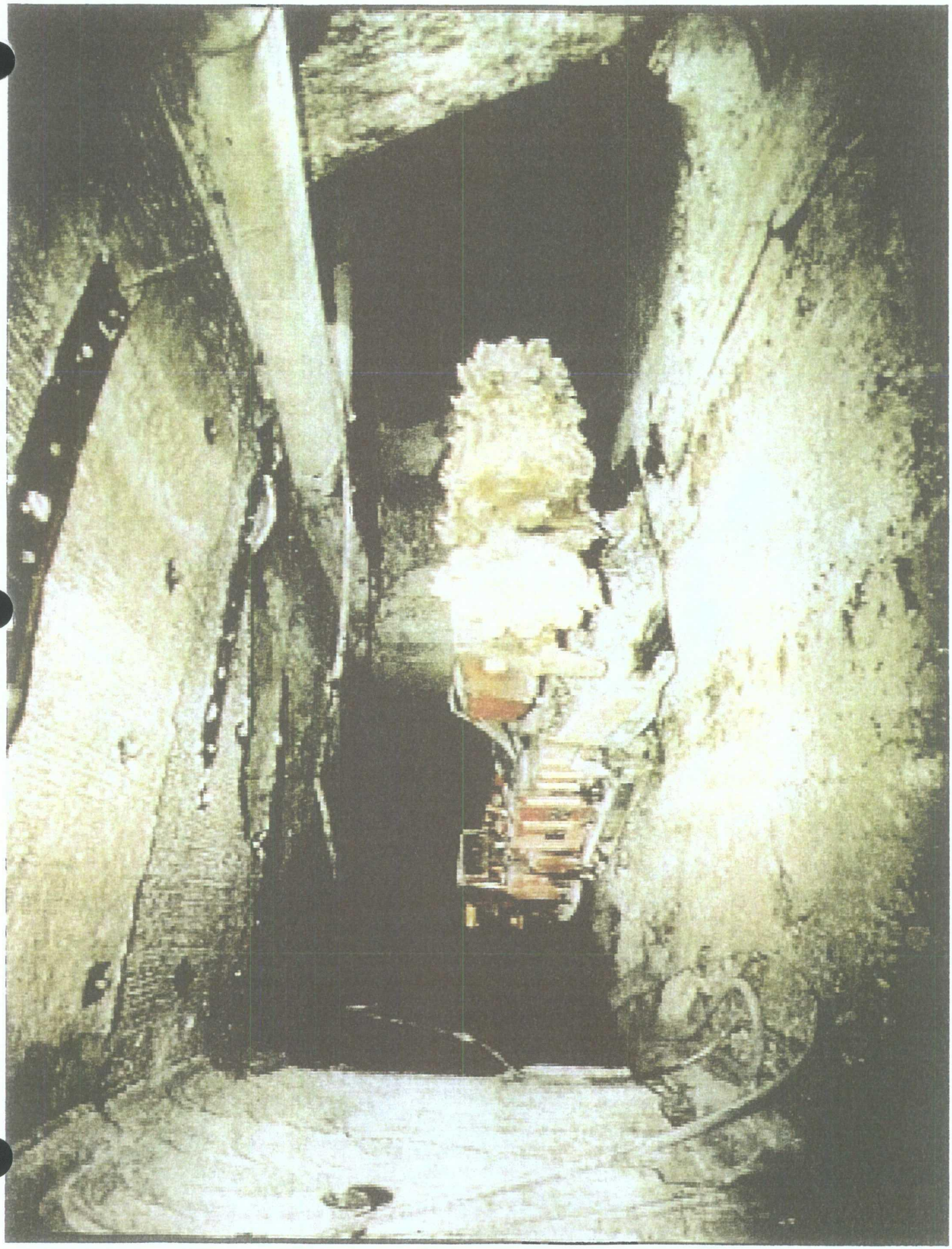
Figure 17

IP001311



IP001312